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WP 11004

DETERMINATION OF WATER RESOURCE CLASSES AND RESOURCE QUALITY OBJECTIVES FOR THE WATER RESOURCES IN THE MZIMVUBU CATCHMENT

RIVER EWR REPORT

June 2017

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Bold indicates this report

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Version	Date
First draft	March 2017
Final report	June 2017

EXECUTIVE SUMMARY

BACKGROUND

The Mzimvubu catchment has been prioritised for implementation of the Water Resource Classification System (WRCS) in order to determine appropriate Water Resource Classes (WRC) and Resource Quality Objectives (RQOs) in order to facilitate the sustainable use of water resources without impacting negatively on their ecological integrity.

The main aims of the project, as defined by the Terms of Reference (ToR), are to undertake the following:

- Coordinate the implementation of the WRCS as required in Regulation 810 in Government Gazette 33541 dated 17 September 2010, by classifying all significant water resources in the Mzimvubu catchment, and
- determine RQOs using the DWS's procedures to determine and implement RQOs for the defined classes.

This report documents the results of the EcoClassification and EWR assessment for four Ecological Water Requirement (EWR) sites situated in the Tsitsa, Thina, Kinira and Mzimvubu rivers, following the Intermediate Ecological Reserve Methodology (IERM) (DWAF, 1999).

STUDY AREA

The study area is represented by the Mzimvubu catchment which consists of the main Mzimvubu River, the Tsitsa, Thina, Kinira and Mzintlava main tributaries and the estuary at Port St Johns.

The basic characteristics of the four Intermediate EWR sites are listed below.

EWR site	River	MRU[1]	SQ[2]	Latitude	Longitude	Eco Region (Level II)	Geomorphic zone	Quat[3]
MzimEWR1	Tsitsa	MRU Tsitsa C	T35E-05977	31.14800	28.67400	16.06	Lower foothills	T35E
MzimEWR2	Thina	MRU Thina C	T34K-05835	31.07200	28.91300	16.06	Lower/upper foothills transition	T34J
MzimEWR3	Kinira	MRU EWR3 (Kinira)	T33G-05395	30.75800	28.99400	16.05	Lower foothills/ lowland river transition	T33G
MzimEWR4	Mzimvubu	MRU Mzim	T36A-06250	31.39636	29.29671	31.01	Lower foothills	T36A

1 Management Resource Unit 2 Sub Quaternary reach 3 Quaternary catchment

ECOCLASSIFICATION RESULTS

The EcoClassification results are summarised below.

MZIMEWR1: TSITSA RIVER	
EIS: MODERATE Highest scoring metrics were Rare and endangered taxa, unique instream biota, biota intolerant to physico-chemical changes and high taxon richness. Important migration route for eels. **PES: C** ▪ Sedimentation due to catchment erosion. ▪ Presence of alien predatory and habitat modifying fish species, erosion, and loss of vegetation. ▪ Alien vegetation removal, grazing pressure and wood removal. **REC: C** The EIS was moderate and the REC is set to maintain the PES as most impacts relate to non-flow related impacts.	

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

MZIMEWR2: THINA RIVER	
EIS: MODERATE Highest scoring metrics were unique instream biota, diversity of instream habitat types and features and high taxon richness. Important migration route for eels. **PES: C** ▪ Sedimentation due to localised disturbance. ▪ Presence of alien predatory and habitat modifying fish species, erosion, and loss of vegetation. ▪ Overgrazing from livestock and the presence of alien plant species. **REC: C** The EIS was moderate and the REC is set to maintain the PES as most impacts relate to non-flow related impacts.	

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

MZIMEWR3: KINIRA RIVER	
EIS: MODERATE Highest scoring metrics were Rare and endangered taxa, unique instream biota, and high taxon richness. Important migration route for eels. **PES: C** ▪ Sedimentation due to catchment erosion. ▪ Alien predatory and habitat modifying fish species, and loss of vegetation due to grazing. ▪ Overgrazing and the presence of terrestrial tree species within the riparian zone as well as browsing pressure. ▪ Targeted wood removal. **REC: C** The EIS was moderate and the REC is set to maintain the PES as most impacts relate to non-flow related impacts.	

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

MZIMEWR4: MZIMVUBU RIVER		
EIS: MODERATE Rare and endangered riparian species, unique instream biota, diversity of instream and riparian types and features and high taxon richness. Important migration route for eels. **PES: C** ▪ Sedimentation due to catchment erosion. ▪ Presence of alien predatory and habitat modifying fish species and loss of vegetation. ▪ Alien vegetation removal, grazing pressure and wood removal. **REC: C** The EIS was moderate and the REC is set to maintain the PES as most impacts relate to non-flow related impacts.	**Component**	**PES and REC**
	IHI Hydrology	A/B
	Physico-chemical	A/B
	Geomorphology	C
	Fish	C
	Invertebrates	C
	Instream	C
	Riparian vegetation	C/D
	EcoStatus	C
	Instream IHI	B/C
	Riparian IHI	C
	EIS	**MODERATE**

EWR QUANTIFICATION

The final flow requirements are expressed as a percentage of the Natural Mean Annual Runoff (nMAR) and shown below.

Site	EcoStatus	nMAR (MCM[1])	pMAR[2] (MCM)	% of nMAR	Low flows (MCM)	Low flows (%)	High flows (MCM)	High flows (%)	Total flows (MCM)	Total (%)
MzimEWR1	PES; REC: C	438.04	413.16	94.32	87.43	20	48.25	11	135.68	31
	D EC				67.66	15.4	42.16	9.6	109.82	25.1
MzimEWR2	PES; REC: C	404.51	393.23	97.21	89.24	22.1	32.41	8	121.65	30.1
	D EC				60.63	15	29.5	7.3	90.13	22.3
MzimEWR3	PES; REC: C	407.12	399.3	98.08	82.87	20.3	52.57	12.9	135.44	33.3
	D EC				63.83	15.7	45.83	11.3	109.66	26.9
MzimEWR4	PES; REC: C	2655.13	2532.21	95.37	331.16	12.5	301.3	11.3	632.46	23.8
	D EC				201.32	7.6	267.95	10.1	469.27	17.7

1 Million Cubic Metres 2 Present Day MAR

CONCLUSIONS AND RECOMMENDATIONS

The confidence in the EcoClassification is Moderate to High which is acceptable for an Intermediate assessment. Furthermore, no further work on the EcoClassification is required as it will not influence the EWR determination. However, monitoring is essential to ensure that the ecological objectives in terms of the REC are achieved and the EC will therefore be verified during monitoring.

In general, the EWR requirements for low flows have a Moderate to High (MzimEWR1) confidence. Additional biological surveys could improve the confidence but it is more important to first improve the confidence of the hydraulics. The hydraulic modelling is mostly Moderate for low flows. This is due to the fact that the previous hydraulic measurements could not be used as effectively as possible due to inadequate placing of benchmarks and the selection of an unsuitable cross-section (MzimEWR2). As the hydraulics confidence represent the overall confidence in most cases for low flows, the highest priority if results needed to be improved would be to obtain additional calibrations at low flows. MzimEWR3 will however need the cross-section to move to a more suitable place. It must also be noted that as a new EWR site had to be selected in the Mzimvubu River (MzimEWR4), only one hydraulic calibration could be obtained, which is problematic for an

Intermediate level study taking into account the complexity of this cross-section. In summary, improvement in confidence in the EWR results should be focussed on improving the hydraulics, and then reviewing the EWR requirements if necessary. This action could be addressed through a specific monitoring exercise, which could be undertaken as part of general monitoring activities in the catchment.

Confidence summary

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

EWR site	MzimEWR1	MzimEWR2	MzimEWR3	MzimEWR4
Data availability	3.0	3.0	2.9	2.9
EcoClassification	3.2	3.3	3.1	3.3
Low flow EWR (biotic responses)	3.5	2.5	2.5	3.0
High flow EWR (biophysical responses)	3.3	2.0	2.8	2.5
Hydrology	3.5	2.5	2.5	2.5
Hydraulics (low)	2	1	2	2
Hydraulics (high)	3	3	3	3
Overall low flow EWR confidence	**2**	**1**	**2**	**2**
Overall high flow EWR confidence	**3**	**2**	**2.8**	**2.5**

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LIST OF ABBREVIATIONS

ASGISA-EC	Accelerated and Shared Growth Initiative for South Africa-Eastern Cape
ASPT	Average Score Per Taxon
BHNR	Basic Human Needs Reserve
DRIFT	Downstream Response to Imposed Flow Transformation
DRM	Desktop Reserve Model
DWA	Department Water Affairs (Name change from DWAF applicable after April 2009)
DWAF	Department Water Affairs and Forestry
DWS	Department Water and Sanitation (Name change from DWA applicable after May 2014)
EC	Ecological Category
EIA	Environmental Impact Assessment
EIS	Ecological Importance and Sensitivity
EWR	Ecological Water Requirements
FDI	Flow Dependent Macroinvertebrate
FFHA	Fish Flow Habitat Assessment
FIFHA	Fish Invertebrate Flow Habitat Assessment model
FRAI	Fish Response Assessment Index
FROC	Frequency of Occurrence
GAI	Geomorphology Assessment Index
HFSR	Habitat Flow Stressor Response method
HFSR-RM	Habitat Flow Stressor Response-Reserve Model
IERM	Intermediate Ecological Reserve Methodology
IHI	Index of Habitat Integrity
IUAs	Integrated Units of Analysis
LB	Left Bank
MAR	Mean Annual Runoff
MCB	Macro Channel Bank
MCM	Million Cubic Metres
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
PESEIS	Present Ecological State, Ecological Importance and Ecological Sensitivity
pMAR	Present Day MAR
Quat	Quaternary catchment
RB	Right Bank
RDRM	Revised Desktop Reserve Model
REC	Recommended Ecological Category
RHP	River Health Programme
SANBI	South African National Biodiversity Institute
SASS5	South African Scoring System version 5
SPATSIM	SPatial And Time Series Information Modelling framework
SQ	Sub Quaternary
VEGRAI	Riparian Vegetation Response Assessment Index
VBA	Visual Basic for Applications

WMA	Water Management Area
WRYM	Water Resources Yield Model
WWTW	Wastewater Treatment Works
ToR	Terms of Reference
WRCS	Water Resource Classification System
RQOs	Resource Quality Objectives

SASS5 Sampling biotopes

GSM	Gravel-Sand-Mud
MV	Marginal Vegetation
SIC	Stones-in-Current
SOC	Stones-out-of-Current

GLOSSARY

Alternative Ecological Category (AEC)	The AEC represents any other category than the PES and REC for which flow requirements may be set. This terminology was used during Preliminary Reserve determination.
EcoClassification	EcoClassification (or the Ecological Classification process) refers to the determination and categorisation of the Present Ecological State (PES; health or integrity) of various physical attributes of rivers relative to the natural reference condition. A range of models are used during EcoClassification, each of which relate to the indicators assessed.
Ecological Category (EC)	ECs are determined for all components of the ecosystem for driver (abiotic) and response (biotic) components. These are integrated into an overall or integrated state called the EcoStatus. This level of information with the entire component ECs is only available when detailed studies are undertaken. For more desktop type studies, only a single EC may be available which represent the EcoStatus. **Whenever an EC is referred to without specifying that it is applicable to a specific component, this will always refer to the EcoStatus.**
Ecological Importance and Sensitivity (EIS)	Key indicators in the ecological classification of water resources. Ecological importance relates to the presence, representativeness and diversity of species of biota and habitat. Ecological sensitivity relates to the vulnerability of the habitat and biota to modifications that may occur in flows, water levels and physico-chemical conditions.
Ecological Water Requirements (EWR)	The flow patterns (magnitude, timing and duration) and water quality needed to maintain a riverine ecosystem in a particular condition. This term is used to refer to both the quantity and quality components.
EcoStatus	EcoStatus is 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 and is capacity to provide a variety of goods and services.
EWR sites	Specific points on the river as determined through the 'hotspot' and site selection process. An EWR site consists of a length of river which may consist of various cross-sections assessed for both hydraulic and ecological purposes. These sites provide sufficient indicators to assess environmental flows and assess the condition of biophysical components (drivers such as hydrology, geomorphology and physico-chemical conditions) and biological responses (*viz*. fish, macroinvertebrates and riparian vegetation).
HABFLOW	Hydraulic model that models or predicts the percentage of occurrence of velocity depth classes at different discharges.
Management Resource Units (Rivers)	The purpose of distinguishing MRUs from RUs is to identify a management unit within which the EWR can be implemented and managed based on one set of identified flow requirements. This means that an EWR site in the MRU, according to the EWR site selection criteria in context of the MRU, will provide for the whole MRU. MRUs are usually defined for river reaches only and differ from Resource Units in that is a more detailed assessment.
Present	The current state or condition of a water resource in terms of its biophysical

Ecological State (PES)	components (drivers) such as hydrology, geomorphology and water quality and biological responses *viz*. fish, invertebrates, riparian vegetation). The degree to which ecological conditions of an area have been modified from natural (reference) conditions.
Recommended Ecological Category (REC)	The Recommended Ecological Category is the future ecological state (Ecological Categories A to D) that can be recommended for a resource unit depending on the EIS and PES. The REC is determined based on ecological criteria and considers the EIS, the restoration potential of the system and attainability thereof.
Resource Quality Objectives (RQOs)	RQOs are numeric or descriptive goals that can be monitored for compliance to the WRC, for each part of each water resource.
Resource Units (RUs)	RUs are delineated during an Ecological Reserve determination study, as each will warrant its own specification of the Reserve, and the geographic boundaries of each must be clearly delineated. These sections of a river frequently have different natural flow patterns, react differently to stress according to their sensitivity, and require individual specifications of the Reserve appropriate for that reach. RUs are nested within Integrated Units of Analysis (IUAs) and may contain an Ecological Water Requirement site.
Revised Desktop Reserve Model (RDRM)	The output from the RDRM is an estimated EWR for each Ecological Category, at a desktop level for biophysical nodes other than EWR sites. Due to the large study area, additional EWRs are estimated for every Resource Unit identified which is not addressed by the more detailed EWR assessment at EWR sites. These EWRs are therefore estimated using the RDRM.
Scenario	Scenarios, in the context of water resource management and planning, are plausible definitions (settings) of factors (variables) that influence the water balance and water quality in a catchment and the system as a whole. Each scenario represents an alternative future condition, generally reflecting a change to the present condition.
Sub-quaternary catchments (SQ)	A finer subdivision of the quaternary catchments (the catchment areas of tributaries of main stem rivers in quaternary catchments), to a sub-quaternary or quinary level.
Water Resource Class (WRC)	The Water Resource Class is representative of those attributes that the DWS (as the custodian) and society require of different water resources. The decision-making toward a WRC require a wide range of trade-offs to be assessed and evaluated at a number of scales. Final outcome of the process is a set of desired characteristics for use and ecological condition each of the water resources in a given catchment. The WRCS defines three management classes, Class I, II, and III, based on extent of use and alteration of ecological condition from the predevelopment condition.
Water Resource Classification System (WRCS)	The Water Resource Classification System is a defined set of guidelines and procedures for determining the different classes of water resources (South African National Water Act (Act 36 of 1998) Chapter 3, Part 1, Section 2(a)). The outcome of the Classification Process will be the setting of the class, Reserve and Resource Quality Objectives by the Minister or delegated authority for every significant water resource (river, estuary, wetland and aquifer) under consideration. This class, which will range from Minimally used to Heavily used, essentially describes the desired condition of the resource, and concomitantly, the degree to which it can be utilised.

1 INTRODUCTION

1.1 BACKGROUND

The Mzimvubu catchment has been prioritised for implementation of the Water Resource Classification System (WRCS) in order to determine appropriate Water Resource Classes and Resource Quality Objectives (RQOs) in order to facilitate the sustainable use of water resources without impacting negatively on their ecological integrity. These activities will guide the management of the T3 Mzimvubu primary catchment toward meeting the departmental objectives of maintaining, and if possible, improving the present state of the Mzimvubu River and its four main tributaries, namely the Tsitsa, Thina, Kinira and Mzintlava. This project is driven by threatened ecosystem services in the Mzimvubu catchment, due to the variety of inappropriate land uses and alien plant infestation that result in extensive erosion and degradation. Degradation can be observed in soil erosion, damage to infrastructure, water supply shortages and loss of grazing.

The Department of Water and Sanitation (DWS) has initiated a study to determine Classes and associated RQOs for the Mzimvubu catchment in Water Management Area (WMA) 7.

The main aims of the project, as defined by the Terms of Reference (ToR), are to undertake the following:

- Coordinate the implementation of the WRCS as required in Regulation 810 in Government Gazette 33541 dated 17 September 2010, by classifying all significant water resources in the Mzimvubu catchment, and
- determine RQOs using the DWS's procedures to determine and implement RQOs for the defined classes.

An additional aim was to consolidate and undertake additional work as required to improve the work previously done on Ecological Water Requirements (EWR) and the Basic Human Needs Reserve (BHNR) for the purposes of Classification.

1.2 STUDY AREA OVERVIEW

The study area is represented by the Mzimvubu catchment which consists of the main Mzimvubu River, the Tsitsa, Thina, Kinira and Mzintlava main tributaries and the estuary at Port St Johns. The river reaches sizeable proportions after the confluence of these four tributaries in the Lower Mzimvubu area, approximately 120 km from its source, where the impressive Tsitsa Falls can be found near Shawbury Mission. The Mzimvubu catchment and river system lies along the northern boundary of the Eastern Cape and extends for over 200 km from its source in the Maloti-Drakensberg watershed on the Lesotho escarpment to the estuary at Port St Johns. The catchment is in Primary T, comprises of T31–36 and stretches from the Mzimkhulu River on the north-eastern side to the Mbashe and Mthatha river catchments in the south. The Mzimvubu river catchment is found in WMA 7, i.e. the Mzimvubu to Tsitsikamma WMA.

1.3 STUDY PROJECT PLAN

The Mzimvubu study is being undertaken according to the Project Plan in **Figure 1.1** with each step broken down into sub-steps. This report pertains to the EWR quantification part of Step 3.

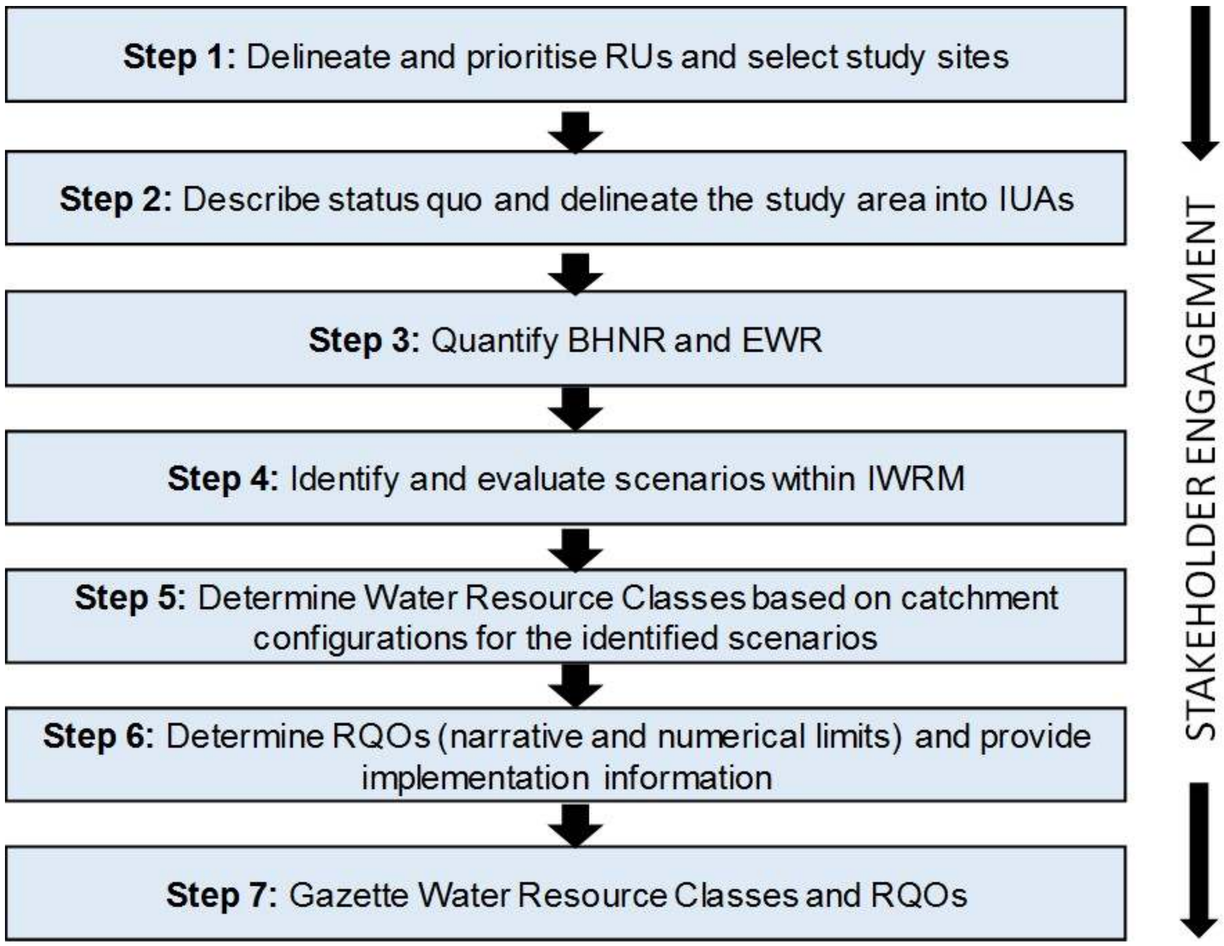

Figure 1.1 Project plan for the Mzimvubu Classification and RQO study

1.1 EWR SITES

Existing EWR sites selected during the Feasibility Study for the Mzimvubu Water Project (DWS, 2014a) was used during this study. No EWR site existed in the high priority reach of the lower Mzimvubu, so an EWR site was selected in this reach (MzimEWR4). The details of the EWR sites are provided in **Table 1.1** and **Figure 1.2**.

A description of each EWR site is provided in **Table 1.1**. Additional detailed data are available from a geomorphological summary report authored by Prof K Rowntree and provided electronically.

Table 1.1 EWR sites selected in the study area

EWR site	River	MRU[1]	SQ[2]	Latitude	Longitude	Eco Region (Level II)	Geomorphic Zone	Quat[3]
MzimEWR1	Tsitsa	MRU Tsitsa C	T35E-05977	31.14800	28.67400	16.06	Lower foothills	T35E
MzimEWR2	Thina	MRU Thina C	T34K-05835	31.07200	28.91300	16.06	Lower/upper foothills transition	T34J
MzimEWR3	Kinira	MRU EWR3 (Kinira)	T33G-05395	30.75800	28.99400	16.05	Lower foothills/ lowland river transition	T33G
MzimEWR4	Mzimvubu	MRU Mzim	T36A-06250	31.39636	29.29671	31.01	Lower foothills	T36A

1 Management Resource Unit 2 Sub Quaternary reach 3 Quaternary catchment

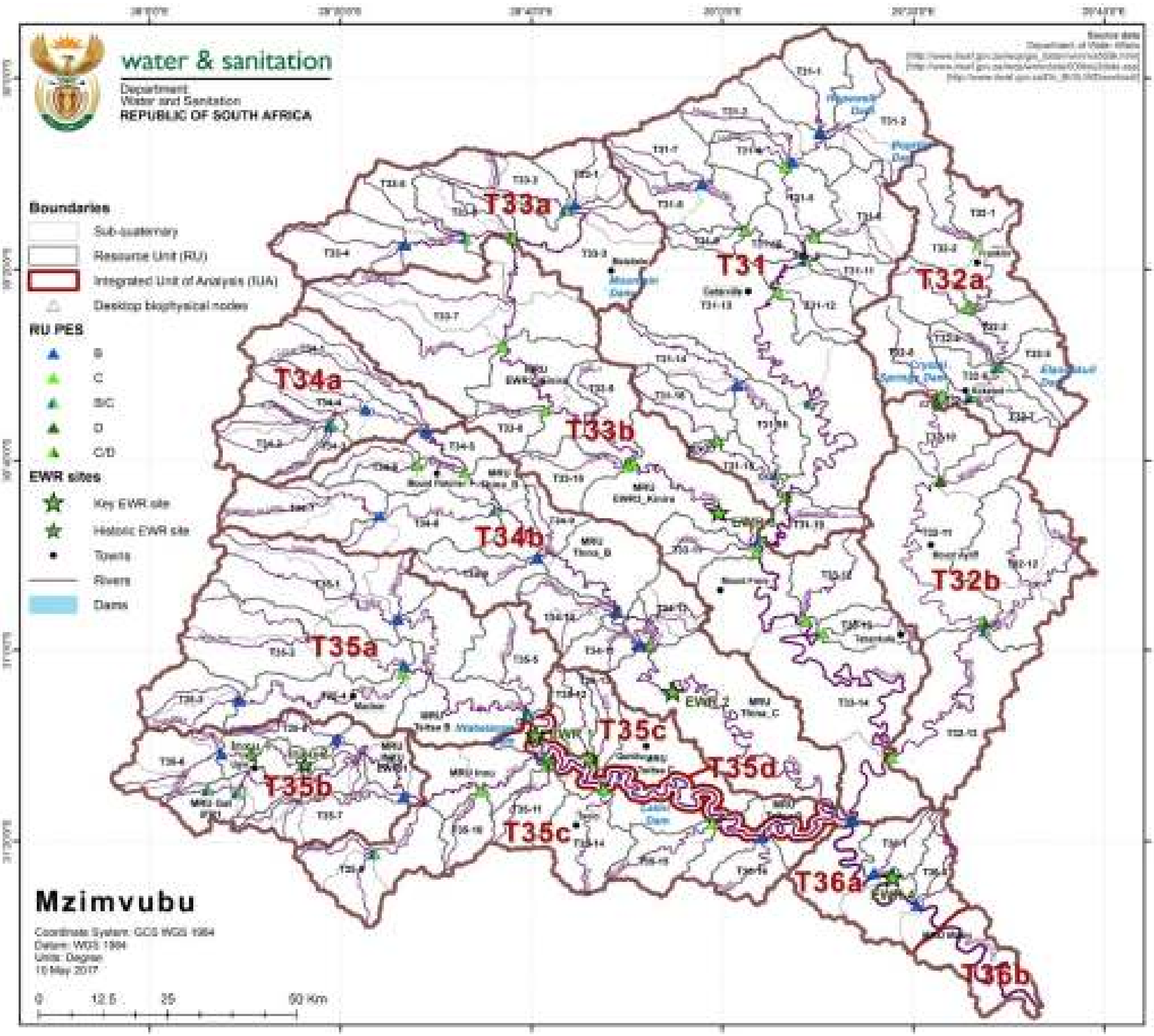

Figure 1.2 EWR sites, biophysical nodes, RUs and IUAs in Mzimvubu catchment T3

1.1.1 MzimEWR1: Tsitsa River

MzimEWR1 on the Tsitsa River lies in a V-shaped valley but has a relatively low gradient (**Figure 1.3**). There is little space to accommodate the formation of flood zones. A narrow flood bench consisting of sand and boulder flanks the channel beneath a higher terrace that is locally present. A lateral zone of shallow flow over embedded gravel and cobble is present along the left side of the rapid. This may be the result of erosion of the adjacent flood bench, possibly by the April 2013 flood. This flood has only been exceeded once since 1968, in 1976. There is no evidence from the flow record that floods have increased or diminished in size over this time period. The upstream catchment consists of both commercial farm land, forestry and communally settled areas. High settlement density coupled with highly erodible soils has led to widespread gullying on the communal lands. This is especially severe locally upstream where active gullies erode into dispersive soils. Cultivation on commercial farms (predominantly potatoes, soya and maize) is responsible for sheet erosion whilst forestry operations are also likely to lead to elevated sediment flux. The increase in sediment delivery to the EWR site is large.

The in-channel morphology consists of a pool-rapid sequence. The rapid is dominated by medium to large boulder with little mobile material. Locally pockets of fine gravel and coarse are present in the lee of boulders, especially towards the left side. A small area of mobile gravel and cobble provides riffle-type habitat towards the downstream right bank. A large sand bar, emerged at low flows, has formed in the downstream pool. As noted above this was not evident in 1949 and may be caused by an increased sediment flux. A number of factors contribute to bank instability at this site. Dense stands of *Acacia mearnsii* are associated with undercut banks. Livestock grazing also reduces the cover on banks and flood benches. The high density of upstream gully networks will also lead to flashier runoff that can cause bank erosion. It should be noted that downstream of the Inxu (Wildebees) River confluence the character of the river changes. A lower reach gradient (from 0.008 to 0.002) and increased sediment input by the Inxu contribute to significant deposition and the formation of a mobile bed with sand bars (Huchzermeyer, unpublished MSc thesis).

Figure 1.3 MzimEWR1: Site map

1.1.2 MzimEWR2: Thina River

MzimEWR2 on the Thina River lies in a more open valley with a high terrace on the right bank and gentle slopes on the left bank (**Figure 1.4**). Upstream catchment land use consists of communal land with nucleated settlements. The headwaters of the Thina comprise steep valleys with a high erosion potential. Duplex soils in the middle catchment increase the erosion risk. Land use has changed from widespread cultivation to a dominance of grazing. There is little forestry development and no commercial agriculture. The increase in sediment delivery to the EWR site is large.

There have been a series of moderately large floods between 2011 and 2014 that are likely to be reflected in the present morphology. In places along the right bank the channel is undercutting a bedrock cliff so there is no possibility of developing a riparian zone other than a marginal zone. Elsewhere a broad sandy flood bench has developed which supports a grass cover. This is crossed by a narrow flood channel on the left bank. On the right bank the flood bench is bordered by a steep macro-channel with *Vachellia karroo.* The macro-channel bank probably suffers erosion during extreme flood events. The left bank macro-channel bank is less steep, has a sparse cover of grass and shows signs of surface wash erosion. Where the flood bench is directly adjacent to the low flow channel the banks are well protected by vegetation. Elsewhere the grass covered flood bench is separated from the low flow channel by a wide boulder bar with varying degrees of sand deposition. This bar is currently being mined for its large material which creates a major disturbance at the site.

In-channel morphology consists of a series of long pools and short rapids. These in turn support pool, glide and run hydraulic habitats in the pools at low flow and rapid, riffle or run habitats within the rapids. A large backwater pool lies below the cobble bar at the site, separated from the main flow by a boulder ridge. Bed material in the main channel consists either of bedrock pavement, which was exposed along the right bank at the time of the site visit, or poorly sorted boulder, cobble and gravel. Sparse grass and or reeds were growing in the channel in more stable areas. Over most of the channel embeddedness of gravel and cobble by fines is limited in extent but there are local areas of deposition close the bank. This deposition may reflect recovery of the channel following erosion in the period of high floods between 2011 and 2014.

Figure 1.4 MzimEWR2: Site map

1.1.3 MzimEWR3: Kinira River

MzimEWR3 is situated shortly below a steep gorge in an open valley setting with a terrace flanking the right bank of the channel (**Figure 1.5**). A gentle hillslope flanks the left bank. Upstream the land use is dominated by communal land with extensive grazing and severe gullying over most of the catchment. This raises the sediment delivery factor to severe at this site. There is limited forestry and no commercial farming in the catchment but as noted above there is a large wetland in the headwaters of one tributary that will help to attenuate floods to some extent. Significant areas (1/4 to 1/3) of the wetland area is cultivated.

Overall morphology at MzimEWR3 is similar to that at MzimEWR2, with well-developed sandy flood benches, boulder bars and pool-rapid instream morphology. Well-rounded polished imbricated (stable) boulders and sand dominate the channel bed. Deposition on the flood benches and in-channel is far more evident at this site. There is significant erosion of the right macro-channel bank.

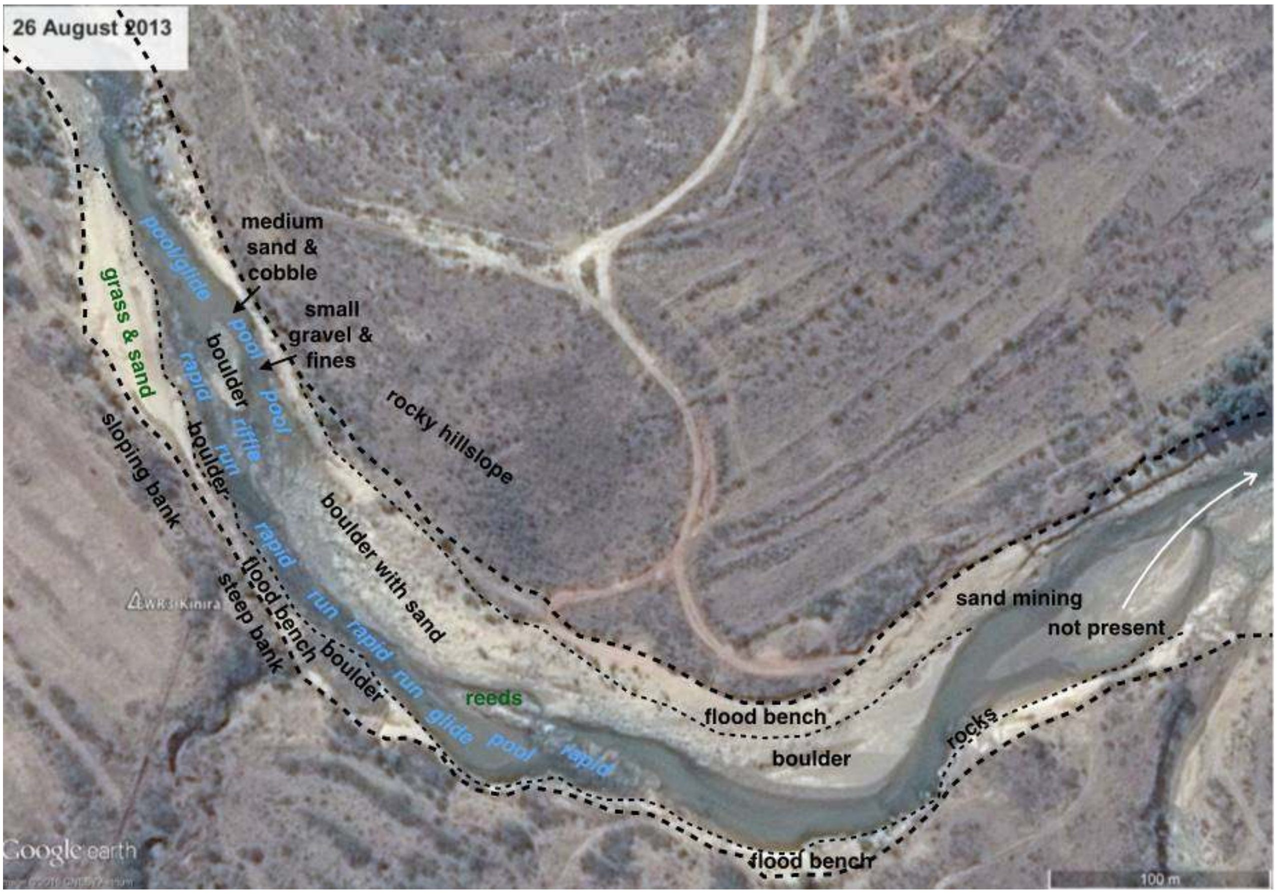

Figure 1.5 MzimEWR3: Site map

1.1.4 MzimEWR4: Mzimvubu River

MzimEWR4 is situated in a deep, highly confined valley, giving little potential for floodplain development (**Figure 1.6**). This site receives water and sediment from the entire Mzimvubu catchment which is dominated by communal land with extensive grazing but also includes commercial farmland in the east and west and commercial forestry in the west. This site therefore integrates the responses described for the previous three sites, plus an area of commercial farmland in the upper Mzimvubu River near Kokstad. The erosion potential for the area in along the gorge is low so local input of sediment will also be low. Delivery of sediment from the upstream catchment will be somewhat decreased by storage in the large catchment area, but generally steep slopes will act against this. The sediment flux through the Mzimvubu site was assessed as moderate to large.

Overall morphology is dominated by lateral and transverse boulder bars. A large transverse bar in the upper site creates a barrier across the channel causing pool formation upstream. Multiple channels cross the bar, creating riffle habitat among cobble and boulder. The bar and multiple channels have persisted since 1948. Lateral bars constrict the adjacent channel and create pools upstream. The surveyed transect lies just upstream of the channel constriction which results in fast flow over a bedrock channel dominated by sculptured bedrock that forms large roughness elements. Bedrock also forms the right channel bank. The upstream pool had a smoother bedrock floor with silt and sand deposits along the edge. The bars are composed of large rounded boulders with local sand or gravel deposits. At the edge of the fast flowing channel the boulders provide shallow pool habitat.

The boulder bar in the downstream area of the site is flanked on the right bank by a grassy flood bench and higher terrace. A flood channel crosses the flood bench. Significant encroachment of woody vegetation on to the terrace has occurred since 1948. In contrast vegetation, and possibly fine sediment, has been lost from the terrace located on the right bank below the transverse boulder bar. This terrace (or flood bench) is at a similar height to the channel upstream of the transverse bar so is liable to be flooded. There is a steep drop below the bar so the terrace stands several metres above the adjacent channel. Thus this feature can be flooded by overflow from the upstream channel but is unlikely to receive overbank flooding from the downstream channel.

Figure 1.6 MzimEWR4: Site map

1.2 DATA AND INFORMATION AVAILABILITY

Information collated during physical surveys was used to provide the results in this report, together with historical data and other literature sources. The data and information availability are summarised in **Table 1.2**.

Table 1.2 Data and information availability

Hydrology
MzimEWR1 ▪ Natural Hydrology: Was derived from DWS Feasibility Study for the Mzimvubu Water Project (DWS, 2014b) (hydrological calibration was possible at two gauges (T3H006 and T3H009 upstream and downstream of the EWR1), which was scaled to obtain representative natural flow at the EWR site. Confidence: 3.5 ▪ Present Hydrology: The Water Resource Yield Model (WRYM) system configuration sourced from the DWS Feasibility Study for the Mzimvubu Water Project (DWS, 2014b) was refined to include simulation of flows at the EWR site. Catchment developments (forestry, small dams, irrigation and urban/rural water use and return flows) were disaggregated based on information obtained from the DWS Feasibility Study

for the Mzimvubu Water Project (DWS, 2014b), ASGISA-EC Mzimvubu Development Project (DWAF, 2009), DWS All Towns Study (DWS, 2015), visual inspection of satellite imagery and catchment area scaling.

Confidence: 3.5

MzimEWR2

- Natural Hydrology: Derived from ASGISA-EC Mzimvubu Development Project (DWAF, 2009) (made use of the WR2005 hydrology i.e. uncalibrated) and was scaled to obtain representative natural flow at the EWR site.

Confidence: 2.5

- Present Hydrology: The Water Resource Yield Model (WRYM) system configuration sourced from the ASGISA-EC Mzimvubu Development Project (DWAF, 2009), was refined to include simulation of flows at the EWR site. Catchment developments (forestry, small dams, irrigation and urban/rural water use and return flows) were disaggregated based on information obtained from the ASGISA-EC Mzimvubu Development Project (DWAF, 2009), DWS All Towns Study (DWS, 2015), visual inspection of satellite imagery and catchment area scaling.

Confidence: 2.5

MzimEWR3

- Natural Hydrology: The DWS Feasibility Study for the Mzimvubu Water Project hydrology (DWS, 2014b) MAR is between 46% and 48% higher than the WR2005 and WR2012 hydrology and the findings of further investigation undertaken by the team confirmed that the hydrology is unacceptable. The ASGISA-EC Mzimvubu Development Project (DWAF, 2009) (made use of the WR2005 hydrology i.e. uncalibrated) was utilised and scaled to obtain representative natural flow at the EWR site.

Confidence: 2.5

- Present Hydrology: The WRYM system configuration sourced from the ASGISA-EC Mzimvubu Development Project (DWAF, 2009) was refined to include simulation of flows at the EWR site. Catchment developments (forestry, small dams, irrigation and urban/rural water use and return flows) were disaggregated based on information obtained from the ASGISA-EC Mzimvubu Development Project (DWAF, 2009), DWS All Towns Study (DWS, 2015), visual inspection of satellite imagery and catchment area scaling.

Confidence: 2.5

MzimEWR4

- Natural Hydrology: Was derived from the ASGISA-EC Mzimvubu Development Project (DWAF, 2009) (made use of the WR2005 hydrology i.e. uncalibrated) as well as the contributing upstream DWS Feasibility Study for the Mzimvubu Water Project hydrology used for the iTsitsa (T35) (DWS, 2014b) and was scaled to obtain representative natural flow at the EWR site.

Confidence: 2.5

- Present Hydrology: The WRYM system configuration sourced from the ASGISA-EC Mzimvubu Development Project (DWAF, 2009) was refined to include simulation of flows at the EWR site. Catchment developments (forestry, small dams, irrigation and urban/rural water use and return flows) were disaggregated based on information obtained from the ASGISA-EC Mzimvubu Development Project (DWAF, 2009), DWS All Towns Study (DWS, 2015), visual inspection of satellite imagery and catchment area scaling.

Confidence: 2.5

Physico-chemistry

MzimEWR1

- Reference condition was represented by the A Category benchmark tables in DWAF (2008). This was considered suitably representative of the natural state in the area.
- The gauging weir, T3H006Q001 (2000–2016), is on the Tsitsa River downstream of MzimEWR1, and not in the same Level II EcoRegion as the EWR site (16.05 vs 16.06). Data from this site was used for the assessment, and complemented by on-site data and land-use information.

Confidence: 2.5

MzimEWR2

- Reference condition was represented by the A Category benchmark tables in DWAF (2008). This was considered suitably representative of the natural state in the area.
- The gauging weir, T3H005Q01 (2000–2016), is on the Thina River and upstream of MzimEWR2 in the same Level II EcoRegion (16.06). Data from this site were used for the assessment, and complemented by on-site data and land-use information.

Confidence: 3.5

MzimEWR3

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

- The gauging weir, T3H019Q01 (2007–2016), is on the Kinira River and downstream of MzimEWR3 in the same Level II EcoRegion (16.05). Data from this site were used for the assessment, and complemented by on-site data and land-use information.

Confidence: 3.5

MzimEWR4

- Reference condition was represented by the A Category benchmark tables in DWAF (2008). This was considered suitably representative of the natural state in the area.
- The gauging weir, T3H020Q01 (2009–2016), is on the Mzimvubu River upstream of MzimEWR4 in the same Level II EcoRegion (31.01). Data from this site were used for the assessment, and complemented by on-site data and land-use information.

Confidence: 3.5

Geomorphology

MzimEWR1

- Reference condition was assessed from river zonation classification based on reach gradient Rowntree *et al*. 2000); Modification from reference condition (Present Ecological State - PES) based on assessment of drivers calibrated against assessed morphological change.
- Driver change assessed from catchment observations, flood data for T3H006, gully mapping from Le Roux *et al*. (2015). Frequent visits to catchment over 2915 and 2016.
- On site observations and recent Google images (2014) were compared to aerial imagery from 1949.
- Riparian status confirmed from vegetation data for this study.
- Additional data was available from Huchzermeyer (unpublished MSc thesis).

Confidence: 3.5

MzimEWR2

- Reference condition was assessed from river zonation classification based on reach gradient Rowntree *et al*. 2000); Modification from reference condition (PES) based on assessment of drivers calibrated against assessed morphological change.
- Driver change assessed from catchment observations, flood data for T3H005, gully mapping from Le Roux *et al*. (2015). Familiar with headwater catchment (sediment research 2012–2013).
- On site observations and recent Google images (2013) were compared to aerial imagery from 1949.
- Riparian status confirmed from vegetation data for this study.

Confidence: 3.3

MzimEWR3

- Reference condition was assessed from river zonation classification based on reach gradient Rowntree *et al*. 2000); Modification from reference condition (PES) based on assessment of drivers calibrated against assessed morphological change.
- Driver change assessed from catchment observations, flood data for T3H002, gully mapping from Le Roux *et al*. (2015).
- On site observations and recent Google images (2016) were compared to aerial imagery from 1948.

Confidence 3

MzimEWR4

- Reference condition was assessed from river zonation classification based on reach gradient Rowntree *et al*. 2000); modification from reference condition (PES) based on assessment of drivers calibrated against assessed morphological change.
- Driver change assessed from catchment observations, flood data for T3H020 (7 years of data), gully mapping from Le Roux *et al*. (2015).
- On site observations and recent Google images (2013) were compared to aerial imagery from 1948. Google images from 2005 to present show impact of the May 2013 flood.

Confidence 3

Riparian vegetation

All EWR sites

- Data collected during site visit (September 2016).
- Historical anecdotal information on the vegetation of the area (Skead, 2009).
- Vegetation Biomes, Bioregions and Vegetation Types (Mucina and Rutherford, 2006, 2012).
- 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.

Confidence: 3.5

Fish
MzimEWR1; MzimEWR3; MzimEWR4 ▪ Single site visit (September 2016). ▪ Limited historic data for river system. ▪ 2013 desktop Present Ecological State, Ecological Importance and Ecological Sensitivity (PESEIS) (DWS, 2014c). ▪ Atlas of Southern African Freshwater fishes (Scott *et al*., 2006). ▪ Reference: Fish Frequency of Occurrence (FROC) Report (Kleynhans and Louw, 2007a). Confidence: 2 **MzimEWR2** ▪ Single site visit (September 2016). ▪ Very limited historic data for river system. ▪ 2013 desktop PESEIS (DWS, 2014c) (including Fish.kml distribution maps). ▪ Atlas of Southern African Freshwater fishes (Scott *et al*., 2006). ▪ Reference: FROC Report (Kleynhans and Louw, 2007a). Confidence: 2
Macroinvertebrates
All EWR sites ▪ Single site visit (September 2016). ▪ Extensive historic data for the river system available - River Health Programme (RHP) database (1993–2013). ▪ 2013 desktop PESEIS (DWS, 2014c). Confidence: 3
Diatoms
MzimEWR1 The diatom results are based on one sample collected during September 2016 at the EWR site. Sourced data for the Tsitsa River included: ▪ A diatom assessment undertaken as part of the Feasibility Study for the Mzimvubu Water Project (DWS, 2014a) at the EWR site (T35E-05977). Two site visits were undertaken, one in April 2013 to undertake sampling for the post high flow event (moderate to high flows) and in July 2013 to undertake the low flow sampling. ▪ A diatom assessment undertaken as part of the Environmental Impact Assessment (EIA) for the Mzimvubu Water Project (DWS, 2014b) and entailed a Rapid Reserve Determination for the Tsitsa River downstream of the proposed Lalini Dam (T35L). This site is located approximately 80 km downstream of MzimEWR1 in T35L-05976 and was sampled during August 2014. Confidence: 3 **MzimEWR2; MzimEWR3; MzimEWR4** The diatom results are based on one sample collected during September 2016 at the respective EWR site. No historic or other present data could be sourced for the Thina, Kinira and Mzimvubu River. Confidence: 1.5

1.3 PURPOSE AND OUTLINE OF THIS REPORT

This report documents the results of the EcoClassification and EWR assessment for the four EWR sites situated in the Tsitsa, Thina, Kinira and Mzimvubu rivers. 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.

Chapters 3, 5, 7, and 9: EcoClassification

The EcoClassification results are provided for each EWR site.

Chapters 4, 6, 8, and 10: EWR Requirements

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

Chapter 11: Conclusions and Recommendations

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

Chapter 12: References

Appendix A: Final output results (EWR rules) for all categories

2 APPROACH

The Intermediate Ecological Reserve Methodology (IERM) (DWAF, 1999) was followed. Within that, the Level IV EcoClassification (Kleynhans and Louw, 2007a) and the Habitat Flow Stressor Response (O'Keeffe *et al.*, 2002; IWR Source-to-Sea, 2004) approach was followed. The previous biological data was not available for use during the study, as it had not been released by the consultants concerned. The previous hydraulic data was accessed and used where possible but due to the fact that benchmarks were either insufficient or lost, cross-sectional detail was insufficient and riparian markers on the cross-section were not surveyed. These minimum input requirements for the Comprehensive Ecological Reserve Methodology were therefore not met. 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): Rowntree (2013).
- Fish Response Assessment Index (FRAI): Kleynhans (2007).
- Macroinvertebrate Response Assessment Index (MIRAI): Thirion (2007).
- Riparian Vegetation Response Assessment Index (VEGRAI): Kleynhans *et al*. (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 have to be considered.

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

- Drivers (physico-chemical (i.e. water quality), 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).

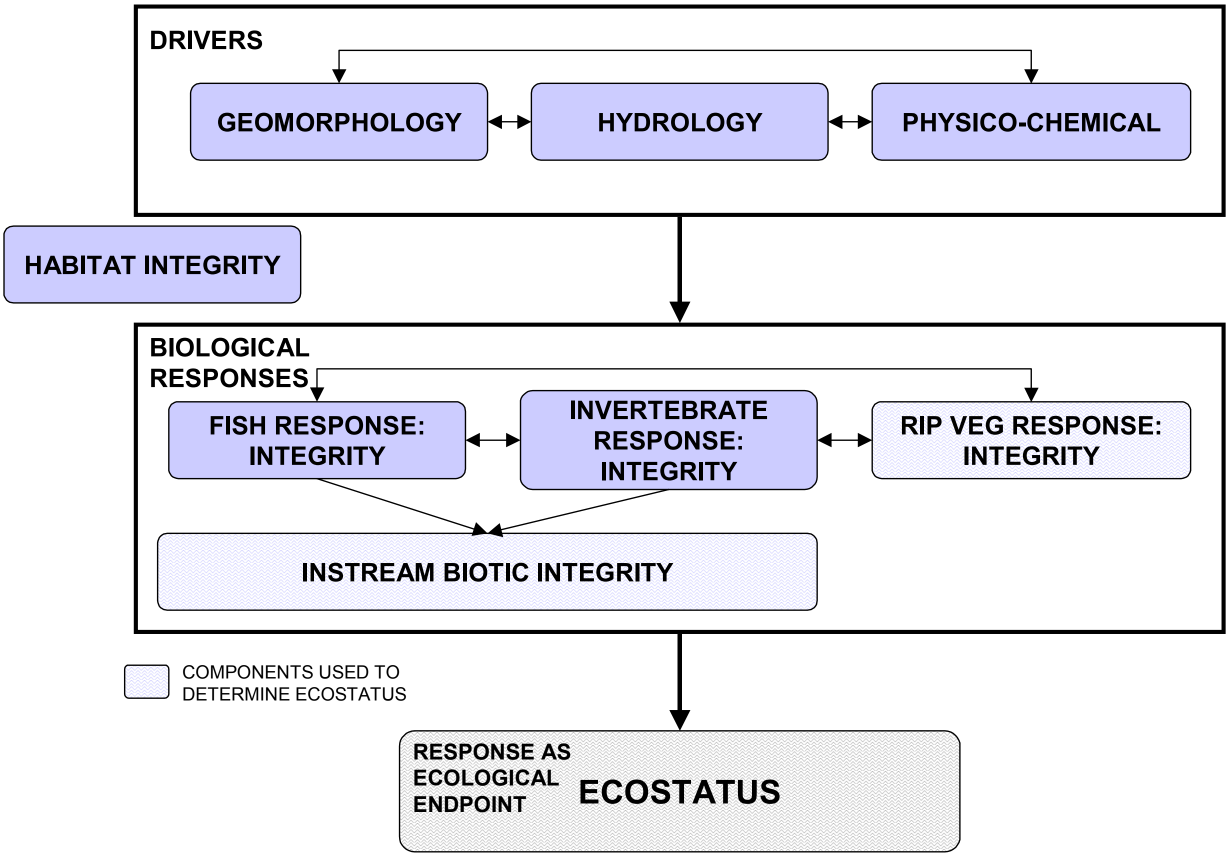

Figure 2.1 EcoStatus Level 4 determination

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 are determined for a range of ECs. The range of ECs could include the PES, REC (if different from the PES) and any other category necessary.

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 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 thereof. 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 attainability of 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, 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) was used to determine the EWRs. This method is one of the methods used to determine EWRs at a detailed level and a version of this has been built into the Revised Desktop Reserve Model (RDRM) (Hughes *et al*., 2011).

The process used to determine EWRs is summarised below:

2.2.1 Low flows: Stress flow index

The basic approach to the low flow assessment 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 the critical habitat of an indicator guild to reductions in low flows. The stress index therefore describes the habitat conditions and the associated response of fish and macroinvertebrates over a range of low flows. An integrated stress curve is developed which consists of the highest flow (fish or invertebrate) at any stress value.

The stress index involves describing the instantaneous response of habitat to flow and incorporates biotic aspects such as life-cycles, etc., relevant for the specific site and indicator group, using a 0 to 10 index, where:

- 0 – Optimum habitat with least amount of stress possible for the indicator groups (fixed at the natural maximum baseflow based on the 20% point on the monthly flow duration for the 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.

For the application of the IERM in the Mzimvubu study, stress indices were constructed by the fish and invertebrate specialists for “wettest” and “driest” months, and these replaced the default indices in the RDRM to provide higher confidence information.

2.2.2 Use of the FFHA to provide fish input into the integrated stress flow index

The Fish Flow Habitat Assessment (FFHA) (developed by Dr Kleynhans from DWS) was the primary tool used during the determination of fish stress and for setting EWR for fish for the Mzimvubu study. The FFHA is a Microsoft Excel based index that integrates hydrology, hydraulics and fish habitat requirements (for indicator species or guild) for the EWR site. The index is first populated with the relevant hydrology (separated baseflows for natural and present day flows) and hydraulics (HABFLO) of the EWR site. The hydraulic information (HydraDry and HydraWet sheets) are the primary sources of information used to determine the fish stress index. The maximum baseflows are used to fix the zero stress level (for wet and dry season). A sliding scale is then used from 0 (optimal habitat conditions) to 10 (no flow, but surface water may be present) to determine how stress on fish (habitat) changes with a change in discharge. Photographs reflecting the different flows observed at the site, as well as the fish found at specific flows (particularly data from the EWR survey), play an important role in this phase of the process and is used to guide the setting of stress levels. The FFH_DRY and FFH_WET sheets are also used during this process as they provide summarised information of specific habitat composition (such as amount of Fast Deep habitat in wetted perimeter). A specific fish species (indicator species) or guild (such as small-rheophilic) will be used as a determining factor in determining the stress index. The end result of this process is an indication of the discharge at each stress point (0, 1, 2……. to 10) as linked to fish habitat requirements.

Fish information (through use of the FFHA tool) is then used together with the macroinvertebrate stress values to generate an integrated stress curve (based on maximum discharges for each stress point).

2.2.3 Determination of the low flows: Fish process

The integrated stress index is 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 for the highest and lowest flow months. 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.

At this stage, only the instantaneous response of habitat and biota to flow reduction has been assessed. This means that the actual stress requirements AT SPECIFIC DURATIONS AND DURING SPECIFIC SEASONS to maintain the biota in a certain ecological state has not yet been assessed. The information used to determine the EC for the instream biota is considered when determining the stress required to maintain or achieve this ecological state. The stress requirement is set at a minimum for drought and conditions at the 50% or 40% (flow exceedance 50 or 60). Drought stress is always set at 5% exceedance (flow exceedance would be 95%). Any stress requirements for other percentage points can also be provided.

The FFHA is also used as tool to aid the determination of the fish flow requirements. A valuable feature of the FFHA is the use of the hydrology and associated stress index to reflect the stress level at each flow duration percentage (for natural, present day or any other flow duration, such as different flow scenarios), entered into the HYDRA sheet. The flow duration percentage and their relative discharge and interpolated fish stress is reflected separately for the dry (SCEN_DRY FLOW INPUT) and wet (SCEN_WET FLOW INPUT) seasons. The flows, at each flow duration, are also assigned to a specific EC and an overall Category for the specific scenario (present day or flow scenarios) is also indicated. These categories are determined based on the deviation from natural flows (which reflects an A Category). It is important to note that this Category is not representative of the overall fish EC which was determined through the EcoClassification process (using tools such as the FRAI (Kleynhans, 2007)). The FRAI considers various non-flow-related impacts (such as alien species, migration impacts, etc.) for all fish species at the EWR site/reach, while the FFHA reflects the status of the indicator fish species/guild based on the flow available at different flow durations. The FFHA should therefore be used with caution and not blindly applied for a specific fish EC.

The FFHA (sheets SCEN_DRY FLOW INPUT and SCEN_WET FLOW INPUT) is then used to test the response of different flows on the indicator species/guild, as reflected by the change in stress (and EC) when changed from present day, to determine the acceptable flows that is required to maintain this species/guild in a specific EC. The general assumption is that should the flows be adequate to maintain the indicator species/guild in a specific EC, the rest of the fish species (less tolerant to flow modification) should also be catered for. It must again be stressed that the FFHA is specifically based on the response of fish to flow, and does not consider non-flow related impacts. It is however a very valuable index to assist in determining the ecological water (flow) requirements.

Drs Kleynhans and Thirion have recently developed the Fish Invertebrate Flow Habitat Assessment model (FIFHA) (Kleynhans and Thirion, 2017). This index is broadly based on the FFHA approach but is mainly aimed at **monitoring** of EWR flows at EWR sites. This model is furthermore still under development (BETA version), and the secondary use of this index in setting flows during the EWR process needs to be determined and tested, before it can replace the use of the FFHA.

Fish flow related habitat requirements are interpreted according to velocity-depth classes as defined by Kleynhans (1999) and adapted to make provision for a flexible number of velocity depth classes (Birkhead, 2010). Velocity-depth classes described in this report are provided in **Table 2.3**.

Table 2.3 Fish velocity-depth classes

Acronym	Velocity-depth classes	Depth (m)	Velocity (m/s)
FD	Fast Deep fish habitat	> 0.3	> 0.3
FI	Fast Intermediate fish habitat	> 0.2 m; ≤ 0.3 m	> 0.3
FS	Fast Shallow fish habitat	> 0.1 m; ≤ 0.2 m	> 0.3

2.2.4 Determination of the low flows: Macroinvertebrate process

The EWRs for macroinvertebrates are initially expressed using macroinvertebrate flow related habitat requirements according to velocity-substrate classes (Birkhead, 2010). Velocity-substrate classes described in this report are provided in Table 2.4.

Table 2.4 Macroinvertebrate velocity-substrate classes

Acronym	Velocity-substrate classes	Substrate	Velocity (m/s)
FCS	Fast Coarse Substrate	Coarse: Cobbles, bedrock, boulders	> 0.3 – 0.6
SCS	Slow Coarse Substrate	Coarse: Cobbles, bedrock, boulders	> 0.1 – 0.3
SFS	Slow Fine Substrate	Fine: Gravel, sand, mud, fines	> 0.1 – 0.3
VFCS	Very Fast Coarse Substrate	Coarse: Cobbles, bedrock, boulders	> 0.6

EWR low flows are set for wet and dry season 60% and 95% exceedance and any additional point for maintaining an Ecological Category. This is a structured, logical process in which the specialist consults the hydraulic lookup tables, the final stress indices, and the present day flow data in order to decide on adequate discharges (within the present day range) to maintain the indicator taxa in their current condition (PES) during the relevant seasons. For example, if one were setting an EWR maintenance (60% exceedance) low flow for a February wet season and a B category river, one would first consider what type of hydraulic habitat (depth, %FCS, %VFCS) and velocity one would need to support a late-summer 'B' invertebrate community which included numerous sensitive flow-dependent taxa. With these requirements in mind, one would consult the hydraulic look-up table and select a discharge which supplied the relevant depth and width to inundate adequate MV and cobble habitat, relevant velocity range to support the FDIs, and adequate proportion of FCS and VFCS across the channel. The discharge selected would typically occur within the lower half of the 0 to 10 wet-season stress index range, which had already been set in a previous step.

In the example from the hydraulic lookup table below, one would select a discharge in the vicinity of 4m^3/s, which is associated with hydraulic habitat variables which satisfy the requirements discussed above (red circle). This discharge is linked to a wet season stress between the values of 5 and 6, which is appropriate for mid-summer maintenance conditions.

Maxdepth (m)	Avdepth (m)	Discharge (m3/s)	Width (m)	Perim (m)	AvVel (m/s)	Vel98 (m/s)	's(%) vSFS	SFS	FCS	vFCS	FFS	WET (MAR) STRESS	Description of habitat and invertebrate community
0.7	0.27	2.58	37.79	39.19	0.25	0.85	15	18	13	4	13	6	All hydraulic habitats represented, with some loss of Very Fast Flow over Coarse Sediment (VFCS). FDIs present
0.72	0.28	3.156	40.19	41.64	0.28	0.93	14	17	15	5	15		
0.74	0.29	3.838	40.92	42.42	0.32	1.07	12	15	17	7	17		
0.76	0.31	4.643	41.25	42.78	0.36	1.2	10	14	17	9	17	5	All important hydraulic habitats represented. Healthy diverse community which includes the more sensitive FDI taxa (at least 5) at A to B abundances
0.78	0.33	5.59	41.51	43.07	0.41	1.33	8	13	17	11	17		
0.8	0.35	6.698	41.76	43.36	0.46	1.5	7	12	16	15	16	4	

Each discharge value thus assigned is motivated in writing, describing the hydraulic habitat variables at that flow, and how these conditions meet the requirements of the macroinvertebrate fauna or indicator taxa for the relevant season and flow exceedance value.

2.2.5 Determination of low flows: Finalising the low flow EWR using instream biota input

Stress durations at key points (drought and maintenance) are provided by the fish and macroinvertebrate specialists for wet and dry months using available methods and tools (such as FFHA, etc.).

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 the intermediate assessment, stress-discharge relationships for the two seasons are 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 flow-durations and stress-durations for the PES categories are then assessed (by ecologists) using the default RDRM "shifts" (relative to natural and taking cognisance of present day), and are adjusted based on ecological feedback, if required. Similarly, for the alternative EC, these shifts are 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).

2.2.6 Low flow check using riparian vegetation

Once the low flow requirements have been determined for fish and macroinvertebrates, the flows are assessed to determine whether they are sufficient to support similar requirements for riparian vegetation, bearing in mind that an additional flood component is also specified for vegetation. The elevational and hydraulic niche of surveyed marginal zone vegetation is compared to what is provided by specified low flows. If the resulting response of marginal zone vegetation is expected to be within the norms of dormant and growing season dynamics, then flows are assumed to be sufficient. If resultant responses include extreme responses such as death or reproductive failure, flows are adjusted in order to alter the response to within expected ranges.

2.2.7 Low flow EWR: Data management and specialist interaction

A data-sharing facility in the form on an Excel file with Visual Basic for Applications (VBA) script has been set up (by Dr Birkhead). The following interactive spreadsheets are included:

- Stress Profiles (used for capturing the stress index).
- EWR Specialist Flow Duration Points (used for capturing EWR flows).
- High Flows and % MARs (used for capturing high flows – mostly vegetation and geomorphology).
- Natural Flow Duration Curves (FDCs) for all EWR sites (reference).
- Present Day FDCs for all EWR sites (reference).
- EWR Model FDCs (the EWR “modelled” flow assurance rules/tables captured from the EWR methodology’s output).
- High Flows (time series of EWR high flows for different ECs).
- FDC plots (plots showing stress exceedance and discharge exceedance for Natural, Present Day, PES and Alternative EC conditions based on discharge data and specialist input).

This file, together with the hydraulic lookup tables and cross-sectional profiles form the basis of the method used. A structured, stepwise, logical and traceable sequence of actions follows to set EWR flows:

- First the maximum baseflows for the wettest and driest month in their respective seasons are provided (from the baseflow separated naturalised flow data). Maximum baseflow is assigned as the stress, and the 10 stress index is a zero discharge (as discussed in **Section 2.2.1**). The hydraulic lookup tables and cross sectional profiles are then used to logically associate stress values of 1 to 9 to discharges in the zero to maximum discharge flow range, using the various hydraulic variables per discharge value (e.g., width, depth, velocity, % distribution of hydraulic biotopes specific to invertebrates) to guide this process. The set of values generated is referred to as the "stress index". At least three of the ten discharge/stress associations must be motivated in writing.
- This process is followed for wet and dry seasons, for both macroinvertebrates and fish. An "integrated stress index" is taken as the maximum stress value per discharge value (either for fish or macroinvertebrates). The final stress index or stress curve is developed by smoothing the stress/discharge curves generated by these points.
- EWR low flows are then set for wet and dry season maintenance (e.g. 60% exceedance) and drought (e.g. 95% exceedance) for the PES. This is again a structured, logical process in which specialists consult the hydraulic lookup tables, the final stress indices, and the present day flow data in order to decide on adequate discharges (within the present day range) to maintain the indicator taxa in their current condition (PES) during the relevant seasons. Each discharge value thus assigned is motivated in writing, describing the hydraulic habitat variables at that flow, and how these conditions meet the requirements of the macroinvertebrate fauna or indicator taxa for the relevant season and flow exceedance value.
- These low flow values are used to develop low flow assurance rules for wet and dry seasons by the EWR modeller. For each season (wet and dry), four plots are generated: Total Flows – Discharge vs Exceedance, Total Flows – Stress vs. exceedance, Baseflows – Discharge vs Exceedance, and Baseflows – Stress vs. Exceedance. Natural, Present Day, and PES (as generated) curves are plotted onto each plot.
- The low flow specialists then check the PES data and plots to ensure that adequate flows (and associated hydraulic habitat) have been recommended at each flow exceedance for the wet and the dry season, for the relevant PES. If not, these values are then adjusted.

2.2.8 High flows

The high flows for the Mzimvubu study are determined as follows:

- Five flood classes are defined at each site for an A category. These include within-year floods and extend to floods with a return interval of up to 1 in 5 years.
- Discharge and elevational ranges for each flood class together with their geomorphological and riparian vegetation functions/indicators are identified and tabled at each site by the relevant specialists.
- The frequency of occurrence of each flood class is identified.
- As part of defining flood classes (magnitude and frequency) nearby gauge data (usually average daily hydrology) are used to assess whether floods are realistic for that particular catchment.
- The floods are evaluated by the hydrologist to determine whether these would have occurred in the natural record. A nearby gauge with daily data is needed for this assessment, without which it is difficult to judge whether floods are realistic.

- The RDRM is currently being amended under the auspices of a Water Research Commission project, to refine the framework that the RDRM provides for dealing with the high flow component of EWR determination (at all levels of assessment). The revised high flow method is a substantial improvement, but is not yet integrated into the RDRM software. To make use of the functionality it provides, a standalone version of the high flow approach was used. The method uses the following input data: catchment area, shape, and slope; event peak (instantaneous); and frequency (intra-annual, annual, and inter-annual), to compute the hydrograph shape/duration and flow volume per event. Given the number of events (intra-annual), these are then used to compute high flow volumes corresponding to various return periods from annual (1:1) to 1:5. These are then compared to the natural high flow volumes (from the total and separated baseflows) to determine by how much natural high flow volumes should be reduced based on the required events/volumes. Finally, the individual event volumes are assigned to months in the time series, proceeding (for each year) from months with the highest to the lowest volumes. Since the software is not yet integrated into the RDRM (within SPATSIM), to make use of this improved approach it was necessary to develop code to integrate the low flow requirements (from the RDRM/SPATSIM) with the high flow requirements (from the standalone RDRM high flow model). This required adding the low (RDRM/SPATSIM) and high (RDRM/standalone) flow time series, and generating the required Reserve assurance tables (i.e. the .rul tables)

2.2.9 Final flow requirements

The RDRM produces a “report”, which documents the parameter values of variables used in the RDRM, and the EWR rules (as flow-assurance tables) for all ECs. Since the high flow analysis was performed using a standalone model (not yet integrated into the RDRM), some of the output was generated outside of the RDRM/SPATSIM.

3 ECOCLASSIFICATION: MZIMEWR1 (TSITSA RIVER)

3.1 EIS RESULTS

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

- Rare and endangered species: Prosopistomatidae (mayflies).
- Unique instream biota: Catadromous *Anguilla mossambica* and *Barbus/Enteromius anoplus*[1] complex of species.
- Biota intolerant to physico-chemical changes: Approximately 10 out of 19 invertebrate taxa.
- Macroinvertebrate taxon richness is high.
- Important migration route for eels.

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**.

Table 3.1 MzimEWR1: Present Ecological State

IHI Hydrology: PES: Instream A/B: Confidence 4; Riparian A/B Confidence 4
▪ Natural Mean Annual Runoff (nMAR): 438.0 million m^3/a. ▪ Present day Mean Annual Runoff (pMAR): 413.2 million m^3/a. The major causes for the change from reference is afforestation, urban (Maclear) and rural water use and dams supporting the urban requirements as well as some irrigation.
Physico-chemistry: PES: B (86.4%), Confidence: 2.5
Few water quality issues are present in this part of the catchment, where land use is primarily dryland farming and rural settlements. Limited irrigation occurs along the rivers. Water quality impacts are present around towns such as downstream Tsolo (T35K) and upstream at Ugie and Maclear, as well as the Waste Water Treatment Works (WWTW) at Nessie Knight Hospital, but little evidence of these issues were prevalent at the EWR site. The main water quality issues are erosion and elevated turbidity levels. Supporting information, specifically relating to diatoms are provided electronically.
Geomorphology: PES: C (67.8), Confidence: 3.6
The main concerns at this site are increased sediment flux due to catchment erosion and modification of riparian vegetation (see riparian vegetation). Sedimentation increases embeddedness of coarse substrate and reduces pool depth. Turbidity will also have increased both in terms of degree and duration. Modified riparian vegetation decreases bank stability and increases erosion, especially of lower (marginal) features. Two points to note: 1) an extreme flood event was experienced at this site in May 2013, the second highest flood since 1968, which may have caused short term channel change 2) this site is atypical of the longer reach within which it is located. The site itself has a significantly higher gradient than the reach upstream and downstream. Below the Inxu confluence the increased sediment input coupled with a low gradient results in a sand bed river.
IHI: PES: Instream B/C (79.4%) Confidence 3.1; Riparian C (72.7%) Confidence 3
Instream: The major issues relate to turbidity, sedimentation, and bank and bed modification from catchment and localised erosion which are all non-flow related impacts. **Riparian:** The major issues were linked to erosion, sedimentation and the presence of alien vegetation. These are non-flow related impacts.
Riparian vegetation: PES: C/D (59%), Confidence: 3.5
In 1862 J.S. Dobie noted of the Tsitsa: "Trees, thorny acacia etc... [mostly reference to terrestrial vegetation]... camped on bank of river to breakfast and wash... trees like those of the Tina... overlooking the valley... undulating country of old dried grass... a little Niagara in rainy season." MzimEWR1 occurs in the Grassland Biome in the East Griqualand Grassland vegetation type (Mucina and Rutherford, 2006, 2012 update). Overall one would therefore expect minimal woody cover or

[1] *Barbus anoplus*: Current IUCN rating of this species remains Least Concern, although this complex is currently under revision (should be indicated as Data Deficient: Taxonomy). It however justifies elevated current conservation status.

scattered riparian obligate trees, but a system dominated by sedges and grasses. Under reference conditions therefore the marginal zone would be dominated by hydrophilic grasses and sedges with less shading by woody species than at present, and the upper zone would be dominated by a mixture of terrestrial and hydrophilic grasses, with scattered shrubs, notably *Diospyros lyceoides*. The major impacts were the presence of alien vegetation and severe grazing pressure. **Marginal zone:** Dominated by sedges and to a lesser extent by grasses where alluvium persisted, or between gravel. *Pycreus rehmannianus* mats occurred in places and shaded areas very sparse or dominated by forbs. The right bank (RB) alluvial bars were dominated by *Pycreus* and moss (a sign of persistent shading). The left bank (LB) was closer to reference due to the lack of shading (and Wattle) and dominated by taller sedges. Dominant species throughout the zone included *Juncus effasus, Cyperus longus, Cotula coronopifolia, Persicaria lapathifolia, Pycreus rehmannianus* and *Arundinella napalensis.* Grazing pressure was severe and probably the reason for the absence of marginal woody species such as *Salix mucronata* and *Gomphostigma virgatum.* **Upper zone:** The LB was dominated by *C. longus* (sedge) and *A. napalensis* (a tall hydrophilic clumped grass), with scattered *Diospyros lyceoides* shrubs. The RB was well shaded and dominated by black and silver Wattle of all sizes, with scattered indigenous shrubs here and there. On some bars grasses formed cropped "lawns" due to grazing pressure being severe. There was also evidence of wood removal. **Macro-Channel Bank (MCB):** Dominated by terrestrial grasses on the LB and tall and dense black and silver Wattle on the RB (*Acacia dealbata* and *A. mearnsii*), with scattered indigenous and terrestrial shrub or small trees e.g., *Buddleja salvifolia, Searsia dentata, Leucosidea sericea* and *Ziziphus mucronata*. A species list is provided in the VEGRAI which is provided electronically.
Fish: PES: C (67.9%), Confidence: 3
This river system has a natural low fish species diversity, with only two indigenous species expected under natural conditions. These include the longfin eel (*Anguilla mossambica*) and chubbyhead barb (*Barbus/Enteromius anoplus*). *A. mossambica* was relatively abundant at the site during the EWR survey (September 2016), while no *B. anoplus* were sampled. The presence of one predatory alien fish species, namely largemouth bass (*Micropterus salmoides*) was also confirmed. Based on other available data for the region, it is also expected that other alien species may be present (*Cyprinus carpio* and possibly also *Oncorhynchus mykiss*). It is estimated that the *A. mossambica* population have been impacted slightly by reduced substrate quality (sedimentation causing loss of habitat for food sources), reduced pool depth (due to sedimentation), and increased turbidity reducing visibility for feeding (decreased abundance of invertebrates observed). The primary impacts on *B. anoplus* is associated with the loss of vegetation as cover and food source (due to overgrazing, trampling, erosion, alien plant encroachment) and the presence of aggressive predatory alien species (*M. salmoides* and *O. mykiss*).
Macroinvertebrates: PES: C (72.9%), Confidence: 3
Reference condition: Data were sourced from a number of data sets including DWS RHP sites as listed below: ▪ T3TSIT_NGRFL in T35A-05750 - Upstream but in the same Level 2 EcoRegion. ▪ T3TSITS-ATPK in T35A-05596 - Upstream in Level 2 EcoRegion 15.07. ▪ T3KUNT-CHL19 in T35C-05874 - On a tributary in Level 2 EcoRegion 16.04. ▪ The PESEIS project, invert data for SQ catchment T35E-5976 (DWS, 2014c). ▪ Data from the Environmental Impact Assessment (EIA) for the Mzimvubu Water Project (DWS, 2014b) at the same site. To compile the final reference state, only taxa which were either collected at the RHP or former EWR sites, or those from the PESEIS results (DWS, 2014c) with a confidence of 5 were used. **Survey:** The invertebrate community was sampled on 19 September 2016. The following biotopes were sampled: Stones (in and out of current – SIC and SOC), Gravel/Sand/Mud (GSM), and very sparse Marginal Vegetation (MV). The community was diverse with highly sensitive elements, but unnaturally low abundances in the more sensitive taxa. The high-scoring, flow-dependent taxa included perlid stoneflies, prosopistomatid, teloganodid and heptageniid mayflies and >2 baetid spp. All of these taxa require good water quality. Notably absent from the sample were the taxa with a preference for MV (e.g., Dytiscidae, Hydrophilidae, Physidae, and Coenagrionidae) and those with a preference for the water column (hemipteran taxa). The SASS[1] score was 134, with 19 taxa and an ASPT[2] of 7.1. **Indicator taxa:** Perlidae, Heptageniidae, Telagonodidae, and Psephenidae **Major non-flow related impacts included:**

- Paucity of marginal vegetation, particularly leafy marginal vegetation (e.g., *Persicaria* species) at the site, due to high grazing pressure and shading by non-indigenous woody species, and the absence of sedges on the right bank (due to shading).
- High sediment deposition due to catchment erosion. This results in deterioration of instream habitat, particularly embeddedness of cobble substrates, and high concentrations of fines on the upper surface of the cobble substrates.

1 South African Scoring System 2 Average Score Per Taxon

The PES EcoStatus is a C EC and the EcoStatus models are provided electronically. Key non-flow related impacts included:

- Sedimentation due to catchment erosion.
- Presence of alien predatory and habitat modifying fish species, erosion, and loss of vegetation.
- Alien vegetation removal, grazing pressure and wood removal.

3.3 RECOMMENDED ECOLOGICAL CATEGORY

The REC was determined based on ecological criteria only and considered the EIS, the restoration potential and attainability thereof. As the EIS was MODERATE, no improvement was required. The REC was therefore set to maintain the PES of a C EC for which EWRs will be set.

3.4 ECOCLASSIFICATION SUMMARY

The EcoClassification results are summarised in **Table 3.2**.

Table 3.2 MzimEWR1: Summary of EcoClassification results

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

4 ECOLOGICAL FLOW REQUIREMENTS: MZIMEWR1 (TSITSA RIVER)

4.1 FLOW STRESS RELATIONSHIP

A stress flow index was developed by specialists, using all available information (HABFLOW, survey results, photographs of previous flows at site, etc.). These results were input into the Habitat Flow Stressor Response-Reserve Model (HFSR-RM[2]) to generate the integrated index which consists of either the fish or invertebrate stress that requires the highest discharge for the same stress. The integrated stress curve will be smoothed in the model.

The fish and macroinvertebrate stress flow index as well as the integrated stress are provided in **Figure 4.1**. A description of the habitat and response associated with the key stress is provided in **Table 4.1** and **4.2**.

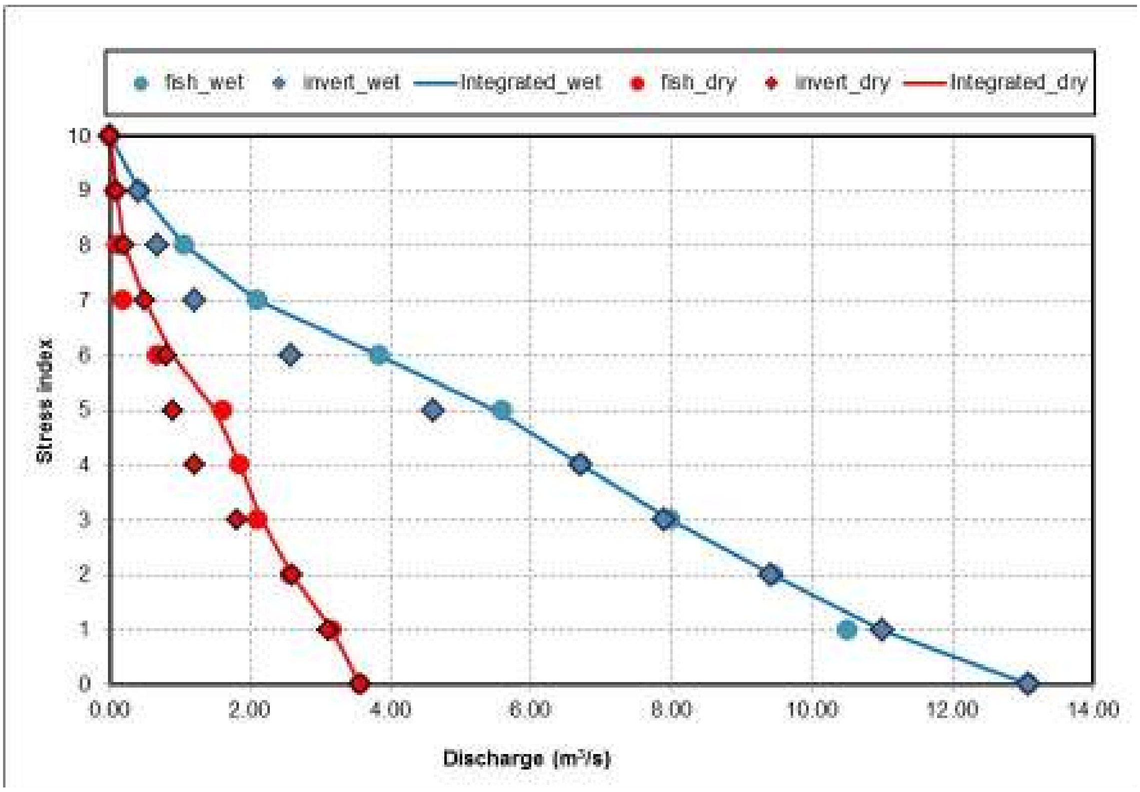

Figure 4.1 MzimEWR1: Integrated stress index for the wet and dry season

[2] This model refers to the component of the RDRM model used in detailed EWR assessment where the inputs is provided by specialists and not through the desktop application

Table 4.1 MzimEWR1: Summarised habitat/biotic responses for the dry and wet season for fish

Fish stress	Dry season		Wet season	
	Flow (m^3/s)	Habitat and stress description	Flow (m^3/s)	Habitat and stress description
0	3.57	Maximum dry season baseflow (optimal wet season habitat suitability).	13.47	Maximum wet season baseflow (optimal wet season habitat suitability).
1	3.16	Approximately 20% loss of dry season suitable habitat FS[1], FI[2] and FD[3]) for indicator species (*A. mossambica*).	10.51	Approximately 10% loss of wet season optimal habitat (FI and FD) for indicator species (*A. mossambica*).
5	1.61	Approximately 50% loss of dry season suitable habitat (FS, FI and FD) for indicator species (*A. mossambica*).	5.60	Approximately 50% loss of wet season optimal habitat (FI and FD) for indicator species (*A. mossambica*).
7	0.19	Approximately 90% loss of dry season suitable habitat (FS, FI and FD) for indicator species (*A. mossambica*).	2.1	Approximately 80% loss of wet season optimal habitat (FI and FD) for indicator species (*A. mossambica*).
9	0.08	Loss of most dry season suitable habitat (FS, FI and FD) for indicator species (*A. mossambica*). Adequate to maintain suitable habitat for survival of species (also maintaining water quality in pools).	0.42	95% Loss of most suitable fast habitat (FI and FD) for indicator species (*A. mossambica*). Average depth becoming less than suitable to allow free longitudinal movement.

1 Fast Shallow fish habitat.

2 Fast Intermediate fish habitat.

3 Fast Deep fish habitat.

Table 4.2 MzimEWR1: Summarised habitat/biotic responses for the dry and wet season for macroinvertebrates

Invertebrate stress	Dry season		Wet season	
	Flow (m^3/s)	Habitat and stress description	Flow (m^3/s)	Habitat and stress description
0	3.57	Broad range of flow velocities and diverse hydraulic habitat. All indicator taxa present.	13.01	Broad range of flow velocities and diverse hydraulic habitat. All indicator taxa present.
2	2.60	All hydraulic habitats are present at these flows. MV is sparse, particularly on the RB. Indicator taxa are present and higher scoring Flow Dependent Macroinvertebrates (FDIs) should be present but at very low abundances.	9.40	Hydraulic habitat conditions are optimal for the late summer invertebrate community. At these discharges there are high velocities across the cross section (cobble habitat). The more sensitive elements are important in maintaining habitat for the more sensitive elements of the community. Indicator taxa and higher scoring FDIs are expected (the latter at very low abundances).

Invertebrate stress	Dry season		Wet season	
	Flow (m^3/s)	Habitat and stress description	Flow (m^3/s)	Habitat and stress description
7	0.49	No flow habitats are available, and average depth is less than 0.2 m (max. 0.5 m). Velocities are moderate and there will be a small element of FCS habitat but no VFCS. Only the lower-scoring FDIs will be present.	1.20	Limited flow through cobble habitat, and areas of low to moderate velocity (0.1 - 0.5 m/s). These conditions will sustain the less sensitive taxa (scoring <10). Habitat is likely to become clogged with sediment and/or draped with fines. Indicator taxa will decline in abundances and condition.

4.2 HYDROLOGICAL CONSIDERATIONS

The wettest and driest months were identified as March and August respectively. Droughts are set at 95% exceedance (flow). The maximum baseflow for the dry season (August) is set at 3.565 m^3/s and for the wet season (March) at 13.077 m^3/s.

4.3 INSTREAM BIOTA LOW FLOW EWR REQUIREMENTS

4.3.1 PES and REC requirements

The required stress to maintain the REC of a C was determined by specialists and descriptions of key stress points (**Table 4.3**) are provided below.

A number of taxa scoring >13 were collected at MzimEWR1, however these were found in very low abundances[3] (Heptageniidae 1, Telagonodidae 1, Prosopistomatidae low A). Setting flows for the most sensitive of these, at such low abundances, is unrealistic as it would require 80 – 90% of current flow. The indicator taxa selected are perlid stoneflies, which are not the most sensitive taxa (scoring 12), but which occur in higher abundances throughout the Mzimvubu system, and have specific requirements for high velocity (>0.6 m/s), cobble habitat and clean water preferences. The secondary indicator taxon is Heptageniidae (score 13) which have similar preferences. **Note that these indicators apply to all sites.** EcoSpecs for MzimEWR1 should be set to ensure that most sensitive taxa are catered for, and that rehabilitation objectives include the restoration of suitable hydraulic habitat for these. This is very important from a regional biodiversity perspective.

Table 4.3 MzimEWR1: Habitat and instream biota description and associated stress requirements for a PES and REC: C

Dry season		Wet season	
Flow (m^3/s)	Description	Flow (m^3/s)	Description
Duration: 95% (Drought)			
0.45	**Fish:** This flow will equate to a fish stress of 6.5. Less than 20% of the habitats FS, FI and FD) will be maintained, ensuring some suitable fast habitats are available at site. Water quality in pools will also be maintained to ensure survival of *A. mossambica* during dry season droughts.	1.10	**Fish:** This flow will equate to a fish stress of 8. Less than 10% of the optimal habitat (FI and FD) will be maintained, but is should be adequate to sustain the *A. mossambica* assemblage at the site (adequate depth in fast and slow habitats).

[3] SASS5 abundances: 1 = 1; A = 2 – 10; B = 10 – 100; C = 100 – 1000 and D = >10000.

Dry season		Wet season	
Flow (m^3/s)	**Description**	**Flow (m^3/s)**	**Description**
0.65	**Macroinvertebrates:** Integrated stress of 7. No flow habitats are available, and average depth is less than 0.2 m (maximum 0.5 m). There will be a small element of FCS habitat but no VFCS.	1.06	**Macroinvertebrates:** Invertebrate stress of 7 and an integrated stress of 8. There is very limited flow in the system, and small areas of low to moderate velocity (0.1 – 0.5 m/s). These conditions will sustain the less sensitive taxa only (scoring <9). Habitat is likely to become clogged and/or draped with fines and indicator taxa will be present in very low numbers or absent.
Duration: 60%			
0.95	**Fish:** A fish stress of 5.7 is expected at these flows. More than 50% of the required fast habitats (FS, FI and FD) will be available and should be adequate to maintain the PES.	3.90	**Fish:** This flow will equate to a fish stress of 6. Approximately 40% of the optimal habitat (FI and FD) will be maintained and should be adequate to maintain the *A. mossambica* assemblage at the site in its PES.
0.90	**Macroinvertebrates:** Integrated stress of 6. Average to maximum velocity: 0.16 – 0.56 m/s. Average depth: 0.21 – 0.56 m. All hydraulic habitats present but very little VFCS present. FDIs will be present but the more sensitive taxa are unlikely to persist unless higher flows occur.	4.0	**Macroinvertebrates:** Integrated stress of 6. All hydraulic habitats are represented, with areas of moderate to high velocity flows. A diverse invertebrate community is expected, with A-B abundances in the majority of taxa. At least 5 FDI taxa should occur. A robust Category C summer community should be maintained (note: this does not necessarily include the taxa scoring >13).

The requirements are illustrated as flow duration curves in **Figures 4.2** and **4.3**.

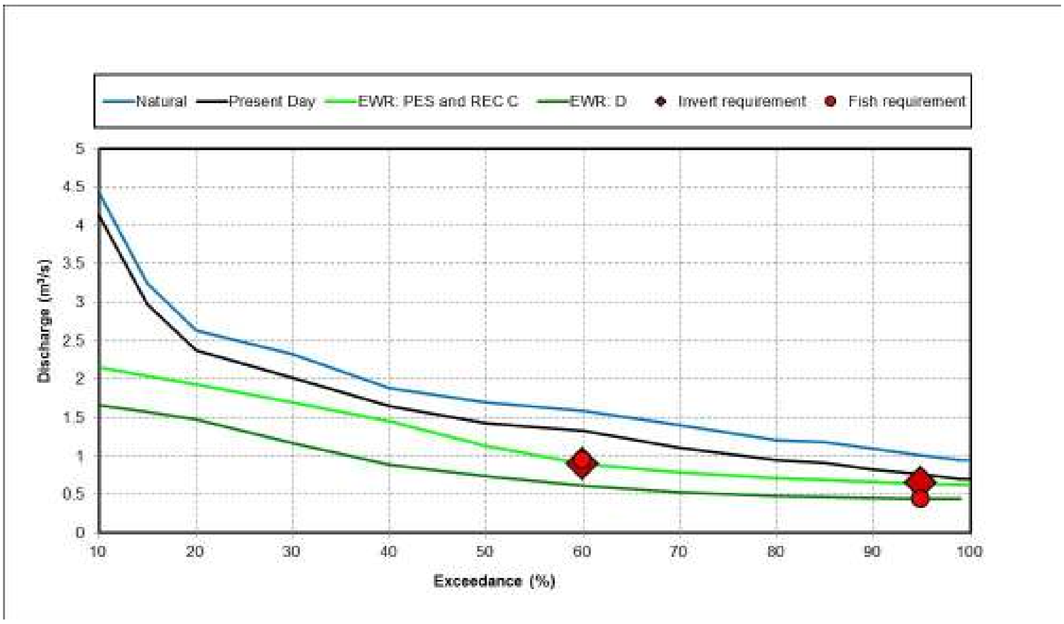

Figure 4.2 MzimEWR1: Flow duration graph for the low flows during dry season (August)

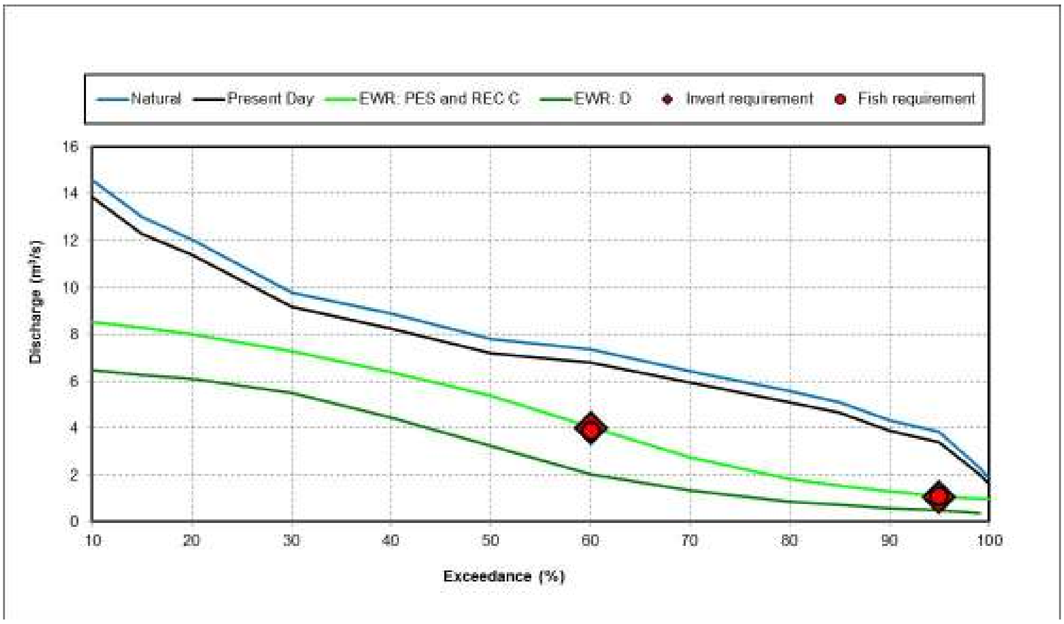

Figure 4.3 MzimEWR1: Flow duration graph for the low flows during wet season (March)

4.3.2 D Ecological Category

The REC results of a C were used in the RDRM model to derive a D EC. These were checked by specialists to determine whether these discharges and the associated hydraulic habitat would result in a D EC or whether changes to the D flow requirements are necessary. The associated habitat and responses of the D EC flow regime are provided in **Table 4.4**.

Table 4.4 MzimEWR1: Habitat and instream biota description and associated stress requirements for an EC: D

Dry season		Wet season	
Flow (m^3/s)	**Description**	**Flow (m^3/s)**	**Description**
Duration: 95% (Drought)			
0.31	**Fish:** This flow will result in an increase in fish stress from 6.5 to 6.7. At this fish stress level approximately 90% of the dry season suitable habitat (FS, FI and FD) will be lost.	0.57	**Fish:** This flow will result in an increase in fish stress from 8 to 8.7. At this fish stress level approximately 90% of the wet season suitable habitat (FI and FD) will be lost.
	Macroinvertebrates: This flow will result in an increase in integrated stress from 7 to 7.8. A large proportion of the cobble habitat will be exposed or in poor condition, and only resilient taxa will be present.		**Macroinvertebrates:** This flow will result in an increase in integrated stress from 8 to 8.5. Only lower-scoring FDIs (e.g. Simuliidae) are expected to be present.
Duration: 60%			
0.51	**Fish:** This flow will result in an increase in fish stress from 5.7 to 6.3 is expected at these flows. At this fish stress level, only 20% (compared to natural) of the dry season suitable habitat (FS, FI and FD) will be available for indicator species (*A. mossambica*).	2.69	**Fish:** This flow will result in an increase in fish stress from 6 to 6.6. At this fish stress level approximately 60% (when compared to natural) of the wet season suitable habitat (FI and FD) will be lost.
	Macroinvertebrates: This flow will result in an increase in integrated stress from 6		**Macroinvertebrates:** This flow will result in an increase in integrated stress from 6

Dry season		Wet season	
Flow (m^3/s)	Description	Flow (m^3/s)	Description
	to 6.9, which is appropriate to a dry season D category condition.		to 6.7, which is appropriate to a mid-summer D Category condition. The loss of depth and FCS and VFCS habitat results in an overall loss in invertebrate sensitivity and abundances.

4.4 VERIFICATION OF LOW FLOWS: RIPARIAN VEGETATION

Marginal zone vegetation at the site, and notably *C. longus*, was used to confirm whether specified low flow requirements for fish and invertebrates would also suffice for riparian vegetation. The sedge population had an elevational range from 0.44 to 1.44 m above the channel. This equates to a discharge range of 0.34 to 31.8 m^3/s in order to activate the lower and upper limits of the population respectively. On average, the lower limit of the sedge population will be inundated for 100% of the time with specified low flows (Total flows; blue values in flow duration table, **Table 4.5**), while the upper limit will be flooded for 1% of the time in March only (Total flows; red values in flow duration table, **Table 4.5**). A discharge of 2.3 m^3/s is required to flood about 25% of the sedge population, which according to specified low flows occurs for 60 to 80% of the time in wet season months and 5 to 20% of the time in dry season months (yellow values in flow duration table, **Table 4.5**). Similarly, a discharge of 11.6 m^3/s is required to flood about 50% of the sedge population, which according to specified low flows occurs for 15 to 30% of the time in wet season months and mostly not in dry season months using total flows (green values in flow duration table, **Table 4.5**). These flows are sufficient to facilitate survival of marginal zone vegetation in the dry season, and together with specified floods, growth and reproduction in the wet season. It is important to note that this assessment assumes that the flooding component will occur in addition to specified low flows.

Table 4.5 MzimEWR1: EWR model flow duration table for PES: C (Total flows)

	0.1	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99	99.9
Jan	30.730	30.730	17.566	14.250	11.698	9.730	8.242	7.065	4.865	4.075	3.033	2.430	1.588	1.160	0.866	0.651	0.651
Feb	31.497	31.497	27.884	17.661	16.029	14.835	12.482	9.816	6.674	4.545	3.340	2.555	1.825	1.336	1.110	0.946	0.946
Mar	36.665	36.665	22.473	17.967	15.788	14.581	10.574	8.545	7.237	5.463	3.828	2.768	2.119	1.421	1.113	0.973	0.973
Apr	17.035	17.035	9.854	8.518	8.264	7.924	7.243	6.344	5.131	3.720	2.219	1.682	1.452	1.242	1.022	0.818	0.818
May	12.306	12.306	5.398	4.986	4.192	4.145	3.607	3.131	2.501	1.804	1.329	1.086	1.003	0.919	0.824	0.780	0.780
Jun	9.635	9.635	3.970	2.984	2.979	2.875	2.263	1.920	1.367	1.039	0.942	0.857	0.792	0.755	0.721	0.671	0.671
Jul	15.932	15.932	3.798	2.785	2.447	2.418	1.785	1.615	1.275	0.972	0.865	0.791	0.746	0.717	0.668	0.581	0.581
Aug	5.294	5.294	3.517	2.949	2.045	1.927	1.685	1.433	1.121	0.894	0.782	0.707	0.680	0.655	0.640	0.630	0.630
Sep	15.126	15.126	3.803	3.066	3.047	2.627	1.618	1.533	1.214	0.839	0.707	0.669	0.587	0.503	0.456	0.456	0.456
Oct	10.564	10.564	5.762	4.011	3.968	3.682	3.062	2.712	1.496	1.166	0.987	0.836	0.791	0.754	0.704	0.618	0.618
Nov	20.424	20.424	14.479	11.731	9.925	6.475	4.912	4.095	3.159	2.166	1.341	1.114	1.023	0.916	0.815	0.772	0.772
Dec	28.084	28.084	15.462	13.459	12.990	12.564	7.908	5.857	4.154	3.081	2.498	1.321	1.158	0.970	0.734	0.457	0.457

4.5 HIGH FLOW REQUIREMENTS

Motivations are provided in **Table 4.6** and final high flow results are provided in **Table 4.7**.

Table 4.6 MzimEWR1: Identification of a range of flow events (peak discharge and frequency) to maintain a Category A Ecological State

Flood Class (Peak in m^3/s)	Frequency (events per year)	Motivation
Class I (22)	4:1	**Geomorphology:** Flood reaches onto inset bench, fines highly mobile, some cobble mobility. **Riparian vegetation:** Within year floods required to maintain water sensitive marginal zone species (non-sedges) that grow on the inset benches where soil moisture levels need to be maintained in order to promote survival and reproduction during the growing months.
Class II (32)	3:1	**Geomorphology:** Maintenance of inset bench through deposition of fine sediment, maximum sediment mobility from fine gravel to cobble. Removal of fines from rapid/rifle. **Riparian vegetation:** Floods marginal zone sedges: Wet season baseflows should inundate some of the marginal zone vegetation, so these floods are required to inundate more than that. Required to inundate marginal zone vegetation to the upper limit of *Cyperus longus*. Prevents establishment of terrestrial or alien species (some species, and at least temporarily) in the marginal zone. Provides recruitment opportunities in the marginal zone. Stimulates growth and reproduction. Prevents encroachment of marginal zone vegetation towards the active channel. Promotes accumulation of nutrients/sediment. Causes small disturbance but promotes habitat and species diversity.
Class III (140)	1	**Geomorphology:** Reaches onto flood bench; high sediment mobility through rapid; fine gravel highly mobile, cobbles mobile. Scour of pools. **Riparian vegetation:** Activates and floods upper zone riparian tufted grasses such as River Grass (*Arundinella napalensis*). 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.
Class IV(178)	1:2	**Geomorphology:** Maintains flood bench through sediment deposition; scour of sand from pools. **Riparian vegetation:** Floods lower limit of Wattles, keeps alien and terrestrial woody species from encroaching further into the channel or in-channel features. Also maintains vegetation patchiness and heterogeneity.
Class V (468)	1:5	**Geomorphology:** Covers flood bench – sand deposition; high flows continue to scour fine gravel from pools. **Riparian vegetation:** Tree line, floods to the lower limit of terrestrial tree/shrub species, prevents terrestrialisation of the riparian zone and promotes overall vegetation patchiness and heterogeneity.

The gauge T3H006 was present in the reach and used to verify high flows.

Table 4.7 MzimEWR1: The recommended number of high flow events for the A category

Flood class	Peak (m^3/s)	Flood frequency[1]	Months[2]	Duration (days)
CLASS I	22	4:1	January, April, October, November, December	2.8
CLASS II	32	3:1	January, April, October, November, December	3
CLASS III	140	1:1	February or March	3.8
CLASS IV	178	1:2	February or March	4
CLASS V	468	1:5	February or March	5.2

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

2. Based on the natural occurrence of floods. These are the months that the floods are most likely, and frequently occur in.

4.6 TOTAL EWR RESULTS

The results are provided as EWR tables (**Table 4.8** and **4.9**) and an EWR rule (**Table 4.10** and **4.11**). Detailed results are provided in the model generated report for each category for both low and total flows and provided in **Appendix A**. A summary of the results is provided in **Table 4.12**.

Table 4.8 MzimEWR1: Low flow EWR table (m^3/s) for a PES and REC: C

Month	Low flows: m^3/s	
	Drought: 95%	60%
Oct	0.70	1.17
Nov	0.82	1.54
Dec	0.73	2.09
Jan	0.87	2.83
Feb	1.11	3.42
Mar	1.06	3.95
Apr	1.02	3.12
May	0.82	1.80
Jun	0.72	1.04
Jul	0.67	0.97
Aug	0.64	0.89
Sep	0.46	0.84

Table 4.9 MzimEWR1: High flow EWR table (MCM) for a PES and REC: C

Month	Total flows (MCM[1])	Low flows (MCM)	High flows (MCM)
Oct	6.11	4.44	**1.67**
Nov	11.55	6.38	**5.17**
Dec	16.83	8.70	**8.13**
Jan	18.04	10.60	**7.45**
Feb	21.96	11.30	**10.65**
Mar	23.17	13.36	**9.81**
Apr	13.15	10.73	**2.41**

1 Million Cubic Metres

Table 4.10 MzimEWR1: Total Assurance rules (m^3/s) for PES and REC: C

Month	0.1%	1%	5%	10%	15%	20%	30%	40%	50%	60%	70%	80%	85%	90%	95%	99%	99.9%
Oct	10.56	10.56	5.76	4.01	3.97	3.68	3.06	2.71	1.50	1.17	0.99	0.84	0.79	0.75	0.70	0.62	0.62
Nov	20.42	20.42	14.48	11.73	9.93	6.48	4.91	4.10	3.16	2.17	1.34	1.11	1.02	0.92	0.82	0.77	0.77
Dec	28.08	28.08	15.46	13.46	12.99	12.56	7.91	5.86	4.15	3.08	2.50	1.32	1.16	0.97	0.73	0.46	0.46
Jan	30.73	30.73	17.57	14.25	11.70	9.73	8.24	7.07	4.87	4.08	3.03	2.43	1.59	1.16	0.87	0.65	0.65
Feb	31.50	31.50	27.88	17.66	16.03	14.84	12.48	9.82	6.67	4.55	3.34	2.56	1.83	1.34	1.11	0.95	0.95
Mar	36.67	36.67	22.47	17.97	15.79	14.58	10.57	8.55	7.24	5.46	3.83	2.77	2.12	1.42	1.11	0.97	0.97
Apr	17.04	17.04	9.85	8.52	8.26	7.92	7.24	6.34	5.13	3.72	2.22	1.68	1.45	1.24	1.02	0.82	0.82
May	12.31	12.31	5.40	4.99	4.19	4.15	3.61	3.13	2.50	1.80	1.33	1.09	1.00	0.92	0.82	0.78	0.78
Jun	9.64	9.64	3.97	2.98	2.98	2.88	2.26	1.92	1.37	1.04	0.94	0.86	0.79	0.76	0.72	0.67	0.67
Jul	15.93	15.93	3.80	2.79	2.45	2.42	1.79	1.62	1.28	0.97	0.87	0.79	0.75	0.72	0.67	0.58	0.58
Aug	5.29	5.29	3.52	2.95	2.05	1.93	1.69	1.43	1.12	0.89	0.78	0.71	0.68	0.66	0.64	0.63	0.63
Sep	15.13	15.13	3.80	3.07	3.05	2.63	1.62	1.53	1.21	0.84	0.71	0.67	0.59	0.50	0.46	0.46	0.46

Table 4.11 MzimEWR1: Total Assurance rules (m^3/s) for D EC

Month	0.1%	1%	5%	10%	15%	20%	30%	40%	50%	60%	70%	80%	85%	90%	95%	99%	99.9%
Oct	9.53	9.53	4.91	3.64	3.19	3.13	2.44	1.86	0.92	0.66	0.52	0.41	0.38	0.36	0.33	0.28	0.28
Nov	19.93	19.93	13.98	10.86	7.67	5.84	4.10	3.02	2.29	1.32	0.70	0.56	0.50	0.44	0.38	0.36	0.36
Dec	27.42	27.42	14.79	12.43	12.32	11.10	6.42	4.40	3.10	2.14	1.38	0.66	0.57	0.47	0.34	0.21	0.21
Jan	29.93	29.93	16.50	13.45	9.60	8.51	7.08	6.05	3.83	2.68	1.89	0.89	0.68	0.55	0.41	0.30	0.30
Feb	30.57	30.57	26.96	16.38	14.25	13.42	10.04	7.50	5.31	3.28	2.16	1.10	0.80	0.65	0.53	0.44	0.44
Mar	35.67	35.67	21.50	16.32	14.77	11.38	8.01	7.20	5.51	4.23	2.35	1.72	0.81	0.65	0.52	0.44	0.44
Apr	16.27	16.27	8.89	7.48	7.44	6.99	6.13	5.23	3.82	1.99	1.27	0.89	0.74	0.61	0.49	0.38	0.38
May	11.76	11.76	4.91	4.04	3.62	3.62	2.97	2.24	1.64	1.06	0.71	0.55	0.49	0.44	0.39	0.36	0.36
Jun	8.13	8.13	3.64	2.65	2.65	2.52	1.82	1.29	0.83	0.59	0.49	0.43	0.38	0.36	0.34	0.31	0.31
Jul	15.63	15.63	3.52	2.49	2.15	2.12	1.42	1.06	0.77	0.55	0.45	0.39	0.36	0.34	0.31	0.27	0.27
Aug	3.41	3.41	2.86	2.70	1.83	1.69	1.34	0.91	0.67	0.50	0.41	0.35	0.33	0.31	0.30	0.29	0.29
Sep	13.91	13.91	3.54	2.83	2.44	1.93	1.33	1.03	0.74	0.51	0.38	0.33	0.29	0.24	0.21	0.21	0.21

Table 4.12 MzimEWR1: Summary of results as a percentage of the nMAR

Site	EcoStatus	nMAR (MCM)	pMAR (MCM)	% of nMAR	Low flows (MCM)	Low flows (%)	High flows (MCM)	High flows (%)	Total flows (MCM)	Total (%)
MzimEWR1	PES; REC: C	438.04	413.16	94.32	87.43	20	48.25	11	135.68	31
	D EC				67.66	15.4	42.16	9.6	109.82	25.1

5 ECOCLASSIFICATION: MZIMEWR2 (THINA RIVER)

5.1 EIS RESULTS

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

- Unique instream biota: Catadromous *Anguilla mossambica* and *Barbus/Enteromius anoplus*[4] complex of species.
- Diversity of types and features: Riffles, rapids and pools.
- Taxon richness is high for macroinvertebrates.
- Important migration route for eels.

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**.

Table 5.1 MzimEWR2: Present Ecological State

IHI Hydrology: PES: Instream A/B Confidence 4; Riparian A/B Confidence 4
▪ nMAR: 404.5 million m^3/a. ▪ pMAR: 393.2 million m^3/a. The major reasons for the change in reference are due to some afforestation and urban (Mount Fletcher) and rural water use.
Physico-chemistry: PES: B (85.5%), Confidence: 3.5
Few water quality issues are present in this part of the catchment, where land use is primarily dryland farming and rural settlements. Sedimentation from erosion and high turbidity levels are evident. Water quality issues are exacerbated at times of low flow. Supporting information, specifically relating to diatoms is provided electronically.
Geomorphology: PES: C (71.8), Confidence: 3.6
The main concerns at this site are increased sediment flux due to catchment erosion and modification of riparian vegetation (see riparian vegetation). Catchment erosion not as severe as for the Tsitsa site. Sedimentation increases embeddedness of coarse substrate and reduces pool depth. Turbidity will also have increased both in terms of degree and duration. Modified riparian vegetation decreases bank stability and increases erosion, especially of lower (marginal) features. Site showed morphological changes since the 1940s but this could be due to natural events. The two largest events (stage height >4.5 m) were experienced in 1951 and 1996; significant floods occurred in 2011, 2013 and 2014 (2.5-3 m). The site itself was highly disturbed by boulder mining but this is unlikely to be typical of the longer reach
IHI: PES: Instream C (75.2%) Confidence 2.8; Riparian C (63.6%) Confidence 3
Instream: The major issues related to turbidity, sedimentation, and bank and bed modification from localised erosion and bed disturbance (collecting sand and rocks) as well as grazing which are all non-flow related impacts. **Riparian:** The major issues were linked to grazing. These are non-flow related impacts.
Riparian vegetation: PES: C/D (60.8%), Confidence: 3.4
In the 1850s, W.T. Brownlee wrote of the Thina: "Of the two streams which, uniting, form the Tine, the one flows for a time north and then taking a sudden turn to the east, drops into a chasm of black rocks 300 to 400 feet deep, and then rushes into a wild gorge whose sides are covered from the bottom to the summit by a dense forest of mountain bamboo [*Thamnocalamus tessellatus*]...". In 1862, J.S. Dobie wrote of the Thina 16 km southwest of Mount Frere: "...on to the valley of Tina down a steep stony hill with a succession of stone steps on the road... Valley pretty but bare and stoney... Extensive mealie fields on each side of the road with women at work" (Skead, 2009). MzimEWR2 occurs in the Savanna Biome in the Eastern Valley Bushveld vegetation type (Mucina and Rutherford, 2006, 2012 update). Overall one would therefore expect some woody influence in the riparian zone, but mostly

[4] *Barbus anoplus*: Current IUCN rating of this species remains Least Concern, although this complex is currently under revision (should be indicated as Data Deficient: Taxonomy). It however justifies elevated current conservation status.

limited to the MCB and upper zones.

Under reference conditions the marginal zone is expected to be dominated by grass and sedge cover where alluvia occur, with *G. virgatum* in rocky areas. Cover would be high in non-rocky areas and *S. mucronata* (obligate riparian tree) would be scattered or clumped along the channel. Similarly, one would expect the upper zone to be mixed woody / non-woody, with taller but scattered Cape Willow and predominantly grass species. See appendix D for a list of expected and observed species, which is provided electronically.

Under current conditions the major impacts at MzimEWR2 are overgrazing from livestock and the presence of alien plant species.

Marginal zone: Four dominant habitats occurred: 1) open bedrock with no vegetation cover (mostly on the RB, but also cobble on LB); 2) a mixture of small woody (*G. virgatum*) and non-woody (dominated by *C. longus* and *Juncus effasus*) vegetation in mixed bedrock/alluvial areas; 3) dense non-woody cover where alluvial deposits occur, dominated by *Leersia hexandra, Panicum shinzii, Phragmites australis, A. napalensis* and *Schoenoplectus corymbosus*; 4) dense non-woody cover surrounding pools, dominated by *Cynodon dactylon* (which had been grazed to form "lawns"). The zone was heavily grazed, but less so than the upper zone.

Upper zone: Comprised cobble beds (sparse) and consolidated alluvial bars (with mostly grass cover). Dominant species included *Vachellia karoo, C. dactylon, A. napalensis, G. virgatum* and *P. australis*. Most *V. karoo* were saplings colonising bars, which indicate that the flooding regime is likely intact. *C. dactylon* had been grazed to form lawns in most areas.

A species list is provided in the VEGRAI which is provided electronically.

Fish: PES: B/C (78.4%), Confidence: 3

This river system has a natural low fish species diversity, with only two indigenous species expected under natural conditions. These include the longfin eel (*A. mossambica*) and chubbyhead barb (*B./E. anoplus*). *B. anoplus* was abundant at the site during the EWR survey (September 2016), while no *A. mossambica* were sampled. It was also promising that no alien fish species were sampled during the EWR survey. Based on available data for the region, it is however expected that three alien species may be present (*M. salmoides, C. carpio* and possibly also *O. mykiss*). It is estimated that the *A. mossambica* population have been impacted slightly by reduced substrate quality (sedimentation causing loss of habitat for food sources), reduced pool depth (due to sedimentation), increased turbidity reduces visibility for feeding. The *B. anoplus* population is in a relatively healthy state and is especially supported by adequate marginal vegetation as cover (feeding and breeding habitats and protection against predation by eels and alien species). This species is at risk and is estimated to be slightly impacted by change in the natural vegetative structure as cover (due to overgrazing, trampling, erosion, alien plant encroachment) and the potential presence of aggressive predatory alien species (*M. salmoides*, and *O. mykiss*).

Macroinvertebrates: PES: C (76.6%), Confidence: 3

Reference condition: Data were sourced from a number of data sets including DWS RHP sites as listed below:

- T3THINA-N2ROA in T34K-05835 – Upstream and in same Level 2 EcoRegion. T3THINA_R316R in T34A-05415 – Well upstream in source area, in Level 2 EcoRegion.
- The PESEIS project, invert data for SQ catchment T34K-05835 (DWS, 2014c). Note that these data in themselves represent a wide variety of data sources (as recorded in the final reports).

To compile the final reference state, only taxa which were either collected at the RHP sites, or those from the EIS PES results with a rating of 5 (i.e., collected) were used.

Survey: The site was sampled on 16 September 2016. The biotopes sampled were Stones (in and out of flow), MV (in and out of flow) and GSM. The sample was diverse with highly sensitive elements, including the flow-dependent perlid stoneflies, teloganodid and heptageniid mayflies and >2 baetid spp. All of these taxa also require good water quality. The SASS score was 145, with 22 taxa and an ASPT of 6.6. The absence of expected taxa (e.g., Prosopistomatidae, Tricorythidae, and Clorocyphidae) was attributed to the impact of altered sediment flux on the cobble habitat (embeddedness of substrates and sediment drapes on the upper surfaces), inter alia.

Indicator taxa: Perlidae, and Heptageniidae

Major non-flow related impacts included:

- High sediment deposition due to catchment erosion. This results in deterioration of instream habitat, particularly embeddedness of cobble substrates, and high concentrations of fines on the upper surface of the cobble substrates.
- High grazing pressure on MV, resulting in sparse available MV.

- Slight deterioration in water quality (increased suspended solids, slight increase in nutrient levels) results in decreased light penetration and increased algal productivity. The latter affects the quality of the cobble habitat, and its availability to invertebrates.

The PES EcoStatus is a C EC and the EcoStatus models are provided electronically. Key non-flow related impacts included:

- Sedimentation due to localised disturbance and bed modification.
- Presence of alien predatory and habitat modifying fish species, erosion, and loss of vegetation.
- Overgrazing from livestock and the presence of alien plant species.

5.3 RECOMMENDED ECOLOGICAL CATEGORY

The REC was determined based on ecological criteria only and considered the EIS, the restoration potential and attainability thereof. As the EIS was MODERATE, no improvement was required. The REC was therefore set to maintain the PES of a C EC.

5.4 ECOCLASSIFICATION SUMMARY

The EcoClassification results are summarised in **Table 5.2**.

Table 5.2 MzimEWR2: Summary of EcoClassification results

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

Both the instream REC and the riparian vegetation REC is impacted on by anthropogenic impacts. The EWRs will therefore be set to maintain the REC EcoStatus of a C EC.

6 ECOLOGICAL FLOW REQUIREMENTS: MZIMEWR2 (THINA RIVER)

6.1 FLOW STRESS RELATIONSHIP

A stress flow index was developed by specialists, using all available information (HABFLOW, survey results, photographs of previous flows at site, etc.). These results were inputted into the Habitat Flow Stressor Response-Reserve Model (HFSR-RM) to generate the integrated index which consists of either the fish or invertebrate stress that requires the highest discharge for the same stress. The integrated stress curve will be smoothed in the model.

The fish and macroinvertebrate stress flow index as well as the integrated stress are provided in **Figure 6.1**. A description of the habitat and response associated with the key stress is provided in **Table 6.1** and **6.2**.

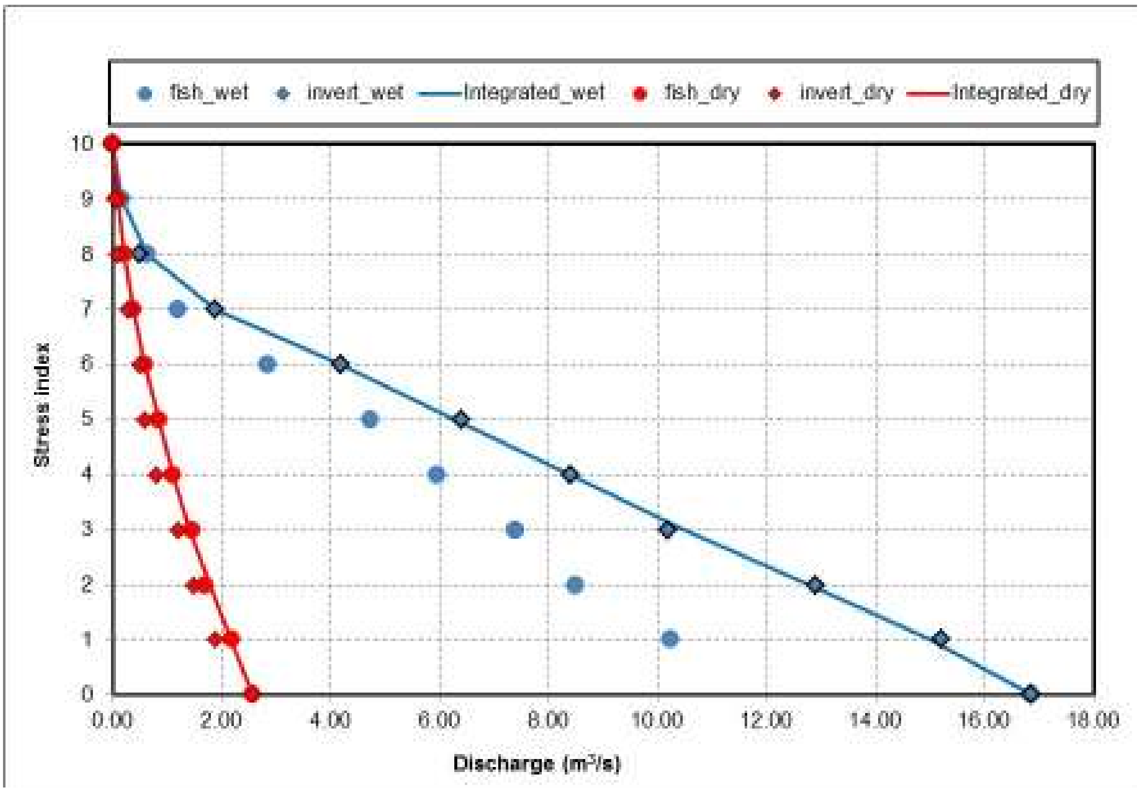

Figure 6.1 MzimEWR2: Integrated stress index for the wet and dry season

Table 6.1 MzimEWR2: Summarised habitat/biotic responses for the dry and wet season for fish

Fish stress	Dry season		Wet season	
	Flow (m^3/s)	**Habitat and stress description**	**Flow (m^3/s)**	**Habitat and stress description**
0	2.57	Optimal dry season habitats (at maximum natural dry season baseflow).	16.85	Optimal wet season habitats (at maximum natural wet season baseflow).

Fish stress	Dry season		Wet season	
	Flow (m^3/s)	Habitat and stress description	Flow (m^3/s)	Habitat and stress description
1			10.25	10% decrease from natural (maximum wet season baseflow) in FD habitats.
4	1.12	Average velocity decreases below 0.3 m/s (fast), resulting in notable change in fast habitat composition at site.		
5	0.85	Only approximate 50% of preferred habitat composition (compared to natural) will be available.	4.74	Less than 70% of optimal wet season habitat (FI and FD) available for indicator species (*A. mossambica*).
9	0.09	Loss of all dry season preferred habitats (FS, FI and FD) for indicator species (*A. mossambica*) resulting in significant deterioration in habitat conditions.	0.16	Loss of all wet season preferred habitat (FI and FD) for indicator species (*A. mossambica*), resulting in notable deterioration in habitat and hence population. Water depth also becoming critically low to allow longitudinal movement (migration) for this catadromous fish species.

Table 6.2 MzimEWR2: Summarised habitat/biotic responses for the dry and wet season for invertebrates

Invertebrate stress	Dry season		Wet season	
	Flow (m^3/s)	Habitat and stress description	Flow (m^3/s)	Habitat and stress description
2	1.50	At this depth (0.36 m) MV is inundated and the MV dependent taxa (up to 10) will be present. Velocities range from 0.3 – 1 m/s and the full range of hydraulic habitats are activated. A diverse community with all FDIs present.	12.90	Large proportion of the habitat is VFCS and all hydraulic habitats are activated. A diverse community with all FDIs expected, at abundances of A to B.
6	0.50	The hydraulic habitat is chiefly SCS with some FCS and no VFCS at this flow. The max velocity is 0.2 m/s and FDIs scoring >12 are likely to be at very low abundances or absent. As no MV is inundated, MV dependent invertebrates may be absent.	4.20	Optimal habitat (with a range of hydraulic habitats and inundated vegetation) is available for a healthy mid-summer invertebrate community, with all expected FDIs present at abundances of A-B.
8	0.09	Very shallow habitat (average depth <0.1 m) and no FCS. The max velocity of 0.2 m/s will not support those FDIs with high velocity (>0.6 m/s) preferences, and their abundances will diminish. Habitat quality is expected to deteriorate. A more resilient invertebrate community with an ASPT in the order of 5 is anticipated.	0.50	The hydraulic habitat is chiefly SCS with some FCS and no VFCS at this flow. The max velocity is 0.2 m/s and FDIs scoring >12 are likely to be at very low abundances or absent. As no MV is inundated, MV dependent invertebrates may be absent.

6.2 HYDROLOGICAL CONSIDERATIONS

The wettest and driest months were identified as February and August respectively. Droughts are set at 95% exceedance (flow). The maximum baseflow for the dry season (August) is set at 2.57 m^3/s and for the wet season (February) at 16.85 m^3/s.

6.3 INSTREAM BIOTA LOW FLOW EWR REQUIREMENTS

6.3.1 PES and REC requirements

The required stress to maintain the REC of a C was determined by specialists and descriptions of key stress points (**Table 6.3**) are provided below. The requirements are illustrated as flow duration curves in **Figure 6.2** and **6.3**.

Table 6.3 MzimEWR2: Habitat and instream biota description and associated stress requirements

Dry season		Wet season	
Flow (m^3/s)	**Description**	**Flow (m^3/s)**	**Description**
Duration: 95% (Drought)			
0.60	**Fish:** This flow will equate to a fish stress of 6. Less than 50% of preferred habitat composition (compared to natural) will be available, but adequate to maintain the present ecological status during dry season droughts.	1.0	**Fish:** This flow will equate to a fish stress of 7.4. Less than 50% optimal habitat available for indicator species and average velocity decreases below 0.3 m/s (fast) resulting in overall decrease in availability of fast habitats. Although the stress will be relatively high it should be adequate to maintain the indicator species (*A. mossambica*) population in its present state during wet season droughts.
0.50	**Macroinvertebrates:** Integrated stress of 6.5. The hydraulic habitat is chiefly SCS and slow to very slow flow over fine sediments. No MV is inundated. FDIs scoring >12 are likely to be at very low abundances or absent. MV dependent invertebrates will be present in low numbers or absent.	1.0	**Macroinvertebrates:** Integrated stress of 7.5. Sparse MV inundation, mostly in the backwater pool upstream. Velocities are largely in the moderate range and there is sparse VFCS. Indicator taxa will be present. High scoring FDIs will be present at low abundances or absent altogether.
Duration: 60%			
0.95	**Fish:** A fish stress of 4.6 is expected at these flows. Approximate 50% of preferred habitat composition (compared to natural) will be available, and the stress on indicator fish is low enough to maintain the population in a good condition (fish Category B/C).	3.0	**Fish:** This flow will equate to a fish stress of 5.9. Less than 70% of optimal wet season habitat (FI and FD) will be available for indicator species (*A. mossambica*), but the stress will be low enough to allow good habitat availability and maintain the fish population in the present state (fish Category B/C).
0.85	**Macroinvertebrates:** Integrated stress of 5. Average to maximum velocity is 0.22 - 0.74 m/s, average depth 0.2 m, all hydraulic habitats present but very little VFCS present. FDIs will be present but the more sensitive taxa are unlikely to persist unless higher flows occur. At this depth much of the cobble habitat will be exposed and not habitable by taxa such as Simuliidae, whose abundances are likely to decline.	3.0	**Macroinvertebrates:** Integrated stress of 6.5 All hydraulic habitats are represented, with areas of moderate to high velocity flows. Marginal vegetation is inundated (at depth 0.5 m). A diverse invertebrate community is expected, with A-B abundances in the majority of taxa. At least five FDI taxa and a suite of taxa with a preference for MV invertebrates should occur. A robust Category C summer community should be maintained (note: this does not necessarily include the taxa scoring >13).

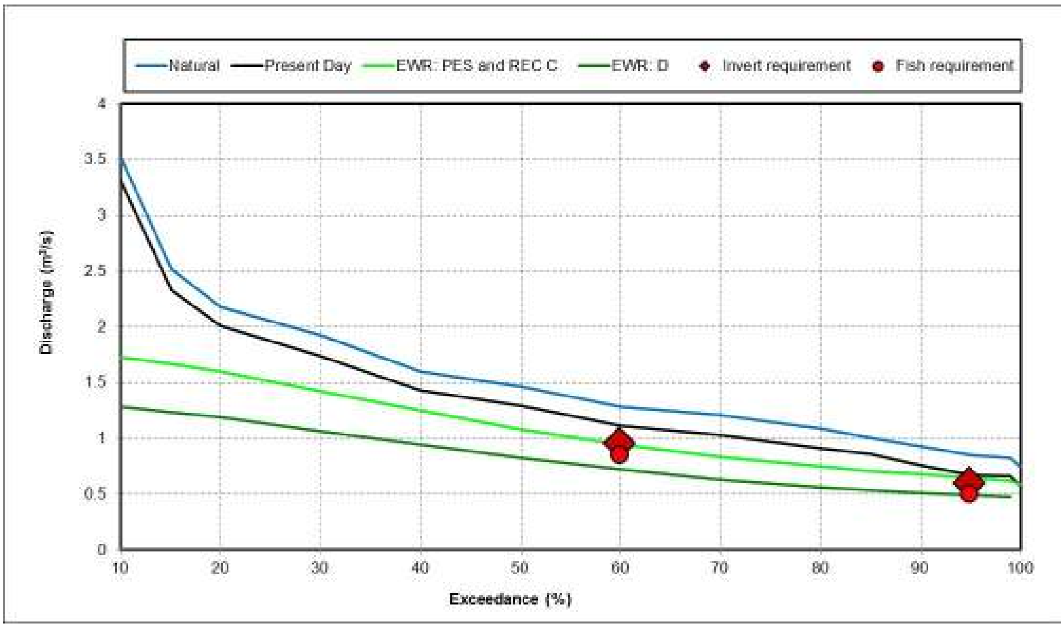

Figure 6.2 MzimEWR2: Flow duration graph for the low flows during dry season (August)

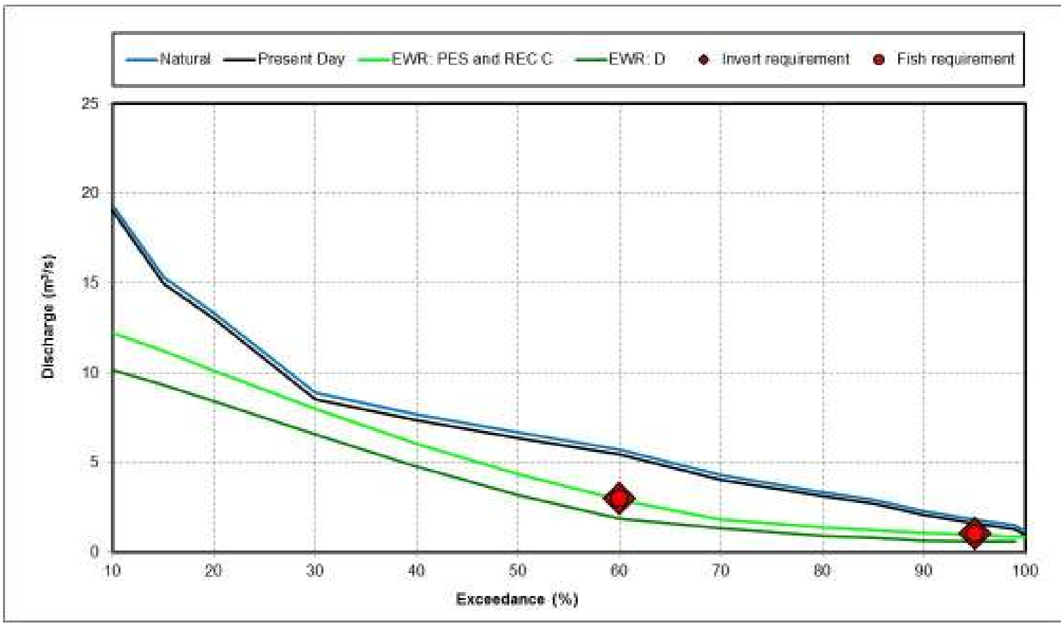

Figure 6.3 MzimEWR2: Flow duration graph for the low flows during wet season (February)

6.3.2 D Ecological Category

The REC results of a C were used in the RDRM model to derive a D EC. These were checked by specialists to determine whether these discharges and the associated hydraulic habitat would result in a D EC or whether changes to the D flow requirements are necessary. The associated habitat and responses of the D EC flow regime are provided in **Table 6.4**.

Table 6.4 MzimEWR2: Habitat and instream biota description and associated stress requirements for an EC: D

Dry season		Wet season	
Flow (m^3/s)	**Description**	**Flow (m^3/s)**	**Description**
Duration: 95% (Drought)			
0.47	**Fish:** This flow will result in an increase in fish stress from 6 to 6.6. At this fish stress level only approximately 17% (compared to natural) of the suitable dry season habitat (FS, FI and FD) will be available for the indicator species (*A. mossambica*).	0.71	**Fish:** This flow will result in an increase in fish stress from 7.4 to 7.9. Only approximately 18% (compared to natural) suitable habitat (FI and FD) will be available to the indicator species (*A. mossambica*). It can be assumed that the overall fish assemblage will decrease towards a lower EC at these flows.
0.46	**Macroinvertebrates:** This flow will result in an increase in integrated stress from 5 to 6.5. Channel width is narrow and a large proportion of cobble habitat is exposed. All MV is exposed. The invertebrate community diversity and abundance is substantially reduced.		**Macroinvertebrates:** This flow will result in an increase in integrated stress from 7.5 to 7.9. The confidence that the wet season maintenance flows will result in a D condition is very low, as these flows were set principally to maintain fish in a D EC.
Duration: 60%			
0.60	**Fish:** This flow will result in an increase in fish stress from 4.6 to 6. At this fish stress level only approximately 30% (compared to natural) of the suitable dry season habitat (FS, FI and FD) will be available for the indicator species (*A. mossambica*).	1.87	**Fish:** This flow will result in an increase in fish stress from 5.9 to 6.5. Only approximately 66% of the optimal wet season habitat (FI and FD) will be provided for the indicator fish species (*A. mossambica*), and a slight decrease towards a D EC can be expected.
	Macroinvertebrates: Integrated stress of 5 is similar to flow conditions for the PES and REC. Hydraulic habitat heterogeneity is only slightly reduced from the PES and REC and FDIs are still expected to be present, but at lower abundances.	1.89	**Macroinvertebrates:** This flow will result in an increase in integrated stress from 6.5 to 7. At this discharge, the available hydraulic habitat will still support FDIs scoring >9, however these will be in low numbers. The higher scoring taxa may disappear if these conditions persist.

6.4 VERIFICATION OF LOW FLOWS: RIPARIAN VEGETATION

Marginal zone vegetation at the site, and notably *Gomphostigma virgatum*, was used to confirm whether specified low flow requirements for fish and invertebrates would also suffice for riparian vegetation. Marginal zone vegetation had an elevational range from 0.37 to 1.21 m above the channel. This equates to a discharge range of 1.75 to 25.65 m^3/s in order to activate the lower and upper limits of the population respectively. On average, the lower limit of the marginal vegetation will be inundated for 60 – 90% of the time in summer with specified low flows, and for 10 – 30% of the time in the dry season (Total flows; blue values in flow duration table, **Table 6.5**), while the upper limit will be flooded for 1 – 5% of the time in the wet season only (Total flows; red values in flow duration table, **Table 6.5**). A discharge of 4.4 m^3/s is required to flood about 25% of the marginal vegetation, which according to specified low flows occurs for 30 to 60% of the time in wet season months and about 1% of the time in dry season months (yellow values in flow duration table, **Table 6.5**). Similarly, a discharge of 9.3 m^3/s is required to flood about 50% of marginal zone vegetation, which according to specified low flows occurs for 10 to 30% of the time in wet season months and mostly not in dry season months using total flows (green values in flow duration table,

Table 6.5). These flows are sufficient to facilitate survival of marginal zone vegetation in the dry season, and together with specified floods, growth and reproduction in the wet season. It is important to note that this assessment assumes that the flooding component will occur in addition to specified low flows.

Table 6.5 MzimEWR2: EWR Model flow duration table for PES: C (Total flows)

	0.1	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99	99.9
Jan	49.119	49.119	31.516	14.438	12.245	10.472	7.891	5.742	4.462	3.105	2.210	1.136	0.980	0.867	0.762	0.632	0.632
Feb	59.777	59.777	43.669	18.248	15.502	14.327	10.560	7.884	6.565	3.997	2.443	1.574	1.222	1.049	0.934	0.860	0.860
Mar	62.182	62.182	35.307	17.023	15.421	14.220	10.817	9.155	5.913	4.579	3.430	2.795	2.262	1.932	1.535	1.201	1.201
Apr	13.741	13.741	9.554	9.302	8.361	8.297	7.113	5.220	4.036	2.878	1.859	1.428	1.282	1.281	1.083	0.891	0.891
May	7.075	7.075	4.809	4.486	3.928	3.528	3.183	2.564	2.040	1.597	1.274	1.096	1.028	0.955	0.883	0.792	0.792
Jun	8.097	8.097	3.568	2.760	2.456	2.369	2.016	1.714	1.383	1.227	0.998	0.872	0.836	0.796	0.781	0.781	0.781
Jul	6.224	6.224	3.324	2.457	1.974	1.909	1.702	1.495	1.236	1.107	0.897	0.792	0.755	0.732	0.724	0.709	0.709
Aug	2.629	2.629	2.389	1.969	1.669	1.595	1.417	1.240	1.055	0.938	0.826	0.739	0.703	0.669	0.645	0.582	0.582
Sep	13.114	13.114	4.226	2.553	1.761	1.642	1.572	1.256	1.019	0.825	0.668	0.599	0.597	0.577	0.523	0.498	0.498
Oct	10.660	10.660	5.233	4.001	3.290	2.959	2.171	1.451	1.195	1.070	0.915	0.796	0.757	0.720	0.678	0.635	0.635
Nov	9.884	9.884	8.858	5.830	5.115	4.786	3.301	2.477	1.571	1.262	1.080	0.912	0.859	0.804	0.754	0.749	0.749
Dec	27.285	27.285	11.047	10.153	8.176	7.526	6.408	4.177	2.699	1.752	1.205	0.954	0.844	0.748	0.627	0.459	0.459

6.5 HIGH FLOW REQUIREMENTS

Motivations are provided in **Table 6.6** and final high flow results are provided in **Table 6.7**.

Table 6.6 MzimEWR2: Identification of a range of flow events (peak discharge and frequency) to maintain a Category A Ecological State

Flood Class (Peak in m^3/s)	**Frequency (events per year)**	**Motivation**
Class I (12)	4:1	**Geomorphology:** Low flows help to flush out fines from channel bed, deposition of sediment on channel margins. This is based on vegetation indicator due to poor morphological indicators but coincides with nick point on cobble bar and inundates rocky shelf on RB. **Riparian vegetation:** Within year floods required to activate and maintain lower portions of the marginal zone shrub population (the rheophytic shrub *G. virgatum*). Floods to the lower limit.
Class II (17)	2:1	**Geomorphology:** Similar function to lower flood. No good indicators so placed half way between 4 per year and 1 year flood. **Riparian vegetation:** Floods marginal zone sedges (notably *C. longus*) where they do occur. Activated the River Grass (*A. napalensis*) population (lower limit). Wet season baseflows should inundate some of the marginal zone vegetation, so these floods are required to inundate more than that. Prevents establishment of terrestrial or alien species (some species, and at least temporarily) in the marginal zone. Provides recruitment opportunities in the marginal zone. Stimulates growth and reproduction. Prevents encroachment of marginal zone vegetation towards the active channel. Causes small disturbance but promotes habitat and species diversity.
Class III (33)	1	**Geomorphology:** Inundates middle flood bench, good scour of fines from channel bed, turns cobbles, deposition on flood bench during flood recession. **Riparian vegetation:** Activates and floods sedge and reed population. Promotes reed and sedge growth but retards encroachment. 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.

Flood Class (Peak in m^3/s)	Frequency (events per year)	Motivation
Class IV (74)	1:2	**Geomorphology:** Inundates higher flood bench maintains, aids recovery after extreme floods through sediment deposition during flood recession. **Riparian vegetation:** Floods lower limit of *V. karoo* saplings and the upper limit of River Grass (*A. napalensis*). Keeps alien and terrestrial woody species from encroaching further into the channel or in-channel features i.e., important for preventing terrestrialisation and preventing invading trees from attaining height. Also maintains vegetation patchiness and heterogeneity.
Class V (466)	1:5	**Geomorphology:** Edge of upper terrace. Maintains higher morphological units, aids recovery after extreme floods through sediment deposition during flood recession. **Riparian vegetation:** Tree line, floods onto the terrace and the lower limit of terrestrial trees (*V. karoo* mostly). Prevents terrestrialisation of the riparian zone and promotes overall vegetation patchiness and heterogeneity in the active channel.

The gauge T3H005 was present in the reach and used to verify high flows.

Table 6.7 MzimEWR2: The recommended number of high flow events required for the A category

Flood Class	Peak (m^3/s)	Flood frequency[1]	Months[2]	Duration (days)
CLASS I	12	4:1	January, April, October, November, December	3.8
CLASS II	17	2:1	January, April, October, November, December	3.8
CLASS III	33	1:1	February or March	4.2
CLASS IV	74	1:2	February or March	4.5
CLASS V	466	1:5	February or March	6.2

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

2. Based on the natural occurrence of floods. These are the months that the floods are most likely, and frequently occur in.

6.6 TOTAL EWR RESULTS

The results are provided as EWR tables (**Table 6.8** and **6.9**) and an EWR rule (**Table 6.10** and **6.11**). Detailed results are provided in the model generated report for each category for both low and total flows and provided in **Appendix A**. A summary of the results is provided in **Table 6.12**.

Table 6.8 MzimEWR2: Low flow EWR table (m³/s) for a PES and REC: C

Month	Low flows: m³/s	
	Drought: 95%	60%
Oct	0.68	1.07
Nov	0.75	1.26
Dec	0.63	1.61
Jan	0.76	2.33
Feb	0.93	2.83
Mar	1.51	3.60
Apr	1.08	2.56
May	0.88	1.60
Jun	0.78	1.23
Jul	0.72	1.11
Aug	0.65	0.94
Sep	0.52	0.83

Table 6.9 MzimEWR2: High flow EWR table (MCM) for a PES and REC: C

Month	Total flows (MCM)	Low flows (MCM)	High flows (MCM)
Oct	5.22	4.01	1.21
Nov	7.13	5.49	1.64
Dec	11.46	8.15	3.31
Jan	17.81	11.22	6.59
Feb	21.88	13.31	8.57
Mar	24.03	15.77	8.25
Apr	12.17	10.79	1.38

Table 6.10 MzimEWR2: Total Assurance rules (m³/s) for PES and REC: C

Month	0.1%	1%	5%	10%	15%	20%	30%	40%	50%	60%	70%	80%	85%	90%	95%	99%	99.9%
Oct	10.94	10.94	5.66	3.87	3.29	2.93	2.08	1.45	1.20	1.07	0.92	0.80	0.76	0.72	0.68	0.64	0.64
Nov	10.51	10.51	8.86	5.98	5.17	4.79	3.30	2.48	1.53	1.26	1.08	0.91	0.86	0.80	0.75	0.75	0.75
Dec	22.94	22.94	10.98	10.15	8.10	7.52	6.29	3.87	2.70	1.65	1.21	0.95	0.84	0.75	0.63	0.46	0.46
Jan	41.12	41.12	26.79	14.44	11.62	10.47	8.00	5.67	4.46	3.07	1.80	1.14	0.98	0.87	0.76	0.63	0.63
Feb	50.06	50.06	37.19	18.52	15.50	14.46	11.51	7.88	5.53	4.00	2.33	1.42	1.16	1.05	0.93	0.86	0.86
Mar	51.91	51.91	30.26	17.13	15.42	12.44	10.70	9.10	5.91	4.48	3.51	2.66	2.01	1.81	1.54	1.20	1.20
Apr	13.74	13.74	9.55	9.30	8.37	8.34	7.11	5.02	4.04	2.77	1.86	1.39	1.28	1.28	1.08	0.89	0.89
May	7.08	7.08	4.76	4.39	3.91	3.53	3.18	2.56	2.04	1.60	1.27	1.10	1.03	0.96	0.88	0.79	0.79
Jun	8.10	8.10	3.57	2.76	2.46	2.37	2.02	1.71	1.38	1.23	1.00	0.87	0.84	0.80	0.78	0.78	0.78
Jul	6.22	6.22	3.32	2.21	1.97	1.91	1.70	1.50	1.24	1.11	0.90	0.79	0.76	0.73	0.72	0.71	0.71
Aug	2.41	2.41	2.38	1.91	1.67	1.60	1.42	1.24	1.06	0.94	0.83	0.74	0.70	0.67	0.65	0.58	0.58
Sep	13.74	13.74	4.21	2.43	1.76	1.64	1.57	1.26	1.02	0.83	0.67	0.60	0.60	0.58	0.52	0.50	0.50

Table 6.11 MzimEWR2: Total Assurance rules (m^3/s) for D EC

Month	0.1%	1%	5%	10%	15%	20%	30%	40%	50%	60%	70%	80%	85%	90%	95%	99%	99.9%
Oct	9.39	9.39	4.35	2.55	2.02	1.83	1.23	0.86	0.74	0.68	0.60	0.54	0.52	0.50	0.47	0.45	0.45
Nov	10.42	10.42	7.23	4.20	3.52	3.23	2.23	1.59	0.96	0.80	0.72	0.62	0.59	0.56	0.53	0.53	0.53
Dec	20.83	20.83	8.86	7.23	6.03	5.34	4.39	2.77	1.72	1.05	0.81	0.65	0.58	0.52	0.44	0.39	0.39
Jan	38.19	38.19	24.20	10.89	9.15	7.95	5.80	3.69	2.90	2.12	1.17	0.79	0.68	0.61	0.54	0.45	0.45
Feb	46.72	46.72	34.03	15.66	12.74	11.63	9.07	6.12	3.96	2.66	1.61	1.01	0.85	0.76	0.67	0.63	0.63
Mar	47.81	47.81	27.11	13.99	11.97	9.11	7.70	6.14	3.99	3.17	2.29	1.60	1.45	1.24	1.07	0.86	0.86
Apr	11.14	11.14	7.26	6.44	6.23	6.16	5.31	3.55	2.88	1.74	1.30	1.03	0.93	0.91	0.77	0.64	0.64
May	5.31	5.31	3.10	2.78	2.30	2.20	2.04	1.65	1.31	1.02	0.86	0.76	0.72	0.68	0.63	0.59	0.59
Jun	6.78	6.78	2.41	1.54	1.41	1.38	1.21	1.05	0.86	0.78	0.66	0.59	0.57	0.56	0.56	0.56	0.56
Jul	5.00	5.00	2.26	1.13	1.11	1.08	1.00	0.90	0.77	0.70	0.59	0.53	0.52	0.51	0.51	0.51	0.51
Aug	1.58	1.58	1.38	0.94	0.92	0.89	0.82	0.74	0.65	0.59	0.54	0.50	0.48	0.46	0.45	0.44	0.44
Sep	11.65	11.65	3.00	1.31	1.06	1.04	1.03	0.77	0.67	0.53	0.46	0.42	0.42	0.40	0.37	0.37	0.37

Table 6.12 MzimEWR2: Summary of results as a percentage of the nMAR

Site	EcoStatus	nMAR (MCM)	pMAR (MCM)	% of nMAR	Low flows (MCM)	Low flows (%)	High flows (MCM)	High flows (%)	Total flows (MCM)	Total (%)
MzimEWR2	PES; REC: C	404.51	393.23	97.21	89.24	22.1	32.41	8	121.65	30.1
	D EC				60.63	15	29.5	7.3	90.13	22.3

7 ECOCLASSIFICATION: MZIMEWR3 (KINIRA RIVER)

7.1 EIS RESULTS

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

- Rare and endangered species: Blepharoceridae and Oligoneuridae.
- Unique instream biota: Catadromous *Anguilla mossambica* and *B./E. anoplus*[5] complex of species.
- Macroinvertebrate taxon richness is high.
- Important migration route for eels.

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**.

Table 7.1 MzimEWR3: Present Ecological State

IHI Hydrology: PES: Instream A/B Confidence 4; Riparian A/B Confidence 4
▪ nMAR: 407.1 million m3/a. ▪ pMAR: 399.3 million m3/a. The major reasons for the change in reference are due to urban (Matatiele and Maluti) and rural water use and some afforestation.
Physico-chemistry: PES: B/C (81.8%), Confidence: 3.5
Extensive erosion is evident in this part of the catchment, with land use being dryland farming and extensive rural settlements. Land degradation is extensive. Some impact is seen on salt and nutrient levels. Supporting information, specifically relating to diatoms is provided electronically.
Geomorphology: PES: C (63%), Confidence: 2.9
The main concerns at this site are increased sediment flux due to catchment erosion and modification of riparian vegetation (see riparian vegetation). Catchment erosion most severe for all sites. Sedimentation increases embeddedness of coarse substrate and reduces pool depth. Frequent areas of overbank deposition; widespread sediment deposits on channel bed and bars. Turbidity will also have increased both in terms of degree and duration. Modified riparian vegetation decreases bank stability and increases erosion, especially of lower (marginal) features. The three largest events (stage height >4 m) were experienced in 1976 and 1984 and 1988; significant floods occurred every year from in 2011 to 2015 (>2 m), a smaller flood (1.2 m) in 2016.
IHI: PES: Instream C (70.1%) Confidence 2.8; Riparian C (68.1%) Confidence 3
Instream: The major issues related to turbidity, catchment sedimentation and grazing which is non-flow related impacts. Riparian: The major issues were linked to erosion, sedimentation and substrate exposure (grazing).
Riparian vegetation: PES: C/D (60.4%), Confidence: 3.2
MzimEWR3 occurs in the Grassland Biome in the East Griqualand Grassland vegetation type (Mucina and Rutherford, 2006, 2012 update). Overall one would therefore expect minimal woody cover or scattered riparian obligate trees, but a system dominated by sedges and grasses, with some herbaceous obligates. Under reference conditions, the marginal zone would be dominated by hydrophilic grasses and sedges, but the site has major bedrock influence so large areas of sparse or no vegetation cover are expected to be natural, with scattered *G. virgatum* shrubs between rocky, rheophytic areas. The upper zone would be dominated by a mixture of terrestrial and hydrophilic grasses, with scattered shrubs, notably *D. lyceoides* and *V. karoo*. Denuded areas where bedrock dominates are also expected and cobble and gravel would support larger *G. virgatum* individuals. The infrequently flooded MCB would likely be dominated by terrestrial grasses with *V. karoo* perhaps forming thickets.

[5] *Barbus anoplus*: Current IUCN rating of this species remains Least Concern, although this complex is currently under revision (should be indicated as Data Deficient: Taxonomy). It however justifies elevated current conservation status.

Under current conditions the major impacts at the site are overgrazing and the presence of terrestrial tree species within the riparian zone.
Marginal zone: Dominant habitats in the marginal zone were sand/coble/gravel with scattered sedges, fine sediments with *Isolepis cernua* var. *cernua* and cobles in the water with *G. virgatum*. Vegetation cover was sparse and clumped with severe grazing pressure. Dominant species included *C. longus, C. dactylon, G. virgatum* and *I. cernua* var. *cernua*. More grass cover is expected under natural conditions, but limited to alluvial deposits. *Persicaria* species and *S. mucronata* were absent.
Upper zone: Mostly coble and unconsolidated alluvium trapped in between. *C. dactylon* was common but sparse and recent *V. karoo* saplings occurred frequently. *Eragrostis* species and *C. longus* also occurred but were scattered and sparse. Grazing and browsing pressure was severe. *S. mucronata* was absent.
MCB: Dominated by terrestrial grasses and *V. karoo* and aerial data show an increase over time from 2010 to 2016.
A species list is provided in the VEGRAI which is provided electronically.

Fish: PES: C (62.7%), Confidence: 3

This river system has a natural low fish species diversity, with only two indigenous species expected under natural conditions. These include the longfin eel (*A. mossambica*) and chubbyhead barb (*B./E. anoplus*). The presence of *Anguilla mossambica* was confirmed at the site during the EWR survey (September 2016), while no *B. anoplus* were sampled (but still expected to be present in reach). The presence of two alien fish species, namely largemouth bass (*M. salmoides*) and common carp (*C. carpio)* was also confirmed. It is estimated that the *A. mossambica* population have been impacted notably by reduced substrate quality (sedimentation causing loss of habitat for food sources), reduced pool depth (due to sedimentation), increased turbidity reduces visibility for feeding and also impact negatively on food sources. The primary impacts on *B./E. anoplus* is associated with the loss of vegetation as cover and food source (due to overgrazing, trampling, erosion, alien plant encroachment, increased turbidity reducing aquatic vegetation growth) and especially the presence of aggressive predatory alien species (*M. salmoides*). The bottom feeding alien *C. carpio* further increase turbidity in an already turbid river, reducing visibility and altering soft bed substrates.

Macroinvertebrates: PES: C (74.7%), Confidence: 2.5

Reference: Data were sourced from a number of data sets including DWS RHP sites as listed below:

- T3KINI_GWEIR T33E-05213 – Upstream, and in Level 2 EcoRegion 16.08.
- T3KIN-MABUA T33A-04892 – Upstream, and in Level 2 EcoRegion15.07).
- T3MZIM_N2ROA T33H-05680 – Downstream of Kinira/Mzimvubu confluence, in Level 2 EcoRegion 16.04)
- The PESEIS project, invert data for SQ catchment T33G-05395 (DWS, 2014c). These in turn are sourced from numerous data sets (as per the final report).

To compile the final reference state, only taxa which were either collected at the RHP sites, or those from the EIS PES results with a rating of 5 (previously collected) were used.
Survey: The invertebrate community was sampled on 20 September 2016. The following biotopes were sampled: Stones (in and out of current), GSM, and MV. The community was diverse with highly sensitive elements, but unnaturally low abundances in the more sensitive taxa. The high-scoring, flow-dependent taxa included blepharocerid dipterans (usually only collected in mountain streams), perlid stoneflies, oligoneurid, prosopistomatid, heptageniid, teloganodid and baetid mayflies. It is important to note that for the first five of these taxa, only a single individual was collected. All of these taxa are flow dependent, have a preference for clean cobble habitats, and require good water quality. Numerous expected taxa were absent from the sample, e.g., Dytiscidae, Hydrophilidae, Physidae, Coenagrionidae, and those with a preference for the water column (hemipterans). The SASS score was 153, with 22 taxa and an ASPT of 7.1.
Indicator taxa: Perlidae, and Heptageniidae
Major non-flow related impacts included:

- High sediment deposition in due to catchment erosion. Associated deterioration of instream habitat, particularly embeddedness of cobble substrates, and high concentrations of fines on the upper surface of the cobble substrates, and along the stream margins.
- Presence of the alien fish Carp and Bass at the site. These species prey on many different invertebrate taxa and will definitely impact abundances of various taxa. In addition, the carp's feeding behaviour causes high turbidity in the river which impacts on both physical and hydraulic habitat.
- High grazing pressure on marginal vegetation, resulting in influx of woody species on the banks, and reduction in the MV habitat.
- Slight deterioration in water quality (increased suspended solids, slight increase in nutrient levels) results in decreased light penetration and increased algal productivity. The latter affects the quality of the cobble habitat, and its availability to invertebrates.

The PES EcoStatus is a C EC and the EcoStatus models are provided electronically. Key non-flow related impacts included:

- Sedimentation due to catchment erosion.
- Alien predatory and habitat modifying fish species, and loss of vegetation due to grazing.
- Overgrazing and the presence of terrestrial tree species within the riparian zone as well as browsing pressure.
- Targeted wood removal.

7.3 RECOMMENDED ECOLOGICAL CATEGORY

The REC was determined based on ecological criteria only and considered the EIS, the restoration potential and attainability thereof. As the EIS was MODERATE, no improvement was required. The REC was therefore set to maintain the PES of a C EC.

7.4 ECOCLASSIFICATION SUMMARY

The EcoClassification results are summarised in **Table 7.2**.

Table 7.2 MzimEWR3: Summary of EcoClassification results

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

Both the instream REC and the riparian vegetation REC is impacted on by anthropogenic impacts. The EWRs will therefore be set to maintain the REC EcoStatus of a C EC.

8 ECOLOGICAL FLOW REQUIREMENTS: MZIMEWR3 (KINIRA RIVER)

8.1 FLOW STRESS RELATIONSHIP

A stress flow index was developed by specialists, using all available information (HABFLOW, survey results, photographs of previous flows at site, etc.). These results were inputted into the Habitat Flow Stressor Response-Reserve Model (HFSR-RM) to generate the integrated index which consists of either the fish or invertebrate stress that requires the highest discharge for the same stress. The integrated stress curve will be smoothed in the model.

The fish and macroinvertebrate stress flow index as well as the integrated stress are provided in **Figure 8.1**. A description of the habitat and response associated with the key stress is provided in **Table 8.1** and **8.2**.

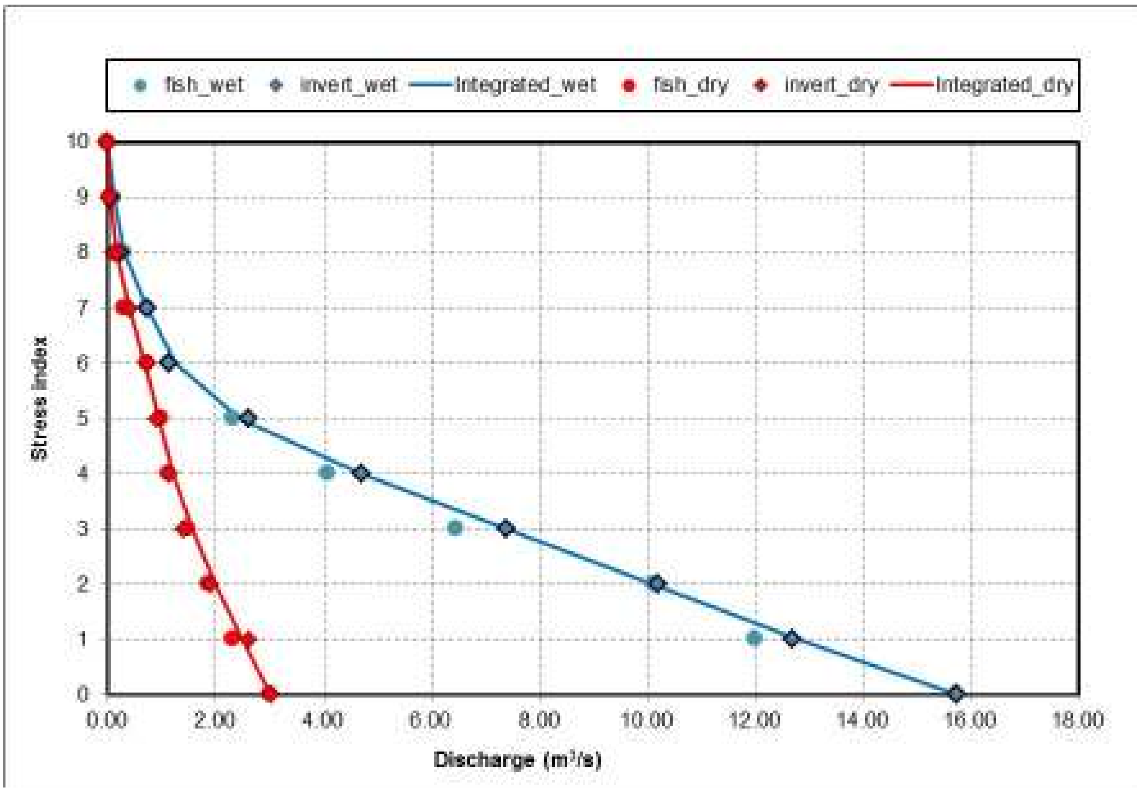

Figure 8.1 MzimEWR3: Integrated stress index for the wet and dry season

Table 8.1 MzimEWR3: Summarised habitat/biotic responses for the dry and wet season for fish

Fish stress	Dry season		Wet season	
	Flow (m^3/s)	**Habitat and stress description**	**Flow (m^3/s)**	**Habitat and stress description**
0	3.01	Optimal dry season habitats (at maximum natural dry season baseflow).	15.74	Optimal wet season habitats (at maximum natural wet season baseflow).

Fish stress	Dry season		Wet season	
	Flow (m^3/s)	Habitat and stress description	Flow (m^3/s)	Habitat and stress description
1			12.01	20% decrease in availability of preferred habitat (compared to natural) of indicator species (*A. mossambica*).
3	1.48	FD habitats decrease with approximately 25% from natural dry season baseflow conditions.		
5			2.33	Less than 60% optimal wet season habitat (FI and FD) available for indicator species (*A. mossambica*).
7	0.30	Loss of all FD habitats and less than 20% suitable habitats will be available.		
9	0.05	No preferred habitat (fast) will be available (for indicator species) and depth limits free longitudinal movement of *A. mossambica*.	0.10	Loss of all wet season preferred habitats (FI and FD) for indicator species (*A. mossambica*).

Table 8.2 MzimEWR3: Summarised habitat/biotic responses for the dry and wet season for invertebrates

Invertebrate stress	Dry season		Wet season	
	Flow (m^3/s)	Habitat and stress description	Flow (m^3/s)	Habitat and stress description
0	3.01		15.74	
2	1.90	A maximum depth of almost 0.5 m inundates MV. All hydraulic habitats are present. Five or more MV dependent invertebrate taxa are expected. Indicator taxa (Perlidae, and Heptageniidae) are present.	10.20	All hydraulic habitats present, MV inundated, and very high velocity flows over cobbles in areas. A well balanced invertebrate community is expected with an ASPT between 6 and 7. All FDIs present, those scoring >12 at low abundances. These discharges will clear fines and shift interstitial sediments, thus maintaining habitat
6	0.72	Very little VFCS available, and habitat condition deteriorates. More sensitive FDIs will be reduced in abundance or absent. No MV inundated at this discharge. MV invertebrate taxa are likely to present in low abundances, or absent.	1.14	Discharge at which the site was sampled. MV is sparse and cobble habitat in a poor condition (heavily silted). Few MV invertebrates are present and FDIs are present only at low abundances.
8	0.10	Minimal FCS and no MV habitat available. Habitat condition will be poor. Community shifts in favour of the more resilient invertebrate taxa and ASPT will be reduced (5 or less). Indicator taxa will be in low numbers or absent.	0.22	Minimal FCS and no MV habitat available. Small areas of flow > 0.3 m/s. Habitat condition will be poor. Community shifts in favour of the more resilient invertebrate taxa and ASPT will be reduced (5 or less). Indicator taxa will be in low numbers or absent.

8.2 HYDROLOGICAL CONSIDERATIONS

The wettest and driest months were identified as February and September respectively. Droughts are set at 95% exceedance (flow). The maximum baseflow for the dry season (September) is set at 3.013 m^3/s and for the wet season (February) at 15.744 m^3/s.

8.3 INSTREAM BIOTA LOW FLOW EWR REQUIREMENTS

8.3.1 PES and REC requirements

The required stress to maintain the REC of a C was determined by specialists and descriptions of key stress points (**Table 8.3**) are provided below. The requirements are illustrated as flow duration curves in **Figure 8.2** and **8.3** in **Section 8.6**.

Table 8.3 MzimEWR3: Habitat and instream biota description and associated stress requirements

Dry season		Wet season	
Flow (m^3/s)	**Description**	**Flow (m^3/s)**	**Description**
Duration: 95% (Drought)			
0.30	**Fish:** This flow will equate to a fish stress of 7. All FD habitats will be absent from the site but other fast habitats (FS and FI) will be adequate to maintain the present ecological status of *A. mossambica* during dry season droughts.	1.10	**Fish:** This flow will equate to a fish stress of 6. FD habitat availability will decrease below 50%, less than 20% but overall fast habitats (FS, FI and FD) should be adequate to sustain indicator species. Although the stress will be relatively high it should be adequate to maintain the indicator species (*A. mossambica*) population in its present state during wet season droughts.
0.30	**Macroinvertebrates:** Integrated stress of 7.3. An associated maximum depth of 0.3 m, and no MV is inundated. Habitat is dominated by SCS and SFS. FDIs and taxa with a preference for MV are likely to decline in abundance and higher scoring taxa may be absent.	1.16	**Macroinvertebrates:** Integrated stress close to 6. MV is sparse and cobble habitat in a poor condition (heavily silted). Few MV invertebrates are present and FDIs are present only at low abundances.
Duration: 60%			
0.70	**Fish:** A fish stress of 6 is expected at these flows. Less than 10% FD habitats will be available but adequate FS and FI will be maintained to ensure that indicator fish population remains in present conditions (Category C).	3.40	**Fish:** This flow will equate to a fish stress of 4.5. A 40% decrease (from natural wet season baseflow) in preferred wet season habitats (FI and FD) will occur at this flow. Adequate velocities and depth will however be maintained to ensure good habitat quality and free longitudinal and lateral movement of the indicator fish species (*A. mossambica*).
0.70	**Macroinvertebrates:** Integrated stress of 5.9. VFCS present but sparse. Maximum depth (0.36 m) just adequate to inundate MV, but this provides poor habitat. Indicator taxa are expected to be present but more sensitive FDIs will be in low numbers or absent.	3.50	**Macroinvertebrates:** Integrated stress in the order of 4.8. All hydraulic habitats present and abundance and adequate depth (0.6 m) to inundate MV. The community will be similar to that collected in September 2016, due to the additional availability and quality of MV and cobble habitat.

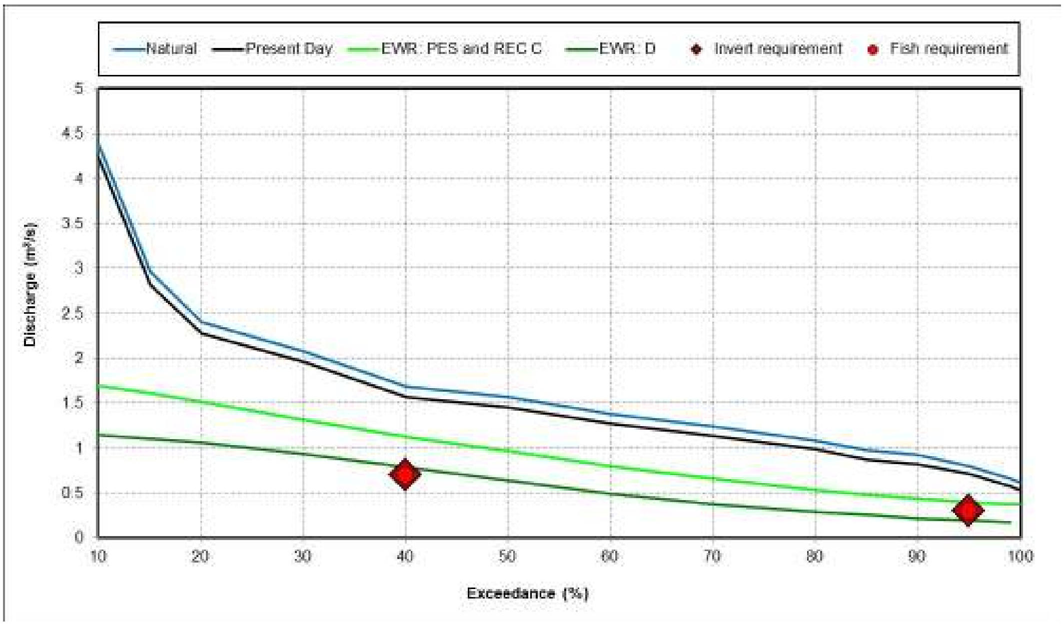

Figure 8.2 MzimEWR3: Flow duration graph for the low flows during dry season (September)

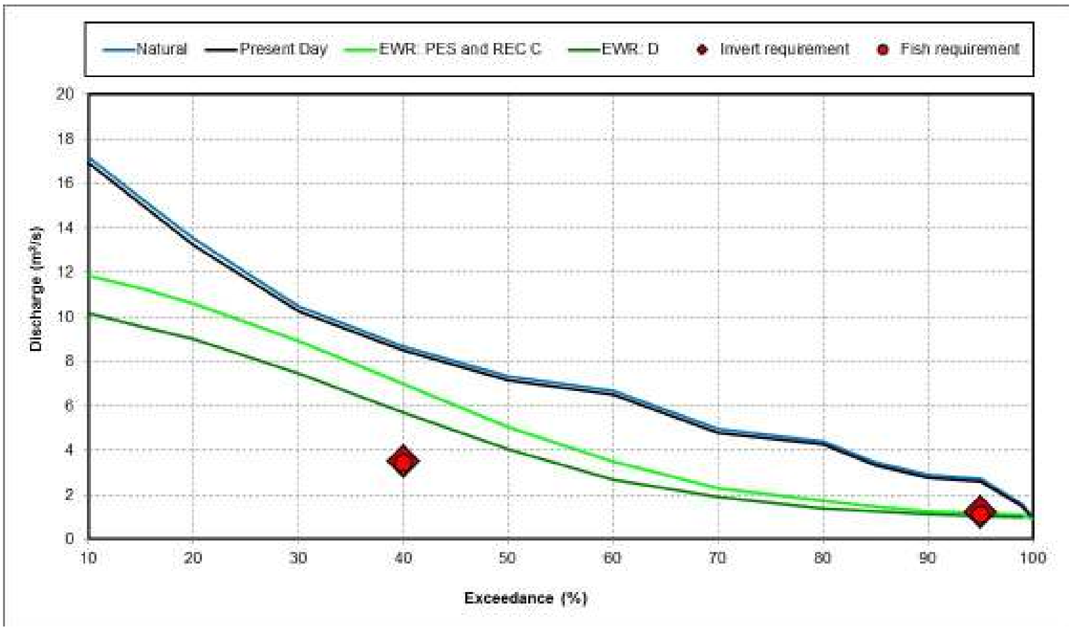

Figure 8.3 MzimEWR3: Flow duration graph for the low flows during wet season (February)

8.3.2 D Ecological Category

The REC results of a C were used in the RDRM model to derive a D EC. These were checked by specialists to determine whether these discharges and the associated hydraulic habitat would result in a D EC or whether changes to the D flow requirements are necessary. The associated habitat and responses of the D EC flow regime are provided in **Table 8.4**.

Table 8.4 MzimEWR3: Habitat and instream biota description and associated stress requirements for an EC: D

Dry season		Wet season	
Flow (m^3/s)	**Description**	**Flow (m^3/s)**	**Description**
Duration: 95% (Drought)			
0.25	**Fish:** This flow will result in an increase in fish stress from 7 to 7.3. Results in a slight decrease in suitable habitats (FS, FI and FD), but adequate to probably decrease the overall suitability towards a lower EC.	0.95	**Fish:** This flow will result in an increase in fish stress from 6 to 6.4. At this stress level, less than 50% optimal wet season habitat (FI and FD) will be available for indicator species (*A. mossambica*).
	Macroinvertebrates: This flow will result in an increase in integrated stress from 7.3 to 7.9. The major difference relative to the PES and REC condition is in the loss of VFCS, FCS and MV. The invertebrate community diversity and abundance is expected to be substantially reduced relative to the C PES and REC.		**Macroinvertebrates:** This flow will result in an increase in integrated stress from 6 to 6.8. While habitat availability is low, there are small elements of moderate velocity habitat still remaining and some FDIs will persist.
Duration: 60%			
0.45	**Fish:** This flow will result in an increase in fish stress from 6 to 6.6. Almost all FD habitats will be absent and less than 40% suitable habitat will be maintained for the indicator fish species (*A. mossambica*).	2.46	**Fish:** This flow will result in an increase in fish stress from 4.5 to 4.9. At this stress level, less than 60% optimal wet season habitat (FI and FD) will be available for indicator species (*A. mossambica*).
	Macroinvertebrates: This flow will result in an increase in integrated stress from 5.9 to 6.8. While habitat availability is low, there are small elements of moderate velocity habitat still remaining and some FDIs will persist. The confidence that the wet season maintenance flows will result in a D condition is low as these flows were set principally to maintain fish in a D EC.	2.50	**Macroinvertebrates:** This flow will result in an increase in integrated stress from 4.8 to 6.5. The major difference between this discharge and the wet season PES and REC discharges (3.5 m^3/s) is in the loss of inundation of MV. Taxa with a preference for this biotope may relocate aerially, or decline in abundances or presence. The available hydraulic habitat will still support FDIs scoring >9, however these will be in low abundances.

8.4 VERIFICATION OF LOW FLOWS: RIPARIAN VEGETATION

Marginal zone vegetation at the site, and notably *G. virgatum* and *C. longus*, was used to confirm whether specified low flow requirements for fish and invertebrates would also suffice for riparian vegetation. Marginal zone vegetation had an elevational range from 0.41 to 1.21 m above the channel. This equates to a discharge range of 1.39 to 23.01 m^3/s in order to activate the lower and upper limits of marginal vegetation respectively. On average, the lower limit of the sedge population will be inundated for 60 – 95% of the time with specified low flows in the wet season and 40 – 50% of the time in the dry season (Total flows; blue values in flow duration table, **Table 8.5**), while the upper limit will not be flooded at any time. A discharge of 3.9 m^3/s is required to flood about 25% of the marginal zone vegetation, which according to specified low flows occurs for 30 to 50% of the time in wet season months and 0 to 5% of the time in dry season months (yellow values in flow duration table, **Table 8.5**). Similarly, a discharge of 8.2 m^3/s is required to flood about 50% of the marginal zone vegetation, which according to specified low flows occurs for 1 to 30% of the time in wet season months and mostly not in dry season months using total flows (green values in flow duration table, **Table 8.5**). These flows are sufficient to facilitate survival of marginal zone vegetation in the dry season, and together with specified floods, growth and reproduction in the wet season. It is important to note that this assessment assumes that the flooding component will occur in addition to specified low flows.

Table 8.5 MzimEWR3: EWR Model flow duration table for PES: C (Total flows)

	0.1	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99	99.9
Jan	14.463	14.463	11.923	10.001	9.021	8.414	6.875	5.209	3.827	2.592	1.847	1.334	1.144	0.927	0.783	0.780	0.780
Feb	12.589	12.589	12.294	11.842	11.258	10.549	8.838	6.901	4.941	3.378	2.235	1.663	1.426	1.230	1.152	0.889	0.889
Mar	18.645	18.645	13.800	10.885	10.725	10.720	9.464	7.294	5.341	3.628	2.964	2.312	2.057	1.763	1.476	1.222	1.222
Apr	12.146	12.146	8.858	7.359	7.358	7.200	6.307	5.245	3.720	2.701	1.956	1.487	1.334	1.125	0.909	0.840	0.840
May	6.891	6.891	5.094	4.723	4.722	4.673	3.563	2.874	2.190	1.653	1.294	0.939	0.844	0.755	0.754	0.754	0.754
Jun	6.360	6.360	4.169	3.124	3.123	3.009	2.549	2.095	1.590	1.247	0.946	0.737	0.712	0.712	0.711	0.711	0.711
Jul	4.633	4.633	3.444	2.801	2.670	2.626	2.274	1.948	1.440	1.109	0.867	0.701	0.699	0.698	0.697	0.697	0.697
Aug	4.920	4.920	3.341	2.549	2.498	2.422	1.929	1.567	1.158	0.996	0.789	0.642	0.605	0.604	0.604	0.604	0.604
Sep	2.968	2.968	2.877	2.739	2.559	2.373	1.956	1.531	1.195	0.971	0.763	0.588	0.514	0.450	0.396	0.365	0.365
Oct	6.505	6.505	4.195	3.282	3.256	3.173	2.423	1.937	1.490	1.171	0.894	0.676	0.609	0.542	0.502	0.501	0.501
Nov	7.878	7.878	5.096	3.767	3.765	3.760	2.998	2.360	1.833	1.410	1.119	0.869	0.732	0.706	0.706	0.706	0.706
Dec	8.959	8.959	7.459	6.576	6.519	6.309	4.954	3.815	2.426	1.652	1.202	0.886	0.745	0.607	0.494	0.468	0.468

8.5 HIGH FLOW REQUIREMENTS

Motivations are provided in **Table 8.6** and final high flow results are provided in **Table 8.7**.

Table 8.6 MzimEWR3: Identification of a range of flow events (peak discharge and frequency) to maintain a Category A Ecological State

Flood Class (Peak in m^3/s)	Frequency (events per year)	Motivation
Class I (19)	4:1	**Geomorphology:** Edge of grassy bench on RB, flushing of fine sediment from edge habitat. **Riparian vegetation:** Within year floods required to activate and maintain lower portions of the marginal zone shrub population (the rheophytic shrub *G. virgatum*). Floods to the upper limit.
Class II (48)	2:1	**Geomorphology:** Back of grassy bench, break of slope on LB; deposition of fine sediment on benches. **Riparian vegetation:** Floods marginal zone sedges (notably *C. longus*): Wet season baseflows should inundate some of the marginal zone vegetation, so these floods are required to inundate more than that. Prevents establishment of terrestrial or alien species (some species, and at least temporarily) in the marginal zone. Provides recruitment opportunities in the marginal zone. Stimulates growth and reproduction. Prevents encroachment of marginal zone vegetation towards the active channel. Causes small disturbance but promotes habitat and species diversity.
Class III (101)	1	**Geomorphology:** Upper limit of boulder with little veg, maximum sediment transport across transect; fine sediment deposition on flood benches during flood recession. **Riparian vegetation:** activates and floods sedge population (*C. longus*) as well as alien weed species. Also floods to the lower limit of *V. karoo* saplings, preventing encroachment of woody trees farther into the riparian zone (prevents terrestrialisation). 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.

Flood Class (Peak in m^3/s)	Frequency (events per year)	Motivation
Class IV (191)	1:2	**Geomorphology:** Break of slope, top of upper flood bench, maintains higher morphological units, aids recovery after extreme floods through sediment deposition during flood recession. **Riparian vegetation:** Floods lower limit of *V. karoo* saplings which extent all the way to 4 m, keeps alien and terrestrial woody species from encroaching further into the channel or in-channel features i.e. important for preventing terrestrialisation and preventing invading trees from attaining height. Also maintains vegetation patchiness and heterogeneity.
Class V (396)	1:5	**Geomorphology:** Edge of upper terrace; maintains higher morphological units, aids recovery after extreme floods through sediment deposition during flood recession. **Riparian vegetation:** Tree line, floods to the lower limit of terrestrial tree/shrub species, (*V. karoo*, and *V. robusta*) prevents terrestrialisation of the riparian zone and promotes overall vegetation patchiness and heterogeneity and non-woody dominance.

The gauge T3H002 was present in the reach and used to verify high flows.

Table 8.7 MzimEWR3: The recommended number of high flow events required for an A EC

Flood Class	Peak (m^3/s)	Flood frequency[1]	Months[2]	Duration (days)
CLASS I	19	4:1	January, December, November, April, October	4
CLASS II	48	2:1	January, December, November, April, October	4.3
CLASS III	101	1:1	February or March	4.8
CLASS IV	191	1:2	February or March	5.3
CLASS V	396	1:5	February or March	6.2

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

2. Based on the natural occurrence of floods. These are the months that the floods are most likely, and frequently occur in.

8.6 TOTAL EWR RESULTS EWR RESULTS

The results are provided as EWR tables (**Table 8.8** and **8.9**) and an EWR rule (**Table 8.10** and **8.11**). Detailed results are provided in the model generated report for each category for both low and total flows and provided in **Appendix A**. A summary of the results is provided in **Table 8.12**.

Table 8.8 MzimEWR3: Low flow EWR table (m^3/s) for a PES and REC: C

Month	Low flows: m^3/s	
	Drought: 95%	60%
Oct	0.43	0.85
Nov	0.62	1.06
Dec	0.40	1.27
Jan	0.70	2.25
Feb	1.15	3.38
Mar	1.29	3.43
Apr	0.83	2.39

Month	Low flows: m³/s	
	Drought: 95%	60%
May	0.67	1.27
Jun	0.63	0.92
Jul	0.64	0.80
Aug	0.53	0.72
Sep	0.30	0.69

Table 8.9 MzimEWR3: High flow EWR table (MCM) for a PES and REC: C

Month	Total flows (MCM)	Low flows (MCM)	High flows (MCM)
Oct	5.48	3.51	1.97
Nov	7.01	4.28	2.73
Dec	12.22	7.03	5.20
Jan	23.27	11.55	11.72
Feb	27.45	14.22	13.23
Mar	26.43	15.04	11.39
Apr	11.59	9.65	1.95

Table 8.10 MzimEWR3: Total Assurance rules (m^3/s) for PES and REC: C

Month	0.1%	1%	5%	10%	15%	20%	30%	40%	50%	60%	70%	80%	85%	90%	95%	99%	99.9%
Oct	18.93	18.93	6.77	4.97	3.10	2.98	2.15	1.35	1.09	0.85	0.64	0.49	0.45	0.43	0.43	0.43	0.43
Nov	21.78	21.78	11.31	5.44	3.51	3.51	2.93	2.27	1.39	1.06	0.84	0.65	0.62	0.62	0.62	0.62	0.62
Dec	25.18	25.18	13.19	11.81	9.96	8.74	6.49	4.13	2.94	1.27	0.92	0.67	0.57	0.47	0.40	0.40	0.40
Jan	47.40	47.40	34.33	19.21	16.09	13.79	9.76	7.32	5.19	3.50	2.52	1.19	1.04	0.81	0.70	0.70	0.70
Feb	39.71	39.71	36.44	26.34	24.74	19.28	14.95	11.26	8.09	5.31	3.26	2.53	2.07	1.27	1.15	0.89	0.89
Mar	51.60	51.60	28.15	23.17	18.02	17.07	10.42	9.10	7.44	4.28	3.39	2.06	1.77	1.51	1.29	1.09	1.09
Apr	17.20	17.20	12.44	8.95	7.20	6.81	6.21	5.29	3.65	2.39	1.77	1.36	1.27	1.07	0.83	0.77	0.77
May	19.91	19.91	5.77	3.29	3.28	3.25	2.54	2.16	1.71	1.27	1.00	0.72	0.67	0.67	0.67	0.67	0.67
Jun	21.55	21.55	4.26	2.00	1.95	1.89	1.67	1.48	1.18	0.92	0.69	0.63	0.63	0.63	0.63	0.63	0.63
Jul	8.33	8.33	3.86	2.19	1.81	1.61	1.46	1.36	1.05	0.80	0.64	0.64	0.64	0.64	0.64	0.64	0.64
Aug	11.42	11.42	4.43	2.19	1.72	1.53	1.32	1.12	0.98	0.72	0.56	0.53	0.53	0.53	0.53	0.53	0.53
Sep	36.10	36.10	4.63	2.65	2.53	1.43	1.22	1.04	0.86	0.69	0.54	0.41	0.37	0.33	0.30	0.27	0.27

Table 8.11 MzimEWR3: Total Assurance rules (m^3/s) for D EC

Month	0.1%	1%	5%	10%	15%	20%	30%	40%	50%	60%	70%	80%	85%	90%	95%	99%	99.9%
Oct	12.95	12.95	5.01	3.68	2.35	2.16	1.05	0.86	0.70	0.55	0.44	0.37	0.37	0.37	0.37	0.37	0.37
Nov	20.80	20.80	10.38	4.04	2.65	2.65	2.12	1.17	0.91	0.69	0.58	0.53	0.53	0.53	0.53	0.53	0.53
Dec	24.05	24.05	12.02	10.43	8.72	6.43	4.76	3.14	2.00	0.84	0.64	0.49	0.43	0.37	0.34	0.34	0.34
Jan	45.74	45.74	32.79	17.74	14.55	12.93	7.69	5.28	3.54	2.44	1.77	0.84	0.76	0.64	0.59	0.59	0.59
Feb	38.37	38.37	32.46	24.59	20.28	15.76	10.87	8.75	7.00	3.62	2.60	1.26	1.14	1.02	0.92	0.87	0.87
Mar	49.50	49.50	26.57	21.75	16.41	15.36	8.32	6.77	5.41	3.13	2.55	1.40	1.32	1.20	1.05	0.92	0.92
Apr	15.81	15.81	9.68	7.63	5.70	5.44	4.67	3.71	2.43	1.67	1.30	0.99	0.96	0.85	0.67	0.64	0.64
May	18.61	18.61	4.08	2.26	2.24	2.23	1.75	1.47	1.15	0.84	0.70	0.57	0.57	0.57	0.57	0.57	0.57
Jun	20.75	20.75	3.38	1.34	1.20	1.16	1.07	0.96	0.76	0.59	0.54	0.54	0.54	0.54	0.54	0.53	0.53
Jul	7.78	7.78	3.34	1.66	1.22	0.96	0.92	0.87	0.67	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
Aug	10.84	10.84	3.91	1.75	1.18	0.95	0.88	0.73	0.69	0.47	0.46	0.46	0.46	0.46	0.46	0.46	0.46
Sep	35.33	35.33	3.89	1.93	1.63	0.84	0.75	0.65	0.54	0.44	0.36	0.30	0.28	0.26	0.24	0.23	0.23

Table 8.12 MzimEWR3: Summary of results as a percentage of the nMAR

Site	EcoStatus	nMAR (MCM)	pMAR (MCM)	% of nMAR	Low flows (MCM)	Low flows (%)	High flows (MCM)	High flows (%)	Total flows (MCM)	Total (%)
MzimEWR3	PES; REC: C	407.12	399.3	98.08	82.87	20.3	52.57	12.9	135.44	33.3
	D EC				63.83	15.7	45.83	11.3	109.66	26.9

9 ECOCLASSIFICATION: MZIMEWR4 (MZIMVUBU RIVER)

9.1 EIS RESULTS

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

- Rare and endangered riparian species: *Crinum moorei*.
- Unique instream biota: Four eels, estuarine fish species and *Macrobrancium*.
- Diversity of instream and riparian types and features: Mixture of alluvial and bedrock features. Flood channel with aquatic vegetation, riffles, rapids, pools, and a backwater.
- Macroinvertebrate taxon richness is high.
- Important migration route for eels.

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**.

Table 9.1 MzimEWR4: Present Ecological State

IHI Hydrology: PES: Instream A/B Confidence 4; Riparian A/B Confidence 4
▪ nMAR: 2655.1 million m^3/a. ▪ pMAR: 2532.2 million m^3/a. The major reasons for the change in reference are due to afforestation, irrigation, urban and rural water use as well as dams supporting some of the urban/rural and irrigation water use.
Physico-chemistry: PES: A/B (88.3%), Confidence: 3.5
Few water quality issues are seen in this part of the catchment, where the terrain is rugged with scattered rural settlements. Small agricultural plots are seen on the floodplains. Sedimentation from upstream erosion is evident but the overall erosion status in the immediate vicinity of the site is lower than expected due to storage in the large catchment. Fine sediment deposition takes place on boulder bars but there is little instream deposition (this supporting information is provided electronically). Supporting information, specifically relating to diatoms is provided electronically.
Geomorphology: PES: C (76.5%), Confidence: 2.9
This is a relatively steep (0.002) reach at the lower end of a large river system so stream power is high, especially during floods. Observed historic changes to terrace vegetation can be attributed to the 2013 flood which peaked at 3000 m3/s (4.5 m at the upstream gauge T3H020). The site is dominated by bedrock in the low flow channel and lateral or transverse bars consisting of large rounded boulder. Sand and gravel deposits form in more sheltered areas on bars. Bars contribute to two important habitat areas. Firstly, multiple channels over the transverse bar, creating lower energy riffle habitat. Secondly edge habitat alongside fast runs where main channel narrows downstream. Habitat diversity is high for a 'lowland' river. PES reflects elevated sediment levels but potential for deposition is reduced due to high streampower. Abrasion by sediment will be high (polished boulders).
IHI: PES: Instream B/C (80.1%) Confidence 2.9; Riparian C (75.1%) Confidence 3
Instream: The major issues related to turbidity and sedimentation which are all non-flow related impacts. Riparian: The major issues were linked the presence of alien vegetation in the non-marginal zone. These are non-flow related impacts.
Riparian vegetation: PES: C/D (59.4%), Confidence: 3.4
In 1622 E. Axelson noted (1960) regarding the inland area of the Mzimvubu and Mbhashe rivers: "survivors from the wrecked Portuguese ship 'Joao Baptista' ... commented on the beauty of the countryside, with rolling hills and wide valleys, with grass as tall as lances; and the abundance of cattle made it ever more beautiful in their eyes". In 1862 J.S. Dobie (1945) notes crossing Mzimvubu River 9 km northeast of Mount Frere..."Made a move after sunrise as the feed here very bad, and got to a tableland for breakfast, but grass not much better and water scarce... On over undulating country

to a saddle or ridge leading to higher ground. Here finding good grass and wood, and scrambled through bush in search of water; very little of that, no waterhole, had to make a spout!". MzimEWR4 occurs in the Savanna Biome in the Eastern Valley Bushveld vegetation type (Mucina and Rutherford, 2006, 2012 update). Overall one would therefore expect some woody influence in the riparian zone, but mostly limited to the MCB and upper zones. Under reference conditions one expects the marginal zone to be dominated by grass and sedge cover where alluvia occur, with *G. virgatum* in rocky areas. But because the zone is dominated by bedrock or gravel/cobble, vegetation is expected to be sparse and scattered. The upper zone is expected to be mixed woody / non-woody, with taller but scattered Cape Willow and predominantly grass species. Extensive bedrock and cobble areas would support little vegetation, mostly scattered and sparse. The flood channel areas are frequently wetter and have finer sediment deposits which would support non-woody vegetation, mostly sedges and forbs, all of which would be riparian obligates or preferential. Would expect the MCB to be woody, but dominated by terrestrial species.

Marginal zone: Was mostly bedrock, gravel and cobble and with little or no vegetation. *C. longus, Persicaria senegalensis* and *Juncus effasus* were dominants but were sparse and scattered. *G. virgatum* were also scattered between cobbles close to the active channel. *S. mucronata* was not found. **Upper zone:** Comprised cobble beds (sparse) and consolidated alluvial bars (with mostly grass cover and some shrub). Dominant species included *V. karoo, C. dactylon, Lantana camara, Senna didymobotrya, P. senegalensis, Sesbanea punicea* and *Nicotiniana glauca*. Most *V. karoo* were saplings colonising bars, which indicate that the flooding regime may be intact. *C. dactylon* had been grazed to form lawns in most areas. Alien shrubs formed dense areas. *S. mucronata* and *Combretum erythrophyllum/caffrum* were absent.
A species list is provided in the VEGRAI which is provided electronically.

Fish: PES: C (76.1%), Confidence: 3

This river system has a natural low fish species diversity, with only two indigenous species expected under natural conditions. These include the longfin eel (*Anguilla mossambica*) and chubbyhead barb (*Barbus/Enteromius anoplus*). *A. mossambica* was relatively abundant at the site during the EWR survey (September 2016), while no *B. anoplus* were sampled. The presence of one predatory alien fish species, namely largemouth bass (*Micropterus salmoides*) was also confirmed. Based on other available data for the region, it is also expected that other alien species may be present (*Cyprinus carpio* and possibly also *Oncorhynchus mykiss*). It is estimated that the *A. mossambica* population have been impacted slightly by reduced substrate quality (sedimentation causing loss of habitat for food sources), reduced pool depth (due to sedimentation), and increased turbidity reducing visibility for feeding (decreased abundance of macroinvertebrates observed). The primary impacts on *B. anoplus* is associated with the loss of vegetation as cover and food source (due to overgrazing, trampling, erosion, alien plant encroachment) and the presence of aggressive predatory alien species (*M. salmoides* and *O. mykiss*).

Macroinvertebrates: PES: C (74.1%), Confidence: 3

Reference: Data were sourced from a number of data sets including DWS RHP sites as listed below:

- T3MZIM_FLAGS T32H-05842 - Upstream, and in the same Level 2 EcoRegion.
- T3MZIN-NTSHA - Two data sets, further upstream but in the same Level 2 EcoRegion.
- T3MZIM-BHUJE - Shortly downstream of the site and in the same Level 2 EcoRegion.
- The PESEIS project, invert data for SQ catchment T35A-06354 (DWS, 2014c).

To compile the final reference state, only taxa which were either collected at the RHP or those from the EIS PES results with a rating of 5 (i.e. previously collected) were used.

Survey: The invertebrate community was sampled on 21 September 2016. The following biotopes were sampled in the flood channel upstream of the cross section (the best available habitat at the site that could be sampled): Stones (in and out of current), GSM, and sparse MV. The community was diverse with highly sensitive elements, but as at the other sites, unnaturally low abundances in the more sensitive taxa. The high-scoring, flow-dependent taxa included perlid stoneflies, prosopistomatid, teloganodid and heptageniid mayflies and >2 baetid spp. All of these taxa require good water quality. Notably absent from the sample were the taxa with a preference for MV (e.g. Dytiscidae, Hydrophilidae, Physidae, and Coenagrionidae) and those with a preference for the water column (hemipteran taxa). The SASS score was 160, with 26 taxa and an ASPT of 6.2.

Indicator taxa: Perlidae, Heptageniidae, Telagonodidae, and Psephenidae

Major non-flow related impacts included:

- High grazing pressure on marginal vegetation, resulting in a reduction in the MV sedge and grass habitat which would be expected under natural conditions.

- Sediment deposition due to upstream catchment erosion. This has not has as severe an effect on cobble habitat quality as that of the upstream sites, but is nonetheless a significant impact and is likely on a negative trajectory.
- Presence of the aggressive alien predatory fish (Carp, Bass) at the site. These species predate various invertebrate taxa and will definitely impact their abundances. In addition, the carp's feeding behaviour causes high turbidity in the river which impacts on both physical and hydraulic habitat.
- Slight deterioration in water quality (increased turbidity, slight increase in nutrient levels). The turbidity affects feeding and respiration, and the nutrients result in increased algal productivity, which in turn affects habitat availability and quality.

The PES EcoStatus is a C EC and the EcoStatus models are provided electronically. Key non-flow related impacts included:

- Sedimentation due to catchment erosion.
- Presence of alien predatory and habitat modifying fish species and loss of vegetation.
- Alien vegetation removal, grazing pressure and wood removal.

9.3 RECOMMENDED ECOLOGICAL CATEGORY

The REC was determined based on ecological criteria only and considered the EIS, the restoration potential and attainability thereof. As the EIS was MODERATE, no improvement was required. The REC was therefore set to maintain the PES of a C EC.

9.4 ECOCLASSIFICATION SUMMARY

The EcoClassification results are summarised in **Table 9.2**.

Table 9.2 MzimEWR4: Summary of EcoClassification results

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

Both the instream REC and the riparian vegetation REC is impacted on by anthropogenic impacts. The EWRs will therefore be set to maintain the REC EcoStatus of a C EC.

10 ECOLOGICAL FLOW REQUIREMENTS: MZIMEWR4 (MZIMVUBU RIVER)

10.1 FLOW STRESS RELATIONSHIP

A stress flow index was developed by specialists, using all available information (outputs from HABFLOW (a hydraulic model that models velocity-depth classes), survey results, photographs of previous flows at site, etc.). These results were inputted into the Habitat Flow Stressor Response-Reserve Model (HFSR-RM) to generate the integrated index which consists of either the fish or invertebrate stress that requires the highest discharge for the same stress. The integrated stress curve will be smoothed in the model.

The fish and macroinvertebrate stress flow index as well as the integrated stress are provided in **Figure 10.1**. A description of the habitat and response associated with the key stress is provided in **Table 10.1** and **10.2**.

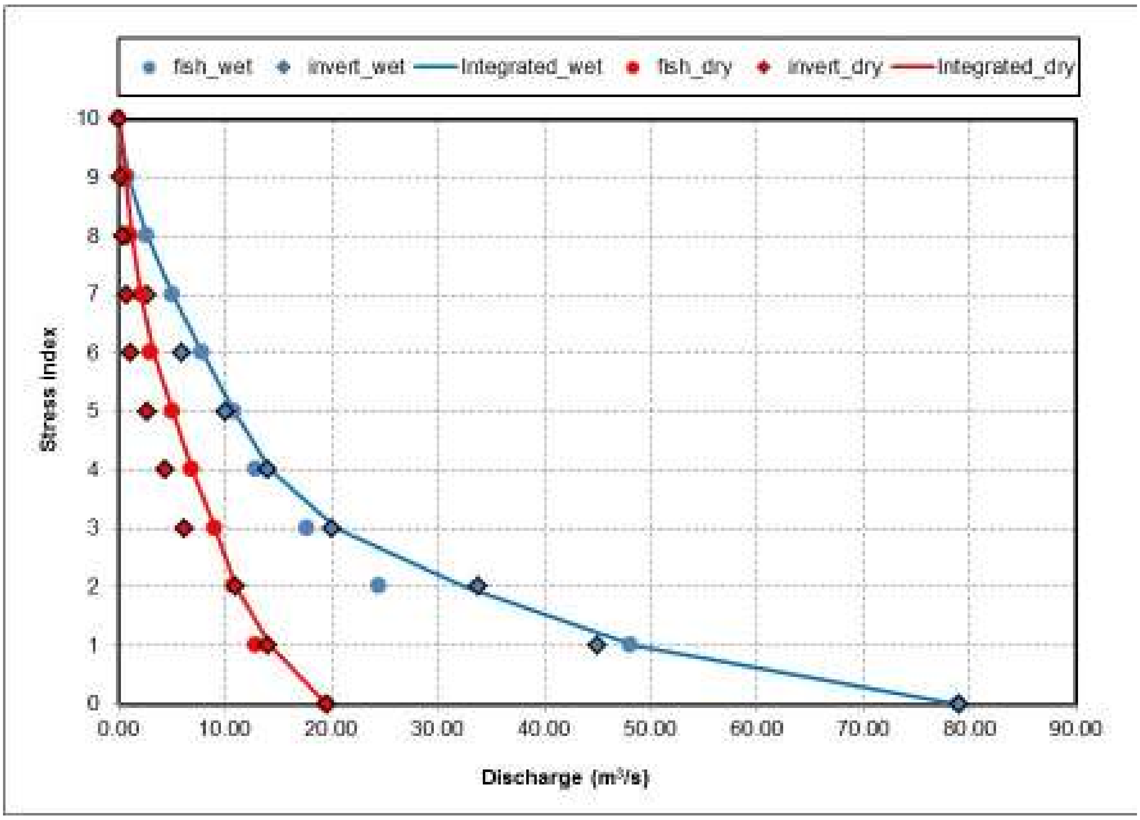

Figure 10.1 MzimEWR4: Integrated stress index for the wet and dry season

Table 10.1 MzimEWR4: Summarised habitat/biotic responses for the dry and wet season for fish

Fish stress	Dry season		Wet season	
	Flow (m^3/s)	**Habitat and stress description**	**Flow (m^3/s)**	**Habitat and stress description**
0	19.62	Maximum dry season baseflow (optimal wet season habitat suitability).	79.0	Maximum wet season baseflow (optimal wet season habitat suitability).

Fish stress	Dry season		Wet season	
	Flow (m^3/s)	Habitat and stress description	Flow (m^3/s)	Habitat and stress description
1	12.94	Average velocity decreases below 0.6 m^3/s (very fast habitats decrease notably).		
2			24.45	Loss of 20% of the natural composition of optimal wet season habitat (FI and FD) for *A. mossambica*.
5	5.07	Less than 7% optimal dry season habitat (FS, FI and FD) available for indicator fish species (*A. mossambica*).	10.89	Loss of approximately 50% of overall habitat (wetter perimeter), with 70% optimal habitat (FI and FD) still available for *A. mossambica*.
7			5.09	Approximately 50% optimal wet season habitats (FI and FD) available for *A. mossambica*.
8	1.11	Average velocity decreases below 0.3 m^3/s resulting in overall decrease in availability of fast habitats.		
9	0.65	Loss of all FD habitats at site, resulting in notable decreased habitat suitability for *A. mossambica* in dry season. Adequate flows to maintain refuge habitats in pools during dry season droughts.	0.85	Less than 20% optimal wet season habitats (FI and FD) available, average depth becomes limiting for longitudinal migration of *A. mossambica*.

There was lengthy specialist discussion regarding the setting of the stress index for this large river, where the maximum summer baseflow was set at 79 m^3/s. This provides a large range of flows over which to assign a narrow range of stress values (0 to 10). The “stress” on the biota at the upper end of the range (at least half the range) is low due to the heterogeneity of hydraulic habitats across a wide channel, and the typical “stresses” are felt by the invertebrates chiefly at the lower end of the range, thus the flow/stress relationship is not linear.

As anticipated, the conclusion reached was that (for the wet season at least), the curve would drop steeply, such that, in the case of the wet season, the flow at a stress of 5 would be in the order of 10 m^3/s (sharp decline from 79 m^3/s). At these lower discharges, there is a clearer relationship between discharge, hydraulic habitat parameters and invertebrate response (stress).

When setting the higher baseflows, the associated stresses for both 60% and 95% exceedance are lower at this site than at other sites. This is attributed to the difficulty of assigning stress values at these higher flows.

Table 10.2 MzimEWR4: Summarised habitat/biotic responses for the dry and wet season for invertebrates

Invertebrate stress	Dry season		Wet season	
	Flow (m^3/s)	Habitat and stress description	Flow (m^3/s)	Habitat and stress description
0	19.60		79.0	
1	14.0	All hydraulic habitat categories are represented with plentiful FCS and VFCS. At average depth 0.47 m and maximum depth 0.9 m, some MV is inundated and habitable (e.g., in the upstream flood channel), so there will be balanced and include MV dependent taxa. All indicator taxa are expected to occur in A-B abundances.	45.0	At the associated depth of around 1.3 m, there is greater variability in shear stress across the channel than there is at higher flows. This equates to a higher availability of lower velocity (<1 m/s) areas which would be habitable by FDIs. At these flows the cobble bars which occur intermittently through the reach will be inundated and will provide extensive, high quality habitat for FDIs (cobble mobility is maintained by the high flows). MV is inundated and the MV community should thrive. Overall a balanced community with a high ASPT is expected.
5	2.70	At this discharge SCS becomes more abundant as FCS and VFCS is proportionally reduced. The community will reflect this loss of high velocity flow areas – abundances of indicators will decline rapidly. There is sparse to no MV habitat at this flow. The more resilient low-scoring taxa are favoured and the ASPT will be reduced.	10.0	All hydraulic habitat categories are represented. At average depth 0.4 m and maximum depth 0.8 m, some MV is inundated and habitable (e.g., in the upstream flood channel). The community is diverse and balanced. All indicator taxa are expected to occur in A-B abundances.
7	0.80	No VFCS and very little FCS remains. No habitable MV. Indicator taxa and those scoring >13 will occur in very low numbers or be absent. Average depth is 0.18 m, which provides adequate depth over cobbles to maintain the more resilient surface-dwelling FDIs such as Simuliidae. Overall the community will shift to a more resilient one with a lower ASPT (5 or less).	2.70	At this discharge SCS becomes more abundant as FCS and VFCS is proportionally reduced. The community will reflect this loss of high velocity flow areas – abundances of indicators will decline rapidly. There is sparse to no MV habitat at this flow. The more resilient low-scoring taxa are favoured and the ASPT will be reduced.

10.2 HYDROLOGICAL CONSIDERATIONS

The wettest and driest months were identified as March and August respectively. Droughts are set at 95% exceedance (flow). The maximum baseflow for the dry season (August) is set at 19.621 m^3/s and for the wet season (March) at 79.15 m^3/s.

10.3 INSTREAM BIOTA LOW FLOW EWR REQUIREMENTS

10.3.1 PES and REC requirements

The required stress to maintain the REC of a C was determined by specialists and descriptions of key stress points (**Table 10.3**) are provided below. The requirements are illustrated as flow duration curves in **Figure 10.2** and **10.3** in **Section 10.6**.

Table 10.3 MzimEWR4: Habitat and instream biota description and associated stress requirements

Dry season		Wet season	
Flow (m^3/s)	**Description**	**Flow (m^3/s)**	**Description**
Duration: 95% (Drought)			
3.0	**Fish:** This flow will equate to a fish stress of 6. Approximately 50% of natural dry season habitat will be available (as wetted perimeter), resulting in notable stress on the indicator fish species (*A. mossambica*). Their preferred habitat will however be adequately maintained to ensure maintenance of PES during dry season droughts.	8.0	**Fish:** This flow will equate to a fish stress of 6. Approximately 60% of wet season optimal habitat (FI and FD) will be maintained for AMOS and should ensure that the present population is maintained during wet season droughts.
2.70	**Macroinvertebrates:** Integrated stress between 6 and 7. Very poor MV habitat at this flow. FCS is slow and the proportions of FCS and VFCS are reduced. The more resilient low-scoring taxa are favoured and the ASPT will be reduced.	7.90	**Macroinvertebrates:** Invertebrate and integrated stress of 6. There is adequate inundation of flood channel and cobble bar areas which provide the best invertebrate habitat (including MV) in this reach. A balanced community of invertebrates will be present, however there are likely to be water quality issues at these flows (elevated nutrients) which will result in changes to habitat quality, and the abundances of indicator taxa (and higher scoring families) are likely to be low.
Duration: 60%			
4.5	**Fish:** A fish stress of 5.2 is expected at these flows. Less than 7% optimal dry season habitat (FS, FI and FD) available for indicator fish species (*A. mossambica*), but adequate to maintain present population in dry season.	15	**Fish:** This flow will equate to a fish stress of 3.5. Approximately 30% loss of natural wet season habitats for *A. mossambica* is expected at this stress level, but conditions should be adequate to sustain the present status of this species at the site.
5	**Macroinvertebrates:** Integrated stress of 5. At these depths (average 0.3 m, maximum 0.6 m) the flood channel will be active and the marginal cobble areas will be inundated (likely no flow), however there will be sparse inundated MV habitat. Aerial taxa with a preference for MV are likely to relocate, and the sedentary taxa will be reduced in abundance or become absent. Habitat quality will deteriorate with the increase in nutrients and algal cover. Indicator taxa should be present but in very low numbers.	14.3	**Macroinvertebrates:** Integrated stress of 4. At the associated depths (average 0.5 m, maximum 0.9 m) there is a good mix of high and low shear stress which relates to good hydraulic habitat diversity and availability. All hydraulic habitats are represented. A diverse invertebrate community is expected, with A-B abundances in the majority of taxa. All FDI taxa should occur. Habitat quality is maintained and a robust late-summer community should be present.

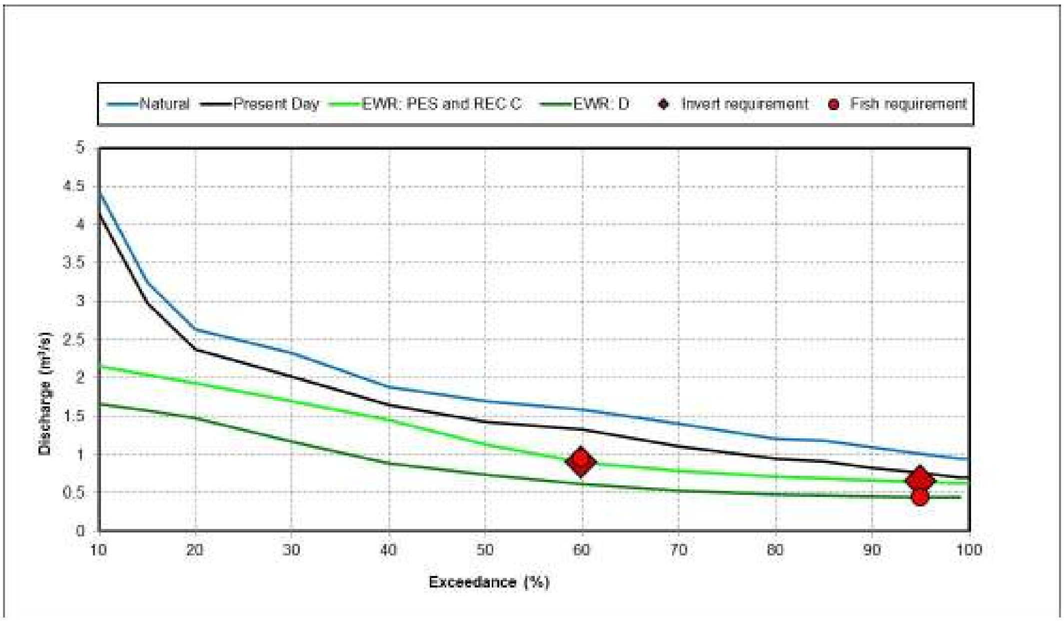

Figure 10.2 MzimEWR4: Flow duration graph for the low flows during dry season (August)

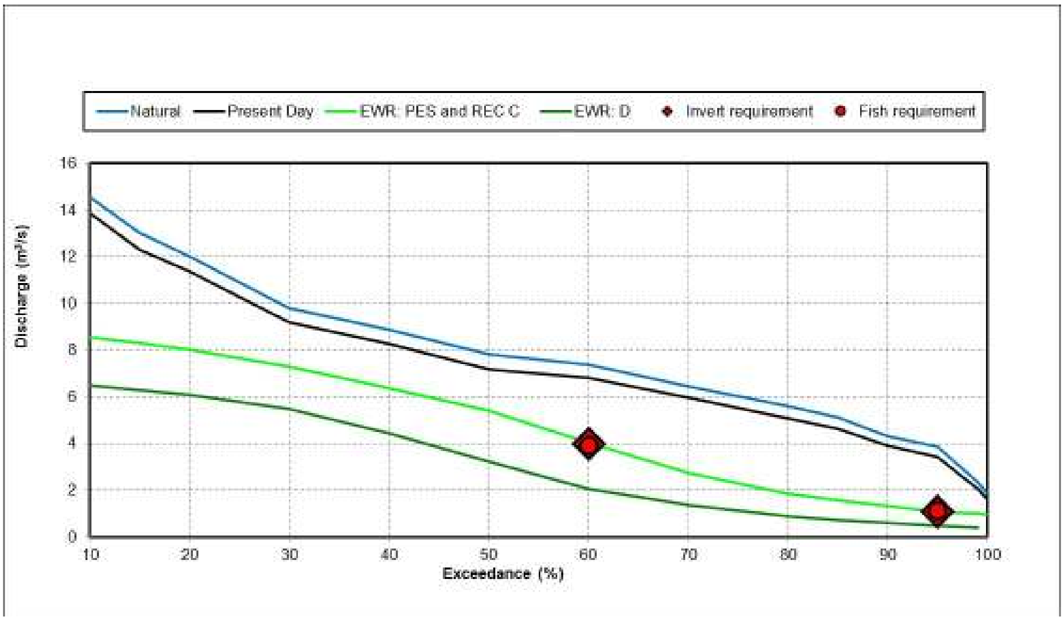

Figure 10.3 MzimEWR4: Flow duration graph for the low flows during wet season (March)

10.3.2 D Ecological Category

The REC results of a C were used in the RDRM model to derive a D EC. These were checked by specialists to determine whether these discharges and the associated hydraulic habitat would result in a D EC or whether changes to the D flow requirements are necessary. The associated habitat and responses of the D EC flow regime are provided in **Table 10.4**.

Table 10.4 MzimEWR4: Habitat and instream biota description and associated stress requirements for an EC: D

Dry season		Wet season	
Flow (m^3/s)	**Description**	**Flow (m^3/s)**	**Description**
Duration: 95% (Drought)			
1.97	**Fish:** This flow will result in an increase in fish stress from 6 to 7.2. At this stress level almost 40% (compared to natural) suitable habitat (FS, FI and FD) for the indicator fish (*A. mossambica*) will be lost.	4.70	**Fish:** This flow will result in an increase in fish stress from 6 to 7.1. Less than 50% optimal wet season habitats (FI and FD) will be available for *A. mossambica* at these flows.
	Macroinvertebrates: This flow will result in an increase in integrated stress from between 6 and 7 to 7.8. The major difference relative to the C PES and REC is the total absence of VFCS, FCS and MV. The invertebrate community diversity and abundance will be substantially reduced.		**Macroinvertebrates:** This flow will result in an increase in integrated stress from 6 to 6.3. There is little MV inundated at this depth (<0.6 m). SCS and VFCS are reduced and the latter is almost absent at this flow. Taxa with a preference for high velocity flows will decrease in number or disappear, while those with a preference for moderate velocities are still expected to be present, at lower abundances than for the PES and REC.
Duration: 60%			
3.02	**Fish:** This flow will result in an increase in fish stress from 5.2 to 6.0. Less than 75% of the optimal (FS, FI and FD) natural dry season habitat will be available to the indicator species (*A. mossambica*) and notable stress can be expected to drive the fish assemblage.	10.2	**Fish:** This flow will result in an increase in fish stress from 3.5 to 5.2. Only approximately 50% of overall wet season habitat (as indicated by wetter perimeter) and only 70% optimal habitat (FI and FD) will be available for *A. mossambica*.
	Macroinvertebrates: This flow will result in an increase in integrated stress from 5 to 6.3. There is little MV inundated at this depth (<0.6 m). SCS and VFCS are reduced and the latter is almost absent at this flow. Taxa with a preference for high velocity flows will decrease in number or disappear, while those with a preference for moderate velocities are still expected to be present, at lower abundances than for the PES and REC.		**Macroinvertebrates:** This flow will result in an increase in integrated stress from 4 to 5.1. This reduction in flow is associated with a slight loss of depth (0.1 m), associated with a slight decrease in the amount of VFCS, SCS and MV available. This will affect the abundance of taxa with a preference for these hydraulic habitats, however FDIs scoring > 9 are still expected to be present, and a fairly balanced community is likely to occur.

10.4 VERIFICATION OF LOW FLOWS: RIPARIAN VEGETATION

Marginal zone vegetation at the site had an elevational range from 0.8 to 1.7 m above the channel. This equates to a discharge range of 10.06 to 96.11 m^3/s in order to activate the lower and upper limits of the zone vegetation respectively. On average, the lower limit of marginal zone vegetation will be inundated for 70 – 80% of the time in the wet season and 5 – 15% of the time in the dry season (Total flows; blue values in flow duration table, **Table 10.5**), while the upper limit will be flooded for 5 – 10% of the time in the wet season only (Total flows; red values in flow duration table, **Table 10.5**). A discharge of 21.5 m^3/s is required to flood about 25% of the marginal zone vegetation, which according to specified low flows occurs for 30 to 70% of the time in wet season months and 0 to 5% of the time in dry season months (yellow values in flow duration table, **Table 10.5**). Similarly, a discharge of 38.7 m^3/s is required to flood about 50% of marginal zone vegetation, which according to specified low flows occurs for 15 to 30% of the time in wet season months and 0 – 1% of the time in dry season months (green values in flow duration table, **Table 10.5**). These flows are sufficient to facilitate survival of marginal zone vegetation in the dry season, and together with specified floods, growth and reproduction in the wet season. It is important to note that this assessment assumes that the flooding component will occur in addition to specified low flows.

Table 10.5 MzimEWR4: EWR Model flow duration table for PES: C (Total flows)

	0.1	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99	99.9
Jan	191.573	191.573	112.740	81.683	49.498	42.399	31.929	29.254	24.318	18.869	10.655	7.240	6.253	5.207	4.686	4.366	4.366
Feb	206.921	206.921	156.694	106.877	84.965	73.325	47.323	33.880	28.920	24.940	20.037	9.456	8.218	6.961	6.532	5.989	5.989
Mar	221.284	221.284	164.243	107.851	75.257	55.944	50.195	35.730	30.289	26.607	23.732	11.439	9.911	8.884	7.870	7.343	7.343
Apr	160.178	160.178	38.623	38.623	33.775	33.603	31.833	25.423	15.367	12.888	10.721	8.756	7.721	6.842	5.974	5.904	5.904
May	119.216	119.216	30.233	15.530	14.484	13.366	13.130	11.534	10.558	8.560	6.894	5.704	5.239	5.010	5.008	5.007	5.007
Jun	62.311	62.311	35.471	10.174	10.144	10.045	9.846	8.370	7.351	5.946	4.935	4.382	4.377	4.375	4.374	4.373	4.373
Jul	58.890	58.890	21.985	8.914	8.871	8.807	8.574	7.410	6.380	5.283	4.529	3.987	3.638	3.427	3.339	3.196	3.196
Aug	19.385	19.385	17.922	7.898	7.774	7.603	7.103	6.471	5.736	4.945	4.192	3.543	3.280	3.122	2.988	2.902	2.902
Sep	54.711	54.711	21.978	14.988	7.602	7.597	6.707	6.143	5.777	4.477	3.737	3.235	3.233	3.231	3.229	3.227	3.227
Oct	67.524	67.524	42.742	21.042	20.984	17.365	8.502	7.657	6.673	5.766	4.781	4.071	3.746	3.482	3.334	3.256	3.256
Nov	142.963	142.963	65.507	50.398	29.987	24.728	22.408	10.013	8.799	7.096	5.774	5.080	4.599	4.496	4.495	4.494	4.494
Dec	129.352	129.352	67.326	57.001	46.047	33.838	31.703	23.604	17.604	8.464	6.917	5.508	4.754	4.213	3.627	3.529	3.529

10.5 HIGH FLOW REQUIREMENTS

Motivations are provided in **Table 10.6** and final high flow results are provided in **Table 10.7**.

Table 10.6 MzimEWR4: Identification of a range of flow events (peak discharge and frequency) to maintain a Category A Ecological State

Flood Class (Peak in m³/s)	Frequency (events per year)	Motivation
Class I (156)	4:1	**Geomorphology:** Overtops cobble bar on left bank and lower bar on left bank. Significant mobility of coarse to fine gravel, but potential for deposition over back of cobble bar on left bank during flood recession. **Riparian vegetation:** Within year floods required to activate and maintain lower portions of the sedge population.
Class II (208)	2:1	**Geomorphology:** Morphological marker. Covers small bench on right bank, just reaches start of main flood bench on left bank. **Riparian vegetation:** Floods marginal zone sedges and vegetation surrounding pool areas: Wet season baseflows should inundate some of the marginal zone vegetation, so these floods are required to inundate more than that. Prevents establishment of terrestrial or alien species (some species, and at least temporarily) in the marginal zone. Provides recruitment opportunities in the marginal zone. Stimulates growth and reproduction. Prevents encroachment of marginal zone vegetation towards the active channel. Causes small disturbance but promotes habitat and species diversity.
Class III 531)	1	**Geomorphology:** Overtops flood bench and activates flood channel. Maximum sheer stress over section and high mobility of all clasts up to cobble. Potential for sediment deposition on flood bench during flood recession. **Riparian vegetation:** Activates and floods sedge population (*C. longus*) as well as alien shrub species (*Senna didymobotrya* and *Sesbanea punicea*). 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.

Flood Class (Peak in m³/s)	Frequency (events per year)	Motivation
Class V (1306)	1:2	**Geomorphology:** Vegetation marker. Halfway up terrace bank. Shear stress and sediment mobility reduced relative to lower water levels. **Riparian vegetation:** Floods lower limit of *V. karoo* saplings, keeps alien and terrestrial woody species from encroaching further into the channel or in-channel features. Also maintains vegetation patchiness and heterogeneity.
Class VI (1624)	1:5	**Geomorphology:** Overtops terrace. Lower shear stress and sediment mobility gives potential for deposition of fines on flood bench and terrace. **Riparian vegetation:** Tree line, floods to the lower limit of terrestrial tree/shrub species (*Ficus sur*, *Spirostachys africana*, *V. karoo*, *V. robusta*) prevents terrestrialisation of the riparian zone and promotes overall vegetation patchiness and heterogeneity.

The gauge T3H020 was present in the reach and used to verify high flows.

Table 10.7 MzimEWR4: The recommended number of high flow events required for an A category

Flood Class	Peak (m^3/s)	Flood frequency[1]	Months[2]	Duration (days)
CLASS I	156	4:1	January, December, November, April, October	5.3
CLASS II	208	2:1	January, December, November, April, October	5.7
CLASS III	531	1:1	February or March	6.7
CLASS IV	1306	1:2	February or March	2
CLASS V	1624	1:5	February or March	8.7

1 Refers to frequency of occurrence per year, i.e. how often the flood occurs per year.
2. Based on the natural occurrence of floods. These are the months that the floods are most likely, and frequently occur in.

10.6 TOTAL EWR RESULTS

The results are provided as EWR tables (**Table 10.8** and **10.9**) and an EWR rule (**Table 10.10** and **10.11**). Detailed results are provided in the model generated report for each category for both low and total flows and provided in **Appendix A**. A summary of the results is provided in **Table 10.12**.

Table 10.8 MzimEWR4: Low flow EWR table (m^3/s) for a PES and REC: C

Month	Low flows: m^3/s	
	Drought: 90%	60%
Oct	3.33	5.77
Nov	4.50	7.10
Dec	3.63	8.46
Jan	4.69	11.08
Feb	6.53	13.33
Mar	7.87	14.83
Apr	5.97	12.89
May	5.01	8.56

Month	Low flows: m³/s	
	Drought: 90%	60%
Jun	4.37	5.95
Jul	3.34	5.28
Aug	2.99	4.95
Sep	3.23	4.48

Table 10.9 MzimEWR4: High flow EWR table (MCM) for a PES and REC: C

Month	Total flows (MCM)	Low flows (MCM)	High flows (MCM)
Oct	20.99	12.59	8.40
Nov	21.59	15.05	6.54
Dec	12.17	11.33	0.83
Jan	7.50	6.92	0.59
Feb	5.37	4.47	0.91
Mar	4.37	4.43	-0.06
Apr	3.67	3.60	0.07

Table 10.10 MzimEWR4: Total Assurance rules (m³/s) for PES and REC: C

Month	0.1%	1%	5%	10%	15%	20%	30%	40%	50%	60%	70%	80%	85%	90%	95%	99%	99.9%
Oct	67.52	67.52	42.74	21.04	20.98	17.37	8.50	7.66	6.67	5.77	4.78	4.07	3.75	3.48	3.33	3.26	3.26
Nov	142.96	142.96	65.51	50.40	29.99	24.73	22.41	10.01	8.80	7.10	5.77	5.08	4.60	4.50	4.50	4.49	4.49
Dec	129.35	129.35	67.33	57.00	46.05	33.84	31.70	23.60	17.60	8.46	6.92	5.51	4.75	4.21	3.63	3.53	3.53
Jan	191.57	191.57	112.74	81.68	49.50	42.40	31.93	29.25	24.32	18.87	10.66	7.24	6.25	5.21	4.69	4.37	4.37
Feb	206.92	206.92	156.69	106.88	84.97	73.33	47.32	33.88	28.92	24.94	20.04	9.46	8.22	6.96	6.53	5.99	5.99
Mar	221.28	221.28	164.24	107.85	75.26	55.94	50.20	35.73	30.29	26.61	23.73	11.44	9.91	8.88	7.87	7.34	7.34
Apr	160.18	160.18	38.62	38.62	33.78	33.60	31.83	25.42	15.37	12.89	10.72	8.76	7.72	6.84	5.97	5.90	5.90
May	119.22	119.22	30.23	15.53	14.48	13.37	13.13	11.53	10.56	8.56	6.89	5.70	5.24	5.01	5.01	5.01	5.01
Jun	62.31	62.31	35.47	10.17	10.14	10.05	9.85	8.37	7.35	5.95	4.94	4.38	4.38	4.38	4.37	4.37	4.37
Jul	58.89	58.89	21.99	8.91	8.87	8.81	8.57	7.41	6.38	5.28	4.53	3.99	3.64	3.43	3.34	3.20	3.20
Aug	19.39	19.39	17.92	7.90	7.77	7.60	7.10	6.47	5.74	4.95	4.19	3.54	3.28	3.12	2.99	2.90	2.90
Sep	54.71	54.71	21.98	14.99	7.60	7.60	6.71	6.14	5.78	4.48	3.74	3.24	3.23	3.23	3.23	3.23	3.23

Table 10.11 MzimEWR4: Total Assurance rules (m³/s) for D EC

Month	0.1%	1%	5%	10%	15%	20%	30%	40%	50%	60%	70%	80%	85%	90%	95%	99%	99.9%
Oct	62.60	62.60	17.42	17.21	15.26	6.02	5.30	4.73	4.04	3.51	2.98	2.59	2.41	2.24	2.15	2.09	2.09
Nov	137.29	137.29	59.83	45.09	24.67	19.68	15.42	6.22	5.26	4.36	3.62	3.24	2.94	2.74	2.71	2.71	2.71
Dec	122.12	122.12	58.77	49.31	37.71	26.61	21.27	17.23	7.97	5.27	4.38	3.51	3.04	2.69	2.30	2.16	2.16
Jan	181.58	181.58	103.55	72.25	40.61	27.79	23.47	20.79	17.65	8.61	5.80	4.47	3.83	3.28	2.91	2.66	2.66
Feb	194.75	194.75	144.53	94.71	72.82	56.03	34.50	23.95	20.29	16.61	8.63	5.54	4.84	4.17	3.85	3.45	3.45
Mar	207.85	207.85	150.98	88.70	58.28	44.51	29.76	25.36	22.65	19.69	10.35	6.63	5.81	5.05	4.43	4.00	4.00
Apr	148.01	148.01	29.27	29.27	24.42	24.07	22.60	10.60	9.70	8.41	7.03	5.59	4.83	4.19	3.57	3.40	3.40
May	68.87	68.87	20.67	9.14	8.60	8.11	8.03	7.11	6.50	5.33	4.36	3.63	3.33	3.13	2.98	2.97	2.97

Month	0.1%	1%	5%	10%	15%	20%	30%	40%	50%	60%	70%	80%	85%	90%	95%	99%	99.9%
Jun	57.46	57.46	17.96	6.31	6.29	6.24	6.11	5.17	4.46	3.62	3.07	2.76	2.64	2.64	2.64	2.64	2.64
Jul	54.80	54.80	17.79	5.56	5.55	5.51	5.35	4.58	3.86	3.20	2.81	2.54	2.34	2.21	2.15	2.06	2.06
Aug	16.41	16.41	12.97	4.97	4.89	4.78	4.46	4.00	3.44	2.99	2.60	2.26	2.12	2.02	1.95	1.90	1.90
Sep	47.80	47.80	17.11	5.44	4.67	4.67	4.12	3.76	3.49	2.82	2.40	2.02	1.92	1.92	1.92	1.91	1.91

Table 10.12 MzimEWR4: Summary of results as a percentage of the nMAR

Site	EcoStatus	nMAR (MCM)	pMAR (MCM)	% of nMAR	Low flows (MCM)	Low flows (%)	High flows (MCM)	High flows (%)	Total flows (MCM)	Total (%)
MzimEWR4	PES; REC: C	2655.13	2532.21	95.37	331.16	12.5	301.30	11.3	632.46	23.8
	D EC				201.32	7.6	267.95	10.1	469.27	17.7

11 CONCLUSIONS AND RECOMMENDATIONS

11.1 ECOCLASSIFICATION

The EcoClassification results are summarised below in **Table 11.1**.

Table 11.1 EcoClassification results summary

MZIMEWR1: TSITSA RIVER

EIS: MODERATE
Highest scoring metrics were Rare and endangered taxa, unique instream biota, biota intolerant to physico-chemical changes and high taxon richness. Important migration route for eels.

PES: C

- Sedimentation due to catchment erosion.
- Presence of alien predatory and habitat modifying fish species, erosion, and loss of vegetation.
- Alien vegetation removal, grazing pressure and wood removal.

REC: C
The EIS was moderate and the REC is set to maintain the PES as most impacts relate to non-flow related impacts.

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

MZIMEWR2: THINA RIVER

EIS: MODERATE
Highest scoring metrics were unique instream biota, diversity of instream habitat types and features and high taxon richness. Important migration route for eels.

PES: C

- Sedimentation due to localised disturbance.
- Presence of alien predatory and habitat modifying fish species, erosion, and loss of vegetation.
- Overgrazing from livestock and the presence of alien plant species.

REC: C
The EIS was moderate and the REC is set to maintain the PES as most impacts relate to non-flow related impacts.

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

MZIMEWR3: KINIRA RIVER

EIS: MODERATE
Highest scoring metrics were Rare and endangered taxa, unique instream biota, and high taxon richness. Important migration route for eels.

PES: C

- Sedimentation due to catchment erosion.
- Alien predatory and habitat modifying fish species, and loss of vegetation due to grazing.
- Overgrazing and the presence of terrestrial tree species within the riparian zone as well as browsing pressure.
- Targeted wood removal.

REC: C
The EIS was moderate and the REC is set to maintain the PES as most impacts relate to non-flow related impacts.

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

MZIMEWR4: MZIMVUBU RIVER		
EIS: MODERATE Rare and endangered riparian species, unique instream biota, diversity of instream and riparian types and features and high taxon richness. Important migration route for eels. **PES: C** ▪ Sedimentation due to catchment erosion. ▪ Presence of alien predatory and habitat modifying fish species and loss of vegetation. ▪ Alien vegetation removal, grazing pressure and wood removal. **REC: C** The EIS was moderate and the REC is set to maintain the PES as most impacts relate to non-flow related impacts.	**Component**	**PES and REC**
	IHI Hydrology	**A/B**
	Physico-chemical	**A/B**
	Geomorphology	**C**
	Fish	**C**
	Invertebrates	**C**
	Instream	**C**
	Riparian vegetation	**C/D**
	EcoStatus	**C**
	Instream IHI	**B/C**
	Riparian IHI	**C**
	EIS	**MODERATE**

The confidence in the EcoClassification process is provided below (**Table 11.2**) and was based on data and information availability and EcoClassification results, as follows:

- Data and information availability: Evaluation based on the adequacy of any available data for interpretation of the EC and alternative ECs.
- EcoClassification: Evaluation based on the confidence in the accuracy of the PES.

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 section.

Table 11.2 Confidence in EcoClassification

Component	MzimEWR1	MzimEWR2	MzimEWR3	MzimEWR4
Data and information availability				
Hydrology	3.5	2.5	2.5	2.5
Water Quality	2.5	3.5	3.5	3.5
Geomorphology	3.5	3.3	3	3
Fish	2	2	2	2
Inverts	3	3	3	3
Vegetation	3.5	3.5	3.5	3.5
Average	**3.0**	**3.0**	**2.9**	**2.9**
Median	**3.3**	**3.2**	**3.0**	**3.0**
EcoClassification				
Hydrology	4	4	4	4
Water Quality	2.5	3.5	3.5	3.5
Geomorphology	3.6	3.6	2.9	2.9
IHI	3	2.9	2.9	3
Fish	3	3	3	3
Inverts	3	3	2.5	3
Vegetation	3.5	3.4	3.2	3.4
Average	**3.2**	**3.3**	**3.1**	**3.3**
Median	**3.0**	**3.4**	**3.0**	**3.0**

The confidence in data availability and EcoClassification was Moderate to High for all the EWR sites.

The impacts are largely non-flow related and due to, amongst others, sedimentation and turbidity (from catchment and localised erosion as well as overgrazing), alien vegetation and alien fish.

11.2 ECOLOGICAL WATER REQUIREMENTS

The final flow requirements are expressed as a percentage of the nMAR in **Table 11.3**.

Table 11.3 Summary of results as a percentage of the nMAR

Site	EcoStatus	nMAR (MCM)	pMAR (MCM)	% of nMAR	Low flows (MCM)	Low flows (%)	High flows (MCM)	High flows (%)	Total flows (MCM)	Total (%)
MzimEWR1	PES; REC: C	438.04	413.16	94.32	87.43	20	48.25	11	135.68	31
	D EC				67.66	15.4	42.16	9.6	109.82	25.1
MzimEWR2	PES; REC: C	404.51	393.23	97.21	89.24	22.1	32.41	8	121.65	30.1
	D EC				60.63	15	29.5	7.3	90.13	22.3
MzimEWR3	PES; REC: C	407.12	399.3	98.08	82.87	20.3	52.57	12.9	135.44	33.3
	D EC				63.83	15.7	45.83	11.3	109.66	26.9
MzimEWR4	PES; REC: C	2655.13	2532.21	95.37	331.16	12.5	301.3	11.3	632.46	23.8
	D EC				201.32	7.6	267.95	10.1	469.27	17.7

11.2.1 Confidence in low flows

Considering the quality of data, the question the confidence assessment should answer is the following:

'How confident are you that the recommended EWRs will achieve th*e EC?'*

Table 11.4 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 11.4 Low flow confidence ratings for biotic responses

EWR site	Fish	Macroinvertebrates	Comment	Overall confidence
MzimEWR1	4	3	**Fish:** Floods would meet all the requirements of fish species expected in reach in terms of provision of spawning habitats, migration cues and depth and flushing of sediments from substrates.	**3.5**
			Macroinvertebrates: All FDIs scoring 13 or less are catered for at 60% exceedances flows. The more sensitive FDIs should be maintained, at very low abundances (sometimes individuals only, with intensive sampling). At 95% FDIs scoring >9 will be reduced in abundances or absent, however eggs should survive and these will reappear in the wet season.	
MzimEWR2	3	2	**Fish:** Only large semi-rheophilic fish species available, but with a notable preference for fast habitats (habitat requirements of indicator species well documented).	**2.5**

EWR site	Fish	Macroinvertebrates	Comment	Overall confidence
			Macroinvertebrates: The wet season flows will maintain the C community, however with no certainty of ensuring the ongoing presence of sensitive FDIs (scoring >13). The dry season flows are sufficient to maintain a C EC, however there will be some loss of abundance and presence of particularly MV taxa.	
MzimEWR3	3	2	**Fish:** Only a large semi-rheophilic fish species available for use to set flows (no rheophilic species present). This species however has a high preference for fast habitats and the habitat requirements of the indicator species is well documented. Flows were also selected conservatively to ensure that current good conditions (in terms of flow) is maintained, since the PES of the fish (Category C) is primarily related to non-flow related impacts.	**2.5**
			Macroinvertebrates: The wet season flows provided will maintain the C community, however with no certainty of ensuring the ongoing presence of sensitive FDIs (scoring >13). The dry season flows are sufficient to maintain a C, with some loss of taxa at the higher exceedances, particularly of sensitive FDI taxa and those with a preference for MV.	
MzimEWR4	3	3	**Fish:** Only large semi-rheophilic fish species available as indicator for low flow conditions, but with a notable preference for fast habitats (habitat requirements of indicator species well documented). Very high habitat diversity at site and adequate abundance and diversity will be maintained at even relatively low (compared to natural) flows.	**3**
			Macroinvertebrates: The most important habitat element in this reach for the invertebrates is the flood channels, cobble bars (with multiple channels) and marginal vegetation (which is sparse). The flows set should activate these habitat areas and to achieve maximum hydraulic habitat diversity where possible, so as to optimise the invertebrate community diversity and sensitivity, and to maintain the PES of C.	

11.2.2 Confidence in high flows

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.

The high flow confidence (**Table 11.5**) represents an average of the riparian vegetation and geomorphology confidences as these two components determine the flood requirements.

Table 11.5 Confidence in recommended high flows

EWR site	Riparian vegetation	Geomorphology	Comment	Overall confidence
MzimEWR1	3	3.5	**Riparian vegetation:** About 65 years of gauge data available (T3H006), as well as surveyed profile with hydraulic lookup tables and riparian vegetation indicators surveyed onto the profile. Flood function is well known for vegetation requirements and response.	**3.3**

EWR site	Riparian vegetation	Geomorphology	Comment	Overall confidence
			Geomorphology: 52 years of satisfactory monthly flood peaks for T3H006. Additional data from Huchzermeyer MSc study. Morphological indicators moderately well-defined and correlate with vegetation indicators. Sediment mobility depends on slope which changes significantly over the discharge range. Errors here will be reflected in sediment mobility assessment.	
MzimEWR2	2	2	**Riparian vegetation:** 75 years of gauge data available (T3H005), as well as surveyed profile with hydraulic lookup tables and riparian vegetation indicators surveyed onto the profile, but indicators were sparse along the transect. Flood function is well known for vegetation requirements and response.	**2**
			Geomorphology: 56 years of reliable monthly flood peak data but poor correlation between flood frequency values and estimates from transect. Poor definition of morphological units at the transect but clear flood benches elsewhere at site. Not easy to tie in. High reliance on vegetation indicators where available. Little justification for 2:1 flood. Low confidence in modelled slope data so no sediment mobility analysis.	
MzimEWR3	3	2.5	**Riparian vegetation:** 47 years of gauge data available (T3H002), as well as surveyed profile with hydraulic lookup tables and riparian vegetation indicators surveyed onto the profile. Flood function is well known for vegetation requirements and response.	**2.8**
			Geomorphology: Gauge frequently overtopped but stage record moderately good. Poor definition of morphological units at the transect but clear flood benches elsewhere at site. Not easy to tie in. High reliance on vegetation indicators.	
MzimEWR4	2.5	2.5	**Riparian vegetation:** Seven years of gauge data available (T3H020), as well as surveyed profile with hydraulic lookup tables and riparian vegetation indicators surveyed onto the profile. Flood function is well known for vegetation requirements and response.	**2.5**
			Geomorphology: Site morphology probably recovering from 2013 flood and morphological indicators not clear; confirmation of recommended floods from vegetation indicators. Very little in-channel mobile sediment; sediment mobility modelled using gravel deposits on edge of boulder bar.	

11.2.3 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, which is different to 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 11.6**.

Table 11.6 Confidence in hydrology

EWR site	Natural hydrology	Present hydrology	Comment	Confidence: Median	Confidence: Average
MzimEWR1	3.5	3.5	**Natural hydrology:** Hydrological calibration was possible at two gauges (T3H006 and T3H009 upstream and downstream of MzimEWR1), which was scaled to obtain representative natural flow at the site. **Present hydrology:** The WRYM system configuration sourced from the DWS Feasibility Study for the Mzimvubu Water Project was refined to include simulation of flows at the EWR site. Catchment developments (forestry, small dams, irrigation and urban/rural water use and return flows) were disaggregated based on information obtained from the DWS Feasibility Study for the Mzimvubu Water Project, ASGISA-EC Mzimvubu Development Project, DWS All Towns Study, visual inspection of satellite imagery and catchment area scaling.	**3.5**	**3.5**
MzimEWR2	2.5	2.5	**Natural Hydrology:** Derived from ASGISA-EC Mzimvubu Development Project (DWAF, 2009) (made use of the WR2005 hydrology i.e., uncalibrated) and was scaled to obtain representative natural flow at the EWR site. **Present Hydrology:** The Water Resource Yield Model (WRYM) system configuration sourced from the ASGISA-EC Mzimvubu Development Project (DWAF, 2009), was refined to include simulation of flows at the EWR site. Catchment developments (forestry, small dams, irrigation and urban/rural water use and return flows) were disaggregated based on information obtained from the ASGISA-EC Mzimvubu Development Project (DWAF, 2009), DWS All Towns Study (DWS, 2015), visual inspection of satellite imagery and catchment area scaling.	**2.5**	**2.5**
MzimEWR3	2.5	2.5	**Natural Hydrology:** The DWS Feasibility Study for the Mzimvubu Water Project hydrology (DWS, 2014b) MAR is between 46% and 48% higher than the WR2005 and WR2012 hydrology and the findings of further investigation undertaken by the team confirmed that the hydrology is unacceptable. The ASGISA-EC Mzimvubu Development Project (DWAF, 2009) (made use of the WR2005 hydrology i.e. uncalibrated) was utilised and scaled to obtain representative natural flow at the EWR site. **Present Hydrology:** The WRYM system configuration sourced from the ASGISA-EC Mzimvubu Development Project (DWAF, 2009) was refined to include simulation of flows at the EWR site. Catchment developments (forestry, small dams, irrigation and urban/rural water use and return flows) were disaggregated based on information obtained from the ASGISA-EC Mzimvubu Development Project (DWAF, 2009), DWS All Towns Study (DWS, 2015), visual inspection of satellite imagery and catchment area scaling	**2.5**	**2.5**
MzimEWR4	2.5	2.5	**Natural Hydrology:** Was derived from the ASGISA-EC Mzimvubu Development Project (DWAF, 2009) (made use of the WR2005 hydrology i.e. uncalibrated) as well as the contributing upstream DWS Feasibility Study for the Mzimvubu Water Project hydrology used for the iTsitsa (T35) (DWS, 2014b) and was scaled to obtain representative natural flow at the EWR site. **Present Hydrology:** The WRYM system configuration sourced from the ASGISA-EC Mzimvubu Development Project (DWAF, 2009) was refined to include simulation of flows at the EWR site. Catchment developments (forestry, small dams, irrigation and urban/rural water use and return flows) were disaggregated based on information obtained from the ASGISA-EC Mzimvubu Development Project (DWAF, 2009), DWS All Towns Study (DWS, 2015), visual inspection of satellite imagery and catchment area scaling.	**2.5**	**2.5**

11.2.4 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. The following rationale was therefore 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 hydraulic confidence was higher than the biological confidence, the biological confidence determined the overall confidence. Hydrology confidence was also considered. If hydrology was used to guide requirements, then that confidence would be overriding in determining the overall confidence.

The overall confidence in the EWR results is provided in **Table 11.7**.

Table 11.7 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
MzimEWR1	3.5	3.5	2	**2**	Measured ratings at 2.1, 7.1 and 10.2 m^3/s; two highest discharges from a previous study (2012/2013), but stage datum subsequently lost. EWR low flows (REC) in the range 0.7 to 2.7, and 0.5 to 1.1 m^3/s (70 and 95%, respectively).	3.3	3	**3**	No measured high flows, but high flows modelled with more certainty than low flows. Reliable gauge data (T3H006) satisfactory monthly flood peak data. Flood function is well known for vegetation requirements and response. Morphological indicators moderately well-defined and correlate with vegetation indicators.
MzimEWR2	2.5	2.5	1	**1**	Measured ratings at 2.0 and 4.9 m^3/s. Higher discharge from a previous study (2012/2013), but cross-section repositioned shifted upstream for this study. EWR low flows (REC) in the range 0.7 to 2.8, and 0.5 to 1.2 m^3/s (70 and 95%, respectively). Hydraulically, a complex site (bedrock influence).	2	3	**2**	No measured high flows, but high flows modelled with more certainty than low flows. Reliable gauge data (T3H005) with reliable monthly flood peak data. Poor correlation between flood frequency values and estimates from transect as well as poor definition of morphological units. Riparian vegetation indicators were sparse along the transect. Although there was a high reliance on vegetation indicators, the flood function is well known for vegetation requirements and response.

Site	Hydrology	Biological responses: Low flows	Hydraulic: Low Flows	OVERALL: LOW FLOWS	Comment	Biophysical responses: High flows	Hydraulics: High Flows	OVERALL: HIGH FLOWS	Comment
MzimEWR3	2.5	2.5	2	**2**	Measured ratings at 1.0 and 3.0 m^3/s. Higher discharge from a previous study (2012/2013). EWR low flows (REC) in the range 0.5 to 2.5, and 0.3 to 1.3 m^3/s (70 and 95%, respectively).	2.8	3	**2.8**	No measured high flows, but high flows modelled with more certainty than low flows. Gauge (T3H002) frequently overtopped but stage record moderately good. Poor definition of morphological units at the transect. Although there was a high reliance on vegetation indicators, the flood function is well known for vegetation requirements and response.
MzimEWR4	2.5	3	2	**2**	Measured rating at 6.2 m^3/s. EWR low flows (REC) in the range 3.8 to 12.7, and 3.0 to 8.0 m^3/s (70 and 95%, respectively). Hydraulically, a complex site.	2.5	3	**2.5**	No measured high flows, but high flows modelled with more certainty than low flows. Short gauge record (T3H020). Site morphology probably recovering from 2013 flood, morphological indicators not clear. Confirmation of recommended floods from vegetation indicators. Flood function is well known for vegetation requirements and response.

11.3 RECOMMENDATIONS

The confidence in the EcoClassification is Moderate to High which is acceptable for an Intermediate assessment. Furthermore, no further work on the EcoClassification is required as it will not influence the EWR determination. However, monitoring is essential to ensure that the ecological objectives in terms of the REC are achieved and the EC will therefore be verified during monitoring.

In general, the EWR requirements for low flows have a Moderate to High (MzimEWR1) confidence. Additional biological surveys could improve the confidence but it is more important to first improve the confidence of the hydraulics. The hydraulic modelling is mostly Moderate for low flows. This is due to the fact that the previous hydraulic measurements could not be used as effectively as possible due to inadequate placing of benchmarks and the selection of an unsuitable cross-section (MzimEWR2). As the hydraulics confidence represents the overall confidence in most cases for low flows, if results need to be improved the highest priority would be to obtain additional calibrations at low flows. MzimEWR3 will however need the cross-section to move to a more suitable place. It must also be noted that as a new EWR site which is arguably the most important had to be selected in the Mzimvubu River, only one hydraulic calibration could be obtained which is problematic for an Intermediate level study taking into account the complexity of this cross-section. In summary, improvement in confidence in the EWR results should be focussed on improving the hydraulics, then reviewing the EWR requirements if necessary, or to address this through a specific monitoring exercise which will slot into the more general monitoring activities.

Table 11.8 Confidence summary

EWR site	MzimEWR1	MzimEWR2	MzimEWR3	MzimEWR4
Data availability	3.0	3.0	2.9	2.9
Eco-Classification	3.2	3.3	3.1	3.3
Low flow EWR (biotic responses)	3.5	2.5	2.5	3.0
High flow EWR (biophysical responses)	3.3	2.0	2.8	2.5
Hydrology	3.5	2.5	2.5	2.5
Hydraulics (low)	2	1	2	2
Hydraulics (high)	3	3	3	3
Overall low flow EWR confidence	**2**	**1**	**2**	**2**
Overall high flow EWR confidence	**3**	**2**	**2.8**	**2.5**

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APPENDIX A: FINAL OUTPUT RESULTS (EWR RULES) FOR ALL CATEGORIES

A.1 MZIMEWR1

A.1.1 Natural flows: Natural discharge (m^3/s) at % points – Baseflows (separated)

Month	0.1	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99	99.9
Oct	9.87	9.87	6.52	4.80	4.18	3.79	3.04	2.57	2.18	2.06	1.76	1.48	1.37	1.29	1.16	0.92	0.92
Nov	11.05	11.05	9.07	8.55	7.33	6.27	5.01	3.97	3.18	2.75	2.51	2.19	2.01	1.65	1.38	1.26	1.26
Dec	14.55	14.55	11.26	10.11	8.84	8.18	6.93	5.63	4.39	3.69	3.14	2.59	2.39	1.84	1.23	0.61	0.61
Jan	17.30	17.30	13.60	11.71	11.07	10.14	7.93	6.92	5.61	5.09	4.17	3.52	3.00	2.31	1.51	0.85	0.85
Feb	21.36	21.36	17.33	15.41	13.99	12.62	10.39	9.17	7.48	6.96	5.77	4.96	4.43	3.70	2.69	1.66	1.66
Mar	24.37	24.37	18.57	15.21	13.03	11.99	9.93	8.86	7.80	7.30	6.42	5.56	4.98	4.25	3.74	1.91	1.91
Apr	19.37	19.37	14.94	12.79	11.29	10.47	8.54	7.58	6.79	5.88	4.95	4.21	3.63	3.09	2.05	1.16	1.16
May	14.89	14.89	10.72	7.16	6.21	5.95	4.75	4.26	3.80	3.25	2.44	1.98	1.88	1.65	1.39	1.21	1.21
Jun	10.58	10.58	7.62	5.88	5.09	4.17	3.21	2.62	2.10	1.85	1.77	1.52	1.43	1.33	1.19	1.01	1.01
Jul	8.77	8.77	6.09	4.34	3.97	3.41	2.48	2.14	1.91	1.68	1.54	1.33	1.30	1.22	1.09	0.91	0.91
Aug	6.96	6.96	5.43	4.65	3.28	2.63	2.34	1.87	1.70	1.57	1.40	1.20	1.15	1.09	1.00	0.95	0.95
Sep	11.33	11.33	5.12	4.33	3.91	2.82	2.34	2.15	1.91	1.53	1.42	1.26	1.20	1.05	0.96	0.82	0.82

A.1.2 Natural flows: Natural discharge (m^3/s) at % points – Total flows

Month	0.1	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99	99.9
Oct	43.01	43.01	30.05	18.74	13.65	11.98	8.58	6.57	4.78	3.71	3.11	2.27	2.13	1.93	1.50	1.08	1.08
Nov	63.70	63.70	48.24	39.17	29.32	24.12	18.97	14.63	9.67	7.08	5.71	3.79	3.32	2.63	1.86	1.34	1.34
Dec	81.87	81.87	56.54	42.09	39.64	36.20	28.32	20.96	13.18	11.12	8.29	6.16	4.77	2.86	1.93	0.61	0.61
Jan	88.56	88.56	66.87	57.13	44.22	38.66	31.52	23.46	17.60	14.86	12.29	9.95	7.01	5.12	2.96	1.42	1.42
Feb	90.92	90.92	82.30	62.63	55.15	49.69	42.23	36.42	28.85	19.81	14.59	9.98	8.57	7.46	5.94	2.23	2.23

Month	0.1	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99	99.9
Mar	108.07	108.07	81.47	59.98	49.45	40.22	34.19	30.36	26.36	19.34	17.13	13.46	9.93	9.14	6.26	4.28	4.28
Apr	82.08	82.08	43.01	32.63	24.49	21.53	19.07	16.74	11.61	10.21	7.47	5.44	4.80	3.44	2.21	1.16	1.16
May	39.87	39.87	15.00	10.72	9.94	8.72	5.83	4.40	3.92	3.32	2.82	2.01	1.89	1.71	1.39	1.21	1.21
Jun	32.69	32.69	11.63	7.61	6.53	5.25	3.51	2.93	2.27	1.94	1.77	1.55	1.43	1.34	1.19	1.01	1.01
Jul	48.03	48.03	17.53	6.80	4.78	4.10	3.58	2.48	2.07	1.82	1.60	1.41	1.30	1.22	1.16	0.91	0.91
Aug	26.57	26.57	16.06	8.38	5.16	4.82	3.13	2.60	2.04	1.76	1.54	1.22	1.17	1.10	1.02	0.95	0.95
Sep	61.69	61.69	15.15	11.81	9.19	5.84	4.29	3.37	2.44	2.22	1.75	1.42	1.27	1.05	0.96	0.82	0.82

A.1.3 Present Day flows: Present day discharge (m^3/s) at % points – Baseflows (separated)

Month	0.1	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99	99.9
Oct	9.32	9.32	6.09	4.38	3.81	3.48	2.68	2.24	1.90	1.77	1.48	1.23	1.09	1.02	0.89	0.68	0.68
Nov	10.49	10.49	8.54	8.07	6.81	5.79	4.58	3.54	2.82	2.47	2.18	1.90	1.71	1.39	1.12	0.98	0.98
Dec	13.82	13.82	10.66	9.50	8.28	7.81	6.40	5.14	3.96	3.28	2.74	2.27	2.03	1.56	0.97	0.48	0.48
Jan	16.52	16.52	12.94	11.04	10.48	9.53	7.34	6.34	5.08	4.67	3.73	2.97	2.60	1.99	1.26	0.69	0.69
Feb	20.48	20.48	16.52	14.73	13.26	11.91	9.71	8.54	6.88	6.36	5.22	4.45	3.96	3.25	2.32	1.43	1.43
Mar	23.59	23.59	17.79	14.50	12.32	11.34	9.32	8.26	7.19	6.72	5.94	5.04	4.50	3.90	3.34	1.66	1.66
Apr	18.63	18.63	14.27	12.15	10.55	9.89	7.92	6.98	6.26	5.34	4.48	3.80	3.24	2.79	1.83	1.02	1.02
May	14.21	14.21	10.09	6.70	5.73	5.52	4.36	3.97	3.43	2.96	2.22	1.75	1.64	1.46	1.19	1.02	1.02
Jun	9.92	9.92	7.11	5.48	4.81	3.89	2.97	2.39	1.89	1.60	1.48	1.31	1.17	1.06	0.99	0.81	0.81
Jul	8.30	8.30	5.72	4.05	3.74	3.10	2.20	1.92	1.61	1.45	1.28	1.07	1.02	0.93	0.84	0.68	0.68
Aug	6.54	6.54	5.05	4.35	3.01	2.37	2.03	1.63	1.42	1.31	1.11	0.95	0.89	0.82	0.75	0.71	0.71
Sep	10.78	10.78	4.75	3.98	3.51	2.51	2.06	1.83	1.61	1.26	1.14	0.95	0.91	0.80	0.69	0.57	0.57

A.1.4 Present Day flows: Present day discharge (m^3/s) at % points – Total flows

Month	0.1	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99	99.9
Oct	41.32	41.32	28.62	17.68	12.68	11.11	7.85	6.08	4.28	3.37	2.77	1.94	1.86	1.64	1.26	0.80	0.80
Nov	61.57	61.57	46.18	37.43	27.75	22.78	17.86	13.59	8.73	6.36	5.24	3.44	2.97	2.36	1.64	1.12	1.12
Dec	79.26	79.26	54.35	40.33	37.84	34.46	26.85	19.49	12.21	10.12	7.47	5.49	4.39	2.55	1.62	0.48	0.48
Jan	85.73	85.73	64.48	54.84	42.36	37.08	29.88	21.96	16.20	13.65	10.89	9.00	6.29	4.54	2.66	1.22	1.22
Feb	88.33	88.33	79.37	60.29	52.83	47.66	40.40	34.62	27.16	18.37	13.60	9.02	7.81	6.83	5.31	1.94	1.94
Mar	105.99	105.99	79.25	57.95	47.44	38.38	32.55	28.92	24.97	18.02	15.92	12.40	9.16	8.55	5.74	3.90	3.90
Apr	79.61	79.61	41.56	31.25	23.11	20.93	17.88	15.88	10.76	9.29	6.95	5.06	4.49	3.17	2.00	1.02	1.02
May	38.54	38.54	14.22	10.04	9.36	8.09	5.47	4.09	3.66	3.02	2.57	1.82	1.66	1.51	1.19	1.02	1.02
Jun	31.34	31.34	11.05	7.01	6.05	4.98	3.11	2.64	1.97	1.68	1.48	1.31	1.17	1.07	0.99	0.81	0.81
Jul	46.30	46.30	16.72	6.08	4.42	3.71	3.18	2.17	1.76	1.55	1.31	1.12	1.03	0.93	0.90	0.68	0.68
Aug	25.38	25.38	15.22	7.98	4.78	4.25	2.76	2.30	1.68	1.47	1.26	0.96	0.91	0.85	0.78	0.71	0.71
Sep	59.80	59.80	14.19	10.94	8.57	5.30	3.85	2.99	2.10	1.89	1.43	1.10	1.01	0.82	0.69	0.57	0.57

A.1.5 Final EWR results: EWR at (m^3/s) at % points – Low flows (PES and REC: C)

Month	0.1	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99	99.9
Oct	3.25	3.25	2.99	2.67	2.67	2.66	2.18	1.90	1.50	1.17	0.99	0.84	0.79	0.75	0.70	0.62	0.62
Nov	4.37	4.37	4.37	4.37	4.37	4.27	3.48	2.92	2.19	1.54	1.30	1.11	1.02	0.92	0.82	0.77	0.77
Dec	5.67	5.67	5.67	5.67	5.67	5.66	4.95	4.09	2.97	2.09	1.62	1.30	1.16	0.97	0.73	0.46	0.46
Jan	6.93	6.93	6.93	6.93	6.93	6.85	5.77	4.89	3.78	2.83	2.05	1.56	1.35	1.13	0.87	0.65	0.65
Feb	8.00	8.00	8.00	8.00	8.00	7.80	6.67	5.93	4.64	3.42	2.35	1.72	1.49	1.29	1.11	0.95	0.95
Mar	8.80	8.80	8.70	8.53	8.29	7.99	7.25	6.34	5.31	3.95	2.65	1.77	1.50	1.26	1.06	0.97	0.97
Apr	6.92	6.92	6.92	6.92	6.92	6.75	5.90	5.29	4.40	3.12	2.22	1.68	1.45	1.24	1.02	0.82	0.82
May	4.99	4.99	4.63	4.16	4.15	4.15	3.61	3.13	2.50	1.80	1.33	1.09	1.00	0.92	0.82	0.78	0.78
Jun	3.38	3.38	3.14	2.98	2.98	2.88	2.26	1.92	1.37	1.04	0.94	0.86	0.79	0.76	0.72	0.67	0.67

Month	0.1	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99	99.9
Jul	2.86	2.86	2.64	2.45	2.45	2.42	1.79	1.62	1.28	0.97	0.87	0.79	0.75	0.72	0.67	0.58	0.58
Aug	2.36	2.36	2.28	2.15	2.04	1.93	1.69	1.43	1.12	0.89	0.78	0.71	0.68	0.66	0.64	0.63	0.63
Sep	3.30	3.30	2.51	2.21	2.20	2.05	1.62	1.53	1.21	0.84	0.71	0.67	0.59	0.50	0.46	0.46	0.46

A.1.6 Final EWR results: EWR at (m^3/s) at % points – Low flows (EC: D)

Month	0.1	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99	99.9
Oct	2.90	2.90	2.68	2.34	2.34	2.33	1.75	1.27	0.92	0.66	0.52	0.41	0.38	0.36	0.33	0.28	0.28
Nov	3.87	3.87	3.87	3.87	3.87	3.75	2.86	2.07	1.41	0.89	0.70	0.56	0.50	0.44	0.38	0.36	0.36
Dec	5.01	5.01	5.01	5.01	5.01	4.98	4.17	3.10	2.01	1.25	0.88	0.66	0.57	0.47	0.34	0.21	0.21
Jan	6.13	6.13	6.13	6.13	6.13	6.04	4.91	3.86	2.67	1.77	1.15	0.81	0.68	0.55	0.41	0.30	0.30
Feb	7.07	7.07	7.07	7.07	7.07	6.88	5.78	4.95	3.45	2.22	1.36	0.92	0.77	0.65	0.53	0.44	0.44
Mar	7.81	7.81	7.71	7.56	7.34	7.07	6.34	5.43	4.04	2.60	1.60	0.98	0.81	0.65	0.52	0.44	0.44
Apr	6.15	6.15	6.14	6.14	6.14	5.95	5.05	4.26	3.22	1.99	1.27	0.89	0.74	0.61	0.49	0.38	0.38
May	4.45	4.45	4.14	3.62	3.62	3.62	2.97	2.24	1.64	1.06	0.71	0.55	0.49	0.44	0.39	0.36	0.36
Jun	3.02	3.02	2.81	2.65	2.65	2.52	1.82	1.29	0.83	0.59	0.49	0.43	0.38	0.36	0.34	0.31	0.31
Jul	2.56	2.56	2.36	2.15	2.15	2.12	1.42	1.06	0.77	0.55	0.45	0.39	0.36	0.34	0.31	0.27	0.27
Aug	2.11	2.11	2.04	1.95	1.83	1.69	1.34	0.91	0.67	0.50	0.41	0.35	0.33	0.31	0.30	0.29	0.29
Sep	2.94	2.94	2.24	1.97	1.96	1.80	1.33	1.03	0.74	0.51	0.38	0.33	0.29	0.24	0.21	0.21	0.21

A.1.7 Final EWR results: EWR at (m^3/s) at % points – Total flows (PES and REC: C)

Month	0.1	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99	99.9
Oct	10.56	10.56	5.76	4.01	3.97	3.68	3.06	2.71	1.50	1.17	0.99	0.84	0.79	0.75	0.70	0.62	0.62
Nov	20.42	20.42	14.48	11.73	9.93	6.48	4.91	4.10	3.16	2.17	1.34	1.11	1.02	0.92	0.82	0.77	0.77
Dec	28.08	28.08	15.46	13.46	12.99	12.56	7.91	5.86	4.15	3.08	2.50	1.32	1.16	0.97	0.73	0.46	0.46
Jan	30.73	30.73	17.57	14.25	11.70	9.73	8.24	7.07	4.87	4.08	3.03	2.43	1.59	1.16	0.87	0.65	0.65
Feb	31.50	31.50	27.88	17.66	16.03	14.84	12.48	9.82	6.67	4.55	3.34	2.56	1.83	1.34	1.11	0.95	0.95

Month	0.1	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99	99.9
Mar	36.67	36.67	22.47	17.97	15.79	14.58	10.57	8.55	7.24	5.46	3.83	2.77	2.12	1.42	1.11	0.97	0.97
Apr	17.04	17.04	9.85	8.52	8.26	7.92	7.24	6.34	5.13	3.72	2.22	1.68	1.45	1.24	1.02	0.82	0.82
May	12.31	12.31	5.40	4.99	4.19	4.15	3.61	3.13	2.50	1.80	1.33	1.09	1.00	0.92	0.82	0.78	0.78
Jun	9.64	9.64	3.97	2.98	2.98	2.88	2.26	1.92	1.37	1.04	0.94	0.86	0.79	0.76	0.72	0.67	0.67
Jul	15.93	15.93	3.80	2.79	2.45	2.42	1.79	1.62	1.28	0.97	0.87	0.79	0.75	0.72	0.67	0.58	0.58
Aug	5.29	5.29	3.52	2.95	2.05	1.93	1.69	1.43	1.12	0.89	0.78	0.71	0.68	0.66	0.64	0.63	0.63
Sep	15.13	15.13	3.80	3.07	3.05	2.63	1.62	1.53	1.21	0.84	0.71	0.67	0.59	0.50	0.46	0.46	0.46

A.1.8 Final EWR results: EWR at (m^3/s) at % points – Total flows (EC: D)

Month	0.1	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99	99.9
Oct	9.53	9.53	4.91	3.64	3.19	3.13	2.44	1.86	0.92	0.66	0.52	0.41	0.38	0.36	0.33	0.28	0.28
Nov	19.93	19.93	13.98	10.86	7.67	5.84	4.10	3.02	2.29	1.32	0.70	0.56	0.50	0.44	0.38	0.36	0.36
Dec	27.42	27.42	14.79	12.43	12.32	11.10	6.42	4.40	3.10	2.14	1.38	0.66	0.57	0.47	0.34	0.21	0.21
Jan	29.93	29.93	16.50	13.45	9.60	8.51	7.08	6.05	3.83	2.68	1.89	0.89	0.68	0.55	0.41	0.30	0.30
Feb	30.57	30.57	26.96	16.38	14.25	13.42	10.04	7.50	5.31	3.28	2.16	1.10	0.80	0.65	0.53	0.44	0.44
Mar	35.67	35.67	21.50	16.32	14.77	11.38	8.01	7.20	5.51	4.23	2.35	1.72	0.81	0.65	0.52	0.44	0.44
Apr	16.27	16.27	8.89	7.48	7.44	6.99	6.13	5.23	3.82	1.99	1.27	0.89	0.74	0.61	0.49	0.38	0.38
May	11.76	11.76	4.91	4.04	3.62	3.62	2.97	2.24	1.64	1.06	0.71	0.55	0.49	0.44	0.39	0.36	0.36
Jun	8.13	8.13	3.64	2.65	2.65	2.52	1.82	1.29	0.83	0.59	0.49	0.43	0.38	0.36	0.34	0.31	0.31
Jul	15.63	15.63	3.52	2.49	2.15	2.12	1.42	1.06	0.77	0.55	0.45	0.39	0.36	0.34	0.31	0.27	0.27
Aug	3.41	3.41	2.86	2.70	1.83	1.69	1.34	0.91	0.67	0.50	0.41	0.35	0.33	0.31	0.30	0.29	0.29
Sep	13.91	13.91	3.54	2.83	2.44	1.93	1.33	1.03	0.74	0.51	0.38	0.33	0.29	0.24	0.21	0.21	0.21

A.2 MZIMEWR2

A.2.1 Natural flows: Natural discharge (m^3/s) at % points – Baseflows (separated)

Month	0.1	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99	99.9
Oct	12.18	12.18	8.21	4.63	3.59	3.44	2.20	1.84	1.63	1.45	1.35	1.16	1.09	1.03	0.93	0.73	0.73
Nov	13.51	13.51	9.90	7.89	6.44	5.38	3.22	2.50	2.11	1.84	1.73	1.46	1.33	1.21	1.09	0.95	0.95
Dec	15.71	15.71	12.54	10.97	9.01	7.20	5.54	4.05	2.79	2.36	1.89	1.54	1.29	1.09	0.88	0.62	0.62
Jan	21.84	21.84	17.21	12.85	10.74	9.14	6.59	5.37	4.36	3.66	2.68	1.94	1.52	1.31	1.14	0.66	0.66
Feb	27.30	27.30	21.51	19.42	15.49	12.97	8.92	7.68	6.67	5.70	4.30	3.28	2.86	2.25	1.81	1.17	1.17
Mar	34.86	34.86	18.94	14.64	13.31	12.54	10.71	7.92	6.74	5.36	4.63	3.88	3.35	2.91	2.28	1.19	1.19
Apr	23.54	23.54	13.25	10.98	9.74	9.38	7.05	5.80	5.09	4.42	3.60	3.05	2.64	2.34	1.43	1.16	1.16
May	14.37	14.37	9.45	7.33	5.35	4.60	3.91	3.15	2.84	2.31	2.11	1.84	1.74	1.55	1.39	0.96	0.96
Jun	11.60	11.60	6.95	4.78	3.92	3.25	2.60	2.25	1.92	1.78	1.55	1.37	1.30	1.19	1.10	1.01	1.01
Jul	10.81	10.81	5.62	3.61	3.13	2.56	2.21	1.89	1.71	1.56	1.32	1.17	1.08	1.02	1.00	0.88	0.88
Aug	6.89	6.89	4.43	3.54	2.53	2.16	1.93	1.60	1.47	1.27	1.20	1.06	1.00	0.93	0.84	0.75	0.75
Sep	20.60	20.60	5.55	3.19	2.79	2.24	1.91	1.68	1.44	1.29	1.18	1.07	1.01	0.90	0.78	0.66	0.66

A.2.2. Natural flows: Natural discharge (m^3/s) at % points – Total flows

Month	0.1	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99	99.9
Oct	54.11	54.11	41.26	15.02	10.50	7.43	4.36	3.57	2.75	2.27	2.13	1.66	1.57	1.35	1.07	0.86	0.86
Nov	79.22	79.22	53.52	37.48	24.51	19.41	8.61	6.87	4.12	3.51	2.71	2.27	2.06	1.84	1.31	1.09	1.09
Dec	93.44	93.44	68.62	50.27	42.35	31.10	22.73	11.70	6.28	4.36	3.23	2.20	1.87	1.26	0.89	0.62	0.62
Jan	118.25	118.25	84.73	63.33	46.30	34.36	28.63	16.29	13.51	9.90	6.34	3.84	3.39	2.63	1.69	0.89	0.89
Feb	144.33	144.33	101.13	88.87	71.13	49.06	39.85	29.45	23.53	17.61	8.97	6.12	4.65	4.16	3.65	1.41	1.41
Mar	158.60	158.60	93.93	62.24	55.66	44.28	36.33	28.89	22.50	15.24	10.97	7.65	6.29	5.42	4.24	1.98	1.98
Apr	59.19	59.19	44.76	28.34	19.77	17.30	13.61	11.34	9.20	7.08	5.20	4.15	3.31	2.82	1.68	1.16	1.16
May	49.12	49.12	13.73	9.03	7.29	6.21	4.41	3.66	2.98	2.54	2.17	1.93	1.78	1.59	1.47	0.96	0.96

Month	0.1	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99	99.9
Jun	47.06	47.06	15.92	6.12	4.51	4.08	3.12	2.49	2.10	1.84	1.59	1.39	1.30	1.19	1.10	1.07	1.07
Jul	60.41	60.41	14.30	4.35	3.84	3.35	2.74	2.25	1.79	1.60	1.34	1.17	1.08	1.02	1.00	0.88	0.88
Aug	25.74	25.74	11.38	4.80	3.85	3.38	2.30	1.97	1.58	1.40	1.28	1.16	1.01	0.93	0.84	0.75	0.75
Sep	121.23	121.23	15.78	8.57	4.52	3.39	2.95	2.33	1.94	1.55	1.33	1.12	1.05	1.00	0.78	0.66	0.66

A.2.3 Present Day flows: Present day discharge (m^3/s) at % points – Baseflows (separated)

Month	0.1	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99	99.9
Oct	11.93	11.93	7.88	4.41	3.36	3.22	2.01	1.67	1.45	1.27	1.17	1.00	0.92	0.85	0.76	0.57	0.57
Nov	13.18	13.18	9.54	7.60	6.20	5.06	2.99	2.31	1.91	1.64	1.53	1.27	1.15	1.08	0.90	0.78	0.78
Dec	15.37	15.37	12.18	10.61	8.65	6.89	5.23	3.79	2.58	2.15	1.71	1.35	1.11	0.91	0.71	0.46	0.46
Jan	21.53	21.53	16.86	12.50	10.38	8.81	6.30	5.10	4.09	3.41	2.47	1.73	1.32	1.18	0.96	0.50	0.50
Feb	27.03	27.03	21.16	19.09	15.09	12.64	8.56	7.36	6.36	5.43	4.03	3.06	2.59	2.04	1.60	0.98	0.98
Mar	34.61	34.61	18.60	14.30	12.95	12.17	10.39	7.60	6.39	5.09	4.39	3.65	3.15	2.69	2.08	1.01	1.01
Apr	23.29	23.29	12.95	10.64	9.44	9.12	6.76	5.58	4.85	4.19	3.38	2.85	2.42	2.14	1.24	1.00	1.00
May	14.12	14.12	9.15	7.13	5.09	4.36	3.69	2.98	2.66	2.14	1.94	1.67	1.55	1.40	1.22	0.79	0.79
Jun	11.33	11.33	6.67	4.60	3.70	3.07	2.43	2.08	1.77	1.60	1.38	1.19	1.11	1.01	0.93	0.83	0.83
Jul	10.50	10.50	5.40	3.43	2.97	2.38	2.04	1.71	1.52	1.39	1.15	1.00	0.91	0.85	0.83	0.71	0.71
Aug	6.66	6.66	4.22	3.33	2.34	1.99	1.74	1.43	1.30	1.11	1.03	0.89	0.83	0.76	0.68	0.58	0.58
Sep	20.30	20.30	5.31	2.99	2.60	2.04	1.74	1.49	1.25	1.11	1.00	0.90	0.83	0.73	0.61	0.50	0.50

A.2.4 Present Day flows: Present day discharge (m^3/s) at % points – Total flows

Month	0.1	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99	99.9
Oct	53.03	53.03	40.09	14.39	10.10	7.17	4.10	3.34	2.54	2.07	1.91	1.46	1.38	1.16	0.88	0.68	0.68
Nov	78.12	78.12	52.17	36.36	23.50	18.85	8.26	6.57	3.82	3.27	2.49	2.06	1.84	1.64	1.13	0.90	0.90
Dec	92.20	92.20	67.47	49.15	41.60	30.09	21.87	11.27	6.01	4.08	3.00	2.02	1.68	1.08	0.71	0.46	0.46
Jan	117.48	117.48	83.69	62.43	45.20	33.59	27.64	15.75	13.00	9.43	6.09	3.61	3.15	2.41	1.50	0.70	0.70

Feb	144.17	144.17	100.40	88.11	69.97	48.44	38.89	28.77	22.78	17.24	8.66	5.85	4.41	3.91	3.42	1.23	1.23
Mar	158.42	158.42	93.07	61.05	54.69	44.07	35.59	28.03	21.60	14.91	10.55	7.35	6.05	5.18	3.97	1.79	1.79
Apr	58.71	58.71	44.17	27.76	19.08	16.83	13.27	10.90	8.97	6.82	4.97	3.95	3.10	2.65	1.50	1.00	1.00
May	48.38	48.38	13.48	8.70	7.10	6.00	4.23	3.49	2.79	2.36	2.01	1.77	1.62	1.43	1.29	0.79	0.79
Jun	46.19	46.19	15.63	5.87	4.34	3.88	2.97	2.33	1.94	1.67	1.42	1.22	1.13	1.01	0.93	0.90	0.90
Jul	59.27	59.27	13.91	4.14	3.66	3.15	2.55	2.08	1.61	1.44	1.18	1.00	0.91	0.85	0.83	0.71	0.71
Aug	24.87	24.87	11.02	4.58	3.64	3.18	2.12	1.79	1.42	1.22	1.11	0.98	0.86	0.76	0.68	0.58	0.58
Sep	120.42	120.42	15.11	8.32	4.28	3.16	2.73	2.14	1.73	1.36	1.14	0.94	0.88	0.82	0.61	0.50	0.50

A.2.5 Final EWR results: EWR at (m^3/s) at % points – Low flows (PES and REC: C)

Month	0.1	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99	99.9
Oct	3.91	3.91	3.39	2.66	2.41	2.38	1.66	1.43	1.20	1.07	0.92	0.80	0.76	0.72	0.68	0.64	0.64
Nov	4.67	4.67	4.57	4.39	4.20	4.03	2.59	1.94	1.53	1.26	1.08	0.91	0.86	0.80	0.75	0.75	0.75
Dec	6.68	6.68	6.68	6.52	6.26	5.82	4.73	3.27	2.10	1.61	1.21	0.95	0.84	0.75	0.63	0.46	0.46
Jan	11.15	11.15	10.82	8.35	7.84	7.57	6.18	4.50	3.20	2.33	1.60	1.14	0.98	0.87	0.76	0.63	0.63
Feb	13.69	13.69	13.10	12.23	11.19	10.08	7.95	5.96	4.28	2.83	1.79	1.36	1.16	1.05	0.93	0.86	0.86
Mar	13.45	13.45	12.11	10.62	10.11	10.08	9.03	6.74	4.93	3.60	2.73	2.24	2.01	1.76	1.51	1.20	1.20
Apr	10.51	10.51	8.19	7.45	7.44	7.42	6.31	4.70	3.53	2.56	1.78	1.39	1.28	1.28	1.08	0.89	0.89
May	5.23	5.23	4.74	4.00	3.70	3.51	3.18	2.56	2.04	1.60	1.27	1.10	1.03	0.96	0.88	0.79	0.79
Jun	3.44	3.44	2.96	2.58	2.46	2.37	2.02	1.71	1.38	1.23	1.00	0.87	0.84	0.80	0.78	0.78	0.78
Jul	3.17	3.17	2.59	2.03	1.97	1.91	1.70	1.50	1.24	1.11	0.90	0.79	0.76	0.73	0.72	0.71	0.71
Aug	1.81	1.81	1.78	1.73	1.67	1.60	1.42	1.24	1.06	0.94	0.83	0.74	0.70	0.67	0.65	0.58	0.58
Sep	7.21	7.21	3.59	1.92	1.76	1.64	1.57	1.26	1.02	0.83	0.67	0.60	0.60	0.58	0.52	0.50	0.50

A.2.6 Final EWR results: EWR at (m^3/s) at % points – Low flows (EC: D)

Month	0.1	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99	99.9
Oct	2.47	2.47	2.08	1.55	1.39	1.38	0.97	0.86	0.74	0.68	0.60	0.54	0.52	0.50	0.47	0.45	0.45

Month	0.1	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99	99.9
Nov	3.03	3.03	2.94	2.76	2.62	2.54	1.61	1.21	0.96	0.80	0.72	0.62	0.59	0.56	0.53	0.53	0.53
Dec	4.57	4.57	4.57	4.40	4.19	3.92	3.24	2.17	1.35	1.03	0.81	0.65	0.58	0.52	0.44	0.39	0.39
Jan	8.22	8.22	7.95	5.89	5.50	5.38	4.43	3.14	2.14	1.51	1.12	0.79	0.68	0.61	0.54	0.45	0.45
Feb	10.34	10.34	9.89	9.25	8.49	7.67	5.97	4.40	2.95	1.83	1.35	1.01	0.85	0.76	0.67	0.63	0.63
Mar	9.35	9.35	8.65	7.78	7.27	7.05	6.09	4.52	3.24	2.32	1.88	1.57	1.41	1.24	1.07	0.86	0.86
Apr	7.67	7.67	5.74	5.32	5.32	5.31	4.54	3.30	2.38	1.67	1.30	1.03	0.93	0.91	0.77	0.64	0.64
May	3.46	3.46	3.08	2.47	2.26	2.19	2.04	1.65	1.31	1.02	0.86	0.76	0.72	0.68	0.63	0.59	0.59
Jun	2.12	2.12	1.77	1.49	1.41	1.38	1.21	1.05	0.86	0.78	0.66	0.59	0.57	0.56	0.56	0.56	0.56
Jul	1.95	1.95	1.56	1.13	1.11	1.08	1.00	0.90	0.77	0.70	0.59	0.53	0.52	0.51	0.51	0.51	0.51
Aug	0.97	0.97	0.96	0.94	0.92	0.89	0.82	0.74	0.65	0.59	0.54	0.50	0.48	0.46	0.45	0.44	0.44
Sep	5.13	5.13	2.38	1.15	1.06	1.04	1.03	0.77	0.67	0.53	0.46	0.42	0.42	0.40	0.37	0.37	0.37

A.2.7 Final EWR results: EWR at (m^3/s) at % points – Total flows (PES and REC: C)

Month	0.1	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99	99.9
Oct	10.94	10.94	5.66	3.87	3.29	2.93	2.08	1.45	1.20	1.07	0.92	0.80	0.76	0.72	0.68	0.64	0.64
Nov	10.51	10.51	8.86	5.98	5.17	4.79	3.30	2.48	1.53	1.26	1.08	0.91	0.86	0.80	0.75	0.75	0.75
Dec	22.94	22.94	10.98	10.15	8.10	7.52	6.29	3.87	2.70	1.65	1.21	0.95	0.84	0.75	0.63	0.46	0.46
Jan	41.12	41.12	26.79	14.44	11.62	10.47	8.00	5.67	4.46	3.07	1.80	1.14	0.98	0.87	0.76	0.63	0.63
Feb	50.06	50.06	37.19	18.52	15.50	14.46	11.51	7.88	5.53	4.00	2.33	1.42	1.16	1.05	0.93	0.86	0.86
Mar	51.91	51.91	30.26	17.13	15.42	12.44	10.70	9.10	5.91	4.48	3.51	2.66	2.01	1.81	1.54	1.20	1.20
Apr	13.74	13.74	9.55	9.30	8.37	8.34	7.11	5.02	4.04	2.77	1.86	1.39	1.28	1.28	1.08	0.89	0.89
May	7.08	7.08	4.76	4.39	3.91	3.53	3.18	2.56	2.04	1.60	1.27	1.10	1.03	0.96	0.88	0.79	0.79
Jun	8.10	8.10	3.57	2.76	2.46	2.37	2.02	1.71	1.38	1.23	1.00	0.87	0.84	0.80	0.78	0.78	0.78
Jul	6.22	6.22	3.32	2.21	1.97	1.91	1.70	1.50	1.24	1.11	0.90	0.79	0.76	0.73	0.72	0.71	0.71
Aug	2.41	2.41	2.38	1.91	1.67	1.60	1.42	1.24	1.06	0.94	0.83	0.74	0.70	0.67	0.65	0.58	0.58
Sep	13.74	13.74	4.21	2.43	1.76	1.64	1.57	1.26	1.02	0.83	0.67	0.60	0.60	0.58	0.52	0.50	0.50

A.2.8 Final EWR results: EWR at (m^3/s) at % points – Total flows (EC: D)

Month	0.1	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99	99.9
Oct	9.39	9.39	4.35	2.55	2.02	1.83	1.23	0.86	0.74	0.68	0.60	0.54	0.52	0.50	0.47	0.45	0.45
Nov	10.42	10.42	7.23	4.20	3.52	3.23	2.23	1.59	0.96	0.80	0.72	0.62	0.59	0.56	0.53	0.53	0.53
Dec	20.83	20.83	8.86	7.23	6.03	5.34	4.39	2.77	1.72	1.05	0.81	0.65	0.58	0.52	0.44	0.39	0.39
Jan	38.19	38.19	24.20	10.89	9.15	7.95	5.80	3.69	2.90	2.12	1.17	0.79	0.68	0.61	0.54	0.45	0.45
Feb	46.72	46.72	34.03	15.66	12.74	11.63	9.07	6.12	3.96	2.66	1.61	1.01	0.85	0.76	0.67	0.63	0.63
Mar	47.81	47.81	27.11	13.99	11.97	9.11	7.70	6.14	3.99	3.17	2.29	1.60	1.45	1.24	1.07	0.86	0.86
Apr	11.14	11.14	7.26	6.44	6.23	6.16	5.31	3.55	2.88	1.74	1.30	1.03	0.93	0.91	0.77	0.64	0.64
May	5.31	5.31	3.10	2.78	2.30	2.20	2.04	1.65	1.31	1.02	0.86	0.76	0.72	0.68	0.63	0.59	0.59
Jun	6.78	6.78	2.41	1.54	1.41	1.38	1.21	1.05	0.86	0.78	0.66	0.59	0.57	0.56	0.56	0.56	0.56
Jul	5.00	5.00	2.26	1.13	1.11	1.08	1.00	0.90	0.77	0.70	0.59	0.53	0.52	0.51	0.51	0.51	0.51
Aug	1.58	1.58	1.38	0.94	0.92	0.89	0.82	0.74	0.65	0.59	0.54	0.50	0.48	0.46	0.45	0.44	0.44
Sep	11.65	11.65	3.00	1.31	1.06	1.04	1.03	0.77	0.67	0.53	0.46	0.42	0.42	0.40	0.37	0.37	0.37

A.3 MZIMEWR3

A.3.1 Natural flows: Natural discharge (m^3/s) at % points – Baseflows (separated)

Month	0.1	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99	99.9
Oct	12.61	12.61	6.32	4.51	3.76	3.26	2.46	2.07	1.86	1.63	1.41	1.18	1.11	1.07	0.88	0.60	0.60
Nov	15.79	15.79	8.36	5.34	4.35	4.09	3.00	2.65	2.39	2.02	1.89	1.62	1.37	1.20	1.06	0.96	0.96
Dec	15.74	15.74	12.25	9.32	7.93	6.75	5.05	4.28	3.07	2.30	2.00	1.57	1.39	1.17	0.87	0.56	0.56
Jan	25.53	25.53	18.15	12.65	11.15	9.37	7.15	5.72	4.89	3.97	3.44	2.71	2.25	1.78	1.36	0.96	0.96
Feb	22.19	22.19	20.53	17.36	15.35	13.40	10.49	8.56	7.33	6.64	4.94	4.14	3.29	2.87	2.41	0.98	0.98
Mar	34.32	34.32	18.16	14.41	12.88	11.95	9.64	8.18	6.87	6.02	5.14	4.57	4.09	3.51	2.73	1.17	1.17
Apr	23.19	23.19	12.41	10.62	9.17	7.97	6.82	6.01	4.92	4.36	3.72	3.22	2.88	2.35	1.63	0.95	0.95
May	12.71	12.71	7.74	5.90	5.49	4.99	3.69	3.13	2.74	2.36	2.21	1.72	1.61	1.44	1.23	0.95	0.95

Month	0.1	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99	99.9
Jun	12.68	12.68	6.28	4.72	3.79	3.06	2.67	2.37	2.05	1.81	1.56	1.40	1.32	1.17	1.09	0.97	0.97
Jul	8.52	8.52	4.89	4.19	3.08	2.63	2.31	2.12	1.74	1.52	1.38	1.22	1.17	1.10	0.98	0.82	0.82
Aug	9.39	9.39	5.00	3.55	2.93	2.49	1.95	1.68	1.48	1.38	1.22	1.13	1.06	0.96	0.87	0.78	0.78
Sep	21.46	21.46	5.97	4.43	2.97	2.40	2.07	1.68	1.56	1.38	1.24	1.06	0.96	0.92	0.77	0.62	0.62

A.3.2 Natural flows: Natural discharge (m^3/s) at % points – Total flows

Month	0.1	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99	99.9
Oct	54.26	54.26	25.92	16.82	12.47	9.67	6.15	3.90	3.24	2.45	2.17	1.82	1.57	1.33	1.05	0.60	0.60
Nov	65.05	65.05	48.10	21.13	16.74	10.85	8.98	6.95	4.88	4.39	3.69	2.40	1.83	1.63	1.27	1.00	1.00
Dec	77.95	77.95	60.78	47.25	36.18	31.53	21.64	14.10	6.82	5.30	4.03	2.41	2.12	1.60	0.91	0.56	0.56
Jan	146.43	146.43	97.54	68.74	47.30	42.96	30.05	20.98	15.89	13.36	9.52	6.41	5.20	3.54	1.82	1.03	1.03
Feb	101.77	101.77	94.48	81.93	70.28	63.35	40.12	33.73	26.97	19.45	12.75	9.57	8.61	6.73	4.63	0.98	0.98
Mar	156.55	156.55	83.74	68.52	51.99	42.63	30.41	24.81	20.47	16.13	12.58	8.43	7.53	6.13	3.56	2.68	2.68
Apr	51.52	51.52	35.36	23.47	21.74	16.72	12.76	10.07	7.65	6.56	5.24	3.58	3.28	2.87	1.83	0.95	0.95
May	55.04	55.04	15.42	7.86	6.54	5.54	4.37	3.49	2.99	2.41	2.26	1.75	1.63	1.45	1.26	0.95	0.95
Jun	58.75	58.75	13.65	6.95	4.77	3.62	2.93	2.44	2.06	1.82	1.59	1.42	1.36	1.19	1.12	0.97	0.97
Jul	37.33	37.33	13.63	5.12	4.52	3.98	2.65	2.33	1.92	1.62	1.45	1.26	1.19	1.12	1.02	0.82	0.82
Aug	37.43	37.43	13.84	6.20	4.30	3.70	2.62	2.12	1.73	1.45	1.36	1.19	1.10	1.00	0.87	0.78	0.78
Sep	125.00	125.00	28.73	12.86	6.89	5.18	3.11	2.47	2.05	1.56	1.33	1.13	1.02	0.93	0.77	0.62	0.62

A.3.3. Present Day flows: Present day discharge (m^3/s) at % points – Baseflows (separated)

Month	0.1	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99	99.9
Oct	12.42	12.42	6.14	4.36	3.63	3.12	2.34	1.95	1.74	1.52	1.30	1.08	1.01	0.97	0.79	0.52	0.52
Nov	15.52	15.52	8.16	5.17	4.20	3.94	2.87	2.52	2.26	1.90	1.77	1.51	1.27	1.12	0.96	0.86	0.86
Dec	15.47	15.47	12.00	9.11	7.75	6.58	4.89	4.13	2.94	2.18	1.89	1.47	1.29	1.07	0.79	0.48	0.48
Jan	25.30	25.30	17.90	12.42	10.91	9.17	6.97	5.56	4.73	3.82	3.29	2.58	2.13	1.67	1.26	0.87	0.87

Month	0.1	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99	99.9
Feb	21.93	21.93	20.25	17.09	15.09	13.13	10.27	8.37	7.13	6.46	4.78	3.98	3.15	2.75	2.29	0.89	0.89
Mar	34.02	34.02	17.91	14.18	12.66	11.72	9.43	8.00	6.71	5.84	4.98	4.42	3.95	3.38	2.60	1.08	1.08
Apr	22.93	22.93	12.20	10.41	8.97	7.78	6.64	5.85	4.77	4.21	3.58	3.08	2.75	2.24	1.52	0.86	0.86
May	12.48	12.48	7.54	5.73	5.33	4.83	3.56	3.00	2.61	2.24	2.09	1.61	1.51	1.34	1.14	0.85	0.85
Jun	12.44	12.44	6.10	4.57	3.64	2.92	2.54	2.25	1.94	1.69	1.45	1.30	1.22	1.07	1.00	0.87	0.87
Jul	8.32	8.32	4.74	4.04	2.95	2.50	2.19	2.00	1.63	1.41	1.27	1.11	1.07	1.00	0.89	0.72	0.72
Aug	9.17	9.17	4.85	3.41	2.80	2.36	1.84	1.57	1.38	1.28	1.12	1.04	0.96	0.86	0.77	0.68	0.68
Sep	21.21	21.21	5.79	4.28	2.82	2.28	1.96	1.57	1.45	1.27	1.14	0.96	0.86	0.82	0.68	0.53	0.53

A.3.4 Present Day flows: Present day discharge (m^3/s) at % points – Total flows

Month	0.1	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99	99.9
Oct	53.32	53.32	25.35	16.52	12.19	9.39	5.95	3.74	3.09	2.32	2.05	1.70	1.46	1.23	0.95	0.52	0.52
Nov	64.37	64.37	47.33	20.70	16.42	10.57	8.75	6.76	4.72	4.21	3.54	2.29	1.72	1.52	1.17	0.91	0.91
Dec	76.99	76.99	59.88	46.54	35.63	31.06	21.23	13.80	6.63	5.13	3.88	2.28	2.00	1.50	0.82	0.48	0.48
Jan	145.58	145.58	96.62	67.82	46.55	42.18	29.53	20.51	15.55	13.06	9.28	6.22	5.03	3.39	1.72	0.93	0.93
Feb	101.00	101.00	93.62	81.25	69.52	62.48	39.43	33.16	26.55	19.00	12.49	9.34	8.38	6.53	4.45	0.89	0.89
Mar	155.72	155.72	83.00	67.72	51.39	42.17	30.01	24.48	20.15	15.85	12.34	8.22	7.33	5.94	3.42	2.55	2.55
Apr	51.15	51.15	34.96	23.15	21.44	16.44	12.51	9.84	7.46	6.38	5.08	3.43	3.14	2.74	1.71	0.86	0.86
May	54.42	54.42	15.11	7.66	6.37	5.38	4.21	3.35	2.85	2.28	2.13	1.64	1.52	1.35	1.17	0.85	0.85
Jun	58.04	58.04	13.39	6.75	4.60	3.48	2.80	2.30	1.94	1.70	1.48	1.32	1.26	1.09	1.02	0.87	0.87
Jul	36.73	36.73	13.37	4.96	4.34	3.83	2.52	2.20	1.81	1.51	1.35	1.16	1.08	1.02	0.92	0.72	0.72
Aug	36.90	36.90	13.58	6.01	4.14	3.53	2.49	1.99	1.61	1.34	1.25	1.08	0.99	0.90	0.77	0.68	0.68
Sep	124.02	124.02	28.22	12.57	6.68	5.00	2.96	2.33	1.93	1.45	1.22	1.02	0.92	0.84	0.68	0.53	0.53

A.3.5 Final EWR results: EWR at (m^3/s) at % points – Low flows (PES and REC: C)

Month	0.1	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99	99.9
Oct	6.12	6.12	3.20	2.12	2.09	2.01	1.57	1.35	1.09	0.85	0.64	0.49	0.45	0.43	0.43	0.43	0.43
Nov	7.47	7.47	4.04	2.48	2.48	2.48	2.03	1.70	1.39	1.06	0.84	0.65	0.62	0.62	0.62	0.62	0.62
Dec	8.58	8.58	6.45	5.19	5.05	4.85	3.85	3.08	1.94	1.27	0.92	0.67	0.57	0.47	0.40	0.40	0.40
Jan	14.13	14.13	11.10	9.10	8.05	7.35	6.06	4.64	3.45	2.25	1.62	1.15	1.00	0.81	0.70	0.70	0.70
Feb	12.59	12.59	12.29	11.84	11.26	10.55	8.84	6.90	4.94	3.38	2.24	1.66	1.43	1.23	1.15	0.89	0.89
Mar	18.33	18.33	13.06	10.44	10.05	9.73	7.64	6.10	4.60	3.43	2.47	1.93	1.73	1.51	1.29	1.09	1.09
Apr	11.73	11.73	7.78	5.98	5.98	5.85	5.36	4.69	3.33	2.39	1.77	1.36	1.27	1.07	0.83	0.77	0.77
May	6.48	6.48	4.01	3.29	3.28	3.25	2.54	2.16	1.71	1.27	1.00	0.72	0.67	0.67	0.67	0.67	0.67
Jun	6.02	6.02	3.27	2.00	1.95	1.89	1.67	1.48	1.18	0.92	0.69	0.63	0.63	0.63	0.63	0.63	0.63
Jul	4.47	4.47	3.00	2.19	1.81	1.61	1.46	1.36	1.05	0.80	0.64	0.64	0.64	0.64	0.64	0.64	0.64
Aug	4.77	4.77	2.94	1.99	1.72	1.53	1.32	1.12	0.98	0.72	0.56	0.53	0.53	0.53	0.53	0.53	0.53
Sep	1.72	1.72	1.67	1.60	1.52	1.43	1.22	1.04	0.86	0.69	0.54	0.41	0.37	0.33	0.30	0.27	0.27

A.3.6 Final EWR results: EWR at (m^3/s) at % points – Low flows (EC: D)

Month	0.1	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99	99.9
Oct	5.30	5.30	2.40	1.37	1.35	1.25	0.99	0.86	0.70	0.55	0.44	0.37	0.37	0.37	0.37	0.37	0.37
Nov	6.49	6.49	3.12	1.62	1.61	1.61	1.34	1.12	0.91	0.69	0.58	0.53	0.53	0.53	0.53	0.53	0.53
Dec	7.49	7.49	5.29	3.98	3.81	3.61	2.84	2.22	1.32	0.84	0.64	0.49	0.43	0.37	0.34	0.34	0.34
Jan	12.46	12.46	9.51	7.67	6.67	5.98	4.85	3.56	2.54	1.56	1.18	0.84	0.76	0.64	0.59	0.59	0.59
Feb	11.25	11.25	10.96	10.51	9.94	9.24	7.55	5.63	3.86	2.40	1.70	1.19	1.09	1.00	0.92	0.87	0.87
Mar	16.22	16.22	11.30	9.06	8.62	8.14	5.79	4.49	3.28	2.45	1.77	1.40	1.32	1.20	1.05	0.92	0.92
Apr	10.29	10.29	6.44	4.67	4.66	4.52	4.19	3.60	2.43	1.67	1.30	0.99	0.96	0.85	0.67	0.64	0.64
May	5.60	5.60	3.08	2.26	2.24	2.23	1.75	1.47	1.15	0.84	0.70	0.57	0.57	0.57	0.57	0.57	0.57
Jun	5.22	5.22	2.50	1.31	1.20	1.16	1.07	0.96	0.76	0.59	0.54	0.54	0.54	0.54	0.54	0.53	0.53
Jul	3.91	3.91	2.48	1.66	1.22	0.96	0.92	0.87	0.67	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55

Month	0.1	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99	99.9
Aug	4.19	4.19	2.44	1.52	1.18	0.95	0.88	0.73	0.69	0.47	0.46	0.46	0.46	0.46	0.46	0.46	0.46
Sep	0.95	0.95	0.93	0.91	0.88	0.84	0.75	0.65	0.54	0.44	0.36	0.30	0.28	0.26	0.24	0.23	0.23

A.3.7 Final EWR results: EWR at (m^3/s) at % points – Total flows (PES and REC: C)

Month	0.1	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99	99.9
Oct	18.93	18.93	6.77	4.97	3.10	2.98	2.15	1.35	1.09	0.85	0.64	0.49	0.45	0.43	0.43	0.43	0.43
Nov	21.78	21.78	11.31	5.44	3.51	3.51	2.93	2.27	1.39	1.06	0.84	0.65	0.62	0.62	0.62	0.62	0.62
Dec	25.18	25.18	13.19	11.81	9.96	8.74	6.49	4.13	2.94	1.27	0.92	0.67	0.57	0.47	0.40	0.40	0.40
Jan	47.40	47.40	34.33	19.21	16.09	13.79	9.76	7.32	5.19	3.50	2.52	1.19	1.04	0.81	0.70	0.70	0.70
Feb	39.71	39.71	36.44	26.34	24.74	19.28	14.95	11.26	8.09	5.31	3.26	2.53	2.07	1.27	1.15	0.89	0.89
Mar	51.60	51.60	28.15	23.17	18.02	17.07	10.42	9.10	7.44	4.28	3.39	2.06	1.77	1.51	1.29	1.09	1.09
Apr	17.20	17.20	12.44	8.95	7.20	6.81	6.21	5.29	3.65	2.39	1.77	1.36	1.27	1.07	0.83	0.77	0.77
May	19.91	19.91	5.77	3.29	3.28	3.25	2.54	2.16	1.71	1.27	1.00	0.72	0.67	0.67	0.67	0.67	0.67
Jun	21.55	21.55	4.26	2.00	1.95	1.89	1.67	1.48	1.18	0.92	0.69	0.63	0.63	0.63	0.63	0.63	0.63
Jul	8.33	8.33	3.86	2.19	1.81	1.61	1.46	1.36	1.05	0.80	0.64	0.64	0.64	0.64	0.64	0.64	0.64
Aug	11.42	11.42	4.43	2.19	1.72	1.53	1.32	1.12	0.98	0.72	0.56	0.53	0.53	0.53	0.53	0.53	0.53
Sep	36.10	36.10	4.63	2.65	2.53	1.43	1.22	1.04	0.86	0.69	0.54	0.41	0.37	0.33	0.30	0.27	0.27

A.3.8 Final EWR results: EWR at (m^3/s) at % points – Total flows (EC: D)

Month	0.1	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99	99.9
Oct	12.95	12.95	5.01	3.68	2.35	2.16	1.05	0.86	0.70	0.55	0.44	0.37	0.37	0.37	0.37	0.37	0.37
Nov	20.80	20.80	10.38	4.04	2.65	2.65	2.12	1.17	0.91	0.69	0.58	0.53	0.53	0.53	0.53	0.53	0.53
Dec	24.05	24.05	12.02	10.43	8.72	6.43	4.76	3.14	2.00	0.84	0.64	0.49	0.43	0.37	0.34	0.34	0.34
Jan	45.74	45.74	32.79	17.74	14.55	12.93	7.69	5.28	3.54	2.44	1.77	0.84	0.76	0.64	0.59	0.59	0.59
Feb	38.37	38.37	32.46	24.59	20.28	15.76	10.87	8.75	7.00	3.62	2.60	1.26	1.14	1.02	0.92	0.87	0.87
Mar	49.50	49.50	26.57	21.75	16.41	15.36	8.32	6.77	5.41	3.13	2.55	1.40	1.32	1.20	1.05	0.92	0.92

Month	0.1	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99	99.9
Apr	15.81	15.81	9.68	7.63	5.70	5.44	4.67	3.71	2.43	1.67	1.30	0.99	0.96	0.85	0.67	0.64	0.64
May	18.61	18.61	4.08	2.26	2.24	2.23	1.75	1.47	1.15	0.84	0.70	0.57	0.57	0.57	0.57	0.57	0.57
Jun	20.75	20.75	3.38	1.34	1.20	1.16	1.07	0.96	0.76	0.59	0.54	0.54	0.54	0.54	0.54	0.53	0.53
Jul	7.78	7.78	3.34	1.66	1.22	0.96	0.92	0.87	0.67	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
Aug	10.84	10.84	3.91	1.75	1.18	0.95	0.88	0.73	0.69	0.47	0.46	0.46	0.46	0.46	0.46	0.46	0.46
Sep	35.33	35.33	3.89	1.93	1.63	0.84	0.75	0.65	0.54	0.44	0.36	0.30	0.28	0.26	0.24	0.23	0.23

A.4 MZIMEWR4

A.4.1 Natural flows: Natural discharge (m^3/s) at % points – Baseflows (separated)

Month	0.1	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99	99.9
Oct	89.65	89.65	43.67	32.72	28.89	23.41	18.84	16.72	13.90	13.01	11.49	10.37	9.58	8.62	8.11	6.68	6.68
Nov	83.44	83.44	65.67	50.22	41.63	36.56	25.63	21.96	19.54	17.12	14.75	13.64	12.13	11.36	10.13	8.48	8.48
Dec	89.73	89.73	73.67	59.55	52.64	48.64	39.11	28.32	22.87	19.73	17.46	14.48	12.44	11.15	8.18	6.20	6.20
Jan	121.19	121.19	103.29	74.62	63.56	56.46	47.12	38.16	31.71	27.28	23.22	19.06	16.39	14.11	10.94	7.81	7.81
Feb	137.24	137.24	124.88	111.28	104.21	78.60	62.33	50.78	44.20	38.78	34.64	27.82	24.01	21.02	18.89	9.55	9.55
Mar	212.24	212.24	118.36	97.69	83.75	78.64	64.60	52.85	45.55	40.62	33.92	31.36	30.25	26.10	19.18	9.91	9.91
Apr	147.94	147.94	94.04	79.11	66.14	62.23	52.10	42.04	37.88	34.53	29.49	25.91	22.89	19.46	12.84	9.78	9.78
May	89.84	89.84	68.73	57.19	40.79	35.18	30.45	25.74	24.04	20.21	17.36	14.92	13.95	13.12	10.80	8.63	8.63
Jun	82.37	82.37	52.54	39.58	31.68	26.08	23.13	18.97	16.18	13.90	12.31	11.40	10.88	9.63	8.92	8.52	8.52
Jul	65.85	65.85	43.73	31.27	26.43	22.23	18.68	15.41	13.67	11.81	10.99	10.17	9.20	8.69	8.17	6.58	6.58
Aug	50.15	50.15	34.50	33.26	23.12	19.23	15.10	14.02	12.12	11.02	10.17	9.00	8.49	7.85	7.18	6.39	6.39
Sep	143.77	143.77	34.94	28.57	22.53	21.06	15.78	14.27	12.66	10.99	9.90	8.99	8.44	7.73	6.83	6.31	6.31

A.4.2 Natural flows: Natural discharge (m^3/s) at % points – Total flows

Month	0.1	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99	99.9
Oct	330.46	330.46	202.87	103.04	85.20	57.42	43.71	33.51	25.74	21.91	18.66	14.01	12.91	12.30	9.33	6.68	6.68
Nov	464.76	464.76	329.78	215.78	141.98	110.01	78.49	59.02	47.09	37.28	29.44	21.20	18.95	16.47	14.08	10.35	10.35
Dec	506.94	506.94	364.54	278.66	223.88	191.29	146.31	80.20	60.98	39.11	35.10	25.44	20.67	16.34	9.97	6.20	6.20
Jan	619.99	619.99	557.61	345.65	241.48	193.79	157.85	126.03	92.38	71.82	64.21	46.36	40.34	29.22	14.67	9.23	9.23
Feb	666.31	666.31	552.92	504.39	425.01	303.90	242.69	173.40	133.85	102.46	79.49	58.60	53.17	47.23	32.11	9.55	9.55
Mar	968.04	968.04	567.39	405.07	283.22	271.61	221.17	175.52	141.74	116.68	86.65	63.36	60.79	53.06	36.83	16.39	16.39
Apr	535.53	535.53	280.68	196.87	126.47	120.24	107.04	83.92	67.57	53.34	41.92	35.60	30.54	24.98	16.05	9.78	9.78
May	413.97	413.97	90.69	71.30	62.46	51.47	35.66	28.90	25.13	21.31	17.83	15.52	14.16	13.29	11.50	8.63	8.63
Jun	290.17	290.17	139.20	53.08	40.02	33.95	24.22	19.36	17.24	13.99	12.36	11.45	10.88	9.63	8.96	8.52	8.52
Jul	316.38	316.38	121.92	40.47	35.57	30.09	24.26	18.43	13.81	12.72	11.12	10.26	9.32	8.72	8.17	6.58	6.58
Aug	157.44	157.44	83.51	57.92	34.35	27.78	21.50	16.66	13.88	11.99	10.56	9.15	8.85	8.08	7.46	6.39	6.39
Sep	845.21	845.21	101.36	72.04	40.47	34.69	23.93	20.01	16.49	14.04	11.31	9.36	8.91	8.19	7.04	6.31	6.31

A.4.3 Present Day flows: Present day discharge (m^3/s) at % points – Baseflows (separated)

Month	0.1	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99	99.9
Oct	85.85	85.85	40.48	29.96	25.70	20.80	15.96	14.13	11.70	10.64	9.01	8.10	7.17	6.25	5.91	4.82	4.82
Nov	79.50	79.50	61.74	46.96	38.48	33.39	22.45	18.98	16.67	14.54	12.21	11.08	9.95	8.92	7.97	6.14	6.14
Dec	85.89	85.89	69.70	55.72	48.98	45.03	35.91	25.37	20.01	17.10	14.90	11.96	10.25	8.82	6.33	4.14	4.14
Jan	117.17	117.17	99.58	70.73	59.45	52.90	44.26	35.08	28.64	24.19	20.61	16.42	14.70	11.69	8.66	6.20	6.20
Feb	132.84	132.84	120.69	107.41	99.89	75.15	58.65	47.05	41.20	35.38	31.48	24.66	21.22	18.32	16.13	7.43	7.43
Mar	208.43	208.43	114.62	93.74	80.02	75.18	61.12	49.77	42.49	37.49	31.02	28.90	27.14	23.60	17.64	8.02	8.02
Apr	144.08	144.08	90.22	75.47	62.54	59.62	48.86	38.78	34.76	31.66	26.71	23.71	20.63	17.38	11.19	8.10	8.10
May	86.09	86.09	65.31	53.67	38.10	32.39	27.97	23.13	21.54	17.98	15.08	12.63	11.72	10.94	8.72	6.57	6.57
Jun	79.02	79.02	49.20	36.46	28.42	23.39	20.57	16.36	13.49	11.34	9.86	8.99	8.31	7.18	6.65	6.25	6.25
Jul	62.61	62.61	40.67	28.49	23.72	19.83	16.08	12.86	10.93	9.23	8.70	7.69	6.84	6.44	5.81	4.45	4.45

Month	0.1	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99	99.9
Aug	46.99	46.99	31.41	30.31	21.09	16.44	12.40	11.39	9.66	8.52	7.73	6.69	6.08	5.58	5.03	4.31	4.31
Sep	139.10	139.10	31.42	25.48	19.88	18.67	13.12	11.69	10.05	8.51	7.41	6.57	5.91	5.44	4.62	4.09	4.09

A.4.4 Present Day flows: Present day discharge (m^3/s) at % points – Total flows

Month	0.1	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99	99.9
Oct	322.93	322.93	194.89	97.80	80.85	53.69	41.22	30.07	22.95	19.18	15.96	11.58	10.57	9.94	7.13	4.82	4.82
Nov	450.65	450.65	316.50	208.59	136.07	104.30	73.73	55.51	44.09	34.19	26.83	19.01	17.01	14.13	12.16	8.46	8.46
Dec	491.41	491.41	352.77	269.21	214.83	183.34	140.32	75.54	57.78	36.38	32.98	23.28	19.13	14.50	8.15	4.14	4.14
Jan	607.80	607.80	546.89	335.85	232.90	187.09	151.11	120.04	86.62	67.44	60.29	42.49	38.01	26.71	12.53	7.41	7.41
Feb	658.20	658.20	542.97	495.22	416.25	295.78	235.77	167.80	128.48	98.36	75.41	54.34	50.30	43.58	30.79	7.43	7.43
Mar	961.58	961.58	559.44	396.30	275.76	266.88	216.49	168.83	138.46	113.49	84.05	60.68	57.66	50.48	34.28	14.73	14.73
Apr	527.13	527.13	274.46	191.75	122.14	116.69	102.27	79.95	64.63	50.29	38.79	33.74	28.36	23.04	13.94	8.10	8.10
May	405.65	405.65	87.02	67.98	59.52	48.58	32.85	26.57	22.46	18.85	15.46	13.13	11.81	11.04	9.47	6.57	6.57
Jun	282.98	282.98	133.73	49.13	37.15	30.68	21.55	16.60	14.38	11.37	9.92	8.99	8.39	7.18	6.65	6.25	6.25
Jul	306.77	306.77	116.20	37.00	32.43	27.24	21.27	15.57	11.38	10.37	8.73	7.81	6.98	6.44	5.81	4.45	4.45
Aug	151.87	151.87	78.43	54.47	31.18	24.44	18.44	13.98	11.19	9.68	7.99	6.86	6.60	5.85	5.21	4.31	4.31
Sep	830.04	830.04	96.34	66.95	36.22	30.91	20.86	16.98	13.60	11.32	8.75	6.90	6.50	5.80	4.76	4.09	4.09

A.4.5 Final EWR results: EWR at (m^3/s) at % points – Low flows (PES and REC: C)

Month	0.1	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99	99.9
Oct	12.73	12.73	10.81	9.69	9.69	9.45	8.50	7.66	6.67	5.77	4.78	4.07	3.75	3.48	3.33	3.26	3.26
Nov	14.32	14.32	14.32	13.49	13.41	13.01	10.99	9.68	8.62	7.10	5.77	5.08	4.60	4.50	4.50	4.49	4.49
Dec	17.79	17.79	17.79	17.79	17.79	17.79	16.43	13.29	10.30	8.46	6.92	5.51	4.75	4.21	3.63	3.53	3.53
Jan	23.19	23.19	23.19	21.52	21.40	20.68	19.12	16.20	13.66	11.08	9.00	7.00	6.03	5.21	4.69	4.37	4.37
Feb	29.06	29.06	29.06	29.06	29.06	25.70	21.91	19.06	16.46	13.33	11.37	8.69	7.75	6.84	6.53	5.99	5.99
Mar	29.72	29.72	29.48	29.06	28.47	27.67	25.21	21.40	18.24	14.83	12.48	10.40	9.50	8.65	7.87	7.34	7.34

Month	0.1	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99	99.9
Apr	22.04	22.04	22.04	22.04	22.04	21.87	20.39	17.27	15.37	12.89	10.72	8.76	7.72	6.84	5.97	5.90	5.90
May	15.60	15.60	15.60	14.99	14.25	13.29	13.13	11.53	10.56	8.56	6.89	5.70	5.24	5.01	5.01	5.01	5.01
Jun	12.50	12.50	12.14	10.17	10.14	10.05	9.85	8.37	7.35	5.95	4.94	4.38	4.38	4.38	4.37	4.37	4.37
Jul	10.68	10.68	10.44	8.91	8.87	8.81	8.57	7.41	6.38	5.28	4.53	3.99	3.64	3.43	3.34	3.20	3.20
Aug	8.03	8.03	7.98	7.90	7.77	7.60	7.10	6.47	5.74	4.95	4.19	3.54	3.28	3.12	2.99	2.90	2.90
Sep	16.86	16.86	10.57	7.69	7.60	7.60	6.71	6.14	5.78	4.48	3.74	3.24	3.23	3.23	3.23	3.23	3.23

A.4.6 Final EWR results: EWR at (m^3/s) at % points – Low flows (EC: D)

Month	0.1	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99	99.9
Oct	7.81	7.81	6.67	6.03	6.02	5.89	5.30	4.73	4.04	3.51	2.98	2.59	2.41	2.24	2.15	2.09	2.09
Nov	8.65	8.65	8.64	8.19	8.15	7.95	6.79	5.97	5.26	4.36	3.62	3.24	2.94	2.74	2.71	2.71	2.71
Dec	10.56	10.56	10.56	10.56	10.56	10.56	9.87	8.16	6.33	5.27	4.38	3.51	3.04	2.69	2.30	2.16	2.16
Jan	13.19	13.19	13.19	12.39	12.35	12.05	11.30	9.94	8.53	7.08	5.80	4.47	3.83	3.28	2.91	2.66	2.66
Feb	16.90	16.90	16.90	16.90	16.90	14.54	12.70	11.66	10.47	8.77	7.53	5.54	4.84	4.17	3.85	3.45	3.45
Mar	16.28	16.28	16.16	15.96	15.67	15.28	14.18	13.15	11.73	10.08	8.34	6.63	5.81	5.05	4.43	4.00	4.00
Apr	12.69	12.69	12.69	12.69	12.69	12.64	11.95	10.60	9.70	8.41	7.03	5.59	4.83	4.19	3.57	3.40	3.40
May	9.32	9.32	9.32	8.98	8.60	8.11	8.03	7.11	6.50	5.33	4.36	3.63	3.33	3.13	2.98	2.97	2.97
Jun	7.65	7.65	7.43	6.31	6.29	6.24	6.11	5.17	4.46	3.62	3.07	2.76	2.64	2.64	2.64	2.64	2.64
Jul	6.60	6.60	6.44	5.56	5.55	5.51	5.35	4.58	3.86	3.20	2.81	2.54	2.34	2.21	2.15	2.06	2.06
Aug	5.06	5.06	5.03	4.97	4.89	4.78	4.46	4.00	3.44	2.99	2.60	2.26	2.12	2.02	1.95	1.90	1.90
Sep	9.95	9.95	6.31	4.68	4.67	4.67	4.12	3.76	3.49	2.82	2.40	2.02	1.92	1.92	1.92	1.91	1.91

A.4.7 Final EWR results: EWR at (m^3/s) at % points – Total flows (PES and REC: C)

Month	0.1	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99	99.9
Oct	67.52	67.52	42.74	21.04	20.98	17.37	8.50	7.66	6.67	5.77	4.78	4.07	3.75	3.48	3.33	3.26	3.26
Nov	142.96	142.96	65.51	50.40	29.99	24.73	22.41	10.01	8.80	7.10	5.77	5.08	4.60	4.50	4.50	4.49	4.49

Dec	129.35	129.35	67.33	57.00	46.05	33.84	31.70	23.60	17.60	8.46	6.92	5.51	4.75	4.21	3.63	3.53	3.53
Jan	191.57	191.57	112.74	81.68	49.50	42.40	31.93	29.25	24.32	18.87	10.66	7.24	6.25	5.21	4.69	4.37	4.37
Feb	206.92	206.92	156.69	106.88	84.97	73.33	47.32	33.88	28.92	24.94	20.04	9.46	8.22	6.96	6.53	5.99	5.99
Mar	221.28	221.28	164.24	107.85	75.26	55.94	50.20	35.73	30.29	26.61	23.73	11.44	9.91	8.88	7.87	7.34	7.34
Apr	160.18	160.18	38.62	38.62	33.78	33.60	31.83	25.42	15.37	12.89	10.72	8.76	7.72	6.84	5.97	5.90	5.90
May	119.22	119.22	30.23	15.53	14.48	13.37	13.13	11.53	10.56	8.56	6.89	5.70	5.24	5.01	5.01	5.01	5.01
Jun	62.31	62.31	35.47	10.17	10.14	10.05	9.85	8.37	7.35	5.95	4.94	4.38	4.38	4.38	4.37	4.37	4.37
Jul	58.89	58.89	21.99	8.91	8.87	8.81	8.57	7.41	6.38	5.28	4.53	3.99	3.64	3.43	3.34	3.20	3.20
Aug	19.39	19.39	17.92	7.90	7.77	7.60	7.10	6.47	5.74	4.95	4.19	3.54	3.28	3.12	2.99	2.90	2.90
Sep	54.71	54.71	21.98	14.99	7.60	7.60	6.71	6.14	5.78	4.48	3.74	3.24	3.23	3.23	3.23	3.23	3.23

A.4.8 Final EWR results: EWR at (m^3/s) at % points: Total flows (EC: D)

Month	0.1	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99	99.9
Oct	62.60	62.60	17.42	17.21	15.26	6.02	5.30	4.73	4.04	3.51	2.98	2.59	2.41	2.24	2.15	2.09	2.09
Nov	137.29	137.29	59.83	45.09	24.67	19.68	15.42	6.22	5.26	4.36	3.62	3.24	2.94	2.74	2.71	2.71	2.71
Dec	122.12	122.12	58.77	49.31	37.71	26.61	21.27	17.23	7.97	5.27	4.38	3.51	3.04	2.69	2.30	2.16	2.16
Jan	181.58	181.58	103.55	72.25	40.61	27.79	23.47	20.79	17.65	8.61	5.80	4.47	3.83	3.28	2.91	2.66	2.66
Feb	194.75	194.75	144.53	94.71	72.82	56.03	34.50	23.95	20.29	16.61	8.63	5.54	4.84	4.17	3.85	3.45	3.45
Mar	207.85	207.85	150.98	88.70	58.28	44.51	29.76	25.36	22.65	19.69	10.35	6.63	5.81	5.05	4.43	4.00	4.00
Apr	148.01	148.01	29.27	29.27	24.42	24.07	22.60	10.60	9.70	8.41	7.03	5.59	4.83	4.19	3.57	3.40	3.40
May	68.87	68.87	20.67	9.14	8.60	8.11	8.03	7.11	6.50	5.33	4.36	3.63	3.33	3.13	2.98	2.97	2.97
Jun	57.46	57.46	17.96	6.31	6.29	6.24	6.11	5.17	4.46	3.62	3.07	2.76	2.64	2.64	2.64	2.64	2.64
Jul	54.80	54.80	17.79	5.56	5.55	5.51	5.35	4.58	3.86	3.20	2.81	2.54	2.34	2.21	2.15	2.06	2.06
Aug	16.41	16.41	12.97	4.97	4.89	4.78	4.46	4.00	3.44	2.99	2.60	2.26	2.12	2.02	1.95	1.90	1.90
Sep	47.80	47.80	17.11	5.44	4.67	4.67	4.12	3.76	3.49	2.82	2.40	2.02	1.92	1.92	1.92	1.91	1.91

APPENDIX B: COMMENTS REPORT

Page / Section	Report statement	Comments	Changes made?	Author comment
DWS Project Management Committee – 10 April 2017				
Report		Editorial comments	Yes	Addressed throughout.
		The report does not have a study area map.	Yes	Map included.
		The report does not have a study area map which shows the location of EWR sites, where biophysical nodes and EWR sites are located in terms of IUA and RU.	Yes	Map included.