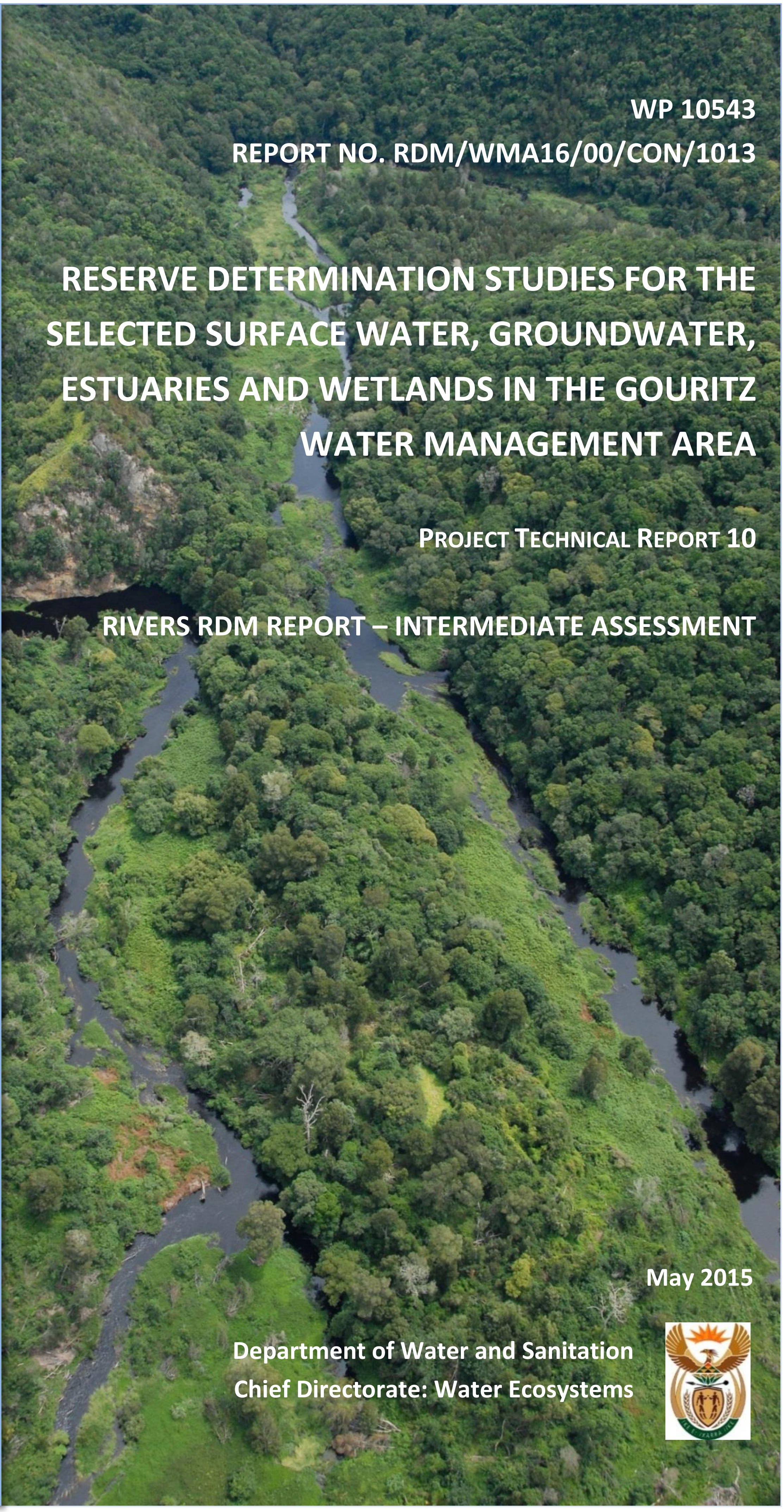

WP 10543

REPORT NO. RDM/WMA16/00/CON/1013

RESERVE DETERMINATION STUDIES FOR THE SELECTED SURFACE WATER, GROUNDWATER, ESTUARIES AND WETLANDS IN THE GOURITZ WATER MANAGEMENT AREA

PROJECT TECHNICAL REPORT 10

RIVERS RDM REPORT – INTERMEDIATE ASSESSMENT

May 2015

Department of Water and Sanitation
Chief Directorate: Water Ecosystems

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DOCUMENT INDEX

Reports as part of this project:

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Report Number 02	RDM/WMA16/00/CON/0213	Desktop EcoClassification Report
Report Number 03, Volume 1	RDM/WMA16/00/CON/0313, Volume 1	Delineation Report, Volume 1 (Groundwater, Estuaries and Wetlands)
Report Number 03, Volume 2	RDM/WMA16/00/CON/0313, Volume 2	Delineation Report, Volume 2 (Rivers)
Report Number 04	RDM/WMA16/02/CON/0413	Groundwater Report
Report Number 05	RDM/WMA16/03/CON/0513	Wetland Report
Report Number 06, Volume 1	RDM/WMA16/04/CON/0613, Volume 1	Estuaries RDM Report – Desktop Assessment
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Report Number 07, Volume 1	RDM/WMA16/04/CON/0713, Volume 1	Estuaries RDM Report – Rapid Assessment, Volume 1 (Klein Brak Estuary)
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Report Number 11	RDM/WMA16/01/CON/1113	Rivers RDM Report – Rapid Assessment
Report Number 12	RDM/WMA16/00/CON/1213	Monitoring Report
Report Number 13	RDM/WMA16/00/CON/1313	Main Report
Report Number 14	RDM/WMA16/00/CON/1413	Study Closure Report

Bold indicates this report.

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DATE:	May 2015
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Prof Denis Hughes of the Institute for Water Research, Rhodes University, produced the EWR outputs from the Revised Desktop Reserve Module.

REPORT SCHEDULE

Version	Date
First draft	May 2015
Final report	October 2015

EXECUTIVE SUMMARY

INTRODUCTION

This report documents the results of the EcoClassification and quantification of the Ecological Water Requirements (EWR) at selected EWR sites in the study area, using the Intermediate Ecological Reserve Methodology (IERM) (DWAF, 1999). Associated with the IERM is the EcoClassification process at Level IV.

EWR SITES

A total of ten Ecological Water Requirements (EWR) sites were selected in the study area. EWRs have already been determined for five sites situated in the Duiwenhoks, the Goukou, the Doring, the Olifants and the Kammanassie rivers and the results are documented in DWS (2014). This report focusses on the EWR determination at the remaining five EWR sites which were assessed following the Intermediate Ecological Reserve Methodology (IERM) (DWAF, 1999) and referred to as Intermediate sites. These sites are described in DWA (2014) and listed below.

EWR sites

EWR site name	SQ[1] reach	River	MRU[2]	Latitude	Longitude	Eco-Region (Level II)	Geo[3] Zone	Alt[4] (m)	Quat[5]
J1TOUW-EWR3	J12M-08904	Touws	MRU Touws B	S33.72707	E21.16507	19.07	E Lower Foothills	271	J12M
J2GAMK-EWR4	J25A-08567	Gamka	MRU Gamka B	S33.36472	E21.63051	19.09	E Lower Foothills	375	J25A
J1BUFF-EWR5	J11H-08557	Buffels	MRU Buffels B	S33.38452	E20.94169	19.09	E Lower Foothills	499	J11H
J4GOUR-EWR6	J40B-09106	Gouritz	MRU Gouritz A	S33.90982	E21.65233	19.08	E Lower Foothills	121	J40B
K6KEUR-EWR8	K60C-09882	Keur-booms	MRU Keurbooms B	S33.88955	E23.24392	20.02	D Upper Foothills	161	K60C

1 Sub Quaternary *2 Management Resource Unit* *3 Geomorphic*
4 Altitude *5 Quaternary catchment*

ECOCLASSIFICATION RESULTS

J1TOUW-EWR3: TOUWS RIVER

EIS: HIGH

*Highest scoring metrics in the EIS model were rare and endangered species (*Pseudobarbus asper*); refugia and critical habitat (deep pools for* P. asper*) and importance as migration route as there are no barriers downstream of the EWR site. Six endemic riparian plant species occur here and the site falls within the endangered Muscadel Riviere Vegetation Type. Important riparian migration corridor as the* Acacia karoo *thicket is distinct from the upland vegetation.*

PES: B/C

- *Reduced base flows and small floods due to farm dams and irrigation and impacts the wet season duration period.*
- *Deteriorated water quality (nutrients) due to agriculture.*
- *Bank modification and instability due to alien invasive vegetation and agricultural practices in the riparian zones.*
- *Alien vegetation species occur in the reach.*

REC: B/C

The EIS was HIGH and the REC should be set to improve the PES. However there is uncertainty in what aspects need to improve as the impacts and the causes are not well understood and known. Currently there is insufficient hydrological data to recommend improved flows to achieve a REC of a B and verification of water use in the area and the re-evaluation of the hydrology and calibration with gauged data would be required. Also many of the vegetation cues were obscured by the big floods during Jan 2014 and biomonitoring of these impacts would be required to determine and confirm the extent of impact on the site.

Component	PES and REC
IHI Hydrology	B/C
Water quality	B/C
Geomorphology	B
Fish	C/D
Invertebrates	B/C
Instream	C
Riparian vegetation	B/C
EcoStatus	B/C
Instream IHI	C
Riparian IHI	C
EIS	HIGH

J2GAMK-EWR4: GAMKA RIVER	
EIS: HIGH *Highest scoring metrics in the EIS model were rare and endangered species (*P. asper*) and diversity of habitat types and features. Five endemic riparian species occur at the site; diversity of riparian/wetland habitat types and features are present and the distinct band of dense woody vegetation provides an effective corridor through a terrestrial landscape that is characterised by sparse, short vegetation and extreme topography.* ***PES: C/D*** ▪ *Altered flow regime due to decreased base flows and flooding events and zero flows at times due to unseasonal and regular flood releases from the Gamkapoort Dam as well as the decreased large floods.* ▪ *Increased turbidity due to dam releases.* ▪ *Presence of alien vegetation species.* ▪ *Predation and competition from alien and non-indigenous fish species.* ***REC: C*** *The EIS was HIGH and the REC was therefore set to improve the PES by:* ▪ *Larger flood releases improving geomorphology.* ▪ *Reducing nutrients although the source of the nutrients must first be identified.* ▪ *Increasing frequency of floods in the summer with less flow regulation (unseasonal floods improving riparian vegetation).* ▪ *Eradicating alien fish species which would be ideal, although this is unlikely. The improvements required for vegetation (previous bullet) is likely to improve the fish as well as the macroinvertebrate community.*	see table below

Component	PES	REC
IHI Hydrology	C/D	
Geomorphology	D	C
Water quality	B/C	B
Fish	C/D	C
Invertebrates	C/D	B/C
Instream	C/D	C
Riparian vegetation	D	C
EcoStatus	C/D	C
Instream IHI	C	
Riparian IHI	C/D	
EIS	HIGH	

J1BUFF-EWR5: BUFFELS RIVER	
EIS: MODERATE *Highest scoring metrics in the EIS model were rare and endangered species (*P. asper*); refugia and critical habitat (deep pools for* P. asper*). Five endemic riparian species occur at the site and there is a diversity of riparian/wetland habitat types and features. An effective riparian/wetland migration corridor is provided by dense woody vegetation (mostly* A. karoo*) but is also diverse due to the presence of pools dominated by grass and sedge that are utilised by waterfowl.* ***PES: C*** ▪ *Decreased baseflows as well as reduced flood frequencies due to Floriskraal Dam. The seasonal distribution of baseflow is greatly affected with the period Mar to Sep showing a significant decrease in flows from natural.* ▪ *Deteriorated water quality and increased water temperatures.* ▪ *Increased woody vegetation encroachment.* ***REC: C*** *The EIS was MODERATE and the REC was therefore set to maintain the PES.*	see table below

Component	PES and REC
IHI Hydrology	D
Geomorphology	D
Water quality	C
Fish	B/C
Invertebrates	C
Instream	C
Riparian vegetation	D
EcoStatus	C
Instream IHI	D
Riparian IHI	D
EIS	MODERATE

J4GOUR-EWR6: GOURITZ RIVER

EIS: MODERATE

*Highest scoring metrics in the EIS model were rare and endangered species (*P. asper*); important migration corridor as it occurs in a larger catchment that fish could move through and there are no barriers downstream of the EWR site. Five endemic riparian species occur at the site*

PES: C

- *Baseflows as well as a decrease in volume, frequency and distribution of moderate-sized floods have occurred due to irrigation, groundwater abstraction, grazing, large dams and domestic water use.*
- *These activities have resulted in deteriorated water quality (high salinity and elevated nutrients).*
- *Some invasion by alien species and overgrazing in the upper and Macro Channel Bank zones is present.*
- *Alien fish species also occur in the reach.*

REC: C

The EIS was MODERATE and the REC was therefore set to maintain the PES.

Component	***PES and REC***
IHI Hydrology	***C***
Geomorphology	***B***
Water quality	***B/C***
Fish	***D***
Invertebrates	***C***
Instream	***C***
Riparian vegetation	***B/C***
EcoStatus	***C***
Instream IHI	***C/D***
Riparian IHI	***C***
EIS	***MODERATE***

K6KEUR-EWR8: KEURBOOMS RIVER

EIS: HIGH

*Highest scoring metrics in the EIS model were rare and endangered species (*P. asper*); unique species (*Pseudobarbus cf. tenuis*); species intolerant to physico-chemical changes and important migration route as the site is located in the lower part of the system and the reach is important for eel migration. Three rare and endangered riparian/wetland species were present as well as two endemic species.*

PES: C

- *Reduced baseflows, flood frequency.*
- *Deteriorated water quality during the dry season due to abstraction (and return flows) for agriculture.*
- *Flow reduction due to extensive forestry plantations in the catchment.*
- *High occurrence of alien plantation species which encroach the natural habitat as well as vegetation clearing.*

REC: B/C

The EIS was HIGH and the REC was therefore set to improve the PES by:

- *Removal of alien vegetation.*
- *Improvement in baseflows.*

Component	***PES***	***REC***
IHI Hydrology	***B***	
Water quality	***B***	***B***
Geomorphology	***B/C***	***B***
Fish	***C***	***B***
Invertebrates	***C***	***B***
Instream	***C***	***B***
Riparian vegetation	***C/D***	***B/C***
EcoStatus	***C***	***B/C***
Instream IHI	***C***	
Riparian IHI	***C/D***	
EIS	***HIGH***	

EWR QUANTIFICATION

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

				Long term mean					
Site	**EcoStatus**	**nMAR (MCM[1])**	**pMAR[2] (MCM)**	**Low flows (MCM)**	**Low flows (%)**	**High flows (MCM)**	**High flows (%)**	**Total flows (MCM)**	**Total (%)**
J1TOUW-EWR3	Instream: C	45.20	22.26	1.15	2.6	11.54	25.6	12.69	28.2
J2GAMK-EWR4	PES: C/D	85.54	61.69	3.94	4.6	17.44	20.4	21.38	25.0
J1BUFF-EWR5	PES; REC: C	29.31	18.67	1.37	4.7	6.85	23.3	8.22	28.0
J4GOUR-EWR6	PES; REC: C	543.52	310.35	27.12	5.0	102.47	18.8	129.59	23.8
K6KEUR-EWR8	Instream PES: C	49.81	30.45	10.66	21.4	8.66	17.4	19.32	38.8
	Instream REC: B			13.93	28.0	9.27	18.6	23.30	46.7

1 Million Cubic Metres *2 Present Day Mean Annual Runoff*

CONCLUSIONS AND RECOMMENDATIONS

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

The confidence for all the EWR parameters (provided below) is mostly Moderate. However, low confidence dominates the biotic responses to low flow parameters for J1TOUW-EWR3 due to non-sensitive fish species naturally present in this reach and recommended low flows do not achieve the EC for macroinvertebrates resuting in a reliance on the recommended high flows materializing in the early to mid summer months.

Confidence in the hydraulic modelling results overrides the confidence in the biophysical responses and EWR determination except at J1TOUW-EWR3. The confidence is generally Moderate for all the EWR sites with high confidence in the high flow determination for J2GAMK-EWR4 and J4GOUR-EWR6. The lowest confidence evaluation is at J1BUFF-EWR5 and this is because all measured flow data used for calibrating the hydraulic model was higher than the low flow EWR determination. Further work to improve the hydraulics would require additional measured calibration at very low flows.

The most effective way of improving confidence is linked to monitoring the ecological status of the river and, if required, improving the hydraulics for low flows at selected sites as part of the monitoring programme. However this will only be successful if good reliable hydrological measurements are available. No specific studies to improve any confidences other than the monitoring are therefore recommended.

Confidence summary

EWR site	***J1TOUW-EWR3***	***J2GAMK-EWR4***	***J1BUFF-EWR5***	***J4GOUR-EWR6***	***K6KEUR-EWR8***
Data availability	*2.7*	*2.7*	*2.9*	*2.9*	*3.1*
Eco-Classification	*2.6*	*2.9*	*2.9*	*2.7*	*2.9*
Low flow EWR (biotic responses)	*1.5*	*2.5*	*2.3*	*2.7*	*3.7*
High flow EWR (biophysical responses)	*2.8*	*2.6*	*3.0*	*3.2*	*3.6*
Hydrology	*2.0*	*1.5*	*3.0*	*2.0*	*3.0*
Hydraulics (low)	*2.5*	*3.0*	*2.0*	*2.5*	*3.0*
Hydraulics (high)	*3.0*	*4.0*	*2.5*	*4.0*	*3.0*
Overall low flow EWR confidence	*2.3*	*2.9*	*2.4*	*2.6*	*3.2*
Overall high flow EWR confidence	*2.9*	*3.3*	*2.8*	*3.6*	*3.3*

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ACRONYMS

AEC	Alternative Ecological Category
Alt	Altitude
ASPT	Average Score Per Taxon
BBM	Building Block Methodology
CEV	Chronic Effects Value
CMA	Catchment Management Area
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
DRIFT	Downstream Response to Imposed Flow Transformation
DRM	Desktop Reserve Model
DWA	Department Water Affairs (Name change from DWAF applicable after April 2009)
DWAF	Department Water Affairs and Forestry
DWS	Department Water and Sanitation (Name change from DWA applicable after May 2014)
EC	Ecological Category
EI-ES	Ecological Importance and Ecological Sensitivity
EIS	Ecological Importance and Sensitivity
EWR	Ecological Water Requirements
FDI	Flow Dependent Macroinvertebrate
FRAI	Fish Response Assessment Index
FROC	Frequency of Occurrence
GAI	Geomorphology Assessment Index
GD	Green Drop
Geo	Geomorphic
HFSR	Habitat Flow Stressor Response method
HFSR-RM	Habitat Flow Stressor Response-Reserve Model
IERM	Intermediate Ecological Reserve Methodlogy
IHI	Index of Habitat Integrity
MAR	Mean Annual Runoff
MCB	Macro Channel Bank
MCM	Million Cubic Metres
MIRAI	Macroinvertebrate Response Assessment Index
MRU	Management Resource Unit
nMAR	natural Mean Annual Runoff
NWA	National Water Act
NWRCS	National Water Resource Classification System
PAI	Physico-chemical Driver Assessment Index
PD	Present Day
PES	Present Ecological State
pMAR	Present Day MAR
Quat	Quaternary catchment
RC	Reference Condition
RDRM	Revised Desktop Reserve Model
REC	Recommended Ecological Category
RHP	River Health Programme

SANBI	South African National Biodiversity Institute
SASS5	South AfricanScoring System version 5
SQ	Sub Quaternary
TIN	Total Inorganic Nitrogen
TWQR	Target Water Quality Range
VEGRAI	Riparian Vegetation Response Assessment Index
WMA	Water Management Area
WMS	Water Management System
WR2005	Water Resources of South Africa, 2005 study
WR2012	Water Resources of South Africa, 2012 study
WRYM-MF	Water Resources Yield Model - Modelling Framework
WWTW	Wastewater Treatment Works
Velocity Depth Classes: Fish and Macro-invertebrates	
FCS	Fast flow over Coarse Substrate
FD	Fast Deep fish habitat
FFS	Fast over fine substrate
FI	Fast Intermediate fish habitat
FS	Fast Shallow fish habitat
FVS	Fast very shallow
GSM	Gravel-Sand-Mud
MV	Marginal Vegetation
MVI	Invertebrates with a preference for Marginal Vegetation
SCS	Slow flow over Coarse Substrate
SCS	Slow flow over Coarse Substrate
SD	Slow Deep fish habitat
SFS	Shallow over fine substrate
SIC	Stones-in-Current
SOC	Stones-out-of-Current
SS	Slow Shallow fish habitat
SVS	Slow very shallow
VCS	Very Coarse Substrate
VFCS	Very Fast flow over Coarse Substrate

1 INTRODUCTION

1.1 BACKGROUND

The National Water Act (Act No. 36 of 1998) (NWA), Section 3 requires that the Reserve be determined for water resources, i.e. the quantity, quality and reliability of water needed to sustain both human use and aquatic ecosystems, so as to meet the requirements for economic development without seriously impacting on the long-term integrity of ecosystems. The Reserve is one of a range of measures aimed at the ecological protection of water resources and the provision of basic human needs (i.e. in areas where people are not supplied directly from a formal water service delivery system and thus directly dependent on the resource according to Schedule 1 of the NWA). Chief Directorate: Water Ecosystems within Department Water and Sanitation (DWS) is tasked with the responsibility of ensuring that the Reserve is considered before water allocation and licensing can proceed.

The requirement for detailed Reserve studies in the Gouritz Water Management Area (WMA) became apparent for the following reasons:

- Various licence applications in the area.
- Gaps that have been identified as part of the Outeniqua Reserve determination completed in 2010.
- The conservation status of various priority water resources in the catchment and existing and proposed impacts on them.
- Increasing development pressures and secondary impacts related from the aforementioned and the subsequent impact on the availability of water.

For management and improved governance reasons, South Africa's 19 WMAs have been consolidated into nine (9) WMAs. The Gouritz WMA (previously WMA 16) now forms part of the previous Breede WMA (WMA 8) which now is known as the Breede-Gouritz WMA. It will be governed by the Breede-Gouritz Catchment Management Agency (CMA).

1.2 STUDY AREA OVERVIEW

Although it is acknowledged that the Breede and Gouritz WMA have been consolidated, the focus of this study is the Gouritz River and its associated catchments. Therefore the study area has been described in terms of the original WMA; the Gouritz WMA – WMA 16.

The Breede-Gouritz WMA is situated on the south coast of the Western Cape, largely falling within the Western Cape Province, and with a surface area of approximately 53 000 km^2. It consists of primary drainage region J (approximately 90 quaternary catchments), and part of primary drainage regions K (K1 to K7) and H (H8 to H9). The WMA therefore consists of approximately 100–105 quaternary catchments. It consists of the large dry inland area that is comprised of the Karoo and Little Karoo, and the smaller humid strip of land along the coastal belt. The main rivers are the Gouritz and its major tributaries, the Buffels, Touws, Groot, Gamka, Olifants and Kammanassie rivers, with smaller coastal rivers draining the coastal belt. All the inland rivers drain via the Gouritz into the Indian Ocean. The mean annual precipitation varies from as high as 865 mm in the coastal areas, which experience all year round rainfall, to as little as 160 mm in the drier areas inland to the north, which experience late summer rainfall. A map of the study area is provided below (**Figure 1.1**).

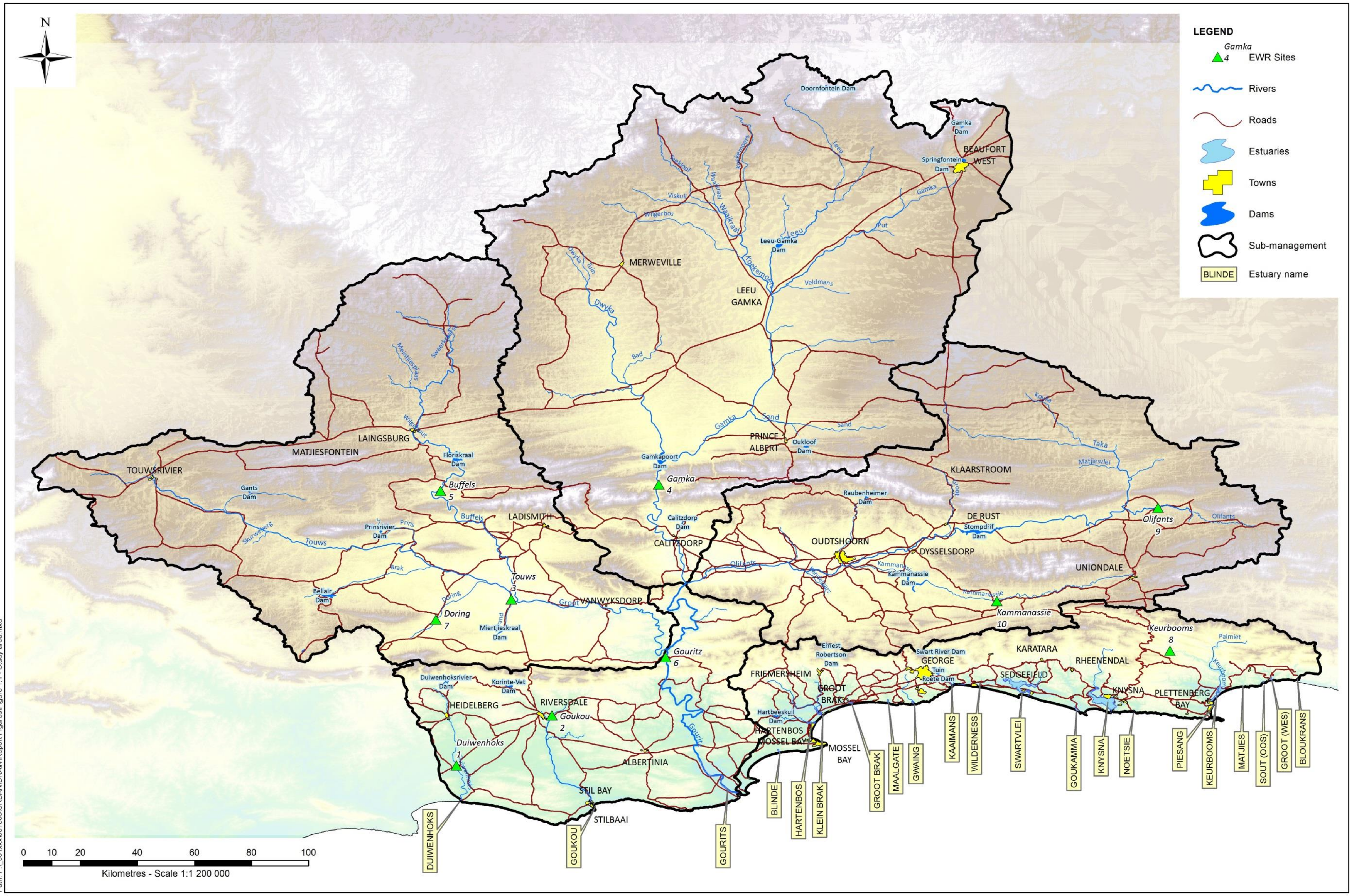


Figure 1.1 Study area

A total of ten Ecological Water Requirements (EWR) sites were selected in the study area. EWRs at Rapid level have already been determined for five sites situated in the Duiwenhoks, the Goukou, the Doring, the Olifants and the Kammanassie Rivers and the results are documented in DWS (2014). This report focusses on the EWR determination at the remaining five EWR sites that were assessed in accordance with the Intermediate Ecological Reserve Methodology (IERM) (DWAF, 1999). These EWR sites are described in DWS (2014) and listed in **Table 1.1**.

Table 1.1 EWR sites

EWR site name	SQ[1] reach	River	MRU[2]	Latitude	Longitude	Eco-Region (Level II)	Geo[3] Zone	Alt[4] (m)	Quat[5]
J1TOUW-EWR3	J12M-08904	Touws	MRU Touws B	S33.72707	E21.16507	19.07	E Lower Foothills	271	J12M
J2GAMK-EWR4	J25A-08567	Gamka	MRU Gamka B	S33.36472	E21.63051	19.09	E Lower Foothills	375	J25A
J1BUFF-EWR5	J11H-08557	Buffels	MRU Buffels B	S33.38452	E20.94169	19.09	E Lower Foothills	499	J11H
J4GOUR-EWR6	J40B-09106	Gouritz	MRU Gouritz A	S33.90982	E21.65233	19.08	E Lower Foothills	121	J40B
K6KEUR-EWR8	K60C-09882	Keur-booms	MRU Keurbooms B	S33.88955	E23.24392	20.02	D Upper Foothills	161	K60C

1 Sub Quaternary 2 Management Resource Unit 3 Geomorphic
4 Altitude 5 Quaternary catchment

1.3 DATA AND INFORMATION AVAILABILITY

Information collated during physical surveys was used to provide the results in this report. See **Appendices A** to **C** for more detailed information regarding methods followed for water quality, diatoms and eco-hydrology respectively. **Appendix D** provides the RDRM reports for all EWR sites. The data and information availability are summarised in **Table 1.2**. The confidence score used in this document is based on a scale of 0 – 5 where:

- A score of 0 – 1.9 suggests that the confidence is low.
- A score of 2 – 3.4: suggests that the confidence is moderate.
- A score of 3.5 – 5: suggests that the confidence is high.

Table 1.2 Data and information availability

Data and information availability
Hydrology ▪ Touws River: J1TOUW-EWR3 o Measured daily flows: The flow gauge J1H018 is located just upstream of the EWR site. Observations started in 1982 and the gauge is still operational. The observed flow record shows long periods of no flow and long periods of low flows with hardly ever any high flows. This gauge is only accurate for low flows and it was therefore only used to evaluate and confirm the occurrence of periods of low and no flow in the Present Day (PD) simulated record. o Simulated monthly natural hydrology: The natural quaternary stream flow data from the Water Resources of South Africa 2005 Study (WR2005) (Middleton and Bailey, 2011) were scaled to obtain a representative natural stream flow record at the EWR site. Because there are large uncertainties regarding the historical agriculture abstractions and sub-surface flow, the flow can be over or underestimated. The confidence in the WR2005 calibrations and the resultant natural data is therefore low. Confidence: 2.

Data and information availability
o Simulated (PD) hydrology: The WRYM model with land-use at the 2004-development level was used to provide PD flow at the EWR site. There is a great deal of uncertainty about the extent of current irrigation upstream of the EWR site. The 1998 are larger than the 2004 irrigated areas as a result of the 2004 floods. Where there were large discrepancies between the 2004 and 1998 irrigated areas, the higher 1998 areas were used to simulate irrigation demands. Confidence 2. ▪ Gamka River: J2GAMK-EWR4 o Measured daily flows: The flow gauge J2H016 at Gamkapoort Dam measures river releases from Gamkapoort Dam. Observations started in 1964 and continued to date. This gauge measures releases and spills from Gamkapoort Dam. This dam rarely spills and the observed record was used to evaluate and confirm the simulated PD simulated record. o Simulated natural hydrology: The WR2005 natural quaternary data are from the WR2005-study and were scaled to obtain representative natural flow record at the EWR site. The catchment area is quite large with uncertainties regarding the historical agriculture abstractions. The confidence in the WR2005 simulated flow data and the resultant natural data is therefore low. Confidence: 1.5. o Simulated PD hydrology: The WRYM model with land-use at the 2004-development level was used to provide PD flow at the EWR site. Confidence: 1.5. ▪ Buffels River: J1BUFF-EWR5 o Measured daily flows: None. The EWR site is downstream of Floriskraal Dam. J1H028 measures spills and river releases but also includes 97% of the flow from J11G. The contribution of J11G is however very small relative to the cumulative run-off at EWR5. The observed record was used to evaluate and confirm the simulated PD simulated record. o Simulated natural hydrology: The WR2005 natural quaternary data from the WR2005-study were scaled to obtain a representative natural flow record at the EWR site. The catchment area is large with uncertainties regarding the historical agriculture abstractions. Confidence: 3.5. o Simulated present day hydrology: The WRYM model with land-use at the 2004-development level was used to provide PD flow at the EWR site. There is low confidence in information on water use upstream of the EWR site but J1H028 provided an indication of the bulk of the flow at J1BUFF-EWR5. Confidence 2.5. ▪ Gouritz River: J4GOUR-EWR6 o Measured daily flows: The flow gauge J4H002 is a flood section and situated upstream of EWR6. The gauge data starts from 1964 to present with 22 years of usable data (Oct 1999 to present). Data for the period 1999 to present were used for comparison with the simulated PD monthly flow to establish the agreement between the simulated data and the observed data. The fit was however not satisfactorily with the simulated data mostly higher than the observed data. The reliability of the flow gaugeis dubious and did not help to improve the confidence in the results. o Simulated natural hydrology: The WR2005 natural quaternary data were scaled to obtain a natural flow record at the EWR site. The catchment upstream of EWR6 is extremely large with uncertainties in the upstream catchment regarding land-use and river losses. Confidence: 2. o Simulated PD hydrology: The WRYM model with land-use at the 2004-development level was used to provide PD flow at the EWR site. There is a great deal of uncertainty about the extent of current irrigation upstream of the EWR site which comprises the entire Gouritz catchment, particularly given that the 1998 irrigated areas are larger than those in 2004. Where there were large discrepancies between the 2004 and 1998 irrigated areas and overestimation of simulated data, the higher 1998 areas were used to simulate irrigation demands. Confidence 2. ▪ Keurbooms River: K6KEUR-EWR8 o Measured daily flows: None. K6H001 is far upstream and K6H019 is far downstream from the EWR site. These two gauges are not representative of the flow at K6KEUR-EWR8 and can therefore not be used for evaluation of the PD flows. o Simulated natural hydrology: The natural monthly quaternary hydro-meteorological data were obtained from Aurecon (Denys, 2014) and the flow data were scaled to obtain representative natural flow at the EWR site. Detailed information available in the Ninham Shand report for the Bitou Municipality Water Augmentation Study (Ninham Shand, 2003). Confidence: 3. o Simulated PD hydrology: There is a reduction in PD of nearly 40% in MAR from natural. The PD WRYM set-up for the Bietou River was obtained from Aurecon, as the Aurecon data were compiled as

Data and information availability
part of a detailed study and thus have a higher confidence than WR2005 data. However no afforestation or alien invasive plants were included in this model set-up. The reason is not explained in the report and inclusion of the above could have resulted in decreased PD base flows. Confidence 3.
Geomorphology ▪ Data on gross morphology, planform and bed-sediment characteristics were collected during site visits (July 2014) at all intermediate EWR sites (J1TOUW-EWR3, J2GAMK-EWR4, J1BUFF-EWR5, J4GOUR-EWR6 and K6KEUR-EWR8). ▪ Historical aerial photographs of the EWR sites, starting in the 1940's for most sites, were sourced from the archives of the Department of Rural Development and Land Reform and used to inform the Reference Condition (RC) and Present Ecological State (PES) assessments. ▪ Google Earth © satellite images of the site and catchment for the last 10 - 15 years were used to inform the PES assessment. ▪ Hydraulic rating curves and lookup tables for each site, and flow records of nearby DWS flow gauges were obtained from www.dwaf.gov.za/hydrology, and used for the sediment transport analyses. ▪ Confidence at J2GAMK-EWR4 (Gamka) is slightly lower than the other sites due to the poor record of natural (pre-dam) flow conditions. Confidence: J1TOUW-EWR3, J1BUFF-EWR5, J4GOUR-EWR6, K6KEUR-EWR8: 3.5 J2GAMK-EWR4: 3
Water quality ▪ Touws River: J1TOUW-EWR3 o RC: Information available to the water quality specialist on water quality conditions and land-use were used as no RC data were available and the A Category benchmarks tables in DWAF (2008) were considered unsuitable due to the high geology-based salinities in the area. o PES: Data were sourced from DWS gauging weir J1H018Q01 (Water Management System (WMS) code 102147), located upstream of the EWR site. (Data record: 2000 – 2014; number of samples (n) = ± 128). Confidence: 2.5 ▪ Gamka River: J2GAMK-EWR4 o RC: A category benchmark tables from DWAF (2008) were used. o PES: Data were sourced from DWS gauging weir J2H016Q01 (WMS code 102173), located downstream Gamkapoort Dam and upstream of the EWR site. (Data record: 2007 – 2014; n = 127). Confidence:3 ▪ Buffels River: J1BUFF-EWR5 o RC: Data were sourced from DWS gauging weir J1H028Q01 (WMS code 102152), located downstream Floriskraal Dam and upstream of the EWR site. Note that the monitoring point is not in the same Level II EcoRegion as the EWR site; however, this was the only data point between the dam and the site. (Data record: 1972 – 1977; n = 54, Conductivity: n = 33). o PES: Data were sourced from DWS gauging weir J1H028Q01 (WMS code 102152) (Data record: 2010 – 2014; n = 44). Confidence: 2.5 ▪ Gouritz River: J4GOUR-EWR6 o RC: Data were sourced from DWS gauging weir J4H002Q01 (WMS code 102201), located upstream of the EWR site. (Data record: 1965 – 1967; n = 29). o PES: Data were sourced from DWS gauging weir J4H002Q01 (Data record: 2010 – 2014; n = 85). Confidence: 3 ▪ Keurbooms River: K6KEUR-EWR8 o RC: A Category benchmark tables from DWAF (2008) were used. o PES: Data were sourced from DWS gauging weir K6H001Q01 (WMS code 102295), located far (about 20 km) upstream of the EWR site. (Data record: 2007 – 2014; n = 121; Fluorine (F) = 107) Confidence: 3

Data and information availability
Riparian vegetation Data for all the sites were obtained from the following sources: ▪ Riparian vegetation data collected during site visit (April and June, 2014) for both Ecological Status (Vegetation Response Assessment Index - VEGRAI level 4; Kleynhans *et al*., 2007) and the determination of flow requirements (surveyed vegetation indicators along hydraulically calibrated profile). ▪ Historical anecdotal information on the vegetation of the area from early (around 1800's or earlier) explorers (Skead, 2009). ▪ Vegetation Biomes, Bioregions and Vegetation Types (Mucina and Rutherford, 2006). ▪ South African National Biodiversity Institute (SANBI) distribution data of plant species (SANBI Plants of southern Africa (POSA), 2009). ▪ Google Earth © satellite imagery (current and historic: all available coverages were used. ▪ Historical aerial photographs: Buffels River from 1944 to present; Gamka River from 1944 to present; Touws River from 1944 to present; Gouritz River from 1953 to present; Keurbooms River from 1961 to present. ▪ Hydraulic rating curves and lookup tables for each site. ▪ Hydrology: Observed data (various weirs) with quality status used in HEC-DSSVue. ▪ 2013 desktop PES, Ecological Importance and Ecological Sensitivity (EI-ES), referred to as the PES/EIS project for Group 5 - Western Cape WMAs: Breede/Overberg, Berg, Gouritz and Olifants/Doorn (DWA, 2013). Confidence: 3.5
Fish ▪ Touws River: J1TOUW-EWR3 ▪ Single site visit (April 2014). ▪ No historic and recent data were available for the Touws River in vicinity of the EWR site, although extrapolated fish data from similar sites in adjacent reaches of Gamka River were available. ▪ PES/EIS data (DWA, 2013). ▪ Atlas of Southern African Freshwater fishes (Scott *et al*., 2006). ▪ Reference Fish Frequency of Occurrence (FROC) data (Kleynhans and Louw, 2007a). Confidence: 2. ▪ Gamka River: J2GAMK-EWR4 ▪ Single site visit (April 2014). ▪ No historic and recent data were available for the Gamka River in vicinity of the EWR, although extrapolated fish data from similar sites in adjacent Gouritz tributaries were available. ▪ PES/EIS data (DWA, 2013). ▪ Atlas of Southern African Freshwater fishes (Scott *et al*., 2006). ▪ FROC data (Kleynhans and Louw, 2007a). Confidence: 2 ▪ Buffels River: J1BUFF-EWR5 ▪ Single site visit (April 2014), with no historic data available for the site. ▪ Limited historic data for Buffels River and extrapolated fish data from similar sites in adjacent Gouritz tributaries. No recent data were available. ▪ PES/EIS data (DWA, 2013). ▪ Atlas of Southern African Freshwater fishes (Scott *et al*., 2006). ▪ FROC data (Kleynhans and Louw, 2007a). Confidence: 2 ▪ Gouritz River: J4GOUR-EWR6 ▪ Single site visit (April 2014). ▪ Some historic data available in the vicinity of the EWR site as well as extrapolated fish data from similar sites in adjacent Gouritz tributaries. However, no recent data were available. ▪ PES/EIS data (DWA, 2013). ▪ Atlas of Southern African Freshwater fishes (Scott *et al*., 2006). ▪ FROC data (Kleynhans and Louw, 2007a). Confidence: 3 ▪ Keurbooms River: K6KEUR-EWR8

Data and information availability
o Single site visit (June 2014). o Good historical data for Keurbooms River available although applicable some distance from the EWR site and also limited recent data available, thus the confidence is low. o PES/EIS data (DWA, 2013). o Atlas of Southern African Freshwater fishes (Scott *et al*., 2006). o FROC data (Kleynhans and Louw, 2007a). Confidence: 2.5
Macroinvertebrates ▪ Single site visit to each of the EWR sites (EWR 3,4,5,6 in April 2014, and EWR 8, 9 in July 2014). ▪ All available River Health Programme (RHP) site data for the Gouritz WMA obtained from DWS: Western Cape Office (ex RHP Database). Note that each data set is accompanied by full sampling information and macro invertebrate abundances are provided. ▪ PES/EIS project data for the Gouritz WMA (DWA, 2013). These data are a summary of all historic samples and are not accompanied by sampling details or invertebrate abundances. ▪ Data for selected sites in the Gouritz WMA area from Southern Waters Consultancy, Cape Town. Confidence: J1TOUW-EWR3, J2GAMK-EWR4, J1BUFF-EWR5, J4GOUR-EWR6 and K6KEUR-EWR8: 3
Diatoms ▪ Touws River: J1TOUW-EWR3 o The diatom results are based on four samples collected in January, February, April and June 2014 respectively at the EWR site. No other data could be sourced for the Touws River. Confidence: 3 ▪ Gamka River: J2GAMK-EWR4 o The diatom results are based on one sample collected in July 2014 at the EWR site. No other data could be sourced for the Gamka River. Although a sample was collected during January 2014, the diatom densities were too low to obtain a viable count of 400. Confidence: 1 ▪ Buffels River: J1BUFF-EWR5 o The diatom results are based on two samples collected in April and July 2014 respectively at the EWR site. No other data could be sourced for the Buffels River. Confidence: 2 ▪ Gouritz River: J4GOUR-EWR6 o The diatom results are based on four samples collected in January, February, April and July 2014 respectively at the EWR site. No other data could be sourced for the Gouritz River. Confidence: 3 ▪ Keurbooms River: K6KEUR-EWR8 o The diatom results are based on three samples collected in February, June and July 2014 respectively at the EWR site. No other data could be sourced for the Keurbooms River. Confidence: 2.5
Ecohydraulics Surveys of the river topography at the EWR sites were done between January and June 2014. During these surveys discharges were measured using the velocity-area method, together with corresponding water levels (stages), and the position of vegetation markers/zones. These data are provided electronically in the supporting information. The methods used to provide hydraulic information to inform the assessment of EWRs are documented in Birkhead (2010). The results of these analyses are tabulated in so-called 'look-up' tables (**Appendix C**), which include the following parameters: discharge; average and maximum depth; wetted width and perimeter; average and maximum (2% exceedance) depth-averaged velocity; flow-classes used for assessing the availability of hydraulic-habitat for fish and macroinvertebrates. These (modelled) data are also included with the electronic supporting files for the ecohydraulics. Confidence: 3

1.4 OBJECTIVES OF THE RESERVE STUDY

This report documents the results of the EcoClassification and quantification of the EWR at a selection EWR sites on the Touws, the Gamka, the Buffels, the Gouritz and the Keurbooms rivers.

1.5 OUTLINE OF THIS REPORT

The report outline is as follows:

- **Section 1** provides general background to the study.
- **Section 2** outlines the methods followed during the Ecological Reserve process. Summarised methods are provided for the EcoClassification and EWR scenario determination.
- **Section 3, 5, 7, 9, 11** and **13** provides the EcoClassification results for the EWR sites. **Section 4, 6, 8, 10, 12** and **14** provide results for EWR scenarios with respect to low and high flows for the respective EWR sites. Aspects covered in these sections are component and integrated/stress curves, generating stress requirements, determining high flows and final results.
- **Section 15** summarises the EcoClassification and EWR scenario results and includes recommendations.
- References are listed in **Section 16**.
- **Appendix A** and **B** are specialist appendices outlining the approach and results of the water quality and diatom assessment undertaken at all the EWR sites.
- **Appendix C** is a specialist appendix which provides more detail regarding the hydraulic data generated for this task and includes a discussion of methods, data collection and results.
- **Appendix D** provides the Revised Desktop Reserve Model (RDRM) output files for all the EWR sites.
- **Appendix E** provides the comments received from various reviewers.

2 APPROACH

The IERM (DWAF, 1999) was followed. Associated with the IERM is the EcoClassification process at Level IV. The approaches are summarised below.

2.1 ECOCLASSIFICATION

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

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

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

The PES is expressed in terms of biophysical components:

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

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

2.1.1 Present Ecological State

The steps followed in the EcoClassification process are as follows:

- Determine the RC for each component.
- Determine the PES for each component and the EcoStatus.
- Determine the trend for each component, as well as for the EcoStatus (dependant on available information).
- Determine the reasons for the PES and whether these are flow or non-flow related.

- Determine the Ecological Importance and Sensitivity (EIS) for the biota and habitat.
- Considering the PES and the EIS, suggest a realistic Recommended Ecological Category (REC) for each component and the EcoStatus.

The Level 4 EcoStatus assessment was applied according to standard methods. The minimum tools required for this assessment are shown in **Figure 2.1** (modified from Kleynhans and Louw, 2007b).

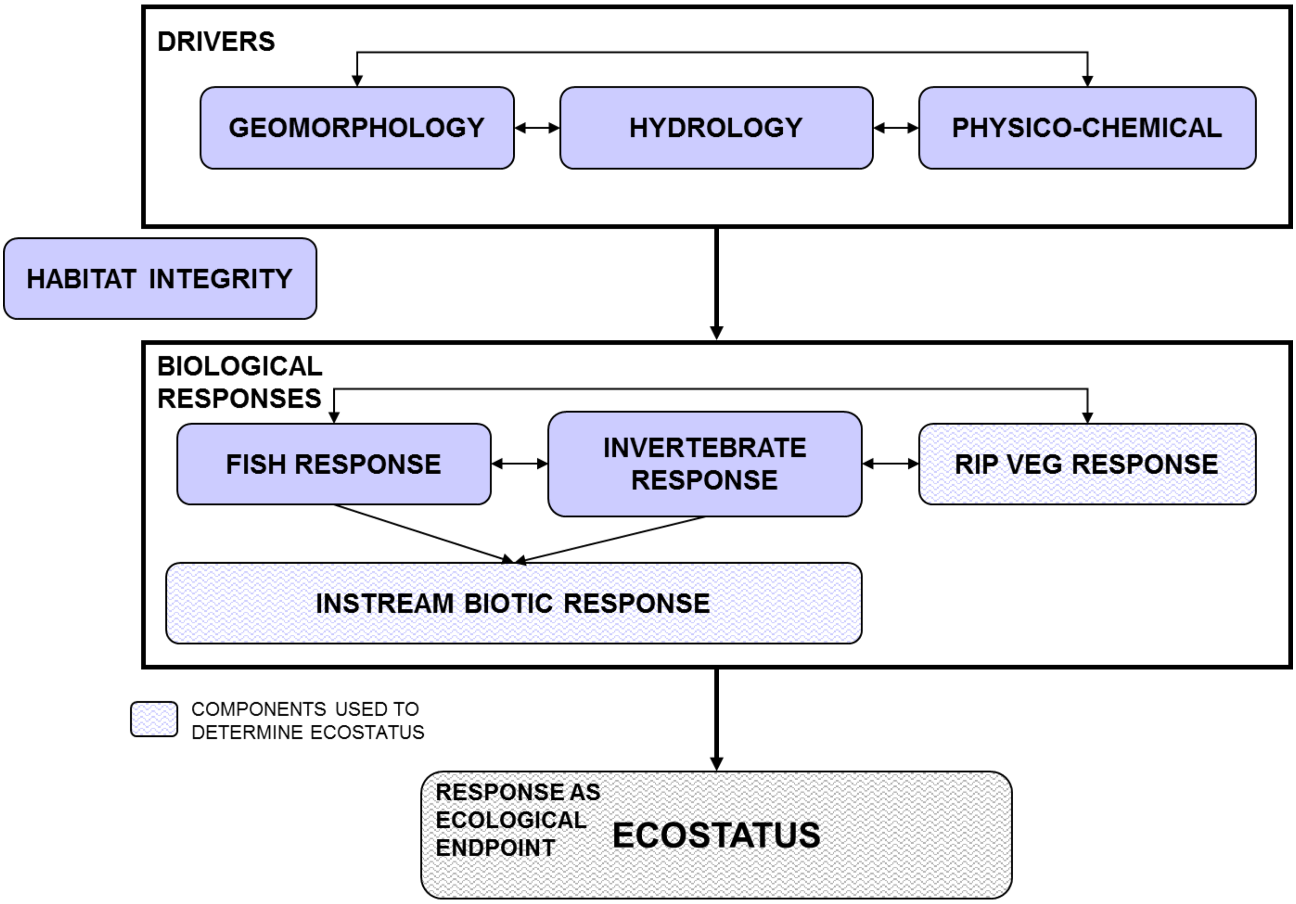


Figure 2.1 EcoStatus Level 4 determination

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

The populated Ecostatus models are provided electronically.

2.1.2 Ecological Importance and Sensitivity

The EIS was calculated using a model developed by Dr Kleynhans in 2010, and representing a refinement of the model in Kleynhans and Louw (2007b) and Louw *et al*. (2010). This model estimates and classifies the EIS of the streams in a catchment using:

- The presence of rare and endangered species, unique species (i.e. endemic or isolated populations) and communities, intolerant species and species diversity for both the instream and riparian components of the river.
- Habitat diversity, including specific habitat types such as reaches with a high diversity of habitat types, e.g. pools, riffles, runs, rapids, waterfalls, riparian forests.
- The importance of a river or stretch of river in providing connectivity between different sections of the river, i.e. whether it provided a migration route or corridor for species.
- The presence of conservation, or relatively natural, areas along the river.
- The sensitivity (or fragility) of the biotic and abiotic components of the system and their resilience (i.e. the ability to recover following disturbance) to environmental changes.

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

Table 2.1 EIS categories (Modified from DWAF, 1999)

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

2.1.3 Recommended Ecological Category

The REC is a recommendation from an ecological perspective that is one of the scenarios considered in the National Water Resource Classification System (NWRCS). This recommendation is based on either maintenance of the PES or an improvement thereon. Improvements are only considered if the EIS is HIGH or VERY HIGH. The guidelines to derive the REC based on the PES and the EIS are indicated in **Table 2.2**. Note that, in all cases, the practicalities of achieving the ecological recommendations are considered.

Table 2.2 Guideline for REC determination

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

2.2 EWR DETERMINATION

The Habitat Flow Stressor Response method (HFSR) (O'Keeffe *et al*., 2002; IWR S2S, 2004; Hughes and Louw, 2010) was used to determine the EWRs. This method is one of the methods used to determine EWRs at a detailed level and a version of this has been built into the RDRM (Hughes *et al*., 2011).

The process used to determine EWRs is summarised below:

2.2.1 Low flows

Step A: Developing the stress-flow index

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

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

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

A process using hydrological and hydraulic information has been built into the RDRM (Hughes *et al*., 2011). The purpose of the hydraulics module is to derive stress indices based on hydraulic habitat, and hence this (i.e. hydraulics) may be excluded in the application of the RDRM at higher levels of assessment, such as in this study. For these assessments, hydraulic information is prepared and used outside of the RDRM framework. For an intermediate Reserve determination, stress indices are constructed by the fish and invertebrate specialists for “wettest” and “driest” months, and these are used instead of the default indices in the RDRM.

Step B: Determining the low flow EWR

The stress index is used to convert natural and PD flow time series to natural and Present Day stress time series. Each stress time series is then converted to a stress duration graph. This provides specialists with information on changes in stress from natural to present conditions, associated with changes in flow. It follows that if flow has reduced from natural conditions, stress would have increased, and vice versa. If specialists do not concur with the (modelled) levels of stress under natural conditions based on their knowledge of the indicator species or guilds, stress indices may be adjusted.

The RDRM allows for “shifts” in stress-flow from natural conditions, and these relate to the different ecological categories (B, C, etc.). Therefore, using the PES, the RDRM can generate stress-flow relationships for different ecological categories. These are, in-turn, assessed by the biotic specialists at specific exceedance percentage points, and adjusted in the RDRM as necessary. In this way, the RDRM is used as a framework for higher confidence EWR assessments.

2.2.2 High flows

The approach to set high flows follows the principles of the Downstream Response to Imposed Flow Transformation (DRIFT; King *et al*., 2003) method and the BBM (King and Louw, 1998). The high flows are determined as follows:

- Discharge ranges for each flood class together with their geomorphological and riparian vegetation functions are identified and tabled by the relevant specialists.
- These are provided to the instream specialists who indicate:
    - the instream functions these floods cater for;
    - whether additional instream functions apart from those provided are required; and
    - whether they require any additional flood classes to the ones identified.
- The annual average frequency of occurrence of floods in each flood class is identified as well as where (early, mid, late) and in which season they should occur.
- The floods are evaluated by the hydrologist to determine whether these would have occurred in the natural record. A nearby gauge with daily data is needed for this assessment, without which it is difficult to judge whether floods are realistic.
- The hydrologist then determines the daily average and documents the months in which the floods are most likely to occur.
- The floods are subsequently entered into the Desktop Reserve Model (DRM) (Hughes and Hannart, 2003) to provide the final .rul and .tab files. The revised process is described below with specific reference to the RDRM:
    - convert each flood to monthly volume using frequencies and durations;

- calculate annual volume for the specified category;
- apply the RDRM high flow method by adjusting the following three parameters:
  a) No high flows permitted when natural high flows are less than a specified percentage of total flows.
  b) Adjustment of the hydrological variability (mainly for volume matching).
  c) Maximum high flows (i.e. at low exceedances) are a specified percentage higher than more frequently occurring natural high flows.

2.2.3 Final flow requirements

The RDRM produces a “report”, which documents the parameter values of variables used in the RDRM, and the EWR rules (as flow-assurance tables) for all ECs.

3 ECOCLASSIFICATION: TOUWS RIVER – J1TOUW-EWR3

3.1 BACKGROUND

The Touws EWR site is situated just upstream of the confluence with the Buffels River and located downstream of JH018. Three irrigation dams are situated in tertiary catchment J12. The upstream area is in a poor to moderate state due to small farm dams in areas, and irrigation which is extensive in some areas. Non-flow related impacts are mainly agricultural encroachment or clearing of riparian zones and/or floodplains, overgrazing in some areas and physical disturbance (manipulation) of morphological features (localised). The downstream area in which the site is located is mostly in moderate condition which is an improvement due to the decreased irrigation in this area. Direct impacts in the downstream zone are mostly non-flow related. Grazing with some dryland agriculture and minimal irrigation occur. **Figure 3.1** provides a map and photographs of the EWR sites.

Figure 3.1 A map, Google image and downstream view of the EWR site

The hydrological modelling indicates that the site was perennial under natural conditions. Present Day (PD) conditions, however, are characterised by very short periods of wet season base flows, interspersed with periods of no flow. The site therefore has PD flow characteristics that are ephemeral to seasonal. **Figure 3.2** shows a typical hydrological regime as daily data from the upstream gauge.

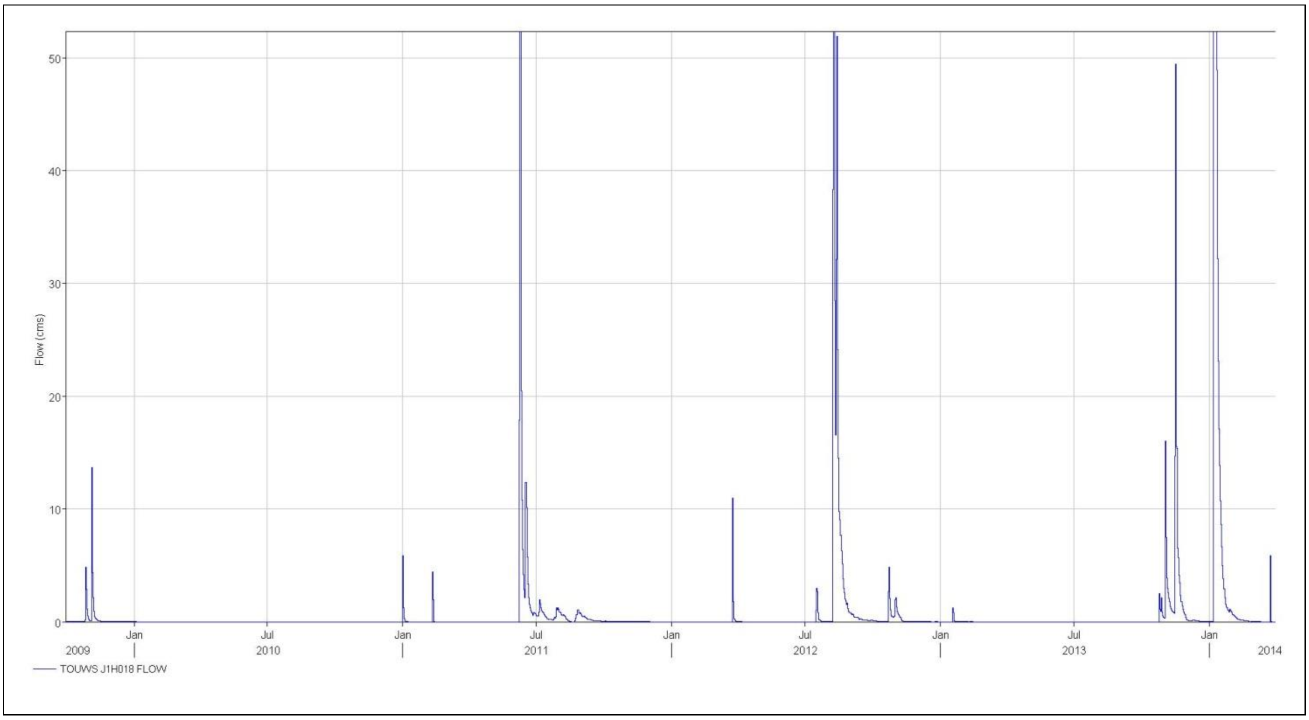


Figure 3.2 The present flow regime illustrating zero flows and large floods

3.2 EIS RESULTS

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

- Rare and endangered species: *Pseudobarbus asper*.
- Refugia and critical habitat: Deep pools are present asrefuge areas for *P. asper*.
- Migration route: Important as there are no barriers downstream of the site up to the sea.
- Rare and Endangered vegetation species: The site occurs within the Muscadel Riviere Vegetation Type; an azonal inland saline vegetation group (Mucina and Rutherford, 2006). There is an estimated 41% of this vegetation unit remaining, with no protection and a conservation status of “Endangered”.
- Unique riparian species: Six endemic riparian plant species occur in the reach; *Cyperus textilis, Diospyros austro-africana* var. *austro-africana, Juncus capensis, Nymania capensis, Salsola aphylla* and *Tamarix usneoides.*
- Migration corridor: The *Acacia karoo* thicket is distinct from the upland vegetation.

3.3 PRESENT ECOLOGICAL STATE

The PES reflects the changes in the EC relative to reference conditions. The summarised PES information is provided in **Table 3.1** and water quality and diatom information is provided in **Appendix A** and **B**, respectively.

Table 3.1 J1TOUW-EWR3: Present Ecological State

IHI Hydrology: B/C, Confidence: 2.8
The natural MAR (nMAR) is 45.02 million cubic metres (MCM) and the PD MAR (pMAR) is 22.26 MCM (49.4% of the nMAR). The observed record is only accurate for low flows. There is good correspondence between the low flows of the observed and simulated PD flow records since 80% of the flows in both records has flows lower than 0.5 million m^3/month. A large change in the seasonal variation of flow from natural to PD was evident. Under natural conditions the average monthly peak flow occurred in April/May but the peak flow has shifted to July under PD conditions. The monthly seasonal distribution changed dramatically from natural to PD with reduced baseflows during the summer months as a result of storage and controlled releases from Floriskraal Dam as well as the impact of smaller farm dams, irrigation, grazing and dometic water use. It is evident that the natural flows have been changed dramatically in terms of volume, with the pMAR only half of the nMAR and also in terms of the seasonal characteristics of the flow regime.
Water quality: B/C (81.8%), Confidence: 2.5
High Electrical Conductivity levels (i.e. a 95th percentile PES value of 1 181.8 mS/m) are the major concern at this site, although it is expected that local geological conditions has contributed to high background salinity levels in the water. Irrigation return flows contribute to further elevation of conductivity levels. Nutrient concentrations are also elevated, which is expected due to farming activities in the area. Temperature and oxygen levels are impacted on by extreme low flows, resulting in higher temperatures and lower oxygen levels.
Geomorphology: PES: B (85.4%), Confidence: 3
Moderate and large floods still occurr within the river system. Farm dams in the catchment reduce small floods and results in sediment trapping, although agricultural land use will have slightly increased sediment yield, offsetting some of this impact. The channel is wide and dominated by well-sorted cobbles and is similar to the RC. The riparian zone was poorly vegetated but was similar to (or slightly reduced from) the RC. The slight loss of vegetation may be associated with reduced baseflows and/or a very slight reduction of floods.
IHI Instream: PES: C (61.8%), Confidence 2.7 IHI Riparian: PES: C (68.3%), Confidence 3.1
The instream IHI is mainly impacted by decreased base flow and flooding due to abstraction for irrigation. Deteriorated water quality caused by agricultural return flows has resulted in bed modification (sedimentation and algae). The riparian IHI is also mainly impacted by hydrology (see above) with some substrate exposure alien vegetation.
Riparian vegetation: B/C (80.3%), Confidence: 3.2
The site occurs within the Muscadel Riviere Vegetation Type, which is characterized by riverine thicket dominated by *A. karoo* and succulent gannabos (*Salsola* species) and forms the basis for the reference state (Mucina and Rutherford, 2006). Dominant species in this vegetation type (and hence expected at the site) are *A. karoo, Salix mucronata, Phragmites australis* and *Salsola aphylla*. Google Earth © images show a distinct increase in woody cover (*A. karoo* notably) from 2003 to 2013 along the upper zone. From historical anecdotal information (Skead, 2009) Lichtenstein (1815; cited in Skead, 2009) described the Touws River in March 1804 as "In comparison with the Karoo vegetation might however here be called flourishing." Based on survey data, the marginal zone is mostly open and unvegetated, but clumps of vegetation that exist are all non-woody species (grasses and sedges) with some scattered reeds. Most habitats are exposed cobble or bedrock with some alluvial deposits and exposed clay lenses covered by grasses and sedges. The lower zone is similar to the marginal zone with the addition of *T. usneoides* as a dominant but sparse species. The alien *T. ramosissima* also occurs at the site, but in low numbers. The upper zone is characterised by open alluvia or bedrock with woody clumps in places dominated by *A. karoo, Tamarix* species (x2), *Lycium* species and *Salsola* species. Vegetation is mostly sparse with scour evident from recent floods, dominated by trees and shrubs but sparse grass cover. The largest impacts are flow related. and it is likely that reduced base flows and small floods has reduced the wet season duration and resulted in a decrease in non-woody vegetation in the marginal and lower zones although the reduction of flooding disturbance is likely to facilitate an increase in woody species abundance. Invasion by alien species was low, <10%, and mostly *Nicotiana glauca* and T. *ramosissima.*

Fish: C/D (59.9%), Confidence: 1.5
Limited fish sampling at or near the EWR site, meant that the reference species had to be extrapolated from fish data found (or anticipated to be present) in other parts of the Gouritz system taken from the PES/EIS project (DWA, 2013) and FROC (Kleynhans and Louw, 2007a). A low confidence (1.5) in the reference species at the site is thus applicable. Reference fish include five species, namely *Labeo umbratus* (LUMB), *Sandelia capensis* (SCAP), *Barbus anoplus* (BANO), *Anguilla mossambica* (AMOS) and *Pseudobarbus asper* (PASP), of which only one reference species, BANO, and the non-indigenous *Labeobarbus aeneus* (BAEN) were captured during the April 2014 survey. Main impacts on fish are: ▪ Loss of vegetation cover in slow shallow (SS) and slow deep (SD) habitats. ▪ Reduced flow and reduced water quality which reduced the FROC of the reference species, giving a PES of C/D. ▪ The very large flood in January 2014 probably removed both marginal and instream vegetation in SS and SD areas, thus impacting on preferred SCAP habitat and spawning substrate.
Macroinvertebrates: B/C (81.2%), Confidence: 2.5
Based on the hydrology being naturally non-perennial, the RC was established for a temporary system. The salinity of this system is also naturally high, which would affect the type of taxa able to survive there. The RC was developed using data collected at RHP site J1TOUW-BOOKE, which was situated upstream of both the J1TOUW-EWR3 and the confluence with the Doring River. The data sets for JITOUW_BOOKE were obtained both from the PES/EIS project (DWA, 2013) and from five DWS: Western Cape data sets for the period 2004 – 2010. Note that the PES/EIS data are highly summarized and exclude sampling details or invertebrate abundances, but does provide details of all macroinvertebrates collected at this site historically. *Note that for all sites, the RC was modified on the basis of discrepancies in habitat between the selected reference site and the sampling site, and on specialist experience.* The South African Scoring System version 5 (SASS5) score for the single sample collected in April 2014 was 57, with 13 taxa and an Average Score per Taxon (ASPT) of 4.4. The only relatively flow-sensitive taxa collected were beatid mayflies, which were collected in numbers among dense filamentous algae at the site. The reference macroinvertebrate community also comprises mainly resilient, non-sensitive taxa, with a Total Score < 9) and an ASPT < 5. The SASS5 score for all taxa collected is less than 100. The largest deviation between the sample and the RC is in the greater proportion of taxa with a preference for slow-flowing water and for the water column, which are two of the most resilient and persistent habitat elements in a river of this nature. Taxa with a preference for high- or moderate quality water, which are low in number even at the reference state, were either fewer in or absent from the sample. Taxa expected but absent from the sample included additional species of Baetidae, Hydracarina, Aeshnidae, Hydrophilidae, Gerridae, Veliidae, and Dytiscidae. The major causes of the alteration in the community are – in order of importance: ▪ The altered hydrology of the site (the moderate confidence hydrology suggests that baseflows have decreased significantly in volume, in time and distribution). The sources of the hydrological changes are farms dams, irrigation, grazing and domestic water use. ▪ The deterioration in habitat quality, and the reduction in water quality. The reduction in water quality is related to agricultural inputs (chiefly nutrients). The deterioration in habitat quality is linked to the hydrological and water quality change, and the high incidence of filamentous algae which obstructs and clogs other habitat elements.

The PES is a B/C. The major causes of the change from RC are mainly flow related. Farm dams and irrigation have resulted in reduced base flows and small floods, which also influence the duration of the seasons (loner dry and shorter wet seasons). Deteriorated water quality is due to elevated nutrient loads. Alien plant species were present.

3.4 RECOMMENDED ECOLOGICAL CATEGORY

The REC is determined based on ecological criteria only and considered the EIS and the restoration potential of the site. The EIS is HIGH and, according to the RDM policy, the REC should be set to improve the PES. However there is uncertainty in what aspects need to improve as the impacts and the causes are not well understood and known. It is likely that some of the ratings for the PES should be higher, which would result in a B EC. In light of this uncertainty and that improvment would require an increase in base flows and small floods, which cannot be supplied without additional infrastructure or restrictions of allocation, the PES is set to maintain the REC.

3.5 ECOCLASSIFICATION SUMMARY

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

Table 3.2 J1TOUW-EWR3: Summary of EcoClassification results

Component	PES and REC
IHI Hydrology	**B/C**
Water quality	**B/C**
Geomorphology	**B**
Fish	**C/D**
Invertebrates	**B/C**
Instream	**C**
Riparian vegetation	**B/C**
EcoStatus	**B/C**
Instream IHI	**C**
Riparian IHI	**C**
EIS	**HIGH**

The instream biota is affected mainly by flow-related impacts and EWRs were set to maintain an Instream REC of a C.

4 EWR REQUIREMENTS: TOUWS RIVER – J1TOUW-EWR3

4.1 FLOW VS STRESS RELATIONSHIP

The fish and macroinvertebrate stress flow index is provided in **Figure 4.1**. The integrated stress curve for both the dry season (red curve) and wet season (blue curve) is illustrated on the graph. A description of the habitat and response associated with the key stress is provided in **Table 4.1** and **4.2**. According to the modelled PD hydrology, no flow may occur in each month, but occurs more frequently in February (the PD hydrology indicates no flow 80% of the time in this month). It is therefore not relevant to provide ecologically-based stress flow indices and descriptors for the driest month. Naturalised flows, however, provide the stress reference for the EWR-related stress, and the modelled naturalised hydrology has substantially higher flows (in fact, perenniality is implied in the natural hydrology). The RDRM therefore requires a stress index function to be specified (between the (natural) base flow of 0.22 m^3/s and zero flow – **Figure 4.1**), even though it is not really relevant when PD flows are taken into account (with no increase of PD flows). For this purpose, a linear relationship is applied (refer to **Figure 4.2**). Of more importance, however, are the stress-shifts from naturalised conditions, and in the absence of further information, approximately PD stress is used for the dry month (February) for the 20% time that low flows are simulated to occur. This is considered more reasonable (and realistic) than reducing flows to zero for 100% of the time (for the dry month), which in any event only reduces the low flow EWR requirement by 0.3%.

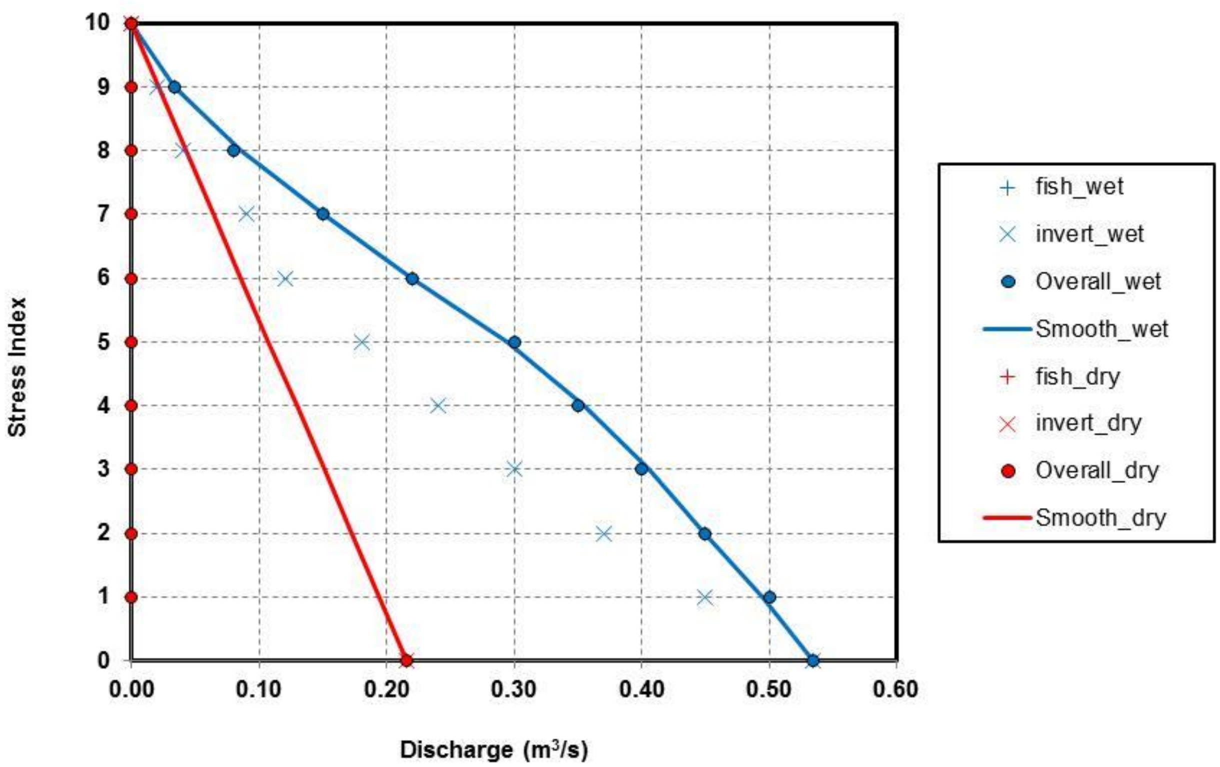


Figure 4.1 J1TOUW-EWR3: Fish, macroinvertebrate and integrated stress index

Table 4.1 J1TOUW-EWR3: Summarised habitat/biotic responses of fish during the wet season

Stress	Flow (m^3/s)	Habitat and stress description
Wet season: May		
9	0.034	Only semi-rheophilic riffle spawning species are present. The small minnow (PASP) and large LUMB requires depths of 15 to 20 cm for spawning and migration. Riffle depths < 20 cm allows for very limited migration of eels and LUMB. Velocities of ≤ 0.05 m/s may be too low for fish spawning, but water depths in riffles are considered the preferred critical parameter for fish due to the wide range of velocities found in riffle areas and the lack of firm data on preferred spawning velocities. Thus if suitable depths are available in riffle areas, it can reasonably be assumed that velocities suitable for spawning will be present. No fast habitats for eels are present at these flows. No water quality problems are expected.
5	0.30	Although limited fast habitat is present, no fast deep (FD) biotopes are available. Average riffle depths of 14 cm and maximum of 25 cm will allow for limited migration and spawning of LUMB, but low velocities (maximum < 0.3 m/s) will reduce spawning success. Spawning in this reach is probably limited to flood or freshet conditions when high flow velocities are present.
2	0.45	Minimal stress is estimated due to good habitat diversity and water quality with all fish functions (apart from spawning) supported. This includes suitable depths for migration over riffles. The primary limiting factor (considered to be natural) is the availability of fast habitats suitable for spawning, which is only associated with flood events.

Table 4.2 J1TOUW-EWR3: Summarised habitat/biotic responses of macroinvertebrates during the wet season

Stress	Flow (m^3/s)	Habitat and stress description
Wet season: May		
9	0.02	No fast surface flow is present. Trickling flows are likely, based on observations during the site visit. The width is 18.8 m, with an ave. depth of 0.1 m and a maximum depth of 0.18 m (surface water is present in limited areas of the channel). All habitat is very shallow and exposed to evaporation. The dominant condition is shallow water over coarse sediments, with small areas of slow flow. Simuliids may persist for up to two weeks in areas of trickling flow where there is adequate depth over the top of cobbles (0.05 m). There is likely to be nutrient enrichment, and if the air temperature is high it is likely that there will be extensive filamentous algae. This provides oxygenation and cover for mayflies and juveniles of other taxa in the short term but, as it decays, will result in an oxygen deficit in the standing water.
3	0.30	The dominant habitat is shallow water (ave. depth 0.14 m) over cobbles, with small areas of moderate to slow flow. During summer, temperatures are high and the macroinvertebrates will use the underside of cobbles, and algal mats for cover. All taxa are maintained. Simuliids will occur in the flow areas.
0	0.53	Limited areas of fast flow (riffles) across the 28.5 m of wetted channel exist. The majority of the channel will be slow flowing with shallow runs/pool type habitat. There is ample habitat for all taxa. Where the max depth of 0.28 m occurs, there should be robust hemipteran and coleopteran communities in the water column. The taxa will seek shelter from high temperatures in the marginal vegetation (MV) and under loose cobbles. Summer high flows will maintain these habitats.

4.2 HYDROLOGICAL CONSIDERATIONS

The wettest and driest months were identified as May and February, respectively. Droughts are set at 95% exceedance (flow). Maintenance flows are set at 60% exceedance (flow).

The hydrological modelling indicates that the site was perennial under natural conditions. PD conditions, however, are characterised by very short periods of wet season base flows, interspersed with periods of no flow. The site therefore has PD flow characteristics that are ephemeral to seasonal.

4.3 INSTREAM BIOTA REQUIREMENTS

The Habitat Flow Stressor Response-Reserve Model (HFSR-RM) generates the stress (and flow) requirements for different ECs. Once specialists are satisfied that these results are adequate to maintain the river at the target EC, descriptions are provided for key stress points (**Table 4.3**). Note that in this case the fish requirement was the highest and drove the final EWR. The lower macroinvertebrate requirements are provided in the table for possible future use if scenarios need to be assessed.

Table 4.3 J1TOUW-EWR3: Stress requirements and habitat and instream biota description

Duration	Stress: Required and (final*)	Flow (m^3/s): Required and (final)	Habitat and stress description
Wet season: May			
95% (Drought)	10	0	**Fish:** All fish are confined to SD and SS habitats. Water quality deteriorates and there is a lack of suitable cover due to scarcity of marginal or instream vegetation and siltation of SD habitats. These conditions increase mortality due to disease, limited available habitats and high predation. Hardy species under stress but survive in refuge pools.
	10	0	**Macroinvertebrates:** Only hardy and resilient taxa scoring 5 or less and with no requirement for moving water remain and occur in low abundances. Aerial taxa may relocate. Summer water temperatures are likely to be high and water quality will worsen as this condition persists.
60% (Maintenance)	9.7	0.006	**Fish:** Low flows keep pools topped up and reduce the deterioration in water quality. Depths over riffles (average: 7 cm; maximum: 12 cm) allow limited movement between pools of small fish (PASP) only. But high mortalities will occur as a result of limited habitat and scarcity of suitable cover.

Duration	Stress: Required and (final*)	Flow (m^3/s): Required and (final)	Habitat and stress description
	9.7	0.006	**Macroinvertebrates:** At this discharge there is minimal surface flow, although there may be trickling flow in small areas. The habitat comprises largely SCS (slow flow over coarse substrate) and SFS (slow flow over fine substrate). The entire habitat is very shallow and exposed to high evaporative rates. During summer, filamentous algae provides habitat for juvenile baetids, but will result in water quality problems if regular events are not experienced. With the assumption that the higher flows will be delivered, as is the case in PD, the EWR flows should maintain the resilient macroinvertebrate fauna in a B/C Category.

* Final HFSR-RM model output values provided in brackets only if different from requirement.

4.4 VERIFICATION OF LOW FLOWS: RIPARIAN VEGETATION

The low flow verification was done by comparing natural, PD and recommended levels of inundation of certain riparian indicators in May (wettest month) and February (driest month), both at the 50th percentile. Data for May are shown in **Table 4.4**. Stream permanency is reduced from Natural (99.5%) to 52.5% but is similar to PD. Discharge at 50% is as follows: Natural – 0.41 m^3/s; PD – 0.08 m^3/s; EWR requirement for PES (Category C) – 0.09 m^3/s. The recommended flows do not exceed natural and in all cases the water level is similar to PD; hence the low flows should maintain the riparian vegetation category. **Table 4.4** provides a summary of the low flow verification.

Table 4.4 J1TOUW-EWR3: Detail of low flow verification (m^3/s) using riparian vegetation

Monthly snap shot						**May**
Inundation (May at 50%)						**50.0%**
Hydrology component				**NAT**	**PD**	**PES B/C**
Discharge (at month and percentile)				0.41	0.08	0.09
Scenario compared to Natural flows				-	Never more	Never more
Stream permanence (%)				99.5	52.5	52.5
Indicators	**Limit of range**	**Zone**	**Elevation**	**NAT**	**PD**	**PES B/C**
Juncus lomatophyllus Indicator range: 0.39*	Lower limit	Marg zone	0.513	0.253	0.313	0.313
	Upper limit	Lower zone	0.907	0.647	0.707	0.707
	% of population inundated			0	0	0
Phragmites australis Indicator range: 0.71*	Lower limit	Marg zone	0.608	0.348	0.408	0.408
	Upper limit	Lower zone	1.317	1.057	1.117	1.117
	% of population inundated			0	0	0

* Upper limit value less the lower limit value = indicator range and applicable to all tables in the report.

4.5 HIGH FLOW REQUIREMENTS

Detailed motivations are provided in **Table 4.5** and final high flow results are provided in **Table 4.6**.

Table 4.5 J1TOUW-EWR3: Identification of instream functions addressed by the identified floods for riparian vegetation and geomorphology

Motivations	Fish flood functions						Macroinvertebrate flood functions			
	Migration cues and spawning	Migration habitat (depth etc.)	Clean spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas
CLASS I (2 - 4)[1]										
Riparian vegetation: The flood is too small to inundate riparian vegetation, but will sustain marginal zone.	✓	✓	✓	✓	✓	✓	✓	✓		✓
CLASS II (7 - 10)										
Riparian vegetation: 10 - 35% of the marginal zone sedges are flooded and are important for growth and reproduction.			✓		✓		✓	✓		✓
CLASS III (30)										
Riparian vegetation: 50 - 100% of the lower zone sedges and 40% of reeds at the site are inundated. The flood is important for growth and production, and for preventing terrestrialisation and/or alien invasion in the marginal and lower zones.			✓		✓					
CLASS IV (70 - 90)										
Riparian vegetation: The lower zone and 94 - 100% of reeds are completely inundated. This flood is important for flushing, scouring, maintaining riparian diversity and for preventing terrestrialisation and/or alien invasion.										
CLASS V (>120)										
Geomorphology: The flood accounts for 37% and 40% of the long term transport of sand and gravels, respectively. It also prevents vegetation encroachment (and the associated increased flood risk) that has affected other regulated rivers in the region. Secondary channels are activated and scoured while pools are flushed. **Riparian vegetation:** The flood will scour most zones, remove vegetation (including alien species) and reduce alien species invasion and terrestrialisation. Approximately 35% of the *Tamarix* population is inundated and woody encroachment into the marginal and lower zones is prevented.	✓									

1 Flood Class and flood range with (peak m^3/s) provided).

DWS Gauge J1H018, which is located upstream of the site, was used to assess historic occurrences of high flows.

Table 4.6 J1TOUW-EWR3: Recommended flood events

Flood class (Peak in m³/s)	Flood requirements*	Months	Daily ave.	Duration (days)
CLASS I (2 - 4)	2	September – November	3.6	6
CLASS II (7 - 10)	1	April – August	8.3	3
CLASS III (30)	1	May – June	23	3.54
CLASS IV (70 - 90)	1:3		50	5
CLASS V (>120)	1:5		82	6

*Refers to frequency of occurrence per year.

The RDRM distributes the high flow volumes across the wet period months according to their natural distribution. The months provided by specialists are those in which floods are recommended, but there will be naturally-determined variations in the final EWR high flow time series.

4.6 EWR RESULTS

The results are provided as an EWR table (**Table 4.7**) and an EWR rule (**Table 4.8**). Flow duration graphs are plotted in **Figures 4.2** and **4.3**. Detailed results are provided in the model generated report for each category in **Appendix D**.

The low flow EWR rule table is used for building rules for EWR releases. The information on specific flood releases is provided in the EWR table. Note that these tables on its own cannot be used for dam or system operation but will feed into an integrated model to determine the operation of the system. Note that high flows (floods), if released from dams, will require hydrodynamic modelling to determine the actual releases to achieve the instantaneous peak at the EWR site. A summary of the results is provided in **Table 4.9**.

Table 4.7 J1TOUW-EWR3: EWR table (m^3/s) for Instream PES and REC: C

Month	Low Flows			High Flows (m^3/s)	
	Drought (90%) (m^3/s)	60% (m^3/s)	50% (m^3/s)	Daily average (m^3/s)	Duration (days)
October	0.000	0.005	0.015		
November	0.000	0.006	0.014	3.6	6
December	0.000	0.005	0.013		
January	0.000	0.004	0.005		
February	0.000	0.000	0.000		
March	0.000	0.003	0.004		
April	0.000	0.003	0.009		
May	0.000	0.009	0.023	23	3.54
June	0.000	0.007	0.016		
July	0.000	0.006	0.016	8.3	3
August	0.000	0.006	0.017		
September	0.000	0.005	0.010	3.6	6

Table 4.8 J1TOUW-EWR3: Low Flow assurance rules (m^3/s) for Instream PES and REC: C

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
October	0.131	0.058	0.032	0.030	0.015	0.005	0.000	0.000	0.000	0.000
November	0.136	0.047	0.041	0.032	0.014	0.006	0.000	0.000	0.000	0.000
December	0.104	0.037	0.025	0.015	0.013	0.005	0.000	0.000	0.000	0.000
January	0.087	0.009	0.005	0.005	0.005	0.004	0.000	0.000	0.000	0.000
February	0.075	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
March	0.116	0.022	0.006	0.004	0.004	0.003	0.000	0.000	0.000	0.000
April	0.182	0.062	0.034	0.022	0.009	0.003	0.000	0.000	0.000	0.000
May	0.163	0.125	0.081	0.047	0.023	0.009	0.000	0.000	0.000	0.000
June	0.133	0.083	0.055	0.027	0.016	0.007	0.000	0.000	0.000	0.000
July	0.107	0.055	0.046	0.037	0.016	0.006	0.000	0.000	0.000	0.000
August	0.132	0.048	0.027	0.024	0.017	0.006	0.001	0.000	0.000	0.000
September	0.096	0.027	0.014	0.013	0.010	0.005	0.000	0.000	0.000	0.000

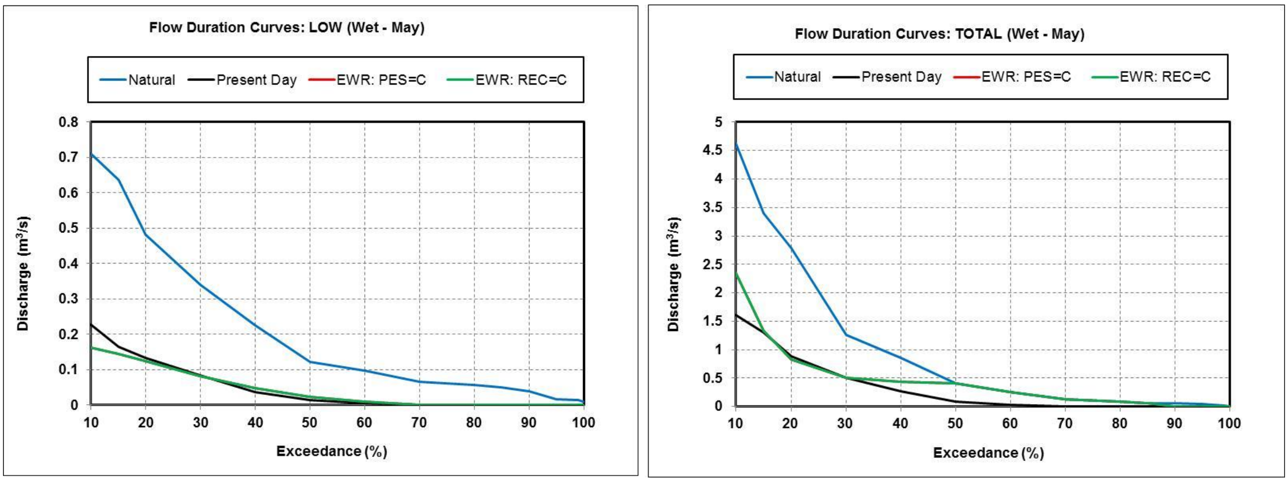


Figure 4.2 J1TOUW-EWR3: Flow duration graph for the wet season low flows (left), total flows (right)

Table 4.9 J1TOUW-EWR3: Summary of results as a percentage of the nMAR

EcoStatus	nMAR (MCM)	pMAR (MCM)	Low flows (MCM)	Low flows (%)	High flows (MCM)	High flows (%)	Total flows (MCM)	Total (%)
Instream PES; REC: C	45.2	22.26	1.152	2.6	11.54	25.6	12.69	28.2

5 ECOCLASSIFICATION: GAMKA RIVER – J2GAMK-EWR4

5.1 BACKGROUND

The EWR site is situated in the Gamkaskloof and Die Hel in the Swartberg Nature Reserve, a World Heritage Site **(Figure 5.1**). The site is situated in Gamka River poort downstream of the bridge. There are three upstream dams; two of which which supply Beaufort West with domestic water and Gamkapoort Dam upstream of the site which supports domestic water requirements and irrigation downstream. The river is therefore used as a conduit to supply downstream users. The manner of operation is pulsed flow releases with no other releases from the dam apart from a constant leak and spills (**Figure 5.2**).

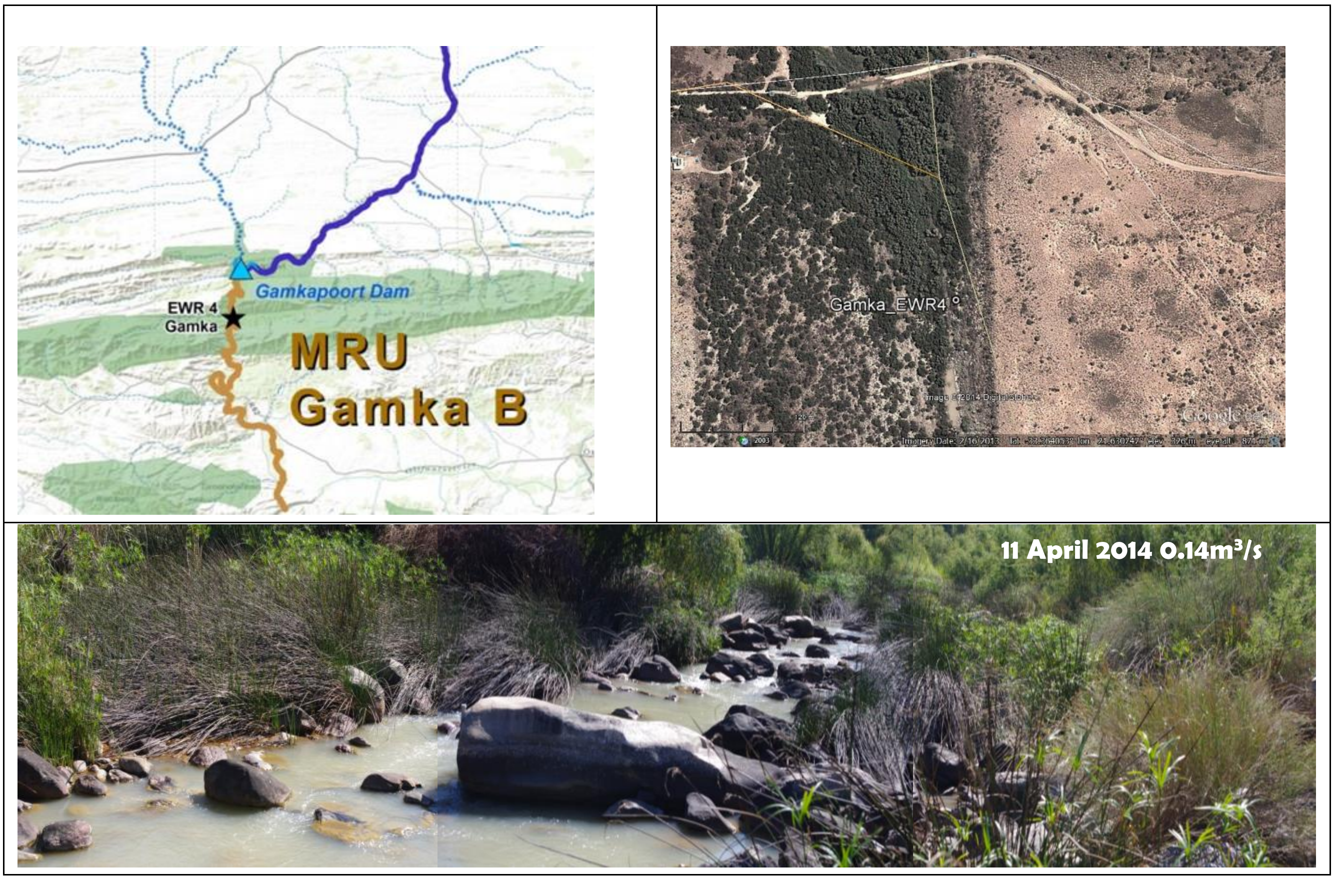


Figure 5.1 A map, Google image and downstream view of the EWR site

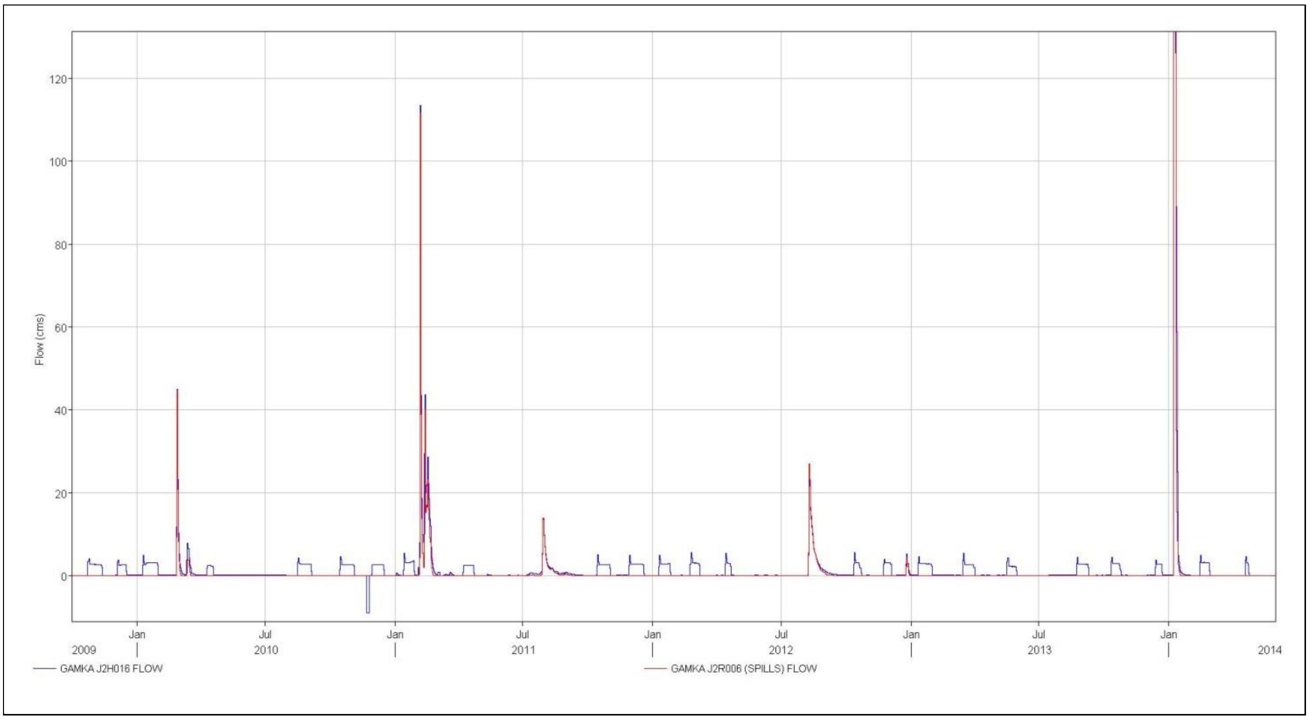


Figure 5.2 The present flow regime illustrating the pulsed operation from Gamkapoort Dam

5.2 EIS RESULTS

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

- Rare and endangered species: *P. asper*.
- Diversity of habitat types and features: Backwaters, floodplain, multi-channels, marginal vegetation, shoots, rapids, deep pools, overhanging vegetation.
- Unique riparian/wetland species: Five endemic riparian species occur at the site: *Cyperus textilis, Diospyros austro-africana* var. *austro-africana, Nymania capensis, Salsola aphylla* and *Tamarix usneoides.*
- Diversity of riparian/wetland habitat types and features: Both alluvial and rocky habitats occur, as well as gorge and pool environments. Areas of cobble/boulder are less frequent but occur while bedrock within the channel and alluvial deposits on the banks are common.
- Riparian/wetland migration corridor: The distinct band of dense woody vegetation (mainly *Salix* species) provides an effective corridor through a terrestrial landscape that is characterised by sparse, short vegetation and extreme topography.

5.3 PRESENT ECOLOGICAL STATE

The PES reflects the changes in the EC relative to reference conditions. The summarised PES information is provided in **Table 5.1** and water quality and diatom information is provided in **Appendix A** and **B**, respectively.

Table 5.1 J2GAMK-EWR4: Present Ecological State

IHI Hydrology: PES: C/D, Confidence: 2.7

The 36 million m^3/a Gamkapoort Dam, built in 1967, is located upstream of the site. The nMAR is 85.54 MCM and the pMAR is 61.69 MCM (72.1% of the nMAR). There are no major differences between observed hydrology and modelled PD hydrology, but the monthly flows obscure the current flow regime, which comprises intermittent flood releases from the dam (one approximately every two months) and only leakage in-between. This means that artificial floods are released through the year, i.e. aseasonally.

Water quality: PES: B/C (80.6%), Confidence: 3

Salt (sodium and chloride) levels are slightly elevated in terms of irrigation guidelines, which were used to provide some indication of salt conditions. This is seen as a slight elevation above what is expected for the area due to influences of background geology on instream salinity levels. The natural state, i.e. before dam construction, is unknown but is expected to be in a poorer water quality state than current conditions which maintains water quality state due to flushing flows from Gamkapoort Dam. Some nutrients and toxics elevations are expected from fertilizer and pesticide use for irrigation purposes, although this is limited. Some turbidity impacts are expected downstream of the dam.

IHI Instream: PES: C (64.5%), Confidence 2.6 **IHI Riparian: PES: C/D 58.3 (%), Confidence 3.3**

The major impacts are altered hydrology due to the operation of the upstream Gamkapoort Dam, chiefly the unseasonal flood releases. The presence of alien vegetation also the riparian zone.

Geomorphology: PES: D (55.6%), Confidence: 3

The operation of the dam has resulted in reduced sediment supply, critically reduced large floods and frequent small floods in the downstream reaches, which has facilitated substantial vegetation encroachment into the channel. The marginal vegetation is dense, bed sediment largely stripped from the site (at the EWR cross-section, mainly only large boulders remained with few gravels or cobbles in the active channel).

Riparian vegetation: PES: D (56.7%), Confidence: 3.8

The site occurs within Gamka Thicket, which refers to a terrestrial vegetation type dominated by spekboom and low shrubs but with mention of *A. karoo* (Mucina and Rutherford, 2006).

On 17 July 1797, J Barrow, travelling from the Dwyka River to the Gamka River, described the Gamka as follows: "...in vain did the eye wander in search of tree or lofty shrub, or blade of grass or living creature...on approaching the river Ghamka the face of the country changed a little for the better. Large mimosas (*A. karoo*) skirted its banks among which were also mingled a species of willow (*Salix mucronata*) ... a considerable stream of water rolled over the bed of the river". (Barrow, 1801; in Skead, 2009). Historical aerial photographs from 1944 show an increase in woody vegetation in all sub-zones, likely a response to flow regulation and flooding regime. Google Earth images show distinct increase in woody cover (*A. karoo* notably) from 2003 to 2013 along the upper zone.

In the marginal and lower zones one would expect less sedge, reed and woody vegetation, which are currently supported by flow regulation, increased stream permanency and flood reduction from the dam. In the upper zone one would expect less dense *A. karoo* and more older and large individuals.

The marginal zone was dominated mostly by non-woody vegetation (sedges) with dense clumps of trees (*S. mucronata*) in places. Four dominant habitats occurred:
1) Boulder/cobble with sedges (*Juncus* species) and patches of *Gomphostigma virgatum*.
2) Dense reedbeds especially at the crossing and directly related to it.
3) Dense stands of *S. mucronata* (also enhanced at crossing).
4) Fans and incoming tributaries which support woody vegetation, mainly *S. mucronata*.

The lower zone was a mixture of woody and non-woody vegetation, overall with cover higher than expected for the RC. Perennial aliens (*Nerium oleander*) were at about 10% cover and encroachment of the sub-zone by *A. karoo* was evident, even after recent large floods. Habitats were similar to the marginal zone but also with:
1) Dense woody areas (*S. mucronata*) with shade, especially at the crossing and fans from tributaries.

2) Tributary seep area with sedges and restios, generally these seep areas supported different species from the rest of the sub-zone.

Both marginal and lower zone vegetation have increased due to altered flow regime.

The upper zone was characterised by *A. karoo* thicket with some terrestrial species and open grassed areas. High flow channels supported sparse clumps of *Juncus* species, indicating likely ephemeral flooding. The main impacts in the sub-zone were increased woody abundance due to reduced flooding disturbance and the presence of perennial aliens.

The trend is likely stable as the overwhelming impact for the reach is altered flow regime and the vegetation would have adjusted by now.

Fish: PES: C/D (60.4%), Confidence: 2.5

Six indigenous species were expected at this site: two eels AMOS and *Anguilla marmorata* (AMAR) and four fish species LUMB, BANO, PASP and SCAP. Only one fish species (LUMB) and an eel (AMAR) were captured during the April 2014 survey. Two alien fish species, namely largemouth bass - *Micropterus salmoides* (MSAL) and common carp - *Cyprinus carpio* (CCAR), and; three non-indigenous species *Tilapia sparrmanii* (TSPA), smallmouth yellowfish - *Labeobarbus aeneus* (BAEN) and Mossambique tilapia - *Oreochromis mossambicus* (OMOS) were also sampled. The reference species were all expected to be present, but at drastically reduced FROCs due to the following impacts:

- Predation and competition from alien fish species.
- Significantly altered flow regime due to releases from the Gamkapoort Dam, with increased flows during the dry season due to dam releases.

Macroinvertebrates: PES: C/D (61.4%), Confidence: 2.5

There was very little information available regarding the daily natural hydrology of this site (i.e. pre- dam construction). In establishing the RC, the assumption was made, based on the flow-sensitivity of the macroinvertebrates occupying the nearby tributary (on which the RHP site occurs), that in the natural state flow was perennial or close to perennial.

The RC was derived on the basis of data obtained from two DWS Western Cape data sets (July 2004) from the RHP sites J2WATE-HELL1 and 2 that are both located on a tributary close to, and upstream of, EWR 4. The tributary joins the Gamka River just upstream of the low-level bridge close to the site and is in the same EcoRegion Level II. These sites are in a World Heritage area and are not subject to many impacts other than abstraction for irrigation. The assumption has been made that the sites are sufficiently similar to J2GAMK-EWR4 to use them as reference sites.

The SASS5 sample yielded a score of 77, with 14 taxa and an ASPT of 5.5. The reference ASPT was 6.6. The only taxa in the sample with a preference for high flow velocities were the low-scoring simuliids. The highest scoring family was Baetidae (> 2 species present, score 12), and the remaining families in the community all scored < 10, indicating a robust, resilient group of macroinvertebrates, adapted to low or zero flow conditions. The PD hydrology for the site indicates that there can be extensive periods of no flow each year.

Taxa expected but not present (RC) included those with a preference for very good water quality (telagonodid mayflies, pyralids, helodid beetles, stoneflies), those with a preference for both good quality water and fast flow and cobble habitat (perlid and notonemourid stoneflies, tricorythid and polymytarcid mayflies, athericid fly larvae) and families with a preference for MV and gravel, sand and mud (GSM).

The major cause of the alteration in the community is altered hydrology and sediment supply as a result of Gamkakloof Dam. It is likely that the low-level bridge just upstream of the site may also have had an impact on habitat quality.

The PES is a C/D and the EcoStatus models are provided electronically. The major issues resulting in the change from RC are the alteration in sediment regime due to the upstream impoundment, the small regular and aseasonal flood releases from the Gamkapoort Dam, and the decreased frequency of large floods. Key non-flow-related impacts include the presence of alien vegetation species and predation and competition from alien and non-indigenous fish species.

5.4 RECOMMENDED ECOLOGICAL CATEGORY

The REC is determined based on ecological criteria only and considered the EIS and the restoration potential of the site. As the EIS is HIGH, improvement is required. The REC is therefore set to improve the PES from a C/D to a C. Improvement will require an improved flooding regime. Acknowledging the current operating rules and possible constraints, the following recommendations were made.

A 50 m^3/s flood is required once a year during the wet season. Furthermore, during the wet season the current evens should be released in a different fashion, i.e. the receding limb shape should change to be a more natural hydrograph shape. These changes, even with the winter unseasonal floods, should result in the improvement in category. Further improvement will be achieved if the unseasonal releases during the dry season is minimised.

The change in hydrograph is to allow successful spawning of fish species in this river reach which utilise these high flows to access suitable habitats for spawning during summer (September to March). These spawning habitats include riffle areas, as well as newly inundated marginal vegetation. Spawning involves upstream migration to these spawning habitats, laying of eggs on suitable substrate, the incubation period for hatching and then initial development of the fish larvae. The process takes from approximately 4 to 8 days. In addition, spawning itself usually takes place on the receding limb of the hydrograph, after the flood peak. Thus a gently sloping receding limb of the hydrograph over at least 4 to 5 days is required to prevent the stranding and drying out of newly laid eggs.

The resulting analysis of the restoration potential (**Table 5.2**), shows that only a half a Category improvement is possible, i.e. a C EC.

Table 5.2 J2GAMK-EWR4: Recommended Ecological Category

Physico-chemical variables: REC: B (82.7%), Confidence:3
The improved flooding regime will result in further flushing of accumulated nutrients, resulting in an improved state (B Category) for water quality. Note that there is some uncertainty regarding the nutrient source as impacts are far upstream.
Geomorphology: REC: C (63.7%), Confidence: 2.5
Release of larger floods would open up the channel of the Gamka downstream of the dam, reinstating larger inchannel habitat conditions which would be more similar to the RC, but would not be able to alleviate the reduced sediment supply.
Riparian vegetation: REC: C (65%), Confidence: 3
The actions required to improve vegetation is increased flood magnitude and frequency in the summer (50 m^3/s every year) and decreased flow regulation with fewer releases in winter as per changed shape of releases (see above recommendations under the REC). The likely response would be: ▪ Marginal zone and Lower zone – Reduced sedge cover. ▪ Upper zone – Scour out some of the woody vegetation.

Fish: REC: C (71.6%), Confidence: 2
Conditions for indigenous fish species improve due to more natural flow pattern in the river via improved management of water releases from the upstream Gamkapoort Dam. This should include reduced winter flows and increased high flows in summer which will provide improved breeding conditions and allow natural upstream spawning migrations to suitable breeding areas for all indigenous species. This should marginally increase the FROCs of indigenous species, elevating the PES by half a category.
Macroinvertebrates: REC: B/C (79.4%), Confidence: 2
The more natural hydrology and higher summer flows is likely to favour an increase in the higher-scoring, sensitive, flow-dependent taxa (e.g. Perlidae, Polymytarcidae, Tricorythidae), and in taxa that favour the water column (e.g. habitat conditions would improve during summer, and breeding and hatching will follow more natural patterns. These factors in combination would shift the invertebrate community composition closer towards that expected under RC.

5.5 ECOCLASSIFICATION SUMMARY

The EcoClassification results are summarised in **Table 5.3**.

Table 5.3 J2GAMK-EWR4: Summary of EcoClassification results

Component	PES	REC
IHI Hydrology	C/D	
Water quality	B/C	B
Geomorphology	D	C
Fish	C/D	C
Invertebrates	C/D	B/C
Instream	C/D	C
Riparian vegetation	D	C
EcoStatus	C/D	C
Instream IHI	C	
Riparian IHI	C/D	
EIS	HIGH	

The instream and riparian vegetation REC are impacted by flow reductions and other anthropogenic impacts. The EWRs were set to maintain the PES of a C/D. Improvement to the REC requires different operating rules using the same volume as being released currently. Setting of an EWR for an improved state will not be required as the low flows and the volume of released floods will stay the same. The distribution and shape of released floods will however change according to the recommendations made. Only descriptive requirements are provided in **Section 6.5** for attaining the REC.

6 EWR REQUIREMENTS: GAMKA RIVER – J2GAMK-EWR4

6.1 FLOW VS STRESS RELATIONSHIP

The fish and macroinvertebrate stress flow index is provided in **Figure 6.1**. The integrated stress curve for both the dry season (red curve) and wet season (blue curve) is illustrated on the graph. A description of the habitat and response associated with the key stress is provided in **Table 6.1** and **6.2**.

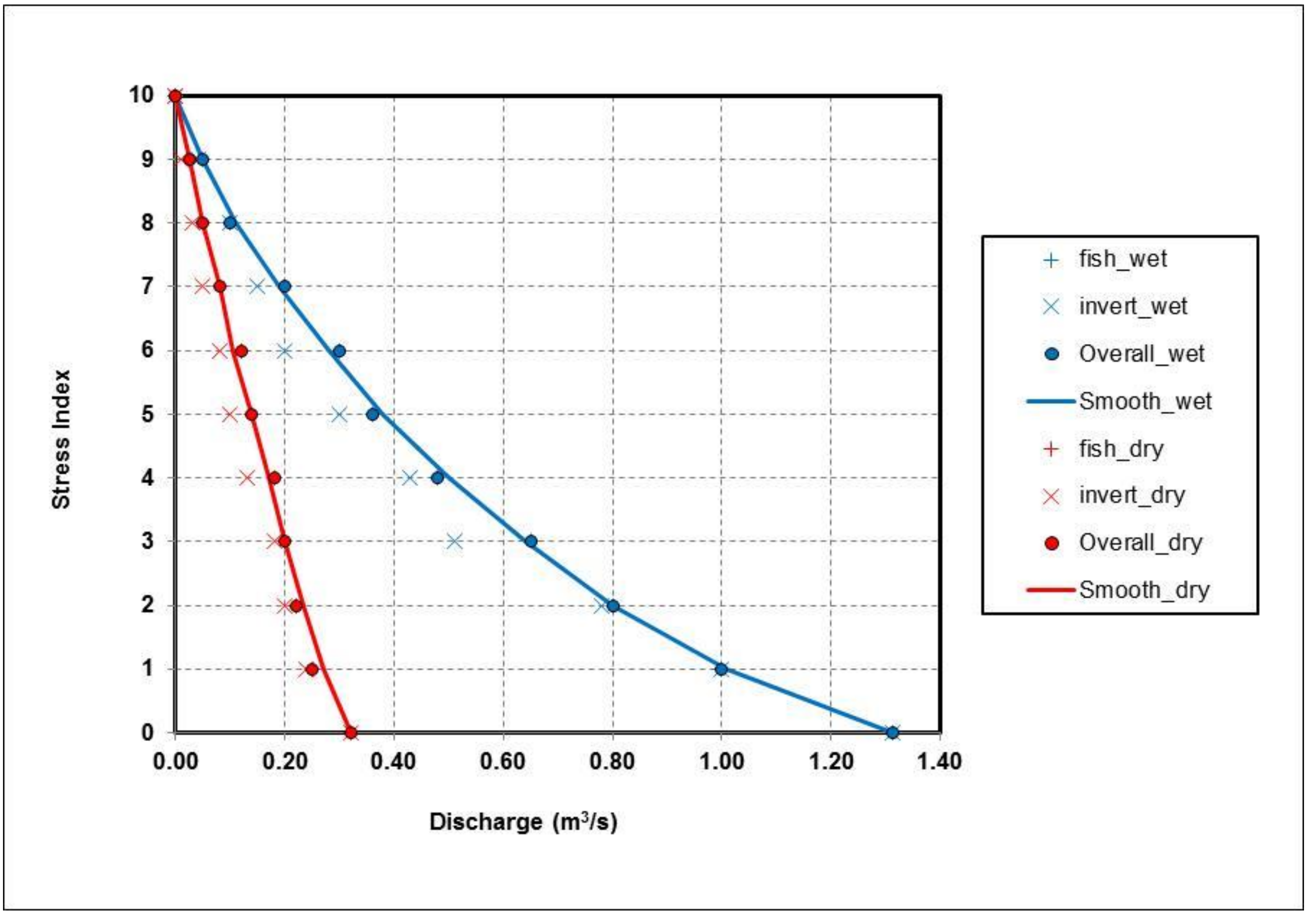


Figure 6.1 J2GAMK-EWR4: Fish, macroinvertebrate and integrated stress index

Table 6.1 J2GAMK-EWR4: Summarised habitat/biotic responses of fish during the dry and wet season

Stress	Flow (m^3/s)	Habitat and stress description
Dry season: July		
9	0.025	No flow dependent fish species are present, so these flows improve water quality and maintain pool habitat. No fast habitats are available for eels, and fish migrations are severely restricted due to shallow depths over critical riffle areas.
5	0.14	Adequate diversity of habitats will be available at this flow, including 50% of natural fast habitats and thus giving a moderate stress on the overall fish assemblage.

Stress	Flow (m^3/s)	Habitat and stress description
2	0.22	Minimal stress is estimated due to good habitat diversity and water quality with all fish functions supported. Riffles deep enough for migration but little fish movement in winter.
Wet season: May		
9	0.05	Only semi-rheophilic riffle spawning species are present, the small minnow (PASP) and large LUMB, requiring depths over 20 cm for spawning. Riffle depths of 8 cm are too shallow for spawning or migrations. No fast deep (FD) eel habitat is present.
5	0.36	Adequate diversity of habitats, including FD eel habitat, will be available at this flow to only have moderate stress on the overall fish assemblage. Although all fast habitat guilds will be provided, they will be reduced by half of the naturally expected composition. Average riffle depths (16 cm) will allow limited LUMB spawning and migration
2	0.8	Minimal stress is estimated due to good habitat diversity, water quality with all fish functions supported. This includes good riffle spawning habitat and no restrictions on migration over riffles. The primary limiting (compared to natural) aspect is reduced abundance of habitats (especially fast habitats).

Table 6.2 J2GAMK-EWR4: Summarised habitat/biotic responses of macroinvertebrates during the dry and wet season

Stress	Flow (m^3/s)	Habitat and stress description
Dry season: July		
6	0.08	Slower flow habitats prevail, with some fast habitat present. Depth and width (4.1 m) are not sufficient to inundate sedge stems but bases are covered and overhanging vegetation provides shelter and a food source. The community is maintained at this flow.
3	0.18	This discharge is associated with largely slow flow over coarse substrates (SCS), with some areas of very fast flow and fast flow. Cobbles and mobile rocks are sparsely distributed and tightly packed, and do not provide good habitat, irrespective of the flow conditions. Marginal zone sedges are only inundated at their bases, and overhanging stems provide some habitat, however this is not high quality.
Wet season: March		
7	0.15	The site was sampled at a discharge close to this on 11 Apr 2014. There are areas of very fast flow and fast flow, but the large boulder-type substrates do not provide suitable habitat for most flow dependent macroinvertebrates (FDIs). Cobbles and mobile rocks are sparsely distributed and packed. Marginal zone sedges are inundated to various degrees, and overhanging stems provide some habitat, however this is not of high quality. The habitat at this flow will maintain the macroinvertebrate community in a C/D Category.
3	0.59	This discharge is close to that of the Jan 14 sample (0.49 m^3/s). All hydraulic habitat types are represented. There is very fast deep flow across the channel (average depth 0.37 cm; maximum 1.2 m). This is likely too fast for most FDI taxa, and this partly explains their absence from the site. The majority of the taxa found in the C/D Category will seek refuge in the slower flowing areas of the river. The marginal zone sedge stems are inundated, providing habitat and shelter for developing juveniles and for taxa with a preference for slow and no flow habitat as well as vegetation.

6.2 HYDROLOGICAL CONSIDERATIONS

The wettest and driest months were identified as March and July. Droughts are set at 95% exceedance (flow). Maintenance flows are set at 60% exceedance (flow). The monthly modelled flows obscure the current flow regime, which comprises intermittent flood releases from the dam (one approximately every two months) and only leakage in-between. To achieve the REC, the operating rules for the flood releases must be revised. As this therefore does not imply a change in volume, an EWR rule has not been generated for the REC. The low flows will be the same for both PES and REC. A guide to the flooding requirements, which must be designed within the existing flood volumes have been provided.

6.3 INSTREAM BIOTA REQUIREMENTS

The HFSR-RM generates the stress (and flow) requirements for different ECs. Once specialists are satisfied that these results are adequate to maintain the river at the target EC, descriptions are provided for key stress points (**Table 6.3**).

Table 6.3 J2GAMK-EWR4: Stress requirements and habitat and instream biota description

Duration	Stress: Required and (final*)	Flow (m^3/s): Required and (final)	Habitat and stress description
Dry season: July			
95% (Drought)	9.6 (9.7)	0.01 (0.006)	**Fish:** Reduced water quality due to low flows, loss of fast flowing habitats, but pools maintained and suitable for all species present. No movement over riffles, but limited natural fish migrations occur. Very low flows occurred under natural conditions in this river.
	9.5	0.008	**Macroinvertebrates:** Trickling flows, with very low depths and width of 2.7 m. Many of the macroinvertebrates in the C/D PES community will persist in pools or shallow areas, at low abundances. Aerial taxa may relocate elsewhere or to deep pools and will disappear if this condition persists.
60% (Maintenance)	7.8 (8.2)	0.055 (0.046)	**Fish:** Increased depths in riffles (average 8 cm; maximum 19 cm) allow limited movement and limited increased habitat availability. Improved water quality due to increased flows. No suitable FD eel habitat present.
50%	7.7 (7.5)	0.059 (0.07)	**Fish:** Depths in riffles of 9 cm and 20 cm maximum. Higher than PD flows and stress levels acceptable for this naturally seasonal type system.
	6.5	0.06	**Macroinvertebrates:** Slower flow habitats prevail, with some fast habitat present. Depth and width (4.1 m) is not sufficient to inundate sedge stems but bases are covered and limited overhanging vegetation provides shelter and a food source. The C/D macroinvertebrate community should be maintained. As flows decrease, FDIs will be reduced in abundance over time.

Duration	Stress: Required and (final*)	Flow (m^3/s): Required and (final)	Habitat and stress description
Wet season: March			
95% (Drought)	9.7	0.015	**Fish:** No FD habitats for eels or for the larger LUMB spawning depths in riffles, with very limited spawning in riffles of small species PASP. Very limited migration possible over riffles due to shallow depths (average 6 cm; maximum 14 cm). High water temperatures and reduced water quality anticipated due to low flows.
	> 9.5 (9.7)	0.015	**Macroinvertebrates:** There is a loss of connectivity (lateral and longitudinal). Many of the more resilient taxa will relocate and persist in pools until conditions become intolerable. Water quality will deteriorate in the shallow pools.
60% (Maintenance)	7.3 (7.7)	0.17 (0.13)	**Fish:** Fast intermediate (FI) habitat now available and suitable depths in riffles (average 11 cm; maximum 24 cm) for spawning of *Pseudobarbus* spp., limited suitable eel habitat and limited safe passage through riffles for migration of all fish and eels. No water quality problems anticipated.
50%	7.0	0.20	**Fish:** Limited (8%) FI habitat available for eels. Riffle depths 13 cm average and 28 cm maximum allowing limited migration of all fish species. Stress levels acceptable in this seasonal type system.
	6.75 (6.0)	0.16 (0.20)	**Macroinvertebrates:** Areas of very fast flow and fast flow. The large boulder-type substrates do not provide suitable habitat for most FDIs. At the site, cobbles are sparsely distributed and tightly packed so that they too do not provide good habitat. There are small mobile cobble areas downstream however. Marginal zone sedges are inundated to various degrees, and overhanging stems provide some shelter. This and higher discharges will maintain the macroinvertebrate community.

* Final HFSR-RM model output values provided in brackets only if different from requirement.

6.4 VERIFICATION OF LOW FLOWS: RIPARIAN VEGETATION

The low flow verification is done by comparing levels of inundation of certain riparian indicators during March and July, both at the 50th percentile. Data are shown below (**Table 6.4**) for the high flow month of March. Stream permanency is maintained throughout with discharge at 50% as follows: Natural – 2.02 m^3/s; PD – 0.18 m^3/s; EWR requirement for PES (Category D) – 0.19 m^3/s. The recommended flows do not exceed Natural, and in all cases the level of vegetation above or below the water level is similar to PD; hence the low flows should maintain the riparian vegetation category. **Table 6.4** provides a summary of the low flow verification.

Table 6.4 J2GAMK-EWR4: Detail of low flow verification (m^3/s) using riparian vegetation

Monthly snap shot						**Mar**
Inundation (Mar at 50%)						**50.0%**
Hydrology component				**NAT**	**PD**	**PES D**
Discharge (at month and percentile)				2.02	0.18	0.19
Scenario compared to Natural flows				-	Never more	Never more
Stream permanence (%)				100	100	100
Indicators	**Range limit**	**Zone**	**Elevation**	**NAT**	**PD**	**PES D**
Cyperus textilis Indicator range: 0.69	Lower limit	Marg zone	0.064	-0.536	-0.196	**-0.196**
	Upper limit	Marg zone	0.757	0.157	0.497	**0.497**
	% of population inundated			77.333	28.259	28.259
Phragmites australis Indicator range: 0.75	Lower limit	Marg zone	0	-0.600	-0.260	**-0.260**
	Upper limit	Lower zone	1.753	1.153	1.493	**1.493**
	% of population inundated			34.236	14.836	14.836
Gomphostigma virgatum Indicator range: 0.77	Lower limit	Marg zone	0.096	-0.504	-0.164	**-0.164**
	Upper limit	Marg zone	0.865	0.265	0.605	**0.605**
	% of population inundated			65.554	21.326	21.326
Cliffortia Indicator range: 1.0	Lower limit	Marg zone	0.757	0.157	0.497	**0.497**
	Upper limit	Lower zone	1.758	1.158	1.498	**1.498**
	% of population inundated			0	0	0
Salix mucronata Indicator range: 0.98	Lower limit	Lower zone	1.161	0.561	0.901	**0.901**
	Upper limit	Upper zone	2.141	1.541	1.881	**1.881**
	% of population inundated			0	0	0
Nerium oleander Indicator range: 2.8	Lower limit	Marg zone	0.811	0.211	0.551	**0.551**
	Upper limit	Upper zone	3.615	3.015	3.355	**3.355**
	% of population inundated			0	0	0

6.5 HIGH FLOW REQUIREMENTS

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

Table 6.5 J2GAMK-EWR4: Identification of instream functions addressed by the identified floods for riparian vegetation and geomorphology

Motivations	Fish flood functions						Macroinvertebrate flood functions						
	Migration cues and spawning	Migration habitat (depth etc.)	Clean spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas	Return more natural cobble habitat	Create suitable habitat for taxa colonising by drift	Create sediment source for preferred vegetation (e.g.*Cyperus* spp)
CLASS I (1.7)[1]													
Geomorphology: These small events flush accumulated fines (deposited suspended load) from the channel bed and margins. These events may now occur as part of the summer releases from the dam.	✓	✓	✓	✓	✓	✓	✓	✓		✓			
CLASS II (5)													
Geomorphology: These small events flush accumulated fines (deposited suspended load) from the channel bed and margins. To achieve these events a small increase in the size of the releases at times will be required. **Riparian vegetation:** This event floods 50 - 100% of marginal zone sedges, 50% of reeds (that occurred at the cross-section), 100% of *G. virgatum* and 10% of *Cliffortia*. It is important for summer growth and reproduction and maintaining the marginal zone free of woody species other than *G. virgatum*. It also prevents woody alien species such as *N. oleander* in the marginal zone.	✓	✓	✓	✓	✓	✓	✓	✓		✓			
CLASS III (10 - 20)													
Riparian vegetation: This event floods most lower zone sedges, 70% of *Cliffortia*, 30% of *S. mucronata* and 25% of the alien woody *N. oleander*. It is also important for summer growth and production and for preventing terrestrialisation and alien invasion in both the marginal and lower zones.	✓	✓	✓	✓	✓	✓			✓				

Motivations	Fish flood functions						Macroinvertebrate flood functions						
	Migration cues and spawning	Migration habitat (depth etc.)	Clean spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas	Return more natural cobble habitat	Create suitable habitat for taxa colonising by drift	Create sediment source for preferred vegetation (e.g.*Cyperus* spp)
CLASS IV (50)													
Geomorphology: For the REC, this flood could be released to provide an annual scour and opening of the active channel to reverse some of the encroachment and channel narrowing impacts that results from regular small releases from the dam. **Riparian vegetation:** This event completely floods the lower zone, 94% of *S. mucronata* and nearly 50% of the alien *N. oleander*. It is important for flushing, scouring, maintaining riparian species and habitat diversity, and preventing terrestrialisation and alien invasion. It creates suitable habitat for taxa colonising by drift.			✓		✓				✓		✓		
CLASS V (>120)													
Geomorphology: This flood class is the effective discharge class for sands, gravels and small cobbles at the EWR site. Old flow gauge records from the 1920 - 1940 (i.e. prior to the dam) indicate that these, or larger, floods may have been the 1:2 year events. These large floods are required to scour the encroached, narrowing channel to widen it and reset vegetation encroachment, to remove some of the unnaturally dense vegetation within the riparian zone, and to scour pools in the reaches downstream. **Riparian vegetation:** This flood will scour most zones, remove vegetation (including aliens species) and prevent alien species invasion and terrestrialisation. It will clear some of the indigenous woody vegetation which will be a change towards reference state. It will also activate high flow channels on the right bank. These floods will ensure a return to more natural cobble habitat, create sediment source for preferred vegetation (e.g. *Cyperus* spp.) and creates suitable habitat for taxa			✓		✓				✓		✓	✓	✓

Motivations	Fish flood functions						Macroinvertebrate flood functions						
	Migration cues and spawning	Migration habitat (depth etc.)	Clean spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas	Return more natural cobble habitat	Create suitable habitat for taxa colonising by drift	Create sediment source for preferred vegetation (e.g.*Cyperus* spp)
colonising by drift.													
CLASS VI (>120)													
Geomorphology: Accounts for 37% and 40% of the long term transport of sand and gravels respectively. It will similarly be responsible for preventing vegetation encroachment (and associated increased flood risk) which has affected other dammed rivers in the region; activate and scour secondary channels in the reach, and flush pools. **Riparian vegetation:** Will scour most zones, remove vegetation (including alien species) and prevent alien species invasion and terrestrialisation. It floods about 35% of the *Tamarix* population and prevents woody encroachment of the marginal and lower zones.	✓												

The DWS gauge J2H016 which measures river releases from Gamkapoort Dam was present in the reach and used to verify high flows.

Table 6.6 J2GAMK-EWR4: Recommended flood events

Flood class (Peak in m^3/s)	Flood requirements*	Months	Daily ave.	Duration (days)
PES: C/D				
CLASS I (1.7)	5	September – December for fish	1.6	6
CLASS II (5)	4	October – April (earlier rather than later within this period for fish)	4.4	6
CLASS III (10 - 20)	2	December – April	16	4
CLASS IV (50)	1:3	March	37	5
CLASS V (>120)	1:5		82	7

Flood class (Peak in m^3/s)	Flood requirements*	Months	Daily ave.	Duration (days)
REC: C				
CLASS I (1.7)	6	September	1.6	6
CLASS II (5)	4	October - April	4.4	6
CLASS III (10 - 20)	2	December - April	16	4
CLASS IV (50)	1	March	37	5
CLASS V (>120)	1		82	7

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

The RDRM model distributes the high flow volumes across the wet period months according to the natural distribution. The months provided by specialists are therefore those in which floods are recommended, but there will be naturally-determined variations in the final EWR high flow time series results.

Improvement will require a change in the PD releases from Gamkapoort Dam. Acknowledging the current operating rules and possible constraints on the dam, the following recommendations were made.

Wet season: A 50 m^3/s flood is required once a year during the wet season. Furthermore, during the wet season the current events should be released in a different fashion, i.e. the receding limb shape should change to be a more natural hydrograph shape. These changes, even with the winter unseasonal floods, should result in the improvement in EcoStatus. Further improvement will be achieved if the unseasonal releases during the dry season are minimised.

The change in hydrograph allows successful spawning of fish species in this river reach which utilise these high flows to access suitable habitats for spawning during summer (September to March). These spawning habitats include riffle areas, as well as newly inundated marginal vegetation. Spawning involves upstream migration to these spawning habitats, laying of eggs on suitable substrate, the incubation period for hatching and then initial development of the fish larvae. The process takes from approximately 4 to 8 days. In addition, spawning itself usually takes place on the receding limb of the hydrograph, after the flood peak. Thus a gently sloping receding limb of the hydrograph over at least 4 to 5 days is required to prevent the stranding and drying out of newly laid eggs.

6.6 EWR RESULTS

The results are provided as an EWR table (**Table 6.7**) and an EWR rule (**Table 6.8**). Flow duration graphs are supplied as **Figure 6.2** and **6.3**. Detailed results are provided in the model generated report for each category in **Appendix D** for both low and total flows.

The low flow EWR rule table is used for building rules for EWR releases. The information on specific flood releases is provided in the EWR table. Note that these tables on its own cannot be used for dam or system operation but will feed into an integrated model to determine the operation of the system. Note that high flows (floods), if released from dams, will require hydrodynamic modelling to determine the actual releases to achieve the instantaneous peak at the EWR site. A summary of the results is provided in **Table 6.9**.

Table 6.7 J2GAMK-EWR4: EWR table (m^3/s) for a PES: C/D

Month	Low flows (m^3/s)			High flows	
	Drought (90%) (m^3/s)	60% (m^3/s)	50% (m^3/s)	Daily average (m^3/s)	Duration (days)
October	0.014	0.060	0.077	1.6	6
November	0.014	0.065	0.096	1.6 4.4	6 6
December	0.013	0.068	0.105	1.6 16	6 4
January	0.011	0.057	0.093	4.4	6
February	0.011	0.066	0.107	4.4	6
March	0.024	0.129	0.195	16	4
April	0.017	0.103	0.158	4.4	6
May	0.018	0.065	0.088		
June	0.015	0.047	0.066		
July	0.010	0.046	0.065		
August	0.012	0.049	0.063		
September	0.012	0.043	0.069	1.6	6

Table 6.8 J2GAMK-EWR4: Low flow assurance rules (m^3/s) for Instream PES: C/D

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
October	0.181	0.175	0.144	0.108	0.077	0.060	0.044	0.028	0.014	0.004
November	0.317	0.225	0.198	0.151	0.096	0.065	0.038	0.020	0.014	0.010
December	0.408	0.276	0.206	0.163	0.105	0.068	0.046	0.024	0.013	0.010
January	0.332	0.255	0.178	0.137	0.093	0.057	0.035	0.020	0.011	0.007
February	0.376	0.277	0.218	0.163	0.107	0.066	0.043	0.023	0.011	0.007
March	0.517	0.446	0.359	0.274	0.195	0.129	0.081	0.047	0.024	0.008
April	0.401	0.352	0.299	0.228	0.158	0.103	0.067	0.039	0.017	0.008
May	0.264	0.223	0.189	0.149	0.088	0.065	0.047	0.030	0.018	0.010
June	0.179	0.136	0.113	0.090	0.066	0.047	0.034	0.024	0.015	0.009
July	0.133	0.121	0.103	0.086	0.065	0.046	0.030	0.018	0.010	0.004
August	0.177	0.137	0.112	0.087	0.063	0.049	0.035	0.019	0.012	0.008
September	0.186	0.149	0.131	0.101	0.069	0.043	0.033	0.022	0.012	0.006

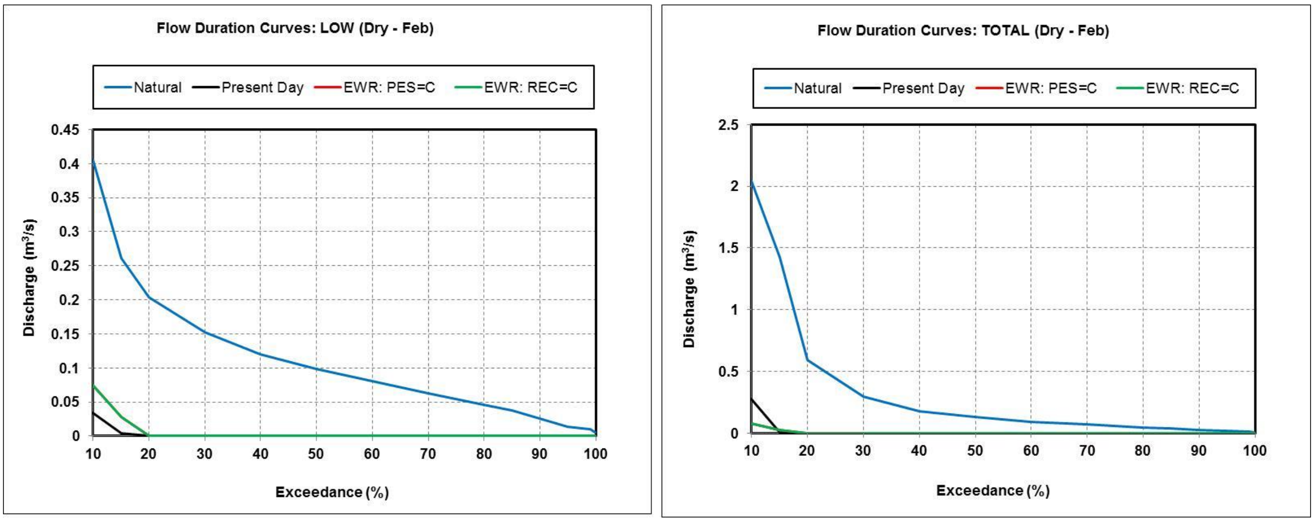


Figure 6.2 J2GAMK-EWR4: Flow duration graph for the dry season low flows (left), total flows (right)

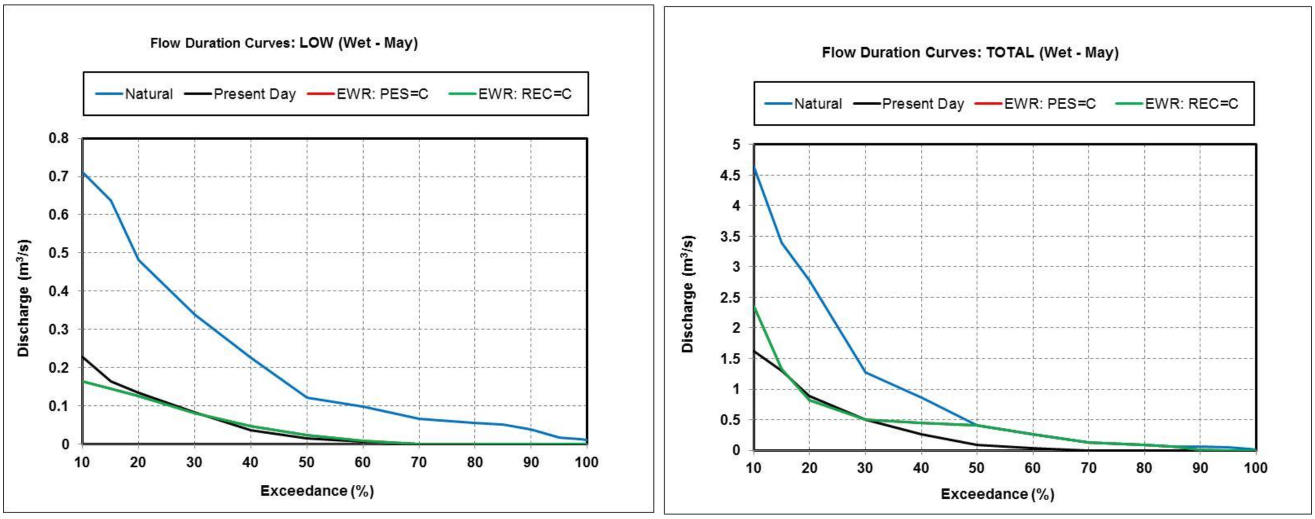


Figure 6.3 J2GAMK-EWR4: Flow duration graph for the wet season low flows (left), total flows (right)

Table 6.9 J2GAMK-EWR4: Summary of results as a percentage of the nMAR

EcoStatus	nMAR (MCM)	pMAR (MCM)	Low flows (MCM)	Low flows (%)	High flows (MCM)	High flows (%)	Total flows (MCM)	Total (%)
PES: C/D	85.54	61.69	3.94	4.6	17.44	20.4	21.38	25.0

7 ECOCLASSIFICATION: BUFFELS RIVER – J1BUFF-EWR5

7.1 BACKGROUND

The main dam in the Buffels River is the Floriskraal Dam (50 MCM) in the Buffels River at the outlet of J11G. The catchment area upstream of this dam is typical Karoo with very little development. Some irrigation (9 million m^3/a) is practised downstream of this dam. The catchment is stressed as a result of irrigation demands exceeding supply. The J1BUFF-EWR5 is situated about 20 km downstream of Floriskraal Dam on a private reserve at Wagendrift Lodge. There is extensive irrigation downstream of Floriskraal Dam. Flood releases (not pulsed) are made irregularly based on requirements to supply downstream users (**Figure 7.1**). An example of a planned release during March 2014 was a discharge of 7 m^3/s and gradually reducing it to 2 m^3/s over 15 days. **Figure 7.2** illustrates the releases from Floriskraal Dam. In this figure, the red line represents the spills and the blue line depicts the dam releases. Also note the very large flood during January 2014 that caused extensive flood damage.

The EWR site is situated within Management Resource Unit (MRU) B (DWA, 2014) which has irrigation as landuse where the relief allows. The EWR site is nested in a Reserve Assessment Unit which is in better condition (being protected in the poort) than the rest of the MRU.

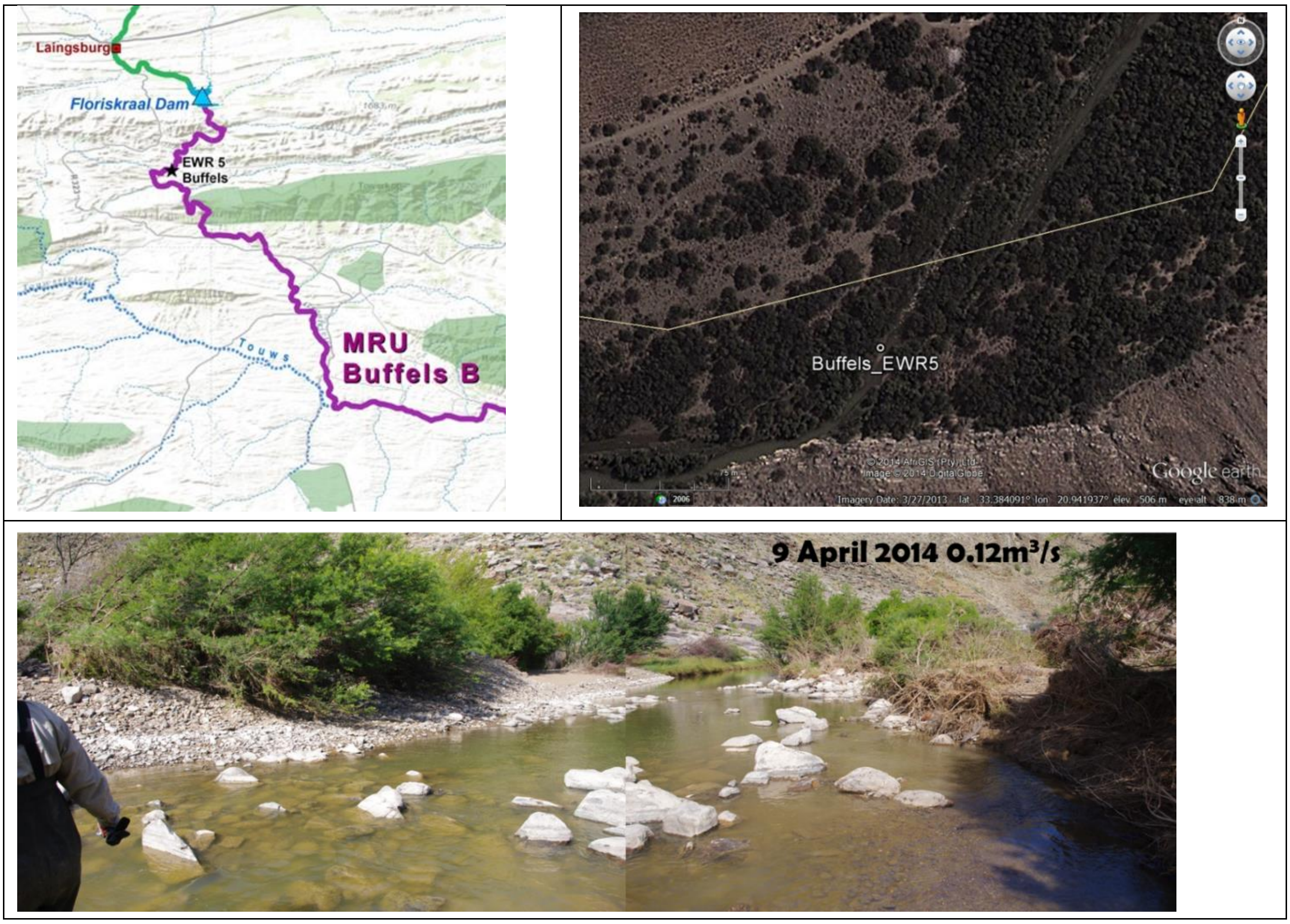


Figure 7.1 A map, Google image and downstream view of the EWR site

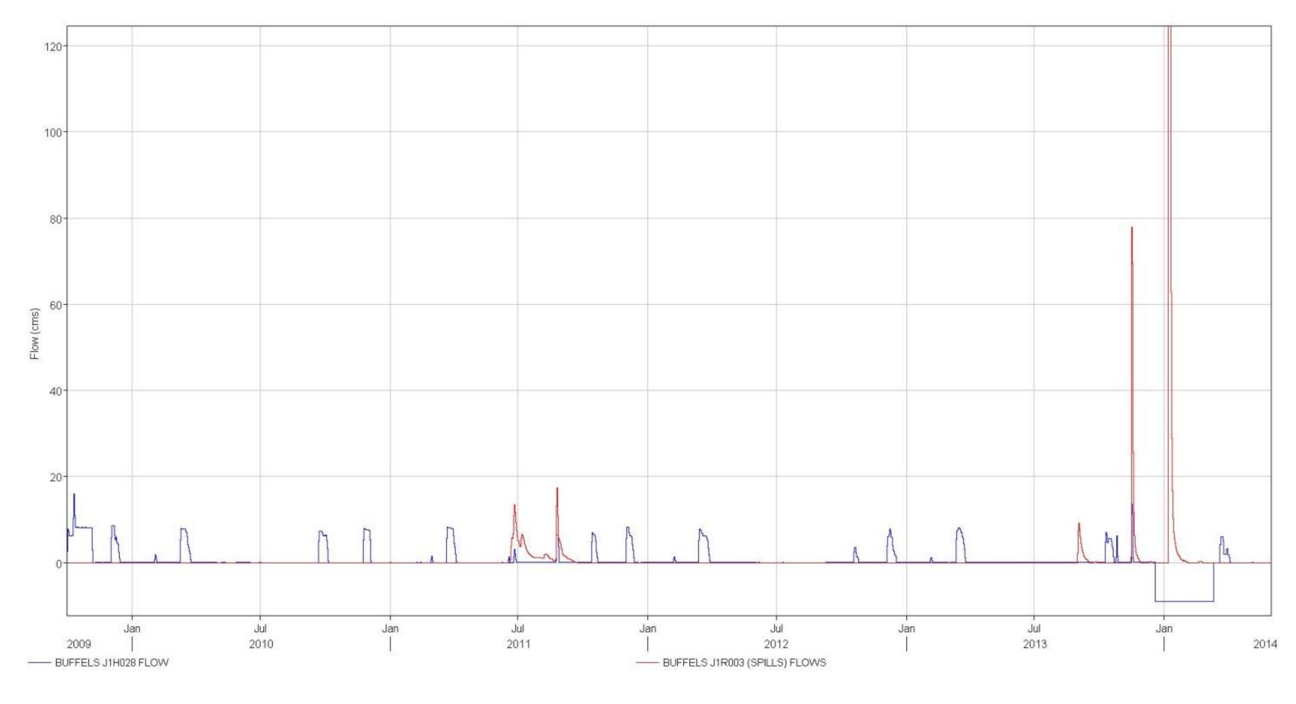


Figure 7.2 Observed data from October 2009 illustrating the releases and spills from Floriskraal Dam

7.2 EIS RESULTS

The EIS evaluation results in a **MODERATE** importance. The highest scoring metrics are:

- Rare and endangered species: The endangered *P. asper* occurs in the reach.
- Refugia and critical habitat: Deep pools are present in a very dry environment.
- Unique riparian/wetland species: Five endemic riparian species occur at the site: *C. textilis, D. austro-africana* var. *austro-africana, N. capensis, S. aphylla* and *T. usneoides.*
- Diversity of riparian/wetland habitat types and features: Both alluvial and rocky habitats occur with a mix of woody and non-woody vegetation. Both faster flowing cobble areas and slow flowing pools exist as well as extensive alluvial banks and flood benches.
- Riparian/wetland migration corridor: An effective corridor is provided by dense woody vegetation (mostly *A. karoo*) but is also diverse due to the presence of pools dominated by grass and sedge that are utilised by waterfowl.

7.3 PRESENT ECOLOGICAL STATE

The PES reflects the changes in the EC relative to reference conditions. The summarised PES information is provided in **Table 7.1** and water quality and diatom information is provided in **Appendix A** and **B**, respectively.

Table 7.1 J1BUFF-EWR5: Present Ecological State

IHI Hydrology: PES: D, Confidence: 2.9

The nMAR is 29.31 MCM and the pMAR is 18.67 MCM (63.7% of the nMAR) at a distance from Floriskraal Dam. The flow contribution of the in-between catchment is very small relative to the larger catchment. For the period from March to September, baseflows have decreased significantly from natural which has affected the seasonal distribution of the flow regime. This is mainly due to Floriskraal Dam and regulated irrigation releases. The dam and releases have also impacted on the frequency of floods and has resulted in decreased flood volumes and frequency.

Water quality: PES: C (75.9%), Confidence: 3

Salt (sodium and chloride) levels are currently slightly elevated in terms of irrigation guidelines. Although nutrient data shows low levels in the water column, nutrients and toxics are expected from fertilizer and pesticide use for irrigation purposes. Significant temperature impacts are expected under low flows. It is expected that flushing flows from Floriskraal Dam will maintain the water quality state, assuming some flushing flows reach the EWR site. Water quality is set at a C EC based on all site-based information, which is slightly worse than the B/C indicated by the physico-chemical data.

Geomorphology: PES: D (56%), Confidence: 3

The very large Floriskraal Dam is located upstream of the EWR site. This dam critically reduce flood flows to the downstream reaches, and this has facilitated a lot of woody vegetation encroachment across the flood of the macro-channel. The 1944 aerial photo shows a far wider channel and open riparian zone, but by 2006 this has been heavily encroached by trees. Flood flows would not be slower (and thus of reduced energy) due to the dramatically increased flow resistance.

IHI Instream: PES: D (56.1%), Confidence 2.8 **IHI Riparian: PES: D (50.3%), Confidence 3.8**

The instream IHI is mainly impacted by the changed flow regime which includes decreased baseflows and flood frequency. Deteriorated water quality due to agricultural return flows has resulted in bed modification (sedimentation and algae) and increased water temperature and nutrient levels.
The riparian IHI is mainly impacted by the altered flow regime and bank structure modification due to the high density of *A. karoo*.

Riparian vegetation: PES: D (57%), Confidence: 3.4

The site occurs within Western Little Karoo which refers to a terrestrial vegetation type dominated by succulent and non-succulent shrubs (Mucina and Rutherford, 2006).

In July of 1797 J. Barrow describes the Buffalo River which passes through Lainsburg as follows: "The banks were skirted by a thicket of the doorn boom, or thorntree [*A. karoo*], a species of mimosa... it makes an impenetrable thicket to most animals except the rhinoceros" (Barrow, 1801, in Skead, 2009). On 2 March 1804 H. Lichenstein describes the Buffalo River as follows: "a small river... which flows into the Dwyka: the place where we camped has water all the year round and is called the Wolvefontein. The mimosas [*A. karoo*] for a considerable way along the riverside bank, downwards... at their roots was growing a small quantity of grass." (Lichtenstein, 1815, in Skead, 2009). The name also suggests Buffalo (mega-herbivores) in the area. Historical aerial photographs from 1944 show an increase in woody vegetation in all sub-zones, likely a response to flow regulation and flood reduction (magnitude and frequency). Google Earth images show distinct increase in woody cover (*A. karoo* notably) since 2006.

Present State:
Dominant species in the marginal zone included *A. karoo, Cyperus longus, Paspalum distichum, Cynodon dactylon,* and several *Juncus* species. The riffle at the cross-section was mostly open boulder/cobble with the understorey scoured out, but with woody vegetation (notably *A. karoo*) dense all the way to the channel and with much overhang and shading of the sub-zone. Pools with grassed and sedge banks occurred farther downstream (also back pools along a high flow channel). The dominant non-woody vegetation was characterised by *P. distichum, C. longus*, soft stem *Juncus* but was encroached by *A. karoo*, mostly younger individuals. *S. mucronata* and *G. virgatum* were absent. The lower zone was dominated by woody thicket, mostly *A. karoo*, but terraced pools (downstream and along high flow channels) were dominated by non-woody vegetation (mostly grasses and sedges) although signs of woody encroachment were evident as younger individuals of *A. karoo* were

regenerating closer to pools. *Salix mucronata* and *C. marginatus* were absent.
The upper zone comprised dense woody thicket dominated by *A. karoo* with shaded high flow channels. Past flood damage was extensive, with some areas being cleared and high incidence of woody debris. High flow channels supported grass and sedge species albeit sparse and pools in areas with non-woody vegetation. Most pool areas were shallow (approx. 0.5m deep) and well grassed. Dominant species were *A. karoo, Searsia lancea, S. lepdictya, Lycium cinereum* and *C. dactylon. Salsola* species, *G. fruticosus* and *Nymania* were absent.

The trend is likely stable as the overwhelming impact for the reach is altered flow regime and vegetation would have adjusted by now.

Fish: PES: B/C (79%), Confidence: 2.5

All four fish species expected in the RC were captured at the EWR site at a slightly higher FROC than predicted. These included PASP, BANO, LUMB and SCAP. No eels were captured but are naturally difficult to catch and probably are present at expected FROC as highly suitable habitat and flows were present. The lower stress on the fish present and thus higher than expected FROCs are considered due to the more constant river flows and low sediment loads due to releases of freshets from the upstream dam and the excellent instream habitat. This includes suitable marginal vegetation cover and spawning substrate in SD and SS habitats (for BANO and SCAP) as well as optimum flows over sediment-free riffle areas to facilitate LUMB and PASP spawning.

Macroinvertebrates: PES: C (72.7%), Confidence: 2

The hydrology of this site has changed extensively due to the presence of the Floriskraal Dam. The dam releases are infrequent (on average once every two months) and largely for agriculture. It is uncertain to what extent (and for what duration) these releases result in surface flow at the site.

The RC has been developed on the basis of data obtained from several sample sets, for three RHP sites sourced from DWS: Western Cape:

- J1GROO-VANZY, 25 km downstream of J1BUFF-EWR5 and located in the Groot River.
- J1GROO-TIGER further downstream of J1GROO-VANZY.
- J1 BUFF- LAINS (J1BUFF-NIROA), upstream of EWR 5, in the Buffels River, and upstream of Floriskraal Dam.

In addition, data from the DWA (RQS) PES/EIS project (DWA, 2013) for J1GROO-VANZY and J1GROO-TIGER were also used.

N*ote that for all sites, the RC is modified where necessary, on the basis of discrepancies in habitat between the selected reference site and the sampling site, and on specialist experience.*

PES:
The SASS5 score for the single sampling on 11 April 2014 was 103, with 19 taxa collected and an ASPT of 5.4. The only group scoring over 10, with a preference for moderate to high flow conditions, were baetid mayflies (> 2 spp). The remainder of the community comprised resilient taxa capable of withstanding low flow conditions, and zero flow conditions over the shorter term (up to 2 weeks). The RC indicates the presence of only one additional sensitive flow-dependent taxon; telagonodid mayflies (score 12). The majority of macroinvertebrate taxa in the RC are however resilient, with a moderate to low sensitivity to water quality, and all scoring < 9.

The sample differed broadly from the RC, not showing any particular conditions in which expected taxa were more noticeably absent than others. The deviation between sample and reference is merely a case of expected taxa missing from all biotopes, flow velocity classes, and water quality conditions. Taxa expected but absent from the sample included additional hydropsychid species, Hydracarina, leptophlebiid mayflies, hydrometrid hempiterans, aeshnid dragonflies, hydrophilids and elmid beetles, planorbid, bulininae and corbiculid snails

The major cause of the broad shift in the community is the altered hydrology of the site. This is due to the presence of the upstream Floriskraal Dam. The seasonal distribution of baseflow is greatly affected with the period March to September showing a significant decrease in flows from natural.

The PES is a C. The major causes of the change from RC are mainly flow related, and include decreased baseflows and reduced flood frequencies. The seasonal distribution of baseflow is greatly affected with the period March to September showing a significant decrease in flows from natural. Poor water quality, higher water temperatures and woody vegetation encroachment also contributed to the PES.

7.4 RECOMMENDED ECOLOGICAL CATEGORY

The REC is determined based on ecological criteria only and considered the EIS and the restoration potential of the site. As the EIS is MODERATE, no improvement is required. The REC is therefore set to attain the PES. No AEC was set due to limited release options from Floriskraal Dam.

7.5 ECOCLASSIFICATION SUMMARY

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

Table 7.2 J1BUFF-EWR5: Summary of EcoClassification results

Component	PES and REC
IHI Hydrology	**D**
Water quality	**C**
Geomorphology	**D**
Fish	**B/C**
Invertebrates	**C**
Instream	**C**
Riparian vegetation	**D**
EcoStatus	**C**
Instream IHI	**D**
Riparian IHI	**D**
EIS	**MODERATE**

Both the instream REC and the riparian vegetation REC are impacted by flows and therefore the EWRs are set to maintain an REC of a C.

8 EWR REQUIREMENTS: BUFFELS RIVER – J1BUFF-EWR5

8.1 FLOW VS STRESS RELATIONSHIP

The fish and macroinvertebrate stress flow index is provided in **Figure 8.1**. The integrated stress curve for both the dry season (red curve) and wet season (blue curve) is illustrated on the graph. A description of the habitat and response associated with the key stress is provided in **Table 8.1** and **8.2**.

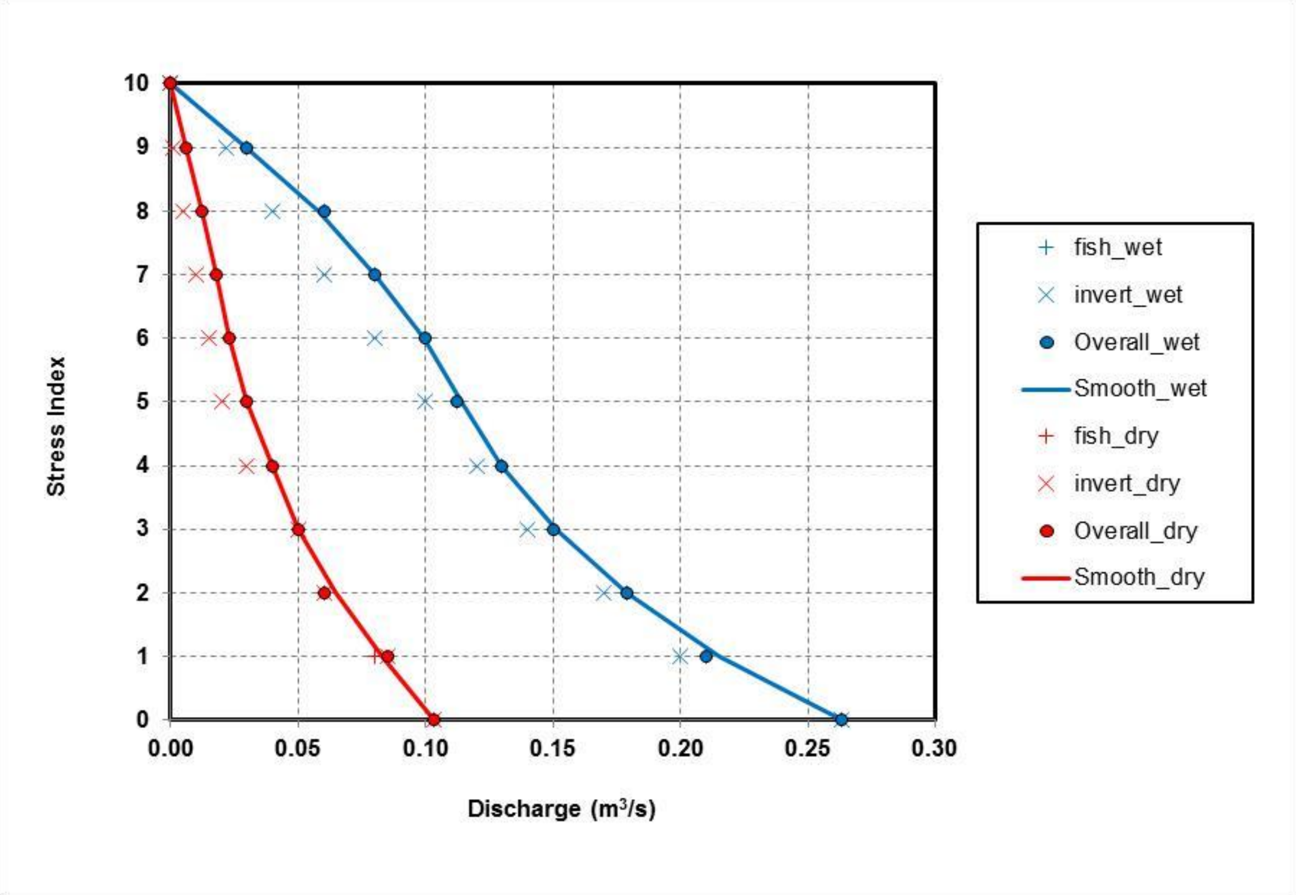


Figure 8.1 J1BUFF-EWR5: Fish, macroinvertebrate and integrated stress index

Table 8.1 J1BUFF-EWR5: Summarised habitat/biotic responses of fish during the dry and wet season

Stress	Flow (m^3/s)	Habitat and stress description
Dry season: September		
9	0.006	No flow dependent fish species are present, so these flows improve water quality and maintain pool habitat compared to no flow conditions. Very limited fast shallow (FS) flowing habitat is available and fish migrations are severely restricted due to shallow depths (less than 10 cm) over critical riffle areas.

Stress	Flow (m^3/s)	Habitat and stress description
5	0.03	Moderate diversity of habitats will be available at this flow. Riffle depths (average 8 cm; maximum 18 cm) will allow some migration of smaller species. A moderate stress is maintained on the overall fish assemblage.
2	0.06	Minimal stress is estimated due to good habitat diversity, with most fast habitats present, except FD. Good water quality is present with all fish functions in dry season are supported. Riffles are deep enough (average 10 cm; maximum 22 cm) to cater for the limited migration in the dry season
Wet season: April		
9	0.03	Semi-rheophilic riffle-spawning species are present including the small minnow (PASP) and large (LUMB), the latter requiring depths over 20 cm in riffles for migration and spawning. Riffle depths (average of 8 cm) at this flow restrict natural fish movement between habitats. Very limited FS flowing habitat are present.
5	0.112	Adequate diversity of habitats are present, including 50% of natural fast habitats, but excludes FD eel habitat. Good water quality is expected at this flow. Riffle depths (average 12 cm; maximum 26 cm) will allow limited LUMB migration, but other small species are catered for. Thus moderate stress on the overall fish assemblage prevails.
2	0.179	Minimal stress is estimated due to good habitat diversity and water quality, with all fish functions supported, including spawning of the relatively small PASP. This includes a stress-free passage through deeper riffles (depth average 15 cm; maximum 30 cm). The primary limiting factor (compared to natural) is reduced abundance of habitats, including the absence of FD habitats preferred by eels.

Table 8.2 J1BUFF-EWR5: Summarised habitat/biotic responses of macroinvertebrates during the dry and wet season

Stress	Flow (m^3/s)	Habitat and stress description
Dry season: September		
7	0.01	The re is no flow and most connectivity is lost and surface water is likely restricted to pools. Taxa with a requirement for flow will relocate to pool areas or shelter in overhanging vegetation, but will gradually be lost.
5	0.02	Surface flow has disappeared and depth is reduced. Lateral and longitudinal connectivity will gradually be lost. Rheophilic hydropsychids and simuliids will decline in abundance but some will relocate to shallow trickle areas. The remainder of the community will survive. Aerial taxa may relocate.
2	0.06	Restricted fast flow areas, inundated marginal vegetation and adequate depth over cobbles is present to maintain an early summer community and to support hatching and developing juveniles.
Wet season: April		
7	0.06	Fast flow areas are reduced and abundances of rheophilic taxa may be reduced. The marginal vegetation (largely *Cyperus* spp.) are inundated to a depth of up to 0.2 m, providing some cover for developing taxa, and there is adequate depth over cobbles to maintain the FDI and other taxa in the community.
5	0.10	Plentiful fast flow habitat present; depth over cobbles and inundated marginal vegetation to keep habitat clear and to maintain the current invertebrate community in a C Category.
2	0.17	Fast flow and plentiful deep habitat available. Marginal vegetation is inundated and provides shelter for juveniles and habitat for adults. Conditions are satisfactory for late summer breeding and egg-laying.

8.2 HYDROLOGICAL CONSIDERATIONS

The wettest and driest months were identified as April and September. Droughts are set at 95% exceedance (flow). Maintenance flows are set at 50% exceedance (flow).

8.3 INSTREAM BIOTA REQUIREMENTS

The HFSR-RM generates the stress (and flow) requirements for different ECs. Once specialists are satisfied that these results are adequate to maintain the river at the target EC, descriptions are provided for key stress points (**Table 8.3**).

Table 8.3 J1BUFF-EWR5: Stress requirements and habitat and instream biota description

Duration	Stress: Required and (final*)	Flow (m^3/s): Required and (final)	Habitat and stress description
Dry season: September			
95% (Drought)	10	0	**Fish:** This is comparable to PD flows and natural situations when the river stops flowing. Only semi-rheophilic fish species are present, as well as species that survive well in pools.
	10	0	**Macroinvertebrates:** The more resilient taxa (scoring 5 and less) remain in pools, and abundances decline as water quality deteriorates and competition for food increases. Aerial taxa are likely to relocate.
50% (Maintenance)	5.0	0.03	**Fish:** A reduction in PD dry season flows in order to move towards a more natural flow pattern in the system, with higher flows in the wet season are required. Flows are required to provide habitat availability and water quality with limited migration between habitats.
	4.0	0.03	**Macroinvertebrates:** This flow will supply a minimum of fast flow habitat to support the rheophilic taxa. (Hydropsychidae and Simuliidae) and those with a preference for flow in cobble areas (e.g. Baetidae). These taxa will occur at low abundances. Water quality is likely to deteriorate as further depth and connectivity is lost.
Wet season: April			
95% (Drought)	10	0	**Fish:** The flow is virtually comparable to natural and the PD situation. No spawning or migration is possible, but fish survive in pools.
	10	0	**Macroinvertebrates:** Higher-scoring taxa are lost and more resilient taxa (scoring 5 and less) remain in pools. Most breeding stages will decline (egg-laying can continue in some instances) and emergence will be hindered in some taxa as pools shrink away from the marginal vegetation zone. Abundances decline as water quality deteriorates and competition for food increases. Aerial taxa are likely to relocate.

Duration	Stress: Required and (final*)	Flow (m^3/s): Required and (final)	Habitat and stress description
50% (Maintenance)	8.6	0.04	**Fish:** Limited habitat for spawning and migration are available. An increase in flows in the spring months (Sep to Dec) is required for fish spawning and migration, which is a naturally secondary wet period. Increased wet season flows are is required to cater for all fish functions (spawning and migration) which are dependent on adequate depths and flows in riffle areas.
	8.0	0.04	**Macroinvertebrates:** The modelled maximum depth is 0.2 m at this discharge. There is a very small proportion (1%) of fast flow, which will support hydropsychid and simuliid populations, but these and other taxa with a preference for flow are likely to decline in abundance and disappear within days to weeks of this flow being further reduced (< 0.03 m^3/s). Marginal vegetation will be activated as the only habitat that is available is overhanging stems. Overall habitat availability is low and the invertebrate community will continue to reflect this.

* Final HFSR-RM model output values provided in brackets only if different from requirement.

8.4 VERIFICATION OF LOW FLOWS: RIPARIAN VEGETATION

The low flow verification is done by comparing levels of inundation of certain riparian indicators during April (wettest month) and September (driest month), both at the 50th percentile. Data are shown below (**Table 8.4**) for the high flow month of April. Stream permanency is reduced from Natural (86.8%) to 75% but is similar to PD. Discharge at 50% is as follows: Natural – 0.18 m^3/s; PD – 0.10 m^3/s; EWR requirement for PES (Category C) – 0.10 m^3/s. Proposed flows exceed Natural from September to January (at 50%) as do PD flows. In all cases the level of vegetation above the water level is similar to PD; hence the proposed low flows do not limit riparian vegetation and should maintain the riparian vegetation category. **Table 8.4** provides a summary of the low flow verification.

Table 8.4 J1BUFF-EWR5: Detail of low flow verification (m^3/s) using riparian vegetation

Monthly snap shot						**Apr**
Inundation (Mar at 50%)						**50.0%**
Hydrology component				**NAT**	**PD**	**PES D**
Discharge (at month and percentile)				0.18	0.10	0.10
Scenario compared to Natural flows				-	More than Natural from Sep to Jan @ 50%	More than Natural from Sep to Jan @ 50%, but less than PD
Stream permanence (%)				86.8	75.0	75.0
Indicators	**Range limit**	**Zone**	**Elevation**	**NAT**	**PD**	**PES D**
Acacia karoo	Lower limit	Marg zone	1.030	0.730	0.790	**0.790**
Juncus	Lower limit	Lower zone	1.115	0.815	0.875	**0.875**
Searsia	Lower limit	Upper zone	1.624	1.324	1.384	**1.384**

8.5 HIGH FLOW REQUIREMENTS

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

Table 8.5 J1BUFF-EWR5: Identification of instream functions addressed by the identified floods for riparian vegetation and geomorphology

Motivations	Fish flood functions						Macroinvertebrate flood functions			
	Migration cues and spawning	Migration habitat (depth etc.)	Clean spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas
CLASS I (1 - 3)[1]										
Fish: Simulates small freshets, important for fish breeding activity in the spring and early summer period. Also stimulates some migratory activity. Duration (receding limb of flood) important to allow adequate time for egg hatching.	✓	✓	✓	✓	✓	✓	✓	✓		✓
CLASS II (7 - 10)										
Geomorphology: Scours the active channel and removes fines from the cobble bed, improving bed conditions. **Riparian vegetation:** Activates sedges and begins to flood *A. karoo* at its lowest limit, but because this release is so regular and larger floods so seldom, *A. karoo* has encroached towards the channel to the flooding level of this event. It is therefore important to prevent further encroachment by *A. karoo*.	✓	✓	✓	✓	✓	✓				
CLASS III (20 - 30)										
Geomorphology: This large flood would have occurred much more regularly under natural conditions. This class of flood would activate secondary channels, scour the channel bed and pools, and provide recharge to the riparian aquifer.	✓	✓	✓	✓	✓	✓				
CLASS IV (>150)										
Geomorphology: This large flood would have occurred much more regularly under natural conditions. This class of flood will activate and scour secondary channels, scour the channel bed and pools, remove encroaching vegetation, widen the channel and provide recharge to the riparian aquifer. **Riparian vegetation:** This event activates higher level trees, such as *Searsia* species eliciting a growth response and will also likely fill pools and backwaters.	✓	✓	✓	✓	✓	✓				

No reliable gauge was present to verify high flows as the EWR site is downstream of Floriskraal Dam.

Table 8.6 J1BUFF-EWR5: Recommended flood events

Flood class (Peak in m^3/s)	Flood requirements*	Months	Daily ave.	Duration (days)
Class I (3)	2	October – February	2.7	5
Class II (10)	2	September – January	8.3	5
Class III (30)	1:3	March	30	7
Class IV (150)	1:3	Winter months (macroinvertebrates)	101	8

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

The RDRM model distributes the high flow volumes across the wet period months according to the natural distribution. The months provided by specialists are therefore those in which floods are recommended, but there will be naturally-determined variations in the final EWR high flow time series results.

8.6 EWR RESULTS

The results are provided as an EWR table (**Table 8.7**) and an EWR rule (**Table 8.8**). Flow duration graphs are supplied as **Figure 8.2** and **8.3**. Detailed results are provided in the model generated report for each category in **Appendix D** for both low and total flows.

The low flow EWR rule table is used for building rules for EWR releases. The information on specific flood releases is provided in the EWR table. Note that these tables on its own cannot be used for dam or system operation but will feed into an integrated model to determine the operation of the system. Note that high flows (floods), if released from dams, will require hydrodynamic modelling to determine the actual releases to achieve the instantaneous peak at the EWR site. A summary of the results is provided in **Table 8.9**.

Table 8.7 J1BUFF-EWR5: EWR table for PES and REC: C EC

Month	Low flows (m^3/s)			High flows	
	Drought (90%) (m^3/s)	60% (m^3/s)	50% (m^3/s)	Daily average (m^3/s)	Duration (days)
October	0.000	0.016	0.027	2.7	5
November	0.000	0.016	0.031	2.7 8.3	5 5
December	0.000	0.016	0.031	2.7	5
January	0.000	0.013	0.028	2.7	5
February	0.000	0.013	0.025	2.7	5
March	0.000	0.016	0.033	30	7
April	0.000	0.021	0.040		

Month	Low flows (m^3/s)			High flows	
	Drought (90%) (m^3/s)	60% (m^3/s)	50% (m^3/s)	Daily average (m^3/s)	Duration (days)
May	0.000	0.022	0.045		
June	0.000	0.026	0.046	101	8
July	0.000	0.021	0.044		
August	0.000	0.023	0.042		
September	0.001	0.022	0.030	8.3	5

Table 8.8 J1BUFF-EWR5: Low flow Assurance rules (m^3/s) PES and REC: C

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
October	0.072	0.057	0.043	0.039	0.027	0.016	0.009	0.005	0.000	0.000
November	0.084	0.079	0.051	0.043	0.031	0.016	0.008	0.004	0.000	0.000
December	0.106	0.082	0.057	0.044	0.031	0.016	0.009	0.003	0.000	0.000
January	0.082	0.075	0.044	0.037	0.028	0.013	0.007	0.003	0.000	0.000
February	0.081	0.068	0.043	0.035	0.025	0.013	0.007	0.003	0.000	0.000
March	0.096	0.091	0.062	0.044	0.033	0.016	0.008	0.004	0.000	0.000
April	0.110	0.101	0.084	0.063	0.040	0.021	0.008	0.000	0.000	0.000
May	0.116	0.094	0.075	0.066	0.045	0.022	0.009	0.004	0.000	0.000
June	0.121	0.095	0.083	0.064	0.046	0.026	0.013	0.005	0.000	0.000
July	0.098	0.094	0.077	0.061	0.044	0.021	0.010	0.004	0.000	0.000
August	0.094	0.083	0.062	0.055	0.042	0.023	0.011	0.004	0.000	0.000
September	0.065	0.061	0.052	0.042	0.030	0.022	0.014	0.007	0.001	0.000

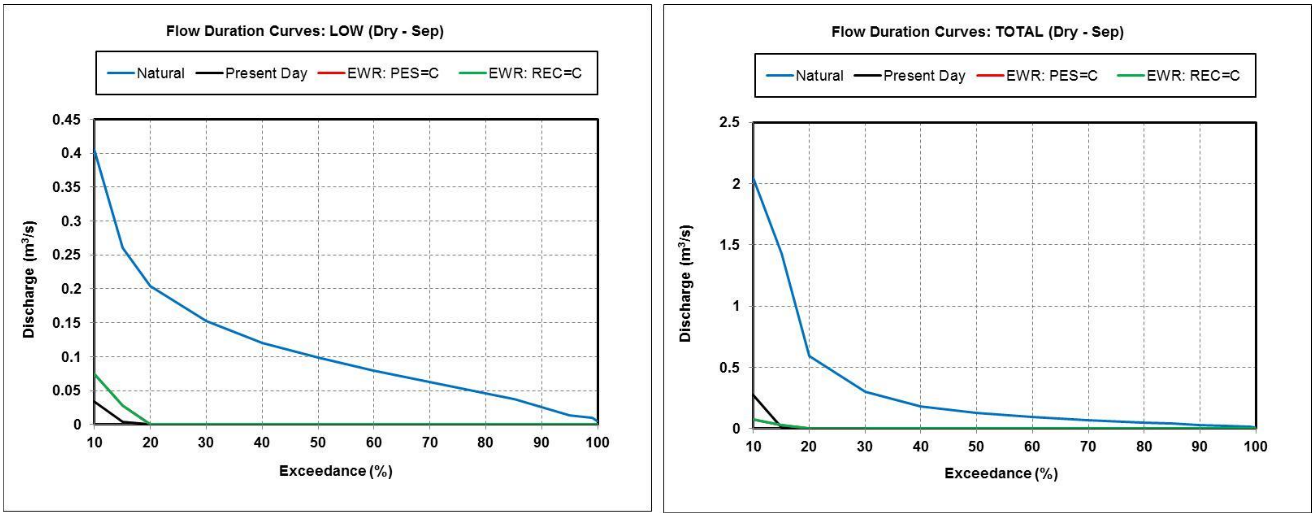
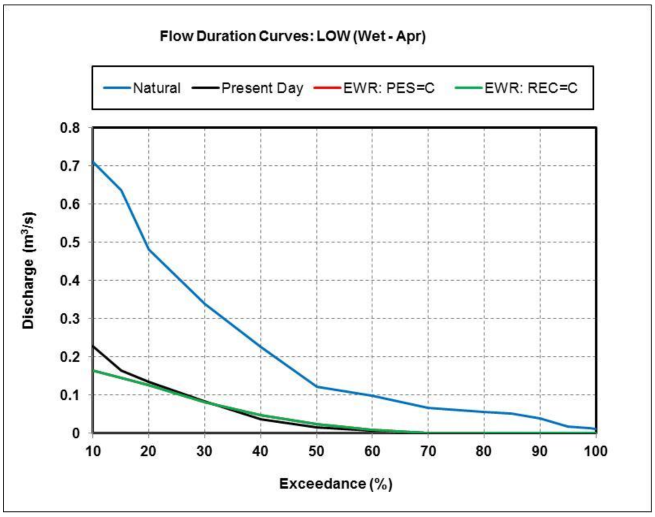


Figure 8.2 J1BUFF-EWR5: Flow duration graph for the dry season low flows (left), total flows (right)



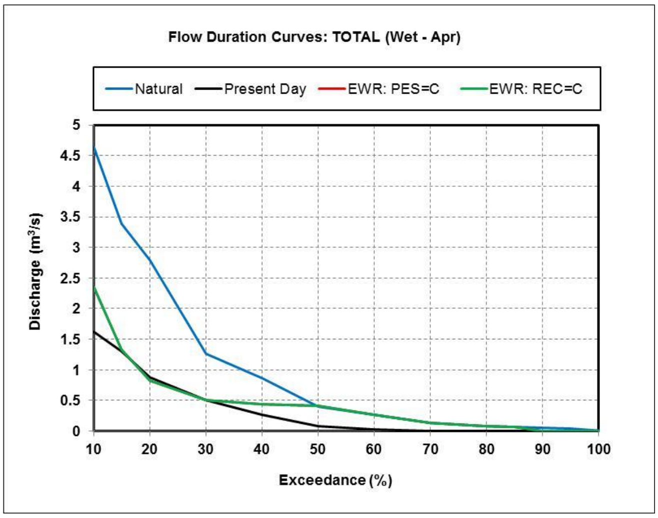


Figure 8.3 J1BUFF-EWR5: Flow duration graph for the wet season low flows (left), total flows (right)

Table 8.9 J1BUFF-EWR5: Summary of results as a percentage of the nMAR

EcoStatus	nMAR (MCM)	pMAR (MCM)	Low flows (MCM)	Low flows (%)	High flows (MCM)	High flows (%)	Total flows (MCM)	Total (%)
PES; REC: C	29.31	18.67	1.37	4.7	6.85	23.3	8.22	28.0

9 ECOCLASSIFICATION: GOURITZ RIVER – J4GOUR-EWR6

9.1 BACKGROUND

J4GOUR-EWR6 is downstream of the confluence of the Buffels (Groot) River. It is situated just upstream of a gorge in the Langeberg Mountains (**Figure 9.1**). The site is situated quite far upstream from J2H002 which is a rated section. Although extremely inaccruate for low flows, the flow regime (**Figure 9.2**) shows that this area is prone to very low flows in the dry season and very large floods in the wet season.

The Gouritz River is short compared to the extensive upstream catchments with the Olifants, Gamka, Buffalo and Touws rivers. J2 and J3 are extenstively impacted by flow related activities. Localised impacts in the Gouritz River consist of irrigation of mainly lucerne and pastures on the banks of the Gouritz River. Various farm dams are found in the Lower Gouritz River.

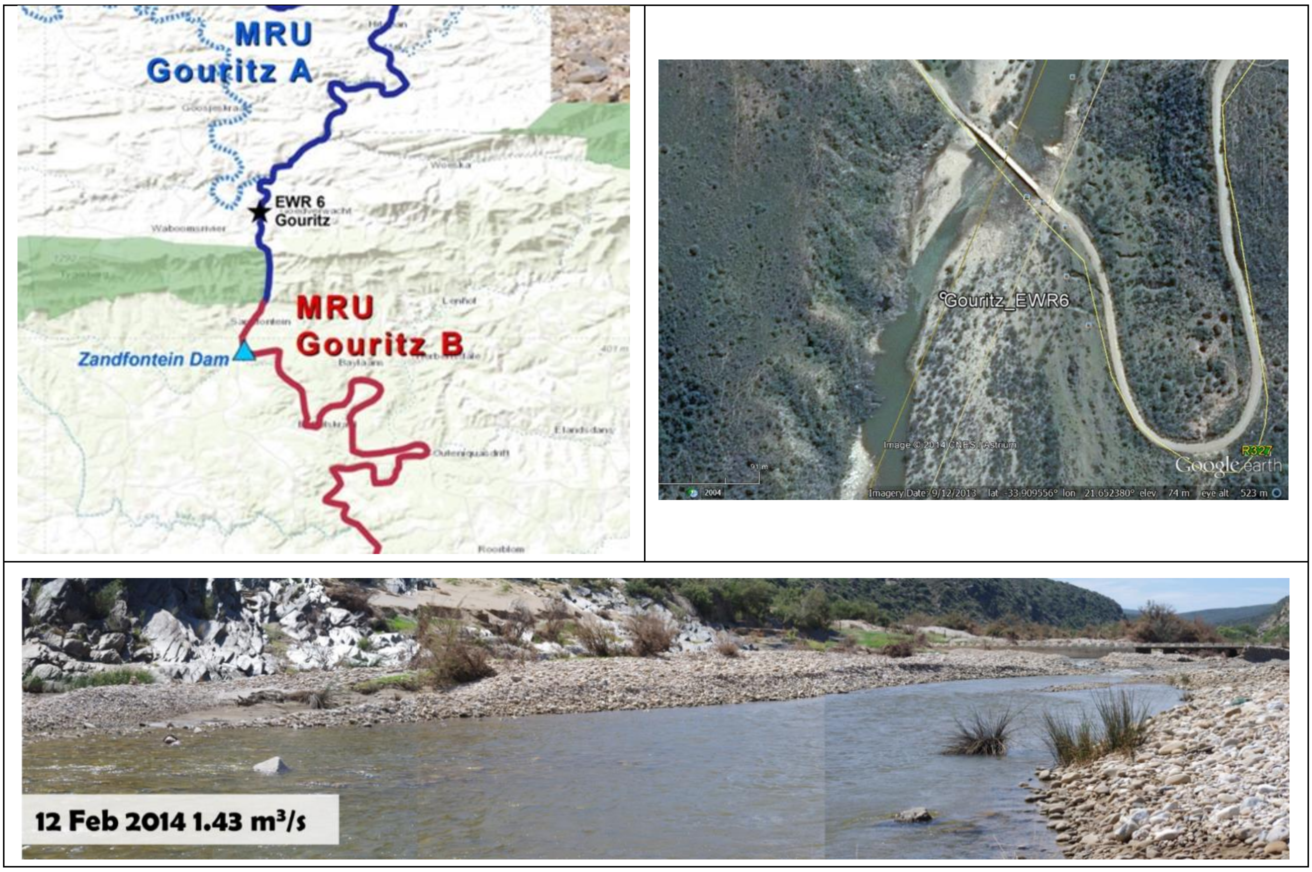


Figure 9.1 A map, Google image and downstream view of the EWR site

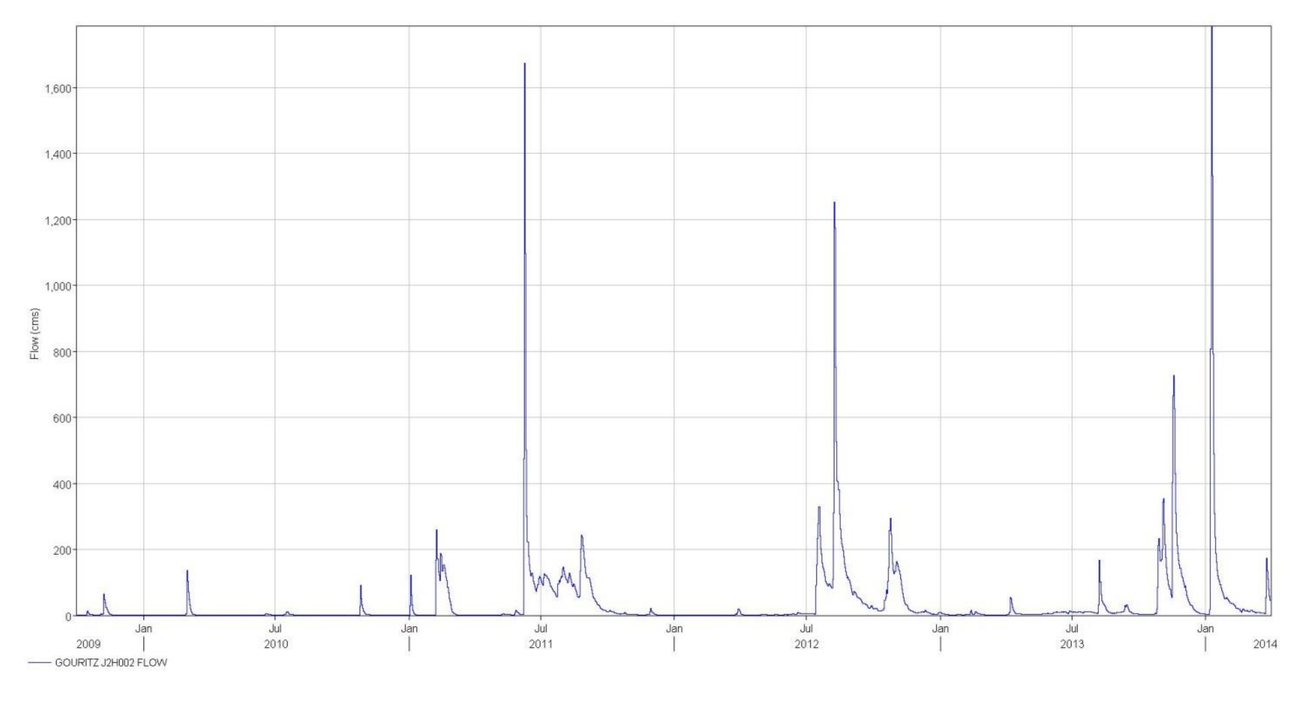


Figure 9.2 Observed data from October 2009 illustrating the flow regime at the EWR site

9.2 EIS RESULTS

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

- Rare and endangered species: The endangered *P. asper* occurs in the reach.
- Migration corridor: Occurs in a larger catchment that fish could move through and there are no barriers downstream of the EWR site.
- Unique riparian/wetland species: Five endemic riparian species occur at the site: *C. textilis, D. austro-africana* var. *austro-africana, N. capensis, S. aphylla* and *T. usneoides.*

9.3 PRESENT ECOLOGICAL STATE

The PES reflects the changes in the EC relative to reference conditions. The summarised PES information is provided in **Table 9.1** and water quality and diatom information is provided in **Appendix A** and **B**, respectively.

Table 9.1 J4GOUR-EWR6: Present Ecological State

IHI Hydrology: PES: C, Confidence: 2.6
The nMAR is 543.52 MCM and the pMAR is 310.35 MCM (57.1% of the nMAR). The hydrology at this point is a culmination of all the J catchments' confidence issues. The gauge close to the site is extremely inaccurate in terms of low flows. Flood flow measurements are also unreliable due to lack of calibration.

Water quality: PES: B/C (81.8%), Confidence:3

Water quality data indicate little change in salt levels since the 1960s, with the exception of sodium. High salt levels are linked to the natural geology, although some irrigation return flows are probably present from upstream systems (particularly the Olifants tributary); also indicated by nutrients in the system. Some impact on temperature and oxygen is expected at low flows. Conditions are expected to deteriorate in the lower catchment due to urban and agricultural activities.

Geomorphology: PES: B (85.4%), Confidence: 2.5

Although there are large dams on several main tributaries, a large portion of the Gouritz catchment remains unregulated where floods are concerned, especially in the southern, higher rainfall zone of the catchment. The PD conditions of the site and reach are not markedly different from the earliest available aerial photograph from 1953. The alterations to the baseflows, slight reductions in floods and probable elevated sediment yields from the catchment appear to have had little impact at the gross planform scale, although one could expect that there has been some reduction in pool depth relative to the RC. The condition as seen at the site in July 2014 may be an overestimate of the average condition as the site was scoured by a large flood in January 2014.

IHI Instream: PES: C/D (61.88%), Confidence 2.5 **IHI Riparian: PES: D (68.3%), Confidence 3.4**

The instream IHI is mainly impacted by decreased base flow and flooding due to abstraction for irrigation. Deteriorated water quality due to agricultural return flows has resulted in bed modification (sedimentation and algae).
The riparian IHI is mainly impacted by bank structure modification due to grazing and increased alien vegetation.

Riparian vegetation: PES: B/C (78.6%), Confidence: 3.3

The site occurs within Western Gwarrieveld which refers to a terrestrial vegetation type dominated by succulent Karoo shrub lands (Mucina and Rutherford, 2006).

In January of 1798 J. Barrow describes the prevalence of very large floods, enough to jump the banks of the Gouritz and destroy farm houses (Barrow, 1801, in Skead, 2009). On 4 May 1816, C.I. La Trobe describes the Gouritz River as follows: "The shores of the Gowritz River are covered with bushes for about 2 miles in breadth." (La Trobe 1816, in Skead, 2009). On 23rd June 1838 C.J.F Bunbury described the Gouritz as follows: "... we crossed the Gauritz River at some distance below Hell Drift... it was here a muddy stream, barely fordable, probably as much as a quarter mile from bank to bank but more than half of this width was dry sand; the banks very high and steep..." (Bunbury, 1848, in Skead, 2009).

Historical aerial photographs from 1957 show an increase in woody vegetation in all sub-zones, likely a response to flow regulation and flood reduction (magnitude and frequency).
Google Earth images show notable increase in woody cover (*A. karoo* notably) since 2004.

Marginal zone: Dominant habitats included cobble beds, but these may be associated with scour due to the low-level crossing, and some areas with fine sediment deposits from recent floods. Farther downstream significant deposits of unconsolidated and sparsely vegetation alluvium is present. Dominant species include *G. virgatum, C. longus, C. textilis, Juncus* species, and *Schoenoplectus* species. The above species occur in very low abundance. And although recent floods had scoured the sub-zone a high abundance even prior to floods is not expected. No hydrophilic grasses were found, which may be due to flood scour or may be a longer term response to reduced flows.
The lower zone was similar to the marginal zone.
Upper zone: Dominant habitats included cobble/boulder bar (may be due to low-level crossing influence) with unconsolidated alluvial deposits farther downstream. Dominant species included *A. karoo, D, lyceoides, N. oleander, C. dactylon, T. usneoides,* and *S. namaquensis*. Sparse non-woody layer, mainly *C. dactylon* and weeds were present, but were dominated by woody species. Woody cover was 50 - 60% in cobble dominated areas and less in alluvial areas. Alluvial areas were mainly open, dominated sparsely by *S. namaquensis, T. usneoides* and *A. karoo. D. austro-africanus* was absent.
Macro Channel Bank: The left bank comprised alluvial banks with a mixture of woody and non-woody vegetation but was dominated by woody species. The right bank comprised rock cliff. Dominant species included *A. karoo, Lycium* species, *Euphorbia* species, *S. namaquensis* and some *Nymania*. Overall the site comprised of woody dominated vegetation with sparse grassed understorey and some

succulent Karoo species (terrestrial) naturally occurring in the sub-zone.
The main impacts were altered flow regime, some invasion by alien species and overgrazing in the upper and Macro Channel Bank zones.

The trend is likely stable although the alien *Nerium oleander* could increase.

Fish: PES: D (50.1%), Confidence: 2

Data from Kleynhans (2007) indicate that under the RC a potential five fish species could be present at the site, namely two eel species AMOS and AMAR and three primary freshwater fish, namely BANO, LUMB and PASP. No recent data are available however, reducing the confidence of this prediction. However, only four species of alien fish (largemouth bass MSAL, smallmouth bass *Micropterus dolomieu* (MDOL), bluegill sunfish *Lepomis macrochirus* (LMAC) and common carp (CCAR) and two translocated indigenous fish; TSPA and smallmouth yellowfish (BAEN) were captured at the site.
The reference fish species are considered present in drastically reduced FROCs due to the following impacts :

- Absence of suitable cover in the form of marginal vegetation (possibly exacerbated by large, scouring flood in January 2014).
- Predation and competition with alien fish species.
- Sedimentation of SD habitat.

Macroinvertebrates: PES: C (74.8%), Confidence: 2.5

The hydrology at this site is moderate confidence. Flow is perennial, with a significant reduction in the volume of baseflows (but apparently not in timing and distribution). The principal effects at this site are in terms of depth and velocity of flows, and related loss of habitat availability and quality. Land-use contributes to the deterioration in water quality. These factors have been taken into account in interpreting the invertebrate results.

The RC is considered robust as it was derived on the basis of multiple samples taken by DWS: Western Cape at three RHP sites in the same EcoRegion Level II - J4CLOE-RPASS (SQ J40C-09105) a tributary of the Gouritz, J4GOUR-VAALH (SQ J40A-08924) on the Gouritz but upstream of EWR6, and J4GOUR-ZANDRE which is located at EWR6.

PES:
SASS5 score at this site at the time of sampling was 117, with 21 taxa recorded and an ASPT of 5.6. The ASPT of the derived RC was 6.3. The only taxa present scoring over 10 in the sample were baetid mayflies (> 2 spp.), which indicate reasonably good water quality, and athericid fly larvae, which have a preference for fast flow and cobble habitat (both of which were abundant at the time of sampling). Taxa scoring over 10 (i.e. sensitive to water quality and generally showing a preference for moderate and fast flow) in the reference state, which were absent from the sample, included notonemourid and perlid stoneflies, telagonodid mayflies, philopotamid and glossosomatid caddisflies.

The critical change at the site from reference appears to be in the reduction in MAR and the associated loss of high and moderate quality water and reduction in fast (deep) flow areas. The sources of loss in MAR are irrigation, groundwater abstraction, grazing and domestic water use. Agricultural return flows contribute to the deterioration in water quality. This has reduced the availability and quality of the preferred habitat of the more sensitive taxa (cobbles, vegetation). It has also affected the community balance, as many of the more robust expected taxa scoring 6 - 10 were also absent (e.g. Aeshnidae, Elmidae, Hydroptilidae, and Leptoceridae). The decrease in volume, frequency and distribution of moderate-sized floods will have affected the habitat quality in that these floods are responsible for resetting and cleaning/clearing particularly the cobble, gravel and marginal vegetation biotopes. It should be noted that the absence of taxa is also partly an artefact of low sample number (n = 1). In contrast, numerous samples were used to compile the RC. This has been taken into account in the MIRAI.

The PES is a C and the EcoStatus models are provided electronically. The major causes of the change from RC are mainly flow related and include reduced lowflows and a decrease in volume, frequency and distribution of moderate-sized floods. These are mainly a result of irrigation, surface and groundwater abstraction, large dams and domestic water use. These activities have also resulted in reduced high salinities and elevated nutrients. Some invasion by alien species and overgrazing in the upper and Macro Channel Bank zones are present. Alien fish species also occur in the reach.

9.4 RECOMMENDED ECOLOGICAL CATEGORY

The REC is determined based on ecological criteria only and considered the EIS and the restoration potential of the site. As the EIS is MODERATE, no improvement is required. The REC is therefore set to maintain the PES. No AEC was set.

9.5 ECOCLASSIFICATION SUMMARY

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

Table 9.2 J4GOUR-EWR6: Summary of EcoClassification results

Component	PES and REC
IHI Hydrology	C
Water quality	B/C
Geomorphology	B
Fish	D
Invertebrates	C
Instream	C
Riparian vegetation	B/C
EcoStatus	C
Instream IHI	C/D
Riparian IHI	C
EIS	**MODERATE**

Both the instream REC and the riparian vegetation REC is impacted on by flows as well as anthropogenic impacts. The EWRs is set to maintain the REC of a C.

10 EWR REQUIREMENTS: GOURITZ RIVER – J4GOUR-EWR6

10.1 FLOW VS STRESS RELATIONSHIP

The fish and macroinvertebrate stress flow index is provided in **Figure 10.1**. The integrated stress curve for both the dry season (red curve) and wet season (blue curve) is illustrated on the graph. A description of the habitat and response associated with the key stress is provided in **Table 10.1** and **10.2**.

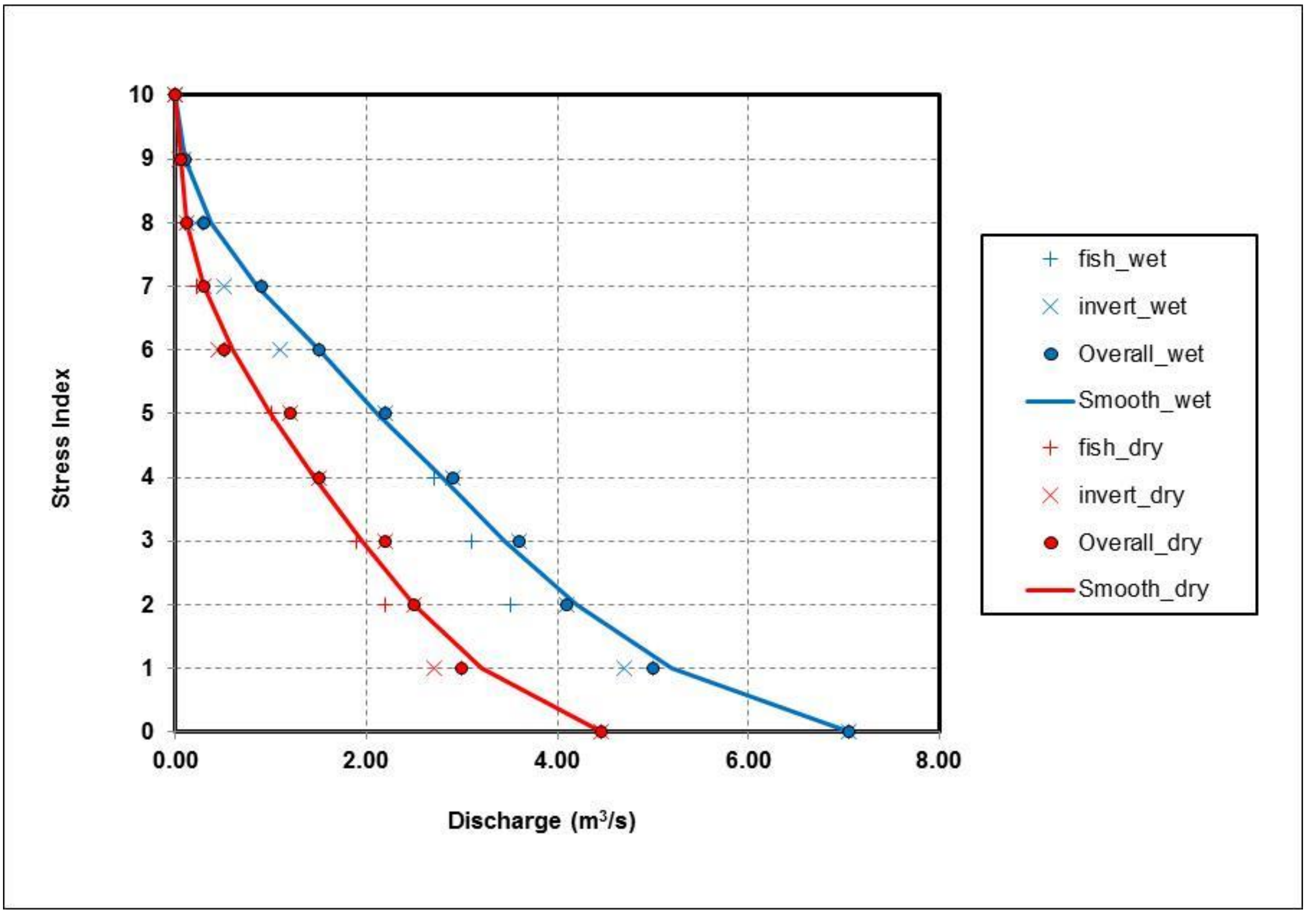


Figure 10.1 J4GOUR-EWR6: Fish, macroinvertebrate and integrated stress index

Table 10.1 J4GOUR-EWR6: Summarised habitat/biotic responses of fish during the dry and wet season

Stress	Flow (m^3/s)	Habitat and stress description
Dry season: January		
9	0.05	No flow dependent fish species are present, only hardy semi-rheophilic species. Flows will ensure adequate water quality in pools and adequate habitat is available for survival, but poor water quality is exacerbated by high temperatures (mid-summer).
5	1.0	Moderate diversity of habitats will be available at this flow and riffle depths (average 16 cm; maximum 46 cm) will allow unrestricted movement of smaller species and some migration of larger LUMB. A moderate stress on the overall fish assemblage exists.

Stress	Flow (m^3/s)	Habitat and stress description
2	2.2	Minimal stress is estimated due to good habitat diversity, including most fast habitats and excellent water quality. Riffles are deep enough (average 22 cm; maximum 55 cm) to cater for the unrestricted migration of all species, although reduced FD eel habitat is present. Thus all fish functions in dry season are supported.
Wet season: November		
9	0.10	Semi-rheophilic riffle spawning species are present, including the small minnow (PASP) and large LUMB), the latter requiring depths over 20 cm in riffles for migration and spawning. Riffle depths (average of 10 cm; maximum 27 cm) at this flow restrict natural LUMB movement between habitats. Limited FI and no FD habitat, preferred by eels is present.
5	2.2	Adequate diversity of habitats are available, including fast habitats but with limited FD eel habitat present. Good water quality is expected at this flow. Riffle depths (average 21 cm; maximum 54 cm) will allow almost unrestricted LUMB migration, but other small species are totally catered for. Thus moderate stress on the overall fish assemblage exists.
2	3.5	Minimal stress is estimated due to good habitat diversity and water quality, with all fish functions supported, including spawning of the both small PASP and large LUMB in deep riffles (average depth 30 cm; maximum 65 cm). This includes stress-free passage through deeper riffles. The primary limiting factor (compared to natural) is slightly reduced FD habitats preferred by eels.

Table 10.2 J4GOUR-EWR6: Summarised habitat/biotic responses of macroinvertebrates during the dry and wet season

Stress	Flow (m^3/s)	Habitat and stress description
Dry season: January		
5	1.2	All hydraulic habitat types are represented. Average depth 0.16 m and maximum 0.48 m, with velocities up to 1.1 m/s. These conditions across the wide channel will sustain the somewhat resilient community and inundate sufficient cover for developing juveniles.
2	2.5	Diverse and plentiful hydraulic habitat provides for all elements of the macroinvertebrate community (FDIs, invertebrates with a preference for MV (MVIs), taxa with preferences for slow flows and for fine sediments).
Wet season: November		
7	0.5	The habitat is dominated by SCS, with some fast and very fast flow over cobbles. With an average depth of 0.13 m, much of the cobble habitat will be exposed and the riffle and rapid areas will be reduced in size. This will be associated with some loss of abundance of FDIs.
2	4.1	The channel downstream of the bridge is well watered, with depth that supports the presence of adequate very fast over coarse substrate (FVCS) and very coarse substrate (VCS) to sustain the mid-summer life-history requirements of the invertebrate community, and to maintain the FDI indicator (Hydropsychidae, Simuliidae) taxa in a C Category.

10.2 HYDROLOGICAL CONSIDERATIONS

The wettest and driest months were identified as November and January, respectively. Droughts are set at 95% exceedance (flow). Maintenance flows are set at 60% exceedance (flow).

10.3 INSTREAM BIOTA REQUIREMENTS

The HFSR-RM generates the stress (and flow) requirements for different ECs. Once specialists are satisfied that these results are adequate to maintain the river at the target EC, descriptions are provided for key stress points (**Table 10.3**).

Table 10.3 J4GOUR-EWR6: Stress requirements and habitat and instream biota description

Duration	Stress: Required and (final*)	Flow (m^3/s): Required and (final)	Habitat and stress description
Dry season: January			
95% (Drought)	6.8	0.27	**Fish:** No FD and limited FI habitat are available, and very limited movement is possible due to shallow depths over riffles.
	7.0	0.30	**Macroinvertebrates:** The habitat is dominated by SCS, with areas of fast shallow flow over cobbles. This condition will sustain the dry season macroinvertebrate community (which includes developing juveniles) in a C Category.
60% (Maintenance)	6.0 (5.8)	0.50 (0.6)	**Fish:** There is a reduced requirement for large scale migration over critical riffle areas, but average depths of 12 cm are problematic for larger LUMB and the scarcity of FD eel habitat ensures moderate stress.
	5.8	0.60	**Macroinvertebrates:** At this discharge the width is ca. 17 m and the maximum depth 0.45 m. The fast flow habitats are abundant and more than satisfy the requirements of the C Category for FDIs.
Wet season: November			
95% (Drought)	8.0	0.30	**Fish:** No FD habitat is present with limited movement possible over riffles due to the shallow depth (average 9 cm; maximum 15 cm).
	7.8	0.30	**Macroinvertebrates:** The modelled hydraulics indicates that there is still limited Fast flow over Coarse Substrate (FCS) and VFCS habitat available. This is likely to be constrained to a narrow channel. Modelled depth and velocity appear adequate to sustain the FDI community in a C Category, depending on how flow is distributed across the channel.
60% (Maintenance)	7.1	0.80	**Fish:** All habitats are available, including FD; allowing some migration for large LUMB and all smaller PASP over riffles with an average depth of 15 cm, maximum of 45 cm. Limited FD habitat for eels is available. Moderate stress exists.
	6.5	0.8	**Macroinvertebrates:** High velocities (max 0.95 m/s) and deep water associated with this flow supplies the habitat requirements of FDIs and those taxa with a preference for MV (overhanging sedges). The conditions are suitable for mid-summer macroinvertebrate community ecology.

* Final HFSR-RM model output values

10.4 VERIFICATION OF LOW FLOWS: RIPARIAN VEGETATION

The low flow verification is done by comparing levels of inundation of certain riparian indicators during November (wettest month) and January (driest month), both at the 50th percentile. Data are shown below (**Table 10.4**) for the high flow month of November. Stream permanency remains at 100%. Discharge at 50% is as follows: Natural – 6.81 m^3/s; PD – 1.47 m^3/s; EWR requirement for PES (Category C) – 1.52 m^3/s. In all cases the level of vegetation above the water level is similar to PD; hence the proposed low flows do not limit riparian vegetation and should maintain the riparian vegetation category. **Table 10.4** provides a summary of the low flow verification.

Table 10.4 J4GOUR-EWR6: Detail of low flow verification (m^3/s) using riparian vegetation

Monthly snap shot						**Nov**
Inundation (Mar at 50%)						**50.0%**
Hydrology component				**NAT**	**PD**	**PES B/C**
Discharge (at month and percentile)				6.81	1.47	1.52
Scenario compared to Natural flows				-	Never higher	Never higher
Stream permanence (%)				100	100	100
Indicators	**Range limit**	**Zone**	**Elevation**	**NAT**	**PD**	**PES B/C**
Cyperus longus Indicator range: 0.41	Lower limit	Marg zone	0.489	-0.311	-0.011	**-0.011**
	Upper limit	Lower zone	0.901	0.101	0.401	**0.401**
	% of population inundated			75.510	2.563	2.563
Schoenoplectus Indicator range: 1.1	Lower limit	Marg zone	0.429	-0.371	-0.071	**-0.071**
	Upper limit	Lower zone	1.530	0.730	1.030	**1.030**
	% of population inundated			33.738	6.492	6.492
Gomphostigma virgatum Indicator range: 1.06	Lower limit	Marg zone	0.489	-0.311	-0.011	**-0.011**
	Upper limit	Upper zone	1.548	0.748	1.048	**1.048**
	% of population inundated			29.341	0.996	0.996

10.5 HIGH FLOW REQUIREMENTS

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

Table 10.5 J4GOUR-EWR6: Identification of instream functions addressed by the identified floods for riparian vegetation and geomorphology

Motivations	Fish flood functions						Macroinvertebrate flood functions			
	Migration cues and spawning	Migration habitat (depth etc.)	Clean spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas
CLASS I (8 - 16)[1]										
Geomorphology: These small, regularly occurring flushing flow only accounts for approximately 4% of the sand transported through the site, but would be important for removing accumulated fines from the channel bed. **Riparian vegetation:** Floods the marginal zone and marginal zone sedges (*C. longus* and *C. textilis*) and 65% of the *G. virgatum* population. Its role is to elicit and maintains growth and reproduction.	✓	✓	✓	✓	✓	✓	✓	✓		✓
CLASS II (25 - 30)										
Riparian vegetation: Floods the lower zone and activates the *A. karoo* population. Its role is to prevent woody encroachment of the marginal and lower zones.	✓	✓	✓	✓	✓	✓				
CLASS III (50 - 60)										
Geomorphology: Responsible for approximately 16% of the sand and gravel transported through the site, and could be expected to scour the bed, slightly widen the channel and flush pools. **Riparian vegetation:** This event floods *N. oleander* at its lower limit, preventing its encroachment to the marginal and lower zones and provides a similar role with regards to *A. karoo*.			✓		✓					
CLASS IV (350)										
Geomorphology: This is the effective discharge class for sands and gravels, accounting for 42 and 43% of the long term transport of these respective sediment classes. This is the most important flood class to preserve in the flood regime, and would be responsible for scouring the bed, banks and pools and removing some vegetation that would otherwise encroach on to low bars and in to the channel.			✓		✓					

Motivations	Fish flood functions						Macroinvertebrate flood functions			
	Migration cues and spawning	Migration habitat (depth etc.)	Clean spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas
CLASS V (>700)										
Geomorphology: This is the effective discharge class for cobbles, accounting for 88% of the long term transport of this sediment class. These large floods would remove vegetation, over widen the channel and scour and redistribute sediment across the channel flood, recreating conditions similar to the expected RC. **Riparian vegetation:** This event floods the upper zone. Its role is to prevent terrestrialisation and the formation of thickets.			✓		✓					

J4H002 was used to verify high flows although it must be noted that the data record has many gaps and the gauge is a rated alluvial section downstream of the site. The period 1990 to date was used.

Table 10.6 J4GOUR-EWR6: Recommended flood events

Flood class (Peak in m^3/s)	Flood requirements*	Months	Daily ave.	Duration (days)
Class I (8 - 16)	5	October - May (fish early spring)	12.8	5
Class II (25 - 30)	2	October - December	23	6
Class III (50 - 60)	3	March - April	43	7
Class IV (350)	1:3		219	9
Class V (>700)	1:3		415	10

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

The RDRM model distributes the high flow volumes across the wet period months according to the natural distribution. The months provided by specialists are therefore those in which floods are recommended, but there will be naturally-determined variations in the final EWR high flow time series results.

10.6 EWR RESULTS

The results are provided as an EWR table (**Table 10.7**) and an EWR rule (**Table 10.8**). Flow duration graphs are supplied as **Figure 10.2** and **10.3**. Detailed results are provided in the model generated report for each category in **Appendix D** for both low and total flows.

The low flow EWR rule table is used for building rules for EWR releases. The information on specific flood releases is provided in the EWR table. Note that these tables on its own cannot be used for dam or system operation but will feed into an integrated model to determine the operation of the system. Note that high flows (floods), if released from dams, will require hydrodynamic modelling to determine the actual releases to achieve the instantaneous peak at the EWR site. A summary of the results is provided in **Table 10.9**.

Table 10.7 J4GOUR-EWR6: EWR table for PES and REC: C EC

Month	Low flows (m^3/s)			High flows	
	Drought (90%) (m^3/s)	60% (m^3/s)	50% (m^3/s)	Daily average (m^3/s)	Duration (days)
October	0.386	0.793	1.123	12.8 23	5 6
November	0.326	0.787	1.043	12.8	5
December	0.326	0.701	0.925	12.8 23	5 6
January	0.292	0.594	0.736	12.8	5
February	0.276	0.490	0.735	12.8	5
March	0.318	0.693	0.907	43	7
April	0.202	0.682	0.900	43	7
May	0.327	0.647	0.833	43	7
June	0.334	0.632	0.852		
July	0.329	0.688	0.872		
August	0.644	0.715	0.903		
September	0.582	0.722	0.933		

Table 10.8 J4GOUR-EWR6: Low flow Assurance rules (m^3/s) PES and REC: C

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
October	1.422	1.422	1.326	1.225	1.123	0.793	0.686	0.540	0.386	0.286
November	1.645	1.587	1.475	1.289	1.043	0.787	0.587	0.417	0.326	0.284
December	1.492	1.446	1.290	1.173	0.925	0.701	0.570	0.418	0.326	0.319
January	1.095	1.045	0.966	0.864	0.736	0.594	0.481	0.376	0.292	0.254
February	1.384	1.183	0.876	0.825	0.735	0.490	0.371	0.298	0.276	0.276
March	1.666	1.328	1.060	1.016	0.907	0.693	0.563	0.420	0.318	0.267
April	1.485	1.425	1.257	1.076	0.900	0.682	0.549	0.413	0.202	0.122
May	1.507	1.322	1.082	0.956	0.833	0.647	0.553	0.421	0.327	0.307
June	1.146	1.131	0.955	0.954	0.852	0.632	0.536	0.415	0.334	0.109
July	1.065	1.064	1.004	0.965	0.872	0.688	0.558	0.421	0.329	0.303
August	1.222	1.182	1.114	1.052	0.903	0.715	0.645	0.644	0.644	0.381
September	1.199	1.198	1.098	1.091	0.933	0.722	0.591	0.583	0.582	0.468

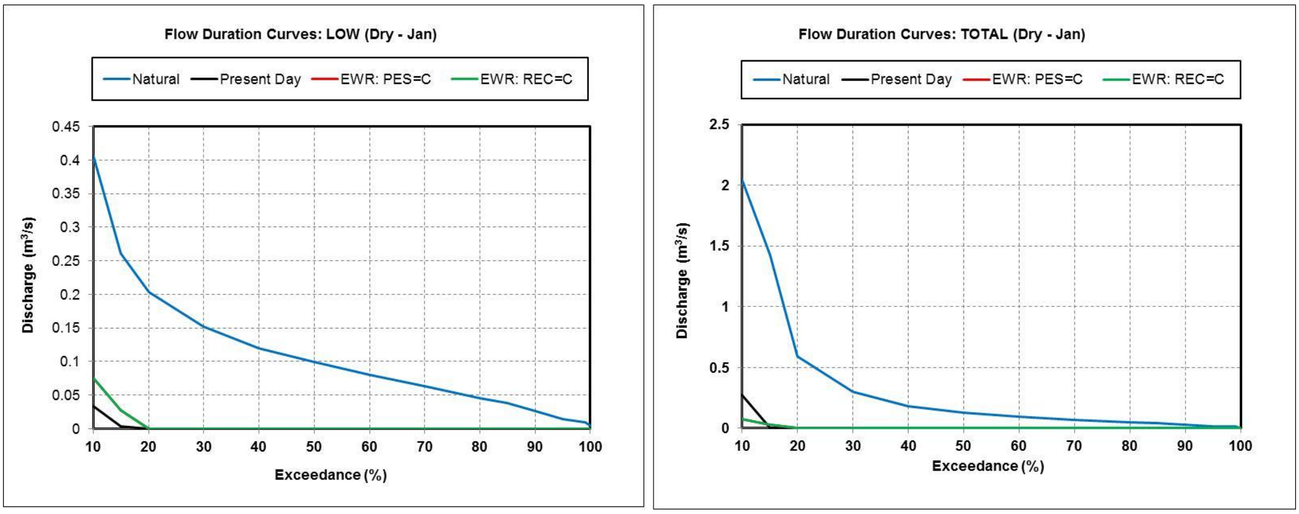


Figure 10.2 J4GOUR-EWR6: Flow duration graph for the dry season (low flows left, total flows right)

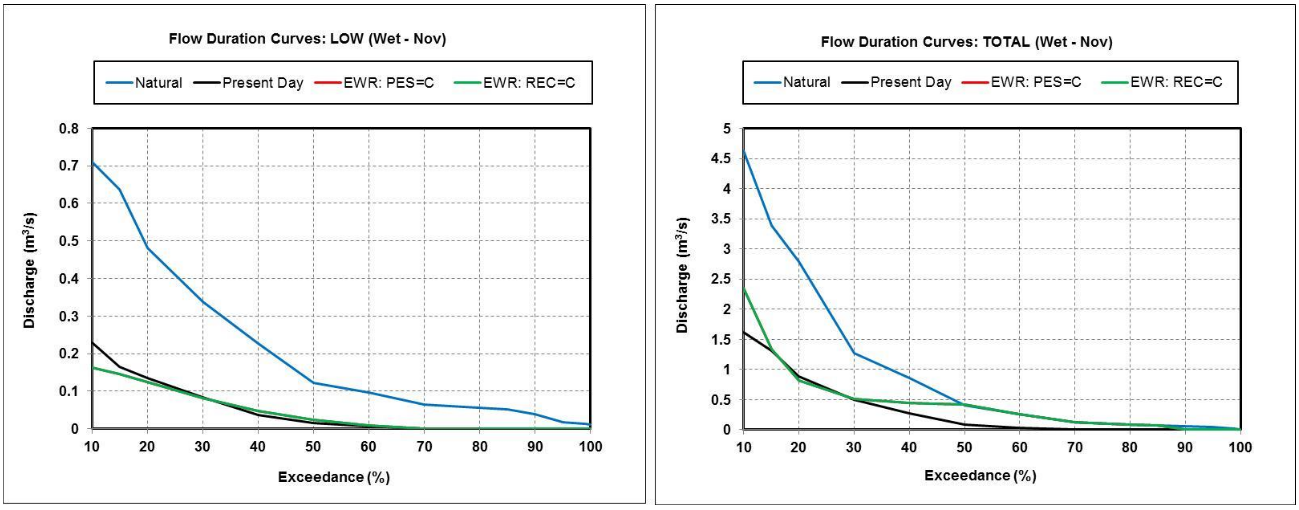


Figure 10.3 J4GOUR-EWR6: Flow duration graph for the wet season (low flows left, total flows right)

Table 10.9 J4GOUR-EWR6: Summary of results as a percentage of the nMAR

EcoStatus	nMAR (MCM)	pMAR (MCM)	Low flows (MCM)	Low flows (%)	High flows (MCM)	High flows (%)	Total flows (MCM)	Total (%)
PES; REC: C	543.52	310.35	27.12	5	102.47	18.8	129.59	23.8

11 ECOCLASSIFICATION: KEURBOOMS RIVER – K6KEUR-EWR8

11.1 BACKGROUND

The area at K6KEUR-EWR8 (**Figure 11.1**) is dominated by forestry. Upstream there is some forestry, agriculture and irrigation. There are no gauging weirs near the EWR site. The river is perennial with low flows being impacted on due to forestry and upstream abstraction. An upstream and downstream gauge has been used to demonstrate the flow variability and perenniality which is very different from the drier systems dealt with in the rest of this report (**Figure 11.2**).

Figure 11.1 A map, Google image and downstream view of the EWR site

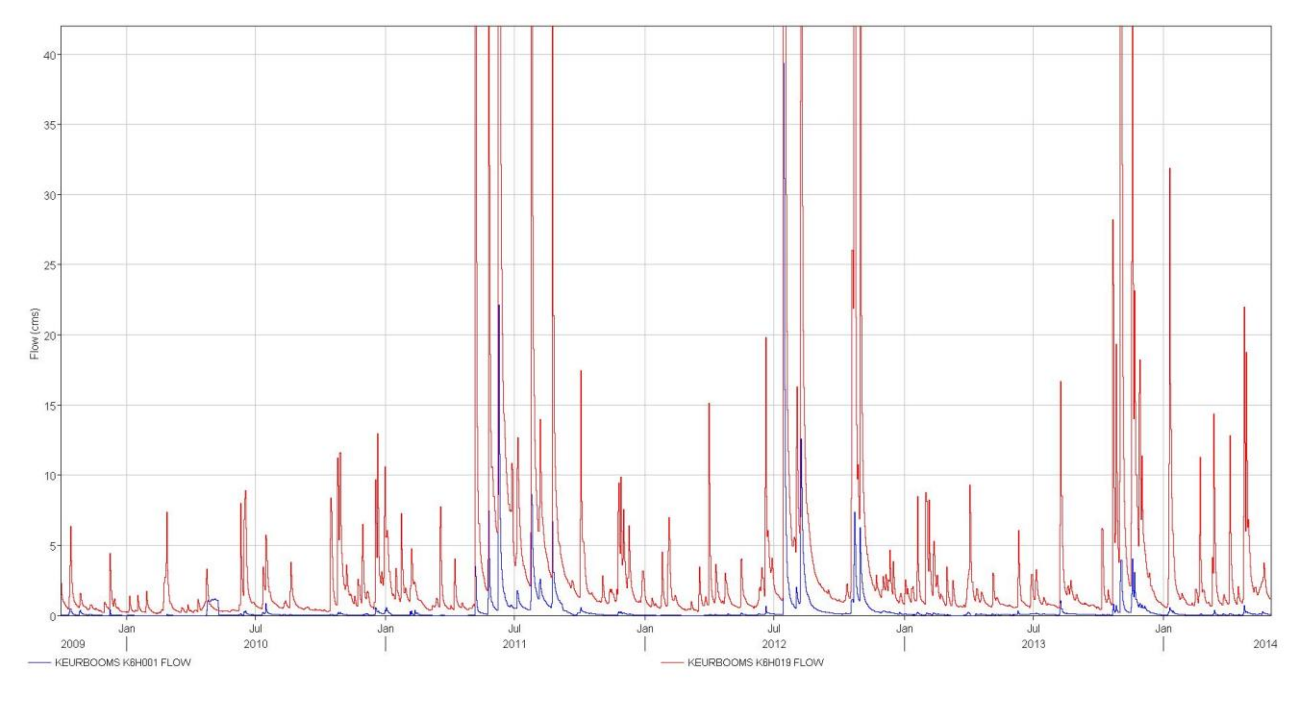


Figure 11.2 Hydrology variability in the Keurbooms from an upstream and downstream gauge

11.2 EIS RESULTS

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

- Rare and endangered species: The endangered *P. asper* occurs in the reach.
- Unique species: *Pseudobarbus cf. tenuis.*
- Species intolerant to physico-chemical changes: A large portion of taxa and species are intolerant to water quality changes.
- Migration route: The site is located in the lower part of the system and the reach is important for eel migration.
- Rare and endangered riparian/wetland species: *Prionium serratum* (Palmiet) occurs at the site and has an IUCN status of "Declining". Similarly, both *Cyathea capensis var. capensis* and *Ilex mitis var. mitis* are also listed as "Declining" and while historical records show their presence in the area, they were not observed at the site.
- Unique riparian/wetland species: The following two endemic riparian species were found at the site: *Brachylaena neriifolia* and *Juncus capensis,* but 12 others were expected and not found.

11.3 PRESENT ECOLOGICAL STATE

The PES reflects the changes in the EC relative to reference conditions. The summarised PES information is provided in **Table 11.1** and water quality and diatom information is provided in **Appendix A** and **B**, respectively.

Table 11.1 K6KEUR-EWR8: Present Ecological State

<table>
<tr><th colspan="2">IHI Hydrology: PES: B, Confidence: 3.4</th></tr>
<tr><td colspan="2">The nMAR is 49.81 MCM and the pMAR is 30.45 MCM (61% of the nMAR). Baseflows have decreased from natural to PD in volume with insignificant changes to the overall monthly distribution of flows. The volume change can be ascribed to upsteam irrigation and farm dams. Most of the changes in flow occur in the intermediate to high flow ranges. Baseflow are not significantly impacted.</td></tr>
<tr><th colspan="2">Water quality: PES: B (82.7%), Confidence:3</th></tr>
<tr><td colspan="2">Salt (sodium and chloride) levels are slightly elevated in terms of the Target Water Quality Range (TWQR) for irrigation. Note that irrigation guidelines are merely used in the absence of ecosystem water quality guidelines for salts to provide some calibration for instream salinity levels.</td></tr>
<tr><th colspan="2">Geomorphology: PES: B/C (79.8%), Confidence: 2.5</th></tr>
<tr><td colspan="2">Although there is some small impact with reduced basefows and floods from farm dams and abstractions upstream, the Keurbooms is primarily impacted by invasive woody vegetation which encroaches on to the macro-channel floor and stabilises the bars, banks and sediment. This reduced flood energies across the flood (macro) channel and would, if not regulated through frequent floods removing the encroaching vegetation, cause incision and narrowing of the low flow channel.</td></tr>
<tr><th>IHI Instream: PES: C (75.6%) Confidence 3.1</th><th>IHI Riparian: PES: C/D (57.6%), Confidence 3.3</th></tr>
<tr><td colspan="2">The instream IHI is impacted to some extent by decreased base flow and flooding frequency due to irrigation and farm dams. Bank modification is present due to by invasive woody vegetation.
The riparian IHI is mainly impacted by bank structure modification and loss of longitudinal connectivity due to clearing and a high density of alien species.</td></tr>
<tr><th colspan="2">Riparian vegetation: PES: C/D (58.7%), Confidence: 3.1</th></tr>
<tr><td colspan="2">The site occurs within Garden Route Shale Fynbos, which refers to a terrestrial vegetation type dominated by tall, dense proteoid and ericaceous fynbos but frequently with gullies and valleys comprising afrotemperate forest (Mucina and Rutherford, 2006).

In September of 1775 A. Sparrman refers to the Keurbooms River: "Keurbooms-river is perhaps so called after a tree of the same name (Sophora capensis Linn.)" [Virgilia oroboides] [but the explorer did not find any, and neither were they observed during the site visit]. (Sparrman, 1786, in Skead, 2009). In 1809 Collins describes the Keurbooms River as follows: "... the country is almost covered with wood..."(Collins, 1860, in Moodie, 1860, in Skead, 2009). Historical aerial photographs from 1961 already show the extent of forestry activities, with much of these invading waterways in the area. Google Earth images show notable decrease in woody cover from 2002 to 2009 presumably from flood disturbance. Prior to 2009 woody cover indicates high density especially of alien plantation species. Rapid encroachment of bars after 2009 by Wattle is evident from the 2013 satellite coverage.

The marginal zone was mostly dominated by open cobble and boulder with little to no vegetation. Some alluvial bars upstream support sparse to moderate non-woody cover, mainly sedges and small shrubs. S. mucronata and G. virgatum were absent. Small patches of P. serratum were observed. The sub-zone was largely as expected although a small percentage (< 10%) of existing cover was by alien vegetation. The lower zone was similar to the marginal zone. The upper zone was dominated by alien plantation species (Wattle and Pine) with distinct cohorts likely related to flooding disturbance (satellite imagery also shows floods are important for clearing alien trees species). Indigenous forest or riparian species were largely absent.</td></tr>
<tr><th colspan="2">Fish: PES: C (76.4%), Confidence: 2.5</th></tr>
<tr><td colspan="2">Under the RC one eel (AMOS) and three fish species (the Forest redfin PASP, the Cape kurper SCAP and the Keurbooms River redfin Pseudobarbus cf. tenuis - PTEN) have been historically recorded in the Keurbooms near the EWR site. In the June 2014 fish survey only PASP and AMOS were captured as well as the alien TSPA. The other reference species were considered to be present, but in very reduced FROCs. This is probably partly due to recent floods removing marginal and instream vegetation in SS and SD habitats, the preferred habitat of both PTEN and SCAP. Reduced baseflows and lowered water quality during the dry season due to abstraction (and return flows) for agriculture and flow reduction due to extensive forestry plantations in the catchment are considered the main causes for the PES.</td></tr>
</table>

Macroinvertebrates: PES: C (70.8%), Confidence: 2.5
The macroinvertebrate RC was derived from data obtained from DWS: Western Cape for RHP sites: K6KEUR-UNION and K6KEUR-DEVLUG (in 2004, 2005, and 2012). Both sites were in the Keurbooms River and upstream of the EWR site. The SASS5 sample score was 150 with 20 macroinvertebrate taxa and an ASPT of 7.5, which was unusually high. Taxa scoring over 10 in the sample, and indicating high water quality, included heptagenid, telagonodid mayflies, > 2 spp. baetid mayflies, perlid stoneflies, and platycnemid damselflies. The high-scoring taxa that were expected but absent included notonemourid stoneflies and barbarochthonid and petrothrincid caddisflies. The MIRAI provided an indication that the largest differences between the derived reference and the PD sample were in lower-scoring taxa with a preference for moderate and slow flow conditions (absent taxa included ecnomid beetles, lestid damselflies, veliid, gerrid and corixid hemipterans), moderate water quality (Hydracarina, ecnomid caddisflies, elmid beetles, tricorythid mayflies were absent) and/or the marginal vegetation habitat (e.g. Lestidae, Hydraenidae, Nepidae, Lymnaeidae were absent). The causes of the changes in the community were considered to be largely the reduced MAR (due to, for example, forestry and small upstream dams), a deterioration in water quality (due to input of sediment from forestry and return flows from agriculture), and the reduction in flood frequency, which at the macroinvertebrate scale resulted in a deterioration of habitat quality and availability.

The PES is a C and the EcoStatus models are provided electronically. Non flow-related impacts are the major cause for the PES and include the high occurrence of alien species (plantation species that encroach on the natural habitat) as well as vegetation clearing. Reduced baseflows, flood frequency and deteriorated water quality during the dry season due to abstraction (and return flows) for agriculture as well as flow reduction due to extensive forestry plantations in the catchment are considered the main flow-related impacts.

11.4 RECOMMENDED ECOLOGICAL CATEGORY

The REC is determined based on ecological criteria only and considered the EIS and the restoration potential of the site. As the EIS is HIGH, improvement is required. The REC is therefore set to improve the PES of a C EC. The following changes would be required to improve the category:

- Removal of alien vegetation.
- Improvement in baseflows.

The resulting analysis (**Table 11.2**) shows that only a half a category improvement would be possible, i.e. a B/C EC (**Table 11.3**).

Table 11.2 K6KEUR-EWR8: Recommended Ecological Category

Geomorphology: REC: B (83%), Confidence: 2.5
Removal and continued control of the invasive woody vegetation would allow for a more natural, dynamic channel to be reinstated.

Riparian vegetation: REC: B/C (78.7%), Confidence: 2.6
The main impact at the Keurbooms is invasion by alien species, mostly Wattle (*Acacia mearnsii*). Recent flooding disturbance masked any response to altered flows and improvement therefore only considers changes in alien species. Hence, the removal of alien plants comprises the improvement of the PES to a B/C. It is assumed that alien cover will be reduced to a maximum of 20%.
Fish: REC: B (82.3%), Confidence: 1.5
Clearing of alien vegetation in riparian zones and catchment will elevate baseflows closer to natural which will improve water quality, particularly in the dry season and increase habitat available for fish. A slight increase in marginal vegetation in SD (pools) and SS areas will prove improved cover for fish. These improvements will increase the FROC of the sensitive and flow-dependent and endangered PTEN (Keurbooms River redfin). This will increase the PES to a B Category. However, the low confidence in the hydrology for this system and lack of accurate data on the ecological requirements of PTEN gives a low confidence regarding this prediction.
Macroinvertebrates: REC: B (82.8%), Confidence: 2
It is expected that the removal of alien riparian vegetation would increase baseflows, which would have the effect of improving the availability and the quality of cobble habitat, and improving water quality. The likely consequence would be conditions favourable to gradual habitation by the more sensitive FDIs expected in the RC, such as notonemourid stoneflies, and barbarochthonid and petrothrincid caddisflies. This would improve PES to a B Category.
Ecostatus: REC: B/C (80.64%)
The removal of exotic vegetation results in an overall improvement in Riparian vegetation by a category, and this in turn improves the condition of instream biota from a C to a low B Category. The EcoStatus therefore improves by half a category to a B/C.

11.5 ECOCLASSIFICATION SUMMARY

The EcoClassification results are summarised in **Table 11.3**.

Table 11.3 K6KEUR-EWR8: Summary of EcoClassification results

Component	PES	REC
IHI Hydrology	B	
Water quality	B	B
Geomorphology	B/C	B
Fish	C	B
Invertebrates	C	B
Instream	C	B
Riparian vegetation	C/D	B/C
EcoStatus	C	B/C
Instream IHI	C	
Riparian IHI	C/D	
EIS	HIGH	

Improvement in the riparian vegetation can be achieved with non-flow related actions. Flow related actions are required to achieve the instream improvement to the B and the EWRs are set to maintain the instream PES of a C and for improvement to a B EC.

12 EWR REQUIREMENTS: KEURBOOMS RIVER – K6KEUR-EWR8

12.1 FLOW VS STRESS RELATIONSHIP

The fish and macroinvertebrate stress flow index is provided in **Figure 12.1**. The integrated stress curve for both the dry season (red curve) and wet season (blue curve) is illustrated on the graph. A description of the habitat and response associated with the key stress is provided in **Table 12.1** and **12.2**.

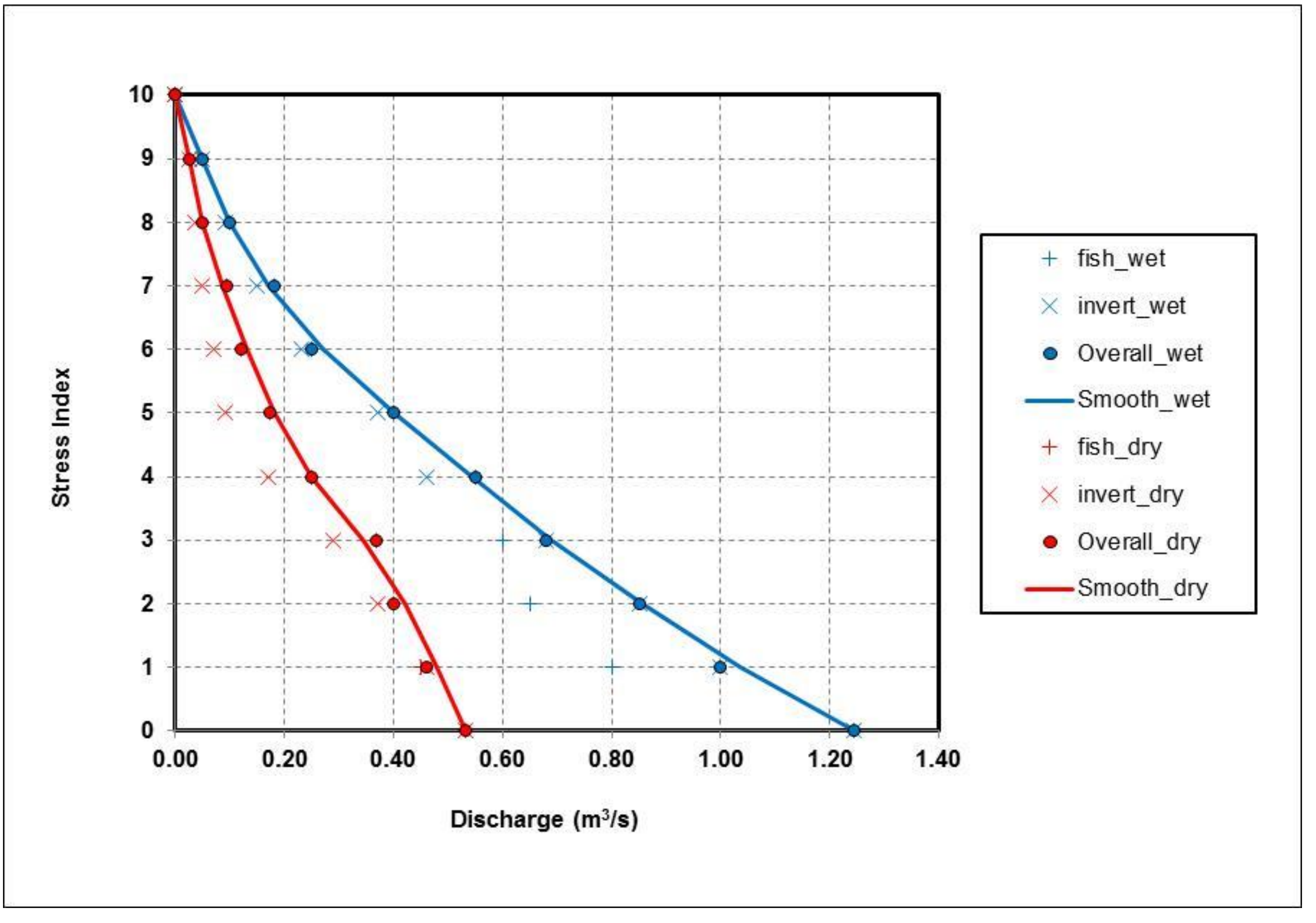


Figure 12.1 K6KEUR-EWR8: Fish, macroinvertebrate and integrated stress index

Table 12.1 K6KEUR-EWR8: Summarised habitat/biotic responses of fish during the dry and wet season

Stress	Flow (m^3/s)	Habitat and stress description
Dry season: February		
9	0.025	Minimal depth will be available and although some migration may be allowed it will be very restricted. Very limited fast habitats (shallow and very shallow) will be provided to allow for some improvement in water quality (compared to zero flow).
5	0.17	Adequate diversity of habitats will be available at this flow having moderate stress on the overall fish assemblage. Although no FD habitats will be available, adequate fast habitats will be provided.

Stress	Flow (m^3/s)	Habitat and stress description
2	0.4	Minimal stress is estimated due to good habitat diversity and water quality with all fish functions supported.
Wet season: September		
9	0.05	Minimal depth will be available to allow for some migration (eels and *Pseudobarbus* spp.), highly reduced habitat availability (wetted perimeter), very poor water quality due to low flow (and velocities) and very limited spawning habitat will be provided for *Pseudobarbus* spp.
5	0.4	Adequate diversity of habitats will be available having moderate stress on the overall fish assemblage. Although all fast habitat guilds will be provided, they will be reduced by half of the naturally expected composition.
2	0.65	Minimal stress is estimated due to good habitat diversity, water quality with all fish functions supported. The primary limiting (compared to natural) aspect is reduced abundance of habitats (especially fast habitats).

Table 12.2 K6KEUR-EWR8: Summarised habitat/biotic responses of macroinvertebrates during the dry and wet season

Stress	Flow (m^3/s)	Habitat and stress description
Dry season: February		
7	0.05	Velocities are inadequate to support VFCS habitat. There is still a small amount of FCS habitat which will maintain the majority of FDIs, however in lower numbers. Water quality deteriorates as depth and connectivity (lateral and longitudinal) is lost. As discharge declines fast flow habitat will disappear and rheophilics will relocate or gradually be lost. There is still adequate depth and width to support the majority of taxa in the C Category.
3	0.29	All hydraulic habitat types are represented. There is adequate depth and width to support a heterogeneous community of both developing individuals and adults. All FDIs are maintained in a healthy state. Taxa with a preference for marginal vegetation are provided for with the inundation of small patches of fringing grasses at the river margin. (average depth 0.13 m; width 10.2 m; velocity 0.25 - 0.82 m/s)
Wet season: September		
9	0.05	There is a loss of VFCS. Trickling flow that remains should be adequate to support developing eggs and juveniles. Habitat availability is becoming low (average depth 0.1 m; velocity 0.1 - 0.4 m/s; 5% FCS; width 4.6 m).
3	0.68	All FDI and other taxa in the sample are adequately catered for in terms of width, depth, habitat availability and velocity (5% VFCS; 22% FCS; velocity 0.25 - 0.82 m/s; depth 0.14 - 0.32 m; width 10.7 m).
0	1.24	Plentiful fast and very fast, flow and adequate depth over cobbles maintains the FDI community. There is adequate depth to maintain all FDI habitats, clear fines and algae, and adequate depth and width to provide maximum inundation of marginal vegetation which is an important habitat for developing juveniles (e.g. Baetidae).

12.2 HYDROLOGICAL CONSIDERATIONS

The wettest and driest months were identified as September and February. Droughts are set at 95% exceedance (flow). Maintenance flows are set at 60% exceedance (flow).

12.3 INSTREAM BIOTA REQUIREMENTS

The HFSR-RM generates the stress (and flow) requirements for different ECs. Once specialists are satisfied that these results are adequate to maintain the river at the target EC, descriptions are provided for key stress points under PES conditions (**Table 12.3**) and for the REC (**Table 12.4**).

Table 12.3 K6KEUR-EWR8: Stress requirements and habitat and instream biota description under PES conditions

Duration	Stress: Required and (final*)	Flow (m^3/s): Required and (final)	Habitat and stress description
Dry season: February			
95% (Drought)	7.8 (7.5)	0.055 (0.69)	**Fish:** Shallow depths (average 10 cm) and only FS habitats in riffles are expected, restricting fish passage and absence of suitable FD eel habitat. High stress is also related to poor water quality and high temperatures during low flows in February.
	7.0	0.05	**Macroinvertebrates:** At this flow there is still a small amount of FCS habitat which should maintain the majority of FDIs, however in lower numbers. Water quality deteriorates as depth decreases (max depth 18 cm) and connectivity (lateral and longitudinal) is lost. There is however still adequate depth and width (4.6 m) to support the majority of taxa found in the C Category.
60% (Maintenance)	5.8 (5.6)	0.13 (0.14)	**Fish:** Increased depths in riffles (average 12 cm; maximum 24 cm) allow easy movement by all species. There is increased habitat availability and improved water quality due to increased flows.
	4.5	0.14	**Macroinvertebrates:** At this discharge there is little very fast flow habitat, and the MVIs are largely exposed. Robust habitat is not provided by these flows.. Taxa that rely on this biotope will either relocate or be lost if this condition persists. Nonetheless, the range of velocities present maintains the majority of the sampled FDI taxa, and the EC of a C.
Wet season: September			
95% (Drought)	6.8 (7.0)	0.19 (0.17)	**Fish:** No FD habitat is available, but suitable fast intermediate habitat and depths (average 13 cm) are present for migration through riffles and for some limited spawning of *Pseudobarbus* spp.
	6.8	0.17	**Macroinvertebrates:** Very fast flow habitat has almost disappeared. Width is reduced and the MVis are exposed as these flows do not provide robust habitat. Taxa that rely on this biotope will either relocate or be lost if this condition persists. Nonetheless, the range of velocities maintains the majority of the sampled FDI taxa, and the EC of a C.

Duration	Stress: Required and (final*)	Flow (m^3/s): Required and (final)	Habitat and stress description
60% (Maintenance)	5.2	0.37	**Fish:** FD habitat is now available and suitable depths in riffles (average 14 cm, maximum 32 cm) exist for spawning of *Pseudobarbus* spp., as well as suitable eel habitat and safe passage through riffles for migration of all fish and eels.
	5.0 (5.2)	0.37	**Macroinvertebrates:** This is the discharge at which the river was sampled in Jun 2014. At this flow all hydraulic habitats are present and plentiful. Some marginal vegetation in the slow and no-flow areas is inundated and this provides refuge and a food source for developing individuals. There is adequate depth and velocity in the cobble areas to maintain all FDIs.

* Final HFSR-RM model output values provided in brackets only if different from requirement.

Table 12.4 K6KEUR-EWR8: Stress requirements and habitat and instream biota description for the REC

Duration	Stress: Required and (final*)	Flow (m^3/s): Required and (final)	Habitat and stress description
Dry season: February			
95% (Drought)	7.4	0.074 (0.076)	**Fish:** Flows are sufficient to maintain good water quality and suitable habitat availability as well as suitable depths (average 11 cm; maximum 20 cm) for moderate passage over riffles
	6.0	0.074	**Macroinvertebrates:** VFCS is absent; however the FDIs with a preference for high velocities (e.g. Perlidae) will persist for a period, until only slow flows occur. Width is inadequate to wet or inundate the MV habitat, and the taxa and juveniles requiring this cover and food source will relocate and be reduced in number.
60% (Maintenance)	4.9	0.18 (0.17)	**Fish:** Increased depths in riffles (average 13 cm; maximum 26 cm) allow virtually optimum migration by all fish and eel species, increased habitat availability and improved water quality due to increased flows.
	4.0	0.18	**Macroinvertebrates:** At this discharge all hydraulic habitat classes are represented, and the requirements of all taxa are catered for. The small proportion of very fast flow habitat (5%) supplies those FDIs with a preference for velocities > 6 m/s (e.g. Perlidae). The persistence of this condition and higher local velocities for up to 40% of the time will create conditions associated with good water quality and heterogeneous habitat, which will support the larger number of sensitive FDI taxa that one would anticipate in the B Category.

Duration	Stress: Required and (final*)	Flow (m^3/s): Required and (final)	Habitat and stress description
Wet season: September			
95% (Drought)	6.0	0.25 (0.20)	**Fish:** Flows ensure excellent water quality. Depths in riffles (average 11 cm; maximum 20 cm) allow restricted fish passage and limited spawning habitat for *Pseudobarbus* spp., as well as limited eel habitat
	6.0	0.25	**Macroinvertebrates:** This discharge supports all hydraulic habitat classes and will enable an invertebrate community comprising taxa with diverse hydraulic habitat preferences to survive the early summer months. The discharge is associated with a width of 8.3 m and an average depth of 0.13 m which will be adequate to wet/inundate grassy marginal vegetation which provides cover for juveniles and many adult taxa. All FDIs anticipated in the B Category are supported.
60% (Maintenance)	4.4	0.49 (0.48)	**Fish:** FD habitat is now available and suitable depths in riffles (average 15 cm; maximum 34 cm) exists for almost optimum spawning of *Pseudobarbus* spp., as well as suitable eel habitat and stress-free passage through riffles for migration of all fish and eels.
	4.1	0.49	**Macroinvertebrates:** This condition is associated with a very wide wetted channel (11 m) and an average depth (0.15 m) that will ensure inundated cobble habitat almost over the full width of the bed, and plentiful flow areas (average depth 0.27 m and velocity is 0.87 m/s). All elements of the invertebrate community are catered for, including the more sensitive FDI taxa (absent under the PES of C). Taxa with a preference for MV are also provided with areas of inundated leafy habitat at this and higher discharges.

* Final HFSR-RM model output values provided in brackets only if different from requirement.

12.4 VERIFICATION OF LOW FLOWS: RIPARIAN VEGETATION

The low flow verification is done by comparing levels of inundation of certain riparian indicators during September and February, both at the 50th percentile. Data are shown below (**Table 12.5**) for the high flow month of September. Stream permanency is maintained throughout with discharge at 50% as follows: Natural – 1.55 m^3/s; PD – 1.16 m^3/s; EWR requirement for PES (Category C) – 0.74 m^3/s; requirement for REC (category B) – 0.92 and requirement for AEC (Category D) 0.63 m^3/s. Proposed flows do not exceed Natural and in all cases *Cliffortia linearis* (a marginal to lower zone shrub) does not become inundated, and the increase in height above channel flow is at worst by 10 cm (comparison of AEC to NAT) and similarly by 15 cm for marginal zone grasses. *Cyperus congestus* (marginal zone sedge) would be slightly inundated under Natural flows (1 cm) at its lowest limit but not during the other flow regimes (PD, PES, REC, AEC) where height above channel flow increases to 10 cm during AEC flows. Proposed low flows do not limit riparian vegetation and should maintain the riparian vegetation category. **Table 12.5** provides a summary of the low flow verification.

Table 12.5 K6KEUR-EWR8: Detail of low flow verification (m3/s) using riparian vegetation

Monthly snap shot									**Sep**
Inundation (Mar at 50%)									**50.0%**
Component				**NAT**	**PD**	**PES C/D**	**REC B/C**	**AEC D**	
Discharge (at month and percentile)				1.55	1.16	0.74	0.92	0.63	
Scenario compared to Natural flows				-	Never more				
Stream permanence (%)				100	100	100	100	100	
Indicators	**Range limit**	**Zone**	**Elevation**	**NAT**	**PD**	**PES C/D**	**REC B/C**	**AEC D**	
Cliffortia linearis	Lower limit	Lower zone	0.769	0.289	0.329	**0.389**	**0.369**	0.409	
Cyperus congestus	Lower limit	Marg zone	0.468	-0.012	0.028	**0.088**	**0.068**	0.108	
Marginal zone grasses Indicator range: 0.10	Lower limit	Marg zone	0.535	0.055	0.095	**0.155**	**0.135**	0.175	
	Upper limit	Marg zone	0.634	0.154	0.194	**0.254**	**0.234**	0.274	
	% of population inundated			0	0	0	0	0	

12.5 HIGH FLOW REQUIREMENTS

Detailed motivations are provided in **Table 12.6** and final high flow results are provided in **Table 12.7**.

Table 12.6 K6KEUR-EWR8: Identification of instream functions addressed by the identified floods for riparian vegetation and geomorphology

Motivations	**Fish flood functions**						**Macroinvertebrate flood functions**			
	Migration cues and spawning	**Migration habitat (depth etc.)**	**Clean spawning substrate**	**Create nursery areas**	**Resetting water quality**	**Inundate vegetation for spawning**	**Breeding and hatching cues**	**Clear fines**	**Scour substrate**	**Reach or inundate specific areas**
CLASS I (2 - 4)[1]										
Geomorphology: Important for regularly flushing sands from the channel bed. These sands accumulate between events from the sands washed off the catchment and in to the river. **Riparian vegetation:** Floods marginal zone grasses and sedges, will recharge bank soil moisture (where applicable) and will elicit a growth response from vegetation. Marginal zone grasses and sedges are 100% inundated, and up to 20 cm water depth is achieved.	✓	✓	✓	✓	✓	✓	✓	✓		✓

Motivations	Fish flood functions						Macroinvertebrate flood functions			
	Migration cues and spawning	Migration habitat (depth etc.)	Clean spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas
CLASS II (10 - 20)										
Geomorphology: Represents the annual flood, and is the effective discharge for sands and gravels at the EWR site and is responsible for the bulk (more than 40%) of sand and gravel movement through the site over the long term. **Riparian vegetation:** Floods the lower zone shrubs such as *C. linearis*, eliciting a growth response and also prevents alien species in the marginal zone. It also inundates 25 - 55% of the youngest (< 2 m tall).Wattle cohort, and this inundation stress is important to retard Wattle invasion in the lower zone.	✓	✓	✓	✓	✓	✓				
CLASS III (50 - 90)										
Geomorphology: Is the effective discharge for cobbles and is responsible for flushing the channel and pools and for activating cobbles to prevent embeddedness. It is also important to keep vegetation encroachment in check. **Riparian vegetation:** Floods and scours youngest Wattle cohort (flooding up to 70 cm), and activates the next Wattle cohort (2 – 4 m tall). Will also scour marginal and lower zones.	✓	✓	✓	✓	✓	✓				
CLASS IV (>100)										
Geomorphology: Responsible for maintaining open river channel and bar conditions through the widespread mobilisation of the cobble bed and bars, and through removal of invasive alien vegetation. **Riparian vegetation:** Will scour most zones, remove vegetation (including aliens species) and prevent alien species invasion and terrestrialisation.	✓	✓	✓	✓	✓	✓				

No reliable DWS gauges were present to verify high flows. K6H001 is situated far upstream and K6H019 far downstream from the EWR site, so effectively records from these two gauges “bracket” historic peaks that can be expected at the site.

Table 12.7 K6KEUR-EWR8: Recommended flood events

Flood class (Peak in m³/s)	Flood requirements*	Months	Daily ave.	Duration (days)
PES and REC				
Class I (2 - 4)	4	May – November (September – December for fish)	4	5
Class II (10 - 20)	1	August/September (September/October for fish)	16	6
Class III (50 - 90)	1:3		63	7
Class IV (> 100)	1:5		69	8

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

The RDRM model distributes the high flow volumes across the wet period months according to the natural distribution. The months provided by specialists are therefore those in which floods are recommended, but there will be naturally-determined variations in the final EWR high flow time series results.

12.6 EWR RESULTS

The results are provided as an EWR table (**Table 12.8; Table 12.10**) and an EWR rule (**Table 12.9; Table 12.11**). Flow duration graphs are supplied as **Figure 12.2** and **12.3**. Detailed results are provided in the model generated report for each category in **Appendix D** for both low and total flows.

The low flow EWR rule table is used for building rules for EWR releases. The information on specific flood releases is provided in the EWR table. Note that these tables on its own cannot be used for dam or system operation but will feed into an integrated model to determine the operation of the system. Note that high flows (floods), if released from dams, will require hydrodynamic modelling to determine the actual releases to achieve the instantaneous peak at the EWR site.A summary of the results is provided in **Table 12.12**.

Table 12.8 K6KEUR-EWR8: EWR table for Instream PES: C EC

Month	Low flows (m³/s)			High flows	
	Drought (90%) (m³/s)	60% (m³/s)	50% (m³/s)	Daily average (m³/s)	Duration (days)
October	0.252	0.405	0.520	4	5
November	0.256	0.368	0.459		
December	0.146	0.279	0.355		
January	0.090	0.175	0.240		
February	0.074	0.137	0.170		
March	0.083	0.146	0.190		
April	0.091	0.162	0.210		
May	0.104	0.193	0.254	4	5

Month	Low flows (m^3/s)			High flows	
	Drought (90%) (m^3/s)	60% (m^3/s)	50% (m^3/s)	Daily average (m^3/s)	Duration (days)
June	0.111	0.213	0.276		
July	0.144	0.262	0.345		
August	0.171	0.316	0.432	4	5
September	0.190	0.370	0.520	4 16	5 6

Table 12.9 K6KEUR-EWR8: Low flow Assurance rules (m^3/s) Instream PES: C EC

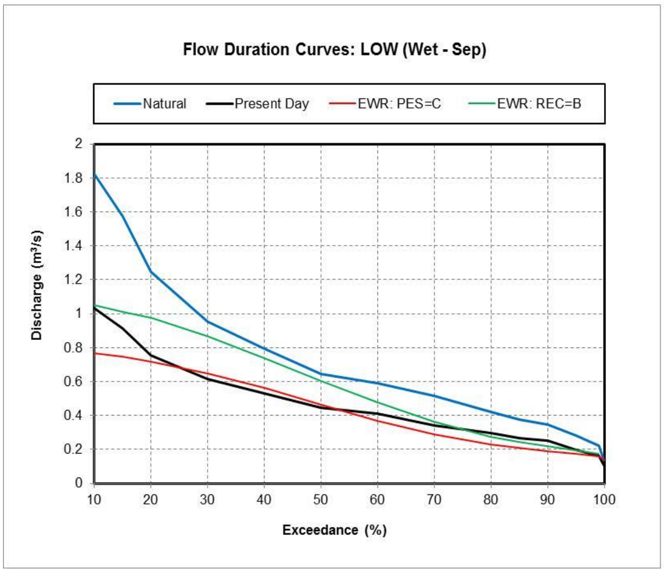
Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
October	0.692	0.678	0.640	0.565	0.520	0.405	0.316	0.281	0.252	0.221
November	0.671	0.630	0.588	0.538	0.459	0.368	0.294	0.262	0.256	0.256
December	0.557	0.498	0.425	0.385	0.355	0.279	0.211	0.172	0.146	0.101
January	0.440	0.393	0.314	0.276	0.240	0.175	0.124	0.108	0.090	0.052
February	0.368	0.331	0.272	0.217	0.170	0.137	0.110	0.088	0.074	0.059
March	0.339	0.331	0.285	0.250	0.190	0.146	0.117	0.099	0.083	0.064
April	0.417	0.335	0.282	0.243	0.210	0.162	0.122	0.107	0.091	0.070
May	0.567	0.451	0.331	0.283	0.254	0.193	0.142	0.115	0.104	0.086
June	0.582	0.477	0.396	0.331	0.276	0.213	0.158	0.127	0.111	0.104
July	0.671	0.511	0.451	0.401	0.345	0.262	0.206	0.167	0.144	0.113
August	0.955	0.719	0.580	0.502	0.432	0.316	0.252	0.213	0.171	0.146
September	0.767	0.716	0.646	0.561	0.464	0.370	0.289	0.231	0.190	0.160

Table 12.10 K6KEUR-EWR8: EWR table for Instream REC: B EC

Month	Low flows (m^3/s)			High flows	
	Drought (90%) (m^3/s)	60% (m^3/s)	50% (m^3/s)	Daily average (m^3/s)	Duration (days)
Oct	0.287	0.514	0.685	4	5
Nov	0.285	0.467	0.604		
Dec	0.166	0.356	0.467		
Jan	0.102	0.220	0.318		
Feb	0.083	0.170	0.227		
Mar	0.094	0.183	0.253		
Apr	0.103	0.204	0.279		
May	0.117	0.244	0.336	4	5
Jun	0.126	0.270	0.365		
Jul	0.164	0.334	0.453		
Aug	0.196	0.405	0.563	4	5
Sep	0.218	0.476	0.604	4 16	5 6

Table 12.11 K6KEUR-EWR8: Total Assurance rules (m^3/s) Instream REC: B EC

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.927	0.917	0.873	0.768	0.685	0.514	0.391	0.334	0.287	0.240
Nov	0.897	0.846	0.792	0.711	0.604	0.467	0.362	0.312	0.285	0.272
Dec	0.729	0.662	0.581	0.523	0.467	0.356	0.261	0.205	0.166	0.127
Jan	0.568	0.520	0.435	0.385	0.318	0.220	0.151	0.129	0.102	0.071
Feb	0.470	0.435	0.381	0.306	0.227	0.170	0.133	0.104	0.083	0.069
Mar	0.442	0.437	0.391	0.350	0.253	0.183	0.143	0.118	0.094	0.082
Apr	0.538	0.443	0.389	0.342	0.279	0.204	0.148	0.127	0.103	0.085
May	0.745	0.599	0.458	0.393	0.336	0.244	0.174	0.136	0.117	0.109
Jun	0.770	0.633	0.544	0.455	0.365	0.270	0.194	0.151	0.126	0.115
Jul	0.897	0.681	0.616	0.543	0.453	0.334	0.255	0.198	0.164	0.125
Aug	1.265	0.966	0.781	0.667	0.563	0.405	0.314	0.253	0.196	0.164
Sep	1.051	0.974	0.865	0.736	0.604	0.476	0.363	0.273	0.218	0.173



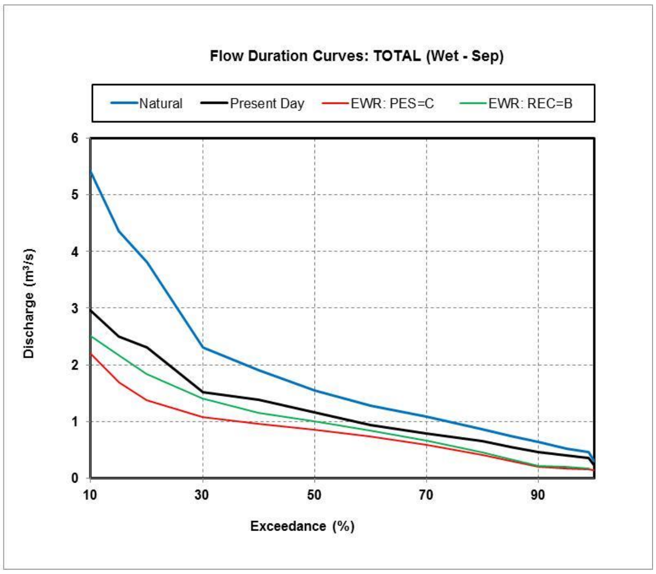
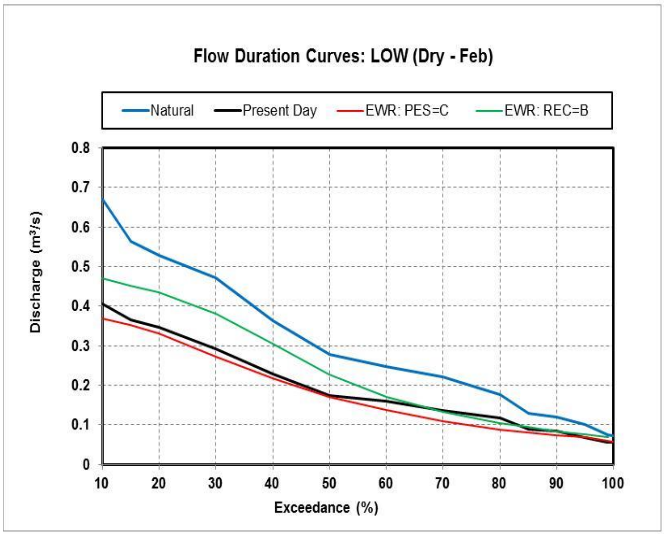


Figure 12.2 K6KEUR-EWR8: Flow duration graph for the dry season low flows (left), total flows (right)



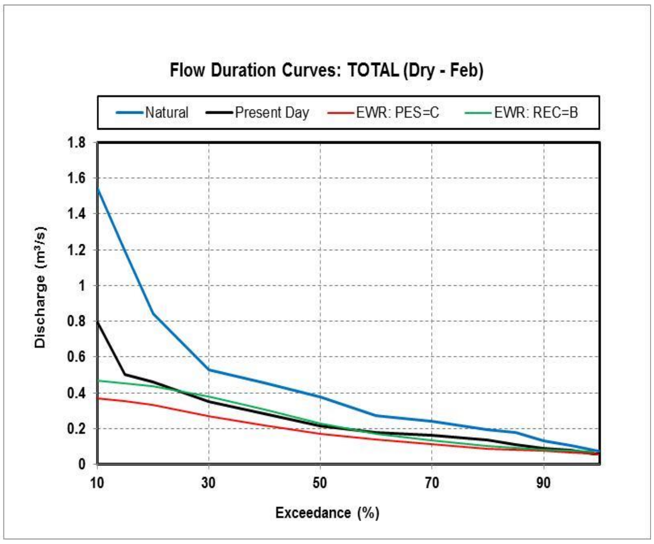


Figure 12.3 K6KEUR-EWR8: Flow duration graph for the wet season low flows (left), total flows (right)

Table 12.12 K6KEUR-EWR8: Summary of results as a percentage of the nMAR

EcoStatus	nMAR (MCM)	pMAR (MCM)	Low flows (MCM)	Low flows (%)	High flows (MCM)	High flows (%)	Total flows (MCM)	Total (%)
Instream PES: C	49.81	30.45	10.66	21.4	8.66	17.4	19.32	38.8
Instream REC: B			13.93	28.0	9.27	18.6	23.3	46.7

13 CONCLUSIONS AND RECOMMENDATIONS

13.1 ECOCLASSIFICATION

The EcoClassification results are summarised below in **Table 13.1**.

Table 13.1 EcoClassification results summary

<table>
<tr><th colspan="2">J1TOUW-EWR3: TOUWS RIVER</th></tr>
<tr><td>

EIS: HIGH
Highest scoring metrics in the EIS model were rare and endangered species (*P. asper*); refugia and critical habitat (deep pools for *P. asper*) and importance as migration route as there are no barriers downstream of the EWR site. Six endemic riparian plant species occur here and the site falls within the endangered Muscadel Riviere Vegetation Type. Important riparian migration corridor as the *A. karoo* thicket is distinct from the upland vegetation.

PES: B/C
▪ Reduced base flows and small floods due to farm dams and irrigation and impacts the wet season duration period.
▪ Deteriorated water quality (nutrients) due to agriculture.
▪ Bank modification and instability due to alien invasive vegetation and agricultural practices in the riparian zones.
▪ Alien vegetation species occur in the reach.

REC: B/C
The EIS was HIGH and the REC should be set to improve the PES. However there is uncertainty in what aspects need to improve as the impacts and the causes are not well understood and known. Currently there is insufficient hydrological data to recommend improved flows to achieve a REC of a B and verification of water use in the area and the re-evaluation of the hydrology and calibration with gauged data would be required. Also many of the vegetation cues were obscured by the big floods during Jan 2014 and biomonitoring of these impacts would be required to determine and confirm the extent of impact on the site.
</td><td>
<table>
<tr><th>Component</th><th>PES and REC</th></tr>
<tr><td>IHI Hydrology</td><td>B/C</td></tr>
<tr><td>Water quality</td><td>B/C</td></tr>
<tr><td>Geomorphology</td><td>B</td></tr>
<tr><td>Fish</td><td>C/D</td></tr>
<tr><td>Invertebrates</td><td>B/C</td></tr>
<tr><td>Instream</td><td>C</td></tr>
<tr><td>Riparian vegetation</td><td>B/C</td></tr>
<tr><td>EcoStatus</td><td>B/C</td></tr>
<tr><td>Instream IHI</td><td>C</td></tr>
<tr><td>Riparian IHI</td><td>C</td></tr>
<tr><td>EIS</td><td>HIGH</td></tr>
</table>
</td></tr>
</table>

J2GAMK-EWR4: GAMKA RIVER

EIS: HIGH
Highest scoring metrics in the EIS model were rare and endangered species (*P. asper*) and diversity of habitat types and features. Five endemic riparian species occur at the site; diversity of riparian/wetland habitat types and features are present and the distinct band of dense woody vegetation provides an effective corridor through a terrestrial landscape that is characterised by sparse, short vegetation and extreme topography.

PES: C/D
- Altered flow regime due to decreased base flows and flooding events and zero flows at times due to unseasonal and regular flood releases from the Gamkapoort Dam as well as the decreased large floods.
- Increased turbidity due to dam releases.
- Presence of alien vegetation species.
- Predation and competition from alien and non-indigenous fish species.

REC: C
The EIS was HIGH and the REC was therefore set to improve the PES by:
- Larger flood releases improving geomorphology.
- Improving nutrients although the source of the nutrients must first be identified.
- Increasing frequency of floods in the summer with less flow regulation (unseasonal floods improving riparian vegetation.
- Eradicating alien fish species which would be ideal, although this is unlikely. The improvements required for vegetation (previous bullet) is likely to improve the fish as well as the macroinvertebrate community.

Component	PES	REC
IHI Hydrology	C/D	
Geomorphology	D	C
Water quality	B/C	B
Fish	C/D	C
Invertebrates	C/D	B/C
Instream	C/D	C
Riparian vegetation	D	C
EcoStatus	C/D	C
Instream IHI	C	
Riparian IHI	C/D	
EIS	HIGH	

J1BUFF-EWR5: BUFFELS RIVER

EIS: MODERATE
Highest scoring metrics in the EIS model were rare and endangered species (*P. asper*); refugia and critical habitat (deep pools for *P. asper*). Five endemic riparian species occur at the site and there is a diversity of riparian/wetland habitat types and features. An effective riparian/wetland migration corridor is provided by dense woody vegetation (mostly *A. karoo*) but is also diverse due to the presence of pools dominated by grass and sedge that are utilised by waterfowl.

PES: C
- Decreased baseflows as well as reduced flood frequencies due to Floriskraal Dam. The seasonal distribution of baseflow is greatly affected with the period Mar to Sep showing a significant decrease in flows from natural.
- Deteriorated water quality and increased water temperatures.
- Increased woody vegetation encroachment.

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

Component	PES and REC
IHI Hydrology	D
Geomorphology	D
Water quality	C
Fish	B/C
Invertebrates	C
Instream	C
Riparian vegetation	D
EcoStatus	C
Instream IHI	D
Riparian IHI	D
EIS	MODERATE

J4GOUR-EWR6: GOURITZ RIVER	
EIS: MODERATE Highest scoring metrics in the EIS model were rare and endangered species (*P. asper*); important migration corridor as it occurs in a larger catchment that fish could move through and there are no barriers downstream of the EWR site. Five endemic riparian species occur at the site **PES: C** ▪ Baseflows as well as a decrease in volume, frequency and distribution of moderate-sized floods have occurred due to irrigation, groundwater abstraction, grazing, large dams and domestic water use. ▪ These activities have resulted in deteriorated water quality (high salinity and elevated nutrients). ▪ Some invasion by alien species and overgrazing in the upper and Macro Channel Bank zones is present. ▪ Alien fish species also occur in the reach. **REC: C** The EIS was MODERATE and the REC was therefore set to maintain the PES.	

Component	PES and REC
IHI Hydrology	C
Geomorphology	B
Water quality	B/C
Fish	D
Invertebrates	C
Instream	C
Riparian vegetation	B/C
EcoStatus	C
Instream IHI	C/D
Riparian IHI	C
EIS	**MODERATE**

K6KEUR-EWR8: KEURBOOMS RIVER	
EIS: HIGH Highest scoring metrics in the EIS model were rare and endangered species (*P. asper*); unique species (*Pseudobarbus cf. tenuis*); species intolerant to physico-chemical changes and important migration route as the site is located in the lower part of the system and the reach is important for eel migration. Three rare and endangered riparian/wetland species were present as well as two endemic species. **PES: C** ▪ Reduced baseflows, flood frequency. ▪ Deteriorated water quality during the dry season due to abstraction (and return flows) for agriculture. ▪ Flow reduction due to extensive forestry plantations in the catchment. ▪ High occurrence of alien plantation species that encroach on the natural habitat as well as vegetation clearing. **REC: B/C** The EIS was HIGH and the REC was therefore set to improve the PES by: ▪ Removal of alien vegetation. ▪ Improvement in baseflows.	

Component	PES	REC
IHI Hydrology	B	
Water quality	B	B
Geomorphology	B/C	B
Fish	C	B
Invertebrates	C	B
Instream	C	B
Riparian vegetation	C/D	B/C
EcoStatus	C	B/C
Instream IHI	C	
Riparian IHI	C/D	
EIS	**HIGH**	

The confidence in the EcoClassification process is provided below (**Table 13.2**) and was based on data and information availability and EcoClassification where:

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

The confidence score is based on a scale of 0 – 5 and colour coded where:
0 – 1.9: Low 2 – 3.4: Moderate 3.5 – 5: High

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

Table 13.2 Confidence in EcoClassification

Component	J1TOUW-EWR3	J2GAMK-EWR4	J1BUFF-EWR5	J4GOUR-EWR6	K6KEUR-EWR8
Data and information availability					
Hydrology	2	1.5	3	2	3
Water Quality	2.5	3	2.5	3	3
Geomorphology	3.5	3	3.5	3.5	3.5
IHI	2.5	3	2.9	2.5	3
Fish	2	2	2	3	2.5
Macroinvertebrates	3	3	3	3	3
Vegetation	3.5	3.5	3.5	3.5	3.5
Average	**2.7**	**2.7**	**2.9**	**2.9**	**3.1**
Median	**2.5**	**3.0**	**3.0**	**3.0**	**3.0**
EcoClassification					
Hydrology	2.8	2.7	2.9	2.6	3.4
Water Quality	2.5	3	3	3	3
Geomorphology	3	3	3	2.5	2.5
IHI	2.9	3	3.3	3	3.2
Fish	1.5	2.5	2.5	2	2.5
Macroinvertebrates	2.5	2.5	2	2.5	2.5
Vegetation	3.2	3.8	3.4	3.3	3.1
Average	**2.6**	**2.9**	**2.9**	**2.7**	**2.9**
Median	**2.8**	**3.0**	**3.0**	**2.6**	**3.0**

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

13.2 ECOLOGICAL WATER REQUIREMENTS

The final flow requirements are expressed as a percentage of the nMAR in **Table 13.3**.

Table 13.3 Summary of results as a percentage of the nMAR

Site	EcoStatus	nMAR (MCM)	pMAR (MCM)	Low flows (MCM)	Low flows (%)	High flows (MCM)	High flows (%)	Total flows (MCM)	Total
J1TOUW-EWR3	Instream: C	45.20	22.26	1.15	2.6	11.54	25.6	12.69	28.2
J2GAMK-EWR4	PES: C/D	85.54	61.69	3.94	4.6	17.44	20.4	21.38	25.0

Site	EcoStatus	nMAR (MCM)	pMAR (MCM)	Low flows (MCM)	Low flows (%)	High flows (MCM)	High flows (%)	Total flows (MCM)	Total
J1BUFF-EWR5	PES; REC: C	29.31	18.67	1.37	4.7	6.85	23.3	8.22	28.0
J4GOUR-EWR6	PES; REC: C	543.52	310.35	27.12	5.0	102.47	18.8	129.59	23.8
K6KEUR-EWR8	Instream PES: C	49.81	30.45	10.66	21.4	8.66	17.4	19.32	38.8
	Instream REC: B	49.81	30.45	13.93	28.0	9.27	18.6	23.3	46.7

13.2.1 Confidence in low flows

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

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

Table 13.4 provides the confidence in the low flow requirements of the biotic components (fish and macroinvertebrates). The final average confidence is representative of these requirements.

Table 13.4 Low flow confidence ratings for biotic responses

EWR site	Fish	Macroinvertebrates	Comment	Overall confidence
J1TOUW-EWR3	1.5	1.5	**Fish:** No recent historical fish data available from river reach, only one of the potentially five reference fish species were captured (namely BANO*)*, probably due to non-flow related factors (e.g. siltation, vegetation removal). However, only non-sensitive species naturally present in this reach. The allocated low flows considered adequate to maintain fish in the specific EC.	**1.5**
			Macroinvertebrates: The low flows recommended will not achieve the EC, and there is a reliance on the recommended high flows materializing in the early to mid summer months.	
J2GAMK-EWR4	2.5	2.5	**Fish:** Semi-rheophilic species captured used as indicator species, but little historical fish data from river reach concerned. Non flow-related impacts influence the PES (e.g. alien fish) so lowered confidence in fish response to recommended flows.	**2.5**
			Macroinvertebrates: The lows flows recommended will provide adequate conditions to sustain the relatively resilient community (at low abundances). However there is a reliance on the delivery of high flows, particularly in early summer, to optimize this habitat for the various life history requirements of the taxa present.	
J1BUFF-EWR5	3	1.5	**Fish:** Good historical data and all four reference species were captured during survey. Only moderate knowledge of life history requirements of important indicator species (PASP) available, reducing confidence. Only hardy species present and low flows allocated should maintain fish in specific ECs.	**2.3**

EWR site	Fish	Macroinvertebrates	Comment	Overall confidence
			Macroinvertebrates: The wet season low flows are unlikely to achieve the EC and there is a reliance on the delivery of high flows during early summer to sustain the flow-dependent taxa in particular.	
J4GOUR-EWR6	2	3.4	**Fish:** Good historical fish data available, but non flow-related impacts (alien fish, siltation) have large influence on PES. None of five possible reference species were captured during present study. Thus low confidence to fish response to recommended flows, although considered adequate to maintain fish in specific EC in terms of available habitats for life history requirements.	**2.7**
			Macroinvertebrates: The recommended flows provide adequate flow habitat in both dry and wet seasons to support the life history stages of the invertebrate taxa, and will maintain the relatively resilient community (with few FDIs) in a C Category.	
K6KEUR-EWR8	4	3.4	**Fish:** Good historical data and important reference *species* (PASP) and eels (AMOS) captured during this study. The life-history requirements of these indicator species are relatively well-known. This gave a high confidence to recommended flows resulting in the specific ECs.	**3.7**
			Macroinvertebrates: The recommended flows for the C PES will be adequate to supply the current community with their life-history requirements through dry and wet seasons. The flows recommended for the B REC will create conditions that may enable more sensitive FDIs to colonise the site successfully, thereby raising the EC.	

13.2.2 Confidence in high flows

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

To determine the confidence, one should consider:

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

The high flow confidence (**Table 13.5**) represents an average of the riparian vegetation and geomorphology confidence as these two components determine the flood requirements.

Table 13.5 Confidence in recommended high flows

EWR site	Fish	Macroinvertebrates	Riparian vegetation	Geom	Comment	Overall confidence
J1TOUW-EWR3	2	1.5	4	3.5	**Fish:** The flows allocated should cater for all the life history stages of all fish species present, including the semi-rheophilic species. The low confidence in the fish distribution data from this river reach and non flow-related impacts on fish, however, have to be considered. **Macroinvertebrates:** The recommended high early summer flows are only possible if upstream water allocations are revised, which is a complex management task. However, if these high flows are delivered to supplement the low flows, the EC is likely to be achieved. **Riparian vegetation:** A rated hydraulic cross-section existed for the site and there were sufficient riparian vegetation indicators that were surveyed in order to determine flood requirements. Riparian vegetation zonation was clear along the upper zone and enabled higher accuracy for determining flood levels. **Geomorphology:** Large floods to keep vegetation encroachment in check have been requested. The hydraulics of the site is reliable and these large floods should be able to achieve this function.	**2.8**
J2GAMK-EWR4	3	1.5	4	2	**Fish:** Recommended high flows in large system will create suitable habitats required for all life-history stages of hardy indigenous fish species present. Response to high flows by alien fish (a non-flow related impact) and this impact on the reference species is largely unknown and lowers confidence levels. **Macroinvertebrates:** Recommended high flows provide cues for life cycle changes (e.g. breeding, emergence) in spring and summer. Floods scouring the bed and clear interstices between rocks (make habitat available), clear vegetation (which has a tendency to encroach in this channel), and move the cobbles in the limited but critical cobble habitat areas. **Riparian vegetation:** A rated hydraulic cross section existed for the site and there were sufficient riparian vegetation indicators that were surveyed in order to determine flood requirements. Riparian vegetation zonation was clear in all sub-zones and enabled higher accuracy for determining flood levels, although these were confounded slightly by upstream inputs and seepage from the tributary. **Geomorphology:** The flood flows set for the Gamka are of low confidence as the channel has now changed and it is uncertain if the requested floods will be able to achieve all the expected functions. Some floods will however at least be able to keep channel narrowing and vegetation encroachment in check.	**2.6**
J1BUFF-EWR5	3.5	3.4	2	3	**Fish:** The high flows and resultant instream habitats created should cater for all life history stages of all four indigenous fish species present, including the more sensitive semi-rheophilic PASP. **Macroinvertebrates:** As these flows can be implemented through operational rules for the upstream Floriskraal Dam, confidence is moderate that they will be delivered. Under this scenario, the achievement of an EC of a C will be possible.	**3.0**

EWR site	Fish	Macroinvertebrates	Riparian vegetation	Geom	Comment	Overall confidence
					Riparian vegetation: There is low confidence that requested floods will achieve the desired EC. Although a rated hydraulic cross-section existed for the site, it was a difficult site to survey vegetation due to the density and height of *A. karoo*. Line of sight was limited as were riparian vegetation indicators along the actual cross-section.	
					Geomorphology: Large floods to keep vegetation encroachment in check have been requested. The hydraulics of the site is of moderate confidence, but these large floods should be able to achieve this function.	
J4GOUR-EWR6	2.5	3.4	3	4	**Fish:** The high flows required for all life history stages of all five reference species potentially present will be catered for, allowing the designated EC to be obtained. However, the unknown response of non flow-related impacts (alien fish, siltation) reduces the confidence levels	**3.2**
					Macroinvertebrates: The high flows and floods requested will suffice to clean, scour and 'reset' the cobble habitat and provide adequate flow depth and diverse and extensive hydraulic habitat for the invertebrate community, including the (limited) marginal vegetation. The EC will be maintained.	
					Riparian vegetation: There is moderate confidence that requested floods will achieve the desired EC. Although a rated hydraulic cross-section existed for the site, it was dominated by cobble and may have been influenced by the upstream road crossing. There was a distinct tree line however which provided good riparian vegetation indicators for the upper zone and higher floods. Riparian vegetation along the marginal zone was less representative however, making it more difficult to assess smaller floods.	
					Geomorphology: Floods to flush the site and maintain the channel have been set. The hydraulics of the site is reliable and these floods should be able to achieve the anticipated functions.	
K6KEUR-EWR8	4.5	3.4	3	3.5	**Fish:** Life history requirements of two indicator fish species found (PASP) and eels (AMOS) are well-known and few non-flow related impact present in reach. High flows allocated should readily meet requirements of these two species.	**3.6**
					Macroinvertebrates: If delivered as recommended (preference for early and mid summer) these flows will clean habitat, provide cues for the invertebrate taxa to hatch, breed and lay eggs, and result in plentiful high quality habitat. The community will thus be sustained in a C Category.	
					Riparian vegetation: There is moderate confidence that requested floods will achieve the desired EC. Although a rated hydraulic cross-section existed for the site, it was dominated by bare cobble and riparian indicators were sparse to absent. Assumptions had to be made for small floods although distinct cohorts of alien Wattle existed and were used to determine the magnitude and frequency of larger floods.	
					Geomorphology: Floods to flush the site and maintain the channel have been set. The hydraulics of the site is reliable and these floods should be able to achieve the anticipated functions.	

13.2.3 Confidence in hydrology

Note: If natural hydrology was used to guide requirements, then that confidence will carry a higher weight than normal. Hydrology confidence is provided from the perspective of its usefulness to the EWR assessment. This will be different than the confidence in the hydrology for water resources management and planning. The scale of requirements is very different, and therefore high confidence hydrology for water resource management purposes often does not provide sufficient confidence for EWR assessment. The hydrology confidence is summarised in **Table 13.6**.

Table 13.6 Confidence in hydrology

EWR site	Natural hydrology	Present hydrology	Comment	Confidence: Median	Confidence: Average
J1TOUW-EWR3	2	2	J1H018 upstream of (upstream of EWR site) with 32 years (1982 to present) of data. However the Water Resources of South Africa 2012 study (WR2012) did not use this gauge for calibration which is the reason why the confidence is low.	2	2
J2GAMK-EWR4	1.5	1.5	J2H016 which measure river releases from Gamkapoort Dam (May 1964 to date). The WR2012 results produced double the volumes of the WR2005-study. The nMAR for the inflow into the dam was increased from 2.2 million m^3/a (WR2005) to 4.3 million m^3/a. There is also station J2H016 downstream of the dam that measures the current flow and is good for measuring low flows and the spills are measured from the dam's spillway. The confidence in the flows at the EWR site for the natural flows are therefore low at 1.5 for both the natural PD.	1.5	1.5
J1BUFF-EWR5	3.5	2.5	No gauge present as the EWR site is downstream of Floriskraal Dam. J1H028 measures the river but the site also includes 97% of flow from J11G. The nMar from J11G is only 2 million m^2/a and the pMAR at the EWR site (including J11G) is 17.5 million m^2/a which means approximately 10% of the flow is not measured by J1H028. The WR2005 calibration against the inflow of J1R003 (Floriskraal) looks reasonable. The contribution of J11G is small (approximately 10% of the MAR). The reason for it being highlighted was to draw attention to the fact that the gauge is not at the EWR site. The flow results from WR2005 and WR2012 are similar. The confidence of the WR2012 in the flow record of J1R003 is also high and therefore there is moderate confidence for both the natural and PD.	3	3
J4GOUR-EWR6	2	2	J4H002 but with many gaps. Data for the period 1990 to present was used. Gauge data starts from 1964 to present with 22 years of usable data (Oct 1999 to present). The WR2012 study classified the station J4H002 as moderate and therefore the confidence is moderate.	2	2
J6KEUR-EWR8	3	3	No reliable gauge present. K6H001 is far upstream and K6H019 far downstream from the EWR site. Data was scaled – the flows are generally higher in the upper reaches of the catchment with a higher MAP. The WR2012 regarded the upper station value as moderate and the other station as high.	3	3

13.2.4 Overall confidence in EWR results

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

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

The overall confidence in the EWR results is provided in **Table 13.7**.

Table 13.7 Overall confidence in EWR results

Site	Hydrology	Biological responses Low flows	Hydraulic: Low Flows	OVERALL: LOW FLOWS	Comment	Biophysical responses: High flows	Hydraulics: High Flows	OVERALL: HIGH FLOWS	Comment
J1TOUW-EWR3	2	1.5	2.5	**1.5**	No recent historical fish data available from river reach and only non-sensitive species naturally present in this reach. For macroinvertebrates the low flows recommended will not achieve the EC, and there is a reliance on the recommended high flows materializing in the early to mid summer months	2.8	3	**2.8**	There is low confidence in the fish distribution data from this river reach and there are non flow-related impacts on fish that have to be considered. The recommended high early summer flows for macroinvertebrates are only possible if upstream water allocations are revised, which is a complex management task. However, if these high flows are delivered to supplement the low flows, the EC is likely to be achieved.

Site	Hydrology	Biological responses Low flows	Hydraulic: Low Flows	OVERALL: LOW FLOWS	Comment	Biophysical responses: High flows	Hydraulics: High Flows	OVERALL: HIGH FLOWS	Comment
J2GAMK-EWR4	1.5	2.5	3	**2.5**	Little historical fish data available and non flow-related impacts influence the PES (e.g. alien fish). For macroinvertebrates there is a reliance on the delivery of high flows, particularly in early summer, to optimize this habitat for the various life history requirements of the taxa present.	2.6	4	**2.6**	The flood flows set for the Gamka are of low confidence as the channel has now changed and it is uncertain if the requested floods will be able to achieve all the expected functions. Reliance on high flows to supplement the low flows to achieve the invert EC.
J1BUFF-EWR5	3	2.3	2	**2**	Wet and dry seasons below measured flow range.	3	2.5	**2.5**	High flows above measured flow range.
J4GOUR-EWR6	2	2.7	2.5	**2.5**	All seasons below measured flow range; two channels at medium range flows.	3.2	4	**3.2**	The unknown response of non flow-related impacts (alien fish, siltation) reduces the confidence levels. Although a rated hydraulic cross-section existed for the site, it was dominated by cobble and may have been influenced by the upstream road crossing. Riparian vegetation along the marginal zone was less representative, making it more difficult to assess smaller floods.
K6KEUR-EWR8	3	3.7	3	**3**	Wet season largely within measured flow range; dry season below measured flow range.	3.6	3	**3**	High flows above measured flow range.

13.3 RECOMMENDATIONS

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

The confidence for all the EWR parameters (**Table 13.8**) is mostly Moderate. However, low confidence dominates the biotic responses to low flow parameters for J1TOUW-EWR3 due to non-sensitive fish species naturally present in this reach and recommended low flows do not achieve the EC for macroinvertebrates resuting in a reliance on the recommended high flows materializing in the early to mid summer months.

Confidence in the hydraulic modelling results overrides the confidence in the biophysical responses and EWR determination except at J1TOUW-EWR3. The confidence is generally Moderate for all the EWR sites with high confidence in the high flow determination for J2GAMK-EWR4 and J4GOUR-EWR6. The lowest confidence evaluation is at J1BUFF-EWR5 and this is because all measured flow data used for calibrating the hydraulic model was higher than the low flow EWR determination. Further work to improve the hydraulics would require additional measured calibration at very low flows.

The most effective way of improving confidence is linked to monitoring the ecological status of the river and, if required, improving the hydraulics for low flows at selected sites as part of the monitoring programme. However this will only be successful if good reliable hydrological measurements are available. No specific studies to improve any confidences other than monitoring are therefore recommended.

Table 13.8 Confidence summary

EWR site	J1TOUW-EWR3	J2GAMK-EWR4	J1BUFF-EWR5	J4GOUR-EWR6	K6KEUR-EWR8
Data availability	2.7	2.7	2.9	2.9	3.1
Eco-Classification	2.6	2.9	2.9	2.7	2.9
Low flow EWR (biotic responses)	1.5	2.5	2.3	2.7	3.7
High flow EWR (biophysical responses)	2.8	2.6	3.0	3.2	3.6
Hydrology	2.0	1.5	3.0	2.0	3.0
Hydraulics (low)	2.5	3.0	2.0	2.5	3.0
Hydraulics (high)	3.0	4.0	2.5	4.0	3.0
Overall low flow EWR confidence	2.3	2.9	2.4	2.6	3.2
Overall high flow EWR confidence	2.9	3.3	2.8	3.6	3.3

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APPENDIX A: WATER QUALITY PRESENT STATE ASSESSMENT

A.1 INTRODUCTION

This assessment is related specifically to the Intermediate river sites in the Gouritz portion (previous WMA 16) of the Breede-Gouritz WMA 8, i.e. Touws (J1TOUW-EWR3; secondary catchment J1), Gamka (J2GAMK-EWR4; secondary catchment J2), Buffels (J1BUFF-EWR5; secondary catchment J1), Gouritz (J4GOUR-EWR6; secondary catchment J4), and Keurbooms rivers (K6KEUR-EWR8; secondary catchment K6). **Table 1.1** in the main report shows the details regarding these EWR sites (DWA, 2014).

A.2 METHODS AND APPROACH

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

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

Water quality data were utilized in the following way: Nutrients, pH, chlorophyll-a, turbidity, DO, temperature and Electrical Conductivity data were compared to values in DWAF (2008), while all ionic data (i.e. macro-ions and salt ions) were compared to benchmark tables in DWAF (2008), and/or the Target Water Quality Range (TWQR) and Chronic Effects Value (CEV) guidelines of the South African aquatic ecosystem guidelines (DWAF, 1996a) where required. Salt ion data were compared to guidelines only, while parameters found in DWAF (2008) could be compared to Reference Condition (RC) values. Available guidelines were used for comparative purposes, e.g. Irrigation guidelines (DWAF, 1996b). Diatom data were utilized as provided by the diatomologist for the study (**Appendix B**). On-site water quality data, measured on site in January and June 2014 (**Table A.1**), were used where relevant.

Table A.1 Water quality variables measured in on site (January/February and June 2014)

River	EWR Site	pH		Electrical conductivity (mS/m)		Temperature (°C)		Dissolved Oxygen (mg/L)	
		Jan/Feb 14	Jun 14	Jan/Feb 14	Jun 14	Jan/Feb 14	Jun 14	Jan/Feb 14	Jun 14
Touws	J1TOUW-EWR3	8.16; 8.12	NS[1]	89.3; 162.0	NS	29.9; 27.4	NS	8.47; 9.55	NS
Gamka	J2GAMK-EWR4	7.35	NS	73.9	NS	23.4	NS	7.91	NS

River	EWR Site	pH		Electrical conductivity (mS/m)		Temperature (°C)		Dissolved Oxygen (mg/L)	
		Jan/Feb 14	Jun 14	Jan/Feb 14	Jun 14	Jan/Feb 14	Jun 14	Jan/Feb 14	Jun 14
Buffels	J1BUFF-EWR5	NS	NS	NS	NS	NS	NS	NS	NS
Gouritz	J4GOUR-EWR6	8.3	NS	43.0; 45.0	NS	30.4; 29.0	NS	8.94	NS
Keurbooms	K6KEUR-EWR8	6.28	6.86	25.5	23.8	28.3	14.3	8.43	11.38

1 Not sampled.

Setting the Reference Condition

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

A.2 WATER QUALITY OVERVIEW: WMA16

The 2011 Planning Level Review of Water Quality in South Africa (DWA, 2011) identified the major water quality issues in the country, as well as which WMAs in which they are prevalent. The following issues were identified for WMA16: Microbial contamination, salinisation and poor quality stormwater run-off and dry weather flow from dense settlements, i.e. conditions associated with urban rivers. Issues such as eutrophication, metal and toxicant contamination were not considered problematic in WMA16, although high phosphate levels were recorded for large parts of the WMA due to agricultural return flows and discharges from wastewater treatment works. **Table A.1** from DWA (2011) summarises the water quality issues across WMA16.

Elevated salinities in the Gouritz River and its major tributaries occur naturally over the inland catchments of the Great and Little Karoo due to geology and high natural evaporation rates (DWA, 2011).

A summary of primary land use activities of the management areas of WMA16, which impact on or determine water quality state, are shown below (RHP, 2007):

- Goukou/Duiwenhoks: Irrigated agriculture (lucerne and pasture)
- Gouritz: Irrigated agriculture (lucerne and pasture), livestock (ostriches and sheep)
- Garden Route: Irrigated agriculture, afforestation (pine), urban

Table A.1 Water quality issues across WMA16 (from DWA, 2011)

Water quality issue	Driver	Effect
Salinisation	Natural geology. High evaporation.	Water unsuitable for irrigation agriculture. Corrosion of appliances and equipment. Alteration of the taste of domestic water.
Urban impacts on water quality	Densely populated urban areas on coast, urban runoff, treated wastewater not meeting standards and runoff from informal settlements.	Poor bacterial quality. Impacts on downstream users. Human health risks. Low dissolved oxygen and ecosystem impacts.
Microbial and organics contamination	Vandalism of sewage reticulation system and pumping infrastructure. Sewage spills into receiving streams e.g. Oudtshoorn.	Poor bacterial quality. Impacts on downstream users. Human health risks. Low dissolved oxygen and ecosystem impacts.
Wood processing waste	Disposal of wood processing waste in the coastal catchment. Some saw mill operators are without permits.	Leachate with high organic acids and COD[1]. Low dissolved oxygen and ecosystem impacts.

1 Chemical Oxygen Demand

A.3 WATER QUALITY OVERVIEW: WMA16

A.3.1 Secondary catchment: J1

Two EWR sites are located in J1, i.e. J1TOUW-EWR3 on the Touws River and J1BUFF-EWR5 on the Buffels River and described in the following sections. Water quality state of the Touws River has been described as Good, while that around Laingsburg on the Buffels River is Fair (RHP, 2007). The main land-use and main towns in the area (taken from RHP, 2007) are summarised below. State of Waste Water Treatment Works (WWTW) is taken from DWA (2012), i.e. the Green Drop (GD) Report for the Western Cape.

Management area	Groot
Main land-use	Dryland and irrigated agriculture (vineyards, fruit, lucerne), livestock (sheep), and conservation areas.
Main town	Touwsrivier, Laingsburg, Matjiesfontein, Ladismith, Vanwyksdorp.
Risk rating of WWTW (high – critical only)	Laingsburg WWTW: High risk rating (poor effluent quality).

A.3.2 Secondary catchment: J2

According to the RHP (2007) the water quality of the Gamka, Dwyka, Huis and Nels rivers is Good.

See table below for main land-use and main towns in the area (taken from RHP, 2007). State of WWTW is taken from DWA (2012), i.e. the GD Report for the Western Cape.

Management area	Gamka
Main land-use	Irrigated agriculture (vineyards, fruit, lucerne, and pastures), livestock (ostriches, sheep), and conservation areas.
Main town	Beaufort West, Merweville, Leeu-Gamka, Prince Albert and Prince Albert Road, Calitzdorp.
Risk rating of WWTW (high – critical only)	Leeu-Gamka WWTW: High risk rating (poor effluent quality).

A.3.3 Secondary catchment: J3

Nutrient enrichment and eutrophication is seen in the Olifants River downstream of Oudtshoorn. There are also impacts related to a number of tanneries in the Oudtshoorn area. This area also experiences impacts on the microbial quality of receiving rivers due to run-off from informal settlements and poorly-serviced housing areas (DWA, 2011). The water quality of the lower Olifants River is described by the RHP (2007) as Fair, with that of the Grobbelaars River tributary being Good.

See table below for main land-use and main towns in the area (taken from RHP, 2007). State of WWTW is taken from DWA (2012), i.e. the GD Report for the Western Cape.

Management area	Olifants
Main land-use	Dryland and irrigated agriculture (lucerne, pastures), livestock (ostriches, sheep), conservation areas.
Main town	Oudtshoorn, Uniondale, De Rust, Dysselsdorp, Klaarstroom.
Risk rating of WWTW (high – critical only)	Uniondale WWTW: Critical risk rating (no monitoring; potential impact on the Holdrif. River just upstream of its confluence with the Kammanassie River). Outeniqua WWTW: Moderate risk rating (effluent quality). Dysselsdorp WWTW: Moderate risk rating (effluent quality).

A.3.4 Secondary catchment: J4

The water quality of the Gouritz River is characterized by elevated salt concentrations, with salinity increasing down the system due to geology (natural source), high evaporation rates and agricultural impacts. Increases in ammonia and nitrates were also noted (DWA, 2011).

See table below for main land-use and main towns in the area (taken from RHP, 2007). State of WWTW is taken from DWA (2012), i.e. the GD Report for the Western Cape.

Management area	Gouritz
Main land-use	Dryland and irrigated agriculture (lucerne, pastures), and livestock (cattle, sheep).
Main town	Herbertsdale, Albertinia, Gouritzmond.
Risk rating of WWTW (high – critical only)	Albertina WWTW: High risk rating (no monitoring).

The upper reaches of the Gouritz River in the Great Karoo are mostly in a Good ecological state, while lower reaches are vulnerable to agricultural and urban development and are therefore in a Fair to Poor ecological condition (RHP, 2007). Also note the illegal landfill at Albertina, which most probably impacts on groundwater and possible also surface water (Umvoto, 2011; cited by Grobler, Exigo, May 2014).

A.3.5 Secondary catchment: K6

DWA (2011) notes sand mining activities in the K catchment, particularly at Wittedrift near Plettenberg Bay, i.e. on the **Bitou River** system. Water quality of the upper Bitou is described as Good, with conditions deteriorating to Fair in the lower reaches (RHP, 2007).

According to the RHP (2007), water quality state of the upper and middle Keurbooms River is Fair, with an improvement toward the lower reaches.

A.4 RESULTS

A.4.1 J1TOUW-EWR3

J1TOUW-EWR3 on the Touws River is downstream of the confluence with the Dorings and upstream of the Brand/Touws and Touws/Groot confluence, and is therefore near the end of the Touws River system.

Data for the assessment was sourced from the gauging weir upstream of the EWR site, i.e. J1H018Q01 on the Touws River (see **Figure A.1**). The data records span from 1982 to 2014 (n = 128), so only used for the present state assessment.

- RC was represented by the specialist assessment as A Category benchmark tables in DWAF (2008) could not be used for the RC due to the high geology-based salinities in the area.
- PES: DWS gauging weir J1H018Q01 (2000 – 2014; n = 128).

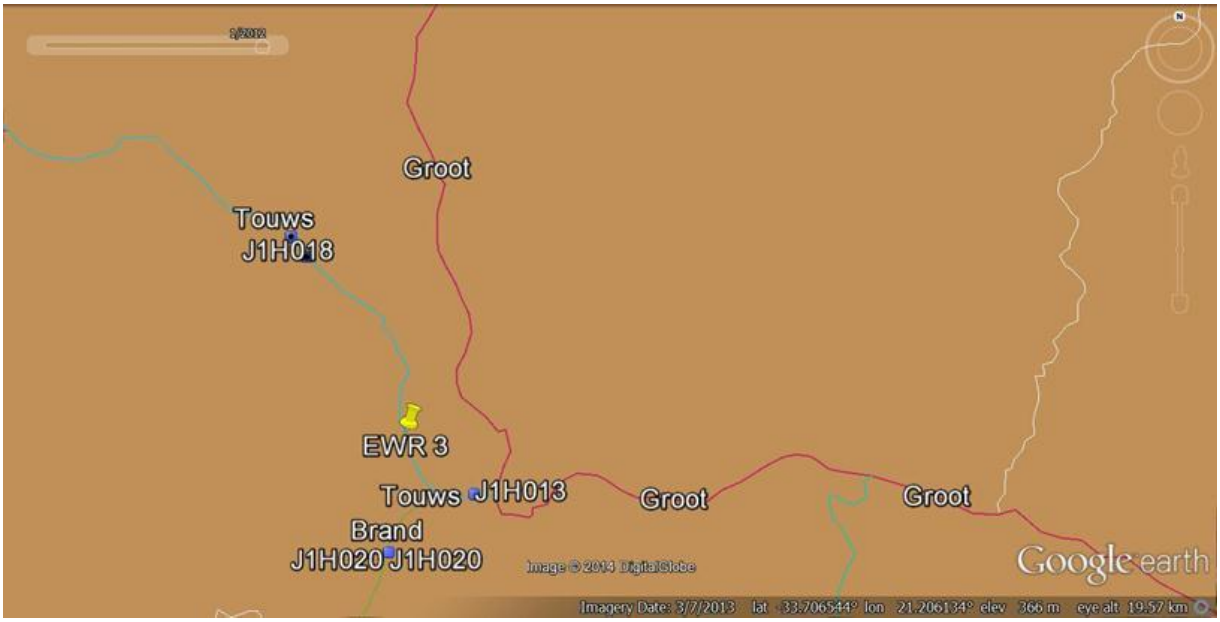

Figure A.1 J1TOUW-EWR3 on the Touws River in relation to monitoring point

Notes from surveys

- All large trees were removed by January 2014 flood.
- Important yellowfish area (*pers. comm.*; van den Heever, Riverside farm), but not indigenous to the system.
- January 2014: Clear shallow water. Little embeddedness or algal growth on substrate (cobble and gravel). High abundance of small fish (fry).
- February 2014: Flows much lower than the January 2014 survey.

The very high Electrical Conductivity levels (i.e. a 95th percentile PES value of 1 181.8 mS/m), are the major parameter of concern at this site, however, the geology of the region also results in high background salinity levels in the water. Some nutrient elevations are evident, which is expected from farming activities in the area. Main land uses, however, are grazing with some dryland agriculture and minimal irrigation. Diatom data (n = 4, January – July 2014) indicates high nutrient levels during January – April, which seem to decrease during July. Organic pollution levels generally fluctuate and reached unacceptable levels. Elevated water temperatures occur at times when water levels are low and water levels generally fluctuate. Diatom valve deformities were noted during April and July 2014 suggesting that metal toxicity impacts the reach. The overall diatom category for the reach was set at a D, with an average Specific Pollution sensitivity Index (SPI) of 8.6.

Table A.2 presents the water quality assessment for the Touws River at J1TOUW-EWR3.

Table A.2 Water quality present state assessment for J1TOUW-EWR3

Water Quality Constituents	PES Value	Category/Comment
Inorganic salt ions (mg/l)		
Sulphate as SO_4	-	-
Sodium as Na	2 016.9	All guidelines exceeded due to high saline geology of

Water Quality Constituents	PES Value	Category/Comment
Magnesium as Mg	370.1	the area. It is assumed that some increase in salinity may be expected due to irrigation return flows. No large urban centres are situated in this area.
Calcium as Ca	258.2	
Chloride as Cl	3 494.6	
Potassium as K	37.06	
Electrical conductivity (mS/m)		
	1181.8	See comment above.
Nutrients (mg/l)		
SRP	0.033	D
TIN	0.079	A
Physical Variables		
pH (5th + 95th %ile)	7.6 and 8.6	B
Temperature (ºC)	-	B. Impacts expected at low flows.
Dissolved oxygen (mg/L)	-	B. Impacts expected at low flows, although on-site data still shows high levels.
Turbidity (NTU)	-	B. Changes in turbidity appear to be largely related to natural with minor man-made modifications.
Response variables		
Chl-*a*: phytoplankton (ug/L)	-	-
Macroinvertebrate score (MIRAI)	74.0%	C
Diatoms	8.6 (average)	D
Fish score (FRAI)	56.8%	D
Toxics		
Ammonia (as N)	0.034	A
Fluoride (as F)	0.43	A
OVERALL SITE CLASSIFICATION (PAI model)		**B/C (81.8%)**

- no data

The water quality category at J1TOUW-EWR3 is expected to be a B/C Category (81.8%). Note that this is a Low confidence assessment as no RC data are available and the A Category benchmarks in DWAF (2008) are not suitable for this site.

A.4.2 J2GAMK-EWR4

Two water quality monitoring points are available for use (**Figure A.2**); J2H016Q01 upstream of the EWR site and J2H010Q01 downstream. The former was selected as it is located in the same Level II EcoRegion as the EWR site. The water quality monitoring point used for the Gamka River is therefore downstream Gamkapoort Dam, and upstream of the EWR site, i.e. J2H016Q01. The site is located in the World Heritage Site in Gamkakloof.

Data for the assessment was sourced from J2H016Q01 on the Gamka River. Although the data record for J1H028Q01 spans from 1982 to 1999 and then from 2007 to 2014, data were only used for the present state assessment as the dam was built in 1970 and the early data record is unlikely to reflect natural conditions:

- RC was represented by the A category benchmark tables in DWAF (2008), as no other data were available to describe natural state.
- PES: DWS gauging weir J2H016Q01 (2007 – 2014; n = 127).

Table A.3 presents the water quality assessment for the Gamka River at J2GAMK-EWR4.

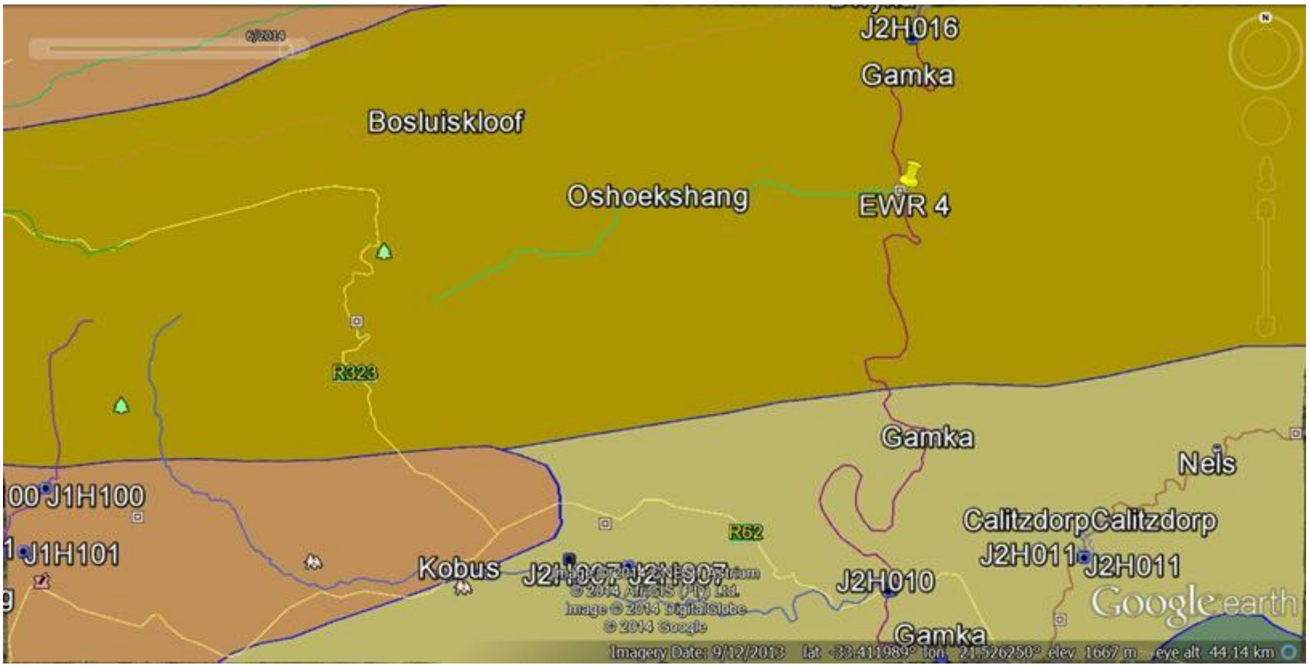

Figure A.2 J2GAMK-EWR4 on the Gamka River in relation to monitoring point J2H016Q01

Notes from the January 2014 survey

- Normal flooding is in summer; November – February. However, Gamkakloof was closed for three weeks in June/July 2012 due to flooding, so winter flooding occur intermittently (Botha, CapeNature; *pers. comm*.).
- Water was very turbid, so little evidence of algae on the rocks.

Table A.3 Water quality present state assessment for J2GAMK-EWR4

Water Quality Constituents	PES Value	Category/Comment
Inorganic salt ions (mg/l)		
Sulphate as SO_4	-	
Sodium as Na	114.0	Exceeds the ≤ 70 mg/L (TWQR) for Agricultural Use: Irrigation.
Magnesium as Mg	20.5	No guideline.
Calcium as Ca	57.6	No guideline.
Chloride as Cl	155.5	Exceeds the ≤ 100 mg/L (TWQR) for Agricultural Use: Irrigation.

Water Quality Constituents	PES Value	Category/Comment
Potassium as K	7.9	No guideline.
Electrical conductivity (mS/m)		
	97.5	C. Natural salinity expected to be higher than the 30 mS/m A category benchmark value in DWAF (2008).
Nutrients (mg/l)		
SRP	0.07	D
TIN (only NO_3-N)	0.523	B
Physical Variables		
pH (5^{th} + 95^{th} %ile)	7.4 and 8.6	D
Temperature (ºC)	-	Impact expected as the site is downstream of Gamkapoort Dam (constructed in 1970).
Dissolved oxygen (mg/L)	-	
Turbidity (NTU)	-	
Response variables		
Chl-*a*: phytoplankton (ug/L)	-	-
Macroinvertebrate score (MIRAI)	61.4%	C/D
Diatoms	9.9	D (n = 1; July 2014)
Fish score (FRAI)	60.4%	C/D
Toxics		
Ammonia (as N)	0.015	A
Fluoride (as F)	0.53	A
OVERALL SITE CLASSIFICATION (PAI model)		**B/C (80.6%)**

- no data

Diatom data (n = 1; July 2014) indicate that nutrient levels, organic pollution and salinity were high and problematic. Moderate oxygenation rates and very heavy pollution levels prevailed. Salt (sodium and chloride) levels are slightly elevated in terms of irrigation guidelines. The natural state, i.e. before dam construction, is unknown but is expected to be worse than current state which includes maintenance of water quality due to flushing flows from Gamkapoort Dam. Some nutrients and toxics elevations are expected from fertilizer and pesticide use for irrigation purposes, although this is limited. Most impacts are upstream Gamkapoort Dam.

The water quality category at J2GAMK-EWR4 is therefore expected to be a B/C Category (80.6%). This category does not reflect the very high pollution levels suggested by the diatom data.

A.4.3 J1BUFF-EWR5

Salinity levels of the Buffels River at Floriskraal Dam are considered Tolerable, but deteriorate to Unacceptable levels further downstream on the Groot River at Vanwyksdorp (DWA, 2011). The RHP (2007) describes water quality of the Groot River as Good, suggesting either a hotspot around Vanwyksdorp or a decline in water quality state between 2007 and 2011.

The EWR site on the Buffels River is downstream Floriskraal Dam, with the water quality monitoring point being from the downstream weir of the dam upstream of the EWR site (see **Figure A.3**), i.e. J1H028Q01. Note that the water quality monitoring point (19.07) is not in the same Level II EcoRegion as the EWR site (19.09); however, this is the only data point between the dam and the EWR site. Note that the river is known as the Groot River further downstream when it confluences with the Touws River. The town of Ladismith is also located downstream of J1BUFF-EWR5. Note that the main irrigation area is between the dam and the EWR site. Releases are regular and presumably mostly utilized by the time it reaches the EWR site.

Data for the assessment was sourced from J1H028Q01 on the Buffels River. The data record for spans from 1972 to 2014, and is therefore used for both RC and present state:

- RC DWS gauging weir J1H028Q01 (1972 – 1977; n = 54, Conductivity – n = 33)
- PES: DWS gauging weir J1H028Q01 (2010 – 2014; n = 44 - 71).

Table A.4 presents the water quality assessment for the Buffels River at J1BUFF-EWR5.

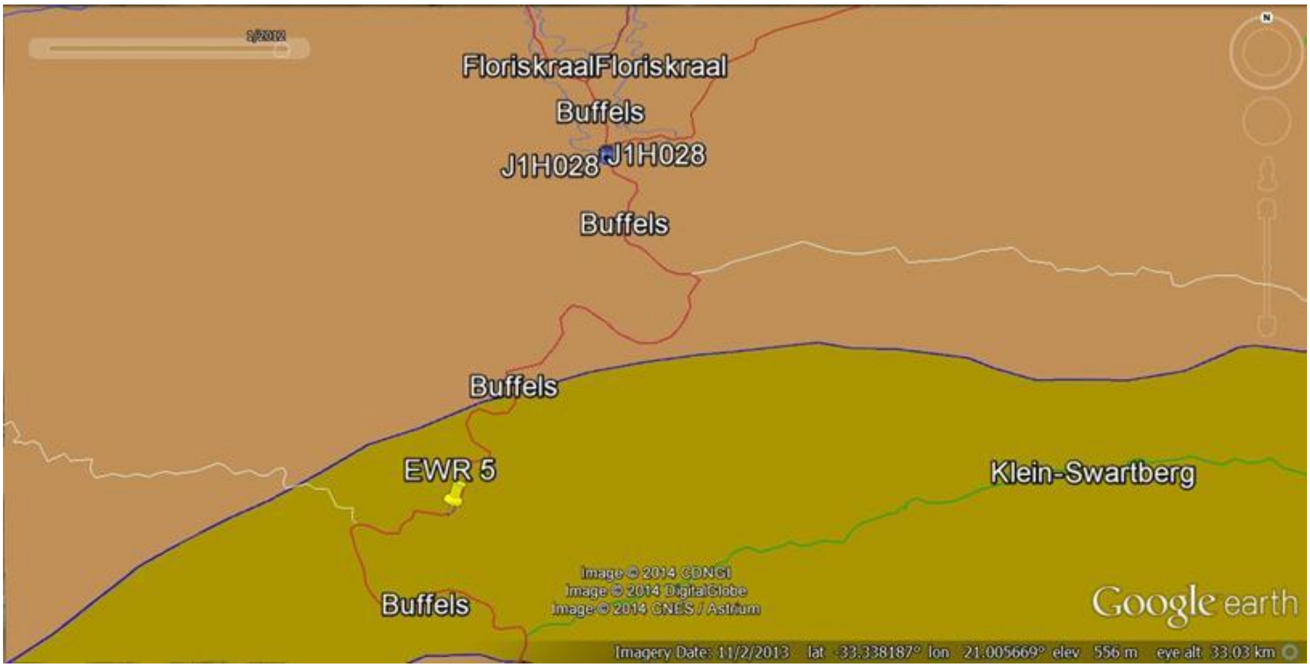

Figure A.3 J1BUFF-EWR5 on the Buffels River in relation to monitoring point J1H028Q01

Notes from the January 2014 survey

- Extensive flood damage present.
- Bed expected to change as the site stabilises after the flood.

Table A.4 Water quality present state assessment for J1BUFF-EWR5

Water Quality Constituents	RC Value	PES Value	Category/Comment
Inorganic salt ions (mg/l)			
Sulphate as SO_4	70.01	61.42	No guideline.
Sodium as Na	95.38	81.44	Exceeds the ≤ 70 mg/L (TWQR) for Agricultural Use: Irrigation.
Magnesium as Mg	21.29	25.2	No guideline.
Calcium as Ca	59.14	48.68	No guideline.
Chloride as Cl	128.0	124.0	Exceeds the ≤ 100 mg/L (TWQR) for Agricultural Use: Irrigation.
Potassium as K	7.89	6.11	No guideline.
Electrical conductivity (mS/m)			
	89.75	78.1	No change from the 1970s.
Nutrients (mg/l)			
SRP	0.043	0.015	B. Levels have decreased since the 1970s.
TIN (only NO_3-N)	0.26	0.26	A/B. No change from the 1970s.
Physical Variables			
pH (5th + 95th %ile)	7.2 and 8.3	7.5 and 8.5	B. No change from the 1970s.
Temperature (ºC)	-		Impact expected as the site is downstream the large Floriskraal Dam (constructed in 1965).
Dissolved oxygen (mg/L)	-		
Turbidity (NTU)	-		
Response variables			
Chl-*a*: phytoplankton (ug/L)	-		-
Macroinvertebrate score (MIRAI)	72.0%		C
Diatoms	11.2 (average)		C/D
Fish score (FRAI)	83.7%		B
Toxics			
Ammonia (as N)	0.005	0.017	A.
Fluoride (as F)	0.61	0.66	A. No change from the 1970s.
OVERALL SITE CLASSIFICATION (PAI model)			**B/C (79.4%)**

- no data

Results indicate little change in water quality state since the 1970s, i.e. after the Floriskraal Dam was built in 1965. The natural state, i.e. before dam construction, is unknown but is expected to be worse than current state which includes maintenance of water quality due to flushing flows from Floriskraal Dam. Salt (sodium and chloride) levels are currently slightly elevated in terms of irrigation guidelines. Although nutrient data shows low levels in the water column, nutrients and toxics are expected from fertilizer and pesticide use for irrigation purposes. The diatom (n = 2) category was set at a C/D. Diatom data indicated that flushing events played a vital role in system recovery in a reach were baseflows have been reduced due to Floriskraal Dam. It is also expected that flushing flows will maintain the water quality, assuming some flushing flows reach the EWR site. Water quality is set at a C, which is probably slightly worse than that indicated by the data (a B/C Category). Based on all above information, the water quality category at J1BUFF-EWR5 is expected to be a C Category (75.9%).

A.4.4 J4GOUR-EWR6

Data for the assessment was sourced from J4H002Q01 on the Gouritz River (**Figure A.4**) and was therefore used for both RC and present state:

- RC DWS gauging weir J4H002Q01 (1965 – 1967; n = 29)
- PES: DWS gauging weir J4H002Q01 (2007 – 2014; n = 86).

Table A.5 presents the water quality assessment for the Gouritz River at J4GOUR-EWR6.

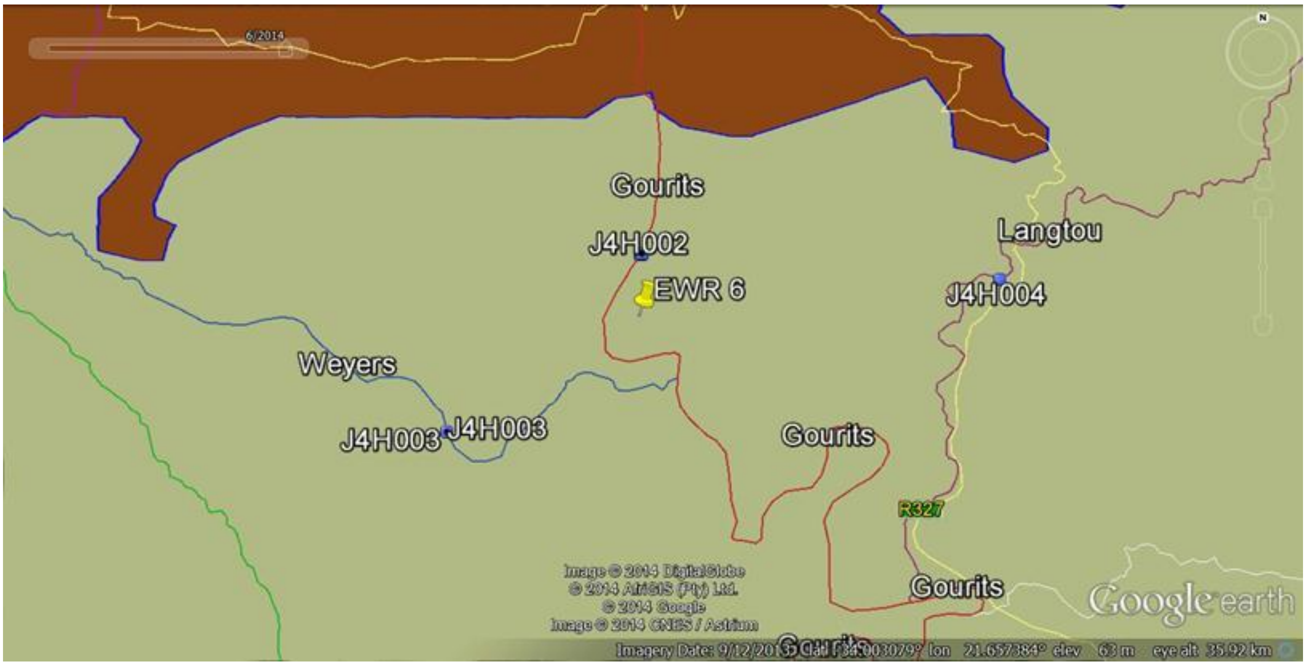

Figure A.4 J4GOUR-EWR6 on the Gouritz River in relation to monitoring point J4H002Q01

Notes from the January 2014 survey

- Downstream confluence with Gamka and with Groot rivers.
- Water was turbid, so little evidence of algae on the rocks.

Table A.5 Water quality present state assessment for J4GOUR-EWR6

Water Quality Constituents	RC Value	PES Value	Category/Comment
Inorganic salt ions (mg/l)			
Sulphate as SO_4	748.8	693.0	No guideline, but a reduction over time.
Sodium as Na	115.2	964.0	Exceeds the ≤ 70 mg/L (TWQR) for Agricultural Use: Irrigation. *Significant increase over time.*
Magnesium as Mg	154.4	127.0	No guideline.
Calcium as Ca	216.0	123.3	No guideline.
Chloride as Cl	1 858.0	1 289.3	Exceeds the ≤ 100 mg/L (TWQR) for Agricultural Use: Irrigation.
Potassium as K	-	9.81	No guideline.
Electrical conductivity (mS/m)			
	666.7	542.5	No change from the 1970s.
Nutrients (mg/l)			
SRP	-	0.015	B/C
TIN (only NO_3-N)	0.02	0.05	A
Physical Variables			
pH (5^{th} + 95^{th} %ile)	6.9 and 7.9	7.8 and 8.65	B
Temperature (ºC)	-		Impact expected at low flows.
Dissolved oxygen (mg/L)	-		
Turbidity (NTU)	-		
Response variables			
Chl-*a*: phytoplankton (ug/L)	-		-
Macroinvertebrate score (MIRAI)	75.0%		C
Diatoms	10.2 (average)		C/D
Fish score (FRAI)	50.1%		D
Toxics			
Ammonia (as N)	-	0.015	A
Fluoride (as F)	0.64	1.082	A. Substantial increase from the 1960s.
OVERALL SITE CLASSIFICATION (PAI model)			**B/C (81.8%)**

- no data

Diatom data (n = 4) indicate that nutrient levels are generally high and problematic during January – April and seem to decrease during July. Organic pollution levels generally fluctuate and can reach levels that are unacceptable. Impacts are mainly associated with agricultural activities which include dryland agriculture and cattle. Elevated water temperatures occur at times when water levels are low and water levels generally fluctuate. No valve deformities were noted during the course of 2014 suggesting that metal toxicity is below detection limits.

Water quality data indicate little change in salt levels since the 1960s, with the exception of sodium. High salt levels are linked to the natural geology, although some irrigation return flows are probably present from upstream system (particularly the Olifants tributary); also indicated by nutrients in the system. The water quality category at J4GOUR-EWR6 is therefore expected to be **a B/C Category (81.8%).** Conditions are expected to deteriorate in the lower catchment due to urban and agricultural activities.

A.4.5 K6KEUR-EWR8

A number of water quality monitoring points are available for the Keurbooms (see **Figure A.5**), with different levels of data quality. Gauging weir K6H001Q01, upstream of the K6KEUR-EWR8 but still within the same Level II EcoRegion, was selected for the assessment.

Data for the assessment was sourced from K6H001Q01 on the Keurbooms River. Although data are available from the 1970s, it was only used for the present state assessment:

- RC was represented by the A category benchmark tables in DWAF (2008).
- PES: DWS gauging weir K6H001Q01 (2007 – 2014; n = 121; F = 107).

Table A.6 presents the water quality assessment for the Gamka River at K6KEUR-EWR8.

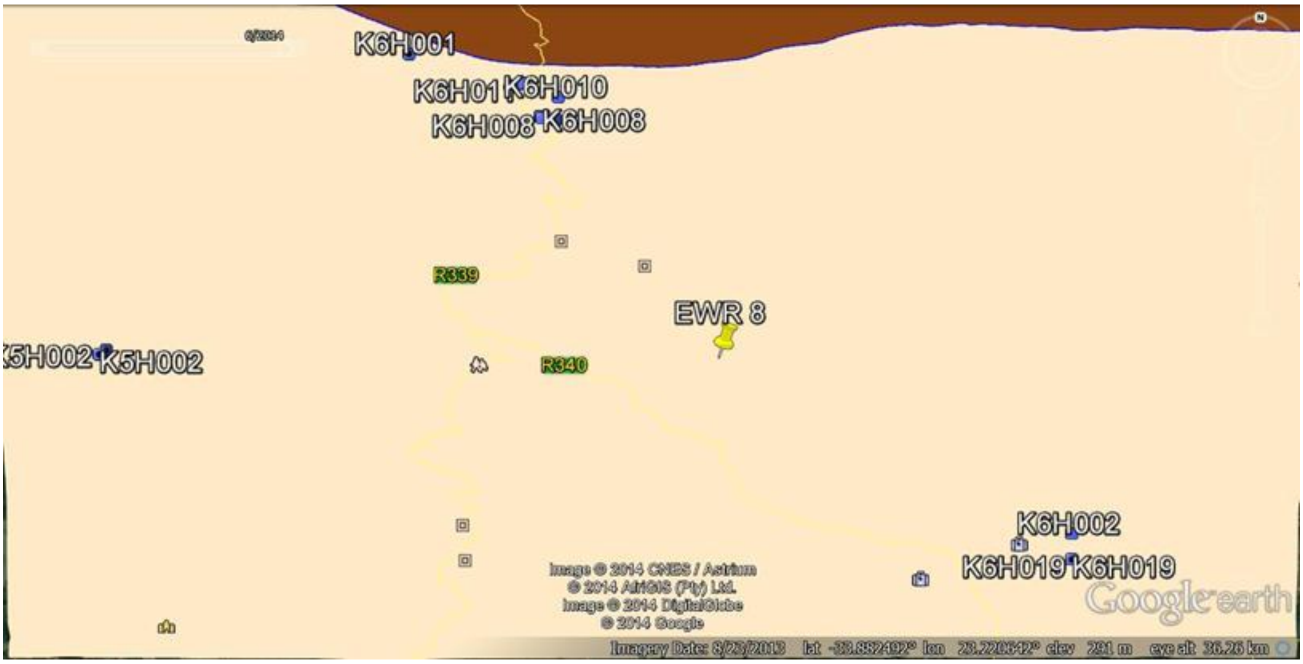

Figure A.5 K6KEUR-EWR8 on the Keurbooms River in relation to water quality monitoring points

Notes from the February 2014 survey

- Agricultural activities present upstream of the gauge.
- Flow was very slow and cobbles embedded with evidence of algal growth.

Table A.6 Water quality present state assessment for K6KEUR-EWR8

Water Quality Constituents	PES Value	Category/Comment
Inorganic salt ions (mg/l)		
Sulphate as SO_4	27.90	No guideline.
Sodium as Na	70.24	Just outside the ≤ 70 mg/L (TWQR) for Agricultural Use: Irrigation.
Magnesium as Mg	11.25	No guideline.
Calcium as Ca	12.08	No guideline.
Chloride as Cl	129.02	Just exceeds the ≤ 100 mg/L (TWQR) for Agricultural Use: Irrigation.
Potassium as K	2.76	No guideline.
Electrical conductivity (mS/m)		
	54.6	B
Nutrients (mg/l)		
SRP	0.012	B
TIN (only NO_3-N)	0.06	A
Physical Variables		
pH (5^{th} + 95^{th} %ile)	6.6 and 7.8	B
Temperature (ºC)	-	B. Some impacts expected at low flows, although on-site data still shows high levels.
Dissolved oxygen (mg/L)	-	
Turbidity (NTU)	-	B. Changes in turbidity appear to be largely related to natural with minor man-made modifications.
Response variables		
Chl-*a*: phytoplankton (ug/L)	-	
Macroinvertebrate score (MIRAI)	64.0%	C
Diatoms	9.9 (average)	C/D (n = 3)
Fish score (FRAI)	76.4%	C
Toxics		
Ammonia (as N)	0.001	A
Fluoride (as F)	0.26	A
OVERALL SITE CLASSIFICATION (PAI model)		**B (82.7%)**

- no data

Diatom data (n = 3) suggested high salinity, nutrient and organic pollution levels. During June 2014 flows were higher and an improvement in water quality was noted with nutrient, salinity and organic pollution levels improving to levels associated with good water quality. July 2014 data also indicated that metal toxicity could potentially be hazardous. Note that the SQ where the monitoring point is, is located is approximately 14 km downstream from where the main irrigation-area is found. The site is over 20 km from this area, so it is unlikely that high water quality impacts would be carried so far downstream. The EWR site itself is located in an area of few potential water quality impacts.

Salt (sodium and chloride) levels are slightly elevated in terms of the TWQR for irrigation. Some nutrients and toxics elevations are expected from fertilizer and pesticide use for irrigation purposes, but water quality is generally in a Good state. The water quality category at K6KEUR-EWR8 is therefore expected to be a B Category (82.7%).

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APPENDIX B: DIATOM RESULTS

B.1 INTRODUCTION

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

B.2 TERMINOLOGY

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

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

B.3 METHODS

B.3.1 Sampling

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

B.3.2 Slide preparation and diatom enumeration

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

B.3.3 Diatom-based water quality indices

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

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

B.4 DATA ANALYSIS

B.4.1 Diatom-based water quality score

The European numerical diatom index, the SPI was used to interpret results. De la Rey *et al*. (2004) concluded that the SPI reflects certain elements of water quality with a high degree of accuracy due to the broad species base of the SPI. The interpretation of the SPI scores was adjusted during 2011 (Taylor and Koekemoer, *in press*) and the new adjusted class limits are provided in **Table B.1**.

Table B.1 Adjusted class limit boundaries for the SPI index applied in this study

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

B.4.2 Diatom based Ecological classification

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

B.5 RESULTS

A summary of the diatom results for the EWR sites located in the Duiwenhoks, Goukou, Doring and Kammanassie rivers are provided in **Table B.2** and include the presence of PTVs and percentage valve deformities based on a total count of 400 diatom valves. The diatom based ecological classification based on Van Dam *et al*. (1994) for diatom-based water quality is given in **Table B.3**. Species lists are provided electronically.

Table B.2 Diatom results

Site	MRU	Date	No species	SPI score	Class	Category	PTV (%)	Deformities (%)		Average SPI score	Overall Category
J1TOUW-EWR3	MRU Touws B	Jan 14	8	5.7	Bad quality	E	94.8	0		8.6	D
		Feb 14	30	6.3	Poor quality	D/E	25.3	0			
		Apr 14	26	10.8	Moderate quality	C/D	64.5	1			
		Jul 14	43	11.5	Moderate quality	C/D	11.8	2.5			
J2GAMK-EWR4	MRU Gamka B	Jul 14	26	9.9	Poor quality	D	71.3	0		9.9	D
J1BUFF-EWR5	MRU Buffels B	Apr 14	22	5.8	Bad quality	E	93	0.25		11.2	C/D
		Jul 14	15	16.5	Good quality	B	1	1.25			
J4GOUR-EWR6	MRU Gouritz A	Jan 14	6	5.9	Bad quality	E	97.5	0		10.2	C/D
		Feb 14	30	9.3	Poor quality	D	10.5	0			
		Apr 14	19	9.6	Poor quality	D	51.3	0			
		Jul 14	24	16.1	Good quality	B	2.3	0			
K6KEUR-EWR8	MRU Keurbooms B	Feb 14	6	5.9	Poor quality	E	97.5	0		9.9	D
		Jun 14	16	16.9	Good quality	B	0.8	0			
		Jul 14	13	6.8	Poor quality	D/E	71.5	1.75			
		Jun 14	21	7	Poor quality	D/E	84.8	0.25			

Table B.3 Generic diatom based ecological classification (Van Dam *et al*., 1994)

Site	Date	pH	Salinity	Organic nitrogen	Oxygen levels	Pollution levels	Trophic status
J1TOUW-EWR3	Jan 14	Alkaline	Brackish fresh	Continuously elevated concentrations of organically bound nitrogen	Moderate (>50% saturation)	Very heavily polluted	Eutrophic
	Feb 14	Alkaline	Brackish fresh	Periodically elevated concentrations of organically bound nitrogen	Moderate (>50% saturation)	Strongly polluted	Eutrophic
	Apr 14	Alkaline	Brackish fresh	Continuously elevated concentrations of organically bound nitrogen	Moderate (>50% saturation)	Very heavily polluted	Eutrophic
	Jul 14	Alkaline	Fresh brackish	Elevated concentrations of organically bound nitrogen	Moderate (>50% saturation)	Very heavily polluted	Eutrophic
J2GAMK-EWR4	Jul 14	Alkaline	Brackish fresh	Continuously elevated concentrations of organically bound nitrogen	Moderate (>50% saturation)	Very heavily polluted	Eutrophic
J1BUFF-EWR5	Apr 14	Alkaline	Brackish fresh	Continuously elevated concentrations of organically bound nitrogen	Moderate (>50% saturation)	Very heavily polluted	Eutrophic
	Jul 14	Alkaline	Fresh brackish	Very small concentrations of organically bound nitrogen	Very high (~100% saturation)	Unpolluted to slightly polluted	Eutrophic
J4GOUR-EWR6	Jan 14	Alkaline	Brackish fresh	Continuously elevated concentrations of organically bound nitrogen	Moderate (>50% saturation)	Very heavily polluted	Eutrophic
	Feb 14	Alkaline	Fresh brackish	Periodically elevated concentrations of organically bound nitrogen	Moderate (>50% saturation)	Very heavily polluted	Eutrophic
	Apr 14	Alkaline	Brackish fresh	Continuously elevated concentrations of organically bound nitrogen	Moderate (>50% saturation)	Very heavily polluted	Eutrophic
	Jul 14	Alkalibiontic	Fresh brackish	Very small concentrations of organically bound nitrogen	High (>75% saturation)	Moderately polluted	Meso-eutrophic
K6KEUR-EWR8	Feb 14	Alkaline	Brackish fresh	Continuously elevated concentrations of organically bound nitrogen	Moderate (>50% saturation)	Very heavily polluted	Eutrophic
	Jun 14	Circumneutral	Fresh brackish	Very small concentrations of organically bound nitrogen	Continuously high (~100% saturation)	Unpolluted to slightly polluted	Oligotrophic
	Jul 14	Alkaline	Brackish fresh	Continuously elevated concentrations of organically bound nitrogen	Moderate (>50% saturation)	Very heavily polluted	Eutrophic

B.5.1 J1TOUW-EWR3

According to DWA (2014), the downstream area of the Touws River (MRU B) is mostly in a C and B state and is improved from MRU A due to the decreased irrigation in this area. Direct impacts in this zone are mostly non-flow related. Grazing with some dryland agriculture and minimal irrigation occur.

The diatom results are based on four samples collected during January, February, April and June 2014 respectively at the EWR site. No historic or other present data could be sourced for the Touws River.

January 2014

The biological water quality at this site was bad with a SPI score of 5.7 (E Ecological Category) (**Table B.2**). Nutrient levels, organic pollution and salinity were high and problematic. Moderate oxygenation rates and very heavy pollution levels prevailed.

Dominant diatom species included:

- *Nitzschia frustulum* was dominant and indicated problematic nutrient and salinity levels. According to Cholnoky (1968), *N. frustulum* is considered a nitrogen heterotroph and Hecky and Kilham (1973) state that *N. frustulum* is extremely tolerant of salinity and high alkalinity, and becomes abundant in brackish waters because competition from other diatom species is reduced.

Species diversity was very low and only eight species were recorded. *N. frustulum* had a 91% dominance and suggested that very high salinity levels prevailed along with high nutrient levels. All species present had a preference for elevated salinity levels. Organic pollution levels were unacceptably high and the diatom community reflected water typically impacted by agricultural activities. Based on the very low species diversity, the impacts at the time of sampling related to cattle and their associated impacts and it was assumed that current impacts were very localized. The diatoms indicated that water levels fluctuated as sub-aerial species were present. This would have an impact on the life-cycle of aquatic macro-invertebrates and fish. No valve deformities were noted suggesting that metal toxicity was below detection limits at the time of sampling.

February 2014

During February there was a slight improvement in diatom-based water quality. The SPI score was 6.3 (D Ecological Category) (**Table B.2**) and the improvement could mainly be attributed to improved nutrient, salinity and organic pollution levels although these levels were still high. Moderate oxygenation rates and strong pollution levels prevailed.

Dominant diatom species included:

- *Achnanthes oblongella*: Preference for circumneutral oligotrophic electrolyte poor streams (Taylor *et al*., 2007b). High abundance could be associated with elevated flows.
- *Cyclotella meneghiniana*: Cosmopolitan distribution with preference for eutrophic electrolyte rich water bodies (Taylor *et al*., 2007b).

- *Nitzschia acicularis*: Found in eutrophic waters with moderate to high electrolyte content and tolerant of strong pollution (Taylor *et al*., 2007b).
- *Navicula erifuga*: Found in eutrophic, brackish waters and tolerant of critical pollution levels (Taylor *et al*., 2007b).
- *Nitzschia frustulum*: See January 2014.
- *Nitzschia species*: Associated with water bodies that have readily available nutrients.
- *Thalassiosira pseudonana*: A halophilic plactonic taxon (Taylor *et al*., 2007b).

The dominance of *N. frustulum* decreased indicating that organic pollution and nutrient levels were less than observed during January 2014. The improved organic pollution levels were also reflected by the dominance of species sensitive to high organic levels which included *A. oblongella* and *N. acicularis*. The presence of *Achnanthidium* species along with *A. oblongella* suggested that flows were recently elevated and would account for the improved conditions observed during February 2014 as these taxa are associated with flushing events. The presence of strictly aquatic diatom taxa was also an indication that water levels increased during the time of sampling. Salinity levels although lower than observed during January 2014 were still high as reflected by the dominance of various species with an affinity for high salinity. The dominance of *N. erifuga* also suggested that the EWR site was impacted by animal/livestock in the area.

April 2014

During April there was a further improvement in diatom-based water quality. The SPI score was 10.8 (C/D Ecological Category) (**Table B.2**) but based on the diatom community composition the water quality was deteriorating due to rising nutrient and organic pollution levels and the diatoms were in a flux of change. Moderate oxygenation rates and very heavy pollution levels prevailed.

Dominant diatom species included:

- *Amphora copulata*: A cosmopolitan species with a preference for moderate electrolyte content but occurring in brackish biotopes (Taylor *et al*., 2007b).
- *Achnanthidium* species: Are associated with elevated flows. The genus generally prefers good water quality with high oxygenation rates (Taylor *et al*., 2007b).
- *Nitzschia frustulum*: See January 2014.

The diatom data indicated that flows could have been recently elevated due to the dominance of *Achnanthidium* species. However compared to April 2014, there was a notable increase in the abundance of *N. frustulum* as well as PTVs which made up 64.5% of the total count which suggested that water quality conditions were deteriorating. *Fragilaria fasciculata* was the sub-dominant during April 2014 and has been reported from critically polluted industrial wastewater (Taylor *et al*., 2007b). It has a preference for $S0_4^{-2}$-dominated habitats, especially $MgS0_4$ and is characterized as most indicative of habitats with high specific conductance and euryhaline conditions (Blinn, 1993). This could be an indication of higher herbicide and pesticide use within the reach. The diatoms indicated that water levels fluctuated as sub-aerial species were present. This would have an impact on the life-cycle of aquatic macro-invertebrates and fish.

Of concern was the occurrence of diatom valve deformities which relates to the presence of metal toxicity. According to Luís *et al*. (2008) several studies on metal polluted rivers have shown that diatoms respond to perturbations not only at the community but also at the individual level with alteration in cell wall morphology. In particular, size reduction and frustule deformations have been sometimes associated with high metal concentrations. The total abundance of valve deformities was 1% which falls within the general threshold which is between 1 - 2% and considered potentially hazardous.

July 2014

The SPI score was 11.5 during July 2014 (C/D Ecological Category) (**Table B.2**) and the diatoms indicated that salinity, nutrient and organic pollution levels improved from April 2014. Moderate oxygenation rates and very heavy pollution levels prevailed.

Dominant diatom species included:

- *Achnanthidium* species: See April 2014.
- *Epithemia adnata*: Tolerant to moderate to high electrolyte content but extends into brackish biotopes. Indicator of elevated water temperatures (Taylor *et al*., 2007b).
- *Gomphonema pumilum* var. *rigidum*: A cosmopolitan species found in meso- to eutrophic waters with moderate electrolyte content. Not tolerant of more than critical levels of pollution (Taylor *et al*., 2007b).
- *Navicula schroeteri* var. *symmetrica*: Cosmopolitan in eutrophic, electrolyte-rich waters. Tolerant of strongly polluted conditions (Taylor *et al*., 2007b).
- *Planothidium engelbrechtii*: Found in saline inland waters with very high electrolyte content tolerating critical to very heavy pollution (Taylor *et al*., 2007b).
- *Planothidium frequentissima*: Prefers moderate to high electrolyte content and tolerates critical pollution levels (Taylor *et al*., 2007b).

N. frustulum was notably absent during July 2014 which accounted for improved nutrient levels as well as organic pollution levels. The high abundance of *Achnanthidium* species and sub-dominance of *Fragilaria capucina* var. *vaucheriae* suggested that a flushing event occurred at some time previous to sampling. However *E. adnata* which is an indicator of elevated water temperatures was also dominant and suggested that at the time of sampling water levels had receded. It was expected that organic pollution levels would increase due to the dominance of *Planothidium* species and the sub-dominance of *Eolimna* species as these species are indicator species for organic pollution. This could most probably be associated with cattle. The diatoms indicated that water levels fluctuated as sub-aerial species were present. This would have an impact on the life-cycle of aquatic macro-invertebrates and fish.

Valve deformities made up 2.5% of the total count which was higher than observed during April 2014. These levels exceeded thresholds and indicated that metal toxicity was present at the site.

Conclusions

MRU Touws B was characterised by generally high salinity levels which could be naturally elevated due to the geology of the area. Nutrient levels are generally high and problematic during January – April and seem to decrease during July. Organic pollution levels generally fluctuate and can reach levels that are unacceptable. Impacts are mainly associated with agricultural activities which include dryland agriculture and cattle. Elevated water temperatures occur at times when water levels are low and water levels generally fluctuate. Valve deformities were noted during April and July 2014 suggesting that metal toxicity impacts the reach.

The overall Ecological Category for the reach was set at a D EC. Although salinity is naturally elevated, salinity and nutrients are however additionally impacted by livestock and some irrigation upstream. Metals could occur naturally although there is insufficient data available to substantiate this.

B.5.2 J2GAMK-EWR4

According to DWA (2014), The lower Gamka River (J23J, J25A, J25C, J25E) is generally in a deteriorated state due to modified flows (Gamkapoort Dam, abstraction for irrigation and towns), as well as non-flow related impacts (extensive agricultural activities along river) as well as water quality deterioration (irrigation return flows and town of Calitzdorp). The section of the river flowing through the Swart Berg Mountains in the Gamkakloof (The Hell) World Heritage Site is in excellent condition however apart from the flow modification from the upstream Gamkapoort Dam.

The diatom results are based on one sample collected during July 2014 at the EWR site. No historic or other present data could be sourced for the Gamka River.

July 2014

The biological water quality at this site was poor with a SPI score of 9.9 (D Ecological Category) (**Table B.2**). Nutrient levels, organic pollution and salinity were high and problematic. Moderate oxygenation rates and very heavy pollution levels prevailed.

Dominant diatom species included:

- *Nitzschia frustulum* was dominant and indicated problematic nutrient and salinity levels. According to Cholnoky (1968), *N. frustulum* is considered a nitrogen heterotroph and Hecky and Kilham (1973) state that *N. frustulum* is extremely tolerant of salinity and high alkalinity, and becomes abundant in brackish waters because competition from other diatom species is reduced.
- *Epithemia adnata*: Tolerant to moderate to high electrolyte content but extends into brackish biotopes. Indicator of elevated water temperatures (Taylor *et al*., 2007b).

N. frustulum was dominant and suggested that very high salinity levels prevailed along with high nutrient levels. The majority of species present had a preference for elevated salinity levels and organic pollution levels were unacceptably high. The presence of *Epithemia adnata* along with *Rhopalodia gibba* suggested that flows were very low and water temperatures were elevated. Indicators of anthropogenic activities occurred in very low abundance suggesting that cattle grazing were the main impact at the site. The presence of *Fragilaria fasciculata* and *Bacillaria paradoxa* (a marine species) suggested that upstream farming was contributing to higher salinity levels in the reach in terms of sulphates. The diatoms indicated that water levels fluctuated as sub-aerial species were present. This would have an impact on the life-cycle of aquatic macro-invertebrates and fish. No valve deformities were noted suggesting that metal toxicity was below detection limits at the time of sampling.

Conclusions

MRU Gamka B was characterised by generally high salinity levels which could be naturally elevated due to the geology of the area. Nutrient levels and organic pollution levels were also problematic. Impacts are mainly associated with agricultural activities associated with cattle farming although upstream agriculture could be contributing to higher salinity loads within the system. Elevated water temperatures occur at times when water levels are low and water levels generally fluctuate.

The overall Ecological Category for the reach was set at a D EC, based on one sample and the confidence in this evaluation of the PES of the reach is very low.

B.5.3 J1BUFF-EWR5

According to DWA (2014), the EWR site is situated in MRU Buffels B downstream of Floriskraal Dam. Irrigation occurs next to the river where the relief allows. This results in the river being in a lower PES apart from areas which are protected within two poorts. These areas have been identified as Reserve Assessment Units (RAUs) and are nested within the MRU. J1BUFF-EWR5 is located in RAU Buffels B.2 and has a a higher PES than the rest of the river due to the reach being protected within a poort.

The diatom results are based on two samples collected during April and July 2014 at the EWR site. No historic or other present data could be sourced for the Buffels River.

April 2014

The biological water quality at this site was bad with a SPI score of 5.8 (E Ecological Category) (**Table B.2**). Nutrient levels, organic pollution and salinity were high and problematic. Moderate oxygenation rates and very heavy pollution levels prevailed.

Dominant diatom species included:

- *Nitzschia frustulum* was dominant and indicated problematic nutrient and salinity levels. According to Cholnoky (1968), *N. frustulum* is considered a nitrogen heterotroph and Hecky and Kilham (1973) state that *N. frustulum* is extremely tolerant of salinity and high alkalinity, and becomes abundant in brackish waters because competition from other diatom species is reduced.

N. frustulum was outrightly dominant at an abundance of 83% and suggested that very high salinity levels prevailed along with high nutrient levels. The majority of species present had a preference for elevated salinity levels and organic pollution levels which were unacceptably high. This site does occur within a poort where anthropogenic activities are limited and the deteriorated water quality could mainly be attributed to very low flows at the time of sampling during which nutrient and organic pollution levels are expected to increase. Flows were very low during sampling and generally baseflows have been reduced and observed conditions would prevail for most of the time during low flow periods. Indicators of anthropogenic activities occurred at sub-dominant level and included *Navicula veneta*, *Craticula molestiformis* and *Gomphonema parvulum* suggesting that although activities are limited in this part of the reach, deteriorated water quality could be originating from upstream farming activities although under the low flow conditions deteriorated water quality is expected. The diatoms indicated that water levels fluctuated as sub-aerial species were present.

This would have an impact on the life-cycle of aquatic macro-invertebrates and fish. Valve deformities were noted, however at very low abundance and metal toxicity was not deemed problematic.

July 2014

There was a marked improvement in water quality during July 2014. The biological water quality at this site was good with a SPI score of 16.5 (B Ecological Category) (**Table B.2**). Nutrient levels, organic pollution and salinity decreased which resulted in water quality improvement. High oxygenation rates and slight pollution levels prevailed.

Dominant species included:

- *Achnanthes oblongella*: Preference for circumneutral oligotrophic electrolyte poor streams (Taylor *et al*., 2007b). High abundance could be associated with elevated flows.
- *Fragilaria capucina* var*. rumpens*: Species associated with elevated flows preference for oligo- to mesotrophic waters (Taylor *et al*., 2007b).

The dominant species indicated that flow where recently elevated and that there was an influx of good water quality. Most of the species present had a preference for good water quality conditions with high oxygenation rates and low nutrient levels. With the influx of flow no indicators of anthropogenic activity was present and generally the diatom community was representative of good water quality conditions. The total abundance of valve deformities was 1.25% which falls within the general threshold which is between 1 - 2% and considered potentially hazardous.

Conclusions

MRU Buffels B was characterised by very bad water quality during April 2014. Although the flows were higher during April compared to June, the diatom community during April reflected conditions typically observed when flows are very low and nutrient and organic pollution levels are very high. Under prolonged conditions as observed during April 2014, the water quality would be a limiting factor for the survival of aquatic biota. Indicators of anthropogenic activities were present suggesting upstream farming activities and irrigation return flows could be the main impact on this reach. During July 2014, water quality conditions improved drastically and the majority of species present were associated with recent elevated flows. There was rain a week before July site visit which could account for the higher flows and better SPI score. The diatom data indicated that flushing events played a vital role in system recovery and in a reach were baseflows have been reduced due to Floriskraal Dam, releases would be very important in terms of providing habitat and cleaning of substrate for biota to successfully breed and ensure maintained viability.

The overall Ecological Category for the reach was set at a C/D EC.

B.5.4 J4GOUR-EWR6

According to DWA (2014), the Gouritz River in J40B remains primarily impacted by upstream flow and water quality alterations, with J40B-9106 also impacted by the activities in catchment J1, but still remaining in a category C due to minimal localised impacts (agriculture). J4GOUR-EWR6 is located in MRU Gouritz A, SQ J40B-09106.

The diatom results are based on four samples collected during January, February, April and July 2014 respectively at the EWR site. No historic or other present data could be sourced for the Gouritz River.

January 2014

The biological water quality at this site was bad with a SPI score of 5.9 (E Ecological Category) (**Table B.2**). Nutrient levels, organic pollution and salinity were high and problematic. Moderate oxygenation rates and very heavy pollution levels prevailed.

Dominant diatom species included:

- *Nitzschia frustulum* was dominant and indicated problematic nutrient and salinity levels. According to Cholnoky (1968), *N. frustulum* is considered a nitrogen heterotroph and Hecky and Kilham (1973) state that *N. frustulum* is extremely tolerant of salinity and high alkalinity, and becomes abundant in brackish waters because competition from other diatom species is reduced.

Species diversity was very low and only nine species were recorded. *N. frustulum* had a 97% dominance and suggested that very high salinity levels prevailed along with high nutrient levels. All species present had a preference for elevated salinity levels. From the photographic records available of the EWR site it seemed that stream flow was higher than observed during February and a higher SPI score was expected. A direct source for the deteriorated water quality at the time of sampling could not be ascertained due to the low species diversity. According to DWA (2014b) salinity is naturally elevated throughout the system and could account for the high levels of salinity that was observed. No indicators of anthropogenic activities were present. The diatoms indicated that water levels fluctuated as sub-aerial species were present. This would have an impact on the life-cycle of aquatic macro-invertebrates and fish. No valve deformities were noted suggesting that metal toxicity was below detection limits at the time of sampling.

February 2014

During February there was an improvement in diatom-based water quality. The SPI score was 9.3 (D Ecological Category) (**Table B.2**) and the improvement could mainly be attributed to improved nutrient, salinity and organic pollution levels although these levels were still high. Moderate oxygenation rates and strong pollution levels prevailed.

Dominant diatom species included:

- *Achnanthidium biasolettianum*: Found in calcareous olig- to mesotrophic waters with moderate to elevated electrolyte content (Taylor *et al*., 2007b).
- *Achnanthes oblongella*: Preference for circumneutral oligotrophic electrolyte poor streams (Taylor *et al*., 2007b). High abundance could be associated with elevated flows.
- *Cyclotella meneghiniana*: Cosmopolitan distribution with preference for eutrophic electrolyte rich water bodies (Taylor *et al*., 2007b).
- *Fragilaria biceps*: Associated with elevated flows found in the benthos of rivers and lakes and is easily suspended in the plankton due to its relatively large surface area (Taylor *et al*., 2007b).
- *Nitzschia acicularis*: Found in eutrophic waters with moderate to high electrolyte content and tolerant of strong pollution (Taylor *et al*., 2007b).

- *Nitzschia species*: Associated with water bodies that have readily available nutrients.
- *Thalassiosira pseudonana*: A halophilic plactonic taxon (Taylor *et al*., 2007b).

N. frustulum was observed in very low numbers during February 2014 and accounted for the lower nutrient levels. The dominance of *Nitzschia* species indicated that although nutrient levels were lower than observed during January 2014, this reach was prone to continual elevated nutrient levels which could become problematic. The source could be linked to cattle and anthropogenic activities in the catchment upstream of the EWR site. The improved organic pollution levels were reflected by the dominance of species sensitive to high organic levels which included *A. oblongella* and *N. acicularis*. The presence of *A. biasolettianum* along with *A. oblongella* and *Fragilaria biceps* suggested that flows were recently elevated and would account for the improved conditions observed during February 2014 as these taxa are associated with flushing events. Salinity levels although lower than observed during January 2014 were still high as reflected by the dominance of various species with an affinity for high salinity which included *C. meneghiniana* and *T. pseudonana*. Although indicators of anthropogenic activity occurred in very low abundance their presence did however suggest that anthropogenic activities did impact the site to a certain extent. The presence of strictly aquatic diatom taxa was also an indication that water levels increased during the time of sampling. No valve deformities were noted suggesting that metal toxicity was below detection limits at the time of sampling.

April 2014

During April the diatom-based water quality remained relatively stable even in the presence of elevted flow based on flow measurements taken at the site at the time of sampling. The SPI score was 9.6 (D Ecological Category) (**Table B.2**) but based on the diatom community composition the water quality was deteriorating due to rising nutrient and organic pollution levels and salinity. Moderate oxygenation rates and very heavy pollution levels prevailed.

Dominant diatom species included:

- *Cyclotella atomus*: Occurs in the plankton of electrolyte rich waters (Taylor *et al*., 2007b).
- *Geissleria acceptata*, which according to Potapova (2009) prefers fresh waters with moderate to high electrolyte content.
- *Nitzschia frustulum*: See January 2014.
- *Nitzschia* species: See February 2014.
- *Stephanodiscus minutulus*: Found in strongly polluted water with a high electrolyte content (Taylor *et al*., 2007b).

Salinity levels increased from April 2014 and this is reflected by the majority of dominant species that have an affinity for high salinity levels. Compared to February 2014, there was a notable increase in the abundance of *N. frustulum* and *Nitzschia* species and suggested that nutrient levels were higher and increasing. *Fragilaria fasciculata* occurred in low abundance and indicated that sulphates could be elevated. Water quality data indicated significant elevated levels of sodium. Indicators of anthropogenic activities occurred at slightly lower abundance than during February 2014, once again suggesting that anthropogenic activities were not the primary impact on the site. Organic pollution levels also increased and PTVs made up 51.3% of the total count compared to 10.5% in February 2014. The diatoms indicated that water levels fluctuated as sub-aerial species were present. This would have an impact on the life-cycle of aquatic macro-invertebrates and fish. No valve deformities were noted suggesting that metal toxicity was below detection limits at the time of sampling.

July 2014

The SPI score was 16.1 during July 2014 (B Ecological Category) (**Table B.2**) and the diatoms indicated that salinity, nutrient and organic pollution levels improved from April 2014. High oxygenation rates and moderate pollution levels prevailed.

Dominant diatom species included:

- *Epithemia adnata*: A cosmopolitan species found in standing and slow flowing waters, tolerant to moderate to high electrolyte content but extends into brackish biotopes. Indicator of elevated water temperatures (Taylor *et al*., 2007b).
- *Gomphonema minutum*: A cosmopolitan species found in eutrophic waters but not tolerant to more than moderate levels of pollution. (Taylor *et al*., 2007b).
- *Rhopalodia gibba*: A cosmopolitan species found in standing and slow flowing waters, especially springs, of moderate to high electrolyte content (Taylor *et al*., 2007b).

The data indicated that flows were recently elevated prior to sampling due to the sub-dominance of *Achnanthidium* species. However *E. adnata* and *R. gibba* were dominant and suggested that flows were low with elevated water temperatures at the time of sampling. Most species present were associated with good to moderate water quality conditions with a preference for moderate salinity nutrient and organic pollution levels. There was a mixture of aquatic and sub-aerial species suggesting that flows were elevated but receded rapidly. No valve deformities were noted suggesting that metal toxicity was below detection limits at the time of sampling.

Conclusions

MRU Gouritz A was characterised by generally high salinity levels which could be naturally elevated due to the geology of the area. Nutrient levels are generally high and problematic during January – April and seem to decrease during July. Organic pollution levels generally fluctuate and can reach levels that are unacceptable. Impacts are mainly associated with agricultural activities which include dryland agriculture and cattle. Elevated water temperatures occur at times when water levels are low and water levels generally fluctuate. No valve deformities were noted during the course of 2014 suggesting that metal toxicity is below detection limits.

The overall Ecological Category for the reach was set at a C/D EC.

B.5.4 K6KEUR-EWR8

According to DWA (2014b), most rivers in the Keurbooms system are in a category B or better, with the impacts that exist being non-flow related vegetation removal or the presence of alien plant species. K6KEUR-EWR8 is located in MRU Keurbooms B, SQ K60C-09882.

The diatom results are based on three samples collected during February, June and July 2014 respectively at the EWR site. No historic or other present data could be sourced for the Keurbooms River.

February 2014

The biological water quality at this site was bad with a SPI score of 5.9 (E Ecological Category) (**Table B.2**). Nutrient levels, organic pollution and salinity were high and problematic. Moderate oxygenation rates and very heavy pollution levels prevailed.

Dominant diatom species included:

- *Nitzschia frustulum* was dominant and indicated problematic nutrient and salinity levels. According to Cholnoky (1968), *N. frustulum* is considered a nitrogen heterotroph and Hecky and Kilham (1973) state that *N. frustulum* is extremely tolerant of salinity and high alkalinity, and becomes abundant in brackish waters because competition from other diatom species is reduced.

Species diversity was very low and only six species were recorded. *N. frustulum* had a 97% dominance and suggested that very high salinity levels prevailed along with high nutrient levels. All species present had a preference for elevated salinity levels. A direct source for the deteriorated water quality at the time of sampling could not be ascertained due to the low species diversity. According to DWA (2014b) elevated salinities are not found to the same extent in the K and coastal (H8 and H9) catchments as elsewhere in the WMA. However, the disposal of wood processing waste, with associated high Chemical Oxygen Demand (COD) concentrations, is an issue in the K primary catchment. High salinities were however observed during February 2014 based on the diatom data. From the photographic record flows were low and it is expected that nutrient levels would be high along with organic pollution.

Based on the very low species diversity, the impacts at the time of sampling related to cattle and their associated impacts and it was assumed that current impacts were localized. The diatoms indicated that water levels fluctuated as sub-aerial species were present. This would have an impact on the life-cycle of aquatic macro-invertebrates and fish. No valve deformities were noted suggesting that metal toxicity was below detection limits at the time of sampling.

June 2014

During June there was a marked improvement in diatom-based water quality. The SPI score was 16.9 (B Ecological Category) (**Table B.2**) and the improvement could mainly be attributed to improved nutrient, salinity and organic pollution levels. Continuously high oxygenation rates and slight pollution levels prevailed.

Dominant diatom species included:

- *Achnanthidium* species: *A*re associated with elevated flows. The genus generally prefers good water quality with high oxygenation rates (Taylor *et al*., 2007b).
- *Achnanthes oblongella*: Preference for circumneutral oligotrophic electrolyte poor streams (Taylor *et al*., 2007b). High abundance could be associated with elevated flows.
- *Fragilaria capucina* var*. rumpens*: Species associated with elevated flows preference for oligo-

to mesotrophic waters (Taylor *et al*., 2007b).

N. frustulum was observed in very low numbers during June 2014 and accounted for the lower nutrient and salinity levels. The presence of *Achnanthidium* species along with *A. oblongella* and *F. capucina* var*. rumpens* suggested that flows were recently elevated and would account for the improved conditions observed during June 2014 as these taxa are associated with flushing events, although the flow data indicated that flows were similar to February 2014. Most of the species present had a preference for good water quality conditions with high oxygenation rates and low nutrient levels. With the influx of flow no indicators of anthropogenic activity was present and generally the diatom community was representative of good water quality conditions. No valve deformities were noted suggesting that metal toxicity was below detection limits at the time of sampling.

July 2014

During July the diatom-based water quality deteriorated notably although flows were higher than in June due to rain the previous week. The SPI score was 6.8 (D/E Ecological Category) (**Table B.2**) and the deteriorated water quality could mainly be attributed to rising salinity, nutrient and organic pollution levels. Moderate oxygenation rates and very heavy pollution levels prevailed.

Dominant diatom species included:

- *Nitzschia frustulum*: See February 2014.
- *Fragilaria fasciculata*: has been reported from critically polluted industrial wastewater (Taylor *et al*., 2007b). It has a preference for $S0_4^{-2}$-dominated habitats, especially $MgS0_4$ and is characterized as most indicative of habitats with high specific conductance and euryhaline conditions (Blinn, 1993).

Compared to June 2014, there was a notable increase in the abundance of *N. frustulum* and suggested that nutrient and salinity levels were higher and increasing. *Fragilaria fasciculata* was also dominant indicated that sulphates could be elevated. The diatom data indicated that most species had a preference for deteriorated water quality. Indicators of anthropogenic activities occurred at slightly higher abundance than during February and June 2014, suggesting that anthropogenic activities were impacting the site to a certain extent. Organic pollution levels also increased and PTVs made up 71.5% of the total count compared to 0.8% in June 2014. The diatoms indicated that water levels fluctuated as sub-aerial species were present. This would have an impact on the life-cycle of aquatic macro-invertebrates and fish. The total abundance of valve deformities was 1.75% which falls within the general threshold which is between 1 - 2% and considered potentially hazardous.

Conclusions

MRU Keurbooms B was characterised by generally high salinity nutrient and organic pollution levels. During June 2014 there was an improvement in water quality with nutrient, salinity and organic pollution levels improving to levels associated with good water quality. Although flows were similar during June and July, the biological water quality deteriorated during July 2014. No valve deformities were noted during February and June 2014, however July 2014 data indicated that metal toxicity could potentially be hazardous.

The overall Ecological Category for the reach was set at a D EC.

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APPENDIX C: ECO-HYDRAULICS

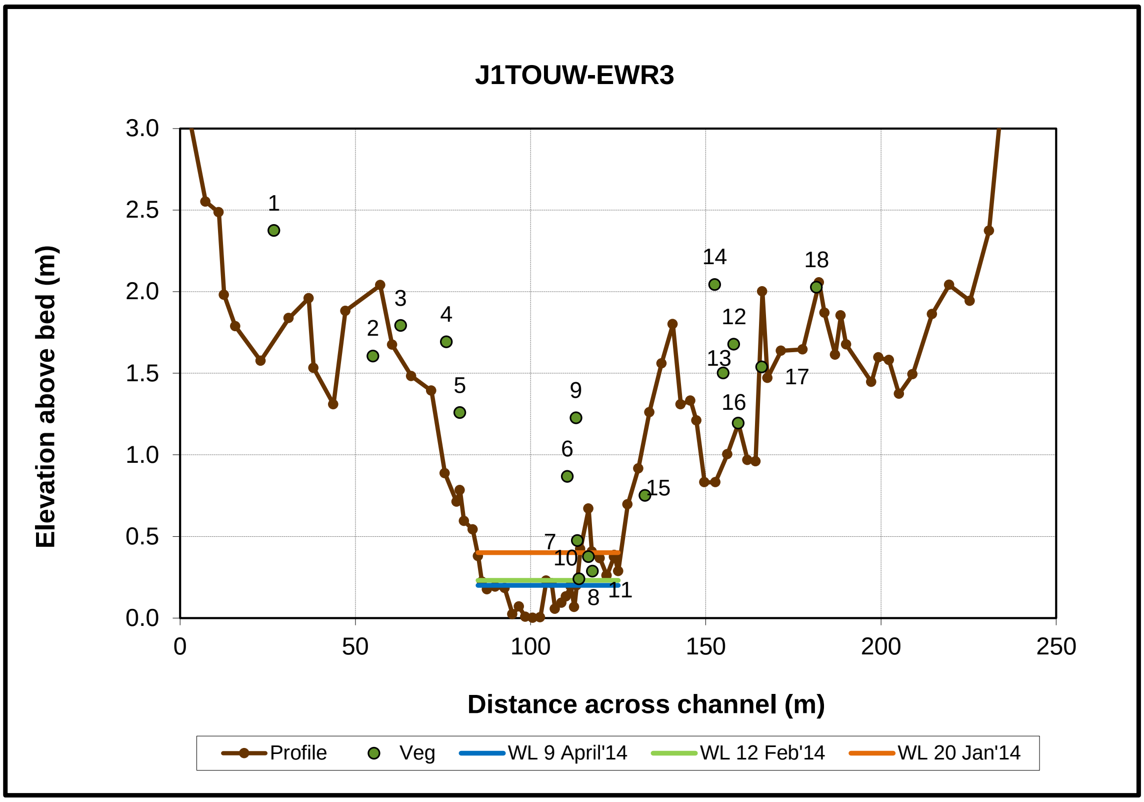
C.1 METHODOLOGY

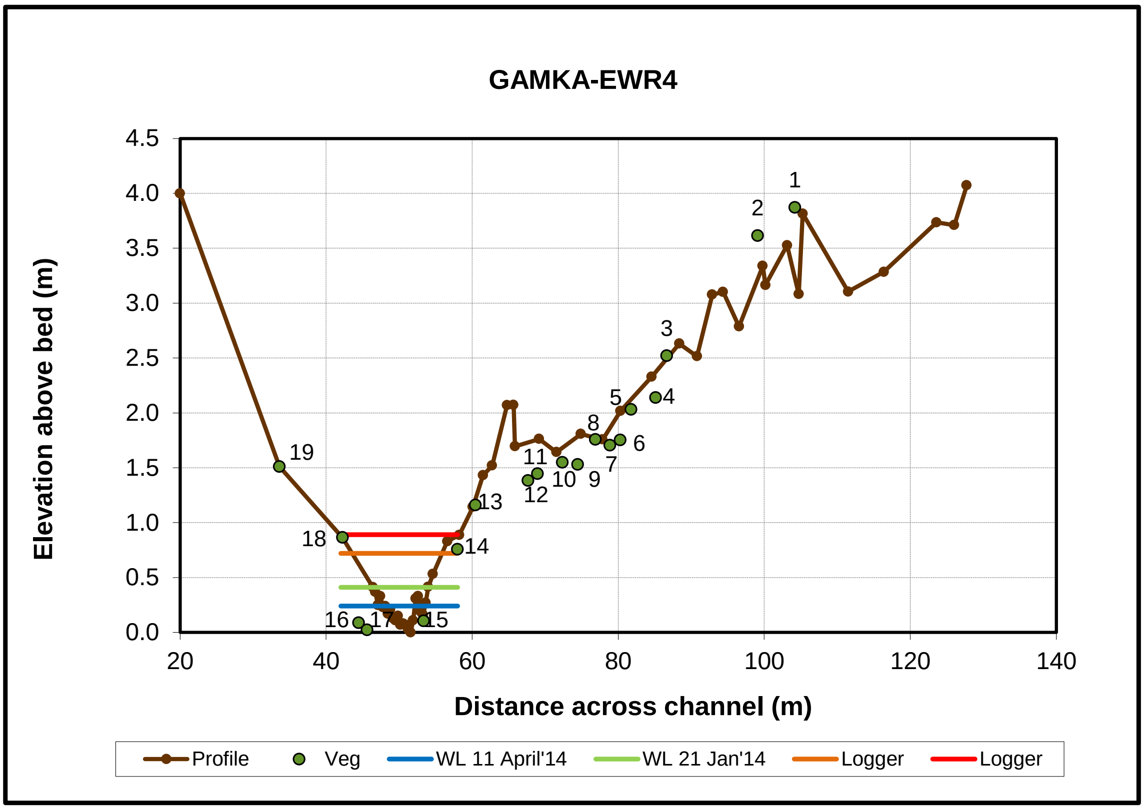
The application of holistic methods for ecological flow determination (refer to Tharme, 1996) requires environmental water requirements (EWRs) to be expressed as discharge rates (including their temporal characteristics) through assessments of the presence of suitable habitat for certain biota at different flows. The interface between the way in which flow requirements are assessed and expressed is through the results of hydraulic measurements, analyses and modelling at sites along rivers. The primary product of these hydraulic analyses are relationships between discharge and the following determinants, which have been found over the course of numerous flow assessments, to be the most useful: depth (maximum and average), velocity (average), wetted perimeter, and width of the water surface. The discharge-depth (or rating) relationship is fundamental to hydraulic analysis, and is generally derived from a combination of measured and synthesized data (refer to Rowlston *et al*. (2000), Birkhead (1999), Jordanova *et al*. (2004), Hirschowitz *et al*. (2007) and Birkhead (2010) for descriptions of procedures for deriving hydraulic information for use in EWRs in South Africa). Once the rating relationship for a river section has been developed, the relationships between discharge and the other hydraulic parameters (listed above) may readily be computed using the cross-sectional geometry, and are generally provided in tabular format using look-up tables (refer to **Table C.2**).

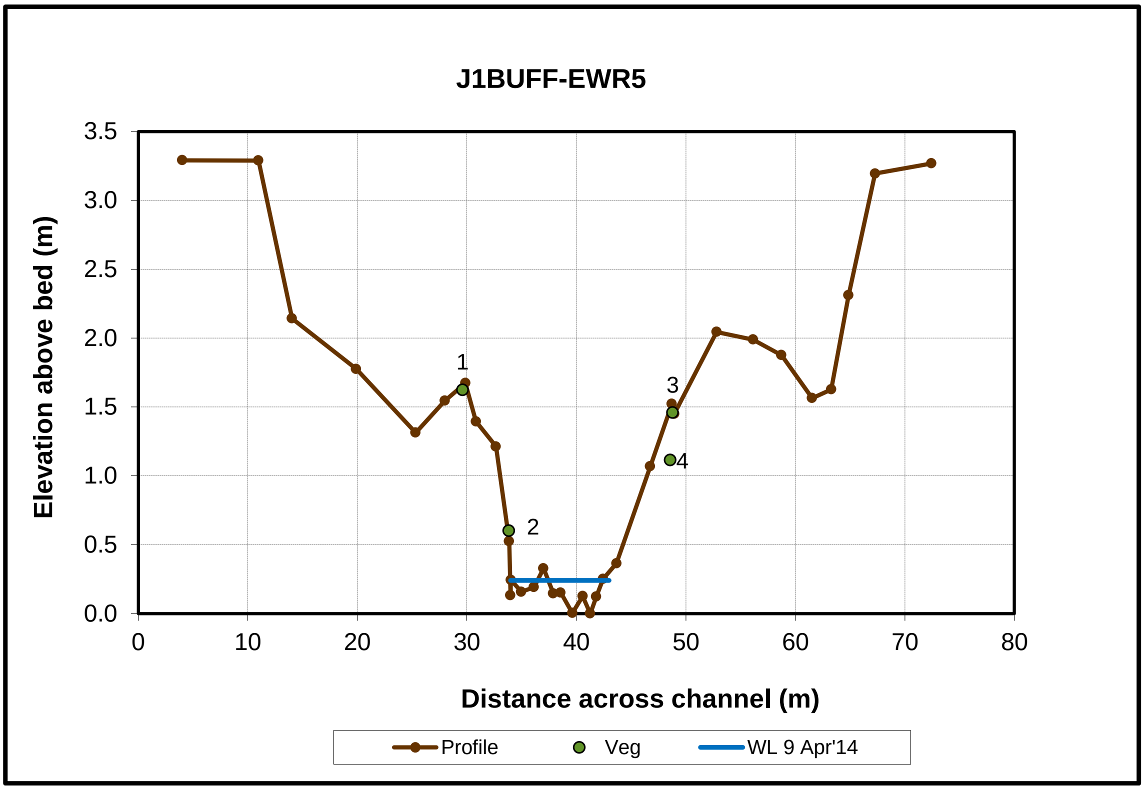
The cross-sectional profile plots and look-up tables comprise the “standard hydraulic data” used in EWR determinations in South Africa. Ecologists use these standard hydraulic data with the aid of site assessments and photographs to determine the quantity and quality of hydraulic habitat at different flows. Substantial experience and interpretation are required to provide assessments of site-based and reach-based biological habitats using cross-sectional surveys and the results of one-dimensional hydraulic analyses (biological habitat refers to the integration of the different components defining habitat, *e.g.* hydraulic, substrate and cover attributes for fish). Procedures have therefore been developed for using standard hydraulic information as the basis for quantifying hydraulic habitat for fish (refer to Hirschowitz *et al*. (2007) and Birkhead (2010) for an explanation of the method). The method allows the assessment of abundance of different flow classes to be applied more consistently in EWRs, and has been used in this study.

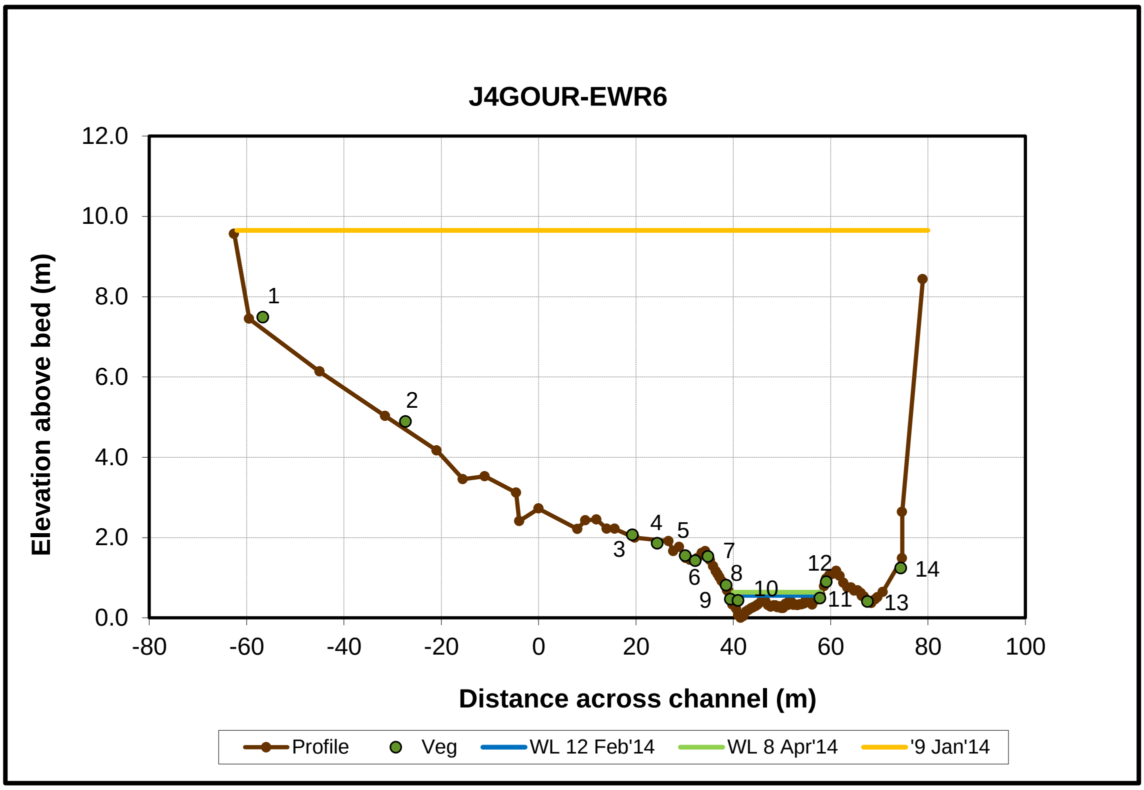
C.2 DATA COLLECTION

The field trips to the study area took place during January and July 2014 when cross-sections, vegetation markers and water levels were surveyed, and discharge was measured (refer to **Figure C.1** and **Table C.1**).


J1TOUW-EWR3
Elevation above bed (m)
Distance across channel (m)
Profile
Veg
WL 9 April'14
WL 12 Feb'14
WL 20 Jan'14


GAMKA-EWR4
Elevation above bed (m)
Distance across channel (m)
Profile
Veg
WL 11 April'14
WL 21 Jan'14
Logger
Logger


J1BUFF-EWR5
Elevation above bed (m)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
10
20
30
40
50
60
70
80
1
2
3
4
Distance across channel (m)
Profile
Veg
WL 9 Apr'14


J4GOUR-EWR6
Elevation above bed (m)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
-80
-60
-40
-20
0
20
40
60
80
100
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Distance across channel (m)
Profile
Veg
WL 12 Feb'14
WL 8 Apr'14
'9 Jan'14

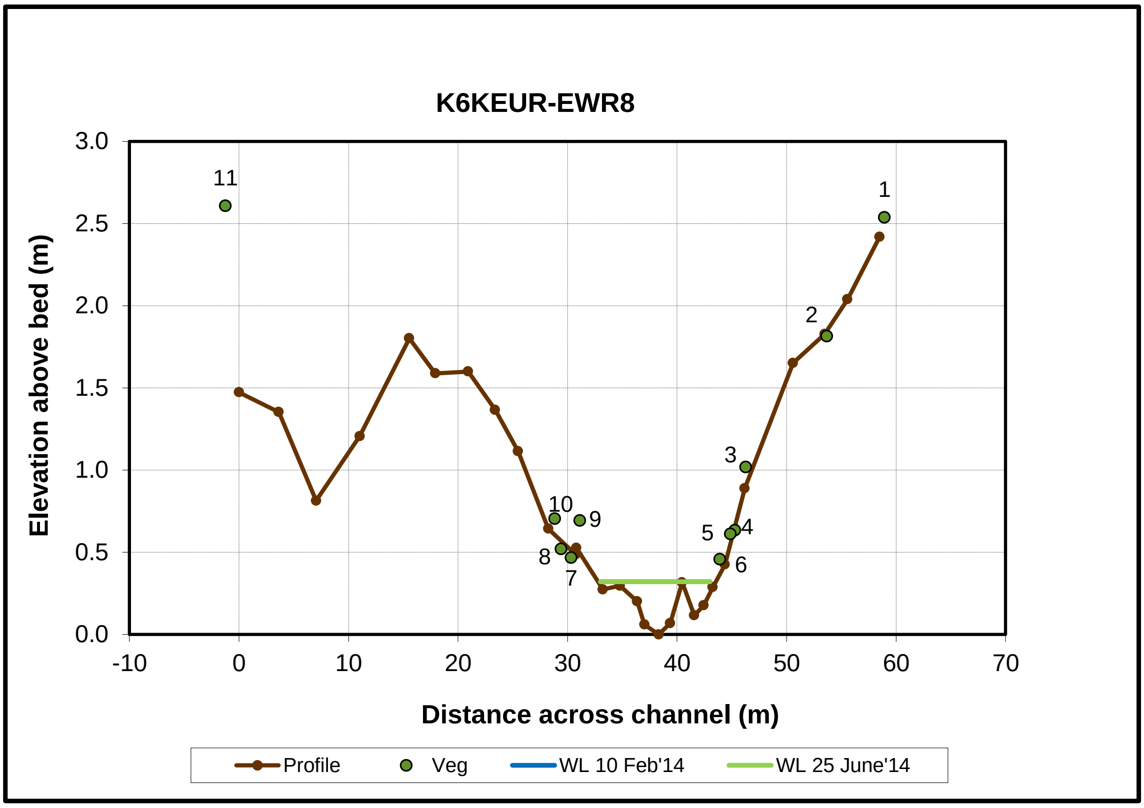


Figure C.1 Cross-sectional profiles surveyed at the Intermediate EWR sites in the study area

Table C.1 Hydraulic data collected at the Intermediate EWR sites in the study area

Site	Date	Discharge (m^3/s)
TOUWS_EWR3	20/01/2014	3.8
	12/02/2014	0.19
	09/04/2014	0.034
J2GAMK-EWR4	21/01/2014	0.48
	11/04/2014	0.14
J1BUFF-EWR5	09/04/2014	0.12
	29/07/2014	0.012
J4GOUR-EWR6	09/01/2014	c. 3500
	12/02/2014	1.43
	30/07/2014	4.47
K6KEUR-EWR8	10/02/14	0.24
	25/06/14	0.33
	31/07/14	0.33
	25/06/14	0.021

C.3 RESULTS

The lookup table is provided in **Table C.2** and shaded rows denote field trip data.

Table C.2 Lookup table providing relevant hydraulic parameters and flow classes used for ecological interpretation at the Intermediate EWR sites in the study area

Max. depth (m)	Ave. depth (m)	Discharge (m^3/s)	Width (m)	Perimeter (m)	Ave. velocity (m/s)	Max. velocity (m/s)	Fish flow class (%)							Macroinvertebrate flow class (%)				
							SVS[1]	SS	SD	FVS[3]	FS	FI	FD	SCS	FCS	VFCS[0]	SFS[4]	FFS[5]
Touws River: J1TOUW-EWR3																		
0.04	0.03	0.000	6.4	6.4	0.00	0.01	100	0	0	0	0	0	0	50	0	0	50	0
0.06	0.04	0.001	8.4	8.4	0.00	0.01	100	0	0	0	0	0	0	50	0	0	50	0
0.08	0.05	0.001	10.8	10.8	0.00	0.01	100	0	0	0	0	0	0	50	0	0	50	0
0.10	0.06	0.003	12.5	12.5	0.00	0.01	95	5	0	0	0	0	0	50	0	0	50	0
0.12	0.07	0.005	14.0	14.0	0.00	0.02	66	34	0	0	0	0	0	50	0	0	50	0
0.14	0.09	0.008	15.4	15.4	0.01	0.02	58	42	0	0	0	0	0	50	0	0	50	0
0.16	0.10	0.013	16.6	16.6	0.01	0.03	49	51	0	0	0	0	0	50	0	0	50	0
0.18	0.11	0.021	18.8	18.8	0.01	0.04	43	57	0	0	0	0	0	50	0	0	50	0
0.20	0.10	0.034	24.5	24.6	0.01	0.05	49	51	0	0	0	0	0	50	0	0	50	0
0.22	0.11	0.087	26.2	26.3	0.03	0.11	46	54	0	0	0	0	0	50	0	0	50	0
0.24	0.13	0.24	27.3	27.4	0.07	0.25	43	56	0	0	0	0	0	50	0	0	50	0
0.26	0.15	0.37	27.6	27.6	0.09	0.32	38	58	0	2	1	1	0	48	2	0	48	2
0.28	0.16	0.53	28.5	28.6	0.11	0.40	28	64	0	2	3	3	0	46	4	0	46	4
0.30	0.17	0.74	29.7	29.8	0.14	0.50	15	73	0	2	5	5	0	44	6	0	44	6
0.32	0.19	1.0	31.1	31.2	0.18	0.60	13	70	0	3	7	5	3	41	7	1	41	9
0.34	0.20	1.4	32.4	32.5	0.22	0.74	11	63	0	4	10	7	5	37	10	3	37	13
0.36	0.21	2.0	33.7	33.8	0.28	0.91	12	50	0	7	12	9	10	31	15	4	31	19
0.38	0.22	2.7	35.5	35.6	0.35	1.13	10	39	0	10	14	12	16	24	18	7	24	26
0.40	0.23	3.8	37.2	37.3	0.45	1.40	7	30	0	13	11	18	21	18	18	14	18	32
0.42	0.24	4.4	38.0	38.1	0.47	1.44	6	30	0	11	8	22	24	18	17	15	18	32
0.44	0.26	5.0	38.6	38.7	0.50	1.52	5	28	0	11	8	20	28	17	16	17	17	33
0.46	0.28	5.6	39.2	39.3	0.52	1.59	4	28	0	9	10	19	30	16	16	18	16	34
0.48	0.29	6.3	39.7	39.9	0.55	1.66	3	28	0	7	12	12	38	15	15	20	15	35
0.50	0.31	7.0	40.3	40.5	0.57	1.70	2	27	1	6	13	9	43	15	14	21	15	35

Max. depth (m)	Ave. depth (m)	Discharge (m^3/s)	Width (m)	Perimeter (m)	Ave. velocity (m/s)	Max. velocity (m/s)	Fish flow class (%)							Macroinvertebrate flow class (%)				
							SVS[1]	SS	SD	FVS[3]	FS	FI	FD	SCS	FCS	VFCS[0]	SFS[4]	FFS[5]
0.52	0.32	7.8	40.9	41.1	0.59	1.74	2	24	3	4	12	9	46	14	14	22	14	36
0.54	0.34	8.6	41.5	41.6	0.61	1.80	2	21	4	5	12	9	48	13	13	23	13	37
0.56	0.35	9.3	42.8	42.9	0.63	1.79	2	18	5	6	9	11	49	13	13	24	13	37
0.58	0.36	10.1	44.1	44.3	0.64	1.82	2	17	6	7	7	12	49	12	13	25	12	38
0.60	0.37	10.9	45.2	45.4	0.66	1.85	3	14	7	8	5	13	51	12	13	25	12	38
0.62	0.38	11.9	45.7	45.9	0.68	1.87	2	13	7	8	5	10	54	11	12	26	11	39
0.64	0.40	12.9	46.2	46.4	0.70	1.88	2	13	7	6	6	10	56	11	12	27	11	39
0.66	0.41	14.0	46.7	46.9	0.72	1.94	2	11	7	6	6	9	58	10	11	29	10	40
0.68	0.43	15.2	47.1	47.3	0.75	1.95	1	10	8	6	7	7	61	10	11	29	10	40
0.70	0.45	16.4	47.4	47.6	0.77	1.96	1	9	9	3	8	7	64	9	11	30	9	41
0.72	0.46	17.5	48.1	48.3	0.79	1.96	1	7	9	4	9	6	65	9	10	31	9	41
0.74	0.47	18.6	49.1	49.3	0.80	1.95	1	7	10	3	8	5	66	9	10	31	9	41
0.76	0.48	19.8	50.2	50.4	0.82	1.98	1	6	9	5	6	7	65	8	10	32	8	42
0.78	0.49	21.0	51.2	51.5	0.83	2.01	1	6	9	7	5	7	65	8	10	32	8	42
0.80	0.50	22.3	52.0	52.2	0.85	2.01	1	5	9	6	5	7	67	8	9	33	8	42
0.82	0.52	23.7	52.6	52.8	0.87	2.03	1	5	9	6	4	8	67	7	9	33	7	43
0.84	0.50	24.2	56.6	56.8	0.85	2.03	2	4	9	11	5	6	63	8	9	33	8	42
0.86	0.51	25.6	57.8	58.0	0.87	2.03	2	4	9	10	6	6	64	7	9	33	7	43
0.88	0.52	27.0	59.0	59.2	0.88	2.05	2	4	9	12	6	4	65	7	9	34	7	43
0.90	0.53	28.5	60.0	60.2	0.90	2.05	1	4	9	9	9	2	66	7	9	34	7	43
0.92	0.54	30.2	60.9	61.1	0.91	2.09	1	4	8	10	8	4	65	7	8	35	7	43
0.94	0.56	31.9	61.8	62.0	0.93	2.10	1	4	8	9	8	5	65	6	8	35	6	44
0.96	0.57	33.6	62.6	62.9	0.95	2.16	1	3	8	9	8	6	65	6	8	36	6	44
0.98	0.56	34.6	66.0	66.2	0.94	2.11	1	4	8	9	11	5	63	6	8	35	6	44
1.00	0.57	36.4	67.1	67.4	0.95	2.11	1	4	7	8	10	6	63	6	8	36	6	44
1.02	0.58	38.3	68.2	68.4	0.97	2.14	1	4	7	9	10	6	64	6	8	36	6	44
1.04	0.59	40.2	69.2	69.5	0.98	2.19	1	4	7	8	12	6	62	6	7	37	6	44
1.06	0.60	42.2	70.3	70.6	1.00	2.15	1	4	7	6	8	11	64	6	8	37	6	44

Max. depth (m)	Ave. depth (m)	Discharge (m^3/s)	Width (m)	Perimeter (m)	Ave. velocity (m/s)	Max. velocity (m/s)	Fish flow class (%)							Macroinvertebrate flow class (%)				
							SVS[1]	SS	SD	FVS[3]	FS	FI	FD	SCS	FCS	VFCS[0]	SFS[4]	FFS[5]
1.08	0.61	44.3	71.3	71.7	1.01	2.17	1	3	7	7	8	10	65	5	7	37	5	45
1.10	0.62	46.4	72.4	72.7	1.03	2.20	1	3	7	6	8	10	65	5	7	38	5	45
1.12	0.63	48.6	73.5	73.8	1.04	2.25	1	3	6	5	8	12	64	5	7	38	5	45
1.14	0.65	50.9	74.5	74.9	1.06	2.27	1	3	6	6	8	7	69	5	7	38	5	45
1.16	0.66	53.2	75.6	75.9	1.07	2.25	0	3	6	4	9	7	71	5	7	38	5	45
1.18	0.67	55.6	76.6	77.0	1.09	2.34	1	3	6	7	8	8	68	5	7	39	5	45
1.20	0.68	58.1	77.4	77.8	1.10	2.34	1	3	6	7	7	7	70	5	6	39	5	45
1.22	0.69	60.9	78.0	78.4	1.12	2.33	0	3	5	4	7	8	72	4	6	39	4	46
1.24	0.71	63.6	78.7	79.1	1.14	2.35	0	3	5	4	6	8	74	4	6	40	4	46
1.26	0.72	66.4	79.3	79.7	1.16	2.40	0	3	5	4	5	7	74	4	6	40	4	46
1.28	0.74	69.3	80.0	80.4	1.18	2.42	0	3	5	3	7	7	75	4	6	40	4	46
1.30	0.75	72.2	80.7	81.1	1.19	2.46	0	2	5	3	6	8	76	4	6	40	4	46
1.32	0.75	74.2	83.2	83.6	1.19	2.49	1	2	5	6	5	6	75	4	6	40	4	46
1.34	0.74	76.1	85.9	86.4	1.19	2.45	1	2	5	7	5	6	75	4	6	40	4	46
1.36	0.75	79.0	87.1	87.5	1.20	2.48	1	2	5	7	4	5	76	4	6	41	4	46
1.38	0.76	81.8	88.5	89.0	1.21	2.53	1	2	5	9	4	5	75	4	6	41	4	46
1.40	0.76	84.1	91.1	91.5	1.22	2.52	1	2	5	9	4	4	75	4	6	41	4	46
1.42	0.75	86.1	94.2	94.7	1.21	2.49	1	2	5	10	5	5	73	4	6	41	4	46
1.44	0.75	88.2	97.4	97.9	1.21	2.51	1	2	5	11	7	4	70	4	6	41	4	46
1.46	0.74	90.1	101.3	101.8	1.20	2.48	1	2	5	11	8	4	69	4	6	41	4	46
1.48	0.73	91.8	105.6	106.1	1.19	2.45	1	2	5	14	8	3	67	4	6	40	4	46
1.50	0.72	94.1	109.4	110.0	1.19	2.45	1	2	5	15	7	5	65	4	6	40	4	46
1.52	0.72	96.6	113.0	113.5	1.19	2.47	1	2	5	16	9	3	64	4	6	40	4	46
1.54	0.72	99.4	116.3	116.9	1.19	2.43	1	2	5	13	8	6	64	4	6	40	4	46
1.56	0.72	102.5	119.4	120.0	1.19	2.49	1	2	4	14	10	7	61	4	6	40	4	46
1.58	0.72	105.5	122.8	123.5	1.19	2.47	1	2	4	14	11	7	61	4	6	40	4	46
1.60	0.70	106.8	129.9	130.6	1.17	2.43	1	2	4	14	14	6	58	4	6	40	4	46
1.62	0.70	109.9	134.0	134.6	1.17	2.43	1	2	4	13	13	9	57	4	6	40	4	46

Max. depth (m)	Ave. depth (m)	Discharge (m^3/s)	Width (m)	Perimeter (m)	Ave. velocity (m/s)	Max. velocity (m/s)	Fish flow class (%)							Macroinvertebrate flow class (%)				
							SVS[1]	SS	SD	FVS[3]	FS	FI	FD	SCS	FCS	VFCS[0]	SFS[4]	FFS[5]
1.64	0.69	112.3	139.7	140.4	1.17	2.38	1	3	4	13	13	9	57	4	6	40	4	46
1.66	0.67	113.6	148.3	149.0	1.14	2.36	2	2	4	20	10	8	55	4	6	40	4	46
1.68	0.67	117.6	152.1	152.8	1.15	2.38	2	3	4	18	11	8	54	4	6	40	4	46
1.70	0.68	122.0	155.3	156.1	1.16	2.38	1	3	4	15	11	9	56	4	6	40	4	46
1.72	0.68	126.6	158.5	159.3	1.17	2.41	1	3	4	14	14	10	55	4	6	40	4	46
1.74	0.69	131.3	161.7	162.5	1.18	2.40	1	3	4	11	13	11	57	4	6	40	4	46
1.76	0.70	136.2	164.9	165.7	1.19	2.44	1	3	4	11	13	11	57	4	6	40	4	46
1.78	0.70	141.2	168.1	168.9	1.19	2.49	1	3	4	8	14	13	57	4	6	41	4	46
1.80	0.71	146.5	171.1	171.9	1.20	2.48	1	3	4	8	13	12	59	4	6	41	4	46
1.82	0.72	152.2	173.5	174.4	1.22	2.47	1	3	4	7	12	13	61	4	6	41	4	46
1.84	0.73	158.1	176.1	177.0	1.23	2.53	1	3	4	7	13	13	61	4	5	41	4	46
1.86	0.74	164.0	178.8	179.7	1.24	2.53	1	3	4	7	11	11	64	4	5	41	4	46
1.88	0.75	170.0	181.4	182.4	1.25	2.58	1	3	3	8	10	11	65	3	5	41	3	47
1.90	0.75	175.6	185.1	186.1	1.26	2.54	0	3	3	5	8	12	68	3	5	41	3	47
1.92	0.76	181.2	189.0	189.9	1.27	2.63	1	3	3	9	8	9	67	3	5	42	3	47
1.94	0.76	187.1	192.8	193.7	1.27	2.58	0	3	3	7	7	9	70	3	5	42	3	47
1.96	0.76	192.4	197.8	198.7	1.28	2.61	1	3	3	8	8	9	69	3	5	42	3	47
1.98	0.77	198.4	202.0	203.0	1.28	2.61	1	2	3	9	7	8	70	3	5	42	3	47
2.00	0.77	204.7	206.0	207.0	1.29	2.61	1	2	3	8	7	8	70	3	5	42	3	47
2.02	0.78	211.3	209.9	210.9	1.30	2.57	0	2	4	7	7	8	71	3	5	42	3	47
2.04	0.78	218.1	213.8	214.8	1.30	2.67	1	2	3	10	8	8	69	3	5	42	3	47
2.06	0.80	227.2	214.6	215.6	1.32	2.69	0	2	3	7	7	8	71	3	5	42	3	47
2.08	0.82	236.8	214.9	215.9	1.35	2.72	0	2	3	7	6	6	75	3	5	42	3	47
2.10	0.84	246.5	215.2	216.2	1.37	2.77	0	2	4	5	7	8	75	3	5	43	3	47
2.12	0.86	256.4	215.5	216.6	1.39	2.84	0	2	3	5	6	7	77	3	4	43	3	47
2.14	0.88	266.5	215.8	216.9	1.41	2.88	0	2	3	4	6	7	78	3	4	43	3	47
2.16	0.89	276.7	216.1	217.2	1.43	2.87	0	2	4	1	6	9	79	3	4	43	3	47
2.18	0.91	287.2	216.4	217.5	1.45	2.96	0	2	4	1	5	9	79	3	4	43	3	47

Max. depth (m)	Ave. depth (m)	Discharge (m^3/s)	Width (m)	Perimeter (m)	Ave. velocity (m/s)	Max. velocity (m/s)	Fish flow class (%)							Macroinvertebrate flow class (%)				
							SVS[1]	SS	SD	FVS[3]	FS	FI	FD	SCS	FCS	VFCS[0]	SFS[4]	FFS[5]
2.20	0.93	297.7	216.8	217.8	1.48	3.01	0	1	4	1	5	8	81	3	4	43	3	47
2.22	0.95	308.5	217.1	218.1	1.50	3.03	0	1	4	0	4	8	83	2	4	44	2	48
2.24	0.97	319.3	217.4	218.5	1.52	3.06	0	1	4	1	4	7	84	2	4	44	2	48
2.26	0.99	330.4	217.7	218.8	1.54	3.12	0	1	4	1	3	6	86	2	4	44	2	48
2.28	1.01	341.6	218.0	219.1	1.56	3.15	0	1	4	0	2	5	88	2	4	44	2	48
2.30	1.02	353.0	218.3	219.4	1.58	3.19	0	1	4	0	2	4	90	2	4	44	2	48
2.32	1.04	364.5	218.6	219.7	1.60	3.26	0	1	4	1	2	3	90	2	4	44	2	48
2.34	1.06	376.2	218.9	220.0	1.62	3.26	0	1	4	0	1	2	93	2	4	44	2	48
2.36	1.08	388.1	219.3	220.4	1.64	3.32	0	1	4	0	0	1	94	2	3	44	2	48
2.38	1.10	400.1	219.5	220.6	1.66	3.38	0	1	4	1	1	1	94	2	3	44	2	48
2.40	1.12	412.5	219.7	220.8	1.68	3.43	0	1	4	1	1	1	94	2	3	45	2	48
2.42	1.14	425.0	219.8	220.9	1.70	3.44	0	1	4	0	0	1	95	2	3	45	2	48
2.44	1.16	437.6	220.0	221.1	1.72	3.47	0	0	4	0	0	1	95	2	3	45	2	48
2.46	1.18	450.5	220.1	221.2	1.74	3.55	0	0	4	1	1	1	94	2	3	45	2	48
2.48	1.19	463.4	220.3	221.4	1.76	3.59	0	0	4	1	1	1	94	2	3	45	2	48
2.50	1.21	475.5	221.2	222.3	1.78	3.60	0	0	4	0	0	1	95	2	3	45	2	48
Gamka River: J2GAMK-EWR4																		
0.08	0.03	0.000	1.7	1.7	0.00	0.02	100	0	0	0	0	0	0	80	0	0	20	0
0.10	0.04	0.002	1.8	1.9	0.02	0.09	99	1	0	0	0	0	0	80	0	0	20	0
0.12	0.05	0.006	2.2	2.3	0.05	0.19	87	13	0	0	0	0	0	80	0	0	20	0
0.14	0.06	0.014	2.7	2.8	0.08	0.28	78	20	0	2	0	0	0	78	2	0	20	0
0.16	0.08	0.025	3.0	3.0	0.11	0.38	68	25	0	5	2	0	0	75	5	0	19	1
0.18	0.08	0.041	3.5	3.6	0.14	0.48	51	38	0	6	4	0	0	72	8	0	18	2
0.20	0.09	0.061	4.1	4.2	0.17	0.55	48	39	0	8	6	0	0	69	10	1	17	3
0.22	0.10	0.087	4.5	4.6	0.19	0.63	41	39	0	10	8	1	0	64	13	2	16	4
0.24	0.11	0.12	5.1	5.2	0.21	0.69	35	41	0	11	10	3	0	61	16	3	15	5
0.26	0.12	0.15	5.4	5.5	0.23	0.76	30	40	0	13	13	4	0	56	19	4	14	6
0.28	0.13	0.20	5.8	5.9	0.26	0.82	25	40	0	13	13	8	0	52	22	5	13	7

Max. depth (m)	Ave. depth (m)	Discharge (m^3/s)	Width (m)	Perimeter (m)	Ave. velocity (m/s)	Max. velocity (m/s)	Fish flow class (%)							Macroinvertebrate flow class (%)				
							SVS[1]	SS	SD	FVS[3]	FS	FI	FD	SCS	FCS	VFCS[0]	SFS[4]	FFS[5]
0.30	0.15	0.24	6.1	6.3	0.28	0.87	19	43	0	12	15	11	0	50	24	6	12	8
0.32	0.15	0.30	6.6	6.8	0.30	0.95	18	39	0	14	15	13	2	46	27	8	11	9
0.34	0.16	0.36	7.0	7.2	0.31	1.01	15	38	0	13	15	14	4	43	28	9	11	9
0.36	0.18	0.43	7.1	7.3	0.33	1.06	12	39	0	11	17	16	5	41	29	11	10	10
0.38	0.20	0.51	7.3	7.5	0.35	1.12	10	39	0	10	16	16	10	39	30	12	10	10
0.40	0.21	0.59	7.5	7.7	0.37	1.18	8	37	0	10	14	17	13	37	29	14	9	11
0.42	0.23	0.68	7.7	7.9	0.39	1.24	6	37	0	8	15	17	16	35	29	16	9	11
0.44	0.24	0.78	8.0	8.2	0.41	1.29	6	36	0	8	14	16	20	33	29	18	8	12
0.46	0.25	0.89	8.3	8.5	0.43	1.34	5	34	0	8	12	17	23	32	29	20	8	12
0.48	0.26	1.0	8.6	8.8	0.45	1.40	5	32	0	9	11	16	26	30	28	22	8	12
0.50	0.27	1.1	8.9	9.1	0.47	1.45	5	31	0	10	9	15	30	29	27	24	7	13
0.52	0.28	1.3	9.2	9.4	0.49	1.52	6	28	1	11	9	13	33	28	26	26	7	13
0.54	0.29	1.4	9.5	9.7	0.51	1.57	5	26	2	10	8	13	35	27	25	28	7	13
0.56	0.30	1.5	9.8	10.0	0.52	1.61	5	25	3	10	8	12	38	26	25	29	7	13
0.58	0.31	1.7	10.1	10.4	0.54	1.66	5	22	4	10	9	11	39	25	24	31	6	14
0.60	0.32	1.9	10.4	10.7	0.56	1.68	4	20	5	10	9	9	42	24	23	33	6	14
0.62	0.33	2.1	10.7	11.0	0.58	1.71	4	19	6	11	9	7	44	23	23	34	6	14
0.64	0.34	2.2	11.0	11.3	0.59	1.72	4	17	7	10	9	7	46	22	23	35	6	14
0.66	0.35	2.4	11.4	11.6	0.61	1.74	4	16	7	10	9	8	46	21	22	36	5	15
0.68	0.36	2.6	11.7	11.9	0.62	1.79	4	14	8	10	10	8	46	20	21	38	5	15
0.70	0.37	2.9	12.0	12.3	0.64	1.78	3	13	9	10	10	8	48	20	21	39	5	15
0.72	0.38	3.1	12.3	12.6	0.65	1.81	3	12	9	9	10	9	48	19	21	40	5	15
0.74	0.39	3.3	12.6	12.9	0.67	1.85	3	11	9	10	9	9	49	18	20	42	5	15
0.76	0.40	3.6	12.9	13.2	0.68	1.85	3	10	10	9	9	9	50	18	20	42	4	16
0.78	0.41	3.8	13.3	13.5	0.70	1.88	3	10	9	10	9	9	51	17	19	44	4	16
0.80	0.42	4.1	13.6	13.9	0.71	1.90	2	9	9	10	9	9	52	17	19	45	4	16
0.82	0.43	4.4	13.9	14.2	0.73	1.91	2	8	10	9	9	9	53	16	18	46	4	16
0.84	0.44	4.7	14.4	14.7	0.74	1.91	2	8	10	9	9	9	53	16	18	46	4	16

Max. depth (m)	Ave. depth (m)	Discharge (m^3/s)	Width (m)	Perimeter (m)	Ave. velocity (m/s)	Max. velocity (m/s)	Fish flow class (%)							Macroinvertebrate flow class (%)				
							SVS[1]	SS	SD	FVS[3]	FS	FI	FD	SCS	FCS	VFCS[0]	SFS[4]	FFS[5]
0.86	0.44	5.0	15.2	15.5	0.75	1.94	3	7	9	12	8	9	52	15	18	47	4	16
0.88	0.43	5.3	16.0	16.3	0.77	1.95	3	7	9	13	8	9	51	15	17	48	4	16
0.90	0.44	5.6	16.6	16.8	0.78	1.99	3	7	8	14	8	8	52	15	17	49	4	16
0.92	0.45	6.0	17.0	17.3	0.79	1.98	3	7	8	14	8	8	52	14	16	50	4	16
0.94	0.46	6.3	17.4	17.7	0.80	1.97	3	7	8	12	10	8	53	14	16	50	3	17
0.96	0.47	6.7	17.8	18.1	0.81	1.97	2	7	8	11	11	7	54	14	16	50	3	17
0.98	0.47	7.1	18.2	18.5	0.82	1.98	2	7	8	10	12	7	54	13	16	51	3	17
1.00	0.48	7.4	18.6	18.9	0.83	2.00	2	7	8	10	13	7	54	13	16	51	3	17
1.02	0.49	7.8	19.0	19.3	0.84	1.99	2	7	8	8	14	7	55	13	16	52	3	17
1.04	0.50	8.3	19.5	19.8	0.85	2.00	1	6	8	8	13	8	55	13	15	52	3	17
1.06	0.51	8.7	19.9	20.2	0.85	2.01	1	6	8	8	12	9	56	12	15	53	3	17
1.08	0.52	9.1	20.3	20.6	0.86	2.03	1	6	7	9	11	10	56	12	15	53	3	17
1.10	0.53	9.6	20.7	21.0	0.87	2.02	1	6	7	8	9	12	57	12	15	54	3	17
1.12	0.54	10.0	21.1	21.4	0.88	2.03	1	6	7	7	9	13	57	11	14	54	3	17
1.14	0.55	10.5	21.5	21.8	0.89	2.03	1	6	7	7	9	12	58	11	14	54	3	17
1.16	0.56	11.0	21.9	22.2	0.90	2.07	1	5	7	8	8	11	59	11	14	55	3	17
1.18	0.57	11.5	22.3	22.6	0.91	2.07	1	5	7	8	8	10	61	11	14	56	3	17
1.20	0.58	12.0	22.6	22.9	0.91	2.08	1	5	7	7	9	9	63	11	14	56	3	17
1.22	0.59	12.5	23.0	23.3	0.92	2.08	1	5	7	7	8	8	64	10	13	56	3	17
1.24	0.60	13.1	23.4	23.7	0.93	2.09	1	5	7	7	8	8	65	10	13	57	3	17
1.26	0.61	13.6	23.7	24.0	0.94	2.07	1	5	7	6	8	8	66	10	13	57	3	17
1.28	0.62	14.2	24.1	24.4	0.95	2.13	1	5	7	5	7	8	66	10	13	57	2	18
1.30	0.63	14.8	24.4	24.8	0.95	2.13	1	4	7	6	7	8	67	10	13	58	2	18
1.32	0.64	15.4	24.8	25.1	0.96	2.12	1	4	7	5	7	8	68	10	13	58	2	18
1.34	0.66	16.0	25.2	25.5	0.97	2.12	1	4	7	5	7	7	69	9	13	58	2	18
1.36	0.67	16.6	25.5	25.9	0.98	2.14	1	4	7	5	7	7	69	9	12	58	2	18
1.38	0.68	17.3	25.9	26.2	0.99	2.16	1	4	7	5	7	7	70	9	12	59	2	18
1.40	0.69	17.9	26.3	26.6	0.99	2.16	1	4	7	5	7	7	70	9	12	59	2	18

Max. depth (m)	Ave. depth (m)	Discharge (m^3/s)	Width (m)	Perimeter (m)	Ave. velocity (m/s)	Max. velocity (m/s)	Fish flow class (%)							Macroinvertebrate flow class (%)				
							SVS[1]	SS	SD	FVS[3]	FS	FI	FD	SCS	FCS	VFCS[0]	SFS[4]	FFS[5]
1.42	0.70	18.6	26.6	27.0	1.00	2.17	1	3	7	5	7	7	71	9	12	59	2	18
1.44	0.71	19.3	27.1	27.4	1.01	2.18	1	3	7	6	6	7	71	9	12	59	2	18
1.46	0.71	20.0	27.6	28.0	1.02	2.18	1	3	7	6	6	6	71	9	12	60	2	18
1.48	0.72	20.7	28.2	28.5	1.02	2.18	1	3	7	6	6	5	71	9	12	60	2	18
1.50	0.72	21.4	28.7	29.1	1.03	2.21	1	3	7	7	6	6	70	8	11	60	2	18
1.52	0.73	22.2	29.2	29.6	1.04	2.20	1	3	7	7	6	5	72	8	11	60	2	18
1.54	0.75	22.9	29.4	29.7	1.05	2.23	1	3	7	7	6	5	72	8	11	61	2	18
1.56	0.76	23.7	29.6	29.9	1.05	2.28	1	3	7	6	7	5	73	8	11	61	2	18
1.58	0.78	24.5	29.7	30.1	1.06	2.26	0	3	7	3	7	6	74	8	11	61	2	18
1.60	0.79	25.3	29.9	30.3	1.07	2.27	0	3	7	3	6	6	74	8	11	61	2	18
1.62	0.81	26.1	30.1	30.5	1.07	2.30	0	3	7	2	7	6	75	8	11	61	2	18
1.64	0.82	26.9	30.3	30.7	1.08	2.31	0	3	7	2	7	6	75	8	11	62	2	18
1.66	0.82	27.8	31.2	31.6	1.09	2.29	0	2	7	3	6	6	75	8	11	62	2	18
1.68	0.81	28.7	32.1	32.5	1.10	2.32	1	2	6	6	6	5	73	7	10	62	2	18
1.70	0.80	29.5	33.4	33.8	1.10	2.32	1	2	6	8	5	6	72	7	10	62	2	18
1.72	0.78	30.4	35.3	35.8	1.11	2.29	1	2	6	11	5	5	70	7	10	62	2	18
1.74	0.76	31.4	37.3	37.8	1.11	2.32	1	2	6	15	5	5	66	7	10	62	2	18
1.76	0.74	32.3	39.4	39.9	1.11	2.33	2	2	5	17	5	5	64	7	10	63	2	18
1.78	0.72	33.2	41.6	42.1	1.12	2.34	2	2	5	19	7	4	61	7	10	63	2	18
1.80	0.70	34.2	43.6	44.1	1.12	2.33	2	2	5	20	8	4	59	7	10	63	2	18
1.82	0.71	35.2	44.6	45.1	1.12	2.32	2	2	5	19	9	4	59	7	10	63	2	18
1.84	0.72	36.2	45.0	45.5	1.12	2.35	2	2	5	16	11	6	59	7	10	63	2	18
1.86	0.74	37.2	45.4	45.9	1.12	2.33	1	3	5	13	12	7	60	7	10	63	2	18
1.88	0.75	38.2	45.7	46.3	1.12	2.36	1	3	5	10	14	9	59	7	10	63	2	18
1.90	0.76	39.3	46.1	46.7	1.12	2.34	1	3	5	8	14	10	59	7	10	63	2	18
1.92	0.78	40.3	46.5	47.1	1.12	2.35	1	3	5	6	14	11	60	7	10	63	2	18
1.94	0.79	41.4	46.9	47.5	1.12	2.33	0	3	5	3	14	13	61	7	10	63	2	18
1.96	0.80	42.5	47.3	47.9	1.12	2.32	0	3	5	3	13	13	62	7	10	63	2	18

Max. depth (m)	Ave. depth (m)	Discharge (m^3/s)	Width (m)	Perimeter (m)	Ave. velocity (m/s)	Max. velocity (m/s)	Fish flow class (%)							Macroinvertebrate flow class (%)				
							SVS[1]	SS	SD	FVS[3]	FS	FI	FD	SCS	FCS	VFCS[0]	SFS[4]	FFS[5]
1.98	0.82	43.6	47.6	48.3	1.12	2.35	0	3	5	3	12	13	64	7	10	63	2	18
2.00	0.83	44.8	48.0	48.7	1.12	2.33	0	3	5	3	9	11	67	7	10	63	2	18
2.02	0.84	45.9	48.4	49.1	1.12	2.34	0	3	5	3	8	11	69	7	10	63	2	18
2.04	0.86	47.1	48.9	49.6	1.13	2.36	0	3	5	3	7	10	71	7	10	63	2	18
2.06	0.87	48.3	49.4	50.1	1.13	2.34	0	3	5	3	5	8	75	7	10	63	2	18
2.08	0.86	49.5	50.7	51.4	1.13	2.36	1	3	5	5	4	6	75	7	10	63	2	18
2.10	0.88	50.7	51.1	51.8	1.13	2.36	0	3	5	5	4	5	77	7	10	63	2	18
2.12	0.89	51.9	51.5	52.2	1.13	2.34	0	3	5	4	4	6	77	7	10	63	2	18
2.14	0.90	53.2	51.8	52.6	1.13	2.37	0	3	5	4	4	5	78	7	10	63	2	18
2.16	0.92	54.5	52.2	53.0	1.14	2.35	0	3	6	4	4	4	79	7	10	63	2	18
2.18	0.93	55.7	52.6	53.4	1.14	2.39	0	3	6	4	4	5	78	7	10	63	2	18
2.20	0.94	57.1	53.0	53.7	1.14	2.38	0	2	6	4	4	4	79	7	10	63	2	18
2.22	0.96	58.4	53.4	54.1	1.14	2.36	0	2	6	4	4	4	80	7	10	63	2	18
2.24	0.97	59.7	53.8	54.5	1.15	2.38	0	2	6	3	4	5	79	7	10	63	2	18
2.26	0.98	61.1	54.1	54.9	1.15	2.37	0	2	7	2	4	5	80	7	10	63	2	18
2.28	1.00	62.5	54.5	55.3	1.15	2.40	0	2	7	3	4	5	80	7	10	63	2	18
2.30	1.01	63.9	54.9	55.7	1.15	2.42	0	2	7	3	4	5	80	7	10	63	2	18
2.32	1.02	65.3	55.3	56.1	1.16	2.42	0	2	7	2	4	5	80	7	10	63	2	18
2.34	1.04	66.7	55.7	56.4	1.16	2.42	0	2	7	2	3	5	81	7	10	63	2	18
2.36	1.05	68.2	56.0	56.8	1.16	2.43	0	1	7	2	3	5	81	7	10	64	2	18
2.38	1.06	69.7	56.4	57.2	1.16	2.44	0	1	7	2	3	5	81	7	10	64	2	18
2.40	1.07	71.1	56.7	57.5	1.17	2.45	0	1	7	2	3	3	83	7	10	64	2	18
2.42	1.09	72.7	57.1	57.9	1.17	2.45	0	1	7	2	3	3	83	7	10	64	2	18
2.44	1.10	74.2	57.5	58.3	1.17	2.47	0	1	7	3	3	3	82	7	10	64	2	18
2.46	1.11	75.7	57.8	58.6	1.18	2.46	0	1	7	3	3	3	82	7	10	64	2	18
2.48	1.13	77.3	58.2	59.0	1.18	2.47	0	1	7	3	3	3	83	7	9	64	2	18
2.50	1.14	78.9	58.5	59.3	1.18	2.49	0	1	7	3	3	3	83	7	9	64	2	18
2.52	1.15	80.5	59.0	59.8	1.18	2.46	0	1	7	2	3	3	84	7	9	64	2	18

Max. depth (m)	Ave. depth (m)	Discharge (m^3/s)	Width (m)	Perimeter (m)	Ave. velocity (m/s)	Max. velocity (m/s)	Fish flow class (%)							Macroinvertebrate flow class (%)				
							SVS[1]	SS	SD	FVS[3]	FS	FI	FD	SCS	FCS	VFCS[0]	SFS[4]	FFS[5]
2.54	1.15	82.1	59.9	60.7	1.19	2.50	0	1	7	3	3	3	82	7	9	64	2	18
2.56	1.16	83.8	60.7	61.5	1.19	2.48	0	1	7	3	3	3	82	7	9	64	2	18
2.58	1.16	85.4	61.6	62.4	1.19	2.47	0	1	7	4	3	3	82	7	9	64	2	18
2.60	1.17	87.1	62.4	63.3	1.20	2.48	0	1	7	4	4	3	81	7	9	64	2	18
2.62	1.17	88.8	63.3	64.1	1.20	2.49	0	1	7	4	4	3	80	7	9	64	2	18
2.64	1.18	90.5	63.8	64.7	1.20	2.48	0	1	7	4	4	3	81	7	9	64	2	18
2.66	1.20	92.3	64.0	64.9	1.20	2.49	0	1	7	4	4	3	81	7	9	64	2	18
2.68	1.21	94.1	64.2	65.0	1.21	2.52	0	1	7	5	4	3	81	7	9	64	2	18
2.70	1.23	95.8	64.4	65.2	1.21	2.50	0	1	7	4	4	3	81	7	9	64	2	18
2.72	1.25	97.6	64.6	65.4	1.21	2.52	0	1	7	4	4	3	81	6	9	64	2	18
2.74	1.26	99.5	64.8	65.6	1.22	2.51	0	1	7	3	3	4	82	7	9	64	2	18
2.76	1.28	101.3	64.9	65.8	1.22	2.51	0	1	7	2	3	3	83	6	9	64	2	18
2.78	1.30	103.2	65.1	66.0	1.22	2.55	0	1	7	2	3	4	83	6	9	65	2	18
2.80	1.31	105.1	65.5	66.4	1.23	2.56	0	1	7	2	2	4	83	6	9	65	2	18
2.82	1.32	107.0	65.9	66.8	1.23	2.57	0	1	7	1	2	5	84	6	9	65	2	18
2.84	1.33	108.9	66.4	67.3	1.23	2.55	0	1	7	1	2	4	84	6	9	65	2	18
2.86	1.34	110.8	66.8	67.7	1.24	2.57	0	1	7	1	2	4	85	6	9	65	2	18
2.88	1.35	112.8	67.2	68.1	1.24	2.60	0	1	7	2	2	4	84	6	9	65	2	18
2.90	1.36	114.8	67.7	68.6	1.24	2.58	0	1	7	2	2	4	84	6	9	65	2	18
2.92	1.38	116.8	68.1	69.0	1.25	2.59	0	1	7	2	2	4	84	6	9	65	2	18
2.94	1.39	118.8	68.56	69.48	1.25	2.62	0	1	7	2	2	4	84	6	9	65	2	18
2.96	1.40	120.9	69.00	69.93	1.25	2.63	0	1	7	3	3	3	84	6	9	65	2	18
2.98	1.41	122.9	69.44	70.38	1.26	2.62	0	1	7	2	2	3	85	6	9	65	2	18
3.00	1.42	125.0	69.88	70.82	1.26	2.65	0	1	7	3	3	3	84	6	9	65	2	18
Buffels River: J1BUFF-EWR5																		
0.04	0.02	0.000	0.9	1.0	0.02	0.09	100	0	0	0	0	0	0	50	0	0	50	0
0.06	0.03	0.001	1.4	1.5	0.03	0.12	100	0	0	0	0	0	0	50	0	0	50	0
0.08	0.04	0.003	1.9	2.0	0.04	0.15	100	0	0	0	0	0	0	50	0	0	50	0

Max. depth (m)	Ave. depth (m)	Discharge (m^3/s)	Width (m)	Perimeter (m)	Ave. velocity (m/s)	Max. velocity (m/s)	Fish flow class (%)							Macroinvertebrate flow class (%)				
							SVS[1]	SS	SD	FVS[3]	FS	FI	FD	SCS	FCS	VFCS[0]	SFS[4]	FFS[5]
0.10	0.05	0.006	2.4	2.5	0.05	0.18	100	0	0	0	0	0	0	50	0	0	50	0
0.12	0.06	0.010	2.9	3.0	0.06	0.20	85	15	0	0	0	0	0	50	0	0	50	0
0.14	0.07	0.016	3.3	3.3	0.07	0.24	71	28	0	0	0	0	0	50	0	0	50	0
0.16	0.07	0.022	4.3	4.4	0.07	0.25	67	32	0	0	0	0	0	50	0	0	50	0
0.18	0.08	0.030	5.4	5.5	0.07	0.26	63	36	0	1	0	0	0	49	1	0	49	1
0.20	0.08	0.043	6.3	6.4	0.08	0.29	60	37	0	1	1	0	0	49	1	0	49	1
0.22	0.10	0.062	6.8	7.0	0.09	0.33	55	41	0	2	2	0	0	48	2	0	48	2
0.24	0.11	0.084	7.4	7.6	0.11	0.37	53	41	0	3	2	1	0	47	3	0	47	3
0.26	0.12	0.11	7.8	8.1	0.12	0.41	40	52	0	3	3	2	0	46	4	0	46	4
0.28	0.13	0.14	8.3	8.5	0.13	0.45	32	59	0	3	4	2	0	45	5	0	45	5
0.30	0.15	0.18	8.7	9.0	0.14	0.49	25	63	0	3	5	3	0	44	5	0	44	6
0.32	0.16	0.22	9.2	9.5	0.15	0.52	22	65	0	3	6	4	0	43	6	1	43	7
0.34	0.17	0.27	9.5	9.8	0.16	0.56	19	66	0	3	6	4	2	42	7	1	42	8
0.36	0.19	0.33	9.7	10.1	0.18	0.61	16	66	0	4	6	5	3	41	8	1	41	9
0.38	0.21	0.39	9.8	10.2	0.19	0.65	12	68	0	3	6	7	4	40	8	2	40	10
0.40	0.22	0.46	9.9	10.3	0.21	0.70	10	67	0	3	6	9	6	38	9	2	38	12
0.42	0.24	0.54	10.0	10.4	0.22	0.73	6	68	0	2	6	11	8	37	11	3	37	13
0.44	0.26	0.63	10.1	10.5	0.24	0.78	4	65	0	2	6	12	10	35	12	3	35	15
0.46	0.28	0.72	10.2	10.6	0.25	0.82	3	64	0	1	6	12	14	33	14	3	33	17
0.48	0.30	0.82	10.3	10.7	0.27	0.87	3	59	0	2	6	10	20	31	15	4	31	19
0.50	0.31	0.93	10.4	10.9	0.28	0.90	2	57	1	2	4	10	25	30	16	4	30	20
0.52	0.33	1.0	10.5	11.0	0.30	0.95	3	51	2	2	4	9	29	28	17	5	28	22
0.54	0.35	1.2	10.6	11.1	0.32	0.99	2	46	5	2	3	10	32	26	18	6	26	24
0.56	0.36	1.3	10.7	11.2	0.33	1.03	2	41	7	2	2	9	36	25	19	6	25	25
0.58	0.38	1.4	10.9	11.4	0.35	1.06	2	37	9	2	2	7	40	24	19	7	24	26
0.60	0.39	1.6	11.0	11.5	0.37	1.10	2	33	10	2	2	6	44	23	20	8	23	27
0.62	0.41	1.7	11.1	11.6	0.39	1.14	2	29	11	3	2	5	48	21	20	9	21	29
0.64	0.42	1.9	11.2	11.7	0.40	1.18	2	25	13	3	3	4	51	20	20	10	20	30

Max. depth (m)	Ave. depth (m)	Discharge (m^3/s)	Width (m)	Perimeter (m)	Ave. velocity (m/s)	Max. velocity (m/s)	Fish flow class (%)							Macroinvertebrate flow class (%)				
							SVS[1]	SS	SD	FVS[3]	FS	FI	FD	SCS	FCS	VFCS[0]	SFS[4]	FFS[5]
0.66	0.44	2.1	11.3	11.9	0.42	1.22	2	21	15	3	3	3	53	19	19	11	19	31
0.68	0.45	2.3	11.5	12.0	0.44	1.25	2	18	16	3	3	3	56	18	20	12	18	32
0.70	0.47	2.5	11.6	12.1	0.46	1.29	2	14	18	3	3	3	57	17	19	14	17	33
0.72	0.48	2.7	11.7	12.3	0.48	1.32	1	12	19	3	4	3	58	16	18	15	16	34
0.74	0.50	2.9	11.8	12.4	0.50	1.36	1	10	20	3	4	3	59	15	18	17	15	35
0.76	0.51	3.2	12.0	12.5	0.52	1.40	1	9	19	3	4	3	61	15	17	18	15	35
0.78	0.53	3.4	12.1	12.7	0.54	1.43	1	8	19	3	4	3	62	14	17	19	14	36
0.80	0.54	3.7	12.2	12.8	0.56	1.46	1	7	19	3	4	3	63	13	16	21	13	37
0.82	0.56	4.0	12.3	12.9	0.58	1.50	1	5	19	3	4	3	64	12	15	22	12	38
0.84	0.57	4.3	12.4	13.0	0.60	1.53	1	5	18	3	4	3	66	12	15	23	12	38
0.86	0.59	4.6	12.6	13.2	0.63	1.56	1	4	17	4	4	4	66	11	14	25	11	39
0.88	0.60	5.0	12.7	13.3	0.65	1.60	1	4	16	4	4	4	67	11	13	26	11	39
0.90	0.62	5.3	12.8	13.4	0.68	1.63	1	4	15	4	4	4	68	10	13	27	10	40
0.92	0.63	5.7	12.9	13.6	0.70	1.65	1	3	15	4	4	4	69	9	12	28	9	41
0.94	0.64	6.1	13.1	13.7	0.73	1.68	1	3	14	4	4	4	70	9	12	29	9	41
0.96	0.66	6.5	13.2	13.8	0.75	1.72	1	3	13	4	4	4	72	8	11	30	8	42
0.98	0.67	7.0	13.3	14.0	0.78	1.74	1	3	12	4	4	4	73	8	11	31	8	42
1.00	0.69	7.4	13.4	14.1	0.81	1.80	1	3	12	4	4	4	74	7	10	32	7	43
1.02	0.70	7.9	13.5	14.2	0.84	1.84	1	3	11	4	4	4	74	7	10	33	7	43
1.04	0.71	8.4	13.7	14.3	0.87	1.87	1	2	10	4	4	4	75	7	9	34	7	43
1.06	0.73	9.0	13.8	14.5	0.90	1.94	1	2	10	4	4	5	76	6	9	35	6	44
1.08	0.74	9.5	13.9	14.6	0.93	1.97	0	2	9	4	4	5	77	6	8	36	6	44
1.10	0.75	10.1	14.0	14.7	0.96	2.00	0	2	8	4	4	5	78	5	8	37	5	45
1.12	0.77	10.8	14.2	14.9	0.99	2.08	0	2	8	4	4	4	78	5	8	37	5	45
1.14	0.78	11.4	14.3	15.0	1.03	2.14	0	2	7	4	4	4	79	5	7	38	5	45
1.16	0.79	12.2	14.4	15.1	1.06	2.20	0	2	7	4	4	4	80	4	7	39	4	46
1.18	0.81	12.9	14.5	15.3	1.10	2.27	0	1	6	3	4	4	81	4	6	39	4	46
1.20	0.82	13.7	14.6	15.4	1.14	2.34	0	1	6	3	4	4	81	4	6	40	4	46

Max. depth (m)	Ave. depth (m)	Discharge (m^3/s)	Width (m)	Perimeter (m)	Ave. velocity (m/s)	Max. velocity (m/s)	Fish flow class (%)							Macroinvertebrate flow class (%)				
							SVS[1]	SS	SD	FVS[3]	FS	FI	FD	SCS	FCS	VFCS[0]	SFS[4]	FFS[5]
1.22	0.83	14.5	14.8	15.6	1.18	2.40	0	1	6	4	4	4	81	4	6	41	4	46
1.24	0.83	15.2	15.1	15.9	1.21	2.45	0	1	5	5	4	4	80	3	6	41	3	47
1.26	0.84	16.0	15.4	16.2	1.24	2.54	0	1	5	6	4	4	80	3	5	42	3	47
1.28	0.84	16.9	15.7	16.5	1.28	2.58	0	1	5	6	4	4	80	3	5	42	3	47
1.30	0.85	17.8	16.0	16.7	1.32	2.66	0	1	5	7	4	4	80	3	5	42	3	47
1.32	0.84	18.7	16.4	17.2	1.35	2.71	0	1	4	7	5	3	79	3	5	42	3	47
1.34	0.83	19.4	17.2	18.0	1.37	2.75	1	1	4	10	6	3	76	3	5	42	3	47
1.36	0.81	20.1	17.9	18.7	1.39	2.80	1	1	4	13	6	4	72	3	5	43	3	47
1.38	0.80	21.0	18.7	19.5	1.41	2.87	1	1	4	16	6	3	70	3	4	43	3	47
1.40	0.79	21.9	19.4	20.2	1.44	2.93	1	1	3	17	7	2	69	3	4	43	3	47
1.42	0.78	23.0	20.0	20.8	1.47	2.96	1	1	3	17	8	3	68	3	4	43	3	47
1.44	0.78	24.2	20.6	21.4	1.51	3.04	1	1	3	16	10	4	66	2	4	44	2	48
1.46	0.77	25.4	21.4	22.2	1.54	3.13	1	1	3	15	11	4	65	2	4	44	2	48
1.48	0.76	26.7	22.2	23.0	1.58	3.20	1	1	3	15	12	6	62	2	4	44	2	48
1.50	0.76	28.0	23.0	23.8	1.61	3.25	1	1	3	14	13	6	62	2	4	44	2	48
1.52	0.75	28.6	23.8	24.6	1.60	3.27	1	1	3	15	15	6	60	2	4	44	2	48
1.54	0.75	29.4	24.5	25.3	1.60	3.22	1	1	3	14	13	9	60	2	4	44	2	48
1.56	0.75	30.2	25.2	26.0	1.60	3.22	1	1	2	14	13	10	59	2	4	44	2	48
1.58	0.73	30.5	26.5	27.4	1.58	3.19	1	1	2	15	13	10	57	2	4	44	2	48
1.60	0.71	30.9	28.0	28.8	1.55	3.12	1	2	2	17	14	10	55	2	4	44	2	48
1.62	0.70	31.3	29.4	30.3	1.53	3.10	1	2	2	18	12	11	54	2	4	44	2	48
1.64	0.69	32.1	30.6	31.5	1.52	3.07	1	2	2	18	12	11	54	2	4	44	2	48
1.66	0.69	33.0	31.5	32.4	1.52	3.08	1	2	2	18	12	11	55	2	4	44	2	48
1.68	0.69	34.0	32.3	33.3	1.52	3.07	1	2	2	18	12	10	56	2	4	44	2	48
1.70	0.70	35.3	32.9	33.9	1.54	3.11	1	2	2	16	13	11	56	2	4	44	2	48
1.72	0.71	36.6	33.5	34.4	1.55	3.10	1	2	2	13	13	11	58	2	4	44	2	48
1.74	0.71	37.9	34.1	35.0	1.56	3.11	1	2	2	11	14	12	59	2	4	44	2	48
1.76	0.72	39.3	34.7	35.6	1.57	3.12	0	2	2	9	14	12	61	2	4	44	2	48

Max. depth (m)	Ave. depth (m)	Discharge (m^3/s)	Width (m)	Perimeter (m)	Ave. velocity (m/s)	Max. velocity (m/s)	Fish flow class (%)							Macroinvertebrate flow class (%)				
							SVS[1]	SS	SD	FVS[3]	FS	FI	FD	SCS	FCS	VFCS[0]	SFS[4]	FFS[5]
1.78	0.73	40.6	35.3	36.3	1.58	3.20	0	2	2	9	14	12	61	2	4	44	2	48
1.80	0.73	42.0	36.0	36.9	1.59	3.23	0	2	2	9	14	12	61	2	4	44	2	48
1.82	0.74	43.4	36.7	37.6	1.60	3.24	0	2	2	8	13	12	62	2	4	44	2	48
1.84	0.75	44.9	37.3	38.3	1.61	3.27	0	2	2	8	11	12	64	2	3	44	2	48
1.86	0.75	46.4	38.0	39.0	1.62	3.27	0	2	2	8	9	12	66	2	3	44	2	48
1.88	0.76	47.8	38.7	39.7	1.63	3.26	0	2	2	7	9	11	69	2	4	44	2	48
1.90	0.76	49.2	39.7	40.7	1.63	3.28	0	2	2	8	8	10	69	2	3	44	2	48
1.92	0.76	50.6	40.7	41.7	1.63	3.32	0	2	2	10	8	9	69	2	3	44	2	48
1.94	0.76	52.1	41.6	42.6	1.64	3.31	0	2	2	10	8	9	69	2	3	44	2	48
1.96	0.77	53.6	42.6	43.6	1.64	3.33	0	2	2	10	8	9	70	2	3	44	2	48
1.98	0.77	55.1	43.5	44.5	1.64	3.36	0	2	2	9	8	9	69	2	3	44	2	48
2.00	0.77	56.4	44.9	45.9	1.64	3.32	0	2	2	10	8	8	69	2	3	44	2	48
2.02	0.76	57.5	46.6	47.6	1.63	3.28	1	2	2	11	9	7	68	2	3	44	2	48
2.04	0.75	58.7	48.3	49.3	1.62	3.24	1	2	2	11	9	7	68	2	4	44	2	48
2.06	0.76	60.9	48.9	50.0	1.63	3.27	1	1	2	11	9	7	68	2	3	44	2	48
2.08	0.78	63.2	49.3	50.3	1.65	3.33	0	2	2	10	9	8	68	2	3	44	2	48
2.10	0.79	65.7	49.7	50.7	1.67	3.40	0	1	2	9	9	8	69	2	3	45	2	48
2.12	0.80	68.1	50.0	51.1	1.69	3.41	0	1	3	8	9	8	71	2	3	45	2	48
2.14	0.82	70.7	50.4	51.5	1.71	3.52	0	1	2	7	9	9	70	2	3	45	2	48
2.16	0.84	73.4	50.5	51.6	1.74	3.54	0	1	2	5	8	10	73	2	3	45	2	48
2.18	0.85	76.3	50.6	51.7	1.76	3.59	0	1	3	4	8	11	73	2	3	45	2	48
2.20	0.87	79.2	50.7	51.8	1.79	3.62	0	1	3	2	7	12	75	2	3	45	2	48
2.22	0.89	82.1	50.8	51.9	1.81	3.66	0	1	3	1	6	11	78	2	3	45	2	48
2.24	0.91	85.1	50.9	52.0	1.84	3.74	0	1	3	2	6	10	79	2	3	45	2	48
2.26	0.93	88.1	51.0	52.1	1.86	3.76	0	1	3	1	5	10	81	2	3	45	2	48
2.28	0.95	91.2	51.1	52.2	1.89	3.84	0	1	3	1	5	9	81	2	3	45	2	48
2.30	0.96	94.3	51.2	52.3	1.91	3.86	0	1	3	0	4	8	84	2	3	45	2	48
2.32	0.98	97.5	51.3	52.5	1.93	3.89	0	1	3	0	3	6	87	2	3	45	2	48

Max. depth (m)	Ave. depth (m)	Discharge (m^3/s)	Width (m)	Perimeter (m)	Ave. velocity (m/s)	Max. velocity (m/s)	Fish flow class (%)							Macroinvertebrate flow class (%)				
							SVS[1]	SS	SD	FVS[3]	FS	FI	FD	SCS	FCS	VFCS[0]	SFS[4]	FFS[5]
2.34	1.00	100.7	51.4	52.6	1.96	3.93	0	1	3	0	2	4	90	2	3	45	2	48
2.36	1.02	103.9	51.5	52.7	1.98	3.98	0	1	3	0	1	3	92	2	3	46	2	48
2.38	1.04	107.2	51.6	52.8	2.00	4.03	0	1	3	0	1	2	93	2	3	46	2	48
2.40	1.05	110.5	51.8	52.9	2.03	4.07	0	1	3	0	1	2	93	2	3	46	2	48
2.42	1.07	113.8	51.9	53.0	2.05	4.12	0	1	3	0	1	2	94	2	2	46	2	48
2.44	1.09	117.2	52.0	53.1	2.07	4.19	0	1	3	0	1	2	94	2	2	46	2	48
2.46	1.11	120.7	52.1	53.3	2.09	4.23	0	1	3	0	1	2	94	2	2	46	2	48
2.48	1.12	124.2	52.2	53.4	2.12	4.26	0	1	3	0	0	1	95	2	2	46	2	48
2.50	1.14	127.7	52.3	53.5	2.14	4.29	0	0	3	0	0	1	95	2	2	46	2	48
2.52	1.16	131.2	52.4	53.6	2.16	4.34	0	0	3	0	0	1	95	2	2	46	2	48
2.54	1.18	134.9	52.5	53.7	2.18	4.37	0	0	3	0	0	1	95	2	2	46	2	48
2.56	1.19	138.5	52.6	53.8	2.20	4.43	0	0	3	0	0	1	95	2	2	46	2	48
2.58	1.21	142.2	52.7	54.0	2.23	4.49	0	0	3	0	0	1	95	2	2	46	2	48
2.60	1.23	145.9	52.8	54.1	2.25	4.54	0	0	3	0	0	1	95	2	2	46	2	48
2.62	1.25	149.7	52.9	54.2	2.27	4.63	0	0	3	1	1	1	95	2	2	46	2	48
2.64	1.26	153.5	53.1	54.3	2.29	4.63	0	0	3	1	1	1	95	2	2	46	2	48
2.66	1.28	157.3	53.2	54.4	2.31	4.69	0	0	3	1	1	1	95	2	2	46	2	48
2.68	1.30	161.2	53.3	54.5	2.33	4.73	0	0	3	1	1	1	95	2	2	46	2	48
2.70	1.32	165.2	53.4	54.6	2.35	4.78	0	0	3	1	1	1	95	2	2	47	2	48
2.72	1.33	169.1	53.5	54.8	2.37	4.82	0	0	3	1	1	1	95	2	2	47	2	48
2.74	1.35	173.1	53.6	54.9	2.39	4.87	0	0	3	1	1	1	95	1	2	47	1	49
2.76	1.37	177.2	53.7	55.0	2.41	4.89	0	0	3	1	1	1	95	1	2	47	1	49
2.78	1.39	181.3	53.8	55.1	2.43	4.91	0	0	3	1	1	1	95	1	2	47	1	49
2.80	1.40	185.4	53.9	55.2	2.45	4.94	0	0	3	1	1	1	95	1	2	47	1	49
2.82	1.42	189.6	54.0	55.3	2.47	5.01	0	0	3	1	1	1	95	1	2	47	1	49
2.84	1.44	193.8	54.1	55.5	2.49	5.07	0	0	3	1	1	1	95	1	2	47	1	49
2.86	1.45	198.0	54.2	55.6	2.51	5.11	0	0	3	1	1	1	95	1	2	47	1	49
2.88	1.47	202.3	54.35	55.68	2.53	5.14	0	0	3	1	1	1	95	1	2	47	1	49

Max. depth (m)	Ave. depth (m)	Discharge (m^3/s)	Width (m)	Perimeter (m)	Ave. velocity (m/s)	Max. velocity (m/s)	Fish flow class (%)							Macroinvertebrate flow class (%)				
							SVS[1]	SS	SD	FVS[3]	FS	FI	FD	SCS	FCS	VFCS[0]	SFS[4]	FFS[5]
2.90	1.49	206.6	54.46	55.80	2.55	5.18	0	0	3	0	1	1	95	1	2	47	1	49
2.92	1.51	211.0	54.57	55.91	2.57	5.22	0	0	3	0	1	1	95	1	2	47	1	49
2.94	1.52	215.4	54.68	56.03	2.59	5.26	0	0	3	0	1	1	95	1	2	47	1	49
2.96	1.54	219.8	54.78	56.14	2.61	5.27	0	0	3	0	0	1	95	1	2	47	1	49
2.98	1.56	224.3	54.89	56.26	2.63	5.34	0	0	3	1	1	1	94	1	2	47	1	49
3.00	1.57	228.8	55.00	56.37	2.64	5.37	0.00	0.00	3.00	1.00	1.00	1.00	94.00	1.00	2.00	47.00	1.00	49.00
Gouritz River: J4GOUR-EWR6																		
0.05	0.03	0.001	1.0	1.0	0.05	0.17	100	0	0	0	0	0	0	70	0	0	30	0
0.10	0.06	0.008	1.5	1.5	0.09	0.32	95	1	0	4	0	0	0	67	3	0	29	1
0.15	0.09	0.022	1.8	1.9	0.13	0.44	41	50	0	4	5	0	0	64	6	0	27	3
0.20	0.11	0.043	2.6	2.7	0.15	0.52	38	49	0	6	7	0	0	61	8	1	26	4
0.25	0.11	0.072	4.0	4.1	0.17	0.55	46	39	0	8	3	4	0	60	9	1	26	4
0.30	0.10	0.12	7.4	7.4	0.17	0.55	55	31	0	9	2	3	0	60	9	1	26	4
0.35	0.10	0.22	12.3	12.4	0.18	0.60	55	27	0	12	3	1	2	57	11	2	25	5
0.40	0.12	0.44	15.5	15.7	0.23	0.75	37	35	0	15	9	2	3	50	16	4	21	9
0.45	0.15	0.81	18.2	18.4	0.29	0.95	20	38	0	15	19	5	4	40	23	6	17	13
0.50	0.18	1.39	20.1	20.3	0.37	1.13	10	34	0	12	23	14	7	31	27	12	13	17
0.55	0.22	2.23	22.1	22.3	0.47	1.29	6	25	2	12	20	23	13	23	27	21	10	20
0.60	0.26	2.85	22.9	23.2	0.48	1.27	4	25	2	8	13	25	23	22	27	22	9	21
0.65	0.29	3.50	24.0	24.3	0.49	1.29	2	25	2	6	11	17	36	21	26	24	9	21
0.70	0.32	4.23	26.0	26.3	0.51	1.31	3	22	3	8	8	13	42	20	25	25	9	21
0.75	0.36	5.04	26.9	27.3	0.52	1.31	3	20	5	7	5	11	49	19	25	26	8	22
0.80	0.39	5.95	28.6	29.0	0.54	1.35	2	17	7	6	9	7	52	18	24	28	8	22
0.85	0.42	6.95	29.6	30.0	0.56	1.36	2	13	10	6	7	6	55	18	23	29	8	22
0.90	0.46	8.05	30.6	31.0	0.58	1.37	1	11	13	4	8	7	57	17	22	30	7	23
0.95	0.49	9.25	31.5	31.9	0.59	1.41	1	9	13	4	5	7	60	16	21	32	7	23
1.00	0.53	10.5	32.4	32.9	0.62	1.45	1	7	14	4	5	7	62	15	21	34	7	23
1.05	0.56	12.0	33.5	34.0	0.64	1.48	1	6	14	5	5	5	64	15	20	36	6	24

Max. depth (m)	Ave. depth (m)	Discharge (m^3/s)	Width (m)	Perimeter (m)	Ave. velocity (m/s)	Max. velocity (m/s)	Fish flow class (%)							Macroinvertebrate flow class (%)				
							SVS[1]	SS	SD	FVS[3]	FS	FI	FD	SCS	FCS	VFCS[0]	SFS[4]	FFS[5]
1.10	0.58	13.5	35.1	35.6	0.66	1.52	2	5	13	6	4	5	65	14	19	37	6	24
1.15	0.61	15.1	36.4	36.9	0.68	1.55	1	5	13	6	5	4	67	13	18	38	6	24
1.20	0.65	16.8	37.1	37.6	0.70	1.59	1	4	13	5	6	3	67	13	17	40	5	25
1.25	0.69	18.7	37.5	38.1	0.72	1.62	0	4	13	2	7	5	69	12	17	41	5	25
1.30	0.73	20.7	38.0	38.6	0.74	1.66	0	4	13	2	5	5	71	12	16	42	5	25
1.35	0.77	22.8	38.5	39.0	0.76	1.69	1	3	12	3	3	5	73	11	15	43	5	25
1.40	0.82	25.0	38.9	39.5	0.79	1.76	0	3	12	3	2	5	75	11	15	45	5	25
1.45	0.83	27.3	40.8	41.4	0.81	1.76	1	2	11	4	2	2	77	10	15	45	4	26
1.50	0.85	29.8	42.3	43.0	0.83	1.79	1	2	11	6	3	2	76	10	14	46	4	26
1.55	0.88	32.4	43.1	43.8	0.86	1.84	1	2	10	4	4	2	76	9	13	47	4	26
1.60	0.91	35.2	43.9	44.7	0.88	1.89	0	2	10	3	6	2	75	9	13	48	4	26
1.65	0.94	38.1	45.1	45.9	0.90	1.90	0	2	10	3	5	3	76	9	12	49	4	26
1.70	0.97	41.1	46.1	47.0	0.92	1.96	1	2	9	5	4	4	75	8	12	50	4	26
1.75	1.00	44.3	47.2	48.1	0.94	2.00	1	2	9	5	3	4	77	8	12	51	3	27
1.80	1.04	47.6	47.6	48.6	0.97	2.01	0	2	9	2	3	5	79	8	11	51	3	27
1.85	1.08	51.1	47.8	48.8	0.99	2.05	0	2	8	1	3	4	81	7	11	52	3	27
1.90	1.13	54.7	48.0	49.1	1.01	2.12	0	2	8	1	2	3	84	7	10	53	3	27
1.95	1.10	58.5	51.3	52.5	1.03	2.17	1	1	7	6	4	3	79	7	10	53	3	27
2.00	1.08	62.4	55.1	56.3	1.05	2.21	1	1	7	9	4	2	75	6	10	54	3	27
2.05	1.11	66.5	56.0	57.3	1.07	2.22	1	1	7	9	4	2	77	6	10	54	3	27
2.10	1.14	70.7	56.9	58.2	1.09	2.24	0	1	7	5	5	5	76	6	9	55	3	27
2.15	1.17	75.1	57.8	59.2	1.11	2.27	0	2	6	3	6	8	76	6	9	55	2	28
2.20	1.20	79.6	58.8	60.2	1.13	2.32	0	2	6	3	6	9	75	6	9	56	2	28
2.25	1.19	84.4	61.9	63.4	1.15	2.32	0	1	6	5	5	6	77	5	9	56	2	28
2.30	1.21	89.3	63.5	65.0	1.16	2.37	0	1	6	5	4	3	80	5	8	56	2	28
2.35	1.23	94.3	65.1	66.7	1.18	2.43	0	2	5	6	5	3	79	5	8	57	2	28
2.40	1.25	99.6	66.7	68.4	1.20	2.46	0	2	5	5	5	5	79	5	8	57	2	28
2.45	1.22	105.0	71.0	72.7	1.21	2.45	0	1	5	6	6	5	77	5	8	57	2	28

Max. depth (m)	Ave. depth (m)	Discharge (m^3/s)	Width (m)	Perimeter (m)	Ave. velocity (m/s)	Max. velocity (m/s)	Fish flow class (%)							Macroinvertebrate flow class (%)				
							SVS[1]	SS	SD	FVS[3]	FS	FI	FD	SCS	FCS	VFCS[0]	SFS[4]	FFS[5]
2.50	1.25	110.5	72.5	74.3	1.22	2.49	0	1	5	6	5	5	77	5	8	58	2	28
2.55	1.27	116.3	73.9	75.8	1.24	2.52	0	1	5	5	5	5	77	5	8	58	2	28
2.60	1.30	122.2	75.4	77.3	1.25	2.56	0	1	5	5	5	4	79	5	7	58	2	28
2.65	1.32	128.3	76.9	78.9	1.26	2.56	0	1	5	3	4	6	80	5	7	58	2	28
2.70	1.34	134.7	78.4	80.4	1.28	2.59	0	1	5	3	4	6	81	4	7	58	2	28
2.75	1.38	141.1	79.1	81.2	1.29	2.63	0	1	5	4	4	5	81	4	7	59	2	28
2.80	1.43	147.8	79.2	81.3	1.31	2.63	0	1	5	2	2	5	84	4	7	59	2	28
2.85	1.48	154.7	79.2	81.5	1.32	2.68	0	1	5	1	2	3	87	4	7	59	2	28
2.90	1.53	161.7	79.3	81.6	1.33	2.70	0	1	5	0	0	3	90	4	7	59	2	28
2.95	1.58	169.0	79.4	81.7	1.35	2.77	0	1	5	0	1	3	90	4	7	59	2	28
3.00	1.62	176.4	79.5	81.8	1.37	2.81	0	1	5	0	0	2	91	4	6	60	2	28
3.05	1.67	184.1	79.6	82.0	1.38	2.80	0	0	5	0	0	1	93	4	6	60	2	28
3.10	1.72	191.9	79.7	82.1	1.40	2.83	0	0	5	0	0	0	93	4	6	60	2	28
3.15	1.76	199.9	80.2	82.7	1.42	2.88	0	0	5	0	0	0	93	4	6	60	2	28
3.20	1.79	208.2	81.1	83.6	1.43	2.90	0	0	5	0	0	0	93	4	6	60	2	28
3.25	1.82	216.6	81.9	84.4	1.45	2.92	0	0	5	1	1	0	93	4	6	60	2	28
3.30	1.85	225.3	82.7	85.3	1.47	2.96	0	0	5	1	1	0	92	4	6	61	2	28
3.35	1.89	234.1	83.5	86.1	1.49	3.00	0	0	5	2	2	1	90	4	6	61	2	28
3.40	1.92	243.2	84.3	87.0	1.50	3.03	0	0	5	2	2	1	90	3	6	61	1	29
3.45	1.95	252.4	85.2	87.8	1.52	3.07	0	0	4	2	2	1	91	3	5	61	1	29
3.50	1.91	261.9	89.2	91.9	1.54	3.13	0	0	4	3	3	2	87	3	5	61	1	29
3.55	1.91	271.6	91.7	94.4	1.55	3.14	0	0	4	4	4	2	86	3	5	61	1	29
3.60	1.95	281.6	92.1	94.8	1.57	3.21	0	0	4	4	4	3	86	3	5	62	1	29
3.65	1.99	291.7	92.5	95.2	1.59	3.21	0	0	4	3	3	2	87	3	5	62	1	29
3.70	2.03	302.0	92.9	95.7	1.60	3.21	0	0	4	3	3	2	87	3	5	62	1	29
3.75	2.07	312.6	93.3	96.1	1.62	3.26	0	0	4	2	2	2	89	3	5	62	1	29
3.80	2.11	323.4	93.7	96.6	1.63	3.27	0	0	4	1	1	2	92	3	5	62	1	29
3.85	2.15	334.4	94.1	97.0	1.65	3.32	0	0	4	1	1	2	92	3	5	62	1	29

Max. depth (m)	Ave. depth (m)	Discharge (m^3/s)	Width (m)	Perimeter (m)	Ave. velocity (m/s)	Max. velocity (m/s)	Fish flow class (%)							Macroinvertebrate flow class (%)				
							SVS[1]	SS	SD	FVS[3]	FS	FI	FD	SCS	FCS	VFCS[0]	SFS[4]	FFS[5]
3.90	2.19	345.7	94.5	97.5	1.67	3.40	0	0	4	1	1	2	92	3	5	62	1	29
3.95	2.23	357.2	95.0	97.9	1.68	3.42	0	0	4	1	1	1	93	3	5	62	1	29
4.00	2.27	368.9	95.4	98.3	1.70	3.46	0	0	4	1	1	1	93	3	5	63	1	29
4.05	2.31	380.8	95.8	98.8	1.72	3.51	0	0	4	1	1	1	93	3	4	63	1	29
4.10	2.35	393.0	96.2	99.2	1.74	3.51	0	0	4	1	1	1	94	3	4	63	1	29
4.15	2.39	405.4	96.6	99.7	1.75	3.56	0	0	4	1	1	1	94	3	4	63	1	29
4.20	2.43	418.0	97.2	100.3	1.77	3.62	0	0	4	1	1	1	93	3	4	63	1	29
4.25	2.46	430.9	97.8	100.9	1.79	3.62	0	0	4	1	1	1	94	3	4	63	1	29
4.30	2.50	444.0	98.5	101.6	1.81	3.69	0	0	4	1	1	1	93	3	4	63	1	29
4.35	2.53	457.4	99.1	102.3	1.82	3.67	0	0	4	1	1	1	93	3	4	63	1	29
4.40	2.56	471.0	99.8	103.0	1.84	3.74	0	0	4	1	1	1	92	3	4	63	1	29
4.45	2.60	484.9	100.4	103.7	1.86	3.75	0	0	4	1	1	1	93	3	4	63	1	29
4.50	2.63	498.9	101.1	104.3	1.88	3.79	0	0	4	1	1	1	93	3	4	63	1	29
4.55	2.66	513.3	101.7	105.0	1.89	3.85	0	0	4	1	1	1	92	3	4	63	1	29
4.60	2.70	527.9	102.4	105.7	1.91	3.87	0	0	4	1	1	1	93	3	4	64	1	29
4.65	2.73	542.7	103.0	106.4	1.93	3.95	0	0	3	1	1	1	93	3	4	64	1	29
4.70	2.76	557.8	103.7	107.0	1.95	3.93	0	0	4	1	1	1	94	3	4	64	1	29
4.75	2.79	573.1	104.3	107.7	1.97	4.01	0	0	3	1	1	1	93	3	4	64	1	29
4.80	2.83	588.7	105.0	108.4	1.98	4.02	0	0	3	1	1	1	94	3	4	64	1	29
4.85	2.86	604.6	105.7	109.1	2.00	4.04	0	0	3	1	1	1	94	3	4	64	1	29
4.90	2.89	620.7	106.3	109.8	2.02	4.11	0	0	3	1	1	1	93	2	4	64	1	29
4.95	2.92	637.1	107.0	110.4	2.04	4.12	0	0	3	1	1	1	94	2	3	64	1	29
5.00	2.96	653.7	107.6	111.1	2.06	4.20	0	0	3	1	1	1	93	2	3	64	1	29
5.05	2.99	670.6	108.3	111.8	2.07	4.20	0	0	3	1	1	1	93	2	3	64	1	29
5.10	3.02	687.7	108.9	112.5	2.09	4.20	0	0	3	1	1	1	94	2	3	64	1	29
5.15	3.05	705.2	109.5	113.1	2.11	4.24	0	0	3	1	1	1	94	2	3	64	1	29
5.20	3.08	722.9	110.2	113.8	2.13	4.33	0	0	3	1	1	1	93	2	3	64	1	29
5.25	3.12	740.8	110.8	114.5	2.15	4.37	0	0	3	1	1	1	93	2	3	64	1	29

Max. depth (m)	Ave. depth (m)	Discharge (m^3/s)	Width (m)	Perimeter (m)	Ave. velocity (m/s)	Max. velocity (m/s)	Fish flow class (%)							Macroinvertebrate flow class (%)				
							SVS[1]	SS	SD	FVS[3]	FS	FI	FD	SCS	FCS	VFCS[0]	SFS[4]	FFS[5]
5.30	3.15	759.0	111.5	115.2	2.16	4.36	0	0	3	1	1	1	94	2	3	64	1	29
5.35	3.18	777.5	112.1	115.8	2.18	4.40	0	0	3	1	1	1	94	2	3	65	1	29
5.40	3.21	796.3	112.8	116.5	2.20	4.48	0	0	3	1	1	1	94	2	3	65	1	29
5.45	3.24	815.3	113.4	117.2	2.22	4.50	0	0	3	1	1	1	94	2	3	65	1	29
5.50	3.27	834.7	114.1	117.9	2.24	4.50	0	0	3	1	1	1	94	2	3	65	1	29
5.55	3.31	854.3	114.7	118.5	2.25	4.54	0	0	3	1	1	1	94	2	3	65	1	29
5.60	3.34	874.1	115.4	119.2	2.27	4.63	0	0	3	1	1	1	94	2	3	65	1	29
5.65	3.37	894.3	116.0	119.9	2.29	4.67	0	0	3	1	1	1	94	2	3	65	1	29
5.70	3.40	914.7	116.6	120.5	2.31	4.68	0	0	3	1	1	1	94	2	3	65	1	29
5.75	3.43	935.4	117.3	121.2	2.32	4.70	0	0	3	1	1	1	94	2	3	65	1	29
5.80	3.46	956.4	117.9	121.9	2.34	4.78	0	0	3	1	1	1	93	2	3	65	1	29
5.85	3.49	977.7	118.6	122.6	2.36	4.78	0	0	3	1	1	1	93	2	3	65	1	29
5.90	3.52	999.3	119.2	123.2	2.38	4.78	0	0	3	1	1	1	94	2	3	65	1	29
5.95	3.55	1021.1	119.9	123.9	2.40	4.82	0	0	3	1	1	1	94	2	3	65	1	29
6.00	3.59	1043.3	120.5	124.6	2.41	4.90	0	0	3	1	1	1	93	2	3	65	1	29
6.05	3.62	1065.7	121.2	125.3	2.43	4.95	0	0	3	1	1	1	93	2	3	65	1	29
6.10	3.65	1088.5	121.8	125.9	2.45	4.94	0	0	3	1	1	1	94	2	3	65	1	29
6.15	3.68	1111.5	122.4	126.6	2.47	5.03	0	0	3	1	1	1	94	2	3	65	1	29
6.20	3.71	1134.8	123.0	127.2	2.49	4.99	0	0	3	1	1	1	94	2	3	65	1	29
6.25	3.74	1158.4	123.6	127.8	2.50	5.03	0	0	3	1	1	1	94	2	3	65	1	29
6.30	3.77	1182.3	124.2	128.4	2.52	5.09	0	0	3	1	1	1	94	2	2	66	1	29
6.35	3.81	1206.5	124.8	129.0	2.54	5.14	0	0	3	1	1	1	94	2	2	66	1	29
6.40	3.84	1231.1	125.4	129.7	2.56	5.18	0	0	3	1	1	1	94	2	2	66	1	29
6.45	3.87	1255.9	126.0	130.3	2.58	5.20	0	0	3	1	1	1	95	2	2	66	1	29
6.50	3.90	1281.0	126.6	130.9	2.59	5.25	0	0	3	1	1	1	95	2	2	66	1	29
6.55	3.93	1306.4	127.1	131.5	2.61	5.33	0	0	3	1	1	1	95	2	2	66	1	29
6.60	3.97	1332.1	127.7	132.1	2.63	5.36	0	0	3	1	1	1	95	2	2	66	1	29
6.65	4.00	1358.1	128.3	132.7	2.65	5.39	0	0	3	1	1	1	95	2	2	66	1	29

Max. depth (m)	Ave. depth (m)	Discharge (m^3/s)	Width (m)	Perimeter (m)	Ave. velocity (m/s)	Max. velocity (m/s)	Fish flow class (%)							Macroinvertebrate flow class (%)				
							SVS[1]	SS	SD	FVS[3]	FS	FI	FD	SCS	FCS	VFCS[0]	SFS[4]	FFS[5]
6.70	4.03	1384.5	128.9	133.4	2.67	5.38	0	0	3	1	1	1	95	2	2	66	1	29
6.75	4.06	1411.1	129.5	134.0	2.68	5.37	0	0	3	1	1	1	95	2	2	66	1	29
6.80	4.09	1438.1	130.1	134.6	2.70	5.41	0	0	3	1	1	1	95	2	2	66	1	29
6.85	4.12	1465.4	130.7	135.2	2.72	5.51	0	0	3	1	1	1	95	2	2	66	1	29
6.90	4.16	1492.9	131.3	135.8	2.74	5.56	0	0	3	1	1	1	95	2	2	66	1	29
6.95	4.19	1520.8	131.8	136.4	2.76	5.55	0	0	3	1	1	1	95	2	2	66	1	29
7.00	4.22	1549.1	132.4	137.0	2.77	5.60	0	0	3	1	1	1	96	2	2	66	1	29
7.05	4.25	1577.6	133.0	137.7	2.79	5.63	0	0	2	1	1	1	96	2	2	66	1	29
7.10	4.28	1606.4	133.6	138.3	2.81	5.72	0	0	2	1	1	1	95	2	2	66	1	29
7.15	4.31	1635.6	134.2	138.9	2.83	5.76	0	0	2	1	1	1	95	2	2	66	1	29
7.20	4.34	1665.1	134.77	139.50	2.84	5.75	0	0	2	1	1	1	96	2	2	66	1	29
7.25	4.37	1694.9	135.36	140.12	2.86	5.75	0	0	2	1	1	1	96	2	2	66	1	29
7.30	4.41	1725.0	135.95	140.73	2.88	5.85	0	0	2	1	1	1	95	2	2	66	1	29
7.35	4.44	1755.5	136.53	141.35	2.90	5.90	0	0	2	1	1	1	95	2	2	66	1	29
7.40	4.47	1786.3	137.12	141.96	2.92	5.96	0	0	2	1	1	1	95	2	2	66	1	29
7.45	4.50	1817.4	137.69	142.56	2.93	5.99	0	0	2	1	1	1	95	2	2	66	1	29
Keurbooms River: K6KEUR-EWR8																		
0.02	0.01	0.000	0.8	0.8	0.02	0.05	100	0	0	0	0	0	0	80	0	0	20	0
0.04	0.02	0.001	1.5	1.5	0.03	0.09	100	0	0	0	0	0	0	80	0	0	20	0
0.06	0.03	0.002	2.2	2.2	0.04	0.13	100	0	0	0	0	0	0	80	0	0	20	0
0.08	0.05	0.006	2.5	2.5	0.05	0.18	100	0	0	0	0	0	0	80	0	0	20	0
0.10	0.06	0.011	2.7	2.7	0.06	0.22	99	1	0	0	0	0	0	80	0	0	20	0
0.12	0.08	0.017	2.9	3.0	0.08	0.27	73	26	0	1	0	0	0	79	1	0	20	0
0.14	0.08	0.025	3.5	3.5	0.09	0.30	56	41	0	2	1	0	0	78	2	0	19	1
0.16	0.09	0.035	4.1	4.1	0.10	0.33	45	51	0	2	2	0	0	76	4	0	19	1
0.18	0.10	0.050	4.6	4.7	0.11	0.38	42	51	0	3	4	0	0	75	5	0	19	1
0.20	0.11	0.070	5.1	5.1	0.13	0.43	42	49	0	4	5	0	0	73	7	0	18	2
0.22	0.11	0.094	5.8	5.8	0.14	0.49	43	46	0	5	4	2	0	71	8	1	18	2

Max. depth (m)	Ave. depth (m)	Discharge (m^3/s)	Width (m)	Perimeter (m)	Ave. velocity (m/s)	Max. velocity (m/s)	Fish flow class (%)							Macroinvertebrate flow class (%)				
							SVS[1]	SS	SD	FVS[3]	FS	FI	FD	SCS	FCS	VFCS[0]	SFS[4]	FFS[5]
0.24	0.12	0.13	6.4	6.5	0.16	0.55	38	48	0	6	5	3	0	69	10	1	17	3
0.26	0.13	0.17	7.1	7.2	0.19	0.63	34	47	0	8	5	6	0	64	13	3	16	4
0.28	0.13	0.23	8.3	8.3	0.21	0.69	33	43	0	10	6	7	0	61	15	4	15	5
0.30	0.12	0.29	10.2	10.3	0.23	0.75	35	36	0	14	7	7	0	57	19	4	14	6
0.32	0.14	0.37	10.7	10.8	0.25	0.82	30	36	0	16	9	7	3	53	22	5	13	7
0.34	0.15	0.46	11.1	11.2	0.27	0.87	25	37	0	16	10	7	5	50	24	6	12	8
0.36	0.17	0.56	11.4	11.5	0.30	0.95	21	36	0	16	11	7	8	46	26	8	12	8
0.38	0.18	0.68	11.8	11.9	0.32	1.01	16	38	0	14	14	9	10	43	28	9	11	9
0.40	0.20	0.80	12.2	12.2	0.34	1.07	9	42	0	9	20	10	11	41	29	10	10	10
0.42	0.21	0.9	12.5	12.6	0.36	1.14	7	41	0	7	21	11	13	38	29	12	10	10
0.44	0.22	1.1	12.8	12.9	0.38	1.21	6	39	0	7	20	13	15	36	29	15	9	11
0.46	0.24	1.3	13.1	13.2	0.40	1.28	5	37	0	7	20	13	18	34	29	17	8	12
0.48	0.25	1.4	13.3	13.4	0.42	1.34	5	36	0	7	14	18	21	32	29	19	8	12
0.50	0.26	1.6	13.9	14.0	0.44	1.38	5	34	0	7	8	23	23	31	28	21	8	12
0.52	0.27	1.8	14.5	14.6	0.46	1.44	5	30	2	9	8	22	24	30	28	23	7	13
0.54	0.28	2.0	14.9	15.1	0.48	1.47	5	28	4	8	7	21	28	29	27	24	7	13
0.56	0.30	2.3	15.3	15.5	0.50	1.53	5	25	5	9	7	19	30	28	26	26	7	13
0.58	0.31	2.5	15.7	15.9	0.52	1.60	5	23	5	9	7	16	35	26	25	29	7	13
0.60	0.32	2.8	16.1	16.3	0.54	1.62	4	22	5	9	8	11	41	25	24	31	6	14
0.62	0.33	3.1	16.5	16.7	0.56	1.69	4	21	5	9	8	9	45	24	23	33	6	14
0.64	0.35	3.4	16.9	17.1	0.58	1.71	3	19	6	9	9	8	47	22	23	35	6	14
0.66	0.36	3.8	17.1	17.3	0.61	1.75	3	17	7	8	10	6	50	21	22	37	5	15
0.68	0.38	4.2	17.3	17.5	0.64	1.79	2	16	7	7	10	7	52	20	21	39	5	15
0.70	0.39	4.6	17.5	17.7	0.67	1.85	2	14	7	7	9	8	53	18	20	42	5	15
0.72	0.41	5.0	17.7	17.9	0.70	1.89	2	13	7	6	9	9	55	17	19	44	4	16
0.74	0.42	5.5	17.9	18.1	0.72	1.92	1	12	7	5	9	10	57	16	18	46	4	16
0.76	0.44	6.0	18.1	18.3	0.75	1.95	1	10	8	5	8	10	59	15	17	47	4	16
0.78	0.45	6.5	18.3	18.5	0.79	1.97	1	8	8	5	7	10	61	14	17	49	4	16

Max. depth (m)	Ave. depth (m)	Discharge (m^3/s)	Width (m)	Perimeter (m)	Ave. velocity (m/s)	Max. velocity (m/s)	Fish flow class (%)							Macroinvertebrate flow class (%)				
							SVS[1]	SS	SD	FVS[3]	FS	FI	FD	SCS	FCS	VFCS[0]	SFS[4]	FFS[5]
0.80	0.47	7.1	18.5	18.7	0.82	2.01	1	7	9	5	6	9	63	13	16	51	3	17
0.82	0.48	7.7	18.8	19.0	0.85	2.02	1	6	9	4	6	10	65	12	15	53	3	17
0.84	0.49	8.2	19.3	19.5	0.87	2.06	1	5	9	6	5	9	65	12	14	54	3	17
0.86	0.49	8.8	19.9	20.0	0.89	2.07	1	5	8	8	4	7	66	11	14	55	3	17
0.88	0.50	9.4	20.4	20.6	0.92	2.09	1	4	8	8	4	6	68	11	14	56	3	17
0.90	0.51	10.1	20.9	21.1	0.95	2.14	1	4	7	10	4	6	68	10	13	57	3	17
0.92	0.51	10.8	21.5	21.7	0.97	2.16	1	4	7	10	6	5	67	10	12	58	2	18
0.94	0.52	11.5	22.0	22.3	1.00	2.19	1	3	7	11	5	5	67	9	12	59	2	18
0.96	0.53	12.3	22.6	22.8	1.03	2.25	1	3	6	11	6	5	67	9	11	60	2	18
0.98	0.54	13.1	23.2	23.4	1.06	2.26	1	3	6	10	9	4	68	8	11	61	2	18
1.00	0.54	14.1	23.7	24.0	1.09	2.30	1	3	6	9	9	4	68	8	11	62	2	18
1.02	0.55	15.0	24.3	24.5	1.13	2.33	1	3	5	9	10	4	67	7	10	63	2	18
1.04	0.56	16.1	24.9	25.1	1.16	2.41	1	3	5	9	10	5	67	7	10	64	2	18
1.06	0.56	17.2	25.4	25.7	1.20	2.51	1	2	5	10	10	6	66	6	9	65	2	18
1.08	0.57	18.4	26.0	26.2	1.24	2.54	1	2	4	8	11	7	66	6	9	66	1	19
1.10	0.58	19.7	26.5	26.8	1.28	2.60	1	2	4	9	10	9	66	5	8	67	1	19
1.12	0.59	21.0	27.1	27.4	1.32	2.67	1	2	4	9	9	10	66	5	8	67	1	19
1.14	0.59	22.5	27.7	28.0	1.37	2.75	1	2	3	9	10	9	66	5	7	68	1	19
1.16	0.60	24.1	28.3	28.6	1.41	2.84	1	2	3	10	10	9	66	4	7	69	1	19
1.18	0.61	25.7	29.0	29.2	1.46	2.98	1	2	3	10	10	9	67	4	7	69	1	19
1.20	0.62	27.5	29.6	29.9	1.51	3.02	0	1	3	9	9	9	69	4	6	70	1	19
1.22	0.62	29.5	30.1	30.4	1.57	3.18	0	1	3	9	9	9	68	4	6	70	1	19
1.24	0.63	31.6	30.7	31.0	1.63	3.27	0	1	3	8	10	9	69	4	6	71	1	19
1.26	0.64	33.9	31.3	31.6	1.69	3.46	0	1	2	9	9	8	69	3	5	71	1	19
1.28	0.65	36.3	31.8	32.1	1.76	3.59	0	1	2	9	9	8	70	3	5	72	1	19
1.30	0.66	39.0	32.4	32.7	1.83	3.67	0	1	2	7	9	8	71	3	5	72	1	19
1.32	0.67	41.9	32.9	33.3	1.91	3.89	0	1	2	8	10	7	71	3	4	73	1	19
1.34	0.67	45.0	33.5	33.8	1.99	4.01	0	1	2	8	8	9	72	3	4	73	1	19

Max. depth (m)	Ave. depth (m)	Discharge (m^3/s)	Width (m)	Perimeter (m)	Ave. velocity (m/s)	Max. velocity (m/s)	Fish flow class (%)							Macroinvertebrate flow class (%)				
							SVS[1]	SS	SD	FVS[3]	FS	FI	FD	SCS	FCS	VFCS[0]	SFS[4]	FFS[5]
1.36	0.68	48.2	34.2	34.6	2.07	4.18	0	1	2	7	8	9	73	3	4	73	1	19
1.38	0.68	51.4	35.3	35.6	2.14	4.32	0	1	2	9	8	7	72	3	4	74	1	19
1.40	0.68	54.9	36.4	36.7	2.22	4.43	0	1	2	9	8	7	72	3	3	74	1	19

1 SVS: Slow very shallow 2 FVS: Fast very shallow 3 SFS: Shallow over fine substrate 4 FFS: Fast over fine substrate

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Tharme, R.E. 1996. Review of international methodologies for the quantification of the instream flow requirements of rivers. Water law review. Final report for policy development. Commissioned by the Department of Water Affairs and Forestry, Pretoria. Freshwater Research Unit, University of Cape Town, Cape Town. 116pp.

APPENDIX D: RDRM OUTPUT FILES

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

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

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

D.1 J1TOUW-EWR3: RDRM REPORT FOR AN INSTREAM PES AND REC: C

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TITLE: RDMR Report
DATE: 2014/09/30

Revised Desktop Model outputs for site: Touw_3

HYDROLOGY DATA SUMMARY

Natural Flows:                          Present Day Flows:
   Area     MAR   Ann.SD    Q75   Ann.     Area     MAR   Ann.SD    Q75   Ann.
  (km^2)       (m^3 * 10^6)        CV     (km^2)       (m^3 * 10^6)        CV
    0.00   45.02   66.57    0.25  1.48      0.00   22.26   60.36    0.00  2.71

% Zero flows =   0.1                    % Zero flows =  47.0
Baseflow Parameters: A = 0.990, B = 0.44Baseflow Parameters: A = 0.990, B = 0.440
BFI = 0.20 : Hydro Index =  34.2        BFI = 0.14 : Hydro Index =  76.5

MONTH   MEAN      SD     CV             MONTH   MEAN      SD     CV
        (m^3 * 10^6)                            (m^3 * 10^6)
 Oct    2.85    6.41    2.25             Oct    0.99    3.39    3.41
 Nov    3.03    6.45    2.13             Nov    0.93    3.16    3.38
 Dec    2.59    6.17    2.38             Dec    0.55    2.12    3.86
 Jan    2.89   12.70    4.39             Jan    1.34    9.45    7.08
 Feb    3.88   16.04    4.14             Feb    1.83   12.63    6.91
 Mar    3.08    8.39    2.72             Mar    1.11    6.91    6.21
 Apr    4.16    8.26    1.98             Apr    1.58    3.98    2.52
 May    4.19    7.14    1.71             May    1.74    3.94    2.26
 Jun    8.48   35.88    4.23             Jun    6.56   35.62    5.43
 Jul    4.22   11.56    2.74             Jul    2.81   11.60    4.13
 Aug    3.66    8.90    2.43             Aug    2.20    6.80    3.09
 Sep    1.98    3.94    1.99             Sep    0.63    1.93    3.08

Critical months: WET : May, DRY : Feb
Using  20th percentile of FDC of separated baseflows
Max. baseflows (m3/s): WET :      0.534, DRY :      0.215

FLOW - STRESSOR RESPONSE DATA SUMMARY

Table of initial SHIFT factors for the Stress Frequency Curves

Category  High SHIFT  Low SHIFT
Wet Season:    A        0.023      0.217
Dry Season:    A        0.000      0.051
Wet Season:  A/B        0.035      0.325
Dry Season:  A/B        1.000      0.125
Wet Season:    B        0.047      0.433
Dry Season:    B        2.000      0.200
Wet Season:  B/C        0.058      0.541
```

Dry Season:	B/C	3.000	0.275
Wet Season:	C	0.070	0.650
Dry Season:	C	4.000	0.350
Wet Season:	C/D	0.082	0.758
Dry Season:	C/D	4.500	0.425
Wet Season:	D	0.093	0.867
Dry Season:	D	5.000	0.500

Perenniality Rules
Non-Perennial Allowed

Alignment of maximum stress to Present Day stress
Not Aligned

Table of flows (m3/2) v stress index

Stress	Wet Season Flow	Dry Season Flow
0	0.542	0.226
1	0.495	0.194
2	0.450	0.172
3	0.405	0.151
4	0.355	0.129
5	0.295	0.108
6	0.220	0.086
7	0.150	0.065
8	0.085	0.043
9	0.034	0.022
10	0.000	0.000

HIGH FLOW ESTIMATION SUMMARY DETAILS

No High flows when natural high flows are < 30% of total flows
Adjusted hydrological variability for high flows is 92.00
Maximum high flows are 1000% greater than normal high flows

Table of normal high flow requirements (Mill. m3)

Category	A	A/B	B	B/C	C	C/D	D
Annual	10.160	9.226	8.354	7.541	6.783	6.078	5.422
Oct	0.621	0.564	0.511	0.461	0.415	0.372	0.332
Nov	0.322	0.292	0.265	0.239	0.215	0.193	0.172
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Jan	0.348	0.316	0.286	0.258	0.233	0.208	0.186
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mar	0.627	0.569	0.515	0.465	0.418	0.375	0.334
Apr	1.440	1.307	1.184	1.068	0.961	0.861	0.768
May	1.589	1.443	1.307	1.180	1.061	0.951	0.848
Jun	1.705	1.548	1.402	1.265	1.138	1.020	0.910
Jul	1.360	1.235	1.118	1.009	0.908	0.814	0.726
Aug	1.387	1.260	1.141	1.030	0.926	0.830	0.740
Sep	0.762	0.691	0.626	0.565	0.508	0.456	0.406

FINAL RESERVE SUMMARY DETAILS

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

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

Category	Low Flows		Total Flows	
	Mill. m3	%MAR	Mill. m3	%MAR
A	4.841	10.8	20.393	45.3
A/B	3.292	7.3	18.183	40.4
B	2.459	5.5	16.253	36.1
B/C	1.760	3.9	14.438	32.1
C	1.152	2.6	12.688	28.2

C/D	0.665	1.5	11.089	24.6
D	0.287	0.6	9.641	21.4

FLOW DURATION and RESERVE ASSURANCE TABLES

Columns are FDC precentage points:

Natural Total flow duration curve (mill. m3)

	10	20	30	40	50	60	70	80	90	99
Oct	8.271	3.179	1.486	0.999	0.618	0.533	0.382	0.238	0.142	0.052
Nov	6.639	3.201	2.047	1.244	0.626	0.428	0.315	0.228	0.144	0.051
Dec	6.909	3.340	1.881	0.804	0.526	0.388	0.292	0.190	0.120	0.029
Jan	4.061	1.728	0.774	0.581	0.411	0.303	0.206	0.147	0.069	0.009
Feb	5.791	1.447	0.739	0.439	0.336	0.225	0.168	0.117	0.065	0.029
Mar	8.108	3.645	2.042	0.814	0.465	0.362	0.271	0.187	0.120	0.048
Apr	13.578	5.213	2.766	1.195	0.866	0.562	0.267	0.181	0.123	0.018
May	12.729	7.457	3.548	2.301	1.104	0.696	0.349	0.222	0.154	0.041
Jun	11.562	6.065	4.257	2.685	1.852	0.998	0.631	0.275	0.162	0.072
Jul	7.832	3.908	2.761	1.851	1.296	0.943	0.609	0.327	0.173	0.074
Aug	7.705	4.401	2.254	1.556	1.222	0.616	0.474	0.303	0.185	0.052
Sep	4.528	2.584	1.441	0.816	0.653	0.448	0.326	0.257	0.157	0.079

Natural Baseflow flow duration curve (mill. m3)

Oct	1.482	0.963	0.599	0.538	0.358	0.280	0.231	0.186	0.099	0.052
Nov	1.571	0.895	0.717	0.539	0.435	0.319	0.236	0.194	0.106	0.051
Dec	1.336	0.837	0.610	0.421	0.368	0.309	0.231	0.155	0.104	0.029
Jan	0.975	0.574	0.415	0.334	0.271	0.222	0.186	0.118	0.064	0.009
Feb	1.079	0.498	0.372	0.293	0.247	0.195	0.154	0.112	0.065	0.022
Mar	1.486	0.667	0.456	0.321	0.266	0.214	0.179	0.134	0.086	0.030
Apr	2.332	0.990	0.660	0.500	0.292	0.213	0.191	0.133	0.098	0.018
May	1.961	1.292	0.913	0.605	0.328	0.259	0.174	0.151	0.109	0.033
Jun	1.666	1.189	0.835	0.694	0.512	0.360	0.274	0.160	0.110	0.032
Jul	1.321	0.950	0.724	0.599	0.453	0.342	0.270	0.193	0.126	0.061
Aug	1.664	0.881	0.608	0.472	0.421	0.363	0.308	0.243	0.130	0.052
Sep	1.280	0.719	0.536	0.410	0.333	0.288	0.232	0.173	0.104	0.070

Category Low Flow Assurance curves (mill. m3)

C Category

Oct	0.352	0.155	0.085	0.081	0.039	0.014	0.001	0.000	0.000	0.000
Nov	0.352	0.121	0.105	0.082	0.035	0.015	0.001	0.000	0.000	0.000
Dec	0.279	0.099	0.066	0.039	0.034	0.014	0.001	0.000	0.000	0.000
Jan	0.233	0.024	0.014	0.013	0.013	0.010	0.001	0.000	0.000	0.000
Feb	0.183	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mar	0.310	0.058	0.017	0.010	0.010	0.007	0.001	0.000	0.000	0.000
Apr	0.473	0.161	0.087	0.057	0.024	0.007	0.001	0.000	0.000	0.000
May	0.436	0.336	0.218	0.125	0.062	0.023	0.000	0.000	0.000	0.000
Jun	0.344	0.216	0.143	0.071	0.041	0.017	0.001	0.000	0.000	0.000
Jul	0.286	0.146	0.124	0.099	0.044	0.016	0.001	0.000	0.000	0.000
Aug	0.353	0.128	0.072	0.063	0.046	0.017	0.002	0.000	0.000	0.000
Sep	0.249	0.070	0.037	0.033	0.027	0.013	0.001	0.000	0.000	0.000

Category Total Flow Assurance curves (mill. m3)

C Category

Oct	2.639	0.884	0.529	0.496	0.453	0.402	0.311	0.181	0.006	0.000
Nov	1.536	0.498	0.336	0.298	0.249	0.216	0.162	0.094	0.003	0.000
Dec	0.279	0.099	0.066	0.039	0.034	0.014	0.001	0.000	0.000	0.000
Jan	1.515	0.433	0.263	0.246	0.245	0.228	0.175	0.102	0.003	0.000
Feb	0.183	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mar	2.616	0.793	0.465	0.429	0.428	0.362	0.271	0.183	0.006	0.000
Apr	5.773	1.851	1.117	1.019	0.866	0.562	0.267	0.181	0.013	0.000
May	6.286	2.202	1.355	1.187	1.104	0.696	0.349	0.222	0.015	0.000
Jun	6.619	2.217	1.363	1.210	1.177	0.998	0.631	0.275	0.016	0.000

Jul	5.292	1.742	1.096	1.008	0.950	0.868	0.609	0.327	0.013	0.000
Aug	5.460	1.756	1.064	0.990	0.970	0.616	0.474	0.303	0.013	0.000
Sep	3.052	0.964	0.582	0.542	0.535	0.448	0.326	0.222	0.007	0.000

D.2 J2GAMK-EWR4: RDRM REPORT FOR A PES: C/D

TITLE: RDMR Report
DATE: 2014/09/30

Revised Desktop Model outputs for site: Gamk_4

HYDROLOGY DATA SUMMARY

Natural Flows:					Present Day Flows:				
Area (km^2)	MAR (m^3 * 10^6)	Ann.SD (m^3 * 10^6)	Q75	Ann. CV	Area (km^2)	MAR (m^3 * 10^6)	Ann.SD (m^3 * 10^6)	Q75	Ann. CV
0.00	85.54	102.29	0.34	1.20	0.00	61.69	87.00	0.47	1.41

% Zero flows = 0.0 | % Zero flows = 0.0
Baseflow Parameters: A = 0.990, B = 0.44 | Baseflow Parameters: A = 0.990, B = 0.440
BFI = 0.20 : Hydro Index = 23.2 | BFI = 0.20 : Hydro Index = 27.8

MONTH	MEAN (m^3 * 10^6)	SD	CV	MONTH	MEAN (m^3 * 10^6)	SD	CV
Oct	3.84	8.05	2.10	Oct	2.83	3.46	1.22
Nov	8.48	22.85	2.69	Nov	6.87	17.05	2.48
Dec	11.53	28.85	2.50	Dec	9.22	22.85	2.48
Jan	6.78	13.49	1.99	Jan	3.34	9.80	2.93
Feb	10.22	24.03	2.35	Feb	9.49	20.28	2.14
Mar	20.89	47.72	2.28	Mar	12.98	38.38	2.96
Apr	10.36	19.62	1.89	Apr	7.22	18.04	2.50
May	4.17	9.02	2.16	May	4.03	4.79	1.19
Jun	1.59	2.89	1.82	Jun	0.85	2.28	2.69
Jul	1.49	3.68	2.48	Jul	0.39	0.87	2.20
Aug	3.22	9.07	2.82	Aug	2.09	7.43	3.55
Sep	2.98	5.92	1.99	Sep	2.37	2.47	1.04

Critical months: WET : Mar, DRY : Jul
Using 20th percentile of FDC of separated baseflows
Max. baseflows (m3/s): WET : 1.313, DRY : 0.322

FLOW - STRESSOR RESPONSE DATA SUMMARY

Table of initial SHIFT factors for the Stress Frequency Curves

Category		High SHIFT	Low SHIFT
Wet Season:	A	0.100	0.058
Dry Season:	A	0.100	0.083
Wet Season:	A/B	0.150	0.116
Dry Season:	A/B	0.150	0.167
Wet Season:	B	0.200	0.175
Dry Season:	B	0.200	0.250
Wet Season:	B/C	0.300	0.234
Dry Season:	B/C	0.300	0.333
Wet Season:	C	0.400	0.292
Dry Season:	C	0.400	0.417
Wet Season:	C/D	0.500	0.350
Dry Season:	C/D	0.500	0.500
Wet Season:	D	0.600	0.408
Dry Season:	D	0.600	0.583

Perenniality Rules

All Seasons Perennial Forced

Alignment of maximum stress to Present Day stress
Not Aligned

Table of flows (m3/2) v stress index

Stress	Wet Season Flow	Dry Season Flow
0	1.323	0.327
1	1.010	0.270
2	0.800	0.235
3	0.640	0.200
4	0.500	0.170
5	0.380	0.140
6	0.280	0.105
7	0.190	0.080
8	0.110	0.050
9	0.050	0.025
10	0.000	0.000

HIGH FLOW ESTIMATION SUMMARY DETAILS

No High flows when natural high flows are < 34% of total flows
Adjusted hydrological variability for high flows is 95.30
Maximum high flows are 850% greater than normal high flows

Table of normal high flow requirements (Mill. m3)

Category	A	A/B	B	B/C	C	C/D	D
Annual	19.426	17.633	15.961	14.402	12.951	11.601	10.345
Oct	1.249	1.134	1.026	0.926	0.833	0.746	0.665
Nov	2.453	2.227	2.016	1.819	1.636	1.465	1.307
Dec	2.006	1.820	1.648	1.487	1.337	1.198	1.068
Jan	1.893	1.718	1.555	1.403	1.262	1.130	1.008
Feb	2.653	2.408	2.180	1.967	1.769	1.584	1.413
Mar	3.902	3.542	3.206	2.893	2.601	2.330	2.078
Apr	3.034	2.754	2.493	2.249	2.023	1.812	1.616
May	1.473	1.337	1.210	1.092	0.982	0.880	0.785
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sep	0.764	0.693	0.627	0.566	0.509	0.456	0.407

FINAL RESERVE SUMMARY DETAILS

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

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

Category	Low Flows		Total Flows	
	Mill. m3	%MAR	Mill. m3	%MAR
A	7.864	9.2	34.816	40.7
A/B	7.014	8.2	31.893	37.3
B	6.188	7.2	29.085	34.0
B/C	5.416	6.3	26.418	30.9
C	4.670	5.5	23.852	27.9
C/D	3.936	4.6	21.377	25.0
D	3.220	3.8	18.985	22.2

FLOW DURATION and RESERVE ASSURANCE TABLES

Columns are FDC precentage points:

10	20	30	40	50	60	70	80	90	99

Natural Total flow duration curve (mill. m3)

Oct	9.144	5.689	2.783	1.331	0.873	0.731	0.569	0.316	0.192	0.030
Nov	16.976	7.675	5.585	3.644	1.581	0.586	0.398	0.283	0.152	0.084
Dec	27.744	10.963	4.955	3.152	1.594	0.964	0.451	0.327	0.176	0.065
Jan	20.570	7.655	4.972	1.971	1.171	0.715	0.420	0.214	0.102	0.040
Feb	38.112	7.335	4.839	3.349	1.901	0.898	0.543	0.286	0.169	0.045
Mar	74.833	21.090	10.735	6.999	5.503	3.798	1.937	1.125	0.252	0.061
Apr	29.590	13.390	7.271	5.127	3.148	2.263	1.263	0.508	0.236	0.051
May	10.395	5.651	2.780	1.789	1.101	0.825	0.507	0.437	0.190	0.058
Jun	3.928	2.089	1.528	0.752	0.540	0.433	0.336	0.267	0.164	0.051
Jul	3.363	1.551	1.021	0.817	0.561	0.354	0.253	0.179	0.105	0.040
Aug	6.955	1.977	1.406	0.801	0.574	0.412	0.324	0.204	0.122	0.056
Sep	10.661	3.561	1.699	0.946	0.701	0.490	0.281	0.241	0.137	0.050

Natural Baseflow flow duration curve (mill. m3)

Oct	1.606	1.222	0.772	0.569	0.484	0.410	0.353	0.255	0.125	0.030
Nov	2.721	1.514	1.111	0.793	0.601	0.420	0.283	0.168	0.127	0.044
Dec	4.555	1.967	1.147	0.898	0.662	0.444	0.356	0.214	0.110	0.058
Jan	3.975	1.964	1.004	0.715	0.572	0.383	0.275	0.178	0.086	0.040
Feb	5.102	1.729	1.291	0.892	0.671	0.442	0.330	0.213	0.096	0.030
Mar	9.897	3.041	1.894	1.300	1.171	0.895	0.712	0.367	0.214	0.041
Apr	4.732	2.344	1.585	1.106	0.943	0.741	0.543	0.308	0.124	0.031
May	3.115	1.489	1.072	0.787	0.545	0.453	0.373	0.255	0.164	0.052
Jun	1.844	0.877	0.687	0.518	0.403	0.327	0.262	0.218	0.119	0.044
Jul	1.472	0.849	0.610	0.493	0.416	0.305	0.233	0.172	0.091	0.036
Aug	1.705	0.962	0.600	0.453	0.385	0.335	0.272	0.155	0.096	0.048
Sep	2.115	1.027	0.758	0.572	0.446	0.298	0.257	0.192	0.095	0.043

Category Low Flow Assurance curves (mill. m3)

C/D Category

Oct	0.485	0.468	0.386	0.288	0.206	0.160	0.119	0.075	0.037	0.012
Nov	0.822	0.582	0.512	0.391	0.249	0.168	0.098	0.053	0.037	0.025
Dec	1.092	0.738	0.551	0.437	0.280	0.183	0.122	0.064	0.035	0.028
Jan	0.890	0.682	0.476	0.368	0.248	0.152	0.095	0.054	0.030	0.019
Feb	0.917	0.677	0.532	0.399	0.261	0.162	0.104	0.057	0.028	0.016
Mar	1.386	1.195	0.962	0.733	0.522	0.345	0.218	0.126	0.064	0.022
Apr	1.040	0.913	0.775	0.590	0.409	0.268	0.173	0.102	0.043	0.020
May	0.706	0.596	0.506	0.399	0.235	0.174	0.126	0.080	0.049	0.027
Jun	0.464	0.352	0.294	0.232	0.172	0.122	0.088	0.063	0.038	0.023
Jul	0.356	0.323	0.275	0.230	0.175	0.122	0.081	0.049	0.026	0.012
Aug	0.473	0.367	0.300	0.233	0.168	0.130	0.094	0.050	0.031	0.021
Sep	0.481	0.386	0.339	0.262	0.179	0.111	0.086	0.056	0.031	0.015

Category Total Flow Assurance curves (mill. m3)

C/D Category

Oct	4.012	1.669	1.173	1.034	0.873	0.731	0.569	0.316	0.047	0.012
Nov	7.747	2.941	2.059	1.857	1.581	0.586	0.398	0.283	0.058	0.025
Dec	6.753	2.666	1.815	1.635	1.475	0.964	0.451	0.327	0.051	0.028
Jan	6.233	2.501	1.670	1.499	1.171	0.715	0.420	0.214	0.046	0.019
Feb	8.405	3.227	2.205	1.984	1.842	0.898	0.543	0.286	0.050	0.016
Mar	12.399	4.946	3.422	3.065	2.848	2.530	1.931	1.125	0.096	0.022
Apr	9.604	3.830	2.688	2.403	2.217	1.967	1.263	0.508	0.068	0.020
May	4.864	2.012	1.435	1.279	1.082	0.825	0.507	0.437	0.061	0.027
Jun	0.464	0.352	0.294	0.232	0.172	0.122	0.088	0.063	0.038	0.023
Jul	0.356	0.323	0.275	0.230	0.175	0.122	0.081	0.049	0.026	0.012
Aug	0.473	0.367	0.300	0.233	0.168	0.130	0.094	0.050	0.031	0.021
Sep	2.637	1.120	0.820	0.719	0.634	0.490	0.281	0.241	0.037	0.015

D.3 J1BUFF-EWR5: RDRM REPORT FOR A PES AND REC: C

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TITLE: RDMR Report
DATE: 2014/12/03

Revised Desktop Model outputs for site: Buff_5

HYDROLOGY DATA SUMMARY

Natural Flows:                          Present Day Flows:
   Area     MAR   Ann.SD    Q75   Ann.     Area     MAR   Ann.SD    Q75   Ann.
  (km^2)       (m^3 * 10^6)        CV     (km^2)       (m^3 * 10^6)        CV
    0.00   29.31   46.84    0.06  1.60      0.00   18.67   37.10    0.00  1.99

% Zero flows =   4.8                    % Zero flows =  15.9
Baseflow Parameters: A = 0.990, B = 0.44Baseflow Parameters: A = 0.990, B = 0.440
BFI = 0.17 : Hydro Index =  41.5        BFI = 0.16 : Hydro Index =  51.3

MONTH   MEAN      SD     CV             MONTH   MEAN      SD     CV
       (m^3 * 10^6)                            (m^3 * 10^6)
 Oct    1.01    2.56    2.53             Oct    1.19    0.90    0.76
 Nov    1.80    4.98    2.77             Nov    1.63    1.83    1.12
 Dec    2.33    6.17    2.65             Dec    2.08    2.18    1.05
 Jan    3.23   18.67    5.77             Jan    3.36   15.45    4.60
 Feb    2.48    9.15    3.68             Feb    2.56    7.33    2.86
 Mar    2.06    4.95    2.41             Mar    1.49    4.03    2.70
 Apr    3.29    8.27    2.51             Apr    0.58    1.17    2.01
 May    2.68    6.48    2.42             May    0.48    2.05    4.27
 Jun    4.79   18.95    3.96             Jun    2.53   14.98    5.92
 Jul    2.99    9.39    3.14             Jul    1.39    6.65    4.78
 Aug    1.82    4.37    2.41             Aug    0.57    2.27    3.96
 Sep    0.83    1.75    2.09             Sep    0.80    0.53    0.66

Critical months: WET : Apr, DRY : Sep
Using  20th percentile of FDC of separated baseflows
Max. baseflows (m3/s): WET :      0.263, DRY :      0.103


FLOW - STRESSOR RESPONSE DATA SUMMARY

Table of initial SHIFT factors for the Stress Frequency Curves

Category  High SHIFT  Low SHIFT
Wet Season:    A       0.005      0.167
Dry Season:    A       0.016      0.060
Wet Season:  A/B       0.007      0.250
Dry Season:  A/B       0.024      0.090
Wet Season:    B       0.010      0.333
Dry Season:    B       0.033      0.120
Wet Season:  B/C       0.012      0.417
Dry Season:  B/C       0.042      0.150
Wet Season:    C       0.015      0.500
Dry Season:    C       0.050      0.180
Wet Season:  C/D       0.018      0.584
Dry Season:  C/D       0.058      0.210
Wet Season:    D       0.020      0.667
Dry Season:    D       0.067      0.240

Perenniality Rules
Non-Perennial Allowed

Alignment of maximum stress to Present Day stress
Not Aligned
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Table of flows (m3/2) v stress index

Stress	Wet Season Flow	Dry Season Flow
0	0.275	0.111
1	0.215	0.083
2	0.179	0.065
3	0.151	0.050
4	0.130	0.040
5	0.114	0.030
6	0.099	0.023
7	0.080	0.018
8	0.058	0.012
9	0.030	0.006
10	0.000	0.000

HIGH FLOW ESTIMATION SUMMARY DETAILS

No High flows when natural high flows are < 20% of total flows
Adjusted hydrological variability for high flows is 100.00
Maximum high flows are 1000% greater than normal high flows

Table of normal high flow requirements (Mill. m3)

Category	A	A/B	B	B/C	C	C/D	D
Annual	6.715	6.092	5.512	4.971	4.468	4.000	3.566
Oct	0.108	0.098	0.088	0.080	0.072	0.064	0.057
Nov	0.242	0.219	0.198	0.179	0.161	0.144	0.128
Dec	0.284	0.258	0.233	0.210	0.189	0.169	0.151
Jan	0.212	0.192	0.174	0.157	0.141	0.126	0.113
Feb	0.244	0.221	0.200	0.181	0.162	0.145	0.130
Mar	0.452	0.410	0.371	0.335	0.301	0.269	0.240
Apr	1.008	0.914	0.827	0.746	0.670	0.600	0.535
May	1.105	1.003	0.907	0.818	0.735	0.658	0.587
Jun	1.208	1.096	0.991	0.894	0.804	0.719	0.641
Jul	0.751	0.681	0.616	0.556	0.500	0.447	0.399
Aug	0.695	0.631	0.571	0.515	0.463	0.414	0.369
Sep	0.407	0.369	0.334	0.301	0.271	0.242	0.216

FINAL RESERVE SUMMARY DETAILS

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

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

Category	Low Flows		Total Flows	
	Mill. m3	%MAR	Mill. m3	%MAR
A	1.956	6.7	11.594	39.6
A/B	1.795	6.1	10.694	36.5
B	1.655	5.6	9.831	33.5
B/C	1.514	5.2	9.005	30.7
C	1.371	4.7	8.220	28.0
C/D	1.229	4.2	7.468	25.5
D	1.082	3.7	6.737	23.0

FLOW DURATION and RESERVE ASSURANCE TABLES

Columns are FDC precentage points:

Natural Total flow duration curve (mill. m3)

	10	20	30	40	50	60	70	80	90	99
Oct	2.499	0.728	0.514	0.296	0.131	0.092	0.072	0.054	0.030	0.000
Nov	4.297	1.818	0.670	0.298	0.161	0.104	0.072	0.050	0.037	0.000
Dec	7.384	2.106	0.910	0.404	0.183	0.116	0.069	0.044	0.030	0.000
Jan	5.268	1.378	0.563	0.234	0.144	0.094	0.044	0.030	0.000	0.000

Feb	4.805	1.662	0.435	0.270	0.139	0.064	0.044	0.034	0.010	0.000
Mar	6.046	3.034	1.348	0.560	0.232	0.114	0.080	0.044	0.030	0.000
Apr	6.413	4.066	1.965	0.960	0.481	0.278	0.115	0.064	0.027	0.000
May	7.615	2.380	1.482	0.892	0.576	0.290	0.124	0.070	0.030	0.003
Jun	8.371	3.302	1.555	0.908	0.650	0.298	0.175	0.084	0.047	0.000
Jul	5.217	2.710	1.229	0.644	0.370	0.220	0.134	0.074	0.042	0.000
Aug	3.455	1.484	0.914	0.554	0.366	0.192	0.109	0.064	0.030	0.000
Sep	2.640	0.924	0.469	0.292	0.200	0.114	0.078	0.044	0.027	0.000

Natural Baseflow flow duration curve (mill. m3)

Oct	0.681	0.266	0.184	0.143	0.092	0.074	0.060	0.044	0.030	0.000
Nov	0.868	0.408	0.202	0.156	0.108	0.074	0.056	0.040	0.032	0.000
Dec	1.215	0.400	0.246	0.152	0.114	0.074	0.059	0.040	0.030	0.000
Jan	0.777	0.334	0.193	0.132	0.100	0.064	0.044	0.030	0.000	0.000
Feb	0.848	0.338	0.183	0.121	0.089	0.060	0.044	0.032	0.010	0.000
Mar	0.876	0.494	0.264	0.161	0.119	0.075	0.052	0.040	0.030	0.000
Apr	1.098	0.625	0.374	0.201	0.143	0.112	0.072	0.040	0.018	0.000
May	1.215	0.523	0.310	0.239	0.159	0.095	0.070	0.043	0.030	0.000
Jun	1.143	0.553	0.384	0.222	0.154	0.124	0.090	0.054	0.028	0.000
Jul	0.925	0.529	0.341	0.214	0.151	0.101	0.071	0.057	0.025	0.000
Aug	0.913	0.423	0.252	0.192	0.151	0.114	0.072	0.055	0.023	0.000
Sep	0.617	0.255	0.214	0.171	0.111	0.093	0.068	0.037	0.019	0.000

Category Low Flow Assurance curves (mill. m3)

C Category

Oct	0.192	0.153	0.116	0.105	0.072	0.042	0.025	0.013	0.000	0.000
Nov	0.217	0.205	0.131	0.111	0.081	0.042	0.022	0.010	0.000	0.000
Dec	0.284	0.219	0.154	0.118	0.083	0.044	0.025	0.009	0.000	0.000
Jan	0.219	0.202	0.119	0.099	0.075	0.036	0.018	0.008	0.000	0.000
Feb	0.197	0.165	0.106	0.085	0.060	0.031	0.016	0.007	0.000	0.000
Mar	0.256	0.244	0.167	0.118	0.089	0.043	0.021	0.010	0.000	0.000
Apr	0.284	0.261	0.218	0.164	0.104	0.054	0.020	0.001	0.000	0.000
May	0.312	0.253	0.201	0.178	0.120	0.059	0.025	0.010	0.000	0.000
Jun	0.314	0.247	0.216	0.166	0.119	0.068	0.034	0.014	0.000	0.000
Jul	0.262	0.251	0.207	0.164	0.117	0.057	0.026	0.012	0.000	0.000
Aug	0.253	0.223	0.165	0.146	0.112	0.062	0.030	0.011	0.000	0.000
Sep	0.169	0.157	0.135	0.110	0.079	0.056	0.036	0.017	0.002	0.000

Category Total Flow Assurance curves (mill. m3)

C Category

Oct	0.580	0.275	0.192	0.177	0.131	0.092	0.072	0.044	0.001	0.000
Nov	1.089	0.479	0.302	0.272	0.161	0.104	0.072	0.050	0.002	0.000
Dec	1.308	0.540	0.355	0.307	0.183	0.116	0.069	0.044	0.003	0.000
Jan	0.983	0.441	0.269	0.234	0.144	0.094	0.044	0.030	0.000	0.000
Feb	1.076	0.441	0.278	0.247	0.139	0.064	0.044	0.034	0.002	0.000
Mar	1.885	0.754	0.486	0.419	0.232	0.114	0.080	0.044	0.004	0.000
Apr	3.914	1.398	0.930	0.835	0.481	0.278	0.115	0.064	0.009	0.000
May	4.294	1.501	0.981	0.892	0.576	0.290	0.124	0.070	0.010	0.000
Jun	4.665	1.611	1.069	0.908	0.650	0.298	0.175	0.084	0.011	0.000
Jul	2.967	1.099	0.737	0.644	0.370	0.220	0.134	0.074	0.007	0.000
Aug	2.758	1.008	0.656	0.554	0.366	0.192	0.109	0.064	0.007	0.000
Sep	1.635	0.616	0.422	0.292	0.200	0.114	0.078	0.044	0.006	0.000

D.4 J4GOUR-EWR6: RDRM REPORT FOR A PES AND REC: C

TITLE: RDMR Report
DATE: 2014/12/04

Revised Desktop Model outputs for site: Gour_6

HYDROLOGY DATA SUMMARY

Natural Flows:

Area (km^2)	MAR (m^3 * 10^6)	Ann.SD (m^3 * 10^6)	Q75	Ann. CV
0.00	543.52	438.43	7.57	0.81

% Zero flows = 0.0
Baseflow Parameters: A = 0.990, B = 0.44
BFI = 0.25 : Hydro Index = 14.9

Present Day Flows:

Area (km^2)	MAR (m^3 * 10^6)	Ann.SD (m^3 * 10^6)	Q75	Ann. CV
0.00	310.35	344.43	2.30	1.11

% Zero flows = 0.0
Baseflow Parameters: A = 0.990, B = 0.440
BFI = 0.20 : Hydro Index = 24.6

Natural:

MONTH	MEAN (m^3 * 10^6)	SD (m^3 * 10^6)	CV
Oct	42.06	54.03	1.28
Nov	58.96	118.27	2.01
Dec	52.88	92.25	1.74
Jan	36.51	82.67	2.26
Feb	44.45	104.22	2.34
Mar	63.04	106.61	1.69
Apr	56.36	91.54	1.62
May	44.75	62.09	1.39
Jun	35.20	63.46	1.80
Jul	31.23	44.03	1.41
Aug	42.05	65.80	1.56
Sep	36.03	47.29	1.31

Present Day:

MONTH	MEAN (m^3 * 10^6)	SD (m^3 * 10^6)	CV
Oct	20.67	35.74	1.73
Nov	33.13	91.92	2.77
Dec	27.11	66.96	2.47
Jan	18.21	61.18	3.36
Feb	23.83	79.13	3.32
Mar	34.09	82.32	2.42
Apr	34.20	64.99	1.90
May	28.82	42.76	1.48
Jun	23.84	54.85	2.30
Jul	20.02	32.98	1.65
Aug	27.39	52.34	1.91
Sep	19.06	32.17	1.69

Critical months: WET : Nov, DRY : Jan
Using 20th percentile of FDC of separated baseflows
Max. baseflows (m3/s): WET : 7.046, DRY : 4.453

FLOW - STRESSOR RESPONSE DATA SUMMARY

Table of initial SHIFT factors for the Stress Frequency Curves

Category		High SHIFT	Low SHIFT
Wet Season:	A	0.057	0.190
Dry Season:	A	0.000	0.156
Wet Season:	A/B	0.085	0.285
Dry Season:	A/B	0.000	0.234
Wet Season:	B	0.113	0.380
Dry Season:	B	0.000	0.313
Wet Season:	B/C	0.141	0.475
Dry Season:	B/C	0.000	0.391
Wet Season:	C	0.170	0.570
Dry Season:	C	0.000	0.470
Wet Season:	C/D	0.199	0.665
Dry Season:	C/D	0.000	0.549
Wet Season:	D	0.227	0.760
Dry Season:	D	0.000	0.627

Perenniality Rules
All Seasons Perennial Forced

Alignment of maximum stress to Present Day stress
Not Aligned

Table of flows (m3/2) v stress index

Stress	Wet Season Flow	Dry Season Flow
0	7.364	4.720
1	5.200	3.200
2	4.200	2.500
3	3.450	1.950
4	2.800	1.450

5	2.100	0.990
6	1.500	0.600
7	0.850	0.300
8	0.370	0.120
9	0.100	0.050
10	0.000	0.000

HIGH FLOW ESTIMATION SUMMARY DETAILS

No High flows when natural high flows are < 20% of total flows
Adjusted hydrological variability for high flows is 6.35
Maximum high flows are 750% greater than normal high flows

Table of normal high flow requirements (Mill. m3)

Category	A	A/B	B	B/C	C	C/D	D
Annual	75.808	70.699	65.751	60.961	56.324	51.837	47.495
Oct	5.130	4.784	4.449	4.125	3.812	3.508	3.214
Nov	4.408	4.111	3.823	3.545	3.275	3.014	2.762
Dec	3.704	3.454	3.212	2.978	2.752	2.532	2.320
Jan	1.874	1.748	1.626	1.507	1.393	1.282	1.174
Feb	1.810	1.688	1.570	1.456	1.345	1.238	1.134
Mar	11.344	10.580	9.839	9.122	8.429	7.757	7.107
Apr	9.705	9.051	8.418	7.804	7.211	6.636	6.081
May	10.212	9.524	8.858	8.212	7.588	6.983	6.398
Jun	6.333	5.906	5.493	5.093	4.705	4.330	3.968
Jul	7.111	6.631	6.167	5.718	5.283	4.862	4.455
Aug	8.245	7.689	7.151	6.630	6.126	5.638	5.166
Sep	5.932	5.532	5.145	4.770	4.407	4.056	3.716

FINAL RESERVE SUMMARY DETAILS

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

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

Category	Low Flows		Total Flows	
	Mill. m3	%MAR	Mill. m3	%MAR
A	59.764	11.0	172.582	31.8
A/B	51.695	9.5	163.686	30.1
B	43.737	8.0	153.994	28.3
B/C	35.435	6.5	142.366	26.2
C	27.120	5.0	129.587	23.8
C/D	19.042	3.5	116.156	21.4
D	12.509	2.3	103.259	19.0

FLOW DURATION and RESERVE ASSURANCE TABLES

Columns are FDC precentage points:

Natural Total flow duration curve (mill. m3)

	10	20	30	40	50	60	70	80	90	99
Oct	100.404	70.048	43.738	24.679	19.796	15.612	12.476	11.064	7.976	4.495
Nov	180.790	73.346	53.023	28.170	18.160	13.637	9.697	6.356	5.176	2.694
Dec	141.189	75.151	35.272	26.069	14.125	11.164	7.652	5.258	3.824	1.843
Jan	93.854	47.282	29.035	15.687	8.406	5.967	4.939	3.594	2.854	0.989
Feb	170.862	49.797	24.292	11.677	8.625	6.165	4.407	3.512	2.833	1.424
Mar	166.525	88.773	52.943	35.280	28.512	18.002	9.778	7.192	3.243	1.788
Apr	140.320	88.828	51.424	39.051	23.042	14.373	10.365	7.055	4.377	1.408
May	160.551	66.325	43.429	28.696	21.590	14.533	8.444	5.901	4.492	2.572
Jun	79.047	41.734	30.160	23.108	16.857	13.217	9.013	6.698	5.012	2.612
Jul	65.072	39.429	31.295	22.951	17.320	13.100	10.031	7.947	5.906	4.000
Aug	102.595	47.917	29.811	23.894	20.577	16.285	13.143	9.136	7.150	5.503
Sep	95.468	52.307	29.257	21.291	17.110	13.616	11.299	9.126	7.113	4.490

Natural Baseflow flow duration curve (mill. m3)

Oct	22.544	16.561	13.377	11.227	10.155	7.871	6.469	5.658	4.157	2.806
Nov	28.356	18.247	14.961	11.200	9.783	8.968	6.349	4.923	3.906	2.161
Dec	24.511	16.730	13.088	10.445	8.234	6.574	5.708	4.288	3.505	1.843
Jan	23.084	11.901	10.139	7.316	5.932	5.159	4.106	3.252	2.802	0.989
Feb	26.957	14.202	8.524	7.361	6.074	4.784	3.507	3.065	2.510	1.424
Mar	31.319	15.989	10.873	9.173	8.028	6.580	5.781	4.604	3.102	1.197
Apr	25.738	16.666	12.734	9.693	7.781	6.506	5.111	4.253	3.278	1.408
May	29.500	15.628	11.264	8.615	6.880	5.825	5.247	4.571	3.445	1.874
Jun	19.688	13.193	9.587	8.531	7.462	5.533	4.960	4.217	3.382	2.234
Jul	18.909	12.455	10.538	8.710	7.480	6.320	5.283	4.533	3.638	1.951
Aug	23.458	13.766	11.573	9.475	7.838	7.005	5.831	5.113	3.855	3.201
Sep	22.660	14.397	11.137	9.846	8.175	7.035	5.825	5.224	4.076	3.208

Category Low Flow Assurance curves (mill. m3)

C Category

Oct	3.809	3.809	3.552	3.281	3.008	2.124	1.838	1.446	1.035	0.766
Nov	4.265	4.113	3.823	3.341	2.703	2.040	1.521	1.080	0.844	0.735
Dec	3.996	3.873	3.456	3.143	2.478	1.878	1.526	1.120	0.872	0.855
Jan	2.934	2.800	2.587	2.315	1.972	1.590	1.288	1.008	0.783	0.681
Feb	3.379	2.888	2.137	2.014	1.794	1.196	0.906	0.728	0.674	0.674
Mar	4.463	3.558	2.840	2.721	2.429	1.856	1.508	1.125	0.852	0.715
Apr	3.848	3.694	3.259	2.788	2.334	1.767	1.422	1.071	0.524	0.316
May	4.037	3.540	2.898	2.561	2.230	1.732	1.481	1.127	0.875	0.823
Jun	2.970	2.932	2.475	2.472	2.209	1.637	1.389	1.076	0.867	0.283
Jul	2.852	2.851	2.690	2.585	2.336	1.842	1.495	1.128	0.882	0.812
Aug	3.273	3.165	2.984	2.818	2.418	1.914	1.728	1.726	1.724	1.020
Sep	3.109	3.104	2.847	2.828	2.418	1.872	1.533	1.512	1.508	1.213

Category Total Flow Assurance curves (mill. m3)

C Category

Oct	27.019	18.217	11.934	8.154	5.707	2.681	1.899	1.446	1.035	0.766
Nov	24.208	16.493	11.025	6.205	3.927	2.615	2.076	1.830	0.889	0.735
Dec	20.753	14.275	9.507	5.461	2.906	2.654	2.336	1.974	0.910	0.855
Jan	11.415	8.064	4.684	2.732	2.468	2.279	1.893	1.617	0.803	0.681
Feb	11.570	7.973	5.095	3.734	3.099	2.457	1.912	1.316	0.693	0.674
Mar	55.789	32.864	13.873	8.418	3.547	1.899	1.508	1.296	0.969	0.715
Apr	47.759	30.952	19.116	12.007	6.764	2.950	1.971	1.091	0.524	0.316
May	50.243	32.222	19.585	12.261	9.866	8.846	5.037	3.560	0.980	0.823
Jun	31.624	20.719	12.823	8.487	6.944	6.048	4.516	2.522	0.931	0.283
Jul	35.024	22.822	14.308	9.339	7.652	5.903	4.478	3.096	0.955	0.812
Aug	40.576	26.322	16.455	10.649	8.583	7.446	5.813	3.691	1.809	1.020
Sep	29.947	19.763	12.539	7.569	5.701	4.658	3.289	2.436	1.568	1.213

D.5 K6KEUR-EWR8: RDRM REPORT FOR AN INSTREAM PES: C

TITLE: RDMR Report
DATE: 12/04/2014

Revised Desktop Model outputs for site: Keur_8

HYDROLOGY DATA SUMMARY

Natural Flows:					Present Day Flows:				
Area	MAR	Ann.SD	Q75	Ann.	Area	MAR	Ann.SD	Q75	Ann.
(km^2)	(m^3 * 10^6)			CV	(km^2)	(m^3 * 10^6)			CV
0.00	49.81	32.69	1.15	0.66	0.00	30.45	18.34	0.78	0.60

% Zero flows = 0.0 % Zero flows = 0.0
Baseflow Parameters: A = 0.960, B = 0.43Baseflow Parameters: A = 0.960, B = 0.430
BFI = 0.38 : Hydro Index = 7.3 BFI = 0.39 : Hydro Index = 6.0

MONTH	MEAN (m^3 * 10^6)	SD	CV
Oct	5.51	4.86	0.88
Nov	5.14	9.32	1.81
Dec	3.11	5.06	1.63
Jan	1.87	3.06	1.63
Feb	1.57	2.03	1.29
Mar	2.05	2.50	1.22
Apr	2.66	4.46	1.67
May	4.93	10.25	2.08
Jun	4.24	6.10	1.44
Jul	4.76	5.57	1.17
Aug	7.72	10.98	1.42
Sep	6.26	6.06	0.97

MONTH	MEAN (m^3 * 10^6)	SD	CV
Oct	3.52	2.59	0.74
Nov	3.14	5.25	1.67
Dec	1.87	2.77	1.48
Jan	1.06	1.51	1.43
Feb	0.87	0.98	1.13
Mar	1.12	1.10	0.98
Apr	1.60	2.43	1.52
May	2.98	5.74	1.93
Jun	2.67	3.25	1.22
Jul	3.02	2.97	0.98
Aug	4.69	6.13	1.31
Sep	3.91	3.16	0.81

Critical months: WET : Sep, DRY : Feb
Using 20th percentile of FDC of separated baseflows
Max. baseflows (m3/s): WET : 1.245, DRY : 0.533

FLOW - STRESSOR RESPONSE DATA SUMMARY

Table of initial SHIFT factors for the Stress Frequency Curves

Category		High SHIFT	Low SHIFT
Wet Season:	A	0.000	0.035
Dry Season:	A	0.000	0.035
Wet Season:	A/B	0.004	0.053
Dry Season:	A/B	0.004	0.053
Wet Season:	B	0.009	0.070
Dry Season:	B	0.009	0.070
Wet Season:	B/C	0.009	0.153
Dry Season:	B/C	0.009	0.153
Wet Season:	C	0.010	0.235
Dry Season:	C	0.010	0.235
Wet Season:	C/D	0.012	0.274
Dry Season:	C/D	0.012	0.274
Wet Season:	D	0.013	0.313
Dry Season:	D	0.013	0.313

Perenniality Rules
All Seasons Perennial Forced

Alignment of maximum stress to Present Day stress
Not Aligned

Table of flows (m3/2) v stress index

Stress	Wet Season Flow	Dry Season Flow
0	1.274	0.585
1	1.035	0.480
2	0.855	0.420
3	0.690	0.345
4	0.545	0.250
5	0.400	0.180
6	0.270	0.130
7	0.170	0.085
8	0.100	0.050
9	0.050	0.025
10	0.000	0.000

HIGH FLOW ESTIMATION SUMMARY DETAILS

No High flows when natural high flows are < 27% of total flows
Adjusted hydrological variability for high flows is 49.00
Maximum high flows are 555% greater than normal high flows

Table of normal high flow requirements (Mill. m3)

Category	A	A/B	B	B/C	C	C/D	D
Annual	10.036	9.170	8.356	7.591	6.872	6.196	5.562
Oct	1.105	1.009	0.920	0.835	0.756	0.682	0.612
Nov	0.560	0.511	0.466	0.423	0.383	0.346	0.310
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mar	0.846	0.773	0.705	0.640	0.579	0.523	0.469
Apr	0.985	0.900	0.820	0.745	0.675	0.608	0.546
May	1.007	0.920	0.839	0.762	0.690	0.622	0.558
Jun	1.357	1.240	1.130	1.026	0.929	0.838	0.752
Jul	1.345	1.229	1.120	1.017	0.921	0.830	0.746
Aug	1.330	1.215	1.107	1.006	0.910	0.821	0.737
Sep	1.501	1.371	1.250	1.135	1.028	0.927	0.832

FINAL RESERVE SUMMARY DETAILS

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

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

Category	Low Flows		Total Flows	
	Mill. m3	%MAR	Mill. m3	%MAR
A	14.613	29.3	25.119	50.4
A/B	14.218	28.5	24.345	48.9
B	13.826	27.8	23.450	47.1
B/C	12.260	24.6	21.451	43.1
C	10.657	21.4	19.321	38.8
C/D	9.893	19.9	17.878	35.9
D	9.138	18.3	16.430	33.0

FLOW DURATION and RESERVE ASSURANCE TABLES

Columns are FDC precentage points:

	10	20	30	40	50	60	70	80	90	99

Natural Total flow duration curve (mill. m3)

	10	20	30	40	50	60	70	80	90	99
Oct	11.892	6.976	5.472	4.543	3.975	3.631	2.958	2.581	1.849	1.395
Nov	9.642	6.472	4.112	3.210	2.646	2.207	1.938	1.686	1.332	0.931
Dec	5.474	3.909	2.885	1.934	1.556	1.348	1.127	0.863	0.623	0.355
Jan	3.457	2.381	1.748	1.225	1.068	0.832	0.628	0.503	0.384	0.191
Feb	3.761	2.040	1.280	1.094	0.931	0.673	0.590	0.473	0.322	0.192
Mar	3.907	2.894	2.368	1.828	1.306	1.106	0.891	0.591	0.333	0.259
Apr	4.186	2.757	2.355	1.950	1.650	1.219	0.989	0.760	0.549	0.246
May	9.864	5.100	3.309	2.522	1.913	1.524	1.084	0.826	0.682	0.292
Jun	7.340	4.832	4.113	2.910	2.428	1.977	1.489	1.091	0.735	0.338
Jul	12.204	5.419	4.242	3.413	2.969	2.683	2.155	1.490	1.167	0.702
Aug	19.616	10.043	6.231	4.644	3.502	3.018	2.485	2.021	1.671	1.044
Sep	13.982	9.804	5.964	4.920	4.038	3.376	2.833	2.267	1.662	1.118

Natural Baseflow flow duration curve (mill. m3)

	10	20	30	40	50	60	70	80	90	99
Oct	3.832	2.938	2.525	2.175	1.990	1.669	1.504	1.322	1.114	0.715
Nov	3.371	2.680	2.237	1.982	1.702	1.551	1.360	1.215	1.063	0.762
Dec	2.576	1.956	1.668	1.473	1.341	1.171	0.979	0.807	0.623	0.355
Jan	1.911	1.528	1.279	1.096	0.933	0.735	0.603	0.502	0.384	0.191
Feb	1.627	1.284	1.147	0.877	0.689	0.609	0.553	0.432	0.296	0.180
Mar	1.468	1.309	1.141	1.033	0.743	0.636	0.575	0.460	0.305	0.229
Apr	1.737	1.290	1.154	0.982	0.837	0.710	0.578	0.503	0.345	0.246
May	2.496	1.811	1.285	1.110	0.997	0.826	0.656	0.531	0.391	0.292

Jun	2.225	1.909	1.582	1.324	1.060	0.913	0.755	0.581	0.458	0.310
Jul	3.655	2.063	1.789	1.535	1.313	1.094	0.986	0.787	0.646	0.342
Aug	4.934	2.918	2.227	1.858	1.575	1.295	1.158	1.005	0.756	0.467
Sep	4.693	3.222	2.452	2.059	1.677	1.523	1.333	1.092	0.907	0.533

Category Low Flow Assurance curves (mill. m3)

C Category

Oct	1.854	1.816	1.714	1.513	1.393	1.084	0.847	0.753	0.676	0.592
Nov	1.740	1.633	1.525	1.394	1.191	0.953	0.761	0.680	0.664	0.664
Dec	1.492	1.333	1.138	1.030	0.952	0.748	0.566	0.462	0.390	0.271
Jan	1.179	1.053	0.842	0.740	0.644	0.468	0.333	0.290	0.241	0.138
Feb	0.897	0.807	0.664	0.529	0.416	0.334	0.268	0.215	0.180	0.144
Mar	0.909	0.887	0.763	0.670	0.509	0.391	0.314	0.266	0.223	0.172
Apr	1.082	0.869	0.730	0.631	0.545	0.420	0.315	0.278	0.235	0.182
May	1.519	1.209	0.886	0.757	0.680	0.518	0.381	0.307	0.278	0.230
Jun	1.509	1.236	1.027	0.857	0.716	0.553	0.410	0.330	0.288	0.269
Jul	1.797	1.370	1.209	1.073	0.925	0.702	0.552	0.447	0.385	0.303
Aug	2.558	1.925	1.553	1.344	1.157	0.846	0.676	0.570	0.459	0.391
Sep	1.987	1.857	1.675	1.453	1.202	0.958	0.748	0.600	0.492	0.414

Category Total Flow Assurance curves (mill. m3)

C Category

Oct	4.591	3.085	2.548	2.272	2.148	1.791	1.413	1.083	0.680	0.592
Nov	3.126	2.276	1.948	1.779	1.574	1.311	1.048	0.848	0.666	0.664
Dec	1.492	1.333	1.138	1.030	0.952	0.748	0.566	0.462	0.390	0.271
Jan	1.179	1.053	0.842	0.740	0.644	0.468	0.333	0.290	0.241	0.138
Feb	0.897	0.807	0.664	0.529	0.416	0.334	0.268	0.215	0.180	0.144
Mar	2.250	1.553	1.265	0.991	0.821	0.717	0.519	0.398	0.226	0.172
Apr	2.714	1.805	1.474	1.309	1.046	0.795	0.650	0.504	0.238	0.182
May	4.015	2.366	1.647	1.449	1.283	1.096	0.780	0.604	0.281	0.230
Jun	4.134	2.795	2.052	1.791	1.643	1.405	1.106	0.735	0.293	0.269
Jul	5.130	2.916	2.224	1.998	1.844	1.563	1.242	0.849	0.390	0.303
Aug	5.853	3.452	2.557	2.259	2.065	1.697	1.358	0.967	0.463	0.391
Sep	5.705	3.581	2.809	2.485	2.228	1.918	1.518	1.049	0.497	0.414

FINAL RESERVE SUMMARY DETAILS

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

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

Category	Low Flows		Total Flows	
	Mill. m3	%MAR	Mill. m3	%MAR
A	14.794	29.7	27.830	55.9
A/B	14.363	28.8	26.400	53.0
B	13.937	28.0	24.977	50.1
B/C	12.282	24.7	22.337	44.8
C	10.665	21.4	19.768	39.7
C/D	9.900	19.9	18.108	36.4
D	9.144	18.4	16.513	33.1

FLOW DURATION and RESERVE ASSURANCE TABLES

Columns are FDC precentage points:

	10	20	30	40	50	60	70	80	90	99

Natural Total flow duration curve (mill. m3)

Oct	11.892	6.976	5.472	4.543	3.975	3.631	2.958	2.581	1.849	1.395
Nov	9.642	6.472	4.112	3.210	2.646	2.207	1.938	1.686	1.332	0.931
Dec	5.474	3.909	2.885	1.934	1.556	1.348	1.127	0.863	0.623	0.355
Jan	3.457	2.381	1.748	1.225	1.068	0.832	0.628	0.503	0.384	0.191
Feb	3.761	2.040	1.280	1.094	0.931	0.673	0.590	0.473	0.322	0.192

Mar	3.907	2.894	2.368	1.828	1.306	1.106	0.891	0.591	0.333	0.259
Apr	4.186	2.757	2.355	1.950	1.650	1.219	0.989	0.760	0.549	0.246
May	9.864	5.100	3.309	2.522	1.913	1.524	1.084	0.826	0.682	0.292
Jun	7.340	4.832	4.113	2.910	2.428	1.977	1.489	1.091	0.735	0.338
Jul	12.204	5.419	4.242	3.413	2.969	2.683	2.155	1.490	1.167	0.702
Aug	19.616	10.043	6.231	4.644	3.502	3.018	2.485	2.021	1.671	1.044
Sep	13.982	9.804	5.964	4.920	4.038	3.376	2.833	2.267	1.662	1.118

Natural Baseflow flow duration curve (mill. m3)

Oct	3.832	2.938	2.525	2.175	1.990	1.669	1.504	1.322	1.114	0.715
Nov	3.371	2.680	2.237	1.982	1.702	1.551	1.360	1.215	1.063	0.762
Dec	2.576	1.956	1.668	1.473	1.341	1.171	0.979	0.807	0.623	0.355
Jan	1.911	1.528	1.279	1.096	0.933	0.735	0.603	0.502	0.384	0.191
Feb	1.627	1.284	1.147	0.877	0.689	0.609	0.553	0.432	0.296	0.180
Mar	1.468	1.309	1.141	1.033	0.743	0.636	0.575	0.460	0.305	0.229
Apr	1.737	1.290	1.154	0.982	0.837	0.710	0.578	0.503	0.345	0.246
May	2.496	1.811	1.285	1.110	0.997	0.826	0.656	0.531	0.391	0.292
Jun	2.225	1.909	1.582	1.324	1.060	0.913	0.755	0.581	0.458	0.310
Jul	3.655	2.063	1.789	1.535	1.313	1.094	0.986	0.787	0.646	0.342
Aug	4.934	2.918	2.227	1.858	1.575	1.295	1.158	1.005	0.756	0.467
Sep	4.693	3.222	2.452	2.059	1.677	1.523	1.333	1.092	0.907	0.533

Category Low Flow Assurance curves (mill. m3)

C Category

Oct	1.854	1.816	1.714	1.513	1.393	1.084	0.847	0.753	0.676	0.592
Nov	1.740	1.633	1.525	1.394	1.191	0.953	0.761	0.680	0.664	0.664
Dec	1.492	1.333	1.138	1.030	0.952	0.748	0.566	0.462	0.390	0.313
Jan	1.179	1.053	0.842	0.740	0.644	0.468	0.333	0.290	0.241	0.178
Feb	0.897	0.807	0.664	0.529	0.416	0.334	0.268	0.215	0.180	0.158
Mar	0.909	0.887	0.763	0.670	0.509	0.391	0.314	0.266	0.223	0.204
Apr	1.082	0.869	0.730	0.631	0.545	0.420	0.315	0.278	0.235	0.204
May	1.519	1.209	0.886	0.757	0.680	0.518	0.381	0.307	0.278	0.272
Jun	1.509	1.236	1.027	0.857	0.716	0.553	0.410	0.330	0.288	0.280
Jul	1.797	1.370	1.209	1.073	0.925	0.702	0.552	0.447	0.385	0.312
Aug	2.558	1.925	1.553	1.344	1.157	0.846	0.676	0.570	0.459	0.400
Sep	1.987	1.857	1.675	1.453	1.202	0.958	0.748	0.600	0.492	0.414

Category Total Flow Assurance curves (mill. m3)

C Category

Oct	4.591	3.085	2.548	2.272	2.148	1.791	1.413	1.083	0.680	0.592
Nov	3.126	2.276	1.948	1.779	1.574	1.311	1.048	0.848	0.666	0.664
Dec	1.492	1.333	1.138	1.030	0.952	0.748	0.566	0.462	0.390	0.313
Jan	1.179	1.053	0.842	0.740	0.644	0.468	0.333	0.290	0.241	0.178
Feb	0.897	0.807	0.664	0.529	0.416	0.334	0.268	0.215	0.180	0.158
Mar	3.006	1.860	1.402	1.252	1.087	0.933	0.748	0.519	0.226	0.204
Apr	3.523	2.001	1.474	1.309	1.219	1.051	0.820	0.573	0.238	0.204
May	4.015	2.366	1.647	1.449	1.369	1.163	0.897	0.607	0.281	0.272
Jun	4.871	2.795	2.052	1.791	1.643	1.421	1.106	0.735	0.293	0.280
Jul	5.130	2.916	2.224	1.998	1.844	1.563	1.242	0.849	0.390	0.312
Aug	5.853	3.452	2.557	2.259	2.065	1.697	1.358	0.967	0.463	0.400
Sep	5.705	3.581	2.809	2.485	2.228	1.918	1.518	1.049	0.497	0.414

D.6 K6KEUR-EWR8: RDRM REPORT FOR AN INSTREAM REC: B

Revised Desktop Model outputs for site: Keur_8

HYDROLOGY DATA SUMMARY

Natural Flows:					Present Day Flows:				
Area	MAR	Ann.SD	Q75	Ann.	Area	MAR	Ann.SD	Q75	Ann.
(km^2)	(m^3 * 10^6)			CV	(km^2)	(m^3 * 10^6)			CV

```
    0.00   49.81   32.69    1.15  0.66      0.00   30.45   18.34    0.78  0.60

% Zero flows =   0.0                    % Zero flows =   0.0
Baseflow Parameters: A = 0.960, B = 0.43Baseflow Parameters: A = 0.960, B = 0.430
BFI = 0.38 : Hydro Index =   7.3        BFI = 0.39 : Hydro Index =   6.0

MONTH   MEAN      SD     CV             MONTH   MEAN      SD     CV
        (m^3 * 10^6)                            (m^3 * 10^6)
 Oct    5.51    4.86    0.88             Oct    3.52    2.59    0.74
 Nov    5.14    9.32    1.81             Nov    3.14    5.25    1.67
 Dec    3.11    5.06    1.63             Dec    1.87    2.77    1.48
 Jan    1.87    3.06    1.63             Jan    1.06    1.51    1.43
 Feb    1.57    2.03    1.29             Feb    0.87    0.98    1.13
 Mar    2.05    2.50    1.22             Mar    1.12    1.10    0.98
 Apr    2.66    4.46    1.67             Apr    1.60    2.43    1.52
 May    4.93   10.25    2.08             May    2.98    5.74    1.93
 Jun    4.24    6.10    1.44             Jun    2.67    3.25    1.22
 Jul    4.76    5.57    1.17             Jul    3.02    2.97    0.98
 Aug    7.72   10.98    1.42             Aug    4.69    6.13    1.31
 Sep    6.26    6.06    0.97             Sep    3.91    3.16    0.81

Critical months: WET : Sep, DRY : Feb
Using  20th percentile of FDC of separated baseflows
Max. baseflows (m3/s): WET :      1.245, DRY :      0.533


HIGH FLOW ESTIMATION SUMMARY DETAILS

No High flows when natural high flows are <  27% of total flows
Adjusted hydrological variability for high flows is  14.41
Maximum high flows are 475% greater than normal high flows

Table of normal high flow requirements (Mill. m3)
Category    B
Annual     6.870
   Oct     0.756
   Nov     0.383
   Dec     0.000
   Jan     0.000
   Feb     0.000
   Mar     0.579
   Apr     0.674
   May     0.689
   Jun     0.929
   Jul     0.921
   Aug     0.910
   Sep     1.027

FINAL RESERVE SUMMARY DETAILS

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

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

Category     Low Flows         Total Flows
          Mill. m3   %MAR    Mill. m3   %MAR
     B      13.934    28.0    23.283    46.7

FLOW DURATION and RESERVE ASSURANCE TABLES

Columns are FDC precentage points:
        10        20        30        40        50        60        70        80        90        99
Natural Total flow duration curve (mill. m3)
Oct  11.892     6.976     5.472     4.543     3.975     3.631     2.958     2.581     1.849     1.395
```

Nov	9.642	6.472	4.112	3.210	2.646	2.207	1.938	1.686	1.332	0.931
Dec	5.474	3.909	2.885	1.934	1.556	1.348	1.127	0.863	0.623	0.355
Jan	3.457	2.381	1.748	1.225	1.068	0.832	0.628	0.503	0.384	0.191
Feb	3.761	2.040	1.280	1.094	0.931	0.673	0.590	0.473	0.322	0.192
Mar	3.907	2.894	2.368	1.828	1.306	1.106	0.891	0.591	0.333	0.259
Apr	4.186	2.757	2.355	1.950	1.650	1.219	0.989	0.760	0.549	0.246
May	9.864	5.100	3.309	2.522	1.913	1.524	1.084	0.826	0.682	0.292
Jun	7.340	4.832	4.113	2.910	2.428	1.977	1.489	1.091	0.735	0.338
Jul	12.204	5.419	4.242	3.413	2.969	2.683	2.155	1.490	1.167	0.702
Aug	19.616	10.043	6.231	4.644	3.502	3.018	2.485	2.021	1.671	1.044
Sep	13.982	9.804	5.964	4.920	4.038	3.376	2.833	2.267	1.662	1.118

Natural Baseflow flow duration curve (mill. m3)

Oct	3.832	2.938	2.525	2.175	1.990	1.669	1.504	1.322	1.114	0.715
Nov	3.371	2.680	2.237	1.982	1.702	1.551	1.360	1.215	1.063	0.762
Dec	2.576	1.956	1.668	1.473	1.341	1.171	0.979	0.807	0.623	0.355
Jan	1.911	1.528	1.279	1.096	0.933	0.735	0.603	0.502	0.384	0.191
Feb	1.627	1.284	1.147	0.877	0.689	0.609	0.553	0.432	0.296	0.180
Mar	1.468	1.309	1.141	1.033	0.743	0.636	0.575	0.460	0.305	0.229
Apr	1.737	1.290	1.154	0.982	0.837	0.710	0.578	0.503	0.345	0.246
May	2.496	1.811	1.285	1.110	0.997	0.826	0.656	0.531	0.391	0.292
Jun	2.225	1.909	1.582	1.324	1.060	0.913	0.755	0.581	0.458	0.310
Jul	3.655	2.063	1.789	1.535	1.313	1.094	0.986	0.787	0.646	0.342
Aug	4.934	2.918	2.227	1.858	1.575	1.295	1.158	1.005	0.756	0.467
Sep	4.693	3.222	2.452	2.059	1.677	1.523	1.333	1.092	0.907	0.533

Category Low Flow Assurance curves (mill. m3)

B Category

Oct	2.482	2.456	2.338	2.058	1.835	1.378	1.046	0.894	0.769	0.644
Nov	2.324	2.194	2.053	1.844	1.566	1.211	0.939	0.808	0.740	0.704
Dec	1.952	1.773	1.557	1.402	1.250	0.954	0.700	0.549	0.445	0.339
Jan	1.522	1.392	1.166	1.030	0.853	0.589	0.405	0.345	0.273	0.191
Feb	1.148	1.061	0.929	0.747	0.554	0.416	0.324	0.255	0.203	0.168
Mar	1.183	1.171	1.048	0.938	0.677	0.490	0.383	0.316	0.252	0.220
Apr	1.394	1.147	1.009	0.886	0.724	0.528	0.383	0.330	0.266	0.220
May	1.995	1.604	1.226	1.052	0.900	0.653	0.466	0.364	0.314	0.291
Jun	1.996	1.642	1.410	1.179	0.945	0.699	0.503	0.392	0.326	0.297
Jul	2.403	1.825	1.649	1.455	1.214	0.894	0.683	0.531	0.439	0.336
Aug	3.389	2.587	2.093	1.787	1.509	1.085	0.842	0.678	0.524	0.438
Sep	2.723	2.524	2.242	1.909	1.566	1.235	0.941	0.708	0.564	0.449

Category Total Flow Assurance curves (mill. m3)

B Category

Oct	5.255	4.090	3.368	2.853	2.591	2.085	1.612	1.224	0.773	0.644
Nov	3.729	3.022	2.575	2.248	1.949	1.569	1.226	0.975	0.742	0.704
Dec	1.952	1.773	1.557	1.402	1.250	0.954	0.700	0.549	0.445	0.339
Jan	1.522	1.392	1.166	1.030	0.853	0.589	0.405	0.345	0.273	0.191
Feb	1.148	1.061	0.929	0.747	0.554	0.416	0.324	0.255	0.203	0.168
Mar	3.308	2.423	1.837	1.548	1.257	1.031	0.816	0.569	0.255	0.220
Apr	3.868	2.604	1.927	1.596	1.399	1.158	0.888	0.624	0.269	0.220
May	4.524	3.094	2.164	1.778	1.590	1.298	0.982	0.664	0.318	0.291
Jun	5.403	3.649	2.675	2.157	1.874	1.567	1.199	0.797	0.331	0.297
Jul	5.781	3.814	2.902	2.424	2.134	1.755	1.372	0.933	0.444	0.336
Aug	6.728	4.554	3.332	2.745	2.418	1.935	1.523	1.076	0.529	0.438
Sep	6.491	4.744	3.641	2.990	2.593	2.196	1.710	1.156	0.569	0.449

APPENDIX E: COMMENTS AND RESPONSE REGISTER

Section	Report Statement	Comments	Addressed in Report?	Author Comment
Comments: Esther Lekalake, received 3 August 2014				
Cover page		Chief Directorate: Water Ecosystems	Yes	
Page xi		Have a brief explanation of the meaning of the figures or colour codes in the table.	Yes	
Page vii (Touws River)		*A. Karoo* should be written in full in the beginning, and later could be abbreviated?	Yes	
Page ix (Olifants river)		The above comment applies for *S. Aphylla.*	Yes	
Page x paragraph 2		The following Typing errors were identified: responses, resulting, influenced.	Yes	
Page x		In the confidence table, can we have a brief explanation of the figures and colour codes?	Yes	
Page1-4 (Buffels River)		The confidence for natural hydrology is 3.5 and the confidence on present day hydrology is 2.5?? Is it correct?	Yes	The confidence in PD is lower as there is low confidence on water use information upstream of the EWR site.
Page 1-4		Consistency regarding present day hydrology vs present hydrology.	Yes	
Page 1-5		Buffels River, the WMS code is it 102152 or 10252?	Yes	
Page 1-6		remove 0 and replace with)	Yes	
Page 2-3		1st paragraph, replace surmised with summarised.	Yes	
Page4-5		Last sentence: is sed correct?	Yes	
Page 7-2		First paragraph, remove the question mark at the end of the sentence	Yes	
Page 7-2		2nd paragraph, is farther correct or further? Also remove ? in some of the sentences.	Yes	
Page 14-1		MCB is not appearing on a list of acronyms.	Yes	
Page 14-1		replace my with may	Yes	
Page 14-2		1 superscript is not explained below the table	Yes	
Comments: Andrew Gordon – DWS WC: Resource Protection, and Thapelo Machaba, DWS: CD: SWRR received 12 August 2015				
Whole Report		Grammar and syntax errors	Yes	Corrected.
Executive	EcoClassification summary table	Highest scoring metrics were… This sentence, especially the first line,	Yes	Corrected.

Section	Report Statement	Comments	Addressed in Report?	Author Comment
Summary		doesn't make sense.		
	EWR quantification table	I wasn't sure why for some sites the instream EcoStatus is presented in this table and for other sites just the PES and for yet other sites both the PES and REC. If the reason for this is detailed in the main body of the report then fine, i haven't got there yet. Further to the comment above. I think it would be useful to provide some text as to why the particular EcoStatus was decided upon. For example, why for J2GAMK-EWR4 was the PES of C/D chosen as the goal and not the REC of C. And why for J1TOUW-EWR3 was an Instream EcoStatus of C chosen and not the overall EcoStatus of B/C?	No	The reasoning for using the Instream or PES/REC EcoStatus is provided in the main body of the report below the EcoStatus table at the end of each EcoClassification chapter.
Figure 1.1		Is it possible to change this map, it is not clear.	No	A3 page format rather than A4.
1.1	A total of ten Ecological Water Requirements (EWR) sites were selected in the study area. EWRs have already been determined for four sites situated in the Duiwenhoks, Goukou, Doring and Kammanassie Rivers and the results are documented in DWS (2014).	Indicate that the four EWR sites were done on the Rapid level.	Yes	
Table 1.2		Add why geomorphology was excluded from Olifants assessment	Yes	This was done as a Rapid but assessed during the Intermediate workshop. To avoid confusion, it has now been removed and included in the Rapid report.
Table 5.1 and 5.2		Add missing EC for fish and Invertebrates. Some ECs incorrect.	Yes	
5.4	Improvement to the REC requires a different operating rules and setting of the EWRs are not required. Only descriptive requirements are provided in Section 6.5 for attaining the REC.	So the operating rules can't be changed? Is this why the REC can't be achieved? Perhaps a little explanation in the text would help the reader.	Yes	The operating rules can be changed and detail is provided under Section 6.2. Text was amended accordingly.
Table 11.3		There is a REC for water quality of B in Table 11.3, but WQ doesn't appear in table 11.2	No	The PES and the REC is the same for WQ. So no improvement in water quality is provided.
Table 17.1		What was the reason of sampling not done?		Those sites were surveyed when the RO representatives were absent, and no instruments were therefore available.

Section	Report Statement	Comments	Addressed in Report?	Author Comment
17.4	Results	The results below addresses the RC & PES but does not address the Water Quality Requirements, will this be addressed in a separate report? Main report maybe?	No	Clarification from the reviewer on the meaning of this comment was not received and could therefore not be addressed. It may refer to the final EcoSpecs for water quality, which appear in the Monitoring Report.
	Secondary catchment: J3 Nutrient enrichment and eutrophication is seen in the Olifants River downstream of Oudtshoorn. There are also impacts related to a number of tanneries in the Oudtshoorn area.	The statement above indicated that eutrophication was not a problem in this WMA? This is a contradiction of statements.	Yes	Section 17.3 states that Issues such as eutrophication, metal and toxicant contamination were not considered problematic in WMA16, although high phosphate levels were recorded for large parts of the WMA due to agricultural return flows and discharges from wastewater treatment works. This indicates that based on information at the time (2011), pockets of eutrophication do exist in the area.
Comments: Dr Cate Brown – External Reviewer, received 29 June 2015				
1.2	Study area overview	This either needs to be updated to incorporate the changes WMA configuration or should revert to a description of the Gouritz WMA. For instance, the Breede River is a significant river in the Breede-Gourtiz WMA. The map also shows only Gouritz WMA, and legend should reflect that	Yes	Addressed and changes made accordingly in report.
1.3	'Information collated during physical surveys was used to provide the results in this report. The data and information availability is summarised in Table 1.2.'	Suggested rewording: 'Information collated from existing reports and collected during field visits was used to inform the results presented in this report. The data and information used are summarised in Table 1.2.'	Yes	
1.3, Table 2.1	Hydrology information	I found the Table 1.2 confusing. The table states that (for the most part) WR2009 data were used for both natural and PD hydrology. However, it also gives a reporting period for gauges where relevant. How were the gauges used – if at all? My guess is that the table does not cover the full suite of available hydrological data and information. Thus, if the gauges are to be included, you should state how they were used. For instance, for J2GAMK-EWR4 you state that the WR2005 data were compared with the gauge data. Did you do this at the other sites? Did it fit? I suggest Table 1.2 is reworded to make it more clear which data were used where. See text – I have tried to help where I can (see text),	Yes	These queries and additional queries/comments in the text were addressed.

Section	Report Statement	Comments	Addressed in Report?	Author Comment
		but please check that I have interpreted the information correctly. For instance: “Touws River: J1TOUW-EWR3 Natural hydrology: The natural quaternary data based on the Water Resources of South Africa, 2005 study (WR2005) (Middleton and Bailey, 2011) was scaled to obtain representative natural flow at the EWR site. There are large uncertainties regarding the historical agriculture abstractions and sub-surface flow. The flow gauge J1H018 is upstream of the EWR site. Observations started in 1982 and the gauge is only good for measuring low flows. Confidence: 2. Present Hydrology: The flow data was based on the WR2005 hydrological data. There is low confidence in information on water use upstream of the EWR site. The initial simulated Present Day (PD) base flow seemed too high and in instances with large discrepancies between the 2004 and 1998 irrigation areas, the higher 1998 areas were adopted to simulate irrigation demands. Confidence 2. Record period: J1H018 upstream of site (1982 to date).” Suggested rewording: ‘Touws River: J1TOUW-EWR3 Measured flows: The flow gauge J1H018 is upstream of the EWR site. Observations started in 1982 and continue to date, but the gauge is only good for measuring low flows (reference), and the gauge data could not be used. Natural hydrology: The quaternary data from the 2005 Water Resources of South Africa study (WR2005; Middleton and Bailey, 2011) were scaled to obtain representative natural flow at the EWR site. There are large uncertainties regarding the historical agriculture abstractions and sub-surface flow, which means that the natural flows may be under-estimated. Confidence: 2. Present Hydrology: Irrigation abstractions were subtracted from the WR2005 data to provide PD flow at the EWR site. There is a great deal of uncertainty about the extent of current irrigation upstream of the EWR site particularly given that the 1998 irrigated areas are larger than those in 2004. Thus, where there were large discrepancies between the 2004 and 1998 irrigated areas, the higher 1998 areas were used to simulate irrigation demands. Confidence 2.’’ See other suggestions in the text. For J4GOUR-EWR6, it states that ‘Gauge data starts from 1964 to		

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		present with 22 years of usable data (Oct 1999 to present). Data for the period 1990 to present were used.' Why did you use nine years of 'unusable' data?		
	Water quality	'Specialist assessment as no RC data and A category benchmarks from DWAF (2008) considered unsuitable'. What does 'specialist assessment' mean? "J1TOUW-EWR3 Specialist assessment as no RC data and A category benchmarks from DWAF (2008) considered unsuitable. J1H018Q01 (Water Management System (WMS) code 102147) (2000 – 2014; n = ± 128) was used for the present state assessment and is located upstream of the EWR site. Confidence: 2.5" Are the two bullets supposed to represent RC and PD? If so – say so. Actually, the whole water quality section is very confusing. For instance: 'J1H028Q01 (WMS code 102152) (1972 – 1977; n = 54, Conductivity: n = 33), downstream Floriskraal Dam and upstream of the EWR site, was used for the present state assessment. Note that the monitoring point is not in the same Level II EcoRegion as the EWR site; however, this is the only data point between the dam and the site. J1H028Q01 (WMS code 10252) (2010 – 2014; n = 44).' Why is J1H028Q01 listed twice with different dates? Was one lot used for Natural and one for PD? Also 'Gouritz River: J4GOUR-EWR6 J4H002Q01 (WMS code 102201) (1965 – 1967; n = 29) was used for the RC and present state assessment and is located upstream of the EWR site. J4H002Q01 (2010 – 2014; n = 85).' Very confusing.	Yes	Issues were addressed and mention was made that detailed methods are provided in Appendix A of the report.
	Geomorphology	Minor comments - see text.	Yes	
	Fish	'Good historical data for Keurbooms River are available although some distance from the EWR site and also limited recent data available, thus the confidence is low.' It do not get it. This site has good historical information and limited recent data, and SO the confidence is low?? Why would confidence be lower than sites for which there are not data?	Yes	
	Diatoms and Ecohydraulics	Minor comments – see text.	Yes	
1.4	Outline of this report	The appendices should be listed as appendices not as sections.	Yes	

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2.1.1	Present Ecological State	This sentence suggests that PES is only determined for components, and once these are put together it is "Ecostatus". Is this so? Why then, through-out the document, is PES (and sometimes PES EcoStatus) used to refer to the combined score? Is this not a case of over-defining things. Are PES and Ecostatus not the same thing? If so, why use Ecostatus at all? This is not helped by Figure 2.1, which uses Integrity. All of this section is quite confusing and would benefit from restructuring.	Yes	PES and EcoStatus is not the same. The text has been clarified to better explain this section.
2.2.1	This depends, however, on the level of uncertainty in the underlying modelled hydrology.	Can you explain more fully? Does this mean, for instance, that if the confidence in the hydrology is low the curves are not adjusted?	Yes	The sentence has been deleted.
3.2, Table 3.1	Hydrology	"Although there is a difference between the observed and present day flow the observation station has many unreliable flows. Observed data are 20% higher than PD modelled data. There are zero flows in the observed data 35% of the time and 54% of the time in the simulated data. However, the simulated flows occurring 35% of the time in the simulated record are very low. It is assumed that agriculture which is the largest water use has not changed dramatically over the last few years. Baseflows have decreased significantly in volume, in time and distribution when compared to natural and these changes are continuous throughout the year. Natural seasonal distribution has changed due to farms dams, irrigation, grazing and domestic water use." I am having some trouble understanding what is meant here: If there are zeros for 54% of the time in the modelled data, then what does the 'simulated flows occurring 35% of the time in the simulated record are very low' refer to? Surely they are zero? Do you mean that flows in the simulated record are either zero or very low for 89% of the time? Why are the observed flows higher? Do you know? Also, what does 'these changes are continuous throughout the year' mean? Do the occur in all seasons, or can you see the decline in the observed record? I think this section would benefit from a rewording that makes it more clear what is being said.	Yes	These queries and additional queries/comments in the text were addressed.
	Water quality	See text for suggested rewording.	Yes	

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		It seems from what has been said that the salinity is naturally high – why then is the high EC a concern? More explanation required – plus some synchronising between the statements from different specialists.		
	Geomorphology, IHI and vegetation	Geomorphology says: '*The riparian zone is poorly vegetated but is similar to (or slightly reduced from) the RC. The slight loss of vegetation may be associated with reduced baseflows and/or a very slight reduction in floods'*. B-category. But, IHI says: '*The riparian IHI is mainly impacted by bank structure modification due to agriculture, cattle grazing and the presence of alien invasive species which have led to bank instability, substrate exposure and generally impacts on lateral connectivity*' - C-category. These do not match. This situation is similar for Instream IHI. Basically there are two different scores for the same thing. One gives a b and one a C. Either these should change – or more explanation is needed to avoid the suggestion of a contradiction.	Yes	Inconsistency was in the IHI and it has been adjusted.
	Fish	The PES project did not collect any fish data – so basically, this assessment is an extrapolation of an extrapolation.	Yes	
	Macroinvertebrates	What is 'same site (2004 – 2010)'? The EWR site or J1TOUW-BOOKE? '*simuliid mayflies'*? I have not heard of these before.	Yes	
3.3	REC: It was likely that some of the ratings for the PES should have been higher, which would have resulted in a B EcoStatus and an improvement would then not be required. Considering these issues and that non-flow related mitigation measures i.e. removal of alien vegetation would not result in the improvement of riparian vegetation, the REC was at PES and it is recommended that monitoring and further studies are conducted.	Why not – the IHI PES says these ae related to: cattle grazing and the presence of alien invasive species "it is recommended that monitoring and further studies are conducted" While I understand the motivation behind this statement, I think these sorts of statements put DWS in a difficult position. Can you elaborate on what needs to be monitored, what studies need to be done, and why? Do you really think further studies will help? If so, then provide a strong motivation for such. Also, please address inconsistencies. For example, your overall conclusion (Section 15.3) is: "Furthermore, no further work on the EcoClassification is required as it will not influence the EWR determination."	Yes	Inconsistencies removed, re monitoring – there is a separate monitoring report and it will be cross-referenced.
4.1	Flow vs stress relationship	I apologise but I do not understand what is being explained here. Are	Yes	

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		you saying that for seasonal rivers you do not do dry season HFSR, but rather use a default function from the RDRM? If so, where does this come from and what are the implications of its use?		
Table 4.1		This table would be easier to interpret if the associated velocities and depths were also reported. For instance, the fish table says: "Only semi-rheophilic riffle spawning species present, the small minnow (PASP) and large LUMB require depths of 15 to 20 cm for spawning and migration. Riffle depths <20 cm allow very limited migration of eels and LUMB." But does not say what the actual velocities and depths are when the discharge is c. 0.034 m3/s. This comment applies to all the other similar tables, e.g. 4.2, 4.3, 6.1, 6.2, 6.4, etc., and is not mentioned again in this review.	No	Point taken – however during previous studies the decision was made not to do this as all the information is available in the hydraulic look-up tables. Repeating information leads to cross-referencing that will be required which becomes a major issue.
Table 4.3	Verification of low flows	See comments in text.	Yes	
Section 4.4 and Table 4.4		Which respective categories? This comment applies to similar tables for other sites and is not mentioned again in this review. Is this table correct? What do the 0.39 and 0.71 stand for? This comment applies to similar tables for other sites and is not mentioned again in this review. Is the PES B/C or C?	Yes	All comments addressed.
Table 4.5	High flow requirements	See comments in text.	Yes	
Section 4.6	EWR results	The use of rules and tables needs to be explained better – many DWS officials /dam operators are understandably confused by this. Perhaps this could be put in a section under approach? This comment applies to all the other EWR results for sites and is not mentioned again in this review.	Yes	
5.2	The major issues resulting in the change from RC are the alteration in sediment regime due to the upstream impoundment, the small regular and aseasonal flood releases from the Gamkapoort Dam, and the decreased frequency of large floods	Surely, this is just localised	No	It affects a major piece of the river reach which is also a hotspot and in a National Park/World Heritage Site. This would affect most of the river reach in the gorge.
5.2, Table 5.1	Hydrology	'*the daily data shows another picture*'. This is very cryptic. I assume you are referring to the pulse releases. If so, say so. Also it doesn't show another picture – the monthly hydrology match, do you have daily	Yes	These queries and additional queries/comments in the text were addressed.

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		modelled hydrology? Because this sentence suggested that the daily hydrological data from the two data sets do not match, whereas I think you mean that the only observed data are the daily, which shows the pulsed releases. Suggested rewording: The 36 million m^3/a Gamkapoort Dam, built in 1967, is located XXXX upstream of the site. The nMAR is 85.54 MCM and the pMAR is 61.69 MCM (72.1% of the nMAR). There are no major differences between the observed and modelled PD hydrology, but the monthly flows obscure the current flow regime, which comprises periodic flood releases from the dam (one approximately every two months throughout the year) and only leakage in-between.		
	Water quality	Try to stay away from subjective adjectives. It is not worse – in is "more saline'. Are these systems not naturally saline – given the geology? Other minor comments - see text.	Yes	
	Geomorphology, IHI and vegetation	"flood reduction (magnitude and frequency)". Is it not more complicated than simple reduction in magnitude and frequency? My understanding is that the small floods have increased in frequency (and are unseasonal) while the bigger floods are reduced in frequency. Check tenses.	Yes	All comments addressed.
	Fish	What is the difference between alien and non-indigenous? Are the dry season flows unnaturally high or is it that the flood frequency in the dry season is unnaturally high?	Yes	
	Macroinvertebrates	One or two RHP sites? The text is unclear.	Yes	
5.3	Larger flood releases would improve the geomorphology.	I disagree. The geomorphology is affected by the sediments as much as the flooding.	Yes	The wrong information was in this section and it has been corrected.
	Water quality – reducing nutrient input, however the source of the nutrients must first be identified.	'improving nutrients'. Do you mean reducing nutrient input? I doubt the nutrients themselves require improvement.		
Table 5.2	The improved flooding regime will result in the flushing of accumulated nutrients and sediments, resulting in a B Category for water quality	This is extremely optimistic. The current flood regime is probably better at doing this – esp nutrients.	Yes	
		Sort out the apparent contradictions. Example: Water quality: 'flushing of accumulated nutrients and sediments'. Geomorphology – 'would not be able to alleviate the reduced sediment supply'. I don't see how you	Yes	

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		can have both.		
	The actions required to improve vegetation is increased flood magnitude and frequency in the summer (50 m^3/s every year) and decreased flow regulation with fewer releases in winter as per changed shape of releases	What does this mean?	Yes	
5.4	Improvement to the REC requires different operating rules and setting of the EWRs are not required (see **Section 6.2**).	I don't get this – why can't you recommend a flow regime that will result in REC.	Yes	Have further clarified
6.2	The wettest and driest months were identified as March and July. Droughts were set at 95% exceedance (flow). Maintenance flows were set at 60% exceedance (flow). It is expected that, in order to maintain PES, the releases from the upstream dam will need to be reconfigured. The monthly modelled flows obscure the current flow regime, which comprises intermittent flood releases from the dam (one approximately every two months) and only leakage in-between. If achieved, adjusting the timing of these releases will maintain PES and possibly better. Thus, no flow regime was set for a lower AEC or for a better REC (refer to Section 6.5	Still – I do not see why you cannot set a EWR for other ECs. Without them it will be very difficult to extrapolate for Classification	Yes	There was inconsistency in this section not spotted by the reviewer. The comment is however not valid in terms of the reason for setting an EWR. It will be explained better.
6.4	Verification of low flows: Riparian vegetation	See previous section for comments. Is the PES C/D or C? Zones incomplete.	Yes	All comments addressed.
6.5	High flow requirements	Do you not think it necessary to limit the dry season releases? Or are you happy with those? It seems to me quite a lot could be achieved by changing the pulses flood release schedule.	No	Limit the dry season releases: Although ideal, it would appear that the wet season floods (distribution and shape) play a

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		Also, were does the water that is released get abstracted – presumably there are sections of this river (further downstream) that are dry all dry season. Do you think it is necessary to comment on any of those?		bigger role than limiting the dry season releases. Yes it would help, but it is acknowledged that within the constraints of the timing when flow is required, this will not be possible. Further secions downstream: The scenario sketched by the reviewer is relevant downstream of the gorge. In this section the category of the river is lower and also the importance will fall to moderate. An improvement is therefore not required in this reach.
6.5	Improvement will require a change in the present day releases from Gamkapoort Dam. Acknowledging the current operating rules and possible constraints on the dam, the following recommendations were made. Wet season: A 50 m^3/s flood is required once a year during the wet season. Furthermore, during the wet season the current events should be released in a different fashion, i.e. the receding limb shape should change to be a more natural hydrograph shape. These changes, even with the winter unseasonal floods, should result in the improvement in EcoStatus. Further improvement will be achieved if the unseasonal releases during the dry season are minimised. The change in hydrograph allows successful spawning of fish species in this river reach which	So no change to the dry season flood releases? What change in the hydrograph?	No	Answered above. Re change in hydrograph. The change is explained in the paragraph immediately above the reference to a change in hydrograph.

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	utilise these high flows to access suitable habitats for spawning during summer (September to March).			
Section 7 -12		Most of the comments for the sites covered Sections 7 – 13 are similar to those for the previous sites. I have also made some notes in the text.	Yes	
Table 13.4	Table 15.4 provides the confidence in the low flow requirements of the biotic components (fish and macroinvertebrates). The final average confidence is representative of these requirements.	"*Good historical data and important reference species (PASP) and eels (AMOS) captured during this study. The life- history requirements of these indicator species are relatively well-known. This gave a high confidence to recommended flows resulting in the specific ECs*." Confidence 3.7. How does this gel with the information given in Table 1.2 for fish? Keurbooms River: K6KEUR-EWR8 Confidence: 2.5 I guess I am not sure how you can have higher confidence in a predicted future than in an evaluation of PES. The same is true for inverts.	No	Confidence is high in the flow requirements to maintain the PES as the requirements for indicator species are known. This differ from the lower confidence in the PES which is dependant on being sure which species and which abundances occur at the site. Due to a once of survey and the presence of alien fish, there is a bigger uncertainty on the PES.
Section 13.2.3	Note: If natural hydrology was used to guide requirements, then that confidence will carry a higher weight than normal. Hydrology confidence is provided from the perspective of its usefulness to the EWR assessment. This will be different than the confidence in the hydrology for water resources management and planning. The scale of requirements is very different, and therefore high confidence hydrology for water resource management purposes often does not provide sufficient confidence for EWR assessment.	I am not sure what is being said here.	Yes	
13.3	Furthermore, no further work on the EcoClassification is required as it will not influence the EWR	See previous comments re inconsistencies	Yes	

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	determination.			
	The most effective way of improving confidence is linked to monitoring the ecological status of the river and, if required, improving the hydraulics for low flows at selected sites as part of the monitoring programme.	This will only work if you have good hydrological mesurements as well	Yes	Agreed
13	'No specific studies to improve any confidences other than the monitoring are therefore recommended'	But you did recommend additional studies at at least one EWR site.	Yes	Have removed the recommendation
Table 13.8	Confidence summary	Olifants. How can confidence be so high if there is no reliable gauge in the area?	No	Specialist opinion verified.
14	References	Formatting of the reference list is inconsistent.	Yes	