

Comprehensive Reserve Determination Study for Selected Water Resources (Rivers, Groundwater and Wetlands) in the INKOMATI WATER MANAGEMENT AREA, MPUMALANGA

PROJECT NO: WP 9133

EWR Scenario Assessment for the Crocodile and Sabie-Sand Systems: VOLUME 2: CROCODILE SYSTEM



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**DEPARTMENT OF WATER AFFAIRS
CHIEF DIRECTORATE: RESOURCE DIRECTED MEASURES**

**COMPREHENSIVE RESERVE DETERMINATION STUDY FOR SELECTED
WATER RESOURCES IN THE INKOMATI WATER MANAGEMENT AREA,
MPUMALANGA.**

**SABIE AND CROCODILE SYSTEMS: SABIE EWR SCENARIO REPORT:
VOLUME 1 & 2 FINAL**

Approved for WFA by:

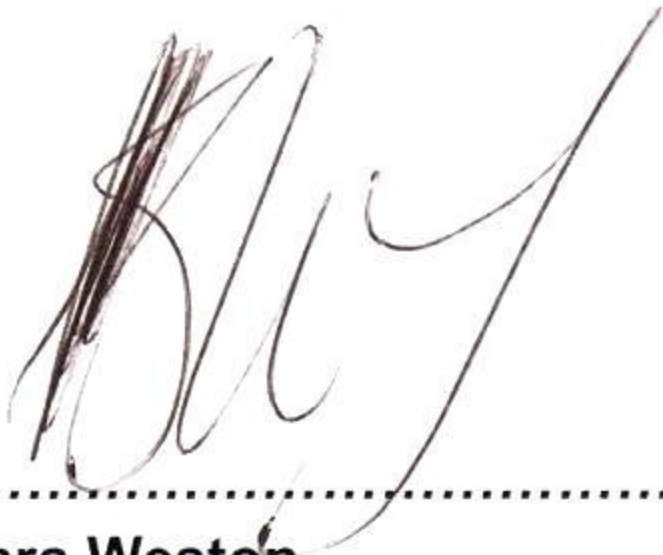


.....
Delana Louw
Technical Project Manager



.....
Adhishri Singh
Administrative Project Manager

Approved for the Chief Directorate: Resource Directed Measures by:



.....
Barbara Weston
Study Manager

Reports as part of this project:

Report no	Report title
26/8/3/10/12/001	Comprehensive Reserve Determination Study for selected water resources in the Inkomati WMA, Mpumalanga: Inception report
26/8/3/10/12/002	Comprehensive Reserve Determination Study for selected water resources in the Inkomati WMA, Mpumalanga: Desktop EcoClassification report
26/8/3/10/12/003	Newsletters
26/8/3/10/12/004	Comprehensive Reserve Determination Study for selected water resources in the Inkomati WMA, Mpumalanga: Basic Human Needs Reserve report
26/8/3/10/12/005	Comprehensive Reserve Determination Study for selected water resources in the Inkomati WMA, Mpumalanga: Groundwater report
26/8/3/10/12/006	Comprehensive Reserve Determination Study for selected water resources in the Inkomati WMA, Mpumalanga: Resource Unit report
26/8/3/10/12/007	Comprehensive Reserve Determination Study for selected water resources in the Inkomati WMA, Mpumalanga: Desktop Estimation report
26/8/3/10/12/008	Comprehensive Reserve Determination Study for selected water resources in the Inkomati WMA, Mpumalanga: Wetland report
26/8/3/10/12/009	Comprehensive Reserve Determination Study for selected water resources in the Inkomati WMA, Mpumalanga: EcoClassification report
26/8/3/10/12/010	Comprehensive Reserve Determination Study for selected water resources in the Inkomati WMA, Mpumalanga: EWR scenario report
26/8/3/10/12/011	Comprehensive Reserve Determination Study for selected water resources in the Inkomati WMA, Mpumalanga: Operation scenarios and consequences report
26/8/3/10/12/012	Comprehensive Reserve Determination Study for selected water resources in the Inkomati WMA, Mpumalanga: EcoSpecs report
26/8/3/10/12/013	Comprehensive Reserve Determination Study for selected water resources in the Inkomati WMA, Mpumalanga: Socio Economic Present State Evaluation Report
26/8/3/10/12/014	Comprehensive Reserve Determination Study for selected water resources in the Inkomati WMA, Mpumalanga: Training audit and report
26/8/3/10/12/015	Comprehensive Reserve Determination Study for selected water resources in the Inkomati WMA, Mpumalanga: Main report
26/8/3/10/12/016	Comprehensive Reserve Determination Study for selected water resources in the Inkomati WMA, Mpumalanga: Electronic information and data

Bold indicates this report

REFERENCES

This report is to be referred in bibliographies as:

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Contributors to the report and specialist meeting:

Dr Birkhead, Drew (Hydraulics)
Dr Deacon, Andrew (Fish)
Mr Hoffman, Andre (Fish)
Prof Hughes, Denis (Hydrology)
Ms Koekemoer, Shael (Editing)
Dr Kleynhans, Neels (Fish and EcoClassification specialist)
Dr Kotze, Piet (Fish)
Ms Louw, Delana (Process facilitator)
Mr Mackenzie, James (Riparian vegetation)
Mr Mallory, Stephen (System Hydrology)
Mr Rountree, Mark (Fluvial Geomorphology)
Ms Singh, Adhishri (Report review)
Ms Thirion, Christa (Macroinvertebrates)
Dr Uys, Mandy (Macroinvertebrates)

Trainees:

The following trainees participated in the workshop:

Mr Desai, Ahmed (Hydraulics)
Mr Hlongwane, Lindo (Geomorphology)
Mr Senoge, Ntaki (Macroinvertebrates)
Ms Vos, Petro (Macroinvertebrates)

EXECUTIVE SUMMARY

BACKGROUND

The Reserve for the Komati River was determined at a Comprehensive level and approved in 2006. Subsequently the Chief Directorate Resource Directed Measures (CD: RDM) identified that the remaining catchments within WMA 5 also requires a high confidence Reserve. High confidence results are needed in light of the initiation of the Compulsory Licensing Process in the WMA and the proposed new developments.

STUDY AREA

The Inkomati WMA is largely located within the Mpumalanga Province. It can be considered to consist of three largely independent catchments, the Komati, Crocodile (East) and Sabie–Sand River catchments. All these rivers drain the WMA and confluence to form the Inkomati River in Mozambique which flows into the Indian Ocean.

The focus of this study is on the Crocodile (X2) catchment. Seven EWR sites were chosen to represent these catchments, the locality and characteristics of which are provided in Table 1.1 and Figure 1-2 below. These EWR sites were chosen according to the criteria described in RDM Report 26/8/3/10/12/006 (DWAF, 2008).

EWR site no	EWR site name	River	Coordinates		EcoRegion (Level 2)	Geomorphic Zone	Quat
			Latitude	Longitude			
EWR 1	Valeyspruit	Crocodile River	S25 29.647	E30 08.656	9.02	Upper Foothills	X21A
EWR 2	Goedehoop	Crocodile River	S25 24.555	E30 18.955	9.04	Upper Foothills	X21B
EWR 3	Poplar Creek	Crocodile River	S25 27.127	E30 40.865	10.02	Lower Foothills	X21E
EWR 4	Kanyamazane	Crocodile River	S25 30.146	E31 10.919	4.04	Lower Foothills	X22K
EWR 5	Malelane	Crocodile River	S25 28.972	E31 30.464	3.07	Lower Foothills	X24D
EWR 6	Nkongoma	Crocodile River	S25 23.430	E31 58.467	12.01	Lower Foothills	X24H
EWR 7	Honeybird	Kaap River	S25 38.968	E31 14.572	4.04	Upper Foothills	X23H

THIS REPORT

This report summarizes the results of the EWR scenario determination task. This task consists of determining the EWR for different ecological river states, i.e. different Ecological Categories. The report consists of a main summary report (Volume 1) supported by the specialist appendices (Volume 3) (RDM Report 26/8/3/10/12/010). Volume 3 will only be made available electronically as part of RDM Report 26/8/3/10/12/016 - Electronic information and data.

APPROACH

The Habitat Flow Stressor Response method (HFSR) (IWR S2S, 2004; O’Keeffe *et al.*, 2002), a modification of the Building Block Methodology (BBM) (King and Louw, 1998) was used to determine the low (base) flow EWRs. The approach to set high flows is a combination of the Downstream Response to Imposed Flow Transformation (DRIFT; Brown and King, 2001) approach and BBM. These results generated will then form the basis against which the ecological consequences of operational flow scenarios will be tested during a further task in this study.

RESULTS

The results are summarised in the table below for the different EWR sites as a percentage of the natural Mean Annual Runoff (nMAR).

EWR site	EC ¹	Maintenance low flows (%nMAR)	Drought low flows (%nMAR)	High flows (%nMAR)	Long term mean (% nMAR)
EWR 1	A/B PES, REC	38.0	15.5	9.4	30.9
	B/C AEC	25.8	15.5	9.4	24.4
EWR 2	B PES, REC	42.2	16.5	6.2	57
	C AEC	20.4	16.5	5.4	37
EWR 3	B/C PES	44	18.1	9.8	>55.2
	B REC	A time series of requirements could not be generated as improvement of the PES required flows to be set higher than the reference time series (present day), during the wet season.			
EWR 4	B PES, REC	28.7	9.9	6.2	34.5
	C/D AEC	13.2	9.9	5.1	21.3
EWR 5	C PES	21.3	12.1	5.3	30
	B REC	34.7	12.1	7.4	41.2
	D AEC	12.1	12.1	2.9	21.3
EWR 6	C PES	13.9	10.6	7.4	24.9
	B REC	27.3	10.6	13.2	41.1
	D AEC	11.6	4.5	4.6	16.5
EWR 7	C PES	14.9	6.6	6.4	23
	B REC	29.6	6.6	7.4	36.8
	D AEC	6	6.6	5.3	16.4

¹ Refer to Report 26/8/3/10/12/009 (DWA, 2009).

CONCLUSIONS AND RECOMMENDATIONS

The confidence in the low and high flow Ecological Reserve requirements for each EWR site is provided in the table below. A score of 1 - 2 indicates a low confidence, 3 - 4 a moderate confidence and 5, high confidence in the results.

EWR SITE	HYDROLOGY	LOW FLOWS			HIGH FLOWS				
		BIOLOGICAL RESPONSES	HYDRAULICS	BIOLOGICAL RESPONSES	BIOLOGICAL RESPONSES	HYDRAULICS	BIOLOGICAL RESPONSES		
EWR 1	2	4	4	4	Biological responses high as well as hydraulics. The hydraulic requirements for low flows largely within the range of measured flows.	3.5	3.5	3.5	All the smaller floods fall within the range of measured flows.
EWR 2	2	4	4	4	Biological responses high as well as hydraulics. The hydraulic requirements for low flows largely within the range of measured flows.	3.8	3	3	Some of the floods fall outside the range of measured flows which results in hydraulic being of a lower confidence than the biophysical responses.
EWR 3	3	2	5	2	Various calibrations available for this site since 1999. This resulted in high confidence in the hydraulics. However, due to the lack of understanding around the invertebrates, the confidence is low.	4	3	3	Some of the floods fall outside the range of measured flows which results in hydraulic being of a lower confidence than the biophysical responses.

EWR SITE	HYDROLOGY	LOW FLOWS			HYDRAULICS	HIGH FLOWS			HYDRAULICS
		BIOLOGICAL RESPONSES	HYDRAULICS	BIOLOGICAL RESPONSES		BIOLOGICAL RESPONSES	HYDRAULICS	BIOLOGICAL RESPONSES	
EWR 4	1.5	4	1	1	This cross-section was very badly selected during previous EWR studies and do not provide any low flow cues nor any useful hydraulics at low flows. Another section was selection downstream of the old section. As only one hydraulic calibration could be obtained, the confidence was very low.	3.8	4	4	All the small and moderate floods fall within the range measured.
EWR 5	2.5	4	3.5	3.5	Biological responses high as well as hydraulics. The hydraulic requirements for low flows largely within the range of measured flows. The site does not provide good habitat, however site selection is problematic in this area with safety and access playing an overriding role.	3.3	4	3.3	Riparian vegetation is the factor that results in a lower biophysical confidence. This is due to the absence of cues at the site and therefore uncertainty in the flooding requirements.
EWR 6	3	4	4	4	Biological responses high as well as hydraulics. The hydraulic requirements for low flows largely within the range of measured flows. There is some uncertainty in flow class modelling as the site is bedrock dominated.	3.8	4	4	Limited range of measured flows but the small and moderate floods should maintain sediment transport at this site.
EWR 7	2	4	3	3	Complex site. Low flows set are below measurements. There is uncertainty in flow class modelling. The hydraulics therefore is the overriding factor with regards to confidence.	2.3	3	2.5	Both riparian and geomorphology cues are lacking and confusing, resulting in a low confidence in the high flows.

Recommendations were determined based on the possibility and necessity of improving the confidence of the individual assessments (biological response and hydraulics) by implementing an Ecological Water Resource Monitoring Programme (EWRMP), hydrological monitoring and hydraulic assessments. This will provide the additional information to improve confidence in the EWRs. These recommendations are summarised in the table below.

EWR sites	Low flow confidence	High flow confidence	Recommendations
EWR 1	4	3.5	EWRM
EWR 2	4	3	EWRM.
EWR 3	2	3	EWRM
EWR 4	1	4	The hydraulics for EWR 4 should be updated with sufficient low flow calibrations to improve the low flow confidence. EWRM.
EWR 5	3.5	3.3	This site is not a good site in terms of providing sufficient cues for EWR assessment, neither for hydraulic analysis. As EWR 6 is the critical site, this site should be seen as supplementary to EWR 6. EWRM.
EWR 6	4	4	EWRM.
EWR 7	3	2.5	EWRM.

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- APPENDIX A** Ecohydrology of the Crocodile River system (AL Birkhead)
- APPENDIX B** Supporting information for the determination of stress indices and EWR scenarios of EWR 1: Valeyspruit
- APPENDIX C** Supporting information for the determination of stress indices and EWR scenarios of EWR 2: Goedehoop
- APPENDIX D** Supporting information for the determination of stress indices and EWR scenarios of EWR 3: Poplar Creek
- APPENDIX E** Supporting information for the determination of stress indices and EWR scenarios of EWR 4: Kanyamazane
- APPENDIX F** Supporting information for the determination of stress indices and EWR scenarios of EWR 5: Malelane
- APPENDIX G** Supporting information for the determination of stress indices and EWR scenarios of EWR 6: Nkongoma
- APPENDIX H** Supporting information for the determination of stress indices and EWR scenarios of EWR 7: Honeybird

ABBREVIATIONS AND ACRONYMS

AEC	Alternative Ecological Category
Ave	Average
BBM	Building Block Methodology
CD: RDM	Chief Directorate: Resource Directed Measures
DLIFR	Drought low flow
D:RQS	Directorate: Resource Quality Services
DRIFT	Downstream Response to Imposed Flow Transformation
DRM	Desktop Reserve Model
DWA	Department of Water Affairs (Name change 2009)
DWAF	Department of Water Affairs and Forestry
EC	Ecological Category
EIS	Ecological Importance and Sensitivity
EWR	Ecological Water Requirements
EWRM	Ecological Water Resource Monitoring
EWRMP	Ecological Water Resource Monitoring Programme
FD	Fast deep fish habitat
FDC	Flow Duration Curves
FDI	Flow dependent macroinvertebrate
FI	Fast intermediate fish habitat
FROC	Frequency of Occurrence
FS	Fast shallow fish habitat
HFSR	Habitat Flow Stressor Response
Integ	Integrated
LSR	Large semi-rheophilic fish species
MAR	Mean Annual Runoff
MCM	Million Cubic Meters
MHIFR	Maintenance high flow
MLIFR	Maintenance low flow
MVI	Marginal vegetation macroinvertebrate
MV	Marginal vegetation
PES	Present Ecological State
REC	Recommended Ecological Category
RHAM	Rapid Habitat Assessment Method
RU	Resource Unit
SD	Slow deep fish habitat
SPATSIM	Spatial and Time Series Information Modelling
SR	Small rheophilic fish species
SSR	Small semi-rheophilic fish species
SS	Slow shallow fish habitat
Veg	Vegetation
WMA	Water Management Area

1 INTRODUCTION

1.1 BACKGROUND

The Reserve for the Komati River was determined at a Comprehensive level and approved in 2006. Subsequently the Chief Directorate Resource Directed Measures (CD: RDM) identified that the remaining catchments within WMA 5 also requires a high confidence Reserve. High confidence results are needed in light of the initiation of the Compulsory Licensing Process in the WMA and the proposed new developments.

Figure 1-1 is a schematic representation of the 8 - step Ecological Reserve process followed in this study. This report summarizes step 4 of the Ecological Reserve process.

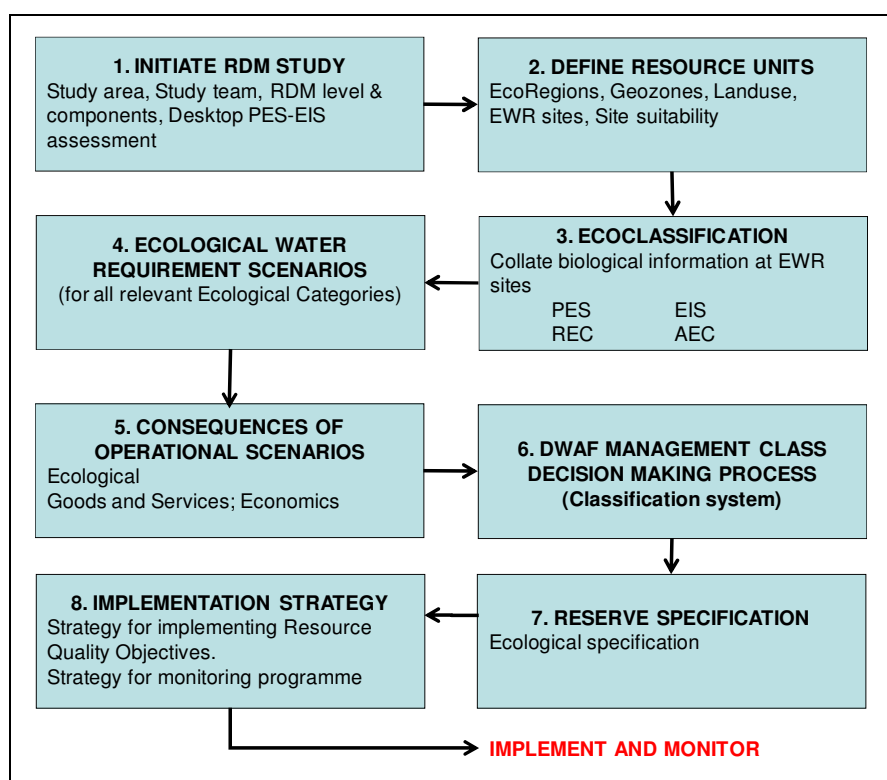


Figure 1-1 The 8-step Ecological Reserve procedure (adapted from DWAF, 1999)

1.2 STUDY AREA

The Inkomati WMA is largely located within the Mpumalanga Province. It can be considered to consist of three largely independent catchments, the Komati, Crocodile (East) and Sabie–Sand River catchments. All these rivers drain the WMA and confluence to form the Incomati River in Mozambique which flows into the Indian Ocean.

The focus of this study is on the Crocodile (X2) catchment. Seven EWR sites were chosen to represent these catchments, the locality and characteristics of which are provided in Table 1.1 and Figure 1-2 below. These EWR sites were chosen according to the criteria described in RDM Report 26/8/3/10/12/006 (DWAF, 2008).

Table 1.1 Locality of EWR sites for the Crocodile River System

EWR site no	EWR site name	River	Coordinates		EcoRegion ¹ (Level 2)	Geomorphic Zone	Quat ²
			Latitude	Longitude			
EWR 1	Valeyspruit	Crocodile River	S25 29.647	E30 08.656	9.02	Upper Foothills	X21A
EWR 2	Goedehoop	Crocodile River	S25 24.555	E30 18.955	9.04	Upper Foothills	X21B
EWR 3	Poplar Creek	Crocodile River	S25 27.127	E30 40.865	10.02	Lower Foothills	X21E
EWR 4	Kanyamazane	Crocodile River	S25 30.146	E31 10.919	4.04	Lower Foothills	X22K
EWR 5	Malelane	Crocodile River	S25 28.972	E31 30.464	3.07	Lower Foothills	X24D
EWR 6	Nkongoma	Crocodile River	S25 23.430	E31 58.467	12.01	Lower Foothills	X24H
EWR 7	Honeybird	Kaap River	S25 38.968	E31 14.572	4.04	Upper Foothills	X23H

¹ Refer to Kleynhans *et al.* (2007) for EcoRegion description

² Quaternary catchment

1.3 PURPOSE OF THE REPORT

This report serves to document the results of the specialist meeting held from 28 – 31 July 2008. The purpose of this report is to determine the low as well as high flows that are required to maintain the current state of ecological health (PES) at each EWR Site. This requires the specialists to determine the flows that would be required to either improve the ecological health of the specific River (the REC) or to maintain the river in a lower health status than its current situation (the AEC). The current state as well as feasible alternatives (REC, AEC) to the current state for the Sabie catchment was described as part of the EcoClassification Task (Report 26/8/3/10/12/009; DWA, 2009). This report subsequently provides the low and high flows that are required to achieve each of these ecological categories, where the results are referred to as EWR scenarios.

1.4 OUTLINE OF THE REPORT

Volume one (this report) is outlined below. It must be noted however that this report should be read in conjunction with EWR scenario Report - Volume 3 (provided as part of RDM report 26/8/3/10/12/016 - Electronic information and data), which contains the relevant supporting specialist information.

Chapter 1: Introduction

This chapter.

Chapter 2: Methodology for setting riverine EWR scenarios

This chapter outlines the methods followed for Step 4 of the Ecological Reserve process.

Chapter 3, 5, 7, 9, 11, 13, 15: Determination of stress indices

The stress indices for all physical and biological components at each EWR site are provided.

Chapter 4, 6, 8, 10, 12, 14, 16: Determination of EWR scenarios

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, general approach to high flows, final results and confidence in the final results.

Chapter 17: Conclusions and Recommendations

The EWR Scenario results are summarised and recommendations are made with regards to actions that should be taken to improve the confidence in these results.

Chapter 18: References

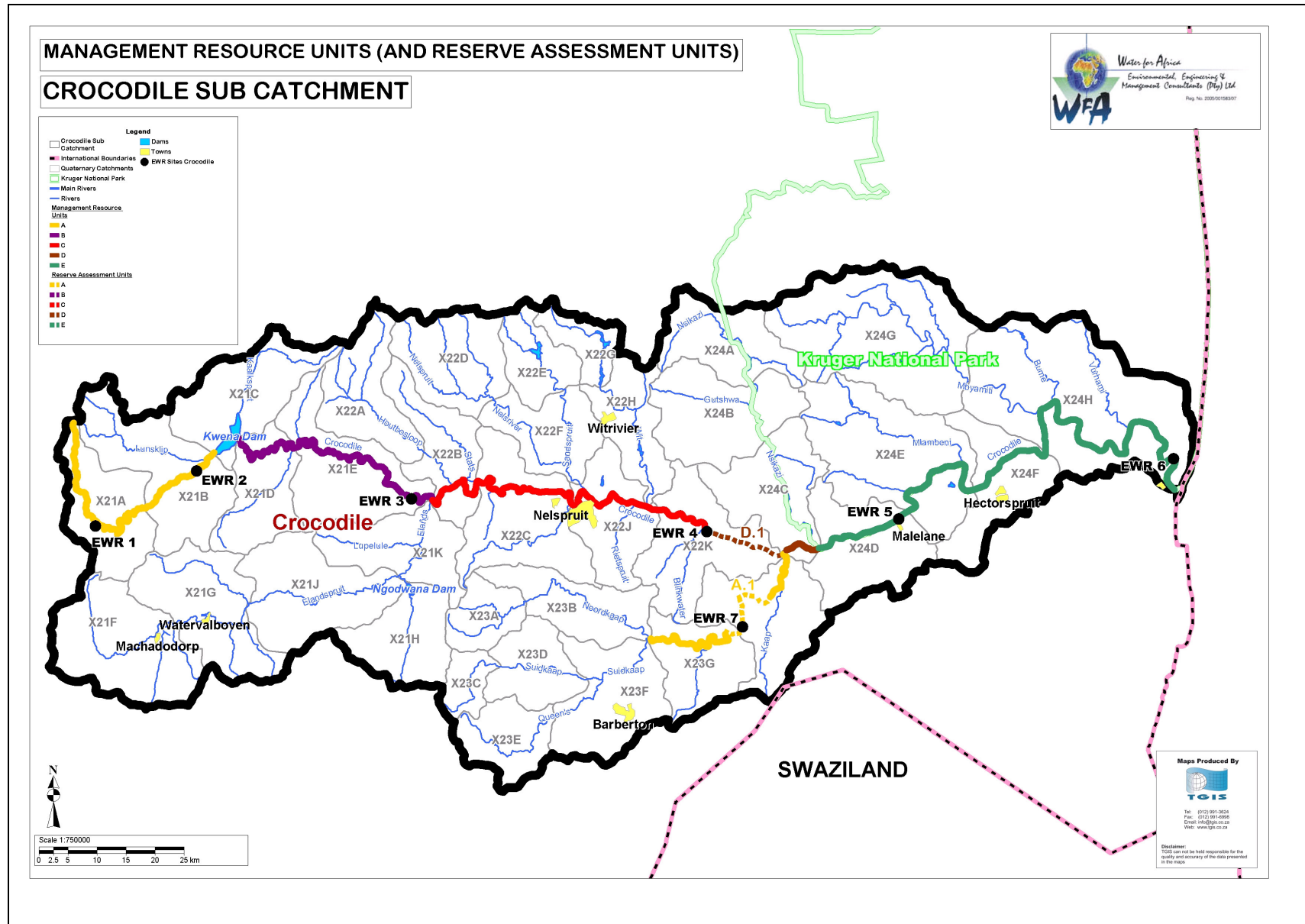


Figure 1-2 Crocodile River catchment and locality of EWR sites

2 METHODOLOGY FOR SETTING RIVERINE EWR SCENARIOS

The section below describes the methods and data that were used to determine the EWR scenarios for each of the 7 EWR sites in the Crocodile River Catchment.

2.1 LOW FLOWS

The Habitat Flow Stressor Response method (HFSR) (IWR S2S, 2004; O’Keeffe *et al.*, 2002), a modification of the Building Block Methodology (BBM) (King and Louw, 1998) was used to determine the low (base) flow EWRs. This method is an accepted DWA method for determining EWRs. A short summary of the approach is provided below. For more detail as well the specific specialist approaches, the reader is referred to the manual and the paper on the principles of the method (albeit out of date). Further development of the approach has since been undertaken in consultation with DWA specialists since 2004 with a manual to follow at some stage. Note that it is not part of the TOR of this study to provide detailed methods.

The basic approach is to set stress indices for fish and macroinvertebrates and, where appropriate, riparian vegetation. The stress index describes the consequences of flow reduction on flow dependant biota and is determined by first assessing the response of habitat to a flow reduction. The habitat flow index is described separately for fish, macroinvertebrates and riparian vegetation as an instantaneous response of habitat to flow in terms of a 0 – 10 index relevant for the specific site. The zero stress (best habitat) and 10 stress (worst habitat) is fixed as follows to ensure that the range for fish macroinvertebrates and riparian vegetation are the same:

- 0: Optimum habitat represented by the maximum natural base flow. Note that without adequate hydrological data, this is difficult to identify.
- 10: No flow.

The second step is to determine the biota stress index which describes the instantaneous response of biota to change in habitat (and therefore flow) in terms of a 0 – 10 stress index. The description of the changes of habitat at each stress level (as described in the habitat stress index) is then related to the response of the fish, macroinvertebrate and riparian vegetation indicators. The biota stress index is described separately for the different indicators. The zero stress, representing optimum habitat, would therefore represent a situation of zero stress to biota with the maximum abundance of species present under these conditions.

The stress index therefore describes the habitat conditions and biota response for fish, macroinvertebrates and riparian vegetation at a range of low flows. The fish, macroinvertebrate and riparian vegetation stress-flow relationship will not be the same as the responses to the same flow will/can result in different stress for these biotic components.

The biotic component indices are then used to convert separate natural and present day flow time series to a stress time series. The stress time series is converted to a stress duration graph 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. If specialists do not agree with the levels of stress under natural conditions based on their knowledge of the species, the stress indices were refined.

Tools used to determine the stress indices are specialist knowledge and information about the indicator species' habitat requirements, the hydraulics in the specific format required, and the natural hydrology.

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 Ecological Category for the instream biota is considered when determining the stress required to maintain or achieve this ecological state. The stress requirement is set for drought and maintenance conditions. Drought stress is set at 5% exceedence. The maintenance stress is set at a percentage which is determined based on the low flow hydrological variability of the specific river being assessed. The more variable the river, the higher the percentage at which maintenance stress is set. Any stress requirements for other percentage points can also be provided.

The requirements are still provided in terms of the separate fish macroinvertebrate and riparian vegetation indices. Obviously one can only deal with one stress-flow relationship, and an integrated stress index is required for this. The integrated stress curve is comprised by the highest stress of either biotic component at any one flow. This forms the integrated stress curve and the results for fish macroinvertebrates and riparian vegetation must therefore be converted to integrated stress in order to be comparable.

Figure 2-1 illustrates an example of a flow stress matrix. The black line represents the integrated stress and the other lines the stress flow relationships for the various biotic components where:

- The large rheophilic (LR) guild is represented by the blue line.
- The small rheophilic (SR) guild is represented by the red line.
- The flow dependant macroinvertebrate (FDI) stress is represented by the purple line; and
- Reed and *Ficus* stress is represented by the green and yellow line respectively.

The integrated curve in this case consists of the LR guild (blue line) for the stress range 0 - 10.

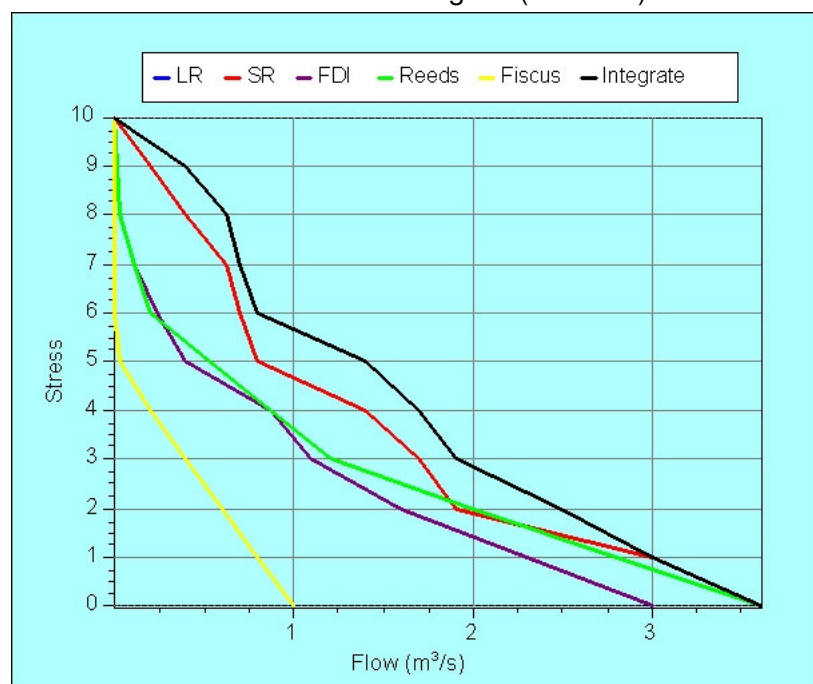


Figure 2-1 Component and integrated stress curves

Specialists determine the required stress (based on the habitat and biota response) for different durations and for different Ecological Categories (ECs). The complexity here, as with all flow requirement methods, is the interpretation of an instantaneous response in terms of duration and seasonal requirements. The biota stress requirement is converted to integrated stress and plotted (as circles) on a flow duration graph (Figure 2.2) which also shows the natural (red line) and present day flow (blue line) converted to integrated stress. This therefore supplies the 'hydrological check' to ensure that the requirements are realistic in terms of the natural hydrology and present day hydrology (only used when realistic and of reasonable confidence is available). The low flow stress requirement for an EC consists of the component requirement with the lowest stress requirement (highest flow requirements). For example, if fish has a requirement at 5% duration of a stress of 6 to achieve a C EC, and macroinvertebrates has a requirement for a C EC of 8, the final requirement will be a stress of 6 as the 6 stress would cater for the macroinvertebrates, whereas the 8 stress could not cater for the fish and will result in the fish being in a lower EC. These final requirements are therefore connected manually (a 'hand drawn line' as the required stress duration).

Figure 2.2 is an example of a stress duration graph and illustrates the stress requirements and stress points required for a B/C PES (green arrowed line), B REC (purple arrowed line) and a C/D AEC (yellow arrowed line). The different coloured circles indicate the requirements of the instream biota for the specific EC. Each circle is labeled as follows and indicates a different biotic component:

- SR – Small rheophilic fish guild.
- LR – Large rheophilic fish guild.
- FDI – Flow dependent macroinvertebrates
- Vegetation – By Family/genus/species

In this example the drought flows (5%) of the different biotic components are the same for all ECs

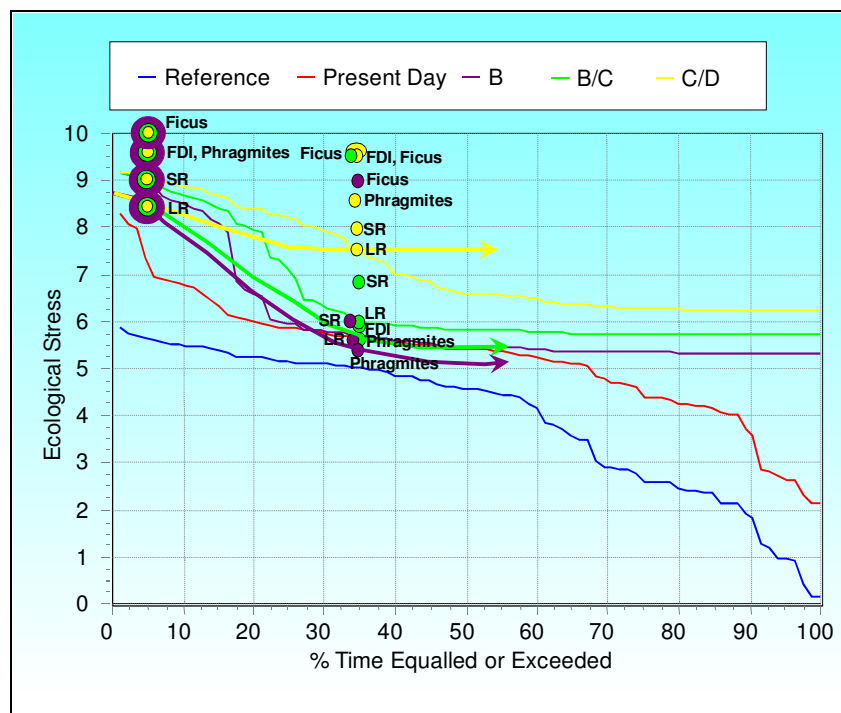


Figure 2-2 Stress duration curve for a B/C PES, B REC and C/D AEC - DRY season

These stress requirements (provided for two key months or the high and low flow season), must now be manipulated to provide a complete low flow regime as follows:

- The Desktop estimates for the same ECs as being assessed, are converted to stress (Stress/Flow & Risk Indicator Model; Hughes and Forsythe, 2006) and also provided on the above graph (B/C PES (green line), B REC (purple line) and a C/D AEC (yellow line). The hydrologist then uses the Desktop estimate and modifies it to fit the specialist requirements. This is done using the Desktop Reserve Model (DRM) and the Flow Stressor response model within SPATSIM¹ (SPAtial and Time Series Modelling) (Hughes and Forsythe, 2006). The process is specifically designed this way as the seasonal characteristics of the hydrology and the rules for the different ECs are built into the Desktop estimate². This would therefore ensure that the requirements set by specialists do not deviate significantly from the natural seasonal variability.
- There are a range of options that one can use to make these modifications to the DRM, such as changing the total volume required for the year, changing specific monthly volumes, changing durations of either drought or maintenance flows, changing the seasonal distribution and changing the category rules and shape factors.
- The DRM will then extrapolate the requirements to the other months or seasons and specialists can check these other months.
- The changes made to the DRM to fit the specialist requirements are documented.

The graphs for the final low flow stress requirements are documented.

2.2 HIGH FLOWS

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

- Geomorphology and riparian vegetation specialists describe a range of floods from very small to large based on the function they perform. Each of these different floods are described by a range of flood peaks that perform a specific function. The smallest group of floods with similar ranges are grouped into Class 1 floods. The second group of floods which is larger than group 1 will be therefore the Class 2 floods etc.
- These are provided to the instream specialists who indicate:
 - o which instream function these floods cater for,
 - o whether additional instream functions are required,
 - o whether they require any additional flood classes to the ones identified.
- The number of floods for each flood class is identified as well as where (early, mid, late) in the season they should occur.
- These numbers of floods are then adjusted for the different Ecological Categories.
- The floods are evaluated by the hydrologist to determine whether they are realistic. A nearby gauge³ with daily data is used for this assessment. Without this information it is difficult to judge whether floods are realistic.

¹ SPATSIM is an integrated data management and modelling software package developed in Delphi using the spatial data handling functions of Map Objects. It has been designed to allow the efficient management, processing and modelling of the type of data associated with a range of water resource assessment approaches used in South Africa including streamflow and other time series data display and analysis, rainfall-runoff models (including the Pitman monthly model) and a variety of Ecological Reserve determination models.

² The desktop estimates for specific ECs include rules for these ECs based on long-term data records and expert information.

³ Refer to report 26/8/3/10/12/009 (Volume 2, Appendix A) on hydrological information.

- The hydrologist then determines the daily average and documents the months in which the floods are spaced.
- The floods are then entered into the DRM to provide the final .rul and .tab files.

2.3 FINAL FLOW REQUIREMENTS

The low and high flows are combined to produce the final flow requirements for each EC as:

- An EWR table, which shows the results of high flows and low flows for each month separately. Floods with a frequency higher than 1:1 are not included.
- An EWR rule table which provides the recommended EWR flows as a duration table, showing flows which should be provided when linked to a natural trigger (natural modelled hydrology in this case). EWR rules are supplied for total flows as well as for low flows only.

The low flow EWR rule table is useful for operating the system, whereas the EWR table must be used for operation of high flows.

3 EWR 1: VALEYSPRUIT (CROCODILE RIVER) - DETERMINATION OF STRESS INDICES

NOTE: All supporting specialist information for EWR 1 is summarized in Volume 3, Appendix B.

Stress indices are set for fish, macroinvertebrates and riparian vegetation to aid in the determination of low flow requirements. The stress index describes the consequences of flow reduction on flow dependant biota. It therefore describes the habitat conditions for fish, macroinvertebrates and riparian vegetation indicator species for various low flows. These habitat conditions for different flows are rated from 10 (zero flows) to 0, which is the optimum habitat for the indicator species. It must be noted that the use of vegetation in this process is still in the developmental phase. The response to stress for riparian vegetation is much slower than that for the instream biota. The riparian vegetation information must therefore be used with care. This is relevant for all the sites.

3.1 INDICATOR SPECIES OR GROUP

3.1.1 Fish indicator group 1: Small semi-rheophilic species (BANO)

The small semi-rheophilic (SSR) species *Barbus anoplus* (BANO) is the only indigenous fish species present at the site and had to serve as the indicator species for this site. BANO only reaches a maximum size of approximately 12 cm. Habitat requirements for different life stages are summarised in Appendix B, Table B1. Its optimal preferred general habitat is Slow Deep (SD) and Slow Shallow (SS) preferably with overhanging vegetation or aquatic vegetation as cover, although they also make use of large substrates (cobbles, boulders and bedrock and even undercut banks) as general habitat. Spawning takes place during the summer when rivers are swollen after rains. It lays its adhesive eggs amidst vegetation. The larvae hatch within 3 days and begin to swim and feed after 6/7 days. Flows should remain adequate to allow migration between reaches, thus pools should remain connected during wet season. Water levels providing inundated vegetation should last long enough for spawning, egg hatching and larvae development. Larvae and juveniles require SS and SD with adequate cover to allow optimal development and survival.

3.1.2 Macroinvertebrate indicator taxa

Flow dependant (FDI) cobble dwelling macroinvertebrate taxa were selected on the basis of their sensitivity to changes in velocity and water quality. Only taxa that occurred commonly at the site were selected and include:

- The mayfly family: Tricorythidae requiring velocities of > 0.6 m/s, but may persist at lower velocities (> 0.1 m/s) and Heptageniidae requiring velocities of $0.3 - 0.6$ m/s but will also survive at faster velocities (> 0.6 m/s), they might persist at slower velocities ($0.1 - 0.3$ m/s).
- The beetle family: Elmidae also require velocities of $0.3 - 0.6$ m/s and may persist at slower ($0.1 - 0.3$ m/s) and faster velocities.

The Heptageniidae are highly sensitive and the Tricorythidae and Elmidae moderately sensitive to water quality conditions. These taxa are not expected to tolerate wide fluctuations in flow and water quality conditions.

3.1.3 Riparian vegetation indicator species

Two indicator species were selected:

- *Juncus lomatophyllus*: Leafy *Juncus* occurs in colonies in/near streams and marshes. The reproductive success is mainly achieved by vegetative growth achieved by the extension of the stolons into viable marginal habitats. This strategy affords *Juncus* the ability to optimise its contact with the river as well as locate itself in areas less disturbed by higher flows. *Juncus* also reproduces by seeds which are probably water borne, mostly during summer, but also throughout the year.
- *Miscanthus*: A grass associated with riparian zones and floodplains and common at the site.

Only *J. lomatophyllus* was assessed as this species was more sensitive to flow changes than *Miscanthus*.

3.2 STRESS FLOW INDEX

A stress flow index is generated for every component, and describes the progressive consequences to the flow dependent biota of flow reduction (O'Keeffe and Hughes, 2004). The stress flow index is generated in terms of habitat response and biotic response and is discussed below.

3.2.1 Habitat response

The habitat flow index is described separately for fish, macroinvertebrates and riparian vegetation as an instantaneous response of habitat to flow in terms of a 0 – 10 index relevant for the specific site where:

- 0 – Optimum habitat (fixed at the natural maximum base flow – calculated using the wettest flow month discharge at the maintenance percentage of 30% – 40% for the Crocodile River at the EWR site).
- 10 - No flow (although there may still be surface water in pools).

The instantaneous response of fish habitat for spawning and nursery habitat, abundance, cover, connectivity, and water quality are derived by considering (amongst others) rated velocity depth classes (in terms of abundance) to flow changes based on a 0 – 10 scale where:

- 0 = Velocity - depth class is absent under the specific flow condition.
- 10 = Velocity - depth class is very abundant under the specific flow condition.

Fish habitat is then rated according to a 0 – 5 scale where:

- 0 = No habitat available.
- 1 = Very low occurrence
- 2 = Low occurrence
- 3 = Moderate occurrence
- 4 = Large/Good occurrence
- 5 = Optimum occurrence

Specific results for the fish indicator species are summarised in Appendix B, Table B2 and FDI in Appendix B, Table B4.

3.2.2 Biota response

The biota stress index is the instantaneous response of biota to change in habitat (and therefore flow), based on a scale of 0 – 10 where:

- 0 = Optimum habitat with least amount of stress possible for the indicator groups **at the site** (fixed at the natural maximum base flow in the same way as for the habitat response).
- 10 = No flow (there can still be surface water in pools). The biota response will depend on the indicator groups present, i.e. rheophilics will have left whereas semi-rheophilics⁴ will still be present and survive.

The fish species response index is calculated using the fish habitat rating (cf Section 3.2.1) (Appendix B, Table B3) for each of the discharges evaluated for assessing habitat response. The macroinvertebrate (FDI) index is derived by considering the habitat response and % occurrence of habitat conditions at different flows. The FDI responses are described and coupled to a stress level (Appendix B, Table B5).

A riparian vegetation stress index is also provided (Appendix B, Table B6). This index considers the following:

- All responses to be assessed in combination with high flows/floods since the response will be dependent on the combined impact of both high and low flows.
- Increases in stress can be caused by progressive drying or inundation.
- Rooting depth is measured as the difference in elevation between the water level and the point at which individuals is rooted.

3.2.3 Integrated stress curve

The integrated stress curve represents the highest stress for fish, macroinvertebrates or riparian vegetation at a specific flow.

The shaded species stress discharges in Table 3.1 indicate the discharge evaluated by specialists to determine the biota stress. The values that are not shaded are interpolated⁵. The highest discharge representing a specific stress is used to define the integrated stress curve. Figure 3-1 illustrates this graphically.

In this specific case, the FDI stress index represents the integrated stress index (these values are the highest flow for a stress), therefore the red line (representing the FDI stress index) is lying 'beneath' the integrated stress line (black) (Figure 3-1).

⁴ Semi-rheophilics: Requiring flowing water during certain phases of the life-cycle. These include fast semi-rheophilics (requiring fast flowing water (>0.3 m/s) during certain phases of the life-cycle) and slow semi-rheophilics (requiring slow flowing water (<0.3 m/s) during certain phases of the life-cycle).

⁵ A method of constructing new data points within the range of a discrete set of known data points (www.wikipedia.org)

Table 3.1 Species stress discharges used to determine biotic stress

Stress	Flow (m ³ /s)				Integrated Flow (m ³ /s)
	SSR	FDI	Sedge <i>Juncus</i>	Grass <i>Miscanthus</i>	
0	0.4	0.34	0.2	0.2	0.4
1	0.25	0.29	0.15	0.147	0.29
2	0.1	0.19	0.1	0.093	0.19
3	0.06	0.15	0.05	0.04	0.15
4	0.04	0.09	0.025	0.027	0.09
5	0.032	0.075	0	0.014	0.075
6	0.025	0.06	0	0	0.06
7	0.019	0.039	0	0	0.039
8	0.013	0.019	0	0	0.019
9	0.007	0.002	0	0	0.007
10	0	0	0	0	0.001

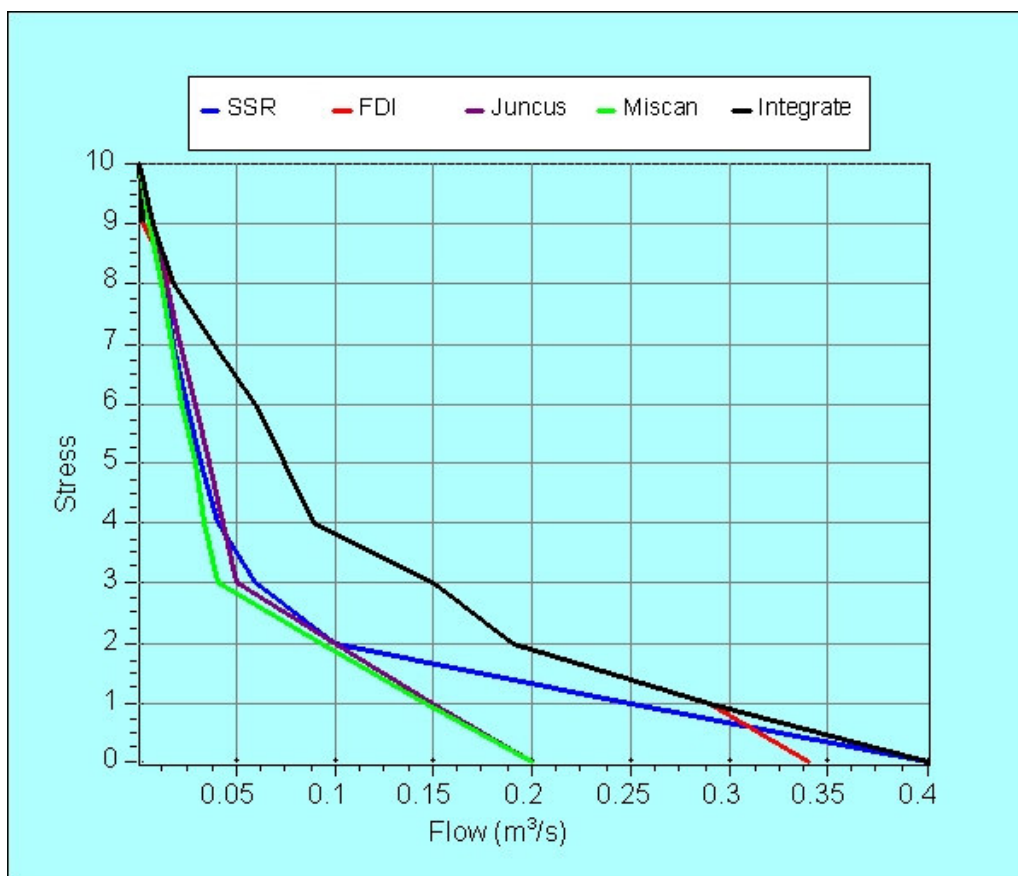


Figure 3-1 Component and integrated stress curves for EWR 1

Table 3.2 provides the summarised biotic response for the integrated stresses.

Table 3.2 Integrated stress and summarised habitat/biotic responses

Integrated stress	Flow m ³ /s	Habitat and/or Biotic responses
0 (SSR)	0.4	SSR guild: All habitat at optimum (5 ⁺) except spawning habitat which is moderate (3). All habitats in excess. All FDI are very abundant and healthy.
1 (FDI)	0.29	SSR guild: Same as above. FDIs: Critical habitats sufficient. 90% rheophilic species persist.
2 (FDI)	0.19	SSR guild: Same as above. FDI: Reduced critical habitat. Most rheophilic species persist, but slight (80%) reduction. Riparian vegetation: Adults with full vigour and at maximum reproductive capacity. 50% of population inundated, upper limit rooting depth at 13 cm.
3 (FDI)	0.15	FDI: Critical habitats limited. Most rheophilic species persist, but abundances reduced.
4 (FDI)	0.09	SSR guild: Habitat as above although the occurrence of cover is high (4). Critical habitat very reduced. All life stages viable in limited areas, critical life stages of some sensitive rheophilic species at risk.
5 (FDI)	0.075	SSR guild: As above.
6 (FDI)	0.06	SSR guild: Spawning and cover habitat is moderate (3) while abundance and connectivity is optimal and water quality high (4). Critical habitat residual. Sensitive rheophilic species rare, critical stages of sensitive rheophilic species non-viable and at risk for some less sensitive species. <i>J. lomatophyllus</i> : Leaf wilting/stress commences, but is slight. Up to 20 cm rooting depth for upper limit, lower limit at water level on average.
7 (FDI)	0.039	SSR guild: Abundance and connectivity is high, water quality is moderate and spawning and cover is low (2 – 2.5). <i>Miscanthus</i> : Leaf wilting/stress commences, but is slight. Rooting depth from 10 to 20 cm.
8 (FDI)	0.019	FDI: No critical habitat. Some rheophilic species persist, but at very low numbers. All life stages of most rheophilic species at risk or non-viable.
9 (SSR)	0.007	
10	0.001	Only pool dwelling species present. Only hyporheic refugia, no surface water for FDI. Indicator taxa no longer present. Riparian vegetation: Leaf wilting obvious, or vegetative parts begin unseasonal discolouration. Flower/fruit abortion widespread.

* Suitability rating 0 (not suitable) – 5 (highly suitable)

4 EWR 1: VALEYSRUIT (CROCODILE RIVER) - DETERMINATION OF EWR SCENARIOS

4.1 ECOCLASSIFICATION SUMMARY OF EWR 1

EWR 1 Valeyspruit (Crocodile River)																																									
<p>EIS: MODERATE Highest scoring metric were diversity of sensitive habitat types present e.g. wetlands, oxbows, sponges.</p> <p>PES: A/B Minor impacts due to farming, exotic vegetation species, trout. Impacts mostly non-flow related</p> <p>REC: A/B Maintain the PES as only moderate EIS.</p> <p>AEC down: B/C Scenario includes decreased low flows due to e.g. increased golf estates, trout farms and increased abstractions for Dullstroom. Growth of Dullstroom will also result in increased sewage. Increased grazing causing trampling and destabilisation of banks.</p>	<table border="1"> <thead> <tr> <th>Driver Components</th> <th>PES & REC Category</th> <th>Trend</th> <th>AEC↓</th> </tr> </thead> <tbody> <tr> <td>HYDROLOGY</td> <td>A/B</td> <td></td> <td>B</td> </tr> <tr> <td>WATER QUALITY</td> <td>A</td> <td></td> <td>B</td> </tr> <tr> <td>GEOMORPHOLOGY</td> <td>B</td> <td>Stable</td> <td>C</td> </tr> <tr> <th>Response Components</th> <th>PES & REC Category</th> <th>Trend</th> <th>AEC↓</th> </tr> <tr> <td>FISH</td> <td>A</td> <td>Stable</td> <td>B/C</td> </tr> <tr> <td>MACRO INVERTEBRATES</td> <td>B</td> <td>Negative</td> <td>B/C</td> </tr> <tr> <td>INSTREAM</td> <td>A/B</td> <td></td> <td>B/C</td> </tr> <tr> <td>RIPARIAN VEGETATION</td> <td>A</td> <td>Stable</td> <td>B</td> </tr> <tr> <td>ECOSTATUS</td> <td>A/B</td> <td></td> <td>B/C</td> </tr> </tbody> </table>	Driver Components	PES & REC Category	Trend	AEC↓	HYDROLOGY	A/B		B	WATER QUALITY	A		B	GEOMORPHOLOGY	B	Stable	C	Response Components	PES & REC Category	Trend	AEC↓	FISH	A	Stable	B/C	MACRO INVERTEBRATES	B	Negative	B/C	INSTREAM	A/B		B/C	RIPARIAN VEGETATION	A	Stable	B	ECOSTATUS	A/B		B/C
Driver Components	PES & REC Category	Trend	AEC↓																																						
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FISH	A	Stable	B/C																																						
MACRO INVERTEBRATES	B	Negative	B/C																																						
INSTREAM	A/B		B/C																																						
RIPARIAN VEGETATION	A	Stable	B																																						
ECOSTATUS	A/B		B/C																																						

4.2 HYDROLOGY

The highest and lowest low flow months selected as the key months are February (wet) and October (dry). The key assurance percentages for which stress requirements had to be set were:

- 95%: Representing droughts for both wet and dry months. This would represent 5% on the stress duration graphs.
- 65%: Representing maintenance flows for both wet and dry months. This would represent 35% on the stress duration graphs.

4.3 LOW FLOW REQUIREMENTS (IN TERMS OF STRESS)

The integrated stress index is used to identify required stress levels at specific durations for the wet and dry month/season. Specialist motivations for the stresses are provided in Appendix B, Section B2.1 – 2.3.

The fish, macroinvertebrate and riparian vegetation flow requirements for different Ecological Categories (ECs) are provided in Table 4.1 and Figure 4-1 and 4-2. The results are plotted for the wet and dry season on stress duration graphs and compared to the Desktop Reserve Model (DRM) low flow estimates for the same range of ECs. The stress requirements (as a ‘hand drawn line’) are illustrated in Figures 4-1 and 4-2.

For easier reference the range of ECs are colour coded in the Tables and Figures:

PES and REC: Purple

AEC: Green

Summarised motivations for the final requirements are provided in Table 4.2.

Table 4.1 Species and integrates stress requirements as well as the final integrated stress and flow requirements

Duration	SSR stress	Integrated stress	FDI stress	Integrated stress	Juncus stress	Integ stress	FINAL* (Integrated stress)*	FLOW (m ³ /s)
PES and REC: A/B EcoStatus		FISH: A		MACROINVERTEBRATES: B		RIP VEG: A		
DRY SEASON								
5%	9	9	8	8	6	10	8	0.019
35%	6	7.75	6	6	3	6.5	6	0.06
WET SEASON								
5%	5	7.4	4	4	3	6.5	4	0.09
35%	2	3.8	2	2	0	1.9	1.9	0.20
AEC: B/C EcoStatus		FISH: B/C		MACROINVERTEBRATES: B/C		RIP VEG: B		
DRY SEASON								
35%	8	8.6	7	7	Not assessed. Impacts are based on non-flow related issues.		7	0.039
WET SEASON								
35%	4	7	3	3	As above.		3	0.15

* Final refers to the final stress selected as the EWR requirement, usually the lowest integrated stress. In some cases, vegetation was ignored due to the much lower confidence in the requirements.

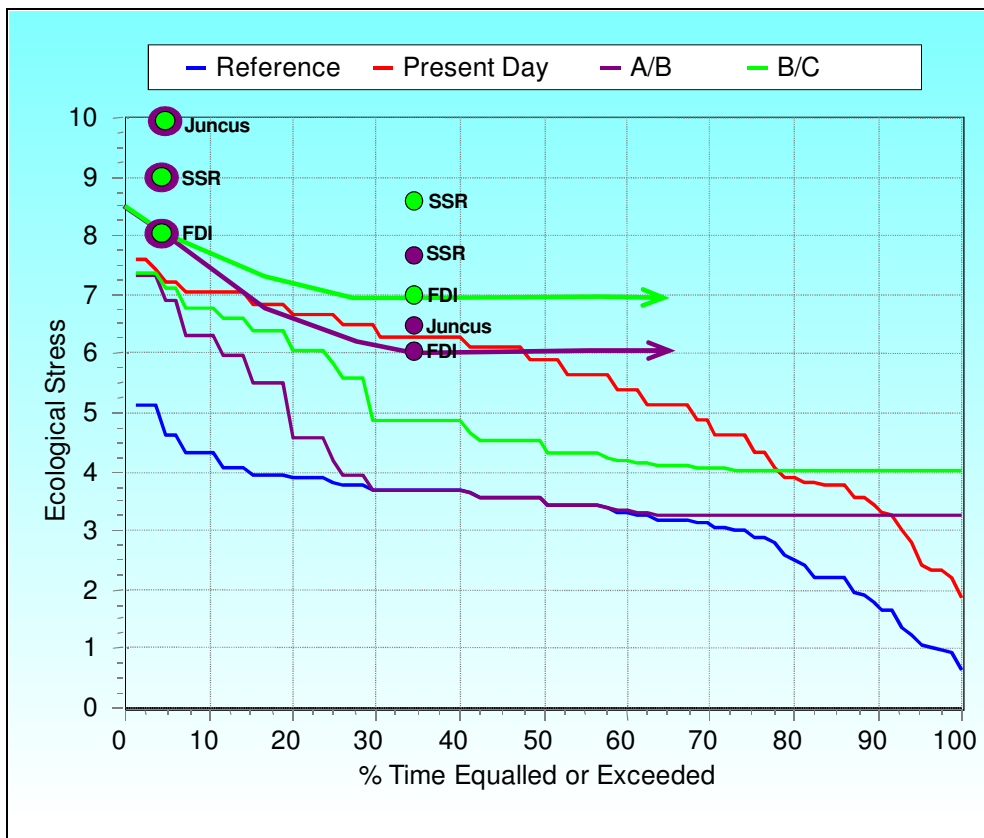


Figure 4-1 EWR 1: Stress duration curve for an A/B PES and REC, and B/C AEC - DRY season

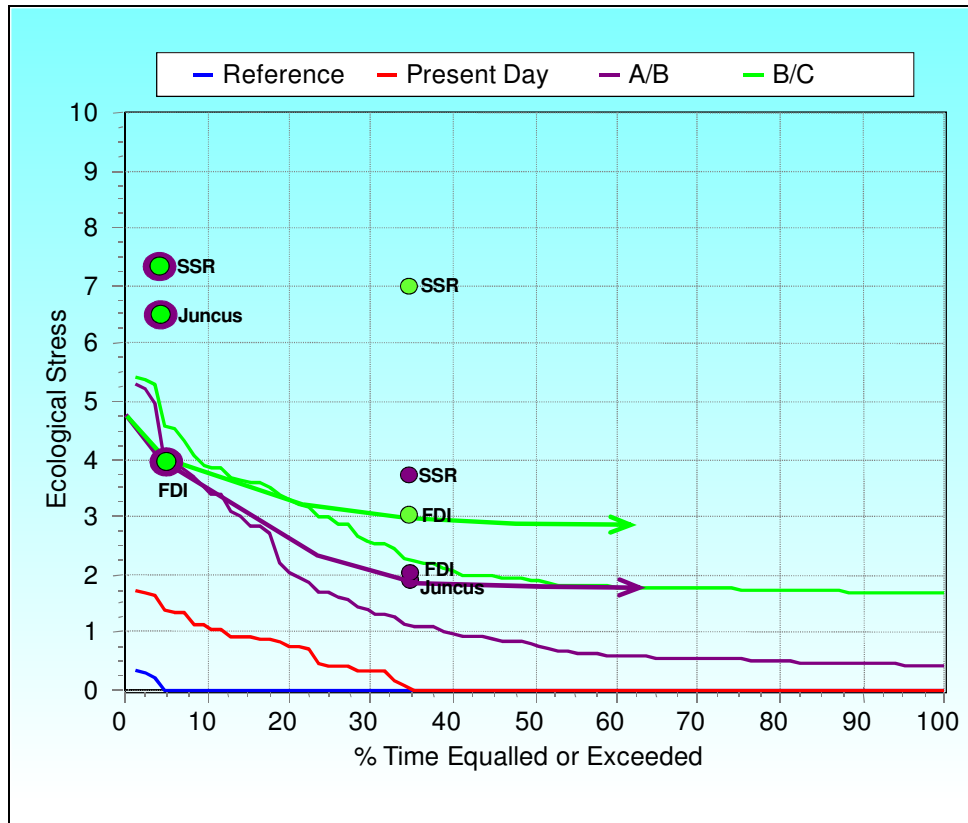


Figure 4-2 EWR 1: Stress duration curve for a A/B PES and REC, and B/C AEC - DRY season - WET season

Table 4.2 Summary of EWR 1 motivations

Month	% Stress duration	Component stress	Integrated stress	Flow m ³ /s	Comment
PES and REC: A/B EcoStatus		FISH: A		MACROINVERTEBRATES: B	
Oct	5% drought	8 FDI	8	0.019	The maximum velocity of 0.32 m/s will ensure that FDI survive during drought periods.
	35% maintenance	6 FDI	6	0.06	Indicator taxa can overwinter without significant detrimental impacts on the overall population.
Feb	5% drought	4 FDI	4	0.09	Ensures a healthy population is present during summer.
	35% maintenance	1.9 <i>Juncus</i>	1.9	0.20	<i>Juncus</i> population will be healthy and abundant.
AEC: B/C EcoStatus		FISH: B/C		MACROINVERTEBRATES: B/C	
Oct	5% drought	8 FDI	8	0.019	See PES.
	35% maintenance	7 FDI	7	0.039	Indicator taxa can overwinter without significant detrimental impacts on the overall population.
Feb	5% drought	4 FDI	4	0.09	See PES
	35% maintenance	3 FDI	3	0.15	Ensures a healthy population is present during summer.

4.3.1 Final low flow requirements

To produce the final results (Figure 4-3), the DRM results for the specific category are modified according to specialists' requirements (Figure 4-1 and 4-2). There are a range of options one can use to make these modifications, such as changing the total volume required for the year,

changing specific monthly volumes, changing durations of either drought or maintenance flows, changing the seasonal distribution and changing the category rules and shape factors. The following changes were required:

- Seasonal distribution factors were changed.
 - o A/B EC: 1.52 for maintenance; 2.75 for drought.
 - o B/C EC: 1.80 for maintenance; 2.75 for drought.

Dry Season (October)

Wet Season (February)

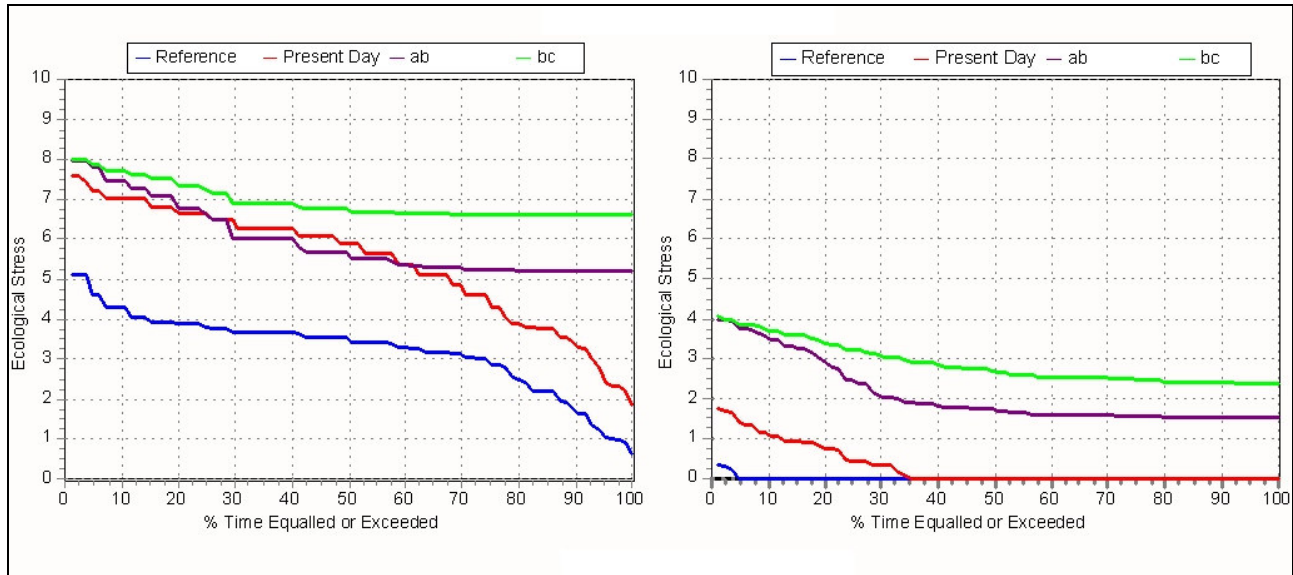


Figure 4-3 EWR 1: Final stress requirements for low flows

4.4 HIGH FLOW REQUIREMENTS

The high flow classes are identified as follows:

- The geomorphologist and riparian vegetation specialist identify the range of flood classes required and list the functions of each flood.
- The instream specialists then indicate which of the instream flooding functions are addressed by the floods identified for geomorphology and riparian vegetation (indicated by a √ in Table 4.3).
- Any of the floods required by the instream biota and not addressed by the floods already identified, must then be described (in terms of ranges and functions) for the instream biota.

Results are provided in Table 4.3 and detailed motivations provided in Table 4.4.

Table 4.3 Identification of instream functions addressed by the identified floods for geomorphology and riparian vegetation

FLOOD CLASS	FLOOD RANGE (m ³ /s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions						Macroinvertebrate flood functions				
			Migration cues	Migration habitat (depth etc.)	Create spawning habitat	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas	Reset water quality
I	0.6 – 2	Vegetation: Annual inundation of <i>Cliffortia/Juncus/Setaria</i> .	√	√	√	√	√	√	√				√
II	3 – 5	Geomorphology: Activate the seasonal channels on the floodplain; scour active channel; recharge the pans. Vegetation: Inundation / activation of <i>Leucosidea</i> .	√	√	√	√	√	√	√	√	√	√	√
III	> 10	Geomorphology: Inundate the floodplain; deposit sediment; scour the active channel; create cut / undercut banks. Vegetation: Inundation of the floodplain, maintain the <i>Miscanthus</i> .	√	√	√	√	√						

Further information is provided in Appendix B, Table B10.

The number of high flow events required for each EC is provided in Table 4.4. No observed daily data was available to check flood requirements against.

Table 4.4 EWR 1: Recommended size and frequency of high flow events

FLOOD CLASS	FLOOD RANGE (m ³ /s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL* (No of events)	MONTHS	DAILY AVERAGE (m ³ /s)	DURATION (Days)
PES and REC SCENARIO: A/B									
I	0.6 – 2	3	3	2 per annum		3	Nov, Dec, Mar	1	3
II	3 – 5	1		1	1:2**	1	Jan	3	3
III	> 10		1:3	1:3	1:3	1:3			
AEC SCENARIO: B/C									
I	0.6 – 2	2	2	2 per annum		2	Nov, Dec, Mar	1	3
II	3 – 5	1		1	1:2	1	Jan	3	3
III	> 10			1:3	1:3	1:3			

* Final refers to the agreed on number of events considering the individual requirements for each component

** Refers to frequency of occurrence, i.e. the flood will occur once in two years.

4.5 FINAL FLOW REQUIREMENTS

The low and high flows were combined to produce the final flow requirements for each EC as:

- An EWR table, which shows the results of high flows and low flows for each month separately (Table 4.5 – 4.6). Floods with a frequency higher than 1:1 are not included.
- An EWR rule table which provides the recommended EWR flows as a duration table, showing flows which should be provided when linked to a natural trigger (natural modelled hydrology in this case). EWR rules are supplied for total flows as well as for low flows only (Appendix B, Section B2.4).

The low flows .rul is useful for operating the system, whereas the EWR table must be used for operation of high flows.

Table 4.5 EWR table for PES and REC: A/B

Desktop version:		2	Virgin MAR (MCM)	15.191
BFI index	0.5	Distribution type		Eastern escarpment
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m ³ /s)	Drought (m ³ /s)	Daily average (m ³ /s) on top of base flow	Duration (days)
OCTOBER	0.065	0.020		
NOVEMBER	0.093	0.035	1	3
DECEMBER	0.111	0.045	1	3
JANUARY	0.157	0.069	3	3
FEBRUARY	0.200	0.090		
MARCH	0.173	0.077	1	3
APRIL	0.166	0.073		
MAY	0.138	0.059		
JUNE	0.114	0.046		
JULY	0.091	0.034		
AUGUST	0.071	0.023		
SEPTEMBER	0.060	0.018		
TOTAL MCM	3.765	1.539	0.933	
% OF VIRGIN	24.78	10.13	6.14	

Table 4.6 EWR table for AEC: B/C

Desktop version:		2	Virgin MAR (MCM)	15.191
BFI index	0.5	Distribution type		Eastern escarpment
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m ³ /s)	Drought (m ³ /s)	Daily average (m ³ /s) on top of base flow	Duration (days)
OCTOBER	0.041	0.020		
NOVEMBER	0.062	0.035	1	3
DECEMBER	0.075	0.045	1	3
JANUARY	0.109	0.069	3	3
FEBRUARY	0.140	0.090		
MARCH	0.121	0.077	1	3
APRIL	0.115	0.073		

MAY	0.095	0.059		
JUNE	0.077	0.046		
JULY	0.060	0.034		
AUGUST	0.045	0.023		
SEPTEMBER	0.038	0.018		
TOTAL MCM	2.558	1.539	0.933	
% OF VIRGIN	16.84	10.13	6.14	

A comparison between the Desktop Reserve Model estimates and the EWR results in terms of percentages of natural flow are provided in Table 4.7.

Table 4.7 Modifications made to the DRM for EWR 1

Changes	PES and REC A/B		AEC B/C	
	DRM	EWR	DRM	EWR
MLIFR - Maintenance low flow	39.8%	38.0%	24.3%	25.8%
DLIFR - Drought low flow	9.6%	15.5%	9.6%	15.5%
MHIFR - Maintenance high flow	9.8%	9.4%	7.8%	9.4%
Long-term % of virgin MAR	48.0%	30.9%	33.0%	24.4%

5 EWR 2: GOEDEHOOP (CROCODILE RIVER) - DETERMINATION OF STRESS INDICES

NOTE: All supporting specialist information for EWR 2 is summarized in Volume 3, Appendix C.

5.1 INDICATOR SPECIES OR GROUP

5.1.1 Fish indicator group 1: Small rheophilic species (AURA, BARG, CPRE)

The small rheophilic (SR) species, *Amphilius uranoscopus* (AURA), *Amphilius natalensis* (ANAT), *Chiloglanis bifurcus* (CBIF), *Chiloglanis pretoriae* (CPRE), and *Barbus argenteus* (BARG) were the best indicators for setting low flows. Information on the habitat requirements for different life stages of CPRE (representing the SR guild) are provided in Appendix C, Table C1. The species require flowing water over substrates during all life stages, with some stages also preferring some overhanging vegetation as cover. Optimal conditions for spawning of this guild consist of FD and FI with good quality substrate (clean cobbles and gravel), while the margins of the FS and SS are important for egg development and nursery areas for larvae. Juvenile and adult stages of this guild have a high preference for FS, FI and FD over substrates.

5.1.2 Macroinvertebrate indicator taxa

Flow dependant (FDI) cobble dwelling macroinvertebrate taxa selected include:

- The mayfly family: Tricorythidae and Heptageniidae – see Section 3.1.2.
- The stonefly family: Perlidae preferring velocities > 0.6 m/s.

Tricorythidae and Heptageniidae are able to survive on vegetation and bedrock. The Perlidae and Heptageniidae are highly sensitive and the Tricorythidae moderately sensitive to water quality conditions. These taxa are not expected to tolerate wide fluctuations in flow and water quality conditions.

5.1.3 Riparian vegetation indicator species

One indicator species were selected:

- *J. lomatophyllus*: See Section 3.1.3

5.2 STRESS FLOW INDEX

The stress flow index is generated in terms of habitat and biotic response and is discussed below.

5.2.1 Habitat response

The habitat flow index is described separately for fish, macroinvertebrates and riparian vegetation as an instantaneous response of habitat to flow in terms of a 0 – 10 index relevant for the specific site where:

- 0 – Optimum habitat (fixed at the natural maximum base flow – calculated using the wettest flow month discharge at the maintenance percentage of 30% – 40% for the Crocodile River at the EWR site).
- 10 - No flow (although there may still be surface water in pools).

The abundance of fish velocity-depth classes are provided in Appendix C, Table C2.

The instantaneous response of FDI taxa provides the % occurrence of various velocity-substrate classes under different flow conditions are provided in Appendix C, Table C4).

5.2.2 Biota response

The biota stress index is the instantaneous response of biota to change in habitat (and therefore flow), based on a scale of 0 – 10.

The fish species response index is calculated using the fish habitat rating (cf Section 3.2.1) (Appendix C, Table C3) for each of the discharges evaluated for assessing habitat response. The FDI index is derived by considering the habitat response and % occurrence of habitat conditions at different flows. The FDI responses are described and coupled to a stress level (Appendix C, Table C5)

A riparian vegetation stress index is also provided (Appendix C, Table C6).

5.2.3 Integrated stress curve

The integrated stress curve represents the highest stress for fish, macroinvertebrates or riparian vegetation at a specific flow.

The shaded species stress discharges in Table 5.1 indicate the discharge evaluated by specialists to determine the biota stress. The values that are not shaded are interpolated. The highest discharge representing a specific stress is used to define the integrated stress curve. Figure 5-1 illustrates this graphically.

In this specific case, the SR fish stress index represents the integrated stress index (these values are the highest flow for a stress). Therefore the blue line (representing the SR stress index) is lying 'beneath' the integrated stress line (black) (Figure 5-1).

Table 5.1 Species stress discharges used to determine biotic stress

Stress	Flow (m ³ /s)			Integrated Flow (m ³ /s)
	SR	FDI	Sedge <i>Juncus</i>	
0	2.04	2.04	0.6	2.04
1	1.67	1.67	0.43	1.67
2	0.87	0.87	0.26	0.87
3	0.52	0.5	0.09	0.52
4	0.39	0.21	0.053	0.39
5	0.29	0.15	0.015	0.29
6	0.21	0.12	0	0.21
7	0.093	0.09	0	0.093
8	0.062	0.06	0	0.062
9	0.032	0.005	0	0.032
10	0	0	0	0

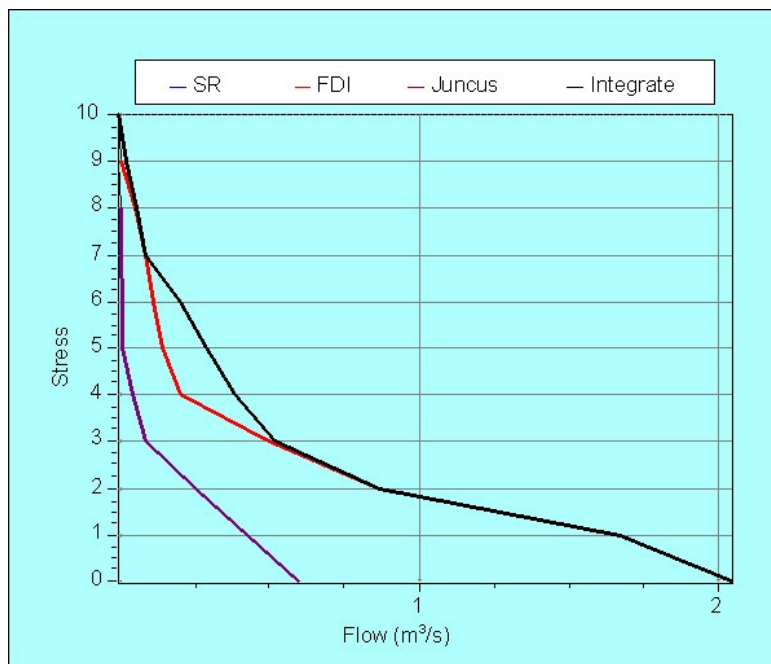


Figure 5-1 Component and integrated stress curves for EWR 2

Table 5.2 provides the summarised biotic response for the integrated stresses.

Table 5.2 Integrated stress and summarised habitat/biotic responses

Integrated stress	Flow m ³ /s	Habitat and/or Biotic responses
0 (SR)	2.04	SR guild: All habitat at optimum (5 ⁺). All habitats in excess, FDI indicator taxa very abundant and healthy.
1 (SR)	1.67	SR guild: Spawning and abundance of habitat is slightly less than optima (4.5) while rest of habitat is optimal. Habitat plentiful and of high quality. 90% of FDI indicator taxa persist.
2 (SR)	0.87	SR guild: Spawning and abundance of habitat is moderate (3.5) while cover is slightly less than optimal and connectivity and water quality is optimal. Critical habitat sufficient. Most FDI indicator taxa persist, but slight (80%) reduction.
3 (SR)	0.52	SR guild: Connectivity and water quality is good, while cover and abundance is moderate. Spawning habitat is low (2.5). Reduced critical habitat. Most FDI indicator taxa persist, but abundances reduced. <i>J lomatophyllus</i> : Adults with full vigour and at maximum reproductive capacity. 50% population inundated, upper limit rooting depth at 20 cm.
4 (SR)	0.39	SR guild: Spawning and abundance is low (2 – 2.5) with good connectivity and moderate cover and water quality.
5 (SR)	0.29	SR guild: Connectivity and water quality is moderate while rest of habitat is low. Critical FDI habitat limited and of moderate quality.
6 (SR)	0.21	SR guild: Most habitats are low with spawning habitat very low. Moderate connectivity exists. Critical habitat very reduced. All life stages viable in limited areas, critical life stages of some sensitive indicator taxa at risk.
7 (SR)	0.093	SR guild: All habitat is low with spawning habitat very low (1). No critical habitat, other habitats moderate quality. Some indicator taxa persist, but most disappear. All life-stages of sensitive indicator taxa at risk or non-viable. <i>J lomatophyllus</i> : Leaf wilting/stress commences, but is slight. Up to 30 cm rooting depth for upper limit, lower limit at water level on average.
8 (SR)	0.062	Flowing water habitats residual and of low quality. Some indicator taxa persist, but at very low numbers. All life stages of most indicator taxa at risk or non-viable.
10 (SR)	0	Only pool dwelling species present. Only hyporheic refugia, no surface water for FDI. Indicator taxa no longer present. <i>J lomatophyllus</i> : Widespread and complete mortality of population.

* Suitability rating 0 (not suitable) – 5 (highly suitable)

6 EWR 2: GOODEHOOP (CROCODILE RIVER) - DETERMINATION OF EWR SCENARIOS

6.1 ECOCLASSIFICATION SUMMARY OF EWR 2

EWR 2 Goedehoop (Crocodile River)					
<p>EIS: HIGH Rare and endangered fish sp which are sensitive to flow and quality changes. High species diversity.</p> <p>PES: B Impacts as for EWR 1 with increased agricultural activities and decreased flows. However, impacts mostly still non-flow related.</p> <p>REC: B Although the EIS is high, the PES is already a B and as the impacts are mostly non-flow related, it would not be realistic to improve the PES.</p> <p>AEC down: C See EWR 1. Possible zero flow situations and additional impacts on moderate events.</p>		Driver Components	PES & REC Category	Trend	AEC↓
		HYDROLOGY	B		C
		WATER QUALITY	B		C
		GEOMORPHOLOGY	B	Stable	B/C
		Response Components	PES & REC Category	Trend	AEC↓
		FISH	B	Stable	C
		MACRO INVERTEBRATES	B	Negative	C
		INSTREAM	B		C
		RIPARIAN VEGETATION	A/B	Negative	B
		ECOSTATUS	B		C

6.2 HYDROLOGY

The highest and lowest low flow months selected as the key months are February (wet) and October (dry). The key assurance percentages for which stress requirements had to be set were:

- 95%: Representing droughts for both wet and dry months. This would represent 5% on the stress duration graphs.
- 65%: Representing maintenance flows for both wet and dry months. This would represent 35% on the stress duration graphs.

6.3 LOW FLOW REQUIREMENTS (IN TERMS OF STRESS)

The integrated stress index is used to identify required stress levels at specific durations for the wet and dry month/season. Specialist motivations for the stresses are provided in Appendix C, Section C2.1 – 2.3.

The fish, macroinvertebrate and riparian vegetation flow requirements for different Ecological Categories (ECs) are provided in Table 6.1 and Figure 6-1 and 6-2. The results are plotted for the wet and dry season on stress duration graphs and compared to the DRM low flow estimates for the same range of ECs. The stress requirements (as a 'hand drawn line') are illustrated in Figures 6-1 and 6-2.

For easier reference the range of ECs are colour coded in the Tables and Figures:

PES and REC: **Purple**

AEC: **Green**

Summarised motivations for the final requirements are provided in Table 6.2.

Table 6.1 Species and integrates stress requirements as well as the final integrated stress and flow requirements

Duration	SR stress	Integrated stress	FDI stress	Integrated stress	Juncus stress	Integ stress	FINAL* (Integrated stress)*	FLOW (m ³ /s)
PES and REC: B EcoStatus		FISH: B		MACROINVERTEBRATES: B		RIP VEG: A/B		
DRY SEASON								
5%	6	6	7	7	8	10	6	0.21
20%	5.25	5.25					5.25	0.27
35%	4.75	4.75	4	6	3	7.5	4.75	0.315
WET SEASON								
5%	3	3	4	6	4	8.5	3	0.52
35%	1.5	1.5	2	2	1	3.75	1.5	1.27
AEC: C EcoStatus		FISH: C		MACROINVERTEBRATES: C		RIP VEG: B		
DRY SEASON								
35%	5.5	5.5	5	6.5	Not assessed. Impacts are based on non-flow related issues.		5.5	0.25
WET SEASON								
35%	2.5	2.5	3	3.1	As above.		2.5	0.695

Final refers to the final stress selected as the EWR requirement, usually the lowest integrated stress. In some cases, vegetation was ignored due to the much lower confidence in the requirements.

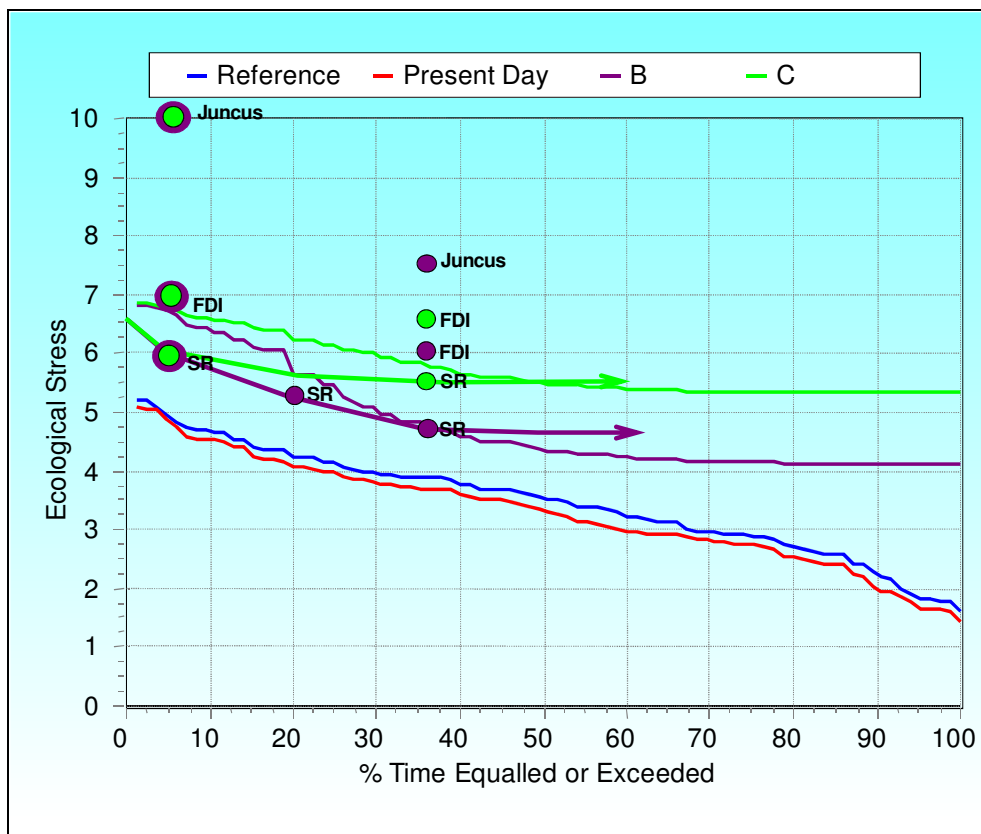


Figure 6-1 EWR 2: Stress duration curve for a B PES and REC, and C AEC - DRY season

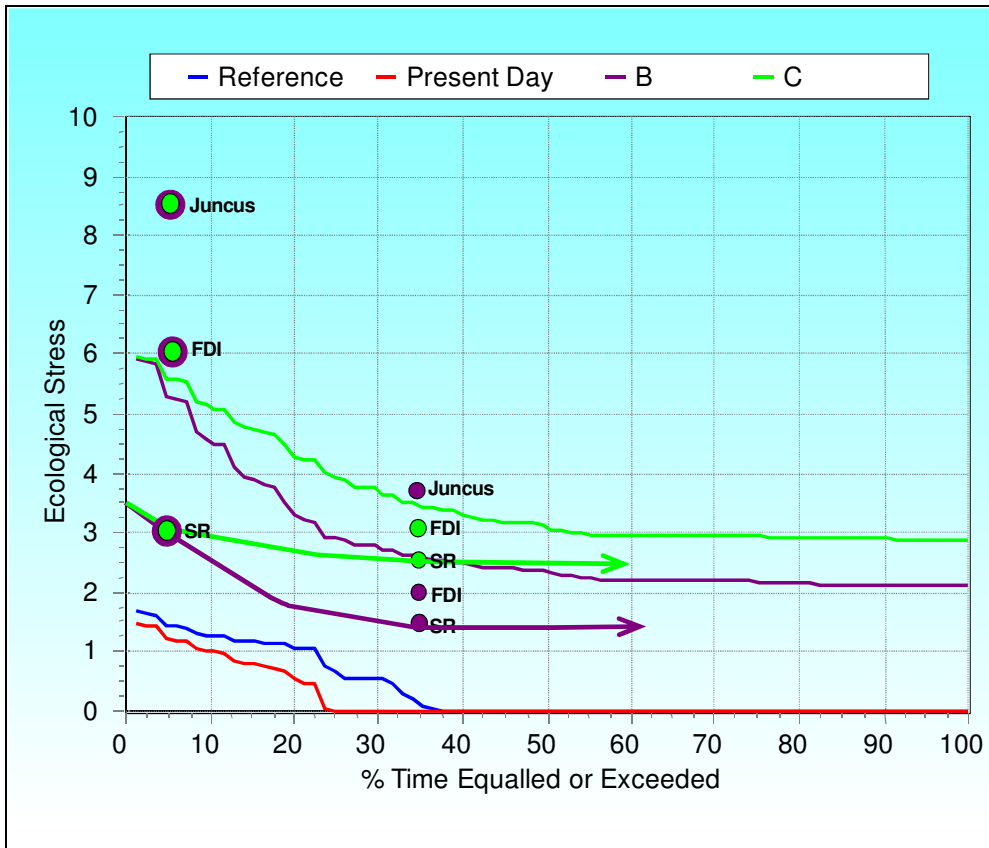


Figure 6-2 EWR 2: Stress duration curve for a B PES and REC, and C AEC - WET season

Table 6.2 Summary of EWR 2 motivations

Month	% Stress duration	Component stress	Integrated stress	Flow m ³ /s	Comment
PES and REC: B EcoStatus FISH: B MACROINVERTEBRATES: B RIP VEG: A/B					
Oct	5% drought	6 SR	6	0.21	Limited FS and FI habitat, crucial for the survival of the SR guild will be present.
	35% maintenance	4.75 SR	4.75	0.27	Reduced presence of FS habitat and therefore a reduced abundance of the SR guild.
Feb	5% drought	3 SR	3	0.52	FD habitats will be lost but adequate FI and FS habitat will be maintained which will ensure spawning.
	35% maintenance	1.5 SR	1.5	1.27	Adequate fats habitats with substrate, the optimally preferred habitats for the SR species should be maintained to ensure optimal or acceptable conditions.
AEC: C EcoStatus FISH: C MACROINVERTEBRATES: C RIP VEG: B					
Oct	5% drought	6 SR	6	0.21	See PES.
	35% maintenance	5.5 SR	5.5	0.25	FD habitat will be lost and FI and FS will be greatly reduced. Decreased Frequency of Occurrence (FROC) of SR guild.
Feb	5% drought	3 SR	3	0.52	See PES
	35% maintenance	2.5 SR	2.5	0.695	Reduced FD habitat although adequate for the requirements of all life stages of SR guild, although the guild will occur at a decreased FROC.

6.3.1 Final low flow requirements

To produce the final results (Figure 6-3), the DRM results for the specific category are modified according to specialists' requirements (Figure 6-1 and 6-2). The following changes were required:

- Seasonal distribution factors were changed.
 - B EC: 1.87 for maintenance; 1.05 for drought.
 - C EC: 1.2 for maintenance; 1.05 for drought.

Dry Season (October)

Wet Season (February)

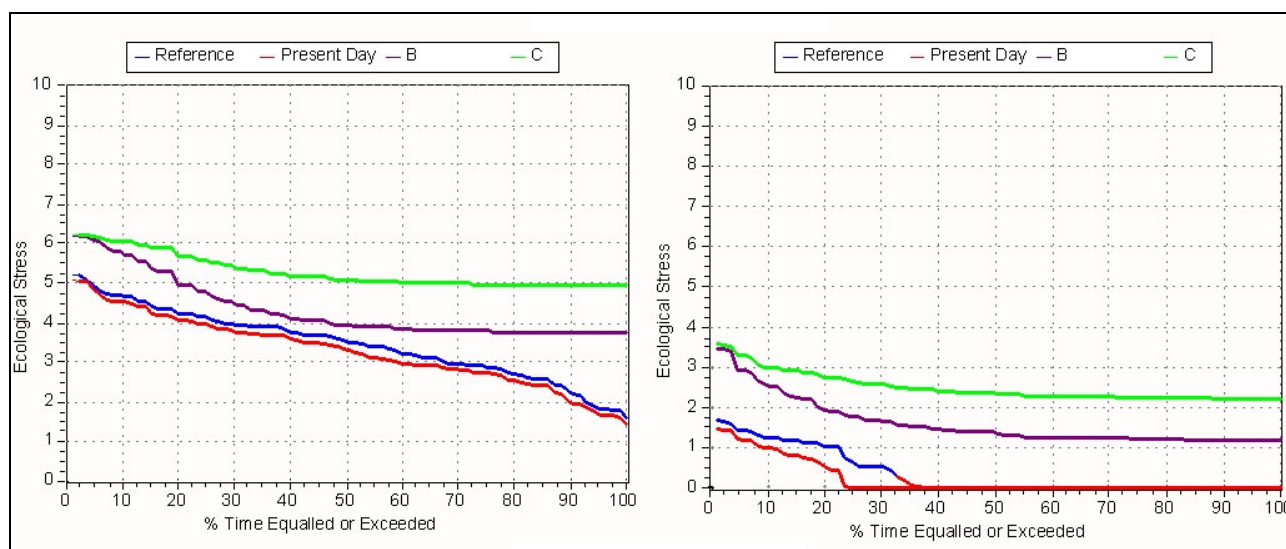


Figure 6-3 EWR 2: Final stress requirements for low flows

6.4 HIGH FLOW REQUIREMENTS

High low classes were identified as outlined in Section 4.4. Results are provided in Table 6.3 and detailed motivations provided in Table 6.4.

Table 6.3 Identification of instream functions addressed by the identified floods for geomorphology and riparian vegetation

FLOOD CLASS	FLOOD RANGE (m ³ /s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions						Macroinvertebrate flood functions				
			Migration cues	Migration habitat (depth etc.)	Clean spawning habitat	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas	Reset water quality
I	2 - 5	Vegetation: Activates and inundates leafy <i>Juncus</i> on the marginal and lower zone.										✓	✓
II	6 - 9	Geomorphology: The effective discharge for sands and gravels. Scour channel, remove fines, and turn the cobbles. Annual flood. Vegetation: Inundates marginal zone and facilitates new <i>Combretum</i> recruitment and survival.	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
III	13 - 25	Vegetation: Inundate and activate the <i>Combretum</i> population to provide recruitment opportunities.	✓	✓	✓	✓	✓	✓					
IV	30 - 35	Geomorphology: Overtop the levees and inundates the floodplain. Scour active channel; turn cobbles. Vegetation: Inundates and maintains <i>Miscanthus</i> on the floodplain.	✓	✓	✓	✓	✓	✓					

Further information is provided in Appendix C, Table C9.

The number of high flow events required for each EC is provided in Table 6.4. No observed daily data was available to check flood requirements against.

Table 6.4 EWR 2: The recommended number of high flow events required

FLOOD CLASS	FLOOD RANGE (m ³ /s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (No of events)	MONTHS	DAILY AVERAGE (m ³ /s)	DURATION (Days)
PES and REC SCENARIO: B									
I	2 - 5	4	4	4		4	Nov, Dec, Jan, Mar, Apr	3	3
II	6 - 9	1		1	1	1	Feb	9	4
III	13 – 25			1:2			Late summer		
IV	30 - 35			1:4	1:2		Dec - Feb		
AEC SCENARIO: C									
I	2 - 5			3		3	Nov, Jan, Mar, Apr	3	3
II	6 - 9			1:2	1	1	Feb	9	4
III	13 – 25			1:3					
IV	30 - 35			1:4+	1:4+				

6.5 FINAL FLOW REQUIREMENTS

The low and high flows were combined to produce the final flow requirements for each EC as:

- An EWR table, which shows the results of high flows and low flows for each month separately (Table 6.5 – 6.6). Floods with a frequency higher than 1:1 is not included.
- An EWR rule table which provides the recommended EWR flows as a duration table, showing flows which should be provided when linked to a natural trigger (natural modelled hydrology in this case). EWR rules are supplied for total flows as well as for low flows only (Appendix C, Section C2.4).

Table 6.5 EWR table for PES and REC: B

Desktop version:		2	Virgin MAR (MCM)	47.111
BFI index		0.5	Distribution type	Eastern escarpment
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m ³ /s)	Drought (m ³ /s)	Daily average (m ³ /s) on top of base flow	Duration (days)
OCTOBER	0.384	0.187		
NOVEMBER	0.568	0.242	3	3
DECEMBER	0.692	0.275	3	3
JANUARY	0.987	0.360	3	3
FEBRUARY	1.270	0.450	9	4
MARCH	1.104	0.394	3	3
APRIL	1.057	0.383	3	3
MAY	0.874	0.328		
JUNE	0.716	0.285		

Desktop version:		2	Virgin MAR (MCM)		47.111
BFI index	0.5	Distribution type		Eastern escarpment	
MONTH	LOW FLOWS		HIGH FLOWS		
	Maintenance (m ³ /s)	Drought (m ³ /s)	Daily average (m ³ /s) on top of base flow	Duration (days)	
JULY	0.567	0.240			
AUGUST	0.425	0.199			
SEPTEMBER	0.350	0.180			
TOTAL MCM	23.528	9.225	3.499		
% OF VIRGIN	49.94	19.58	7.43		

Table 6.6 EWR table for AEC: C

Desktop version:		2	Virgin MAR (MCM)		47.111
BFI index	0.5	Distribution type		Eastern escarpment	
MONTH	LOW FLOWS		HIGH FLOWS		
	Maintenance (m ³ /s)	Drought (m ³ /s)	Daily average (m ³ /s) on top of base flow	Duration (days)	
OCTOBER	0.221	0.187			
NOVEMBER	0.294	0.242	3	3	
DECEMBER	0.339	0.275			
JANUARY	0.452	0.360	3	3	
FEBRUARY	0.569	0.450	9	4	
MARCH	0.497	0.394	3	3	
APRIL	0.482	0.383	3	3	
MAY	0.409	0.328			
JUNE	0.351	0.285			
JULY	0.291	0.240			
AUGUST	0.236	0.199			
SEPTEMBER	0.210	0.180			
TOTAL MCM	11.391	9.225	3.033		
% OF VIRGIN	24.18	19.58	6.44		

A comparison between the Desktop Reserve Model estimates and the EWR results in terms of percentages of natural flow are provided in Table 6.7.

Table 6.7 Modifications made to the DRM for EWR 2

Changes	PES and REC B		AEC C	
	DRM	EWR	DRM	EWR
MLIFR - Maintenance low flow	31.2%	42.2%	18.0%	20.4%
DLIFR - Drought low flow	9.8%	16.5%	9.8%	16.5%
MHIFR - Maintenance high flow	8.5%	6.2%	7.0%	5.4%
Long-term % of virgin MAR	38.9%	57%	28.5%	37%

7 EWR 3: POLAR CREEK (CROCODILE RIVER) - DETERMINATION OF STRESS INDICES

NOTE: All supporting specialist information for EWR 3 is summarized in Volume 3, Appendix D.

7.1 INDICATOR SPECIES OR GROUP

7.1.1 Fish indicator group 1: Small rheophilic species (AURA, BARG, CPRE)

Amphilius uranoscopus (AURA), *Amphilius natalensis* (ANAT), *Chiloglanis bifurcus* (CBIF), *Chiloglanis pretoriae* (CPRE), and *Barbus argenteus* (BARG). See Section 5.1.1 and Appendix C, Table C1.

7.1.2 Macroinvertebrate indicator taxa

Flow dependant (FDI) cobble dwelling macroinvertebrate taxa included:

- The mayfly family: Tricorythidae and Heptageniidae, refer to Section 3.1.2
- The beetle family: Psephenidae requiring velocities of > 0.6 m/s, but may persist at lower velocities (> 0.1 m/s).

All three taxa occur mostly on cobbles. Tricorythidae and Heptageniidae are able to survive on vegetation and bedrock. The Heptageniidae are highly sensitive and the Tricorythidae and Psephenidae moderately sensitive to water quality conditions. These taxa are not expected to tolerate wide fluctuations in flow and water quality conditions.

7.1.3 Riparian vegetation indicator species

Two indicator species were selected:

- *Salix mucronata* and *Cliffortia* spp. are both marginal and lower zone woody species. As obligate riparian species they make good indicators of flow requirements and geomorphology.

7.2 STRESS FLOW INDEX

The stress flow index is generated in terms of habitat and biotic response and is discussed below.

7.2.1 Habitat response

Habitat response is used to derive the biota's response to provide a biota stress index and represents the instantaneous response of habitat to flow changes, based on a site specific 0 – 10 scale for instream biota where:

- 0 – Optimum habitat (fixed at the natural maximum base flow – calculated using the wettest flow month discharge at the maintenance percentage of 30% – 40% for the Crocodile River at the EWR site).
- 10 - No flow (although there may still be surface water in pools).

The abundance of fish velocity-depth classes are provided in Appendix D, Table D1.

The instantaneous response of FDI taxa provides the % occurrence of various velocity-substrate classes under different flow conditions are provided in Appendix D, Table D3).

7.2.2 Biota response

The biota stress index is the instantaneous response of biota to change in habitat (and therefore flow), based on a scale of 0 – 10.

The fish species response index is calculated using the fish habitat rating (cf Section 3.2.1) (Appendix D, Table D2) for each of the discharges evaluated for assessing habitat response. The FDI index is derived by considering the habitat response and % occurrence of habitat conditions at different flows. The FDI responses are described and coupled to a stress level (Appendix D, Table D4)

A riparian vegetation stress index is also provided (Appendix D, Table D5).

7.2.3 Integrated stress curve

The integrated stress curve represents the highest stress for fish, macroinvertebrates or riparian vegetation at a specific flow.

The shaded species stress discharges in Table 7.1 indicate the discharge evaluated by specialists to determine the biota stress. The values that are not shaded are interpolated. The highest discharge representing a specific stress is used to define the integrated stress curve. Figure 7-1 illustrates this graphically.

In this specific case, the SR fish stress index represents the integrated stress index (these values are the highest flow for a stress). Therefore the blue line (representing the SR stress index) is lying 'beneath' the integrated stress line (black) (Figure 7-1).

Table 7.1 Species stress discharges used to determine biotic stress

Stress	Flow (m ³ /s)			Integrated Flow (m ³ /s)
	SR	FDI	Tree <i>Salix</i>	
0	7.3	6.18	2.5	7.3
1	5.17	4.23	1.85	5.17
2	3.08	2.4	1.2	3.08
3	2.73	1.988	0.55	2.73
4	2.11	1.575	0.32	2.11
5	1.58	1.1	0.09	1.58
6	1.13	0.94	0	1.13
7	0.945	0.36	0	0.945
8	0.76	0.31	0	0.76
9	0.361	0.26	0	0.361
10	0	0	0	0

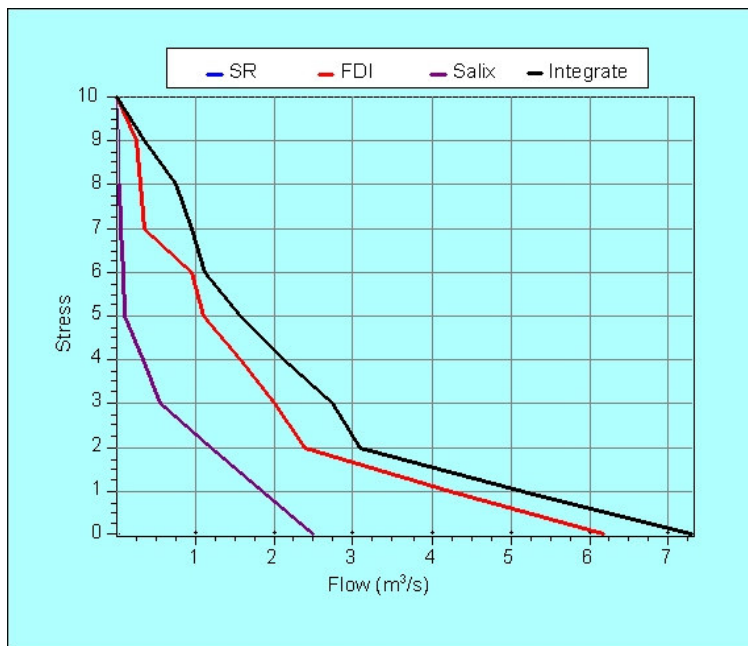


Figure 7-1 Component and integrated stress curves for EWR 3

Table 7.2 provides the summarised biotic response for the integrated stresses.

Table 7.2 Integrated stress and summarised habitat/biotic responses

Integrated stress	Flow m³/s	Habitat and/or Biotic responses
0 (SR)	7.3	SR guild: All habitat is optimal (5*). All habitats in excess. All FDI indicator taxa very abundant and healthy.
1 (SR)	5.17	SR guild: All habitats still optimal although abundance and cover is slightly impacted (4.5). All plentiful, high quality. 90% FDI indicator taxa persist.
2 (SR)	3.08	SR guild: Spawning, connectivity and water quality is very high (4 – 4.5) while abundance and cover is moderate (3 – 3.5).
3 (SR)	2.73	SR guild: Moderate (3) spawning and cover occurs with low (2.5) abundance and good water quality and connectivity. <i>S. mucronata</i> and <i>Cliffortia</i> : Adults with full vigour and at maximum reproductive capacity. 50% <i>Salix</i> population inundated, upper limit rooting depth at 15 to 25 cm. <i>Cliffortia</i> upper limit at 75 cm rooting depth.
4 (SR)	2.155	SR guild: Similar to above although connectivity is moderate (3.5) and cover is low (2.5). Critical habitats sufficient. Most FDI indicator taxa persist, but slight (80%) reduction.
5 (SR)	1.58	SR guild: Most habitat occurs in moderation although abundance is very low (1.5) and cover is low (2). Reduced critical habitat. All life stages viable in limited areas, critical life stages of some sensitive FDI indicator taxa at risk.
6 (SR)	1.13	SR guild: Abundance and cover is very low while water quality is moderate and the rest of the habitat is low. Critical habitats limited. Critical FDI life-stages of sensitive indicator taxa at risk or non-viable.
7 (SR)	0.945	Critical habitat very reduced. Sensitive FDI indicator taxa rare, critical stages of sensitive indicator taxa non-viable and at risk for some less sensitive taxa.
8 (SR)	0.76	<i>S. mucronata</i> and <i>Cliffortia</i> : Leaf wilting/stress commences, but is slight. <i>Salix</i> : 30 to 40 cm rooting depth for upper limit, lower limit at water level on average. <i>Cliffortia</i> : Up to 90 cm rooting depth.
9 (SR)	0.361	All habitat very scarce and nearly absent (0.5). Critical habitat residual. Some FDI indicator taxa persist, but most disappear. All life-stages of sensitive indicator taxa at risk or non-viable.
10 (SR)	0	Only hyporheic refugia, no surface water. FDI Indicator taxa no longer present. <i>S. mucronata</i> and <i>Cliffortia</i> : Widespread and complete mortality of population.

* Suitability rating 0 (not suitable) – 5 (highly suitable)

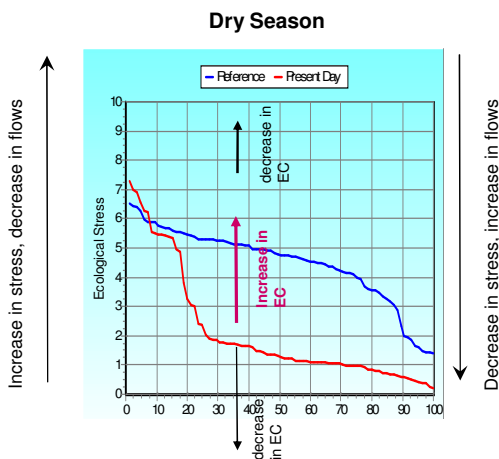
8 EWR 3: POLAR CREEK (CROCODILE RIVER) - DETERMINATION OF EWR SCENARIOS

8.1 ECOCLASSIFICATION SUMMARY OF EWR 3

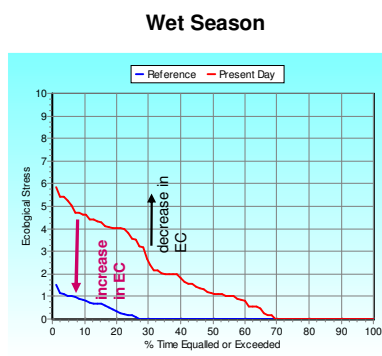
EWR 3 Poplar Creek (Crocodile River)					
<p>EIS: HIGH Rare and endangered fish, vegetation and bird species, some of which are sensitive to flow and quality changes.</p> <p>PES: B/C Major problems related to upstream Kwena Dam and its operation, e.g. migration, sedimentation, changed flow regime. The changed flow regime consists of higher than natural flows in the dry season and much lower low flows in the wet season.</p> <p>REC: B The EIS is high, therefore the REC is an improvement of the PES. This can be achieved by improving the flow regime (low flows) and removal of exotic vegetation species</p> <p>AEC down: C/D Lower flows than natural in both the dry and wet season leading to an impact of the seasonal distribution of the low flows. Associated increase in temperature and oxygen.</p>	Driver Components	PES Category	Trend	REC	AEC↓
	HYDROLOGY	C		B	D
	WATER QUALITY	C		B/C	C/D
	GEOMORPHOLOGY	C	Negative	C	C
	Response Components	PES Category	Trend	REC	AEC↓
	FISH	B	Stable	B	C
	MACRO INVERTEBRATES	C	Negative	B	C/D
	INSTREAM	B/C		B	C
	RIPARIAN VEGETATION	C	Negative	B	D
	ECOSTATUS	B/C		B	C/D

8.2 HYDROLOGY

The present situation is higher flows than natural during parts of the dry season and much lower flows than natural during the wet season. In essence, a seasonal reversal is occurring in terms of flow. The objectives for the improvement of the Ecological Category are to decrease present dry season flows and increase the wet season flows, i.e. improve seasonality.



Dry season: The more the dry season flows (increased stress) are decreased from present, the better the Ecological state, until obviously a point is reached where flows are much lower than natural and the Ecological state will decrease again (see graph illustrating stress).



Wet season: To improve the present situation, the flow must be increased (stress decreased) in the wet season (see graph).

To create a more natural seasonal distribution, the approach followed in the two seasons is opposite to each other. Ecological interpretation to determine how the Ecological Categories react to this situation is complex.

The Desktop Reserve Model (DRM) is used in EWR studies to generate the final time series. The DRM uses a reference time series and it is not possible to set flows higher than the reference time series. The present flows were used as a reference time series; however this could not address the requirement to increase the flows during the wet season. This led to the following:

- REC: A time series of requirements could not be generated as improvement of the PES required flows to be set higher than the reference time series (present day), during the wet season. The points as set will be used to evaluate operational scenarios.
- PES: The low flows for the PES were all set below the present flows (reference time series). This could therefore be modelled. However, when the floods were included, this again increased the flows above the present reference time series. An EWR table (.tab) could be generated, as well as an EWR rule table (.rul), but no time series (.mrv) file as the DRM automatically decreased the flows to the reference time series. This requirement could therefore not be used in a yield model that required a time series rather than a flow duration table.

The highest and lowest low flow months selected as the key months are February (wet) and October (dry). The key assurance percentages for which stress requirements had to be set were:

- 95%: Representing droughts for both wet and dry months. This would represent 5% on the stress duration graphs.
- 65%: Representing maintenance flows for both wet and dry months. This would represent 35% on the stress duration graphs.

8.3 LOW FLOW REQUIREMENTS (IN TERMS OF STRESS)

The integrated stress index is used to identify required stress levels at specific durations for the wet and dry month/season. Specialist motivations for the stresses are provided in Appendix D, Section D2.1 – 2.3.

The fish, macroinvertebrate and riparian vegetation flow requirements for different Ecological Categories (ECs) are provided in Table 8.1 and Figure 8-1 and 8-2. The results are plotted for the wet and dry season on stress duration graphs and compared to the DRM low flow estimates for the same range of ECs. The stress requirements (as a 'hand drawn line') are illustrated in Figures 8-1 and 8-2.

For easier reference the range of ECs are colour coded in the Tables and Figures:

PES: Green REC: Purple

Summarised motivations for the final requirements are provided in Table 8.2.

Table 8.1 Species and integrates stress requirements as well as the final integrated stress and flow requirements

Duration	SR stress	Integrated stress	FDI stress	Integrated stress	<i>Salix mucronata</i> stress	Integ stress	FINAL* (Integrated stress)*	FLOW (m ³ /s)
PES: B/C EcoStatus		FISH: B		MACROINVERTEBRATES: C		RIP VEG: C		
DRY SEASON								
5%	8	8	5	6	5	9.75	6	1.13
35%	3	3	2	3.5	1	4.5	3.5	2.42
WET SEASON								
5%	6.5	6.5	4	5	3	8.75	5	1.58
35%	3	3	2	3.5	0	3.5	3.5	2.42
REC: B EcoStatus		FISH: B		MACROINVERTEBRATES: B		RIP VEG: B		
DRY SEASON								
35%	The REC is the same as the PES.		3	4.2	2	5.75	4.2	2.004
WET SEASON								
35%	As above.		1	1.5	0	3.5	1.5	4.125

• Final refers to the final stress selected as the EWR requirement, usually the lowest integrated stress. In some cases, vegetation was ignored due to the much lower confidence in the requirements.

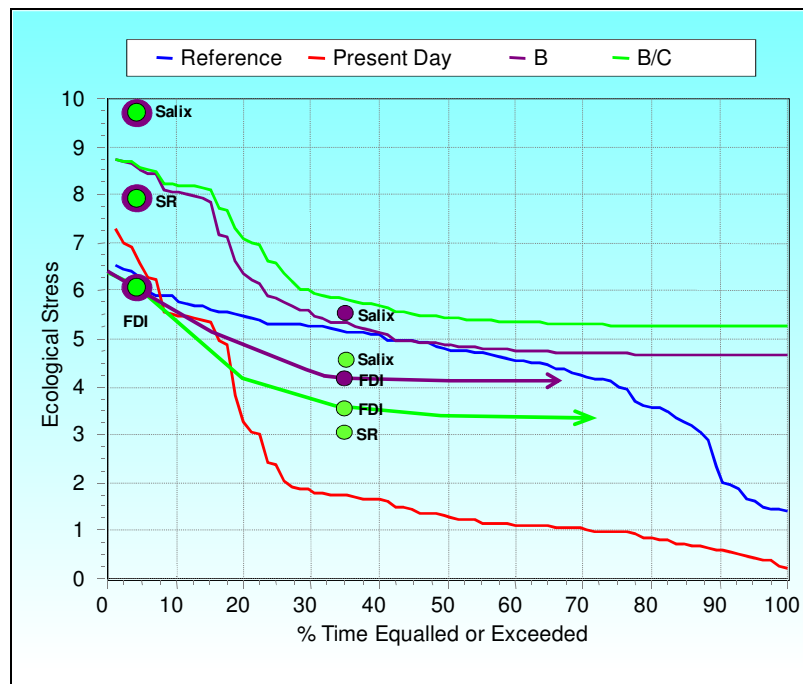


Figure 8-1 EWR 3: Stress duration curve for a B/C PES and B REC - DRY season

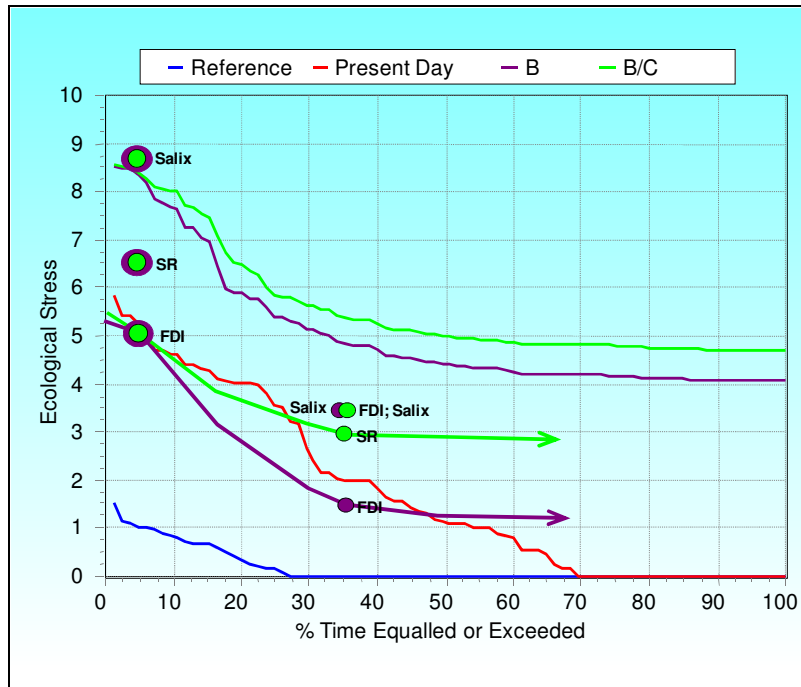


Figure 8-2 EWR 3: Stress duration curve for a B/C PES and B REC - WET season

Table 8.2 Summary of EWR 3 motivations

Month	% Stress duration	Component stress	Integrated stress	Flow m ³ /s	Comment
PES: B/C EcoStatus		FISH: B		MACROINVERTEBRATES: C	
Oct	5% drought	5 FDI	6	1.13	This flow will ensure that a core of selected taxa will survive drought conditions.
	35% maintenance	2 FDI	3.5	2.42	All the selected taxa can overwinter without significant detrimental impacts on the overall population.
Feb	5% drought	4 FDI	5	1.58	Ensures that a healthy population occurs during the summer.
	35% maintenance	2 FDI	3.5	2.42	Ensures that a healthy population occurs during the summer.
REC: B EcoStatus		FISH: B		MACROINVERTEBRATES: B	
Oct	5% drought	5 FDI	6	1.13	See PES.
	35% maintenance	3 FDI	4.2	2.004	See PES.
Feb	5% drought	4 FDI	5	1.58	See PES.
	35% maintenance	1 FDI	1.5	4.125	See PES.

8.3.1 Final low flow requirements

To produce the final results (Figure 8-3), the DRM results for the specific category are modified according to specialists' requirements (Figure 8-1 and 8-2).

To modify the DRM results, seasonal distribution factors of the B/C EC for maintenance was changed to 0.5.

It must be noted however that reference Flow Duration Curves (FDCs) are exceeded by the EWR assurance rules in almost all the wet months for the B/C EC. The resulting time series (limited to reference flows) was therefore not compatible with the EWR rule (.rul (not limited)) file.

Dry Season (October)

Wet Season (February)

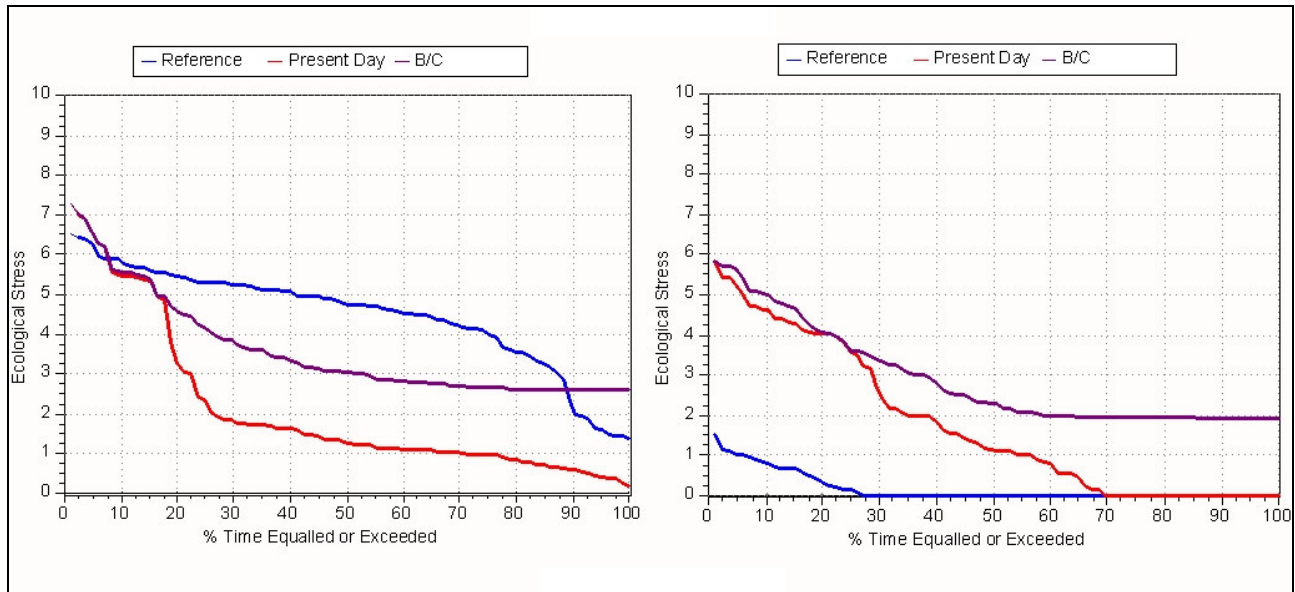


Figure 8-3 EWR 3: Final stress requirements for low flows

8.4 HIGH FLOW REQUIREMENTS

High low classes were identified as outlined in Section 4.4. Results are provided in Table 8.3 and detailed motivations provided in Table 8.4.

Table 8.3 Identification of instream functions addressed by the identified floods for geomorphology and riparian vegetation

FLOOD CLASS	FLOOD RANGE (m ³ /s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions						Macroinvertebrate flood functions				
			Migration cues	Migration habitat (depth etc.)	Create spawning habitat	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas	Reset water quality
I	8	Geomorphology: An important flow class for fines - responsible for about 20% of the PBMT (scours and removes fines), inundates and activates the lower bench. Vegetation: Activation of the <i>S. mucronata</i> .	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
II	15	Geomorphology: An important flow class for fines - responsible for about 20% of the PBMT (scours and removes fines), activates the small cobbles. Vegetation: Inundate and activate <i>Cliffortia</i> .	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
III	30	Geomorphology: The geomorphologically effective flow class; responsible for about 30% of the transport of sands and gravels at the site; activates the cobbles. Vegetation: Annual wetting of the lower zone limit facilitates <i>Combretum</i> juvenile survival.	✓	✓	✓	✓	✓	✓					
IV	> 90	Vegetation: Initiates <i>Combretum</i> recruitment inundates and activates lower and upper zone <i>Combretum</i> respectively.	✓	✓	✓	✓	✓	✓					

Further information is provided in Appendix D, Table D9.

The number of high flow events required for each EC is provided in Table 8.4. No observed daily data was available to check flood requirements against.

Table 8.4 EWR 3: The recommended number of high flow events required

FLOOD RANGE (m ³ /s)	FLOOD CLASS	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (No of events)	MONTHS	DAILY AVERAGE (m ³ /s)	DURATION (Days)
PES SCENARIO: B/C									
I	8	4	4	4	4	4	Nov, Dec, Jan, Apr	8	3
II	15	2	2	2	2	2	Nov, Mar	15	4
III	30		1	1	1	1	Feb	30	5
IV	> 90			1:2 to 1:3			Late summer		

8.5 FINAL FLOW REQUIREMENTS

The low and high flows were combined to produce the final flow requirements for each EC as:

- An EWR table, which shows the results of high flows and low flows for each month separately (Table 8.5). Floods with a frequency higher than 1:1 is not included.
- An EWR rule table which provides the recommended EWR flows as a duration table, showing flows which should be provided when linked to a natural trigger (natural modelled hydrology in this case). EWR rules are supplied for total flows as well as for low flows only (Appendix D, Section D2.4).

Table 8.5 EWR table for PES: B/C

Desktop version:	2	Virgin MAR (MCM)	169.896
BFI index	0.5	Distribution type	Eastern escarpment
MONTH	LOW FLOWS		HIGH FLOWS
	Maintenance (m ³ /s)	Drought (m ³ /s)	Daily average (m ³ /s) on top of base flow
OCTOBER	2.249	0.784	
NOVEMBER	2.285	0.733	8 15
DECEMBER	2.158	0.878	8
JANUARY	2.284	0.968	8
FEBRUARY	2.704	1.195	30
MARCH	2.410	1.058	15
APRIL	2.424	1.046	8
MAY	2.320	0.993	
JUNE	2.448	1.062	
JULY	2.394	1.046	
AUGUST	2.435	1.075	
SEPTEMBER	2.395	0.891	
TOTAL MCM	74.824	30.783	16.584
% OF VIRGIN	44.04	18.12	9.76

A comparison between the Desktop Reserve Model estimates and the EWR results in terms of percentages of natural flow are provided in Table 8.6.

Table 8.6 Modifications made to the DRM for EWR 3

Changes	PES B/C	
	DRM	EWR
MLIFR - Maintenance low flow	18.0%	44.0%
DLIFR - Drought low flow	9.8%	18.1%
MHIFR - Maintenance high flow	7.0%	9.8%
Long-term % of virgin MAR	28.5%	55.2%

9 EWR 4: KANYAMAZANE (CROCODILE RIVER) - DETERMINATION OF STRESS INDICES

NOTE: All supporting specialist information for EWR 4 is summarized in Volume 3, Appendix E.

9.1 INDICATOR SPECIES OR GROUP

9.1.1 Fish indicator group 1: Small rheophilic species (AURA, CPRE, OPER)

Amphilius uranoscopus (AURA) and *Chiloglanis pretoriae* (CPRE). See Section 5.1.1 and Appendix C, Table C1.

Opsaridium peringueyi (OPER) has similar requirements and detail is provided in Appendix E, Table E1.

9.1.2 Fish indicator group 2: Large semi-rheophilic species (BMAR, LCYL, LMOL)

The large semi-rheophilic (LSR) species, especially *Labeobarbus marequensis* (BMAR), *Labeo cylindricus* (LCYL) and *Labeo molybdinus*, (LMOL) are another important indicator guild present at this. Information on the habitat requirements for different life stages of these indicator species are provided in Appendix E, Table E2. These species utilise most habitats (SD, SS, FD, FI and FS) with substrate and water column as preferred cover. They also require overhanging vegetation as nursery habitats. Flows should furthermore remain adequate to allow migration between reaches, thus depth in riffle and rapids should remain adequate, especially during the wet season.

9.1.3 Macroinvertebrate indicator taxa

A number of flow dependent cobble dwelling macroinvertebrate taxa were selected and include:

- Stonefly family: Perlidae, refer to Section 5.1.2.
- Mayfly family: Heptageniidae, refer to Section 3.1.2.
- Beetle family: Elmidae, refer to Section 3.1.2.

9.1.4 Riparian vegetation indicator species

One indicator species was selected:

- *Ludwigia octovalvis*: An erect shrub which can be considered a riparian obligate, although it is an indicator of wet conditions including damp and swampy areas and blooms throughout the year. Can also form floating rafts and occurs in the marginal and lower zones at this site.

9.2 STRESS FLOW INDEX

The stress flow index is generated in terms of habitat and biotic response and is discussed below.

9.2.1 Habitat response

Habitat response is used to derive the biota's response to provide a biota stress index and represents the instantaneous response of habitat to flow changes, based on a site specific 0 – 10 scale for instream biota where:

- 0 – Optimum habitat (fixed at the natural maximum base flow – calculated using the wettest flow month discharge at the maintenance percentage of 30% – 40% for the Crocodile River at the EWR site).
- 10 - No flow (although there may still be surface water in pools).

The abundance of fish velocity-depth classes for the SR and LSR guild is provided in Appendix E, Table E3.

The instantaneous response of FDI taxa provides the % occurrence of various velocity-substrate classes under different flow conditions are provided in Appendix E, Table E5).

9.2.2 Biota response

The biota stress index is the instantaneous response of biota to change in habitat (and therefore flow), based on a scale of 0 – 10.

The fish species response index is calculated using the fish habitat rating (cf Section 3.2.1) (Appendix E, Table E4) for each of the discharges evaluated for assessing habitat response. The FDI index is derived by considering the habitat response and % occurrence of habitat conditions at different flows. The FDI responses are described and coupled to a stress level (Appendix E, Table E6)

A riparian vegetation stress index is also provided (Appendix E, Table E7).

9.2.3 Integrated stress curve

The integrated stress curve represents the highest stress for fish, macroinvertebrates or riparian vegetation at a specific flow.

The shaded species stress discharges in Table 9.1 indicate the discharge evaluated by specialists to determine the biota stress. The values that are not shaded are interpolated. The highest discharge representing a specific stress is used to define the integrated stress curve. Figure 9-1 illustrates this graphically.

In this specific case, the *Ludwigia* stress index represents the integrated stress index (these values are the highest flow for a stress) for stress 1 - 3 and 6 - 10. Therefore the green line (representing the *Ludwigia* stress index) is lying 'beneath' the integrated stress line (black) (Figure 9-1).

Table 9.1 Species stress discharges used to determine biotic stress

Stress	Flow (m ³ /s)				Integrated Flow (m ³ /s)
	SR	LSR	FDI	Shrub <i>Ludwigia</i>	
0	18.6	18.6	15.46	16.6	18.6
1	10.2	10.15	10.76	14.1	14.1
2	5.2	8	6.05	11.6	11.6
3	4.7	5.2	3.59	5.5	5.5
4	3.4	4.7	1.12	2.3	4.7
5	3	3.5	0.73	2.025	3.5
6	1.3	1.3	0.34	1.75	1.75
7	0.975	0.975	0.19	1.2	1.2
8	0.65	0.65	0.049	0.8	0.8
9	0.326	0.326	0.016	0.4	0.4
10	0.001	0.001	0.001	0.001	0.001

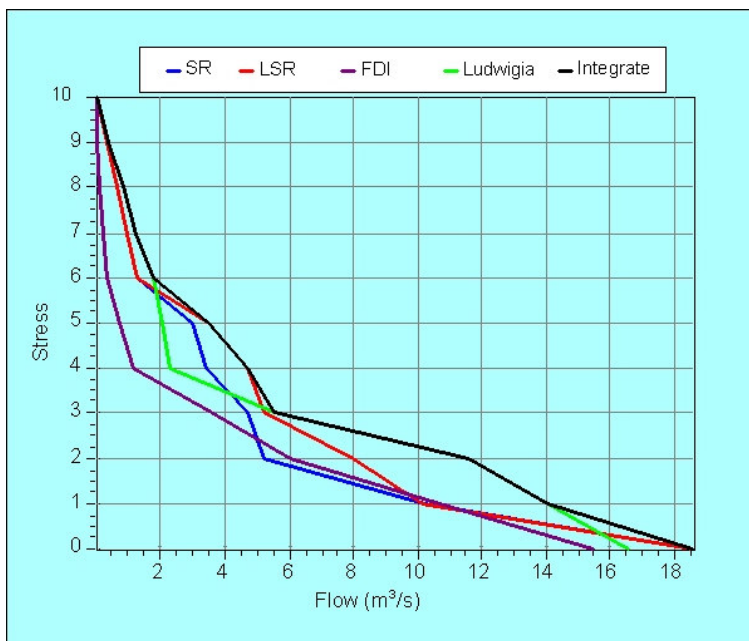


Figure 9-1 Component and integrated stress curves for EWR 4

Table 9.2 provides the summarised biotic response for the integrated stresses.

Table 9.2 Integrated stress and summarised habitat/biotic responses

Integrated stress	Flow m³/s	Habitat and/or Biotic responses
0 (SR)	18.6	All habitat is optimal (5 ⁺) for the SR and LSR guild although abundance and connectivity for the LSR guild is slightly less than optimal (4.5). FDI habitat is plentiful and of high quality. Indicator taxa abundant and healthy. <i>L. octovalvis</i> with full vigour and at maximum reproductive capacity. 50% population inundated, upper limit rooting depth at 14 cm.
1 (Ludwigia)	14.1	Fish guild as above. Critical FDI habitat is sufficient. 90% of indicator taxa persist. Riparian vegetation as above.
2 (Ludwigia)	11.6	All indicators as above.
3 (Ludwigia)	5.5	SR and LSR guild: Water quality is still optimal (5) while the rest of the habitat is good (4 - 4.5). <i>L. octovalvis</i> : Leaf wilting/stress commences, but is slight. Up to 30 cm rooting depth for upper limit, lower limit at is at water level on average.
4 (Ludwigia)	4.7	SR and LSR guild: Water quality optimal with rest of habitats rated as good (4).
5 (Ludwigia)	3.5	SR guild: Most habitats are good (4), but abundance is moderate (3.5). LSR guild: Water quality and connectivity is good while spawning, abundance and cover is moderate (3.5). Reduced critical habitat. Most indicator taxa persist, but slight (80%) reduction. <i>L. octovalvis</i> : Leaf wilting obvious, or vegetative parts begin unseasonal discolouration. Flower/fruit abortion widespread. 30 to 60 cm rooting depth for sufficient soil moisture, no inundation
6 (SR)	1.75	SR guild: Water quality and spawning habitat is moderate rest of habitat occurrence is low (2 - 2.5). LSR guild: All habitat occurrence is low (2 - 2.5).
7 (LSR)	1.2	<i>L. octovalvis</i> : Unseasonal thinning or partial mortality of above-ground parts (majority of the plant/s remains viable, but water stressed). 30 – 90 cm rooting depth for sufficient soil moisture, mortality may occur for lower zone individuals.
8 (LSR)	0.8	<i>L. octovalvis</i> : Unseasonal loss or mortality of above-ground parts (only minor portions of plants remain viable). Rootstocks/rhizomes of some species remain viable. 75 cm to 1 m rooting depth, individuals at upper limit likely to begin dying.
9 (LSR)	0.4	SR and LSR guild: All habitat occurrences are low. Critical FDI habitat very reduced. All life stages viable in limited areas, critical life stages of some sensitive indicator taxa at risk. <i>L. octovalvis</i> : Complete mortality of small proportion of the population.

Integrated stress	Flow m ³ /s	Habitat and/or Biotic responses
10	0.001	Only pool dwelling species present. Only hyporheic refugia, no surface water for FDI. Indicator taxa no longer present. Widespread and complete mortality of population.

* Suitability rating 0 (not suitable) – 5 (highly suitable)

10 EWR 4: KANYAMAZANE (CROCODILE RIVER) - DETERMINATION OF EWR SCENARIOS

10.1 ECOCLASSIFICATION SUMMARY OF EWR 4

EWR 4 KaNyamazane (Crocodile River)					
<p>EIS: HIGH Rare and endangered sp sensitive to flow and quality changes. High species taxon richness and diversity of habitat types.</p> <p>PES: C Combination of flow and non-flow related impacts. Changes mostly related to changes in flow regime due to upstream Kwena Dam and the operation of upstream system. Abstraction, return flows, landuse mismanagement, water quality issues, and sedimentation.</p> <p>REC: B The EIS is HIGH, therefore the REC is an improvement of the PES. Improvements to flow regime will be required. Only successful if combined with removal of exotic vegetation and if there are some improvement in grazing and browsing.</p> <p>AEC down: C/D Montrose Dam with decreased floods. Pools will fill in, bars will appear, riffles will be clogged and covered with sediment, reed growth will increase, the marginal zone will expand and vegetation will encroach.</p>	Driver Components	PES Category	Trend	REC	AEC↓
	HYDROLOGY	C			
	WATER QUALITY	C		B	C
	GEOMORPHOLOGY	B/C	Stable	B	C
	Response Components	PES Category	Trend	REC	AEC↓
	FISH	B	Stable	B	C
	MACRO INVERTEBRATES	C	Stable	B	D
	INSTREAM	B/C		B	C
	RIPARIAN VEGETATION	C	Negative	B	D
	ECOSTATUS	C		B	C/D

10.2 HYDROLOGY

The highest and lowest low flow months selected as the key months are February (wet) and October (dry). The key assurance percentages for which stress requirements had to be set were:

- 95%: Representing droughts for both wet and dry months. This would represent 5% on the stress duration graphs.
- 65%: Representing maintenance flows for both wet and dry months. This would represent 35% on the stress duration graphs.

10.3 LOW FLOW REQUIREMENTS (IN TERMS OF STRESS)

The integrated stress index is used to identify required stress levels at specific durations for the wet and dry month/season. Specialist motivations for the stresses are provided in Appendix E, Section E2.1 – 2.3.

The fish and macroinvertebrate flow requirements for different Ecological Categories (ECs) are provided in Table 10.1 and Figure 10-1 and 10-2. The results are plotted for the wet and dry season on stress duration graphs and compared to the DRM low flow estimates for the same range of ECs. The stress requirements (as a 'hand drawn line') are illustrated in Figures 10-1 and 10-2.

For easier reference the range of ECs are colour coded in the Tables and Figures:

PES: **Green**

REC: **Purple**

AEC: **Yellow**

Summarised motivations for the final requirements are provided in Table 10.2.

Table 10.1 Species and integrates stress requirements as well as the final integrated stress and flow requirements

Duration	SR stress	Integrated stress	LSR stress	Integrated stress	FDI stress	Integrated stress	FINAL* (Integrated stress)*	FLOW (m ³ /s)
PES: C EcoStatus			FISH: B MACROINVERTEBRATES: C				RIP VEG: C	
DRY SEASON								
5%	6	6.8	6.5	7.9	7	9.5	6.8	1.31
35%	3.5	4.5	4.5	4.5	5	8.5	4.5	4.1
WET SEASON								
5%	4	5	4.5	4.5	6	9.4	4.5	4.1
35%	2	3.5	2	2.6	4	7.5	2.6	7.94
REC: B EcoStatus			FISH: B MACROINVERTEBRATES: B				RIP VEG: B	
DRY SEASON								
35%	3.5	4.5	4.5	4.5	4	7.5	4.5	4.1
WET SEASON								
35%	2	3.5	2	2.6	2	2.9	2.6	7.94
AEC: C/D EcoStatus			FISH: C MACROINVERTEBRATES: D				RIP VEG: D	
DRY SEASON								
35%	5	5.3	5.5	5.6	6	9.4	5.3	2.975
WET SEASON								
35%	3.5	4.6	4	4	5	8.5	4	4.7

* Final refers to the final stress selected as the EWR requirement, usually the lowest integrated stress. In some cases, vegetation was ignored due to the much lower confidence in the requirements.

NOTE: For this site the low flow requirements for riparian vegetation were not included due to low confidence in the results.

From Table 10.1 it is evident that the PES and REC low flow requirements are the same. The fish component drives the requirements and is already in a B category. Therefore the low flow requirements are the same for both the PES and REC EcoStatus. The macroinvertebrates require improvement from a C to a B, but the B category requirements are still less than the fish B requirements.

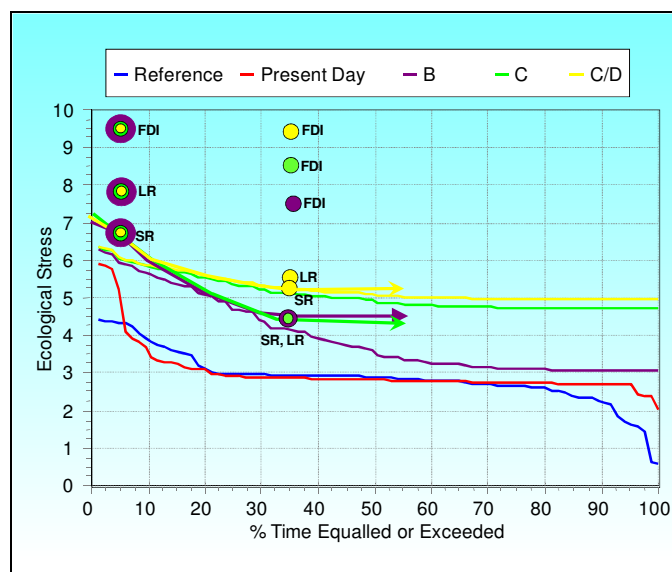


Figure 10-1 EWR 4: Stress duration curve for a C PES, B REC and C/D AEC - DRY season

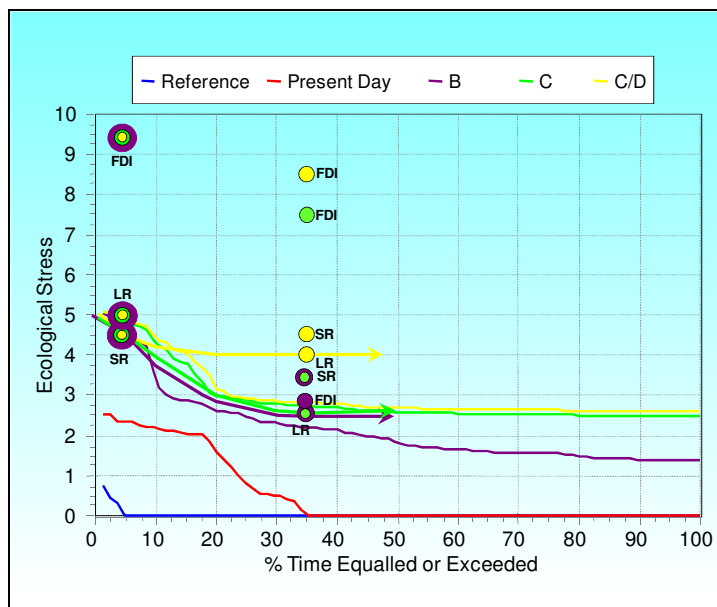


Figure 10-2 EWR 4: Stress duration curve for a C PES, B REC and C/D AEC - WET season

Table 10.2 Summary of EWR 4 motivations

Month	% Stress duration	Component stress	Integrated stress	Flow m ³ /s	Comment
PES: C EcoStatus FISH: B MACROINVERTEBRATES: C RIP VEG: C					
Sep	5% drought	6 SR	6.8	1.31	Maintenance of fast habitat to support viable populations and allow for recovery after drought period.
	35% maintenance	4.5 SR	4.5	4.1	Fast habitats will be maintained to ensure preservation of abundance and cover.
Feb	5% drought	4.5 LSR	4.5	4.1	Adequate flows to maintain enough fast habitats to support viable populations to recover after drought. Abundance and cover will be greatly reduced but adequate to maintain a viable population.
	35% maintenance	2 LSR	2.6	7.94	Good habitats for spawning and suitable habitats for all life stages of this indicator guild.
REC: B EcoStatus FISH: B MACROINVERTEBRATES: B RIP VEG: B					
Sep	5% drought	6 SR	6.8	1.31	See PES.
	35% maintenance	4.5 SR	4.5	4.1	See PES.
Feb	5% drought	4.5 LSR	4.5	4.1	See PES.
	35% maintenance	2 LSR	2.6	7.94	See PES.
AEC: C/D EcoStatus FISH: C MACROINVERTEBRATES: D RIP VEG: D					
Sep	5% drought	6.8 SR	6.8	1.31	See PES.
	35% maintenance	5 SR	5.3	2.975	Most aspects will deteriorate (abundance, cover, and connectivity) resulting in reduced FROC of species.
Feb	5% drought	4.5 LSR	4.5	4.1	See PES.
	35% maintenance	4 LSR	4	4.7	Some spawning habitat will be created but the reduced cover and abundance will result in an overall reduced FROC.

10.3.1 Final low flow requirements

To produce the final results (Figure 10-3), the DRM results for the specific category are modified according to specialists' requirements (Figure 10-1 and 10-2). The following changes were required:

- A result for C/D maintenance could not be achieved. It was necessary to edit the table manually and to create a special set of monthly assurance rules for the wet season to reduce the increase in flows with lower assurance.
- Seasonal distribution factors changed:
 - o B EC: 1.04 for maintenance; 1.5 for drought.
 - o C/D EC: 1.5 for drought.

Dry Season (October)

Wet Season (February)

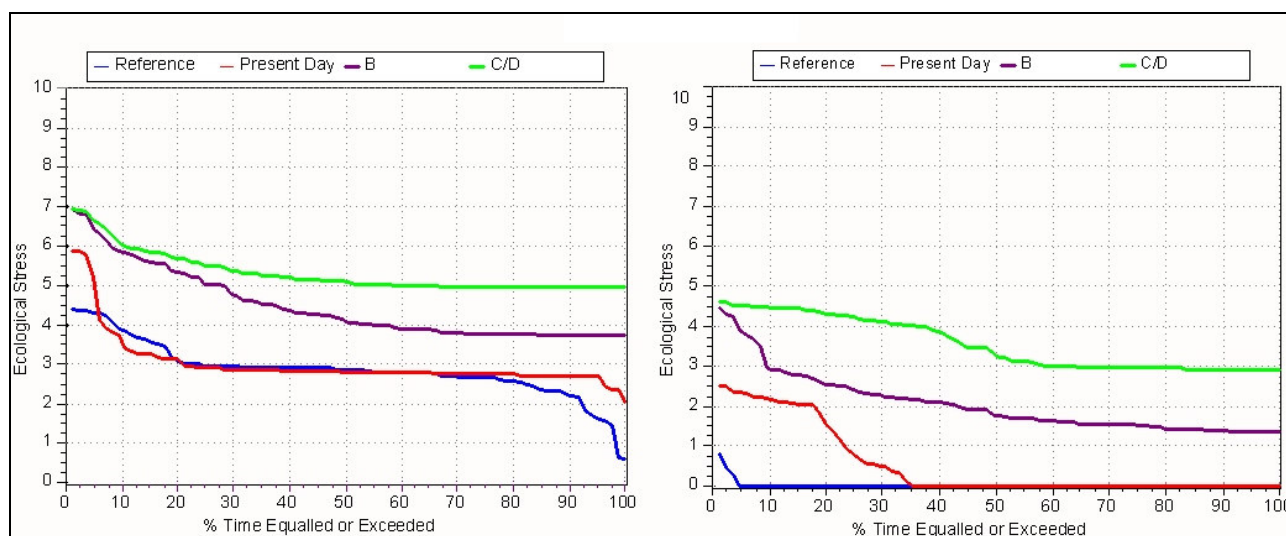


Figure 10-3 EWR 4: Final stress requirements for low flows

10.4 HIGH FLOW REQUIREMENTS

High low classes were identified as outlined in Section 4.4. Results are provided in Table 10.3 and detailed motivations provided in Table 10.4.

Table 10.3 Identification of instream functions addressed by the identified floods for geomorphology and riparian vegetation

FLOOD CLASS	FLOOD RANGE (m ³ /s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions						Macroinvertebrate flood functions					
			Migration cues	Migration habitat (depth etc.)	Clean spawning habitat	Spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas	Reset water quality
I	25 - 40	Geomorphology: This flow is responsible for about 15% of the PBMT. This flow class scours the fines from the bed. Vegetation: Activates and overtops levee on the main channel and inundates the marginal zone. Inundates marginal zone sedges (<i>Cyperus dives</i>) and <i>Persecaria</i> . Lower portions of <i>Phragmites mauritianus</i> and <i>Ludwigia octovalvis</i> become inundated. Will also provide marginal vegetation cover for instream biota. Fewer events for AEC down will allow more sediment to settle, and with less flood disturbance marginal zone vegetation will migrate / expand towards the instream.	√	√	√	√	√	√	√	√	√	√	√	√
II	(40)	Geomorphology: This flow is responsible for about 15% of the PBMT. This flow class scours the fines from the bed and activate some of the cobble areas, as well as inundate the lower terrace.	√	√	√	√	√	√	√	√	√	√	√	√
III	60 - 110	Geomorphology: This flow class represents the effective discharge, and is responsible for about 30% of the PBMT. This flow class would scour the bed, activate gravels and cobbles and inundate and activate middle terraces. Vegetation: Required to inundate the lower zone. Inundates reed beds (<i>P. mauritianus</i>), <i>L. octovalvis</i> and lower portions of <i>Breonadia salicina</i> . Sustains vigour and reproduction in the height of the growing season. Less frequent event for AEC (down) will result in reduced recruitment opportunities for lower zone woody species (<i>C. erythrophyllum</i> and <i>B. salicina</i>).	√	√	√	√	√	√	√	√	√	√	√	√
IV	170 - 220	Geomorphology: This flow is responsible for about 15% of the PBMT. This flow class scours the bed and activates the cobbles. Vegetation: Required for inundation of upper zone terrace. This will activate and inundate <i>C. erythrophyllum</i> and <i>Nuxia oppositifolia</i> populations, and afford recruitment opportunities.	√	√	√	√	√	√	√	√	√	√	√	√
V	330 +	Geomorphology: This was historically the range of the 1:3 year flood, and historically accounted for about 20% of the PBMT. This flow will inundate the upper terrace and activate the back flood channel. Vegetation: Maintains <i>Trichilia emetica</i> and <i>Ficus sur</i> populations on upper portions of the upper zone. Would perform the function of reducing terrestrial species in the riparian zone.	√	√	√	√	√	√	√	√	√	√	√	√

Further information is provided in Appendix E, Table E11.

The number of high flow events required for each EC is provided in Table 10.4. No observed daily data was available to check flood requirements against.

Table 10.4 EWR 4: The recommended number of high flow events required

FLOOD RANGE (m ³ /s)	FLOOD CLASS	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (No of events)	MONTHS	DAILY AVERAGE (m ³ /s)	DURATION (Days)
PES SCENARIO: C									
I	25 - 40	3		4	4	4	Nov, Dec, Jan, Apr	25	4
II	(40)	1			2	2	Feb, Mar	40	4
III	60 - 110	1		1	1	1	Feb	70	5
IV	170 - 220			1:2 - 1:3	1:3	1:2	Late summer		
V	330 +			1:3 - 1:5	>1:5	>1:5	Wet season		
REC SCENARIO: B									
I	25 - 40	4		4	4	4	Nov, Dec, Jan, Apr	25	4
II	(40)	2			2	2	Feb, Mar	40	7
III	60 - 110	1		1	1	1	Jan	70	5
IV	170 - 220			1:2 - 1:3	1:2	1:2	Late summer		
V	330 +			1:3 - 1:5	1:3 - 1:5	1:3 - 1:5	Wet season		
AEC SCENARIO: C/D									
I	25 - 40	2		1	2	2	Mar, Dec	25	4
II	(40)	1			2	2	Feb, Mar	40	4
III	60 - 110			1:2 - 1:3	1:2	1:2	Jan	70	5
IV	170 - 220			1:2 - 1:3	1:3	1:3	Late summer		
V	330 +				>1:5	>1:5	Wet season		

The only difference in floods between a B and a C was in the Class IV category. As the class IV category is not included in the EWR rule table (.rul), it confirmed that separate results for the PES and the REC will not be produced.

10.5 FINAL FLOW REQUIREMENTS

The low and high flows were combined to produce the final flow requirements for each EC as:

- An EWR table, which shows the results of high flows and low flows for each month separately (Table 10.5 – 10.6). Floods with a frequency higher than 1:1 is not included.
- An EWR rule table which provides the recommended EWR flows as a duration table, showing flows which should be provided when linked to a natural trigger (natural modelled hydrology in this case). EWR rules are supplied for total flows as well as for low flows only (Appendix E, Section E2.4).

Table 10.5 EWR table for REC: B

Desktop version:		2	Virgin MAR (MCM)	754.096
BFI index	0.464	Distribution type		Eastern escarpment
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m ³ /s)	Drought (m ³ /s)	Daily average (m ³ /s) on top of base flow	Duration (days)
OCTOBER	4.185	1.252		
NOVEMBER	5.248	1.684	25	4
DECEMBER	6.347	2.165	25	4
JANUARY	8.068	2.892	25	4
FEBRUARY	10.975	4.064	40 70	4 5
MARCH	10.141	3.767	40	4
APRIL	9.351	3.416	25	4
MAY	7.763	2.763		
JUNE	6.653	2.277		
JULY	5.361	1.749		
AUGUST	4.470	1.373		
SEPTEMBER	4.105	1.201		
TOTAL MCM	216.38	74.816	46.971	
% OF VIRGIN	28.69	9.92	6.23	

Table 10.6 EWR table for AEC: C/D

Desktop version:		2	Virgin MAR (MCM)	754.096
BFI index	0.464	Distribution type		Eastern escarpment
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m ³ /s)	Drought (m ³ /s)	Daily average (m ³ /s) on top of base flow	Duration (days)
OCTOBER	2.180	1.252		
NOVEMBER	2.600	1.684		
DECEMBER	3.000	2.165	25	4
JANUARY	3.600	2.892	70	5
FEBRUARY	4.700	4.064	40	4
MARCH	4.400	3.767	25 40	4 4
APRIL	4.100	3.416		
MAY	3.500	2.763		
JUNE	3.100	2.277		
JULY	2.600	1.749		
AUGUST	2.200	1.373		
SEPTEMBER	2.170	1.201		
TOTAL MCM	99.929	74.816	37.921	
% OF VIRGIN	13.25	9.92	5.03	

A comparison between the Desktop Reserve Model estimates and the EWR results in terms of percentages of natural flow are provided in Table 10.7.

Table 10.7 Modifications made to the DRM for EWR 4

Changes	REC: B		AEC C/D	
	DRM	EWR	DRM	EWR
MLIFR - Maintenance low flow	29.7%	28.7%	13.4%	13.2%
DLIFR - Drought low flow	9.3%	9.9%	9.3%	9.9%
MHIFR - Maintenance high flow	8.8%	6.2%	6.6%	5.1%
Long-term % of virgin MAR	37.9%	34.5%	25.9%	21.3%

11 EWR 5: MALELANE (CROCODILE RIVER) - DETERMINATION OF STRESS INDICES

NOTE: All supporting specialist information for EWR 5 is summarized in Volume 3, Appendix F.

11.1 INDICATOR SPECIES OR GROUP

11.1.1 Fish indicator group 1: Small rheophilic species (CPRE, CSWI, OPER)

Chiloglanis pretoriae (CPRE): See Section 5.1.1 and Appendix C, Table C1.

Opsaridium peringueyi (OPER): See Section 9.1.1 and Appendix E, Table E1.

Chiloglanis swierstrai (CSWI): Has similar requirements to CPRE and OPER and is discussed in detail in Appendix F, Table F1.

11.1.2 Fish indicator group 2: Large semi-rheophilic species (BMAR, HVIT, LCON)

Labeobarbus marequensis (BMAR): See Section 9.1.2 and Appendix E, Table E2.

Hydrocynus vittatus (HVIT), and *Labeo congoro* (LCON) have similar requirements and detail is provided in Appendix F, Table F2.

11.1.3 Macroinvertebrate indicator taxa

Flow dependant (FDI) cobble dwelling macroinvertebrate taxa included:

- Beetle family: Elmidae, refer to Section 3.1.2.
- The dragonfly family: Libellulidae also preferring velocities between 0.3 and 0.6 m/s.

The vegetation dwelling macroinvertebrate (MVI) taxa used for this site (Coenagrionidae and Atyidae) are both able to also survive on other substrata such as cobbles. Atyidae are moderately sensitive to water quality changes while Coenagrionidae have a low sensitivity to water quality changes.

11.1.4 Riparian vegetation indicator species

One indicator group was selected:

- *Juncus/Cyperus*: Refer to Section 3.1.3.

11.2 STRESS FLOW INDEX

The stress flow index is generated in terms of habitat and biotic response and is discussed below.

11.2.1 Habitat response

Habitat response is used to derive the biota's response to provide a biota stress index and represents the instantaneous response of habitat to flow changes, based on a site specific 0 – 10 scale for instream biota where:

- 0 – Optimum habitat (fixed at the natural maximum base flow – calculated using the wettest flow month discharge at the maintenance percentage – 30% – 40% for the Crocodile River at the EWR site).
- 10 - No flow (although there may still be surface water in pools).

The abundance of fish velocity-depth classes for the SR and LSR guild is provided in Appendix F, Table F3.

The instantaneous response of FDI and marginal vegetation (MVI) taxa provides the % occurrence of various velocity-substrate classes under different flow conditions are provided in Appendix F, Table F5 and Table F6 respectively..

11.2.2 Biota response

The biota stress index is the instantaneous response of biota to change in habitat (and therefore flow), based on a scale of 0 – 10.

The fish species response index is calculated using the fish habitat rating (cf Section 3.2.1) (Appendix F, Table F4) for each of the discharges evaluated for assessing habitat response. The macroinvertebrate (FDI and MVI) index is derived by considering the habitat response and % occurrence of habitat conditions at different flows. The FDI and MVI responses are described and coupled to a stress level (Appendix F, Table F7 – F8)

A riparian vegetation stress index is also provided (Appendix F, Table F9).

11.2.3 Integrated stress curve

The integrated stress curve represents the highest stress for fish, macroinvertebrates or riparian vegetation at a specific flow.

The shaded species stress discharges in Table 11.1 indicate the discharge evaluated by specialists to determine the biota stress. The values that are not shaded are interpolated. The highest discharge representing a specific stress is used to define the integrated stress curve. Figure 11-1 illustrates this graphically.

In this specific case, the MVI stress index represents the integrated stress index (these values are the highest flow for a stress) for stress 1 - 7. Therefore the green line (representing the MVI stress index) is lying 'beneath' the integrated stress line (black) (Figure 11-1).

Table 11.1 Species stress discharges used to determine biotic stress

Stress	Flow (m ³ /s)					Integrated Flow (m ³ /s)
	SR	LSR	FDI	MVI	Sedges <i>Juncus/Cyperus</i>	
0	35	35	12.6	33.02	8.75	35
1	23.6	23.6	8.12	31	8.133	31
2	12	12	4.7	27.25	7.517	27.25
3	6.9	9.45	2	23.5	6.9	23.5
4	5.4	6.9	1.669	22	5.325	22
5	4.933	5.4	1.338	16	3.75	16
6	4.467	4.7	1.007	8	1.6	8
7	4	4	0.676	4.7	0.89	4.7
8	3.5	3.5	0.345	2	0.18	3.5
9	2.1	2.1	0.014	0.014	0	2.1
10	0	0	0	0	0	0

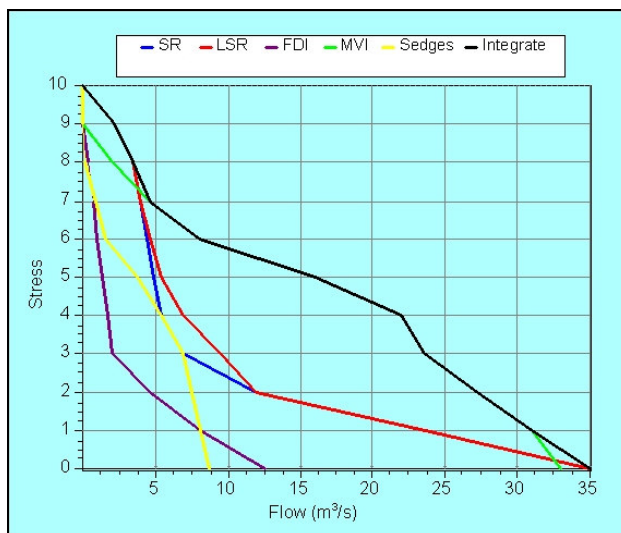


Figure 11-1 Component and integrated stress curves for EWR 5

Table 11.2 provides the summarised biotic response for the integrated stresses.

Table 11.2 Integrated stress and summarised habitat/biotic responses

Integrated stress	Flow m ³ /s	Habitat and/or Biotic responses
0 (SR)	35	All Fish SR and LSR habitats are optimal (5*). All FDI and MVI habitat in habitat in excess. All indicator taxa very abundant and healthy. Riparian vegetation indicators with full vigour and at maximum reproductive capacity.
1 (MVI)	31	Fish guilds as above. FDI and MVI habitat plentiful. 90% of MVI indicator taxa persist, FDI indicator taxa as above. Riparian vegetation as above.
2 (MVI)	27.25	SR and LSR guild: Most habitats optimal with abundance and connectivity slightly less (4.5). Most MVI indicator taxa persist, but slight (80%) reduction. Riparian vegetation as above.
3 (MVI)	23.5	Critical FDI and MVI habitats sufficient. Most MVI indicator taxa persist, but abundances reduced, FDI indicator taxa as above. Riparian vegetation as above.
4 (MVI)	22	Reduced critical habitat and critical quality for both FDI and MVI taxa. All life stages of MVI taxa viable in limited areas, critical life stages of some sensitive indicator taxa at risk. FDI as above.
5 (MVI)	16	Critical FDI and MVI habitats limited and of moderate quality. Critical life-stages of sensitive MVI indicator taxa at risk or non-viable.
6 (MVI)	8	Critical FDI and MVI habitat residual. Sensitive MVI indicator taxa rare, critical stages of sensitive indicator taxa non-viable and at risk for some less sensitive taxa. 90% of FDI indicator taxa persist. Riparian vegetation: Adults with full vigour and at maximum reproductive capacity. 50% population inundated, upper limit rooting depth at 14 cm.
7 (MVI)	4.7	Critical FDI and MVI habitat residual and of low quality. Some MVI indicator taxa persist, but most disappear. All life-stages of sensitive indicator taxa at risk or non-viable. Most FDI indicator taxa persist, but slight (80%) reduction.
8 (SR)	3.5	Abundance (SR and LSR) and cover (LSR) very rare (0.5) while rest of habitat occurrences is very low (1). Riparian vegetation: Leaf wilting obvious, or vegetative parts begin unseasonal discolouration. Flower/fruit abortion widespread. 10 to 30 cm rooting depth for sufficient soil moisture, no inundation.
9 (SR)	2.1	SR guild: Abundance and cover absent while rest of habitats are very rare. LSR guild: Spawning and connectivity is absent; other habitats are very rare. Flowing FDI and MVI water habitats residual and of low quality. Some MVI indicator taxa persist, but at very low numbers. All life stages of most indicator taxa at risk or non-viable. Most FDI indicator taxa persist, but abundances reduced.
10	0	Only pool dwelling species present. Only hyporheic refugia, no surface water for FDI. Indicator taxa no longer present. Widespread and complete mortality of population.

* Suitability rating 0 (not suitable) – 5 (highly suitable)

12 EWR 5: MALELANE (CROCODILE RIVER) - DETERMINATION OF EWR SCENARIOS

12.1 ECOCLASSIFICATION SUMMARY OF EWR 5

EWR 5 Malelane (Crocodile River)					
<p>EIS: VERY HIGH Rare and endangered sp sensitive to flow and quality changes. High species taxon richness and diversity of habitat types, KNP on LB.</p> <p>PES: C Change in low flows, specifically in the dry season. Change in flooding regime. All impacts associated with sugarcane activities.</p> <p>REC: B The EIS is VERY HIGH, therefore the REC is an improvement of the PES. Changes mostly focussing on improving the low flow regime and some land use management.</p> <p>AEC down: D Decreased low flows and periods of zero flows in some stretches of the river which will result in increased algal growth, temperature and nutrient problems, and loss of deeper channel sections, increased reed and vegetation growth.</p>	Driver Components	PES Category	Trend	REC	AEC↓
	HYDROLOGY	C		B	D
	WATER QUALITY	C		B	D
	GEOMORPHOLOGY	C/D	Negative	C	D
	Response Components	PES Category	Trend	REC	AEC↓
	FISH	C	Stable	B	D
	MACRO INVERTEBRATES	C	Stable	B	D
	INSTREAM	C		B	D
	RIPARIAN VEGETATION	C	Negative	B	D
	ECOSTATUS	C		B	D

12.2 HYDROLOGY

The highest and lowest low flow months selected as the key months are February (wet) and October (dry). The key assurance percentages for which stress requirements had to be set were:

- 95%: Representing droughts for both wet and dry months. This would represent 5% on the stress duration graphs.
- 65%: Representing maintenance flows for both wet and dry months. This would represent 35% on the stress duration graphs.

12.3 LOW FLOW REQUIREMENTS (IN TERMS OF STRESS)

The integrated stress index is used to identify required stress levels at specific durations for the wet and dry month/season. Specialist motivations for the stresses are provided in Appendix E, Section F2.1 – 2.3.

The fish and macroinvertebrate flow requirements for different Ecological Categories (ECs) are provided in Table 12.1 and Figure 12-1 and 12-2. The results are plotted for the wet and dry season on stress duration graphs and compared to the DRM low flow estimates for the same range of ECs. The stress requirements (as a ‘hand drawn line’) are illustrated in Figures 12-1 and 12-2.

For easier reference the range of ECs are colour coded in the Tables and Figures:

PES: Green

REC: Purple

AEC: Yellow

Summarised motivations for the final requirements are provided in Table 12.2.

Table 12.1 Species and integrates stress requirements as well as the final integrated stress and flow requirements

Duration	SR stress	Integ stress	LSR stress	Integ stress	FDI stress	Integr stress	MV Invert stress	Integ stress	FINAL* (Integrated stress)*	FLOW (m ³ /s)	
PES: C EcoStatus			FISH: C			MACROINVERTEBRATES: C			RIP VEG: C		
DRY SEASON											
5%	7	7.6	6.5	7.4	8	9.8	8	9	7.4	4.22	
35%	5.5	7	5	6.8	5	9.3	7	7	6.8	5.36	
WET SEASON											
5%	5	7	5	6.8	6	9.5	7	7	6.8	5.36	
35%	2.5	5.8	3.5	5.9	4	9.2	5.5	5.5	5.5	12	
REC: B EcoStatus			FISH: B			MACROINVERTEBRATES: B			RIP VEG: B		
DRY SEASON											
35%	4	6.7	4	6.4	3	9	6.5	6.5	6.4	6.68	
WET SEASON											
35%	2	5.5	2	5.5	2	7	4.5	4.5	4.5	19	
AEC: D EcoStatus			FISH: D			MACROINVERTEBRATES: D			RIP VEG: D		
DRY SEASON											
35%	6.5	7.4	6	7	7	9.6	7.5	8.1	7	4.7	
WET SEASON											
35%	4	6.7	5	6.8	5	9.3	6.5	6.5	6.5	6.35	

* Final refers to the final stress selected as the EWR requirement, usually the lowest integrated stress. In some cases, vegetation was ignored due to the much lower confidence in the requirements.
 NOTE: For this site the low flow requirements for riparian vegetation were not included due to low confidence in the results.

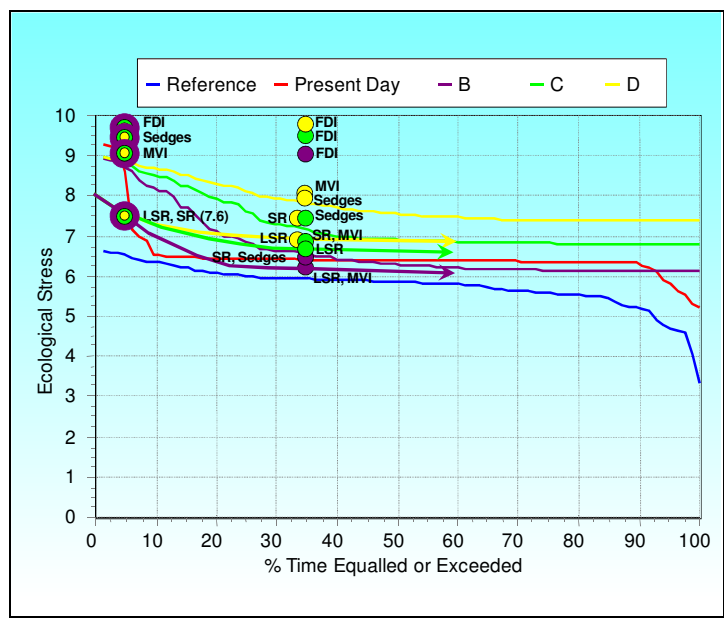


Figure 12-1 EWR 5: Stress duration curve for a C PES, B REC and D AEC - DRY season

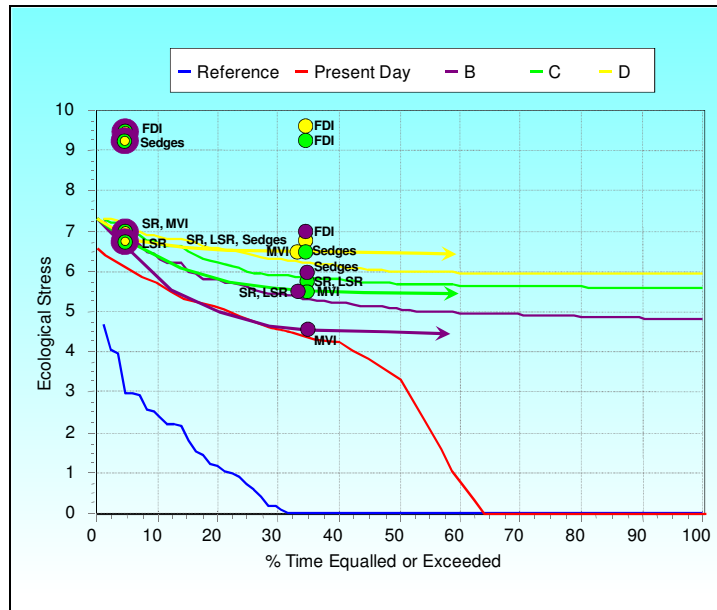


Figure 12-2 EWR 5: Stress duration curve for a C PES, B REC and D AEC - WET season

Table 12.2 Summary of EWR 5 motivations

Month	% Stress duration	Component stress	Integrated stress	Flow m ³ /s	Comment
PES: C EcoStatus FISH: C MACROINVERTEBRATES: C RIP VEG: C					
Sep	5% drought	6.5 LSR	7.4	4.22	This is the maximum stress level allowable where this fish guild will survive through dry drought periods without undue stress on their populations and to allow their recovery afterwards.
	35% maintenance	5 LSR	6.8	5.36	This fish stress level will maintain adequate FD, FI and abundant FS for maintenance of viable populations of this indicator guild during the dry season to maintain within a category C.
Feb	5% drought	5 LSR	6.8	5.36	Adequate fast habitats will still be available to allow some spawning of these species and although highly decreased abundance can be expected, they should be able to maintain adequate populations to recover after the drought period.
	35% maintenance	5.5 MVI	5.5	12	Enough inundated vegetation is required to ensure that the Atyidae and Coenagrionidae can thrive. At this stress fringing vegetation is inundated and aquatic vegetation will be available to provide adequate habitat for the selected taxa.
REC: B EcoStatus FISH: B MACROINVERTEBRATES: B RIP VEG: B					
Sep	5% drought	6.5 LSR	7.4	4.22	See PES.
	35% maintenance	4 LSR	6.4	6.68	These stress levels will result in improvement of preferred habitats for this indicator group during the dry season which should be reflected by increased abundance and overall improved FROC that will result in an improved EC.
Feb	5% drought	5 LSR	6.8	5.36	See PES.
	35% maintenance	4.5 MVI	4.5	19	Enough inundated vegetation is required to ensure that the Atyidae and Coenagrionidae can thrive. At these flows 5% fringing vegetation is inundated and aquatic vegetation will be available to provide adequate habitat for the selected taxa.
AEC: D EcoStatus FISH: D MACROINVERTEBRATES: D RIP VEG: D					

Month	% Stress duration	Component stress	Integrated stress	Flow m ³ /s	Comment
Sep	5% drought	6.7 LSR	7.4	4.22	See PES.
	35% maintenance	6 LSR	7	4.7	At this stress level the preferred habitats as refuge during the dry period will be greatly reduced and only adequate to sustain this indicator group in the reach. Decreased abundance and cover will be reflected by an overall decrease in FROC of these species within this river reach with a resultant deterioration in EC.
Feb	5% drought	5 LSR	6.8	5.36	See PES.
	35% maintenance	6.5 MVI	6.5	6.35	Enough inundated vegetation is required to ensure that the Atyidae and Coenagrionidae can thrive. At these flows 2% fringing vegetation is inundated and aquatic vegetation will be available to provide adequate habitat for the selected taxa.

12.3.1 Final low flow requirements

To produce the final results (Figure 12-3), the DRM results for the specific category are modified according to specialists' requirements (Figure 12-1 and 12-2). The following changes were required:

- Some of the default assurance rules changed to give flatter assurance curves for all categories.
- Seasonal distribution factor changes:
 - o B EC: 0.7 for maintenance; 0.2 for drought.
 - o C EC: 0.7 for maintenance; 0.2 for drought.
 - o D EC: 0.2 for maintenance; 0.2 for drought.
- A result for a D maintenance could not be achieved. It was necessary to create a special set of monthly assurance rules for both seasons with much higher shape factors.

Dry Season (September)

Wet Season (February)

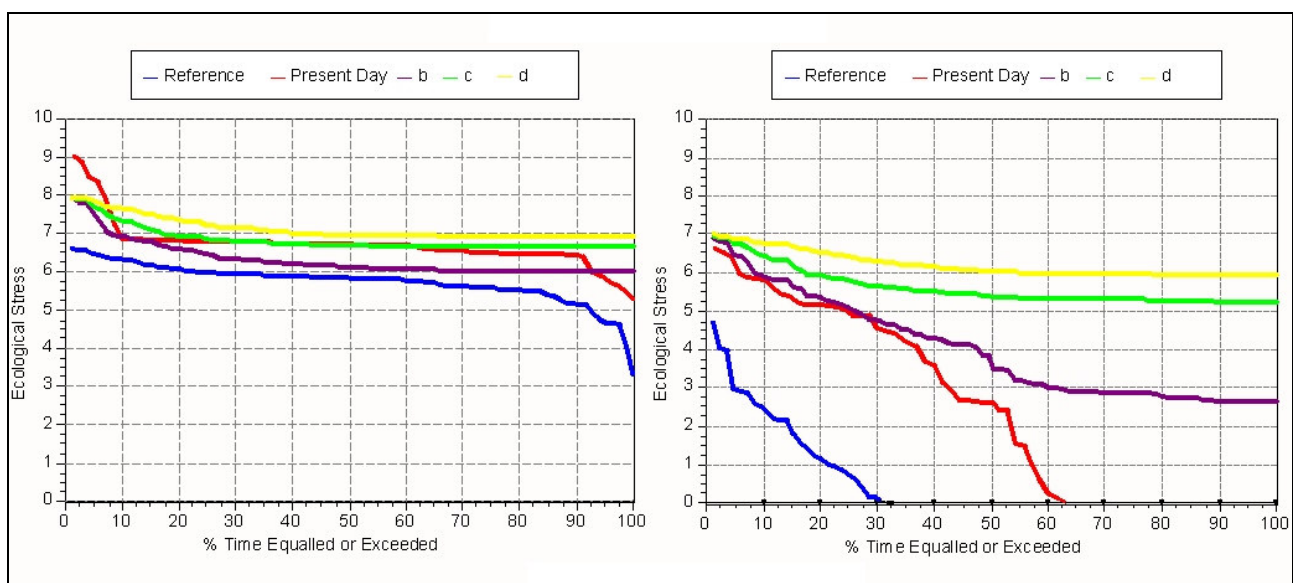


Figure 12-3 EWR 5: Final stress requirements for low flows

12.4 HIGH FLOW REQUIREMENTS

High low classes were identified as outlined in Section 4.4. Results are provided in Table 12.3 and detailed motivations provided in Table 12.4.

Table 12.3 Identification of instream functions addressed by the identified floods for geomorphology and riparian vegetation

FLOOD CLASS	FLOOD RANGE (m ³ /s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions						Macroinvertebrate flood functions				
			Migration cues	Migration habitat (depth etc.)	Clean spawning habitat	Spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas
I	15 - 20	Vegetation: Inundates marginal zone, <i>Cyperus</i> , <i>Juncus</i> , and <i>Persecaria</i> and activates lower level reed beds (<i>P. mauritianus</i>). More frequent smaller floods will reduce reed expansion and promote more open sediment. Reduced small floods for AEC down will reduce flooding disturbance and facilitate reed encroachment/expansion towards the channel.	√	√	√	√	√	√	√	√		√	
II	22 - 50	Geomorphology: Activates benches and responsible for more than 10% of the PBMT. These flows would scour fines from the bed. Vegetation: Inundates about 50% of the lower zone, LHB terraces/bars. Inundates reeds on the lower zone. Similar effect as above for REC and AEC down.	√	√	√	√	√	√	√	√		√	√
III	(60)	Geomorphology: Activates benches and responsible for more than 10% of the PBMT. These flows would scour fines from the bed.	√	√	√	√	√	√	√	√	√	√	√
IV	70 - 100	Geomorphology: This flow class is responsible for about 25% of the PBMT. This flow class would scour the bed, activate gravels and cobbles and inundate and activate islands. Vegetation: Inundates lower zone and reeds as above. Similar effect as above for REC and AEC down.	√	√	√	√	√	√	√	√	√	√	√
V	370 +	Geomorphology: This flow class represents the effective discharge for this site, accounting for more than 30% of the PBMT. This flow class would scour the bed, activating cobbles and gravels and inundating the islands and deposition sediment in the vegetation. Vegetation: Inundates a portion of the upper zone and upper zone reeds.	√	√	√	√	√	√	√				

Further information is provided in Appendix F, Table F14.

The number of high flow events required for each EC is provided in Table 12.4. No observed daily data was available to check flood requirements against.

Table 12.4 EWR 5: The recommended number of high flow events required

FLOOD CLASS	FLOOD RANGE (m ³ /s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (No of events)	MONTHS	DAILY AVERAGE (m ³ /s)	DURATION (Days)
PES SCENARIO: C									
I	15 - 20	4	4	4		4	Nov, Dec, Jan, Mar	8	4
II	22 - 50	2	2	2	2	2	Dec, Mar	30	4
III	(60)				2	2	Feb, Mar	50	4
IV	70 - 100			1	1	1	Feb	90	5
V	370 +			1:3+	1:3	1:3	Summer to late summer		
REC SCENARIO: B									
I	15 - 20	6	6	6		6	Nov, Dec, Jan, Feb, Mar	8	4
II	22 - 50	3	3	3	3	3	Dec, Jan, Mar	30	4
III	(60)				3	3	Jan, Feb, Mar	50	4
IV	70 - 100			1	1	1	Feb	90	5
V	370 +			1:3+	1:2 - 1:3	1:3	Summer to late summer		
AEC SCENARIO: D									
I	15 - 20	2	2	2		2	Nov and Mar	12	4
II	22 - 50	1	1	1	2	2	Dec, Jan	35	4
III	(60)				1	1	Feb	60	5
IV	70 - 100			1:2	1:2	1:2	Summer to late summer		
V	370 +			1:3+	1:5	1:5	Summer to late summer		

12.5 FINAL FLOW REQUIREMENTS

The low and high flows were combined to produce the final flow requirements for each EC as:

- An EWR table, which shows the results of high flows and low flows for each month separately (Table 12.5 – 12.7). Floods with a frequency higher than 1:1 is not included.
- An EWR rule table which provides the recommended EWR flows as a duration table, showing flows which should be provided when linked to a natural trigger (natural modelled hydrology in this case). EWR rules are supplied for total flows as well as for low flows only (Appendix F, Section F2.4).

Table 12.5 EWR table for PES: C

Desktop version:		2	Virgin MAR (MCM)	1006.234
BFI index	0.485	Distribution type		Eastern Escarpment
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m ³ /s)	Drought (m ³ /s)	Daily average (m ³ /s) on top of base flow	Duration (days)
OCTOBER	4.706	3.422		
NOVEMBER	5.571	3.672	8	4
DECEMBER	6.365	3.739	8 30	4 4
JANUARY	7.597	3.974	8	4
FEBRUARY	10.008	4.706	50 90	4 5

Desktop version:		2	Virgin MAR (MCM)	1006.234
BFI index	0.485	Distribution type		Eastern Escarpment
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m ³ /s)	Drought (m ³ /s)	Daily average (m ³ /s) on top of base flow	Duration (days)
MARCH	9.214	4.283	8 30 50	4 4 4
APRIL	8.708	4.271		
MAY	7.497	3.955		
JUNE	6.776	3.902		
JULY	5.739	3.620		
AUGUST	4.996	3.478		
SEPTEMBER	4.707	3.507		
TOTAL MCM	214.498	122.077	53.222	
% OF VIRGIN	21.32	12.13	5.29	

Table 12.6 EWR table for REC: B

Desktop version:		2	Virgin MAR (MCM)	1006.234
BFI index	0.485	Distribution type		Eastern Escarpment
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m ³ /s)	Drought (m ³ /s)	Daily average (m ³ /s) on top of base flow	Duration (days)
OCTOBER	7.898	3.422		
NOVEMBER	9.231	3.672	8	4
DECEMBER	10.405	3.739	8 30	4 4
JANUARY	12.266	3.974	8 30 50	4 4 4
FEBRUARY	15.994	4.706	8 50 90	4 4 5
MARCH	14.709	4.283	8 30 50	4 4 4
APRIL	13.972	4.271		
MAY	12.115	3.955		
JUNE	11.052	3.902		
JULY	9.459	3.620		
AUGUST	8.336	3.478		
SEPTEMBER	7.925	3.507		
TOTAL MCM	349.407	122.077	74.104	
% OF VIRGIN	34.72	12.13	7.36	

Table 12.7 EWR table for AEC: D

Desktop version:		2	Virgin MAR (MCM)	1006.234
BFI index	0.485	Distribution type		Eastern Escarpment
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m ³ /s)	Drought (m ³ /s)	Daily average (m ³ /s) on top of base flow	Duration (days)
OCTOBER	3.422	3.422		
NOVEMBER	3.672	3.672	12	4
DECEMBER	3.739	3.739	35	4
JANUARY	3.974	3.974	35	4

Desktop version:		2	Virgin MAR (MCM)	1006.234
BFI index	0.485	Distribution type		Eastern Escarpment
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m ³ /s)	Drought (m ³ /s)	Daily average (m ³ /s) on top of base flow	Duration (days)
FEBRUARY	4.706	4.706	60	5
MARCH	4.283	4.283	12	4
APRIL	4.271	4.271		
MAY	3.955	3.955		
JUNE	3.902	3.902		
JULY	3.620	3.620		
AUGUST	3.478	3.478		
SEPTEMBER	3.507	3.507		
TOTAL MCM	122.077	122.077	29.341	
% OF VIRGIN	12.13	12.13	2.92	

A comparison between the Desktop Reserve Model estimates and the EWR results in terms of percentages of natural flow are provided in Table 12.8.

Table 12.8 Modifications made to the DRM for EWR 5

Changes	PES C		REC B		AEC D	
	DRM	EWR	DRM	EWR	DRM	EWR
MLIFR - Maintenance low flow	17.2%	21.3%	29.7%	34.7%	9.3%	12.1%
DLIFR - Drought low flow	9.3%	12.1%	9.3%	12.1%	9.3%	12.1%
MHIFR - Maintenance high flow	7.3%	5.3%	8.8%	7.4%	6.4%	2.9%
Long-term % of virgin MAR	27.9%	30.0%	37.9%	40.2%	23.2%	21.3%

13 EWR 6: NKONGOMA (CROCODILE RIVER) - DETERMINATION OF STRESS INDICES

NOTE: All supporting specialist information for EWR 6 is summarized in Volume 3, Appendix G.

13.1 INDICATOR SPECIES OR GROUP

13.1.1 Fish indicator group 1: Small rheophilic species (CPRE, SCWI)

Chiloglanis pretoriae (CPRE): See Section 5.1.1 and Appendix C, Table C1.

Chiloglanis swierstrai (SCWI): See Section 11.1.1 and Appendix F, Table F1.

13.1.2 Fish indicator group 2: Large semi-rheophilic species (BMAR, HVIT, LCON)

Labeobarbus marequensis (BMAR): See Section 9.1.2 and Appendix E, Table E2.

Hydrocynus vittatus (HVIT) and *Labeo congoro* (LCON): See Section 11.1.2 and Appendix F, Table F2.

13.1.3 Macroinvertebrate indicator taxa

Flow dependant (FDI) cobble dwelling macroinvertebrate taxa included:

- Beetle family: Elmidae, refer to Section 3.1.2.
- The dragonfly family: Libellulidae, refer to Section 11.1.3.
- The mayfly family: Tricorythidae, refer to Section 3.1.2.

13.1.4 Riparian vegetation indicator species

Two indicator species were selected:

- *Cyperus marginatus*: Hardy reed that is an obligate hydrophyte⁶. Has a wide habitat tolerance, but optimal habitat and largest stands usually occur in the marginal and lower zones, associated with permanent or near-permanent water. Prefers alluvial sediments and facilitates sedimentation. Drought and flood resistant, but a heavy water user, and a fair indicator of flow if high density, high vigour stands are used.

13.2 STRESS FLOW INDEX

The stress flow index is generated in terms of habitat and biotic response and is discussed below.

13.2.1 Habitat response

Habitat response is used to derive the biota's response to provide a biota stress index and represents the instantaneous response of habitat to flow changes, based on a site specific 0 – 10 scale for instream biota where:

- 0 – Optimum habitat (fixed at the natural maximum base flow – calculated using the wettest flow month discharge at the maintenance percentage – 30% – 40% for the Crocodile River at the EWR site).
- 10 - No flow (although there may still be surface water in pools).

⁶ Plants that have adapted to live in or on aquatic environments.

The abundance of fish velocity-depth classes for the SR and LSR guild is provided in Appendix G, Table G1.

The instantaneous response of FDI taxa provides the % occurrence of various velocity-substrate classes under different flow conditions are provided in Appendix G, Table G2.

13.2.2 Biota response

The biota stress index is the instantaneous response of biota to change in habitat (and therefore flow), based on a scale of 0 – 10.

The fish species response index is calculated using the fish habitat rating (cf Section 3.2.1) (Appendix G, Table G3) for each of the discharges evaluated for assessing habitat response. The FDI index is derived by considering the habitat response and % occurrence of habitat conditions at different flows. The FDI responses are described and coupled to a stress level (Appendix G, Table G4)

A riparian vegetation stress index is also provided (Appendix G, Table G5).

13.2.3 Integrated stress curve

The integrated stress curve represents the highest stress for fish, macroinvertebrates or riparian vegetation at a specific flow.

The shaded species stress discharges in Table 13.1 indicate the discharge evaluated by specialists to determine the biota stress. The values that are not shaded are interpolated. The highest discharge representing a specific stress is used to define the integrated stress curve. Figure 13-1 illustrates this graphically.

In this specific case, the LSR stress index represents the integrated stress index (these values are the highest flow for a stress). Therefore the red line (representing the LSR stress index) is lying 'beneath' the integrated stress line (black) (Figure 13-1).

Table 13.1 Species stress discharges used to determine biotic stress

Stress	Flow (m ³ /s)				Integrated Flow (m ³ /s)
	SR	LSR	FDI	Sedge <i>Cyperus</i>	
0	22.8	22.8	21.1	2.5	22.8
1	15	18.9	16.9	2.05	18.9
2	12.35	15.5	12.7	1.6	15.5
3	9.7	12.35	8	1.15	12.35
4	8.475	9.7	4.29	0.725	9.7
5	7.25	8.475	3.22	0.3	8.475
6	6.55	7.25	2.58	0.21	7.25
7	5.32	5.32	1.94	0.12	5.32
8	3.83	3.83	0.48	0.03	3.83
9	1.7	1.7	0.02	0	1.7
10	0	0	0	0	0

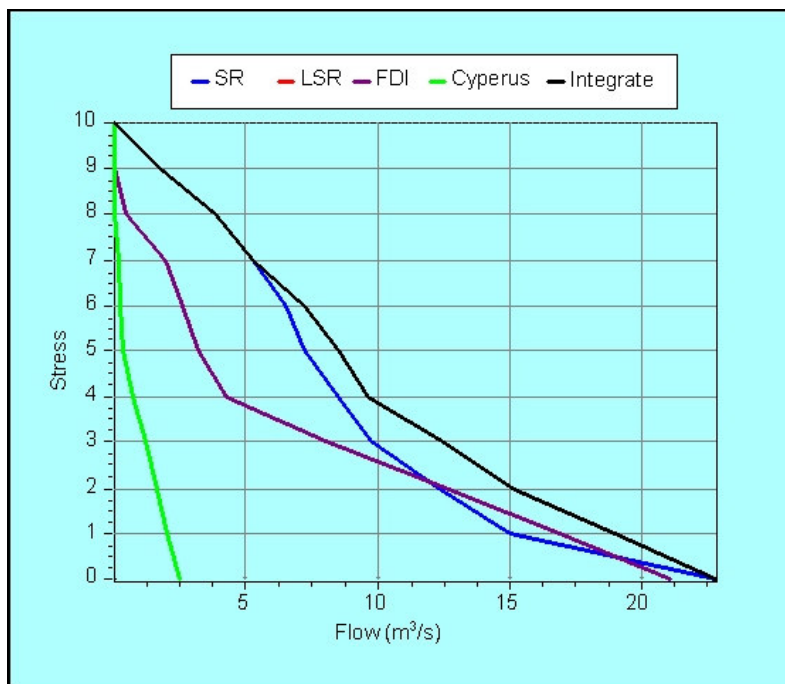


Figure 13-1 Component and integrated stress curves for EWR 6

Table 13.2 Integrated stress and summarised habitat/biotic responses

Integrated stress	Flow m ³ /s	Habitat and/or Biotic responses
0 (SR)	22.8	All Fish SR and LSR habitats are optimal (5*) although connectivity for the LSR guild is slightly impacted (4.5). Critical FDI habitats sufficient. All indicator taxa very abundant and healthy.
1 (LSR)	18.9	Fish guild: As above.
2 (LSR)	15.5	SR guild: Abundance and water quality is optimal while rest of habitats is slightly less than optimal (4.5). LSR guild: Water quality is optimal and spawning, nursery and abundance is very good (4). Cover and connectivity is moderate (3.5).
3 (LSR)	12.35	Reduced FDI critical habitat with reduced critical quality. Most indicator taxa persist, but slight (80%) reduction.
4 (LSR)	9.7	All fish habitat is moderate (3 – 3.5), but cover and connectivity for the LSR guild is low (3.5)
5 (LSR)	8.475	Critical FDI habitats limited with moderate quality. Most indicator taxa persist, but abundances reduced.
6 (LSR)	7.25	All fish habitat is low and connectivity for the LSR guild is very low (1.5).
7 (LSR)	5.32	All fish habitats are low (1 – 1.5) although connectivity, water quality and cover is low (2) for the SR guild.
8 (LSR)	3.83	All fish habitat is very low (1) and connectivity and water quality for the LSR guild is very rare (0.5). Critical FDI habitat residual. Critical life-stages of sensitive indicator taxa at risk or non-viable. Adults with full vigour and at maximum reproductive capacity. 50% population inundated, upper limit rooting depth at 12 cm.
9 (LSR)	1.7	All fish habitat is very rare (0.5). No critical FDI habitat, other habitats moderate quality. Some indicator taxa persist, but most disappear. All life-stages of sensitive indicator taxa at risk or non-viable.
10	0	Flowing water habitats residual low quality. Indicator taxa no longer present. <i>C. marginatus</i> : Complete mortality of small proportion of the population.

* Suitability rating 0 (not suitable) – 5 (highly suitable)

14 EWR 6: NKONGOMA (CROCODILE RIVER) - DETERMINATION OF EWR SCENARIOS

14.1 ECOCLASSIFICATION SUMMARY OF EWR 6

EWR 6 Nkongoma (Crocodile River)					
<p>EIS: VERY HIGH Rare and endangered sp sensitive to flow and quality changes. High species taxon richness and diversity of habitat types, KNP on LB.</p> <p>PES: C Change in low flows, even zero flows present, specifically in the dry season. Change in flooding regime. All impacts associated with sugarcane activities.</p> <p>REC: B The EIS is VERY HIGH, therefore the REC is an improvement of the PES. Changes mostly focussing on improving the low flow regime and some land use management.</p> <p>AEC down: D Decreased low flows and periods of zero flows in some stretches of the river which will result in increased algal growth, temperature and nutrient problems, and loss of deeper channel sections, increased reed and vegetation growth.</p>	Driver Components	PES Category	Trend	REC	AEC _↓
	HYDROLOGY	D		B	D
	WATER QUALITY	C		B	D
	GEOMORPHOLOGY	C	Negative	C	C/D
	Response Components	PES Category	Trend	REC	AEC _↓
	FISH	C	Stable	B	D
	MACRO INVERTEBRATES	C	Stable	B	C/D
	INSTREAM	C		B	D
	RIPARIAN VEGETATION	C	Negative	B	D
	ECOSTATUS	C		B	D

14.2 HYDROLOGY

The highest and lowest low flow months selected as the key months are February (wet) and October (dry). The key assurance percentages for which stress requirements had to be set were:

- 95%: Representing droughts for both wet and dry months. This would represent 5% on the stress duration graphs.
- 65%: Representing maintenance flows for both wet and dry months. This would represent 35% on the stress duration graphs.

14.3 LOW FLOW REQUIREMENTS (IN TERMS OF STRESS)

The integrated stress index is used to identify required stress levels at specific durations for the wet and dry month/season. Specialist motivations for the stresses are provided in Appendix E, Section G2.1 – 2.3.

The fish and macroinvertebrate flow requirements for different Ecological Categories (ECs) are provided in Table 14.1 and Figure 14-1 and 14-2. The results are plotted for the wet and dry season on stress duration graphs and compared to the DRM low flow estimates for the same range of ECs. The stress requirements (as a ‘hand drawn line’) are illustrated in Figures 14-1 and 14.2.

For easier reference the range of ECs are colour coded in the Tables and Figures:

PES: **Green**

REC: **Purple**

AEC: **Yellow**

Summarised motivations for the final requirements are provided in Table 14.2.

Table 14.1 Species and integrates stress requirements as well as the final integrated stress and flow requirement Final requirement tables

Duration	SR stress	Integ stress	LSR stress	Integ stress	FDI stress	Integr stress	FINAL* (Integrated stress)*	FLOW (m ³ /s)
PES: C EcoStatus		FISH: C		MACROINVERTEBRATES: C		RIP VEG: C		
DRY SEASON								
5%	9.2	9.2	9	9	9	9.9	9.2	1.36
35%	8.9	8.9	8.9	8.9	7	8.9	8.9	1.91
WET SEASON								
5%	5.5	6.2	6	6	6	8.5	6	7.25
35%	3.5	4.5	3.6	3.6	3.5	6.6	3.6	10.76
REC: B EcoStatus		FISH: B		MACROINVERTEBRATES: B		RIP VEG: B		
DRY SEASON								
35%	7.7	7.7	7.5	7.5	5	8.3	7.5	4.575
WET SEASON								
35%	2	3	1.9	1.9	2	3	1.9	15.84
AEC: D EcoStatus		FISH: D		MACROINVERTEBRATES: C		RIP VEG: D		
DRY SEASON								
5%	9.6	9.6	9.6	9.6			9.6	0.681
35%	9.3	9.3	9.3	9.3	8	9.8	9.3	1.19
WET SEASON								
35%	5.5	6.2	5.5	5.5	5	8.1	5.5	7.86

Final refers to the final stress selected as the EWR requirement, usually the lowest integrated stress. In some cases, vegetation was ignored due to the much lower confidence in the requirements.

NOTE: For this site the low flow requirements for riparian vegetation were not included due to low confidence in the results.

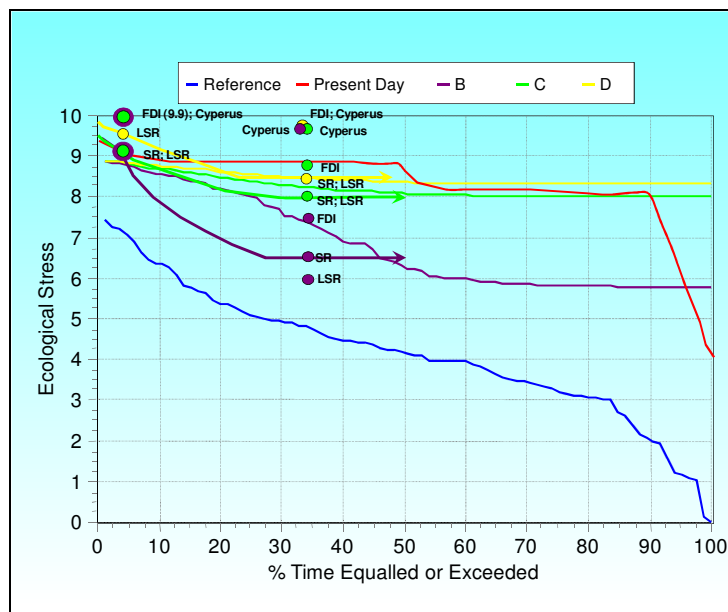


Figure 14-1 EWR 6: Stress duration curve for a C PES, B REC and D AEC - DRY season

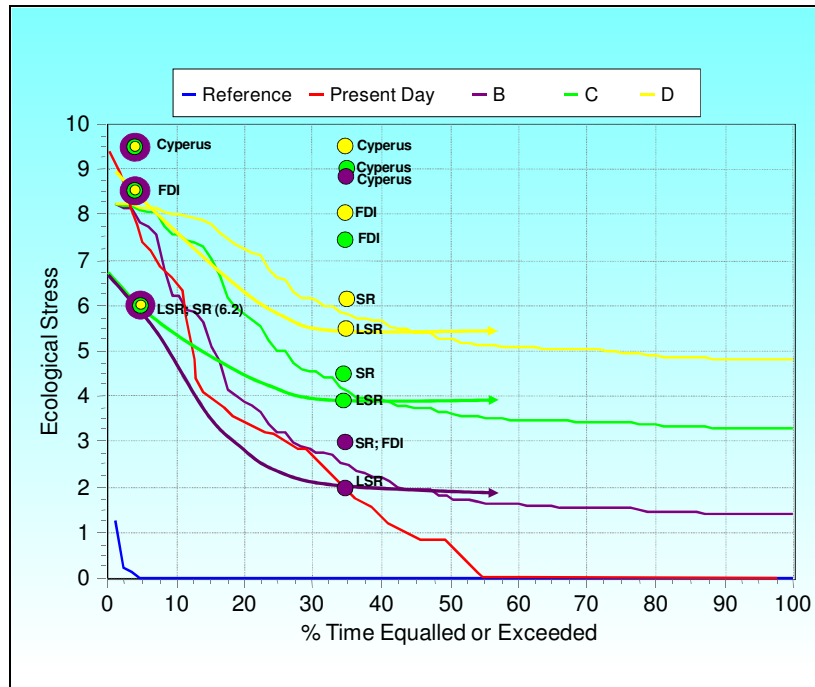


Figure 14-2 EWR 6: Stress duration curve for a C PES, B REC and D AEC - WET season

Table 14.2 Summary of EWR 6 motivations

Month	% Stress duration	Component stress	Integrated stress	Flow m ³ /s	Comment
PES: C EcoStatus					
FISH: C					
MACROINVERTEBRATES: C					
RIP VEG: C					
Sep	5% drought	9.2 SR	9.2	1.36	This is the maximum allowable fish stress level where this indicator guild will be able to sustain viable populations during a dry period drought to enable recovery when conditions improve.
	30% maintenance	8.9 SR	8.9	1.91	This recommended fish stress level will maintain some FD, FI and abundant FS for maintenance of viable populations of this indicator guild during the dry season.
Feb	5% drought	6 LSR	6	7.25	This is the maximum stress level allowable where this fish guild will survive through dry drought periods without undue stress on their populations and to allow their recovery afterwards.
	35% maintenance	3.6 LSR	3.6	10.76	This flow and stress level will allow moderate conditions for all requirements (spawning, nursery habitat, cover and abundance, water quality and connectivity). These favourable conditions during the wet season will ensure that the PES is maintained at this site.
REC: B EcoStatus					
FISH: B					
MACROINVERTEBRATES: B					
RIP VEG: B					
Sep	5% drought	9.2 SR	9.2	1.36	See PES.
	35% maintenance	7.5 LSR	7.5	4.58	These stress levels will result in improvement of preferred habitats for this indicator group during the dry season which should be reflected by increased abundance and overall improved FROC that will result in an improved ecological category.
Feb	5% drought	6 LSR	6	7.25	See PES.
	35% maintenance	1.9 LSR	1.9	15.84	Increased availability and abundance of critical habitats required during the wet season (especially spawning and nursery) should be reflected by improved reproduction potential and an overall improvement in the composition of this indicator group in this river reach, with an expected improvement towards a category B.

Month	% Stress duration	Component stress	Integrated stress	Flow m ³ /s	Comment
AEC: D EcoStatus		FISH: D		MACROINVERTEBRATES: C	
				RIP VEG: D	
Sep	5% drought	9.6 SR	9.6	0681	At this stress level the habitat suitability to maintain abundance, provide cover, connectivity and adequate water quality will be very poor to critical and extreme stress on this fish guild will result in critical deterioration in the PES. It can be expected that this fish guild may not be able to survive at this stress level and may require recolonisation from other reaches or the downstream Komati River after conditions recover.
	35% maintenance	9.3 LSR	9.3	1.19	At this stress level the preferred habitats as refuge during the dry period will be greatly reduced and only adequate to sustain this indicator group in the reach. Decreased abundance and cover will be reflected by an overall decrease in FROC of these species within this river reach with a resultant deterioration in EC.
Feb	5% drought	6 LSR	6	7.25	See PES.
	35% maintenance	5.5 LSR	5.5	7.86	Very limited habitats will be available for the critical life stages during the wet season, namely spawning, egg development and nursery areas, which will be reflected in overall decreased abundance and FROC of all these species within this guild.

14.3.1 Final low flow requirements

To produce the final results (Figure 14-3), the DRM results for the specific category are modified according to specialists' requirements (Figure 14-1 and 14-2). The following changes were required:

- Seasonal distribution factor changes:
 - 0 B EC: 0.71 for maintenance; 1.65 for drought.
 - 0 C EC: 1.1 for maintenance; 1.65 for drought.
 - 0 D EC: 1.65 for maintenance; 1.65 for drought.
- Some of the default assurance rules changed to give flatter assurance curves for a D EC (special assurance monthly rule table was used):
 - 0 Low flow max = 100 for all months.
 - 0 Wet season shapes (Feb = 7).
 - 0 DC lower shift = 0 for Feb.
 - 0

Note that during the operational scenario phase, it became apparent that some of the results were higher than present day hydrology in certain months. The reason is that the DRM determines the monthly flows in months other than those specified and follows a natural seasonal distribution. This result was that some months occurred with higher flows than present day. During the scenario phase these months were adjusted to reflect lower flows than natural and the EWR and EWR Rule tables represent these adjustments.

Dry Season (September)

Wet Season (February)

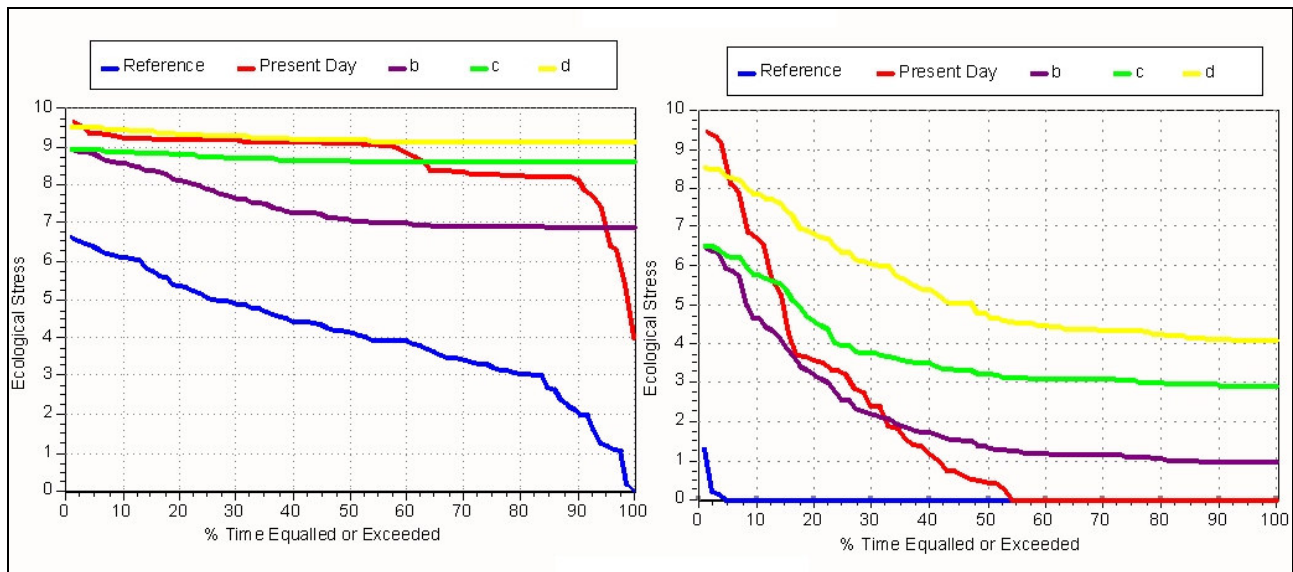


Figure 14-3 EWR 6: Final stress requirements for low flows

14.4 HIGH FLOW REQUIREMENTS

The High low classes were identified as outlined in Section 4.4. Results are provided in Table 14.3 and detailed motivations provided in Table 14.4.

Table 14.3 Identification of instream functions addressed by the identified floods for geomorphology and riparian vegetation

FLOOD CLASS	FLOOD RANGE (m ³ /s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions						Macroinvertebrate flood functions				
			Migration cues	Migration habitat (depth etc.)	Clean spawning habitat	Spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas
I	20 – 30	Vegetation: Inundates the marginal zone and marginal zone sedges (<i>C. marginatus</i>). Lower portions of <i>P. mauritianus</i> and <i>L. octovalvis</i> also inundated. Fewer events for AEC down will allow more sediment to settle, and with less flood disturbance marginal zone vegetation will migrate / expand towards the instream.	√	√	√	√	√	√	√	√	√	√	√
II	60 - 100	Geomorphology: This flow class is responsible for more than 10% of the PBMT. These flows would scour fines from the bed. Vegetation: Required to inundate about 50% of the lower zone. Inundates reed beds (<i>P. mauritianus</i>), <i>Ludwigia</i> and lower portions of <i>B. salicina</i> . Sustains vigour and reproduction in the height of the growing season. Less frequent event for AEC (down) will result in reduced recruitment opportunities for lower zone woody species (<i>C. erythrophyllum</i> , <i>B. salicina</i>).	√	√	√	√	√	√	√	√	√	√	√
III	130 - 160	Geomorphology: This flow class is responsible for more than 25% of the PBMT. This flow class would scour the bed, activate gravels. Vegetation: Required for inundation of the lower zone. This will inundate <i>B. salicina</i> and afford recruitment opportunities.	√	√	√	√	√	√					

FLOOD CLASS	FLOOD RANGE (m ³ /s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions					Macroinvertebrate flood functions						
			Migration cues	Migration habitat (depth etc.)	Clean spawning habitat	Spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas	Reset water quality
		as well as upper limit of lower zone reeds.												
IV	200 - 350	Geomorphology: This flow class represents the effective discharge for this site, accounting for more than 35% of the PBMT. This flow class would scour the bed, activating cobbles and gravels. Vegetation: Activates and inundates portions of the upper zone bars/benches. Maintains <i>Nuxia oppositifolia</i> and <i>Flugea virosa</i> populations and activates upper zone reeds (low density). Would perform the function of reducing terrestrial species in the riparian zone.	√	√	√	√	√	√	√					

Further information is provided in Appendix G, Table G10.

The number of high flow events required for each EC is provided in Table 14.4. No observed daily data was available to check flood requirements against.

Table 14.4 EWR 6: The recommended number of high flow events required

FLOOD CLASS	FLOOD RANGE (m ³ /s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (No of events)	MONTHS	DAILY AVERAGE (m ³ /s)	DURATION (Days)
PES SCENARIO: C									
I	20 – 30			4		4	Nov, Dec, Jan, Mar	12	4
II	60 - 100			2	2	2	Dec, Mar	60	4
III	130 - 160			1	1	1	Feb	120	6
IV	200 - 350			1:2 - 3	1:3				
REC SCENARIO: B									
I	20 – 30			6		6	Nov, Dec, Jan (2), Feb, Mar	10	4
II	60 - 100			3		3	Dec, Jan, Mar	50	4
III	130 - 160			2	3	2	Jan, Feb, Mar	100	5
IV	200 - 350			1:2 - 3	1		Feb	180	6
AEC SCENARIO: D									
I	20 – 30			2		2	Nov, Mar	15	4
II	60 - 100			1		1	Jan	70	5
III	130 - 160			1:2	1	1:2	Feb	130	6
IV	200 - 350			1:2 - 3	1:2				

14.5 FINAL FLOW REQUIREMENTS

The low and high flows were combined to produce the final flow requirements for each EC as:

- An EWR table, which shows the results of high flows and low flows for each month separately (Table 14.5 – 14.7). Floods with a frequency higher than 1:1 is not included.
- An EWR rule table which provides the recommended EWR flows as a duration table, showing flows which should be provided when linked to a natural trigger (natural modelled hydrology in this case). EWR rules are supplied for total flows as well as for low flows only (Appendix G, Section G2.4).

Table 14.5 EWR table for PES: C

Desktop version:		2	Virgin MAR (MCM)	1063.131
BFI index	0.478	Distribution type		Eastern Escarpment
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m ³ /s)	Drought (m ³ /s)	Daily average (m ³ /s) on top of base flow	Duration (days)
OCTOBER	3.136	1.863		
NOVEMBER	3.896	2.496	12	4
DECEMBER	4.694	3.220	12 60	4 4
JANUARY	5.903	4.274	12	4
FEBRUARY	8.213	6.195	120	6
MARCH	7.555	5.715	12 60	4 4
APRIL	6.915	5.128		
MAY	5.709	4.105		
JUNE	4.988	3.447		
JULY	4.077	2.682		
AUGUST	3.402	2.094		
SEPTEMBER	3.100	1.802		
TOTAL MCM	161.196	112.509	79.730	
% OF VIRGIN	15.16	10.58	7.50	

Table 14.6 EWR table for REC: B

Desktop version:		2	Virgin MAR (MCM)	1063.131
BFI index	0.478	Distribution type		Eastern Escarpment
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m ³ /s)	Drought (m ³ /s)	Daily average (m ³ /s) on top of base flow	Duration (days)
OCTOBER	7.218	1.863		
NOVEMBER	8.446	2.496	10	4
DECEMBER	9.567	3.220	10 50	4 4
JANUARY	11.391	4.274	10 50 100	4 4 5
FEBRUARY	15.142	6.195	10 100 180	4 5 6
MARCH	13.884	5.715	10 50 100	4 4 5
APRIL	13.002	5.128		

Desktop version:		2	Virgin MAR (MCM)	1063.131
BFI index	0.478	Distribution type		Eastern Escarpment
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m ³ /s)	Drought (m ³ /s)	Daily average (m ³ /s) on top of base flow	Duration (days)
MAY	11.099	4.105		
JUNE	10.093	3.447		
JULY	8.637	2.682		
AUGUST	7.619	2.094		
SEPTEMBER	7.249	1.802		
TOTAL MCM	323.089	112.509	140.728	
% OF VIRGIN	30.39	10.58	13.24	

Table 14.7 EWR table for AEC: D

Desktop version:		2	Virgin MAR (MCM)	1063.131
BFI index	0.478	Distribution type		Eastern Escarpment
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m ³ /s)	Drought (m ³ /s)	Daily average (m ³ /s) on top of base flow	Duration (days)
OCTOBER	1.4	0.8		
NOVEMBER	2.3	0.7	15	4
DECEMBER	3.5	1.4		
JANUARY	5.2	1.4	70	5
FEBRUARY	8	1.2	130	6
MARCH	7	1.1	15	4
APRIL	5.5	1		
MAY	1.5	0.9		
JUNE	1.4	0.8		
JULY	1.3	0.8		
AUGUST	1.3	0.8		
SEPTEMBER	1.2	0.8		
TOTAL MCM	103.1	30.74	49.542	
% OF VIRGIN	9.7	2.89	4.66	

A comparison between the Desktop Reserve Model estimates and the EWR results in terms of percentages of natural flow are provided in Table 14.8.

Table 14.8 Modifications made to the DRM for EWR 6

Changes	PES C		REC B		AEC D	
	DRM	EWR	DRM	EWR	DRM	EWR
MLIFR - Maintenance low flow	16.4%	13.9%	28.2%	30.4%	8.8%	11.6%
DLIFR - Drought low flow	8.8%	10.6%	8.8%	10.6%	8.8%	4.5%
MHIFR - Maintenance high flow	7.6%	7.4%	9.2%	13.2%	6.6%	4.6%
Long-term % of virgin MAR	27.2%	24.9%	36.8%	43.9%	22.6%	14.3%

15 EWR 7: HONEYBIRD (KAAP RIVER) - DETERMINATION OF STRESS INDICES

NOTE: All supporting specialist information for EWR 7 is summarized in Volume 3, Appendix H.

15.1 INDICATOR SPECIES OR GROUP

15.1.1 Fish indicator group 1: Small rheophilic species (CPRE, OPER)

Chiloglanis pretoriae (CPRE): See Section 5.1.1 and Appendix C, Table C1.

Opsaridium peringueyi (OPER): See Section 9.1.1 and Appendix E, Table E1.

15.1.2 Fish indicator group 2: Large semi-rheophilic species (BMAR, LCYL, LMOL)

Labeobarbus marequensis (BMAR): See Section 9.1.2 and Appendix E, Table E2.

15.1.3 Macroinvertebrate indicator taxa

The following Flow dependant (FDI) cobble dwelling macroinvertebrate taxa were selected:

- Stonefly family: Perlidae, refer to Section 5.1.2.
- Mayfly family: Heptageniidae, refer to Section 5.1.2.
- Beetle family: Elmidae, refer to Section 3.1.2.
- Beetle family: Psephenidae, refer to Section 7.1.2.

15.1.4 Riparian vegetation indicator species

One indicator species was selected:

- *Phragmites mauritianus*: Hardy reed that is an obligate⁷ hydrophyte. It has a wide habitat tolerance, but optimal habitat and largest stands usually occur in the marginal and lower zones, associated with permanent or near-permanent water with a preference for alluvial sediments and facilitates sedimentation. Drought and flood resistant, but a heavy water user, and a fair indicator of flow if high density, high vigour stands are used.

15.2 STRESS FLOW INDEX

The stress flow index is generated in terms of habitat and biotic response and is discussed below.

15.2.1 Habitat response

Habitat response is used to derive the biota's response to provide a biota stress index and represents the instantaneous response of habitat to flow changes, based on a site specific 0 – 10 scale for instream biota where:

- 0 – Optimum habitat (fixed at the natural maximum base flow – calculated using the wettest flow month discharge at the maintenance percentage – 30% – 40% for the Kaap River at the EWR site).
- 10 - No flow (although there may still be surface water in pools).
-

⁷ The probability of occurrence in the riparian zone is more than 90%.

The abundance of fish velocity-depth classes are provided in Appendix H, Table H1.

The instantaneous response of FDI taxa provides the % occurrence of various velocity-substrate classes under different flow conditions are provided in Appendix H, Table H3).

15.2.2 Biota response

The biota stress index is the instantaneous response of biota to change in habitat (and therefore flow), based on a scale of 0 – 10.

The fish species response index is calculated using the fish habitat rating (cf Section 3.2.1) (Appendix H, Table H2) for each of the discharges evaluated for assessing habitat response. The FDI index is derived by considering the habitat response and % occurrence of habitat conditions at different flows. The FDI responses are described and coupled to a stress level (Appendix H, Table H4)

A riparian vegetation stress index is also provided (Appendix H, Table H5).

15.2.3 Integrated stress curve

The integrated stress curve represents the highest stress for fish, macroinvertebrates or riparian vegetation at a specific flow.

The shaded species stress discharges in Table 15.1 indicate the discharge evaluated by specialists to determine the biota stress. The values that are not shaded are interpolated. The highest discharge representing a specific stress is used to define the integrated stress curve. Figure 15-1 illustrates this graphically.

In this specific case, the LSR fish stress index represents the integrated stress index (these values are the highest flow for a stress). Therefore the red line (representing the LSR stress index) is lying 'beneath' the integrated stress line (black) (Figure 15-1).

Table 15.1 Species stress discharges used to determine biotic stress

Stress	Flow (m ³ /s)				Integrated Flow (m ³ /s)
	SR	LSR	FDI	Reeds <i>Phragmites</i>	
0	5.02	5.02	1.37	1.4	5.02
1	2.56	2.56	0.96	1.03	2.56
2	1.9	1.9	0.605	0.66	1.9
3	1.37	1.37	0.25	0.29	1.37
4	0.8	0.8	0.09	0.19	0.8
5	0.43	0.615	0.077	0.097	0.615
6	0.315	0.43	0.063	0.001	0.43
7	0.201	0.315	0.05	0	0.315
8	0.086	0.201	0.006	0	0.201
9	0.044	0.086	0.002	0	0.086
10	0	0	0	0	0

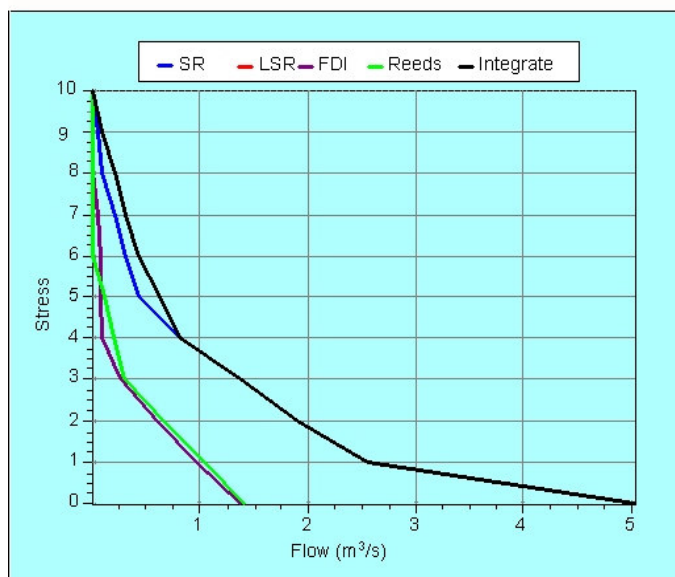


Figure 15-1 Component and integrated stress curves for EWR 7

Table 15.2 provides the summarised biotic response for the integrated stresses.

Table 15.2 Integrated stress and summarised habitat/biotic responses

Integrated stress	Flow m ³ /s	Habitat and/or Biotic responses
0 (SR)	5.02	SR and LSR guild: All habitats are optimal (5 [*]). All FDI habitats in excess and of high quality. Taxa abundant and healthy.
1 (SR)	2.56	SR guild: Cover and connectivity slightly less than optimal (4.5) with rest of habitats optimal. LSR guild: Cover and water quality slightly less than optimal (4.5) with rest of habitats optimal. All FDI habitats plentiful. Taxa abundant and healthy.
2 (SR)	1.9	
3 (SR)	1.37	SR guild: Cover and connectivity is moderate (3 – 3.5) while other habitat occurrences are good (4). LSR guild: Water quality is good and other habitat occurrence is moderate (3 – 3.5). Reduced critical FDI habitat. All indicator taxa very abundant and healthy. <i>P mauritianus</i> : Adults with full vigour and at maximum reproductive capacity. 50% population inundated, upper limit rooting depth at 28 cm.
4 (SR)	0.8	SR guild: Connectivity is low (2.5) and all other habitat is moderate. LSR guild: Water quality is moderate and all other habitat is low. Critical FDI habitat limited. Most indicator taxa persist.
5 (LSR)	0.615	
6 (LSR)	0.43	SR and LSR guild: Water quality is moderate and all other habitat occurrence range between 2 – 2.5 (low).
8 (LSR)	0.201	Critical FDI habitat very reduced. Most indicator taxa persist, but abundances reduced. <i>P. mauritianus</i> : Leaf wilting/stress commences, but is slight. Up to 43 cm rooting depth for upper limit, lower limit is at water level on average.
9 (LSR)	0.086	SR guild: Connectivity is very rare (0.5) while other habitats are very low (1). LSR guild: All habitat occurrences are very rare. Critical FDI habitat residual. All life stages viable in limited areas, critical life stages of some sensitive indicator taxa at risk.
10	0	Only pool dwelling species present. Only hyporheic refugia, no surface water for FDI. Indicator taxa no longer present. Widespread and complete mortality of population.

* Suitability rating 0 (not suitable) – 5 (highly suitable)

16 EWR 7: HONEYBIRD (KAAP RIVER) - DETERMINATION OF EWR SCENARIOS

16.1 ECOCLASSIFICATION SUMMARY OF EWR 7

EWR 7 Kaap (KaaP River)																																																						
<p>EIS: HIGH Rare and endangered sp sensitive to flow and quality changes. High species taxon richness and habitat types sensitive to flow and quality changes.</p> <p>PES: C Changes are flow and non-flow related. Low to zero flows present due to upstream abstractions. Land-use activities related to agriculture and mining. Extensive exotic vegetation present.</p> <p>REC B: The EIS is HIGH, therefore the REC is an improvement of the PES. No zero flows, increased low flows, more moderate floods. This must happen in conjunction with exotic vegetation removal.</p> <p>AEC down D: Mountain View Dam will be present which will result in much lower flows than present and decreased floods. The channel will be narrower, some riffles will be sandier and smaller in general which will result in more reeds and a narrower marginal zone.</p>																																																						
	<table border="1"> <thead> <tr> <th>Driver Components</th> <th>PES Category</th> <th>Trend</th> <th>REC</th> <th>AEC ↓</th> </tr> </thead> <tbody> <tr> <td>HYDROLOGY</td> <td>D</td> <td></td> <td>C</td> <td>D</td> </tr> <tr> <td>WATER QUALITY</td> <td>B</td> <td></td> <td>B</td> <td>C</td> </tr> <tr> <td>GEOMORPHOLOGY</td> <td>B</td> <td>Negative</td> <td>B</td> <td>C</td> </tr> <tr> <th>Response Components</th> <th>PES Category</th> <th>Trend</th> <th>REC</th> <th>AEC ↓</th> </tr> <tr> <td>FISH</td> <td>C</td> <td>Stable</td> <td>B</td> <td>D</td> </tr> <tr> <td>MACRO INVERTEBRATES</td> <td>B</td> <td>Stable</td> <td>B</td> <td>C</td> </tr> <tr> <td>INSTREAM</td> <td>B/C</td> <td></td> <td>B</td> <td>C</td> </tr> <tr> <td>RIPARIAN VEGETATION</td> <td>C/D</td> <td>Negative</td> <td>B/C</td> <td>D</td> </tr> <tr> <td>ECOSTATUS</td> <td>C</td> <td></td> <td>B</td> <td>D</td> </tr> </tbody> </table>	Driver Components	PES Category	Trend	REC	AEC ↓	HYDROLOGY	D		C	D	WATER QUALITY	B		B	C	GEOMORPHOLOGY	B	Negative	B	C	Response Components	PES Category	Trend	REC	AEC ↓	FISH	C	Stable	B	D	MACRO INVERTEBRATES	B	Stable	B	C	INSTREAM	B/C		B	C	RIPARIAN VEGETATION	C/D	Negative	B/C	D	ECOSTATUS	C		B	D			
Driver Components	PES Category	Trend	REC	AEC ↓																																																		
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INSTREAM	B/C		B	C																																																		
RIPARIAN VEGETATION	C/D	Negative	B/C	D																																																		
ECOSTATUS	C		B	D																																																		

16.2 HYDROLOGY

The highest and lowest low flow months selected as the key months are February (wet) and October (dry). The key assurance percentages for which stress requirements had to be set were:

- 95%: Representing droughts for both wet and dry months. This would represent 5% on the stress duration graphs.
- 65%: Representing maintenance flows for both wet and dry months. This would represent 35% on the stress duration graphs.

16.3 LOW FLOW REQUIREMENTS (IN TERMS OF STRESS)

The integrated stress index is used to identify required stress levels at specific durations for the wet and dry month/season. Specialist motivations for the stresses are provided in Appendix E, Section H2.1 – 2.3.

The fish, macroinvertebrate and riparian vegetation flow requirements for different Ecological Categories (ECs) are provided in Table 16.1 and Figure 16-1 and 16-2. The results are plotted for the wet and dry season on stress duration graphs and compared to the DRM low flow estimates for the same range of ECs. The stress requirements (as a 'hand drawn line') are illustrated in Figures 16-1 and 16-2.

For easier reference the range of ECs are colour coded in the Tables and Figures:

PES: Green REC: Purple AEC: Yellow

Summarised motivations for the final requirements are provided in Table 16.2.

Table 16.1 Species and integrates stress requirements as well as the final integrated stress and flow requirements

Duration	SR stress	Integrated stress	LSR stress	Integrated stress	FDI stress	Integrated stress	Phragmites stress	Integ stress	FINAL* (Integrated stress)*	FLOW (m³/s)
PES: C EcoStatus FISH: C MACROINVERTEBRATES: B RIP VEG: C/D										
DRY SEASON										
5%	8	9	9	9	7	9.5	6	10	9	0.086
35%	5.5	6.5	6.5	6.5	3	7.5	4	8.5	6.5	0.374
WET SEASON										
5%	4.5	5	4.5	4.5	5	9	5	9	4.5	0.708
35%	3	3	3	3	2	5.1	3	7.5	3	1.37
REC: B EcoStatus FISH: B MACROINVERTEBRATES: B RIP VEG: B/C										
DRY SEASON										
35%	4	4	4.2	4.2	The REC is the same as the PES.		3	7.5	4	0.8
WET SEASON										
35%	1.5	1.5	2	2	As above.		2	5	1.5	2.23
AEC: D EcoStatus FISH: D MACROINVERTEBRATES: C RIP VEG: D										
DRY SEASON										
35%	7	8.2	8.5	8.5	5	9	5	9	8.2	0.178
WET SEASON										
35%	4	4	4	4	3	7.5	4	8.5	4	0.8

* Final refers to the final stress selected as the EWR requirement, usually the lowest integrated stress. In some cases, vegetation was ignored due to the much lower confidence in the requirements.

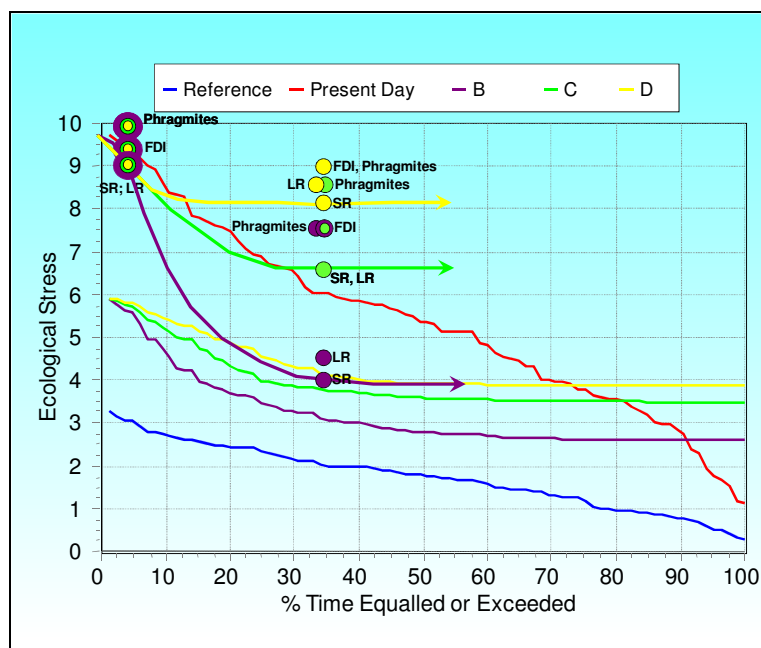


Figure 16-1 EWR 7: Stress duration curve for a C PES, B REC and D AEC - DRY season

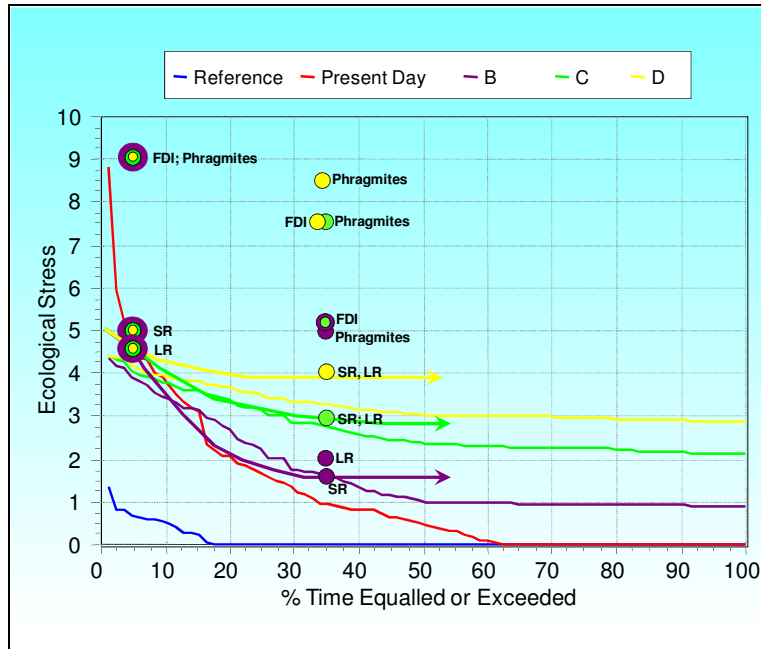


Figure 16-2 EWR 7: Stress duration curve for a C PES, B REC and D AEC - WET season

Table 16.2 Summary of EWR 7 motivations

Month	% Stress duration	Component stress	Integrated stress	Flow m ³ /s	Comment
PES: C EcoStatus FISH: C MACROINVERTEBRATES: B RIP VEG: C/D					
Oct	5% drought	9 SR	9	0.086	Some FS and very limited FI will be maintained and FD will be lost. FI and FS habitats will support small population that should be able to recover after drought.
	35% maintenance	6.5 SR	6.5	0.374	Adequate FS and some FI and FD to support refuge habitats for the small rheophilic species at the site during dry period.
Feb	5% drought	4.5 LSR	4.5	0.708	Some FS will be maintained to ensure maintenance of acceptable water quality (enough oxygen and limited temperature fluctuations) and allow adequate recovery after the stressed period.
	35% maintenance	3 SR	3	1.370	Adequate FD, FI and FS to allow successful breeding and habitats for all life stages. Due to the high stress conditions during dry period it is eminent to maintain adequate conditions during the wet season to ensure the survival of this indicator guild at this site.
REC: B EcoStatus FISH: B MACROINVERTEBRATES: B RIP VEG: B/C					
Oct	5% drought	9 SR	9	0.086	See PES.
	35% maintenance	4 SR	4	0.8	FD habitats decrease visibly from those observed under reference dry period conditions but FROC of indicator species will still be better than PES.
Feb	5% drought	4.5 LSR	4.5	0.708	See PES.
	35% maintenance	1.5 SR	1.5	2.23	High abundance of FD, FI and FS will be available at this fish stress level to provide excellent habitat for this fish guild to complete all their life stages successfully.
AEC: D EcoStatus FISH: D MACROINVERTEBRATES: C RIP VEG: D					
Oct	5% drought	9 SR	9	0.086	See PES.
	35% maintenance	8.2 SR	8.2	0.178	This fish stress level will maintain some FS while FI and FD may be lost which may be reflected by a critical decrease in abundance, resulting in decreased FROC.

Month	% Stress duration	Component stress	Integrated stress	Flow m ³ /s	Comment
Feb	5% drought	4.5 LSR	4.5	0.708	See PES.
	35% maintenance	4 SR	4	0.8	FS habitats will be reduced, with some FD and FI still available. It can be expected that this change in habitats (from present conditions) will result in decreased FROC.

16.3.1 Final low flow requirements

To produce the final results (Figure 16-3), the DRM results for the specific category are modified according to specialists' requirements (Figure 16-1 and 16-2). The following changes were required:

- Seasonal distribution factors changed (>8) and edited manually:
 - 0 B EC: Maintenance changed to 1.94.
 - 0 C EC: Maintenance changed to 3.0.
 - 0 D EC: Maintenance changed to 3.5.

Dry Season (October)

Wet Season (February)

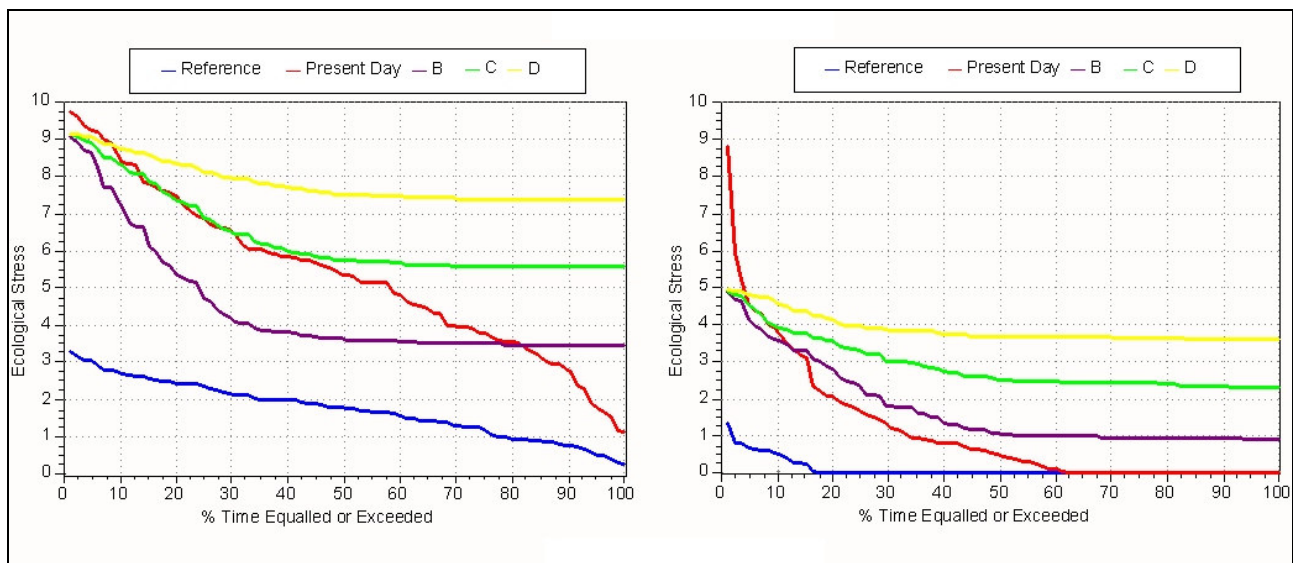


Figure 16-3 EWR 7: Final stress requirements for low flows

16.4 HIGH FLOW REQUIREMENTS

High low classes were identified as outlined in Section 4.4. Results are provided in Table 16.3 and detailed motivations provided in Table 16.4.

Table 16.3 Identification of instream functions addressed by the identified floods for geomorphology and riparian vegetation

FLOOD CLASS	FLOOD RANGE (m ³ /s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions						Macroinvertebrate flood functions					
			Migration cues	Migration habitat (depth etc.)	Clean spawning habitat	Spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas	Reset water quality
I	5 - 8	Vegetation: Required to inundate the marginal zone; activates and inundates portions of <i>P. mauritianus</i> and <i>S. mucronata</i> .	√	√	√	√	√	√	√		√	√	√	√
II	8 – 12	Geomorphology: This flow class is responsible for about 20% of the PBMT. These flows would inundate the active low bench on the right bank and scour fines from the bed; activating the gravels and some smaller cobbles. Vegetation: Inundates marginal zone reed beds and about 50% of the lower zone. Inundates the upper limit of <i>S. mucronata</i> , and activates the lower limit of <i>F. sycomorus</i> .	√	√	√	√	√	√	√		√	√	√	√
III	17	Geomorphology: This flow class represents the effective discharge for this site under present day flow conditions. It is responsible for approximately 35% of the PBMT at the site. These flows would inundate and activate the benches on both the left and right banks, and scour fines and activate the gravels and small cobbles.	√	√	√	√	√	√	√					
IV	25 – 80	Geomorphology: This flow class is responsible for about 20% of the PBMT. These flows would scour inundate the active low bench on the right bank, as well as scour the bed; activate the cobbles and allow for deposition within the dense vegetation of the benches. Vegetation: Inundates the lower zone and portions of the upper zone; activates and maintains <i>S. cordatum</i> and <i>F. sycomorus</i> populations.	√	√	√	√	√	√	√					
V	> 130	Vegetation: Activates the lower limit of <i>Acacia robusta</i> on the upper zone.	√	√	√	√	√	√	√					

Further information is provided in Appendix H, Table E10.

The number of high flow events required for each EC is provided in Table 16.4. No observed daily data was available to check flood requirements against.

Table 16.4 EWR 7: The recommended number of high flow events required

FLOOD CLASS	FLOOD RANGE (m ³ /s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (No of events)	MONTHS	DAILY AVERAGE (m ³ /s)	DURATION (Days)
PES SCENARIO: C									
I	5 - 8	4		4		4	Nov, Dec, Jan, Mar	5	3
II	8 – 12	2		1	2	2	Jan, Feb	8	3
III	(17)				1	1	Feb	20	4

FLOOD CLASS	FLOOD RANGE (m ³ /s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (No of events)	MONTHS	DAILY AVERAGE (m ³ /s)	DURATION (Days)
IV	25 – 80			1:2	1:3	1:2			
V	> 130			1:3 +		1:3			
REC SCENARIO: B									
I	5 - 8	4		4		4	Nov, Dec, Jan, Mar	5	3
II	8 – 12	2		2	3	3	Dec, Jan, Feb	8	3
III	(17)				1	1	Jan	15	4
IV	25 – 80			1	1:3	1	Feb	25	4
V	> 130			1:3		1:3			
AEC SCENARIO: D									
I	5 - 8	2		2		2	Dec, Mar	6	3
II	8 – 12	2		1	2	2	Jan, Feb	12	4
III	(17)				1:2	1:2	Feb	15	4
IV	25 – 80			1:2	1:5	1:2			
V	> 130			1:3		1:3			

16.5 FINAL FLOW REQUIREMENTS

The low and high flows were combined to produce the final flow requirements for each EC as:

- An EWR table, which shows the results of high flows and low flows for each month separately (Table 16.5 – 16.6). Floods with a frequency higher than 1:1 is not included.
- An EWR rule table which provides the recommended EWR flows as a duration table, showing flows which should be provided when linked to a natural trigger (natural modelled hydrology in this case). EWR rules are supplied for total flows as well as for low flows only (Appendix H, Section H2.4).

Table 16.5 EWR table for PES: C

Desktop version:		2	Virgin MAR (MCM)	169.018
BFI index	0.558	Distribution type		Eastern escarpment
MONTH	LOW FLOWS		HIGH FLOWS	
	Maint ¹	Drought	Daily average (m ³ /s) on top of base flow	Duration (days)
OCTOBER	0.374	0.090		
NOVEMBER	0.551	0.200	5	3
DECEMBER	0.735	0.320	5	3
JANUARY	0.924	0.430	5 8	3 3
FEBRUARY	1.245	0.620	8 20	3 4
MARCH	1.204	0.610	5	3
APRIL	1.141	0.560		
MAY	0.991	0.470		
JUNE	0.903	0.410		

Desktop version:		2	Virgin MAR (MCM)	169.018
BFI index	0.558	Distribution type		Eastern escarpment
MONTH	LOW FLOWS		HIGH FLOWS	
	Maint ¹	Drought	Daily average (m ³ /s) on top of base flow	Duration (days)
JULY	0.711	0.300		
AUGUST	0.506	0.160		
SEPTEMBER	0.366	0.070		
TOTAL MCM	25.271	11.089	9.248	
% OF VIRGIN	14.95	6.56	5.47	

Table 16.6 EWR table for REC: B

Desktop version:		2	Virgin MAR (MCM)	169.018
BFI index	0.558	Distribution type		Eastern escarpment
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m ³ /s)	Drought (m ³ /s)	Daily average (m ³ /s) on top of base flow	Duration (days)
OCTOBER	0.918	0.090		
NOVEMBER	1.204	0.200	5	3
DECEMBER	1.477	0.320	5 8	3 3
JANUARY	1.769	0.430	5 8 15	3 3 4
FEBRUARY	2.302	0.620	8 25	3 4
MARCH	2.202	0.610	5	3
APRIL	2.116	0.560		
MAY	1.873	0.470		
JUNE	1.748	0.410		
JULY	1.439	0.300		
AUGUST	1.123	0.160		
SEPTEMBER	0.917	0.070		
TOTAL MCM	50.012	11.089	14.155	
% OF VIRGIN	29.59	6.56	8.37	

Table 16.7 EWR table for AEC: D

Desktop version:		2	Virgin MAR (MCM)	169.018
BFI index	0.558	Distribution type		Eastern escarpment
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m ³ /s)	Drought (m ³ /s)	Daily average (m ³ /s) on top of base flow	Duration (days)
OCTOBER	0.140	0.090		
NOVEMBER	0.216	0.200		
DECEMBER	0.295	0.320	6	3
JANUARY	0.377	0.430	12	4
FEBRUARY	0.512	0.620	12 15	4 4
MARCH	0.497	0.610	6	3
APRIL	0.469	0.560		
MAY	0.405	0.470		
JUNE	0.367	0.410		
JULY	0.285	0.300		

Desktop version:	2	Virgin MAR (MCM)	169.018
BFI index	0.558	Distribution type	Eastern escarpment
MONTH	LOW FLOWS		HIGH FLOWS
	Maintenance (m³/s)	Drought (m³/s)	Daily average (m³/s) on top of base flow
AUGUST	0.197	0.160	
SEPTEMBER	0.136	0.070	
TOTAL MCM	10.200	11.089	8.942
% OF VIRGIN	6.03	6.56	5.29

A comparison between the Desktop Reserve Model estimates and the EWR results in terms of percentages of natural flow are provided in Table 16.8.

Table 16.8 Modifications made to the DRM for EWR 7

Changes	PES C		REC B		AEC D	
	DRM	EWR	DRM	EWR	DRM	EWR
MLIFR - Maintenance low flow	18.9	14.9	32.9	29.6	10.4	6.0
DLIFR - Drought low flow	10.4	6.6	10.4	6.6	10.4	6.6
MHIFR - Maintenance high flow	6.8	6.4	8.2	7.4	5.8	5.3
Long-term % of virgin MAR	29.3	23.0	40.3	36.8	24.6	16.4

17 CONCLUSIONS AND RECOMMENDATIONS

The following process was followed to identify realistic recommendations:

- Identify the confidences associated with the low and high flow results; and
- based on this, make realistic recommendations on any work that can be undertaken to improve the confidences.
- Evaluate whether these recommendations can be accommodated in a monitoring programme that should follow EWR assessments or whether specific work is required.

17.1 SUMMARY OF FINAL RESULTS

The final flow requirements are expressed as a percentage of the natural MAR in Table 17.1. The natural MARs are provided below:

EWR 1	15.2 MCM
EWR 2	47.1 MCM
EWR 3	194.9 MCM (Present hydrology - 169.9 MCM)
EWR 4	754.1 MCM
EWR 5	1006.2 MCM
EWR 6	1063.1 MCM
EWR 7	169 MCM

Table 17.1 Summary of results as a percentage of the natural MAR

EWR site	EC ¹	Maintenance low flows (%nMAR)	Drought low flows (%nMAR)	High flows (%nMAR)	Long term mean (% nMAR)
EWR 1	A/B PES, REC	38.0	15.5	9.4	30.9
	B/C AEC	25.8	15.5	9.4	24.4
EWR 2	B PES, REC	42.2	16.5	6.2	57
	C AEC	20.4	16.5	5.4	37
EWR 3	B/C PES	44	18.1	9.8	>55.2
	B REC	A time series of requirements could not be generated as improvement of the PES required flows to be set higher than the reference time series (present day), during the wet season.			
EWR 4	B PES, REC	28.7	9.9	6.2	34.5
	C/D AEC	13.2	9.9	5.1	21.3
EWR 5	C PES	21.3	12.1	5.3	30
	B REC	34.7	12.1	7.4	41.2
	D AEC	12.1	12.1	2.9	21.3
EWR 6	C PES	13.9	10.6	7.4	24.9
	B REC	27.3	10.6	13.2	41.1
	D AEC	11.6	4.5	4.6	14.3
EWR 7	C PES	14.9	6.6	6.4	23
	B REC	29.6	6.6	7.4	36.8
	D AEC	6	6.6	5.3	16.4

¹ Refer to Report 26/8/3/10/12/009 (DWA, 2009).

17.2 CONFIDENCES

17.2.1 Confidence in low flow EWR

The question that the confidences should answer is the following:

‘How confident are you that the low flow (with the associated high flows) recommended will achieve the EC?’

To determine the confidence, one should consider:

- The quality of available data; and
- whether the component requirement represents the critical requirement. For example, if the macroinvertebrate stress requirement of a 4 at 30% was the final recommendation, and fish was 7 at 30%, then fish should have very high confidence that the recommended flow will achieve the EC. The reason is that the fish will receive more flow than required, so even if the fish data availability and understanding of habitat requirements are of low confidence, the confidence that this much higher recommended requirement based on macroinvertebrates will cater for fish requirements should result in high confidence that the EC will be maintained and/or achieved.

Table 17.2 provides the confidence for the low flow biotic components (fish, macroinvertebrates and riparian vegetation). The shaded green columns indicate which of these components dictated the final requirements. The final confidence is representative of these requirements. If both drove the flow requirement, then an average of the confidence was be provided.

Confidence rating used in this Chapter are as follows:

- 1: Very low confidence
- 2: Low confidence
- 3: Medium confidence
- 4: High confidence
- 5: Very high confidence

Table 17.2 Confidence in low flows for biotic responses

EWR SITE	FISH	MACROINVERTEBRATES	RIPARIAN VEGETATION	COMMENT	OVERALL CONFIDENCE
EWR 1	5	4	4	<p>Fish: The dry season flows and wet season drought flows are driven by the macroinvertebrates. Wet season maintenance flows are driven by riparian vegetation. These flows exceeds the requested flows (maximum allowable stress levels) for BANO by a large margin and it can be expected that the requested flows will be more than adequate to sustain BANO within the PES and AEC EcoStatus. . The requirements and habitat preferences of different life stages of this species had also been well documented. The data and information gathered during the present study regarding this species at this specific EWR was very good.</p> <p>Macroinvertebrates: The macroinvertebrates are driving the low flows during both the dry and wet seasons. The flows recommended will allow enough habitat for all three indicator taxa. The available data shows that all three indicator taxa occur at a B abundance in most of the samples collected during the last eleven years (1996 to 2007).</p> <p>Riparian vegetation: <i>Juncus</i> and FDI are driving the wet season maintenance requirements, but due to the low confidence in the process, the FDI confidence should be applicable. For all the other flows, the FDI requirements are much higher than the riparian vegetation requirements.</p>	4

EWR SITE	FISH	MACROINVERTEBRATES	RIPARIAN VEGETATION	COMMENT	OVERALL CONFIDENCE
EWR 2	4	4	5	<p>Fish: The wet and dry season fish stress levels are the determining factors for setting flows at this site. Although the stress levels are relatively high for the indicator group in some cases, it is estimated that the required flows should provide adequate habitats for all life stages of the indicator guild (small rheophilic) to sustain viable assemblages and maintain the fish within the required EC. The requirements and habitat preferences of different life stages of some of these species are well documented. The data and information gathered regarding this species specifically sampled at this EWR site is also good.</p> <p>Macroinvertebrates: The macroinvertebrates are not driving the low flows during both the dry and wet seasons. The flows provided are more than those requested and will allow enough habitat for all three indicator taxa. The available data shows that Perlidae only occurred once at an abundance of A, Heptageniidae occurred mostly at a B abundance and Tricorythidae occurred regularly at a B abundance. The data set includes data from dry and wet years, 1996 to 2007.</p> <p>Riparian vegetation: Confidence that integrated stress flow will achieve objectives for riparian vegetation (i.e. maintain site at A EC) as more flow is being provided as recommended for the riparian vegetation.</p>	4
EWR 3	4	2	4	<p>Fish: The flows are driven by macroinvertebrate requirements and therefore exceed the requirements as set for fish. It can therefore be expected that fish requirements will at least be met and probably exceeded during the wet season, for both the PES and REC. Requirements of different life stages of the indicator guild for fish should therefore be met during both the wet and dry season. The requirements and habitat preferences of different life stages of some of these species is well documented. The data and information gathered regarding this species specifically sampled at this EWR site is also good.</p> <p>Macroinvertebrates: The macroinvertebrates are driving the requirements. Setting requirements are complicated due the lack of understanding of the impact of the changed seasonal patterns. Due to the uncertainty whether the recommended flow will achieve the PES and REC, the confidence is low even though extensive survey data exists for this site.</p> <p>Riparian vegetation: Confidence that integrated stress flow will achieve objectives for riparian vegetation (i.e. maintain site at desired category)</p>	2
EWR 4	4	4	4	<p>Fish: Requested flows are driven by fish requirements and the flows set should be adequate to create adequate habitat for all requirements of different life stages. Two indicator groups were used (SR and LSR guild), covering a range of habitats and flows that should be adequate to sustain all fish species expected at site. Requirements of different life stages of the indicator guild for fish should therefore be met during both the wet and dry season. The requirements and habitat preferences of different life stages of the indicator species are well documented. The data and information gathered regarding these species specifically sampled at this EWR site is moderate. Hydraulic information for pool and riffle habitats available (low confidence in hydraulic conversions to fish stress and habitat compositions).</p> <p>Macroinvertebrates: The fish requirements are driving the low flows during both the dry and wet seasons. The flows provided are more than those requested and will allow enough habitat for all three indicator taxa. The available data shows that Perlidae only occurred during wetter years at an abundance of A, Heptageniidae occurred mostly at an A abundance and Elmidae occurred regularly at A or B abundances. The data set includes data from dry and wet years between 1993 to 2007</p> <p>Riparian vegetation: Although the stress process required higher flows than the instream biota, this was ignored due to low confidence in the stress interpretation for vegetation. Following the normal approach of checking the instream requirements to determine adequacy for vegetation using the profile and hydraulics, the confidence is high that these flows will maintain/achieve the vegetation ECs.</p>	4
EWR 5	4	2.5	3	<p>Fish: Requested flows for the PES, REC and AEC (except wet season maintenance) are driven by fish requirements (varying between two indicator groups) and the flows set should be adequate to create adequate habitat for all requirements of different life stages. Two indicator groups were used (SR and LSR), covering a range of habitats and flows that should be adequate to sustain all fish species expected at site. Requirements of different life stages of the indicator guild for fish should also be met during both the wet and dry season. The requirements and habitat preferences of different life stages of the indicator species are well documented. The data and information gathered regarding these species during the current study at this EWR site is moderate.</p> <p>Macroinvertebrates: The recommended flows for the PES, REC and AEC (wet season maintenance) are based on the requirements of the MVI. At the flows set there is enough inundated vegetation is present for indicator taxa to thrive. Under these conditions aquatic vegetation will be available to provide adequate habitat for the selected taxa.</p> <p>Riparian vegetation: Confidence that integrated stress flow will achieve objectives for riparian vegetation (i.e. maintain site at desired category).</p>	4
F	4	4.5	4	Fish: See EWR 5.	4

EWR SITE	FISH	MACROINVERTEBRATES	RIPARIAN VEGETATION	COMMENT	OVERALL CONFIDENCE
				<p>Macroinvertebrates: The recommended flows are driven by fish and are considerably more than what was requested by the invertebrates. Although there is only limited data available for this site, it is highly unlikely that the invertebrates will not attain the required categories for the specified flows.</p> <p>Riparian vegetation: Confidence that integrated stress flow will achieve objectives for riparian vegetation (i.e. maintain site at the desired category).</p>	
EWR 7	4	4	4	<p>Fish: Requested flows for PES, REC and AEC are driven by fish requirements (varying between two indicator groups) and the flows set should be adequate to create adequate habitat for al requirements of different life stages. Two indicator groups were used (SR and LSR guild), covering a range of habitats and flows that should be adequate to sustain all fish species expected at site. Requirements of different life stages of the indicator guild for fish should also be met during both the wet and dry season. The requirements and habitat preferences of different life stages of the indicator species are well documented. The data and information gathered regarding these species during the current study at this EWR site is good.</p> <p>Macroinvertebrates: The recommended flows are driven by fish and are considerably more than what was requested by the invertebrates. Although there is only limited macroinvertebrate data available for this site, it is highly unlikely that the macroinvertebrates will not attain the required categories for the specified flows.</p> <p>Riparian vegetation: Confidence that integrated stress flow will achieve objectives for riparian vegetation (i.e. maintain site at the desired category).</p>	4

17.2.2 Confidence in high flow EWR

The question that the confidences should answer is the following:

‘How confident are you that the high flow (with the associated high flows) recommended will achieve the EC?’

To determine the confidence, one should consider

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

The high flow confidence (Table 17.3) represents an average of the riparian vegetation and geomorphology confidence as these two components determine the flood requirements.

Table 17.3 Confidence in high flows

EWR SITE	FISH	MACROINVERTEBRATES	RIPARIAN VEGETATION	GEOMORPHOLOGY	COMMENT	OVERALL CONFIDENCE
EWR 1	4.5	3	4	3	<p>Fish: The recommended floods are adequate in terms of frequency, size and duration to provide various functions regarding fish migration, creation of migration and spawning habitats (flooded vegetation) and nursery areas.</p> <p>Macroinvertebrates: The recommended floods are adequate in terms of frequency, size and duration to provide various functions (clearing fines, scouring the substrate, providing breeding and hatching cues and flooding the vegetation to provide extra habitat).</p>	3.5

EWRS SITE	FISH	MACROINVERTEBRATES	RIPARIAN VEGETATION	GEOMORPHOLOGY	COMMENT	OVERALL CONFIDENCE
					<p>Riparian vegetation: Sufficient vegetation survey points to assess flow requirements.</p> <p>Geomorphology: Very little data is available – there are no daily flow records to evaluate the requested flows against present day flows; and this lack of daily observed flows precluded sediment transport analysis for this site. However, due to the depositional alluvial nature of the reach, morphological cues are present and well developed. Flood flow requests are based upon the morphological cues of the site and reach, and the final integrated flood request is higher than was requested by the geomorphological cues alone. Therefore a moderate confidence despite the paucity of data.</p>	
EWRS 2	3	3	4	3.5	<p>Fish: The recommended floods should be adequate in terms of frequency, size and duration to provide various functions regarding fish migration, creation of migration and spawning habitats (flooded vegetation) and nursery areas.</p> <p>Macroinvertebrates: The recommended floods are adequate in terms of frequency, size and duration to provide various functions (clearing fines, scouring the substrate, providing breeding and hatching cues and flooding the vegetation to provide extra habitat.</p> <p>Riparian vegetation: High quality hydraulic data available and vegetation survey points adequate. Channel shape is simple so increases confidence in estimate.</p> <p>Geomorphology: Previous PBMT results were available, although this was conducted with modelled virgin flow data (not observed daily flows). Again at this site there are no daily flow records available to evaluate the requested flows against present day flows. However, due to the depositional alluvial nature of the reach, morphological cues are present and relatively well developed. Flood flow requests are based upon both PBMT modelling and the morphological cues of the site and reach.</p>	3.8
EWRS 3	3.5	2	4	4	<p>Fish: The recommended floods should be adequate in terms of frequency, size and duration to provide various functions regarding fish migration, creation of migration and spawning habitats (flooded vegetation) and nursery areas.</p> <p>Macroinvertebrates: The recommended floods are adequate in terms of frequency, size and duration to provide various functions (clearing fines, scouring the substrate, providing breeding and hatching cues and flooding the vegetation to provide extra habitat. More floods were requested for the PES category than would have been requested under normal circumstances to improve the variability in the flow.</p> <p>Riparian vegetation: Vegetation survey points adequate. Riparian obligates sufficiently common to facilitate high confidence flow estimation. Hydrological data able to verify flood requirements.</p> <p>Geomorphology: Previous PBMT results were available at this site, as well as some depositional alluvial morphological cues. Although we are fairly confident in the data for this site, the effects of the upstream large dam (the cutting off of sediment supply) will possibly continue to promote incision at the site, and thus degradation as a result of non-flow related factors may result. In an effort to limit this possible continuing incision, the small floods up to the annual event only have been requested.</p>	4
EWRS 4	3.5	3	4	3.5	<p>Fish: The recommended floods should be adequate in terms of frequency, size and duration to provide various functions regarding fish migration, creation of migration and spawning habitats (flooded vegetation) and nursery areas.</p> <p>Macroinvertebrates: The recommended floods are adequate in terms of frequency, size and duration to provide various functions (clearing fines, scouring the substrate, providing breeding and hatching cues and flooding the vegetation to provide extra habitat.</p> <p>Riparian vegetation: High quality hydraulic data available and vegetation survey points adequate. Riparian obligates sufficient for setting high flows and hydrological data able to verify biological requirement.</p> <p>Geomorphology: Fairly good morphological cues combined with available present day as well as virgin condition potential bed material transport (PBMT) results were available. The latter indicated that there has been a significant (65%) decline in the PBMT at this site – essentially the ability of the river at this site to transport sediment loads has been reduced by more than half. This is particularly problematic given that most of the sediment from this catchment arises in the lower areas (where EWR 4 is located). Loss of bedrock-influenced areas, deep pools and reduction in channel width are therefore the likely consequences that have resulted in this reach. Given the large reduction in transport potential, it is critical to maintain as much of the remaining transport potential of the river as possible. The requested flows should allow for this.</p>	3.8
EWRS 5	3.5	3	3	2.5	<p>Fish: The recommended floods should be adequate in terms of frequency, size and duration to provide various functions regarding fish migration, creation of migration and spawning habitats (flooded vegetation) and nursery areas. Receding limb of higher floods classes also provide important functions.</p>	3

EWR SITE	FISH	MACROINVERTEBRATES	RIPARIAN VEGETATION	GEOMORPHOLOGY	COMMENT	OVERALL CONFIDENCE
					<p>Macroinvertebrates: The recommended floods are adequate in terms of frequency, size and duration to provide various functions (clearing fines, scouring the substrate, providing breeding and hatching cues and flooding the vegetation to provide extra habitat.</p> <p>Riparian vegetation: Confidence in hydrological data high, but vegetation indicators not abundant for larger floods.</p> <p>Geomorphology: There are no morphological cues at this site (i.e. no clear terraces or benches within this section of the river). The present state is in a C/D category as a result of the narrowing and stabilization of the active channel (and vegetation encroachment onto the macro-channel floor). Maintenance of the potential for continued transport of sediment will be provided by the requested flow classes, as together these account for more than 70% of the present day PBMT at the site.</p>	
EWR 6	3.5	4	4	4	<p>Fish: The recommended floods should be adequate in terms of frequency, size and duration to provide various functions regarding fish migration, creation of migration and spawning habitats (flooded vegetation) and nursery areas. Receding limb of higher floods classes also provide important functions.</p> <p>Macroinvertebrates: The recommended floods are adequate in terms of frequency, size and duration to provide various functions (clearing fines, scouring the substrate, flushing out the Thiaridae and flooding the vegetation to provide extra habitat</p> <p>Riparian vegetation: High quality hydrology data available and vegetation survey points adequate. Riparian obligates sufficient for setting high flows and hydrological data able to verify biological requirement. Various surveys during recent years have been undertaken and a good photographic record is available.</p> <p>Geomorphology: Due to the strongly bedrock nature of the site, there are no clear morphological cues at this site (i.e. no clear terraces or benches within this section of the river). The present state is in a C category as a result of the narrowing and stabilization of the active channel and some vegetation encroachment onto the macro-channel floor. Maintenance of the potential for continued transport of sediment will be provided by the requested flow classes, together these account for more than 70% of the present day PBMT at the site.</p>	4
EWR 7	3.5	4	2	2.5	<p>Fish: The recommended floods should be adequate in terms of frequency, size and duration to provide various functions regarding fish migration, creation of migration and spawning habitats (flooded vegetation) and nursery areas. Receding limb of higher floods classes also provide important functions.</p> <p>Macroinvertebrates: The recommended floods are adequate in terms of frequency, size and duration to satisfy the required functions, namely clearing fines, scouring the substrate, inundating the marginal vegetation and improving the water quality.</p> <p>Riparian vegetation: Hydrological data is of low confidence. There is also significant lateral seepage on the RB at this site which has obscured the biological response to discharge, and the LB is choked with alien vegetation.</p> <p>Geomorphology: Due to the strongly bedrock nature of the site, there are few morphological cues at this site against which to verify the effective discharge/s for the site. The present state is in a B category. To maintain the PES, it is necessary to maintain the potential for continued transport of sediment through the site. This will be achieved by the requested flow classes, as together these account for more than 70% of the present day PBMT at the site. The confidence is however somewhat low due to the limited confidence in the available hydrology (no nearby gauges) and moderate confidence hydraulics for the site, since these factors directly affect the confidence of the PBMT modelling results.</p>	2.3

17.2.3 Hydrology confidence

Note: if natural hydrology is 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 EWR assessments. This will be different than the confidence in the hydrology for water resources management and planning. The scale of requirements is very different, and that is why high confidence hydrology for water resource management purposes often does not provide sufficient confidence for EWR assessment. The confidence in hydrology for the respective EWR sites is provided in Table 17.4.

Table 17.4 Confidence in hydrology

EWR site	Natural hydrology	Present hydrology	Observed hydrology	Local knowledge / information	Comment	Confidence: Median	Confidence: Average
1	3	2	0	2	Due to the lack of any gauges to calibrated hydrology against, it does influence the hydrology confidence. Present day hydrology uncertain due to lack of information on present uses.	2	1.8
2	3	2	0	2	See above.	2	1.8
3	4	3	3	3	The downstream gauge as well as information from Kwena Dam provides more reliable information in both the observed data as well as the modeled data.	3	3.3
4	3	2	1	1	The hydrology is complicated due to the large amount of return flows, and abstractions occurring in the immediate vicinity of the site. The nearby gauge probably does not measure the highest range of high flows, and as there are abstractions immediately from the gauge, uncertainty exist regarding how to read the measurements.	1.5	1.8
5	4	1	2	3	Even through the present day modeling is of high confidence for water resource modeling, it does not cater for site specific information required. The large number of abstractions and return lows that result in very different flows at the site than those modeled, leads to confusion. The monthly modeling also does not demonstrate the daily fluctuations which are present. The gauge is situated quite a distance from the site and even though providing good information on floods, it is not necessarily relevant for the baseflows due to abstractions between the EWR site and the gauge. The uncertainty around the trans-boundary flows adds to the low confidence.	2.5	2.5
6	4	1	3	3	See above.	3	2.8
7	3	2	1	2	There is only one gauge far downstream of the site in the system that provides useful information.	2	2

17.2.4 Overall confidence

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

- If the hydraulics confidence is lower than the biological responses confidence, the hydraulics confidence determines the overall confidence. Hydrology confidence is also considered, especially if used to guide the requirements.
- If the biological confidence is lower than the hydraulics confidence, the biological confidence determines the overall confidence. Hydrology confidence is also considered. If hydrology is used to guide requirements, than that confidence will be overriding.

Colour coding of confidences in Table 17.5 – 17.6 are as follows:

Green: High to Very High

Yellow: Medium to high

Red: Very low to Medium

Table 17.5 Overall Confidence in EWR Results

EWR SITE	HYDROLOGY	LOW FLOWS			COMMENT	HIGH FLOWS			COMMENT
		BIOLOGICAL RESPONSES	HYDRAULICS	BIOLOGICAL RESPONSES		BIOLOGICAL RESPONSES	HYDRAULICS	BIOLOGICAL RESPONSES	
EWR 1	2	4	4	4	Biological responses high as well as hydraulics. The hydraulic requirements for low flows largely within the range of measured flows.	3.5	3.5	3.5	All the smaller floods fall within the range of measured flows.
EWR 2	2	4	4	4	Biological responses high as well as hydraulics. The hydraulic requirements for low flows largely within the range of measured flows.	3.8	3	3	Some of the floods fall outside the range of measured flows which results in hydraulic being of a lower confidence than the biophysical responses.
EWR 3	3	2	5	2	Various calibrations available for this site since 1999. This resulted in high confidence in the hydraulics. However, due to the lack of understanding around the invertebrates, the confidence is low.	4	3	3	Some of the floods fall outside the range of measured flows which results in hydraulic being of a lower confidence than the biophysical responses.
EWR 4	1.5	4	1	1	This cross-section was very badly selected during previous EWR studies and do not provide any low flow cues nor any useful hydraulics at low flows. Another section was selection downstream of the old section. As only one hydraulic calibration could be obtained, the confidence was very low.	3.8	4	4	All the small and moderate floods fall within the range measured.
EWR 5	2.5	4	3.5	3.5	Biological responses high as well as hydraulics. The hydraulic requirements for low flows largely within the range of measured flows. The site does not provide good habitat, however site selection is problematic in this area with safety and access playing an overriding role.	3.3	4	3.3	Riparian vegetation is the factor that results in a lower biophysical confidence. This is due to the absence of cues at the site and therefore uncertainty in the flooding requirements.
EWR 6	3	4	4	4	Biological responses high as well as hydraulics. The hydraulic requirements for low flows largely within the range of measured flows. There is some uncertainty in flow class modelling as the site is bedrock dominated.	3.8	4	4	Limited range of measured flows but the small and moderate floods should maintain sediment transport at this site.
EWR 7	2	4	3	3	Complex site. Low flows set are below measurements. There is uncertainty in flow class modelling. The hydraulics therefore is the overriding factor with regards to confidence.	2.3	3	2.5	Both riparian and geomorphology cues are lacking and confusing, resulting in a low confidence in the high flows.

17.3 RECOMMENDATIONS

The biological confidences for the low flows are all High apart from EWR 3 which is Low. The low confidence at EWR 3 is due to the lack of understanding of the macroinvertebrate response to changed seasonality and the increase of flows above natural. This confidence can be improved through Ecological Water Resource Monitoring (EWRM). The hydraulic confidences for the low flows range from moderate to very high at all the sites apart from EWR 4. EWR 4 is low due to the badly placed cross-section as selected during the 2002 EWR study. This cross-section cannot supply adequate information for low flows. If scenarios result in flows at or lower than recommended, it will be useful to update the hydraulics of the new cross-section and verify the low flow requirements.

The overall confidence in the low flows range from Very Low to High. The two sites with a Very Low (hydraulics) and Low rating (biota) is EWR 4 and 3 respectively. The reasons are provided in the paragraph above. Sites with moderate confidence do not require specific work to improve confidence. It must be noted that improving confidence in biota from moderate is hardly ever recommended. EWRs should rather be monitored to confirm basic assumptions in EWR assessments.

The confidences in the high flows range from Moderate to High at all the sites apart from the biophysical confidence at EWR 7 (confidence: 2.3). This low confidence is due to the lack of geomorphological and riparian vegetation cues at the site and can therefore be attributed to the nature of the site, rather than a lack of information or knowledge. Additional work will not improve this confidence.

Additional work to improve the moderate confidences for the high flows is not recommended as high flows cannot be managed at any of the sites apart from EWR 3 (which has a high biophysical confidence in any case).

It is strongly recommended that an EWRMP with the application of the Rapid Habitat Assessment Method (RHAM) programme be initiated as soon as possible. The information gathered during this study is suitable for the baseline, but if too much time elapses between the baseline and monitoring, new surveys and the EcoClassification process will have to be undertaken. A summary of the recommendations is provided in Table 16.6.

Table 17.6 Summary of recommendations required to improve confidences

EWR sites	Low flow confidence	High flow confidence	Recommendations
EWR 1	4	3.5	EWRM
EWR 2	4	3	EWRM.
EWR 3	2	3	EWRM
EWR 4	1	4	The hydraulics for EWR 4 should be updated with sufficient low flow calibrations to improve the low flow confidence. EWRM.
EWR 5	3.5	3.3	This site is not a good site in terms of providing sufficient cues for EWR assessment, neither for hydraulic analysis. As EWR 6 is the critical site, this site should be seen as supplementary to EWR 6. EWRM.
EWR 6	4	4	EWRM
EWR 7	3	2.5	EWRM.

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