Department of Water Affairs
Chief Directorate: Resource Directed Measures

COMPREHENSIVE RESERVE DETERMINATION STUDY FOR SELECTED WATER RESOURCES (RIVERS, GROUNDWATER AND WETLANDS) IN THE INKOMATI WATER MANAGEMENT AREA, MPUMALANGA

SABIE-SAND AND CROCODILE SYSTEMS: ECOCLASSIFICATION REPORT – VOLUME 2

DECEMBER 2009

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DWA Project No: WP 9133
Report No: 26/8/3/10/12/009

Reports as part of this project:

Report no	Report title
26/8/3/10/14/001	Intermediate Reserve Determination Study for the Surface and Groundwater Resources in the Mokolo Catchment, Limpopo Province: Inception report
26/8/3/10/14/002	Intermediate Reserve Determination Study for the Surface and Groundwater Resources in the Mokolo Catchment, Limpopo Province: Desktop EcoClassification report
26/8/3/10/14/003	Intermediate Reserve Determination Study for the Surface and Groundwater Resources in the Mokolo Catchment, Limpopo Province: Newsletters
26/8/3/10/14/004	Intermediate Reserve Determination Study for the Surface and Groundwater Resources in the Mokolo Catchment, Limpopo Province: Basic Human Needs Reserve report
26/8/3/10/14/005	Intermediate Reserve Determination Study for the Surface and Groundwater Resources in the Mokolo Catchment, Limpopo Province: Groundwater report
26/8/3/10/14/006	Intermediate Reserve Determination Study for the Surface and Groundwater Resources in the Mokolo Catchment, Limpopo Province: Resource Unit report
26/8/3/10/14/007	Intermediate Reserve Determination Study for the Surface and Groundwater Resources in the Mokolo Catchment, Limpopo Province: Desktop Estimation report
26/8/3/10/14/008	**Intermediate Reserve Determination Study for the Surface and Groundwater Resources in the Mokolo Catchment, Limpopo Province: EcoClassification report**
26/8/3/10/14/009	Intermediate Reserve Determination Study for the Surface and Groundwater Resources in the Mokolo Catchment, Limpopo Province: EWR scenario report
26/8/3/10/14/010	Intermediate Reserve Determination Study for the Surface and Groundwater Resources in the Mokolo Catchment, Limpopo Province: Ecological, Goods & Services and Socio-Economic consequences of various Operational Scenarios.
26/8/3/10/14/011	Intermediate Reserve Determination Study for the Surface and Groundwater Resources in the Mokolo Catchment, Limpopo Province: EcoSpecs report
26/8/3/10/14/012	Intermediate Reserve Determination Study for the Surface and Groundwater Resources in the Mokolo Catchment, Limpopo Province: Socio Economic Present State Evaluation Report
26/8/3/10/14/013	Intermediate Reserve Determination Study for the Surface and Groundwater Resources in the Mokolo Catchment, Limpopo Province: Training audit and report
26/8/3/10/14/014	Intermediate Reserve Determination Study for the Surface and Groundwater Resources in the Mokolo Catchment, Limpopo Province: Main report
26/8/3/10/14/015	Intermediate Reserve Determination Study for the Surface and Groundwater Resources in the Mokolo Catchment, Limpopo Province: Wetland report
26/8/3/10/14/016	Intermediate Reserve Determination Study for the Surface and Groundwater Resources in the Mokolo Catchment, Limpopo Province: Electronic information and data

Bold indicates this report

REFERENCES

This report is to be referred in bibliographies as:

Department of Water Affairs, South Africa. 2009. Comprehensive Reserve Determination Study for Selected Water Resources (Rivers, Groundwater and Wetlands) in the Inkomati Water Management Area, Mpumalanga. Sabie and Crocodile Systems: EcoClassification Report - Volume 2. Prepared by Water for Africa, edited by Louw, MD and Koekemoer, S. RDM Report no 26/8/3/10/12/009.

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ABBREVIATIONS AND ACRONYMS

AEC	Alternative Ecological Category
ASPT	Average Score Per Taxon
CD: RDM	Chief Directorate: Resource Directed Measures
Conf	Confidence
D:RQS	Directorate: Resource Quality Services
DO	Dissolved Oxygen
DWAF	Department of Water Affairs and Forestry
EC	Ecological Category
EC	Electrical Conductivity
EIS	Ecological Importance and Sensitivity
EWR	Ecological Water Requirements
F	Flow related
FD	Fast Deep
FRAI	Fish Response Assessment Index
FROC	Fish Frequency of Occurrence
FS	Fast Shallow
Geom	Geomorphology
GSM	Gravel, sand, mud habitat
HAI	Hydrology Assessment Index
Hydro	Hydrology
IIHI	Index of Instream Habitat Integrity
Inverts	Macroinvertebrates
IRHI	Index of Riparian Habitat Integrity
ISP	Internal Strategic Perspective
KNP	Kruger National Park
LB	Left Bank
mamsl	Metres above mean sea level
MCM	Million Cubic Metres
MIRAI	Macro Invertebrate Response Assessment Index
MRU	Management Resource Unit
MV	Marginal Vegetation
NF	Non Flow related
NRHP	National River Health Programme
NRU	Natural Resource Unit
PAI	Physico-Chemical Driver Assessment Index
PES	Present Ecological State
Physico-chem	Physico chemical
Quat	Quaternary catchment
RAU	Resource Assessment Unit
RB	Right Bank
RC	Reference Condition
REC	Recommended Ecological Category
RHP	River Health Programme
Rip Veg	Riparian vegetation
RU	Resource Unit
SANBI	South African National Biodiversity Institute
SASS5	South African Scoring System version 5
SD	Standard deviation
SIC	Stones-in-current habitat
SOOC	Stones-out-of-current habitat
SPI	Specific Pollution sensitivity Index
SRP	Soluble Reactive Phosphate

SS	Slow Shallow
STW	Sewage Treatment Works
TEACHA	Tool for Ecological Aquatic Chemical Habitat Assessment
TIN	Total Inorganic Nitrogen
VEGRAI	Riparian Vegetation Response Assessment Index
WARMS	Water Resource Management System
WFW	Working for Water
WMA	Water Management Area
WMS	Water Management System
WQSU	Water Quality Sub-Unit
WWTW	Waste Water Treatment Works

APPENDIX A: HYDROLOGY AND WATER RESOURCES OF THE MOKOLO SYSTEM

Hydrology: Prof DA Hughes, Institute for Water Research
Water Resources: Mr S Mallory, Water for Africa
Hydrological causes and sources upstream of EWR sites in the Crocodile and Sabie System: Mr S Mallory and Ms Delana Louw, Water for Africa

A1 HYDROLOGY OF THE CROCODILE-EAST AND SABIE RIVERS CATCHMENT

A1.1 INTRODUCTION

For the purposes of this specialist appendices CE refers to the EWR sites situated in the Crocodile River System and SB refers to the EWR sites situated in the Sabie River system. Numbering corresponds to the EWR site numbers.

The location of the EWR sites (CE1 to CE7 and SB1 to SB8), the quaternary catchment boundaries, rivers and old IFR sites are shown in Figure A1. Sites CE1 to CE6 are on the Crocodile River, site CE7 on the Kaap River, Sites SB1 to SB3 are on the Sabie River, site SB4 on the Mac Mac River, site SB6 on the Mutlumuvi River and sites SB7 and SB8 are on the Sand River.

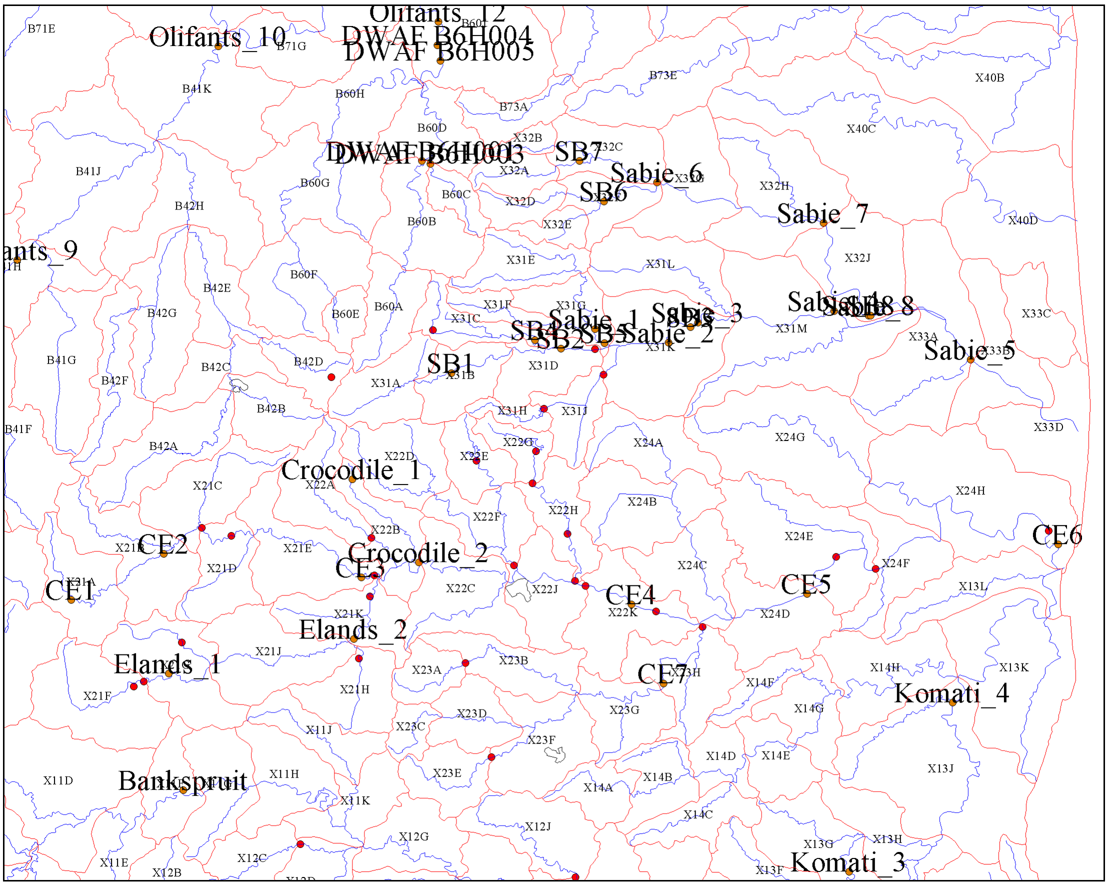

Figure A1 EWR sites and quaternary catchments

A1.2 DWAF STREAMFLOW GAUGES

There are several DWAF daily streamflow gauges and these are referred to during the individual site reports (Section A1.3) and Section A1.4.

A1.3 PRESENT DAY HYDROLOGICAL IMPACTS

The natural and present day time series of monthly flows were provided by the systems modellers and these have been compared with the observed records as part of the assessment of the present day hydrological impacts.

A1.3.1 HAI for CE1 – EWR 1: Valyspruit (Crocodile River)

The present day flows are very similar to natural with only small impacts on all flows (Table A1 and Figures A1 and A2).

Table A1 HAI details for Site CE1

HYDROLOGY METRICS	RATING	CONFIDENCE
LOW FLOWS	2.0	4.00
ZERO FLOW DURATION	0.0	4.00
SEASONALITY	0.0	4.00
MODERATE EVENTS	0.0	4.00
EVENT HYDROLOGY(HIGH FLOWS-FLOODS)	0.0	4.00

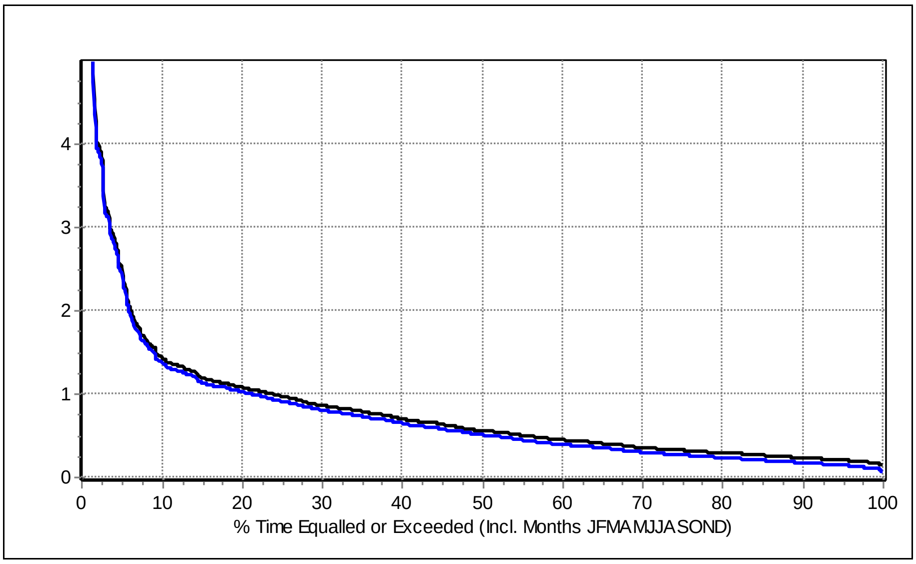

Figure A2 Annual monthly flow duration curves (data 1920 to 2004) for site CE1 (Black = Natural, Blue = Present Day)

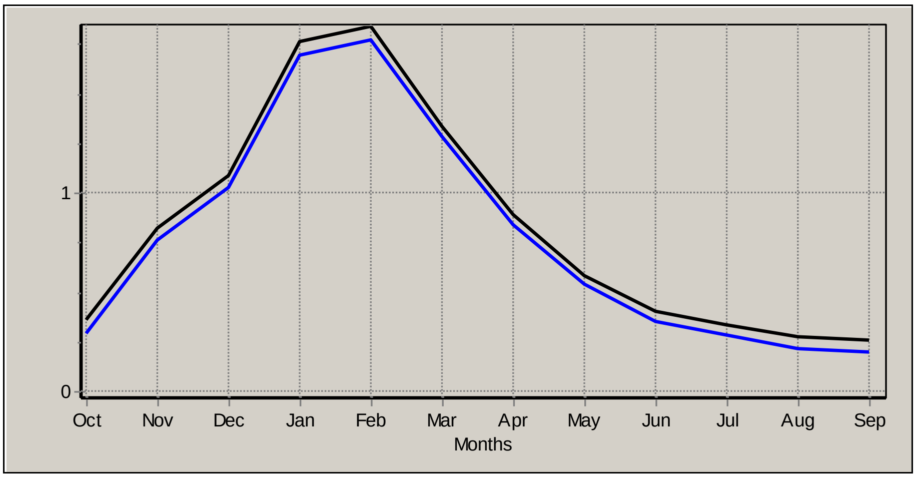

Figure A3 Seasonal distributions (data 1920 to 2004) for site CE1 (Black = Natural, Blue = Present Day)

A1.3.2 HAI for CE2 – EWR 2: Goedenhoop (Crocodile River)

The present day flows are very similar to natural with only small impacts on all flows (Table A2 and Figures A4 and A5).

Table A2 HAI details for Site CE2

HYDROLOGY METRICS	RATING	CONFIDENCE
LOW FLOWS	2.0	4.00
ZERO FLOW DURATION	0.0	4.00
SEASONALITY	0.0	4.00
MODERATE EVENTS	0.0	4.00
EVENT HYDROLOGY(HIGH FLOWS-FLOODS)	0.0	4.00

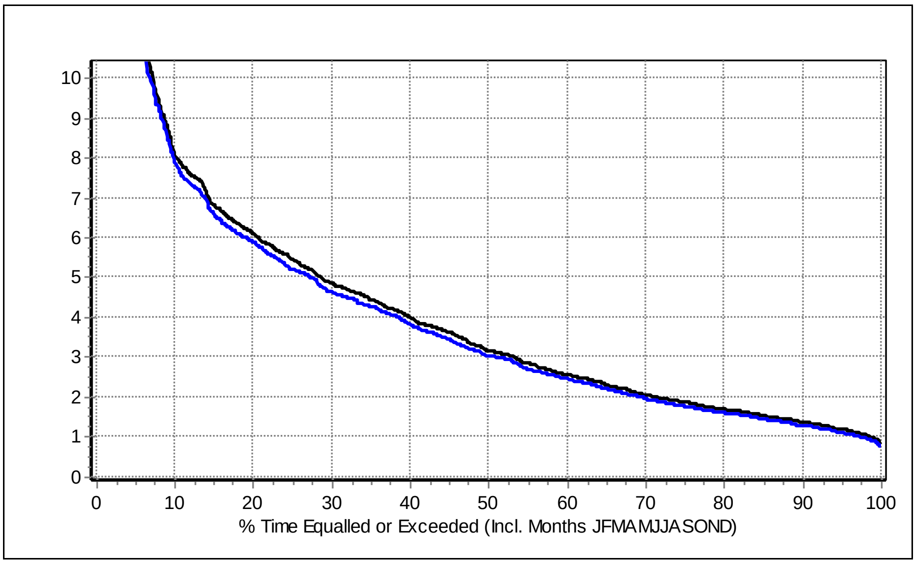

Figure A4 Annual monthly flow duration curves (data 1920 to 2004) for site CE2 (Black = Natural, Blue = Present Day)

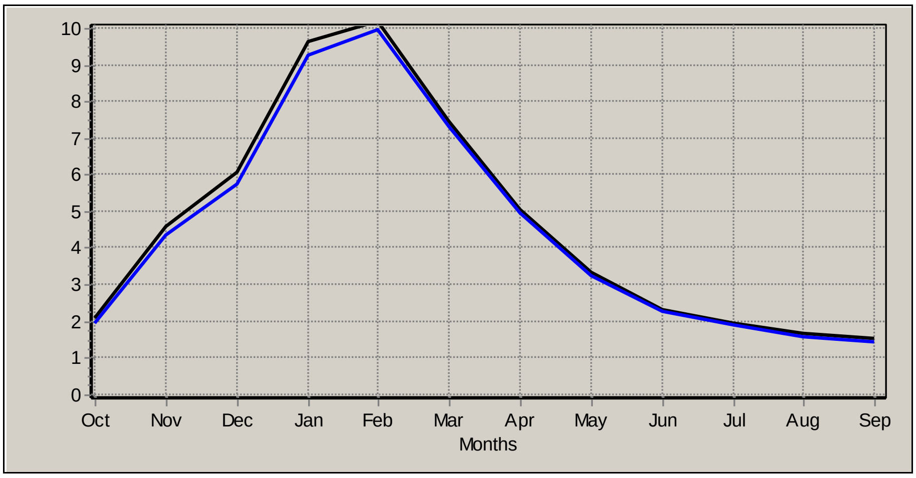

Figure A5 Seasonal distributions (data 1920 to 2004) for site CE2 (Black = Natural, Blue = Present Day)

A1.3.3 HAI for CE3 – EWR 3: Poplar Creek (Crocodile River)

The natural and present day flow duration curves and seasonal distributions are shown in Figures A6 and A7 and together illustrate very large changes in the flow regime. Except in very wet years, the seasonality has been almost completely reversed. It is therefore very difficult to apply the normal procedure for the HAI ratings, however, almost all of the indices of change will be very high (Table A3). The simulated present day flows are not very consistent with the observed records at X2H013 (just downstream of the site).

Table A3 HAI details for Site CE3

HYDROLOGY METRICS	RATING	CONFIDENCE
LOW FLOWS	4.0	3.00
ZERO FLOW DURATION	0.0	3.00
SEASONALITY	5.0	3.00
MODERATE EVENTS	4.0	3.00
EVENT HYDROLOGY(HIGH FLOWS-FLOODS)	4.0	3.00

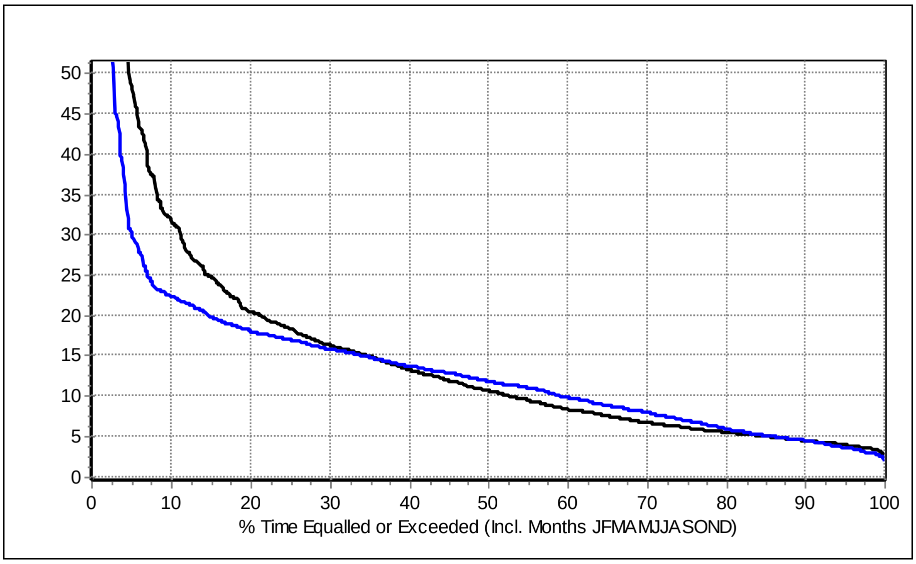

Figure A6 Annual monthly flow duration curves (data 1920 to 2004) for site CE3 (Black = Natural, Blue = Present Day)

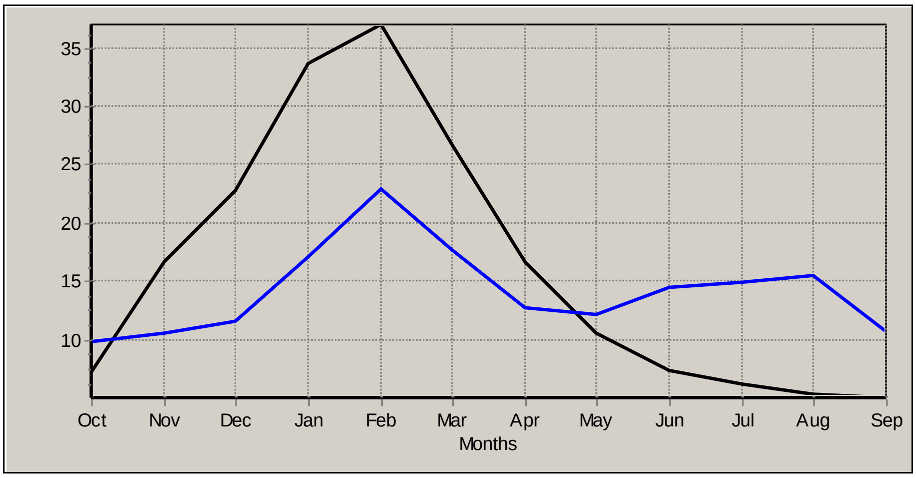

Figure A7 Seasonal distributions (data 1920 to 2004) for site CE3 (Black = Natural, Blue = Present Day)

A1.3.4 HAI for CE4 – EWR 4: KaNyamazane (Crocodile River)

Figures A8 and A9 illustrate the flow regime changes, while Table A4 provides the HAI values. The biggest changes appear to be in the moderate events, with some reductions in low flows. The observed records at X2H032 (just down steam) suggest greater impacts on low flows than indicated by the simulated present day flows.

Table A4 HAI details for Site CE4

HYDROLOGY METRICS	RATING	CONFIDENCE
LOW FLOWS	2.0	3.00
ZERO FLOW DURATION	0.0	3.00
SEASONALITY	0.0	5.00
MODERATE EVENTS	4.0	4.00
EVENT HYDROLOGY(HIGH FLOWS-FLOODS)	2.0	4.00

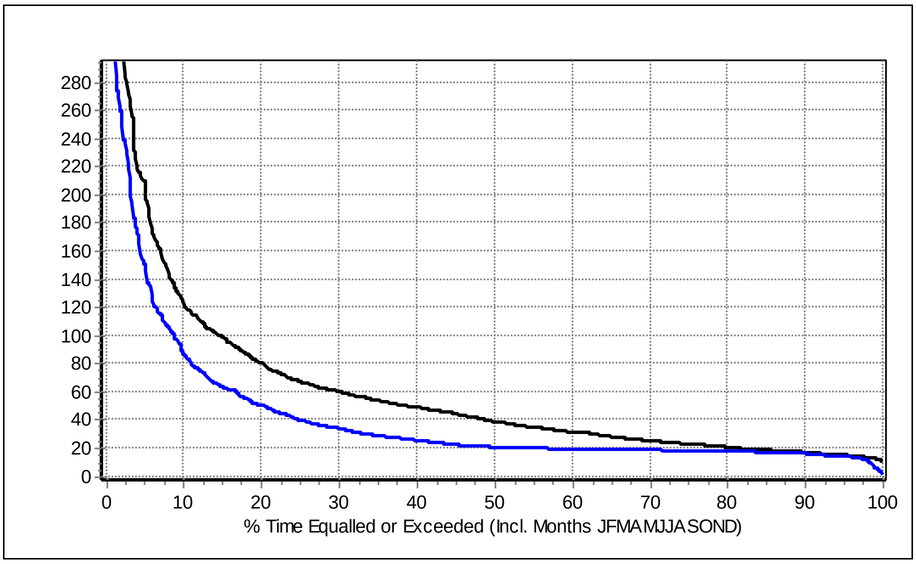

Figure A8 **Annual monthly flow duration curves (data 1920 to 2004) for site CE4 (Black = Natural, Blue = Present Day)**

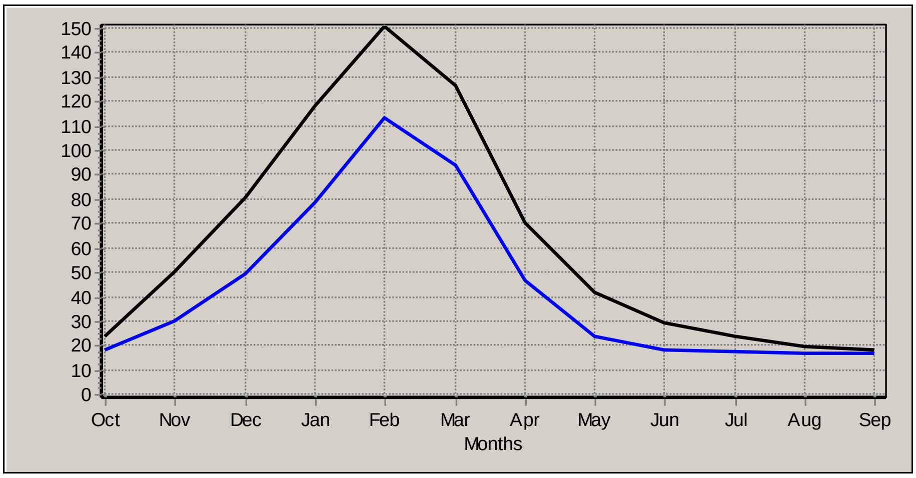

Figure A9 **Seasonal distributions (data 1920 to 2004) for site CE4 (Black = Natural, Blue = Present Day)**

A1.3.5 HAI for CE5 – EWR 5: Malelane (Crocodile River)

Figures A10 and A11 illustrate that there are large differences between the natural and present day flow regimes and that most of the changes are in the low and moderate flows (Table A5). The observed flows at X2H046 (just downstream of the site) are a reasonable match to the simulated present day flows.

Table A5 HAI details for Site CE5

HYDROLOGY METRICS	RATING	CONFIDENCE
LOW FLOWS	3.0	3.00
ZERO FLOW DURATION	1.0	3.00
SEASONALITY	0.0	5.00
MODERATE EVENTS	4.0	3.00
EVENT HYDROLOGY(HIGH FLOWS-FLOODS)	2.0	3.00

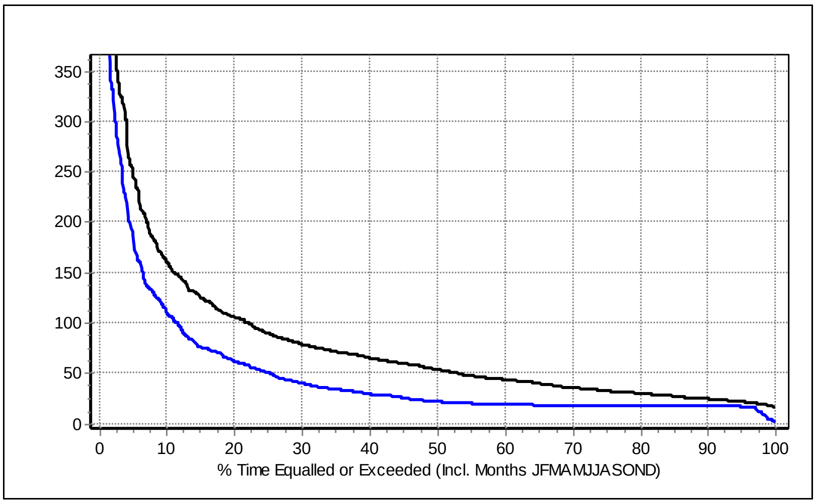

Figure A10 Annual monthly flow duration curves (data 1920 to 2004) for site CE5 (Black = Natural, Blue = Present Day)

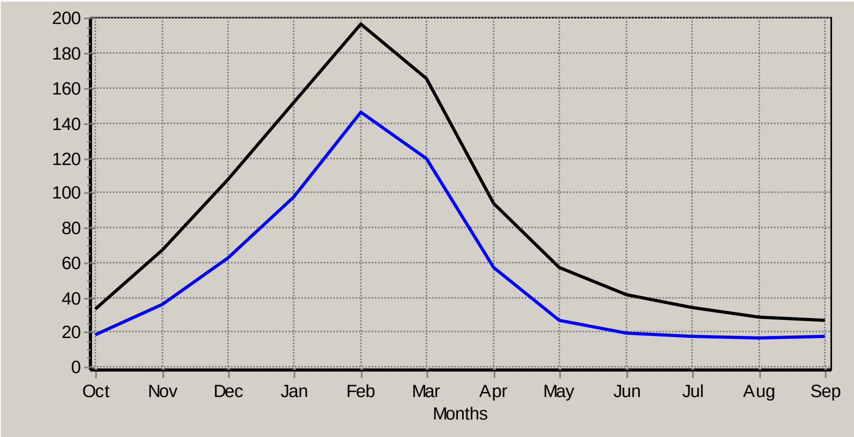

Figure A11 Seasonal distributions (data 1920 to 2004) for site CE5 (Black = Natural, Blue = Present Day)

A1.3.6 HAI for CE6 – EWR 6: Nkongoma (Crocodile River)

There has been a substantial decrease in low flows (Figures A12 and A13) and during most dry seasons the flow is very low (but only zero for about 3% of the time). There is a reasonable match between the simulated present day flows and the observed flows at X2H016 (just upstream).

Table A6 HAI details for Site CE6

HYDROLOGY METRICS	RATING	CONFIDENCE
LOW FLOWS	5.0	4.00
ZERO FLOW DURATION	1.0	4.00
SEASONALITY	0.0	5.00
MODERATE EVENTS	4.0	3.00
EVENT HYDROLOGY(HIGH FLOWS-FLOODS)	3.0	3.00

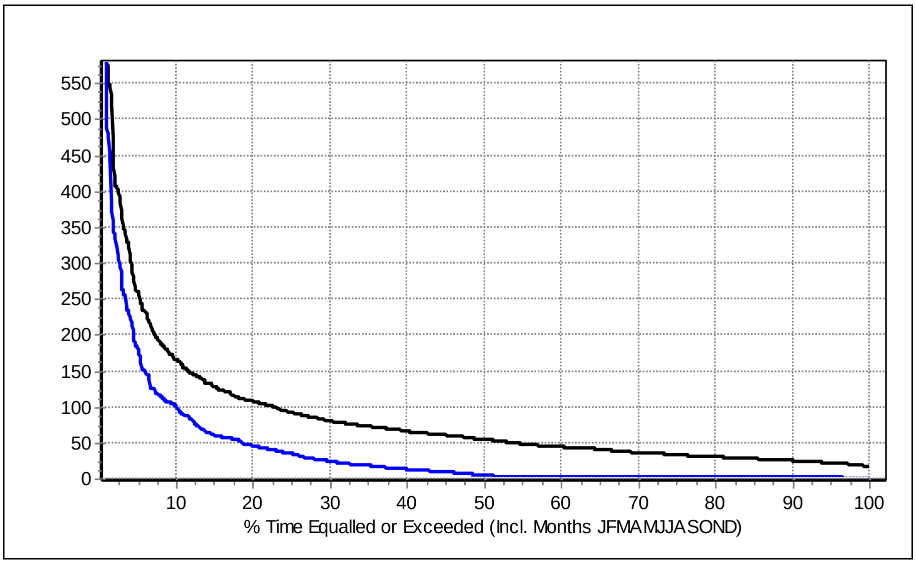

Figure A12 Annual monthly flow duration curves (data 1920 to 2004) for site CE6 (Black = Natural, Blue = Present Day)

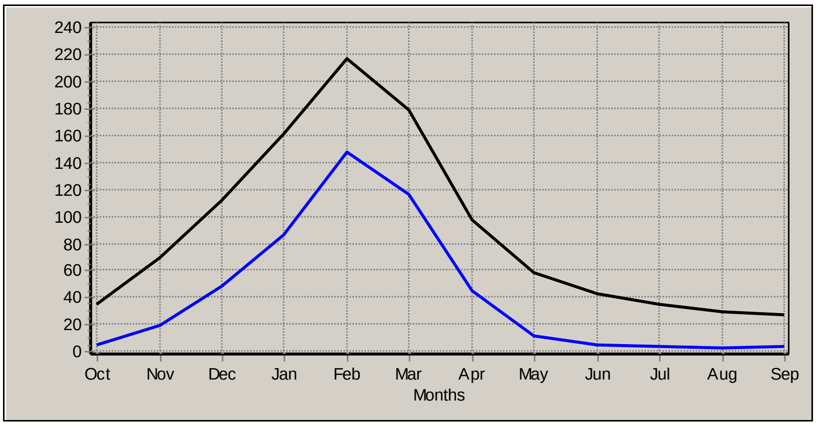

Figure A13 Seasonal distributions (data 1920 to 2004) for site CE6 (Black = Natural, Blue = Present Day)

A1.3.7 HAI for CE7 – EWR 7: Honeybird (Kaap River)

Figures A14 and A15 illustrate the differences between the natural and present day flow regimes, while Table A7 lists the indices of change. Zero flows appear to now exist for some 6% of the time and other low flows are similarly impacted. There is a reasonable match between the simulated present day flows and the later period of observed flows at X2H022 (quite far downstream).

Table A7 HAI details for Site CE7

HYDROLOGY METRICS	RATING	CONFIDENCE
LOW FLOWS	5.0	3.00
ZERO FLOW DURATION	3.0	3.00
SEASONALITY	0.0	5.00
MODERATE EVENTS	3.0	3.00
EVENT HYDROLOGY(HIGH FLOWS-FLOODS)	3.0	3.00

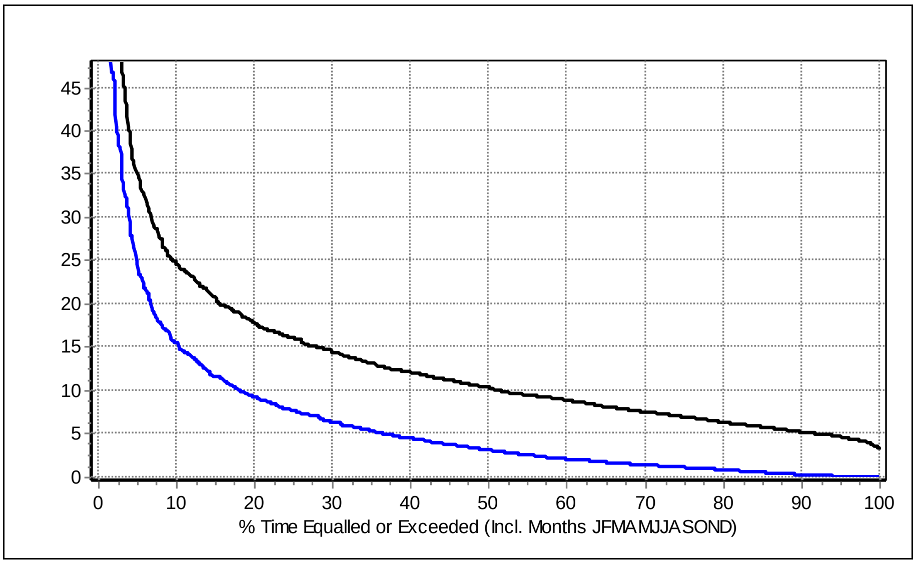

Figure A14 Annual monthly flow duration curves (data 1920 to 2004) for site CE7 (Black = Natural, Blue = Present Day)

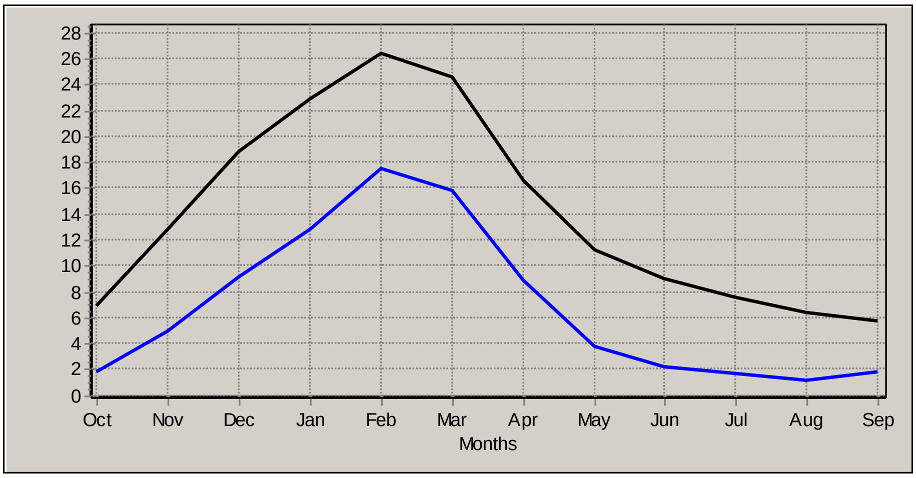

Figure A15 Seasonal distributions (data 1920 to 2004) for site CE7 (Black = Natural, Blue = Present Day)

A1.3.8 HAI for SB1 – EWR 1: Upper Sabie (Sabie River)

Figures A16 and A17 (and Table A8) illustrate that there have been some changes to the flow regime. Many of these are associated with plantation forests in the catchment that have been present for many years. Gauge X3H001 is the closest, but is too far upstream to be very useful.

Table A8 HAI details for Site SB1

HYDROLOGY METRICS	RATING	CONFIDENCE
LOW FLOWS	3.0	3.00
ZERO FLOW DURATION	0.0	4.00
SEASONALITY	0.0	5.00
MODERATE EVENTS	2.0	3.00
EVENT HYDROLOGY(HIGH FLOWS-FLOODS)	2.0	3.00

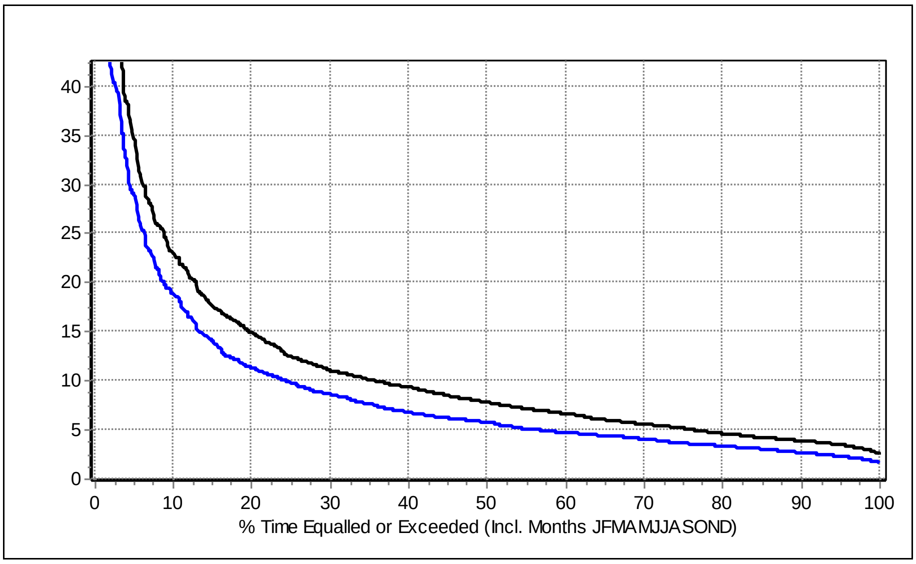

Figure A16 Annual monthly flow duration curves (data 1920 to 2004) for site SB1 (Black = Natural, Blue = Present Day)

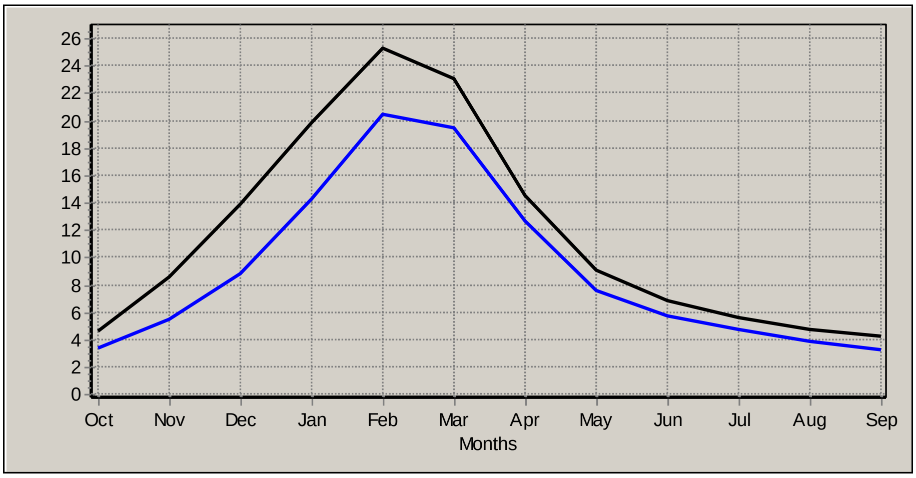

Figure A17 Seasonal distributions (data 1920 to 2004) for site SB1 (Black = Natural, Blue = Present Day)

A1.3.9 HAI for SB2 – EWR 2: Aan de Vliet (Sabie River)

Figures A18 and A19 (and Table A9) illustrate that there have been some changes to the flow regime. Many of these are associated with plantation forests in the catchment that have been present for many years. The simulated present day flows are reasonably consistent with the gauged flows at X3H006 (just downstream).

Table A9 HAI details for Site SB2

HYDROLOGY METRICS	RATING	CONFIDENCE
LOW FLOWS	3.0	3.00
ZERO FLOW DURATION	0.0	4.00
SEASONALITY	0.0	5.00
MODERATE EVENTS	2.0	3.00
EVENT HYDROLOGY(HIGH FLOWS-FLOODS)	2.0	3.00

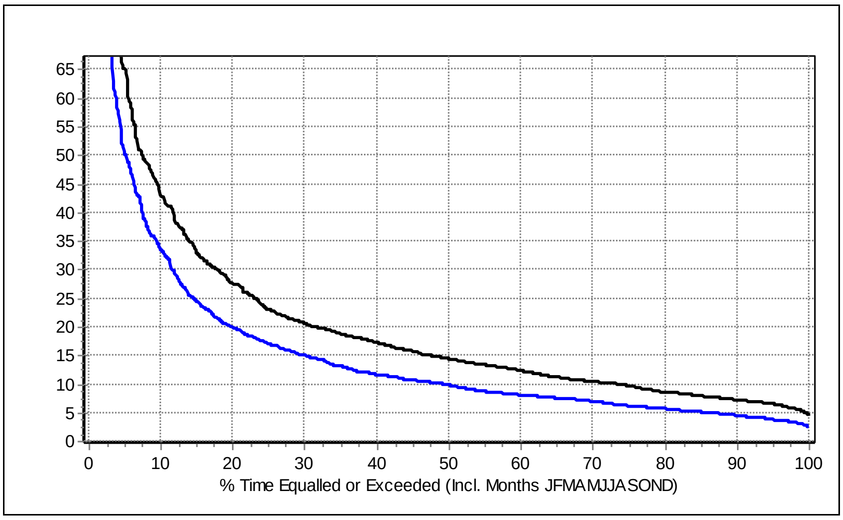

Figure A18 Annual monthly flow duration curves (data 1920 to 2004) for site SB2 (Black = Natural, Blue = Present Day)

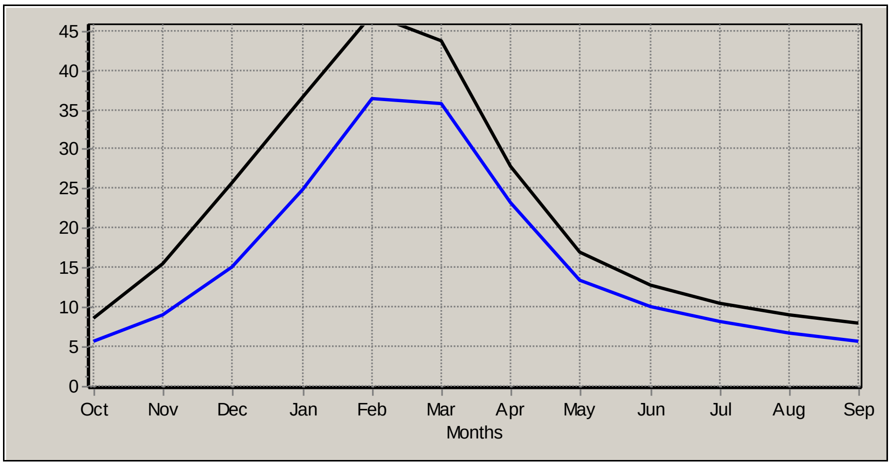

Figure A 19 Seasonal distributions (data 1920 to 2004) for site SB2 (Black = Natural, Blue = Present Day)

A1.3.10 HAI for SB3 – EWR 3: Kidney (Sabie River)

Figures A20 and A21 (and Table A10) illustrate that there have been some changes to the flow regime. Many of these are associated with plantation forests in the catchment that have been present for many years. There is a relatively short record of flows at X3H021 (downstream) and the observed flows are reasonably consistent with the simulated data.

Table A10 HAI details for Site SB3

HYDROLOGY METRICS	RATING	CONFIDENCE
LOW FLOWS	4.0	3.00
ZERO FLOW DURATION	0.0	4.00
SEASONALITY	0.0	5.00
MODERATE EVENTS	3.0	3.00
EVENT HYDROLOGY(HIGH FLOWS-FLOODS)	2.0	3.00

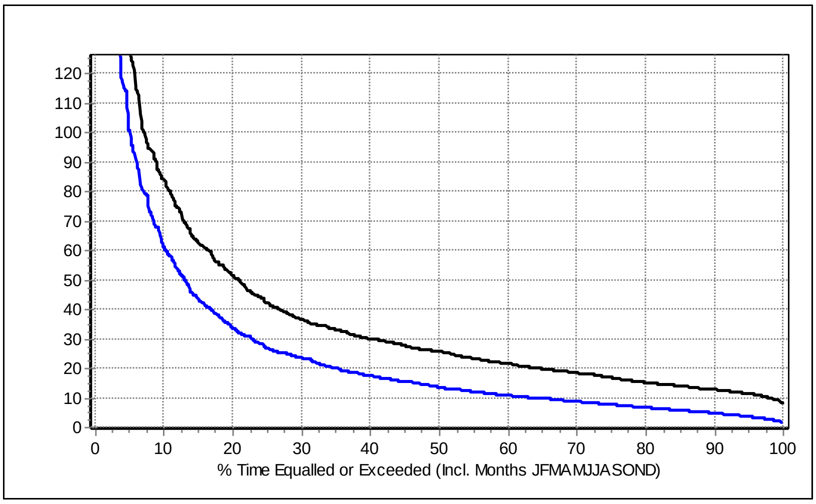

Figure A20 Annual monthly flow duration curves (data 1920 to 2004) for site SB3 (Black = Natural, Blue = Present Day)

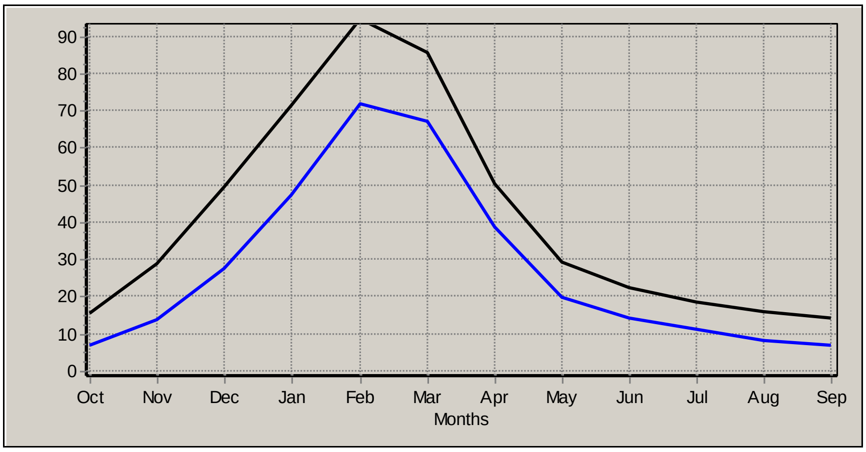

Figure A21 Seasonal distributions (data 1920 to 2004) for site SB3 (Black = Natural, Blue = Present Day)

A1.3.11 HAI for SB4 – EWR 4: Mac Mac (Mac Mac River)

Similar changes to the main Sabie River sites. No suitable flow gauging site.

Table A11 HAI details for Site SB4

HYDROLOGY METRICS	RATING	CONFIDENCE
LOW FLOWS	3.0	3.00
ZERO FLOW DURATION	0.0	4.00
SEASONALITY	0.0	5.00
MODERATE EVENTS	2.0	3.00
EVENT HYDROLOGY(HIGH FLOWS-FLOODS)	1.0	3.00

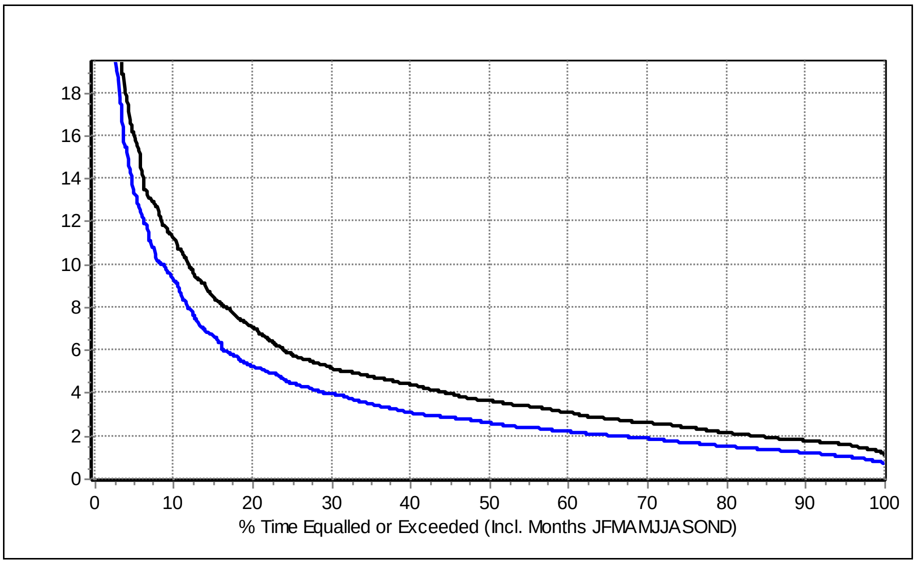

Figure A22 Annual monthly flow duration curves (data 1920 to 2004) for site SB4 (Black = Natural, Blue = Present Day)

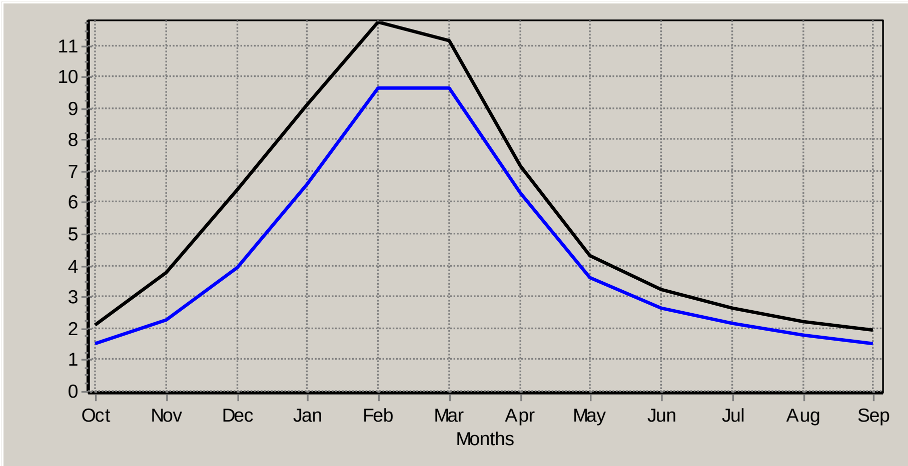

Figure A23 Seasonal distributions (data 1920 to 2004) for site SB4 (Black = Natural, Blue = Present Day)

A1.3.12 HAI for SB5 – EWR 5: Marite (Marite River)

Similar changes to the main Sabie River sites.

Table A12 HAI details for Site SB5

HYDROLOGY METRICS	RATING	CONFIDENCE
LOW FLOWS	4.0	3.00
ZERO FLOW DURATION	0.0	4.00
SEASONALITY	0.0	5.00
MODERATE EVENTS	3.0	3.00
EVENT HYDROLOGY(HIGH FLOWS-FLOODS)	2.0	3.00

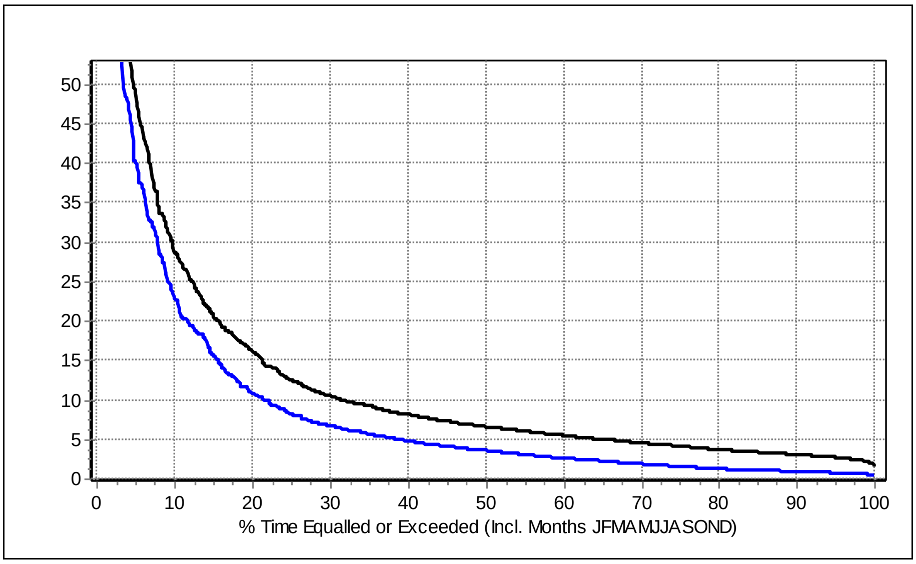

Figure A24 Annual monthly flow duration curves (data 1920 to 2004) for site SB5 (Black = Natural, Blue = Present Day)

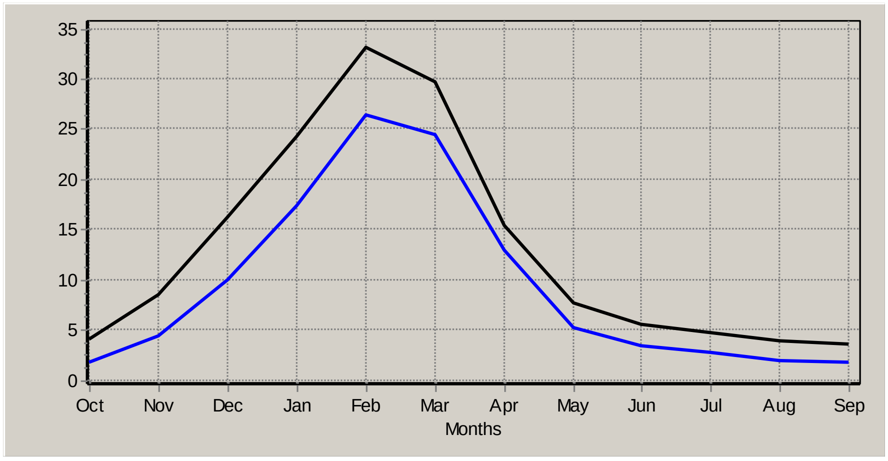

Figure A25 Seasonal distributions (data 1920 to 2004) for site SB5 (Black = Natural, Blue = Present Day)

A1.3.13 HAI for SB6 – EWR 6: Mutlumuvi (Mutlumuvi River)

Quite large reductions in low flows (some zero flows).

Table A13 HAI details for Site SB6

HYDROLOGY METRICS	RATING	CONFIDENCE
LOW FLOWS	4.0	3.00
ZERO FLOW DURATION	1.0	3.00
SEASONALITY	0.0	5.00
MODERATE EVENTS	1.0	3.00
EVENT HYDROLOGY(HIGH FLOWS-FLOODS)	0.0	3.00

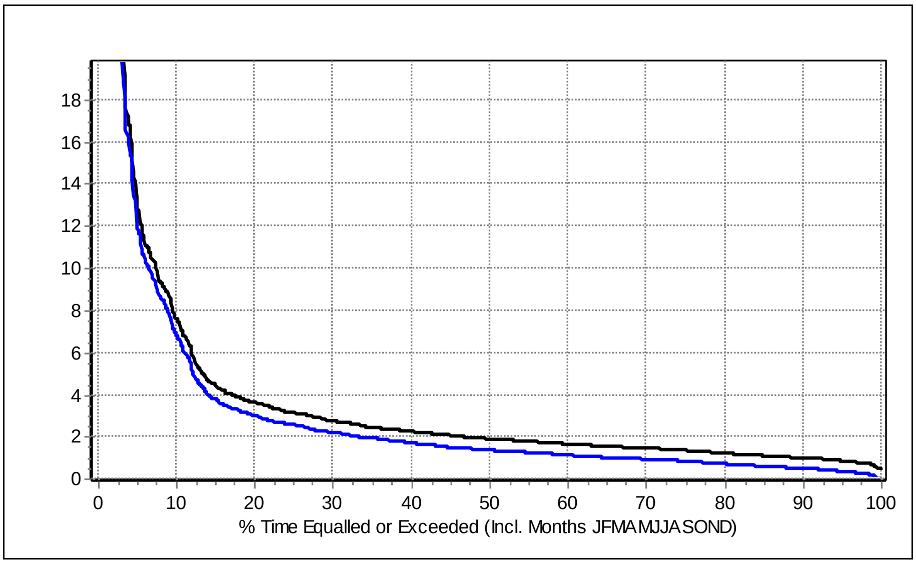

Figure A26 Annual monthly flow duration curves (data 1920 to 2004) for site SB6 (Black = Natural, Blue = Present Day)

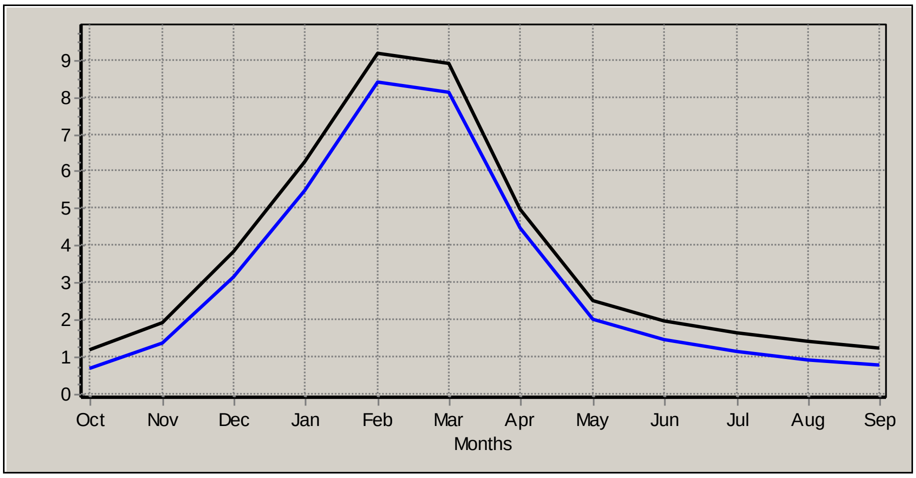

Figure A27 Seasonal distributions (data 1920 to 2004) for site SB6 (Black = Natural, Blue = Present Day)

A1.3.14 HAI for SB7 – EWR 7: Tlulandziteka (Tlulandziteka River)

Not many changes at this site.

Table A14 HAI details for Site SB7

HYDROLOGY METRICS	RATING	CONFIDENCE
LOW FLOWS	2.0	3.00
ZERO FLOW DURATION	0.0	4.00
SEASONALITY	0.0	5.00
MODERATE EVENTS	1.0	3.00
EVENT HYDROLOGY(HIGH FLOWS-FLOODS)	0.0	3.00

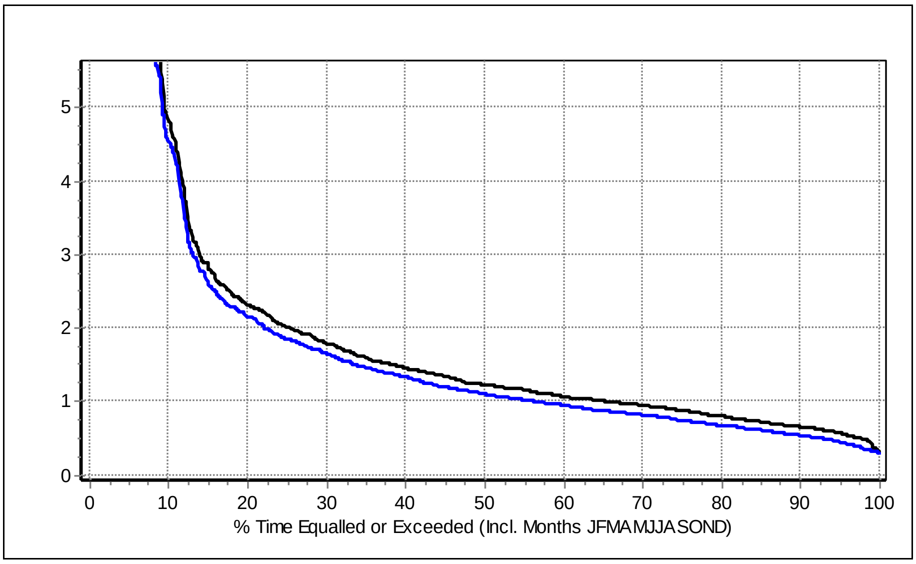

Figure A28 Annual monthly flow duration curves (data 1920 to 2004) for site SB7 (Black = Natural, Blue = Present Day)

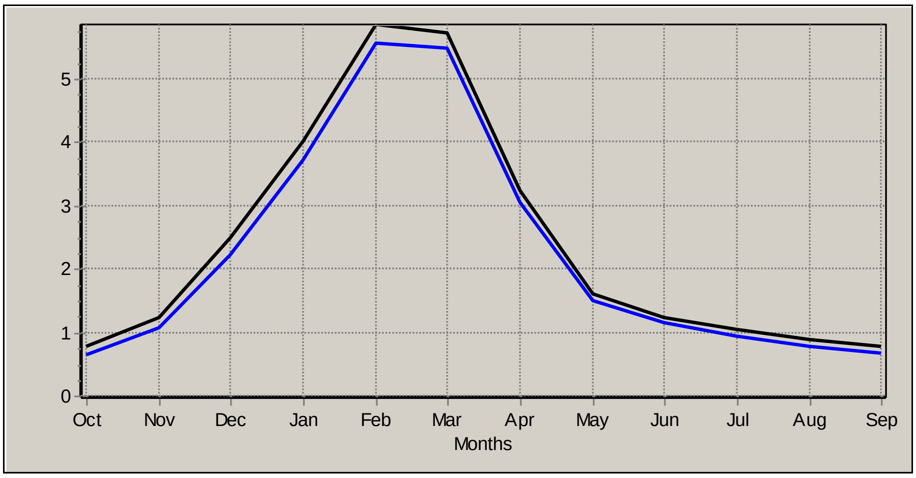

Figure A29 Seasonal distributions (data 1920 to 2004) for site SB7 (Black = Natural, Blue = Present Day)

A1.3.15 HAI for SB8 – EWR 8: Sand (Sand River)

Large changes to low flows but not to most of the other flows. The available gauge records (quite far upstream at X3H008) are reasonably consistent with the simulated flows.

Table A15 HAI details for Site SB8

HYDROLOGY METRICS	RATING	CONFIDENCE
LOW FLOWS	5.0	3.00
ZERO FLOW DURATION	2.0	3.00
SEASONALITY	0.0	5.00
MODERATE EVENTS	1.0	3.00
EVENT HYDROLOGY(HIGH FLOWS-FLOODS)	0.0	3.00

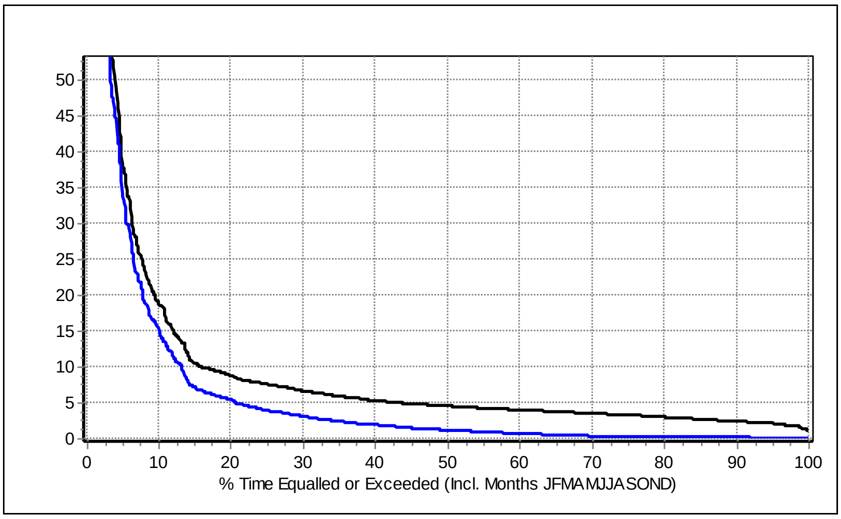

Figure A30 Annual monthly flow duration curves (data 1920 to 2004) for site SB8 (Black = Natural, Blue = Present Day)

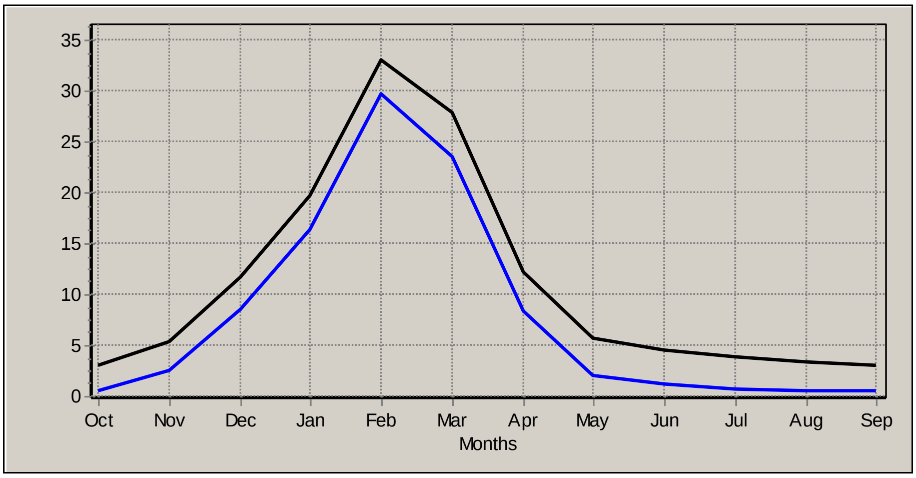

Figure A31 Seasonal distributions (data 1920 to 2004) for site SB8 (Black = Natural, Blue = Present Day)

A1.4 OBSERVED FLOW DATA

Observed flow data is provided below.

Table A16 List of available observed flow data

Station Name	EWR Site	Start date	End Date
X2R005	Downstream CE2	01/1985	2008
X2H033	Downstream CE2	07/1970	05/1992
X2H013	Close to CE3	02/1959	2008
X2H006	Upstream CE4	10/1929	2008
X2H032	Downstream CE4	10/1968	2008
X2H046	Downstream CE5	10/1985	2008
X2H016	Upstream CE6	09/1960	2008
X2H022	Downstream CE7	09/1960	2008
X3H001	Upstream SB1	04/1948	2008
X3H006	Downstream SB2	10/1958	09/1990
X3H021	Downstream SB3	12/1990	2008
X3H008	Upstream SB8	10/1967	2008

A1.5 RANGE OF BASE FLOWS

Table A17 provides an indication of the range of baseflows that could be expected at all sites under natural conditions. Note that the maximum values given for SB8 on the Sand River are very uncertain.

Table A17 Range of baseflows for the 15 sites

Site	Data Source	Min. Baseflow ($m^3 s^{-1}$)	Max. Baseflow ($m^3 s^{-1}$)
CE1	Monthly	0.05	0.4
CE2	X2H033 & Monthly	0.3	2.3
CE3	X2H013 & Monthly	1.0	10.0 to 12.0
CE4	X2H032 & Monthly	4.2	35.0 to 40.0
CE5	X2H046 & Monthly	6.0	50.0 to 70.0
CE6	X2H016 & Monthly	6.2	50.0 to 70.0
CE7	X2H022 & Monthly	1.2	8.0 to 10.0
SB1	X3H001 & Monthly	0.95	6.0 to 8.0
SB2	X3H006 & Monthly	1.7	12.0 to 14.0
SB3	X3H021 & Monthly	3.1	20.0 to 30.0
SB4	Monthly	0.4	2.5 to 3.5
SB5	Monthly	0.7	7.0 to 8.0
SB6	Monthly	0.17	1.6 to 1.8
SB7	Monthly	0.12	1.0 to 1.2
SB8	X3H008 & Monthly	0.38	4.0 to 8.0

A2 HYDROLOGY AND WATER RESOURCES OF THE MOKOLO CATCHMENT

A2.1 CROCODILE RIVER SYSTEM

A summary of the system hydrology is provided below.

Table A18 EWR 1: Valeyspruit (Crocodile River)

EWR 1: Valeyspruit (Crocodile River)		
Are there reliable gauges near to the site?		No. The nearest reliable gauge is the Kwena Dam situated at the outlet of X21C. There is a gauge X2H074 in the X21B catchment about 20 km down stream of EWR 1 but this was not used in the hydrology study. It seems there is no data for this gauge.
How long a record is available?		1985 to 2008.
Does it measure low flows accurately?		No. This record is calculated from stage measurements in the Kwena Dam and low flows are probably not accurate.
Will it record zero flows accurately?		No.
What are the highest flows it can record before it drowns out?		The spillway of Kwena will never drown. The spillway is rated up to 5 248 m^3/s.
Rate your confidence in your modelled naturalised hydrology and provide reasons (1 (low) – 5 (high)		2.5 = Relatively low confidence.
Rate your confidence in your modelled present day hydrology and provide reasons (1 (low) – 5 (high)		2.5 = Relatively low confidence.
Are there major differences between observed hydrology and modelled present hydrology? Why? If present hydrology reflects recent changes, provide info. If changes have been gradual, note that.		There have not been significant changes in this catchment over the period of recorded flow. The only change has been the construction of many trout dams which would reduce low flow and delay the first freshettes. Also Dullstroom's abstraction has increased somewhat over the last few 5 to 10 years.
BASE (LOW) FLOWS	Have base flows changed from natural? (in volume, and/or time and/or distribution)	Marginal change. Volume is slightly less due to small abstraction by Dullstroom for domestic use.
	Are the changes an increase or decrease?	Decrease.
	Are the changes continuous through the year or only in specific seasons/months?	Continuous.
	Have the natural seasonal distribution changed and if yes, how and why?	The seasonal distribution has only been slightly changed.
	Why has the base flow changed, i.e. what is the water being used for.	Used for domestic purposes. Trout dams also reduce the baseflow due to evaporation losses and delay the onset of the first freshette of spring.
	What (in m^3/s) is the natural range of baseflows (lowest to highest). If possible, provide for the wet season, and dry season.	
	What (in m^3/s) is the present day range of baseflows (lowest to highest). If possible, provide for the wet season, and dry season.	
MODERATE FLOODS (HIGH FLOWS)	Has the frequency of floods changed from natural?	Probably not. Lots of dams but they are all small. Only impact on small freshes.
	Are the changes an increase or a decrease? If an increase, is it due to dam releases, urban runoff, or something else	Change in onset of first fresh.
	Are there any changes in seasonality of the floods? And if yes, how.	No.
	Why has the flooding regime changed?	Trout dams.
LARGE FLOODS (HIGH FLOWS)	Has the frequency of floods changed from natural?	No.
	Are the changes an increase or a decrease? If an increase, is it due to dam releases, urban runoff, or something else.	Increase/Decrease
	Are there any changes in seasonality of the floods? And if yes, how.	Yes/No.

EWR 1: Valeyspruit (Crocodile River)		
	Why have the flooding changed?	
Have any frequency analysis of floods been undertaken and if so, what are the flood peaks (in m^3/s). E.g. 1:2 = X m^3/s etc.		No.
Any general comments or anything else one should take note of?		

Table A19 EWR 2: Goedehoop (Crocodile River)

EWR 2: Goedenhoop (Crocodile River)		
Are there reliable gauges near to the site?		No. The nearest reliable gauge is the Kwena Dam situated at the outlet of X21C. There is a gauge X2H074 in the X21B catchment a few kilometres upstream of EWR 2 but this was not used in the hydrology study. It seems there is not data for this gauge.
How long a record is available?		1985 to 2008.
Does it measure low flows accurately?		No. This record is calculated from stage measurements in the Kwena Dam and low flows are probably not accurate.
Will it record zero flows accurately?		No.
What are the highest flows it can record before it drowns out?		The spillway of Kwena will never drown. The spillway is rated up to 5 248 m^3/s
Rate your confidence in your modelled naturalised hydrology and provide reasons (1 (low) – 5 (high)		2 = Relatively low confidence.
Rate your confidence in your modelled present day hydrology and provide reasons (1 (low) – 5 (high)		2 = Relatively low confidence.
Are there major differences between observed hydrology and modelled present hydrology? Why? If present hydrology reflects recent changes, provide info. If changes have been gradual, note that.		There have not been significant changes in this catchment over the period of recorded flow. The only change has been the construction of many trout dams which would reduce low flow and delay the first freshettes of spring. Also Dullstrrom's abstraction has increased somewhat over the last few 5 to 10 years. Some abstraction for agriculture also takes place.
BASE (LOW) FLOWS	Have base flows changed from natural? (in volume, and/or time and/or distribution)	Marginal change. Volume is slightly less due to small abstraction by Dullstroom for domestic use.
	Are the changes an increase or decrease?	Decrease.
	Are the changes continuous through the year or only in specific seasons/months?	Continuous.
	Have the natural seasonal distribution changed and if yes, how and why?	The seasonal distribution has only been slightly changed.
	Why has the base flow changed, i.e. what is the water being used for.	Used for domestic purposes. Trout dams also reduce the baseflow due to evaporation losses and delay the onset of the first freshette of spring.
	What (in m^3/s) is the natural range of baseflows (lowest to highest). If possible, provide for the wet season, and dry season.	
	What (in m^3/s) is the present day range of baseflows (lowest to highest). If possible, provide for the wet season, and dry season.	
MODERATE FLOODS (HIGH FLOWS)	Has the frequency of floods changed from natural?	Probably not. Lots of dams but they are all small.
	Are the changes an increase or a decrease? If an increase, is it due to dam releases, urban runoff, or something else	
	Are there any changes in seasonality of the floods? And if yes, how.	No.
	Why has the flooding regime changed?	
LARGE FLOODS (HIGH FLOWS)	Has the frequency of floods changed from natural?	No.
	Are the changes an increase or a decrease? If an increase, is it due to dam releases, urban runoff, or something else.	Increase/Decrease.
	Are there any changes in seasonality of the floods? And if yes, how.	No.
	Why have the flooding changed?	
Have any frequency analysis of floods been undertaken and if so, what are the flood peaks (in m^3/s). E.g. 1:2 = X m^3/s etc.		No.

Any general comments or anything else one should take note of?	

Table A20 EWR 3: Poplar Creek (Crocodile River)

EWR 3: Poplar Creek (Crocodile River)		
Are there reliable gauges near to the site?		The Montrose gauge (X2H013) is located just downstream of EWR 3 but this gauge is not considered to be particularly reliable.
How long a record is available?		1959 – 2006.
Does it measure low flows accurately?		No. Thought to overestimate the low-flow.
Will it record zero flows accurately?		Probably.
What are the highest flows it can record before it drowns out?		136 m^3/s
Rate your confidence in your modelled naturalised hydrology and provide reasons (1 (low) – 5 (high)		3 = Medium confidence. Although low flows may not be accurate, gauge record is long and 95% complete.
Rate your confidence in your modelled present hydrology and provide reasons (1 (low) – 5 (high)		3 = Medium confidence. Some uncertainty as to low flows.
Are there major differences between observed hydrology & modelled present hydrology? Why? If present hydrology reflects recent changes, provide info. If changes have been gradual, note that.		The presence of the Kwena Dam upstream of EWR 3 will have had a major influence on the hydrology of the catchment. Large releases are made from the Kwena Dam to irrigators DS of the dam. The Kwena Dam was completed in 1984 and after this date the natural and actual flow would have deviated significantly.
BASE (LOW) FLOWS	Have base flows changed from natural? (in volume, and/or time and/or distribution)	Yes. Baseflow volume is greater due to releases from Kwena. Releases are greatest in late winter and early spring hence the distribution of baseflows has also changed.
	Are the changes an increase or decrease?	Increase
	Are the changes continuous through the year or only in specific seasons/months?	Change is throughout the year but most significant during late winter and early spring.
	Have the natural seasonal distribution changed and if yes, how and why?	Yes. See above.
	Why has the base flow changed, i.e. what is the water being used for.	Releases used for irrigation.
	What (in m^3/s) is the natural range of baseflows (lowest to highest). If possible, provide for the wet season, and dry season.	
	What (in m^3/s) is the present day range of baseflows (lowest to highest). If possible, provide for the wet season, and dry season.	
MODERATE FLOODS (HIGH FLOWS)	Has the frequency of floods changed from natural?	Yes.
	Are the changes an increase or a decrease? If an increase, is it due to dam releases, urban runoff, or something else	Decrease due to the presence of the Kwena Dam which will attenuate moderate floods.
	Are there any changes in seasonality of the floods? And if yes, how.	Yes. Moderate flood moved to later in the hydrological year by a month or two.
	Why has the flooding regime changed?	Due to the Kwena Dam.
LARGE FLOODS (HIGH FLOWS)	Has the frequency of floods changed from natural?	Not significantly.
	Are the changes an increase or a decrease? If an increase, is it due to dam releases, urban runoff, or something else.	Decrease.
	Are there any changes in seasonality of the floods? And if yes, how.	Yes.
	Why have the flooding changed?	Kwena Dam.
Have any frequency analysis of floods been undertaken and if so, what are the flood peaks (in m^3/s). E.g. 1:2 = X m^3/s etc.		No.
Any general comments or anything else one should take note of?		

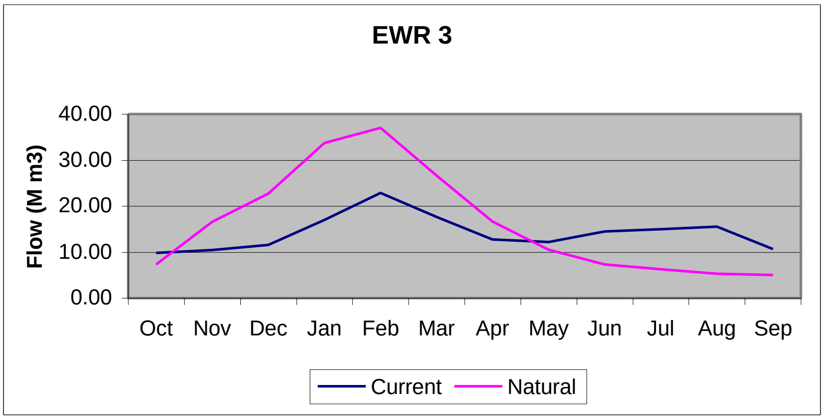

Figure A32 Flow duration curve for EWR 3

Table A21 EWR 4: Mac Mac (Mac Mac River)

EWR 4: Mac Mac (Crocodile River)		
Are there reliable gauges near to the site?		The gauge X2H006 is located approximately 12 km upstream of the EWR 4 site. This gauge is considered to be reliable although probably underestimates high flows.
How long a record is available?		1929 to 2008.
Does it measure low flows accurately?		Yes.
Will it record zero flows accurately?		Yes.
What are the highest flows it can record before it drowns out?		Not specified.
Rate your confidence in your modelled naturalised hydrology and provide reasons (1 (low) – 5 (high)		3 = Uncertainty as to timing and quantity of releases from the Kwena dam for irrigators which affects the flow at this site.
Rate your confidence in your modelled present day hydrology and provide reasons (1 (low) – 5 (high)		3 = Uncertainty as to the irrigation demands which dominate water use in the catchment.
Are there major differences between observed hydrology & modelled present hydrology? Why? If present hydrology reflects recent changes, provide info. If changes have been gradual, note that.		A major change occurred in 1984 when the Kwena Dam was completed. Also increasing irrigation and afforestation over the years have gradually reduced the flow.
BASE (LOW) FLOWS	Have base flows changed from natural? (in volume, and/or time and/or distribution)	Yes. Reduced baseflow, except for late winter and early spring where baseflows are supplemented by releases from Kwena Dam.
	Are the changes an increase or decrease?	Decrease.
	Are the changes continuous through the year or only in specific seasons/months?	
	Have the natural seasonal distribution changed and if yes, how and why?	There is a slight change in the natural seasonal distribution due to water use and releases from the Kwena Dam.
	Why has the base flow changed, i.e. what is the water being used for.	See above. Water is used mainly for irrigation.
	What (in m^3/s) is the natural range of baseflows (lowest to highest). If possible, provide for the wet season, and dry season.	
	What (in m^3/s) is the present day range of baseflows (lowest to highest). If possible, provide for the wet season, and dry season.	
MODERATE FLOODS (HIGH FLOWS)	Has the frequency of floods changed from natural?	No significant change.
	Are the changes an increase or a decrease? If an increase, is it due to dam releases, urban runoff, or something else	
	Are there any changes in seasonality of the floods? And if yes, how.	
	Why has the flooding regime changed?	

EWR 4: Mac Mac (Crocodile River)		
LARGE FLOODS (HIGH FLOWS)	Has the frequency of floods changed from natural?	No.
	Are the changes an increase or a decrease? If an increase, is it due to dam releases, urban runoff, or something else.	
	Are there any changes in seasonality of the floods? And if yes, how.	
	Why have the flooding changed?	
Have any frequency analysis of floods been undertaken and if so, what are the flood peaks (in m^3/s). E.g. 1:2 = X m^3/s etc.		No
Any general comments or anything else one should take note of?		

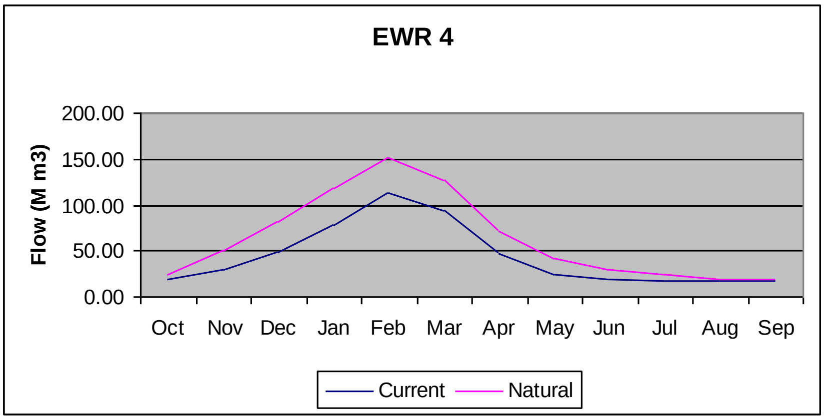

Figure A33 Flow duration curve for EWR 4

Table A22 EWR 5: Malelane (Crocodile River)

EWR 5: Malelane (Crocodile River)		
Are there reliable gauges near to the site?		A reasonably reliable gauge X2H047 is located about 15 km downstream of EWR 5.
How long a record is available?		1985 to present.
Does it measure low flows accurately?		Yes, but unrecorded abstractions are made immediately upstream of the weir.
Will it record zero flows accurately?		No.
What are the highest flows it can record before it drowns out?		Unknown.
Rate your confidence in your modelled naturalised hydrology and provide reasons (1 (low) – 5 (high)		3 = Limited confidence. Uncertainty due to upstream water use.
Rate your confidence in your modelled present day hydrology and provide reasons (1 (low) – 5 (high)		3 = Uncertainty due to upstream water use.
Are there major differences between observed hydrology & modelled present hydrology? Why? If present hydrology reflects recent changes, provide info. If changes have been gradual, note that.		There is a significant reduction in flow due to extensive irrigation and afforestation upstream of the site.
BASE (LOW) FLOWS	Have base flows changed from natural? (in volume, and/or time and/or distribution)	Yes. The volume has reduced but distribution remains approximately the same as natural.
	Are the changes an increase or decrease?	Decrease.
	Are the changes continuous through the year or only in specific seasons/months?	The change is throughout the year.
	Have the natural seasonal distribution changed and if yes, how and why?	Se above.
	Why has the base flow changed, i.e. what is the water being used for.	Water use by irrigation and afforestation.
	What (in m^3/s) is the natural range of baseflows (lowest to highest). If possible, provide for the wet season, and dry season.	
	What (in m^3/s) is the present day range of baseflows (lowest to highest). If possible, provide for the wet season, and dry season.	

MODERATE FLOODS (HIGH FLOWS)	Has the frequency of floods changed from natural?	No.
	Are the changes an increase or a decrease? If an increase, is it due to dam releases, urban runoff, or something else	Decrease in the magnitude of moderate floods due to upstream water use.
	Are there any changes in seasonality of the floods? And if yes, how.	No.
	Why has the flooding regime changed?	Upstream water use.
LARGE FLOODS (HIGH FLOWS)	Has the frequency of floods changed from natural?	No.
	Are the changes an increase or a decrease? If an increase, is it due to dam releases, urban runoff, or something else.	
	Are there any changes in seasonality of the floods? And if yes, how.	
	Why have the flooding changed?	
Have any frequency analysis of floods been undertaken and if so, what are the flood peaks (in m^3/s). E.g. 1:2 = X m^3/s etc.		No.
Any general comments or anything else one should take note of?		

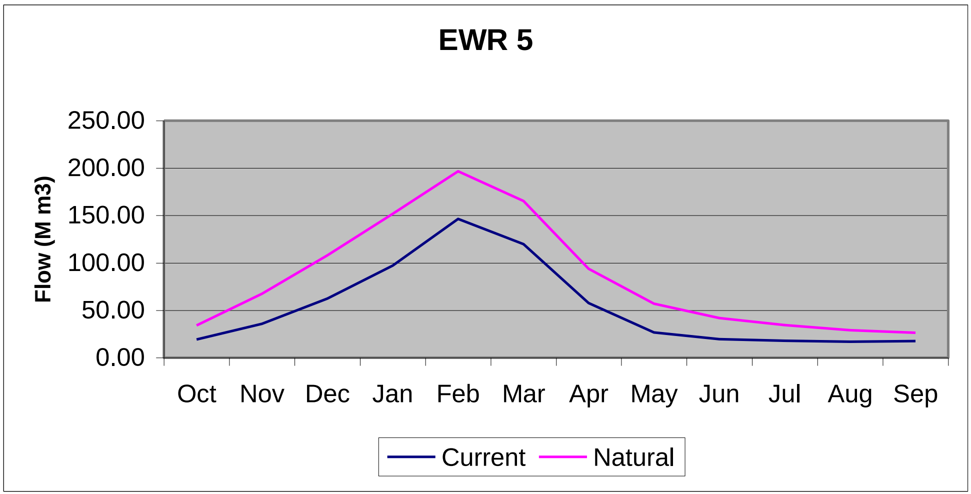

Figure A34 Flow duration curve for EWR 5

Table A23 EWR 6: Nkongoma (Crocodile River)

EWR 6: Nkongoma (Crocodile River)		
Are there reliable gauges near to the site?		A reasonable gauge X2H016 is located about 6 km upstream of EWR 6.
How long a record is available?		1960 to present.
Does it measure low flows accurately?		Probably not due to the accumulation of debris.
Will it record zero flows accurately?		No.
What are the highest flows it can record before it drowns out?		Unknown.
Rate your confidence in your modelled naturalised hydrology and provide reasons (1 (low) – 5 (high)		3 = Limited confidence. Uncertainty due to upstream water use.
Rate your confidence in your modelled present day hydrology and provide reasons (1 (low) – 5 (high)		3 = Uncertainty due to upstream water use.
Are there major differences between observed hydrology & modelled present hydrology? Why? If present hydrology reflects recent changes, provide info. If changes have been gradual, note that.		Yes, There is a large reduction in flow due to extensive irrigation and afforestation upstream of the site.
BASE (LOW) FLOWS	Have base flows changed from natural? (in volume, and/or time and/or distribution)	Yes. The volume has reduced but distribution remains approximately the same as natural.
	Are the changes an increase or decrease?	Decrease.
	Are the changes continuous through the year or only in specific seasons/months?	The change is throughout the year but more pronounced in the winter and early spring.
	Have the natural seasonal distribution changed and if yes, how and why?	See above.
	Why has the base flow changed, i.e. what is the	Water use by irrigation and afforestation.

	water being used for.	
	What (in m³/s) is the natural range of baseflows (lowest to highest). If possible, provide for the wet season, and dry season.	
	What (in m³/s) is the present day range of baseflows (lowest to highest). If possible, provide for the wet season, and dry season.	
MODERATE FLOODS (HIGH FLOWS)	Has the frequency of floods changed from natural?	No.
	Are the changes an increase or a decrease? If an increase, is it due to dam releases, urban runoff, or something else	Decrease in the magnitude of moderate floods due to upstream water use.
	Are there any changes in seasonality of the floods? And if yes, how.	No.
	Why has the flooding regime changed?	Upstream water use.
LARGE FLOODS (HIGH FLOWS)	Has the frequency of floods changed from natural?	No.
	Are the changes an increase or a decrease? If an increase, is it due to dam releases, urban runoff, or something else.	Increase/Decrease.
	Are there any changes in seasonality of the floods? And if yes, how.	Yes/No.
	Why have the flooding changed?	
Have any frequency analysis of floods been undertaken and if so, what are the flood peaks (in m³/s). E.g. 1:2 = X m³/s etc.		No.
Any general comments or anything else one should take note of?		

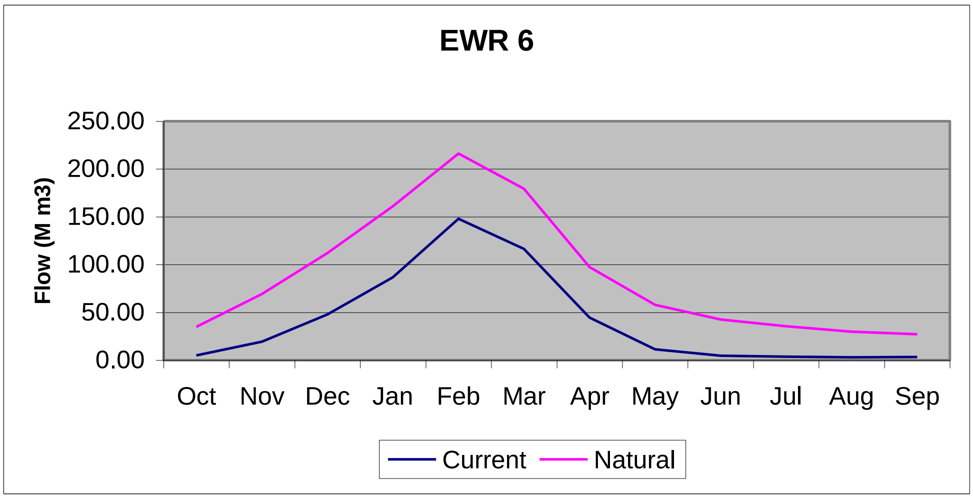

Figure A35 Flow duration curve for EWR 6

Table A24 EWR 7: Honeybird (Kaap River)

EWR 7: Honeybird (Kaap River)	
Are there reliable gauges near to the site?	The gauge X2H022 is located approximate 20 km downstream of EWR 7. It appears as if this is a reasonable gauge.
How long a record is available?	1960 to present.
Does it measure low flows accurately?	Yes.
Will it record zero flows accurately?	Yes.
What are the highest flows it can record before it drowns out?	Unknown
Rate your confidence in your modelled naturalised hydrology and provide reasons (1 (low) – 5 (high)	3 = Limited confidence. Uncertainty due to upstream water use.
Rate your confidence in your modelled present day hydrology and provide reasons (1 (low) – 5 (high)	3 = Uncertainty due to upstream water use.
Are there major differences between observed hydrology & modelled present hydrology? Why? If present hydrology reflects recent changes, provide info. If changes have been	Yes, There is a large reduction in flow due to extensive irrigation and afforestation upstream of the site.

EWR 7: Honeybird (Kaap River)		
gradual, note that.		
BASE (LOW) FLOWS	Have base flows changed from natural? (in volume, and/or time and/or distribution)	Yes. The volume has reduced but distribution remains approximately the same as natural.
	Are the changes an increase or decrease?	Decrease.
	Are the changes continuous through the year or only in specific seasons/months?	The change is throughout the year but more pronounced in the winter and early spring.
	Have the natural seasonal distribution changed and if yes, how and why?	See above.
	Why has the base flow changed, i.e. what is the water being used for.	Water use by irrigation and afforestation.
	What (in m^3/s) is the natural range of baseflows (lowest to highest). If possible, provide for the wet season, and dry season.	
	What (in m^3/s) is the present day range of baseflows (lowest to highest). If possible, provide for the wet season, and dry season.	
MODERATE FLOODS (HIGH FLOWS)	Has the frequency of floods changed from natural?	No.
	Are the changes an increase or a decrease? If an increase, is it due to dam releases, urban runoff, or something else	Decrease in the magnitude of moderate floods due to upstream water use.
	Are there any changes in seasonality of the floods? And if yes, how.	No.
	Why has the flooding regime changed?	Upstream water use.
LARGE FLOODS (HIGH FLOWS)	Has the frequency of floods changed from natural?	No.
	Are the changes an increase or a decrease? If an increase, is it due to dam releases, urban runoff, or something else.	Increase/Decrease.
	Are there any changes in seasonality of the floods? And if yes, how.	Yes/No.
	Why have the flooding changed?	
Have any frequency analysis of floods been undertaken and if so, what are the flood peaks (in m^3/s). E.g. 1:2 = X m^3/s etc.		No.
Any general comments or anything else one should take note of?		

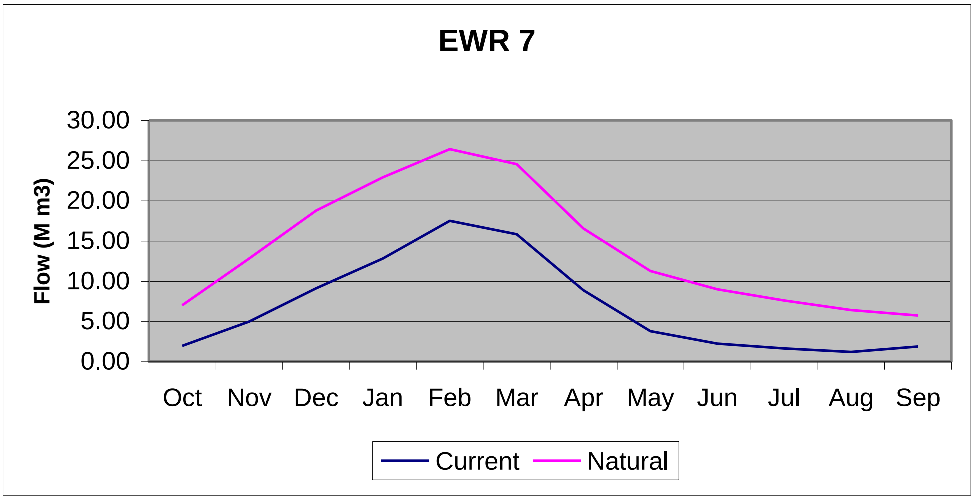

Figure A36 Flow duration curve for EWR 7

A2.2 SABIE RIVER SYSTEM

A summary of the system hydrology is provided below.

Table A25 EWR 1: Sabie (Sabie River)

EWR 1: Sabie (Sabie River)		
Are there reliable gauges near to the site?		The nearest reliable gauge is Sabie River gauge located about 9 km upstream of the EWR site. The gauge seem reasonable but has suspicious zero flows prior to 1969.
How long a record is available?		1948 to present.
Does it measure low flows accurately?		Low flows probably not very accurate.
Will it record zero flows accurately?		No.
What are the highest flows it can record before it drowns out?		Not stated.
Rate your confidence in your modelled naturalised hydrology and provide reasons (1 (low) – 5 (high)		3 = Reasonable confidence.
Rate your confidence in your modelled present day hydrology and provide reasons (1 (low) – 5 (high)		3 = Reasonable confidence.
Are there major differences between observed hydrology & modelled present hydrology? Why? If present hydrology reflects recent changes, provide info. If changes have been gradual, note that.		Yes. Gradual change over time due to afforestation.
BASE (LOW) FLOWS	Have base flows changed from natural? (in volume, and/or time and/or distribution)	Significant reduction in baseflow due to afforestation. Also abstractions from Sabie town.
	Are the changes an increase or decrease?	Decrease.
	Are the changes continuous through the year or only in specific seasons/months?	Continuous.
	Have the natural seasonal distribution changed and if yes, how and why?	Small change in seasonal distribution.
	Why has the base flow changed, i.e. what is the water being used for.	Afforestation.
	What (in m^3/s) is the natural range of baseflows (lowest to highest). If possible, provide for the wet season, and dry season.	
	What (in m^3/s) is the present day range of baseflows (lowest to highest). If possible, provide for the wet season, and dry season.	
MODERATE FLOODS (HIGH FLOWS)	Has the frequency of floods changed from natural?	No.
	Are the changes an increase or a decrease? If an increase, is it due to dam releases, urban runoff, or something else	Slight decrease in flood peaks.
	Are there any changes in seasonality of the floods? And if yes, how.	No.
	Why has the flooding regime changed?	
LARGE FLOODS (HIGH FLOWS)	Has the frequency of floods changed from natural?	No.
	Are the changes an increase or a decrease? If an increase, is it due to dam releases, urban runoff, or something else.	Slight decrease in flood peaks.
	Are there any changes in seasonality of the floods? And if yes, how.	Yes/No.
	Why have the flooding changed?	
Have any frequency analysis of floods been undertaken and if so, what are the flood peaks (in m^3/s). E.g. 1:2 = X m^3/s etc.		No.
Any general comments or anything else one should take note of?		

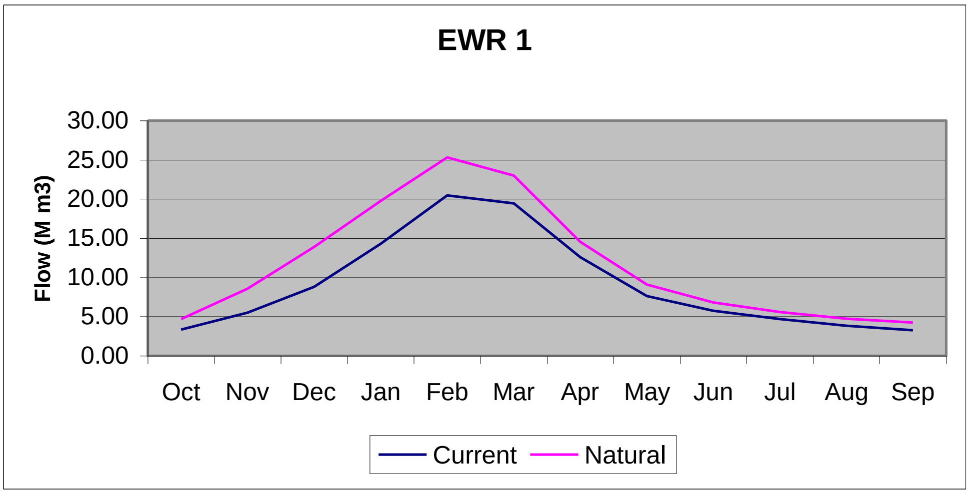

Figure A37 Flow duration curve for EWR 1

Table A26 EWR 2: Aan de Vliet (Sabie River)

EWR 2: Aan de Vliet (Sabie River)		
	Are there reliable gauges near to the site?	The new gauge at Emmet is located just upstream of the EWR site. This is a reliable gauge.
	How long a record is available?	2002 to present.
	Does it measure low flows accurately?	Yes.
	Will it record zero flows accurately?	Yes.
	What are the highest flows it can record before it drowns out?	Not stated.
	Rate your confidence in your modelled naturalised hydrology and provide reasons (1 (low) – 5 (high)	4 = Good confidence.
	Rate your confidence in your modelled present day hydrology and provide reasons (1 (low) – 5 (high)	4 = Good confidence.
	Are there major differences between observed hydrology & modelled present hydrology. Why?. If present hydrology reflects recent changes, provide info. If changes have been gradual, note that.	No.
BASE (LOW) FLOWS	Have base flows changed from natural? (in volume, and/or time and/or distribution)	Significant reduction in baseflow due to afforestation.
	Are the changes an increase or decrease?	Decrease.
	Are the changes continuous through the year or only in specific seasons/months?	Continuous.
	Have the natural seasonal distribution changed and if yes, how and why?	The seasonal distribution has only been slightly changed.
	Why has the base flow changed, i.e. what is the water being used for.	Afforestation. Significant abstractions in tributaries such as the Sabane (and damming) contribute to changes of flow as well as the upstream Sabie Town influences.
	What (in m^3/s) is the natural range of baseflows (lowest to highest). If possible, provide for the wet season, and dry season.	
	What (in m^3/s) is the present day range of baseflows (lowest to highest). If possible, provide for the wet season, and dry season.	
MODERATE FLOODS (HIGH FLOWS)	Has the frequency of floods changed from natural?	No.
	Are the changes an increase or a decrease? If an increase, is it due to dam releases, urban runoff, or something else	Slight decrease in flood peaks.
	Are there any changes in seasonality of the floods? And if yes, how.	No.
	Why has the flooding regime changed?	
LARGE FLOODS (HIGH FLOWS)	Has the frequency of floods changed from natural?	No.
	Are the changes an increase or a decrease? If an increase, is it due to dam releases, urban runoff, or something else.	Slight decrease in flood peaks.
	Are there any changes in seasonality of the floods?	Yes/No.

	And if yes, how.	
	Why have the flooding changed?	
Have any frequency analysis of floods been undertaken and if so, what are the flood peaks (in m^3/s). E.g. 1:2 = X m^3/s etc.		No.
Any general comments or anything else one should take note of?		

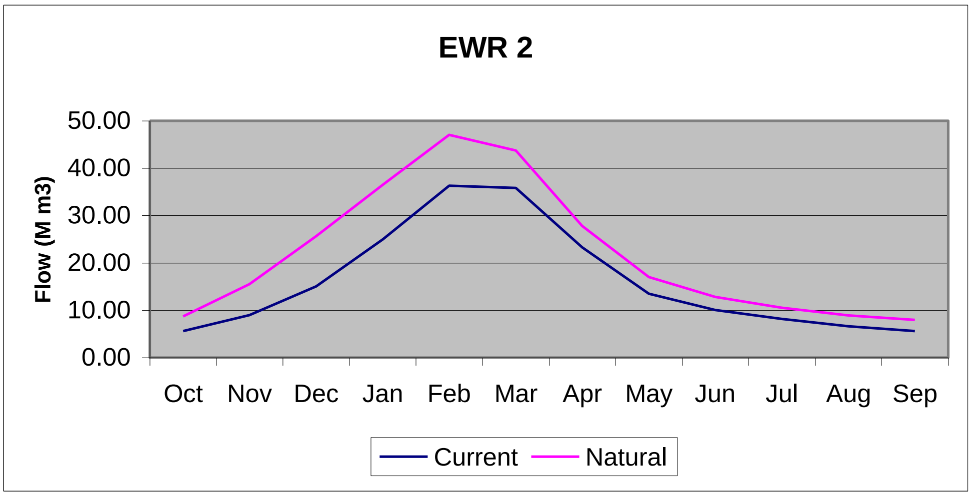

Figure A38 Flow duration graph for EWR 2

Table A27 EWR 3: Kidney (Sabie River)

EWR 3: Kidney (Sabie River)		
Are there reliable gauges near to the site?		No. Gauge X3H021 is located approximately 25 km DS of the EWR site but this gauge is missing quite a lot of data (> 12%) and is reportedly not calibrated correctly due to the addition of a fish ladder.
How long a record is available?		1990 to present.
Does it measure low flows accurately?		No.
Will it record zero flows accurately?		No.
What are the highest flows it can record before it drowns out?		Not stated.
Rate your confidence in your modelled naturalised hydrology and provide reasons (1 (low) – 5 (high)		2.5 = Medium to low confidence.
Rate your confidence in your modelled present day hydrology and provide reasons (1 (low) – 5 (high)		2.5 = Medium to low confidence.
Are there major differences between observed hydrology & modelled present hydrology? Why? If present hydrology reflects recent changes, provide info. If changes have been gradual, note that.		The completion of the Inyaka Dam in 2000 should have changed the hydrology.
BASE (LOW) FLOWS	Have base flows changed from natural? (in volume, and/or time and/or distribution)	Significant reduction in baseflow due to afforestation and irrigation.
	Are the changes an increase or decrease?	Decrease.
	Are the changes continuous through the year or only in specific seasons/months?	Continuous.
	Have the natural seasonal distribution changed and if yes, how & why?	Slightly changed.
	Why has the base flow changed, i.e. what is the water being used for.	Afforestation and irrigation.
	What (in m^3/s) is the natural range of baseflows (lowest to highest). If possible, provide for the wet season, and dry season.	
	What (in m^3/s) is the present day range of baseflows (lowest to highest). If possible, provide for the wet season, and dry season.	

MODERATE FLOODS (HIGH FLOWS)	Has the frequency of floods changed from natural?	Yes.
	Are the changes an increase or a decrease? If an increase, is it due to dam releases, urban runoff, or something else	Decrease in flood frequency due to the Inyaka Dam.
	Are there any changes in seasonality of the floods? And if yes, how.	No.
	Why has the flooding regime changed?	
LARGE FLOODS (HIGH FLOWS)	Has the frequency of floods changed from natural?	No.
	Are the changes an increase or a decrease? If an increase, is it due to dam releases, urban runoff, or something else.	Slight decrease in flood peaks due to afforestation & Inyaka Dam.
	Are there any changes in seasonality of the floods? And if yes, how.	Yes/No.
	Why have the flooding changed?	
Have any frequency analysis of floods been undertaken and if so, what are the flood peaks (in m^3/s). E.g. 1:2 = X m3/s etc.		No.
Any general comments or anything else one should take note of?		

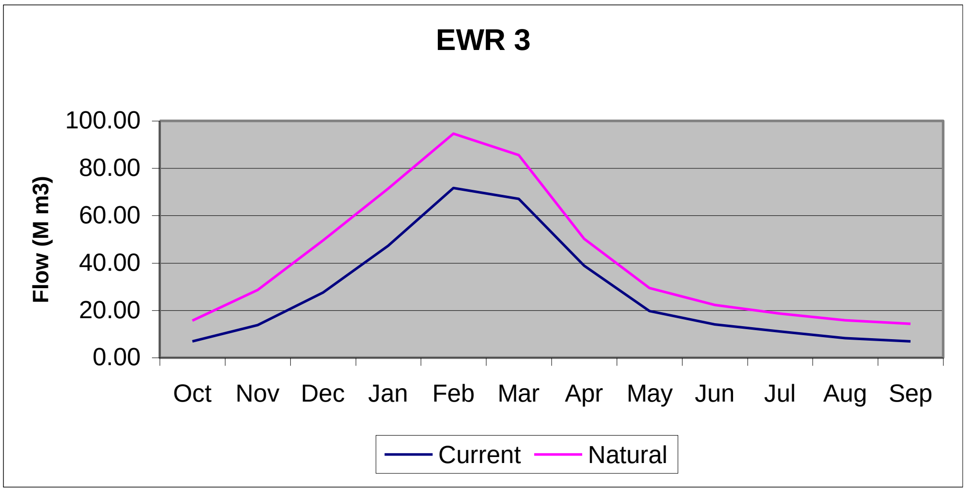

Figure A39 Flow duration curve for EWR 3

EWR 4: Mac Mac (Mac Mac River)		
Are there reliable gauges near to the site?		No. Gauge X3H003 is located approximately 25km US of the EWR but this is too far upstream relative to the catchment size to reliably represent the flow at the EWR site. The gauge does however appear to be relatively reliable with few gaps.
How long a record is available?		1948 to 2006.
Does it measure low flows accurately?		Yes.
Will it record zero flows accurately?		Probably.
What are the highest flows it can record before it drowns out?		Not stated.
Rate your confidence in your modelled naturalised hydrology and provide reasons (1 (low) – 5 (high)		3 = Medium to low confidence.
Rate your confidence in your modelled present day hydrology and provide reasons (1 (low) – 5 (high)		3 = Medium to low confidence.
Are there major differences between observed hydrology & modelled present hydrology. Why?. If present hydrology reflects recent changes, provide info. If changes have been gradual, note that.		No.
BASE (LOW) FLOWS	Have base flows changed from natural? (in volume, and/or time and/or distribution)	Significant reduction in baseflow due to afforestation.
	Are the changes an increase or decrease?	Decrease.
	Are the changes continuous through the year or only in specific seasons/months?	Continuous.
	Have the natural seasonal distribution changed and if yes, how and why?	Slightly.
	Why has the base flow changed, i.e. what is the	Afforestation.

	water being used for.	
	What (in m^3/s) is the natural range of baseflows (lowest to highest). If possible, provide for the wet season, and dry season.	
	What (in m^3/s) is the present day range of baseflows (lowest to highest). If possible, provide for the wet season, and dry season.	
MODERATE FLOODS (HIGH FLOWS)	Has the frequency of floods changed from natural?	Yes.
	Are the changes an increase or a decrease? If an increase, is it due to dam releases, urban runoff, or something else	
	Are there any changes in seasonality of the floods? And if yes, how.	No.
	Why has the flooding regime changed?	
LARGE FLOODS (HIGH FLOWS)	Has the frequency of floods changed from natural?	No.
	Are the changes an increase or a decrease? If an increase, is it due to dam releases, urban runoff, or something else.	Slight decrease in flood peaks due to afforestation.
	Are there any changes in seasonality of the floods? And if yes, how.	Yes/No.
	Why have the flooding changed?	
Have any frequency analysis of floods been undertaken and if so, what are the flood peaks (in m^3/s). E.g. 1:2 = X m^3/s etc.		No.
Any general comments or anything else one should take note of?		

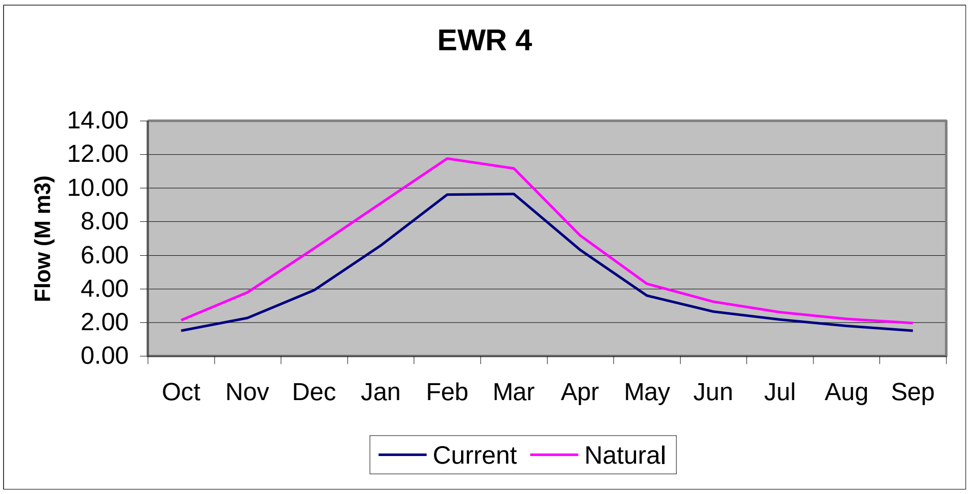

Figure A40 Flow duration curve for EWR 4

EWR 5: Marite (Marite River)	
Are there reliable gauges near to the site?	X3H011 appears to be reliable but is missing quite a bit of data (> 11%) and is located a bit too far upstream of the EWR site relative to the catchment size. The Inyaka Dam now provides a reliable gauge for calibration purposes.
How long a record is available?	1948 to present.
Does it measure low flows accurately?	Yes.
Will it record zero flows accurately?	Probably.
What are the highest flows it can record before it drowns out?	Not stated.
Rate your confidence in your modelled naturalised hydrology and provide reasons (1 (low) – 5 (high)	3 = Medium to low confidence.
Rate your confidence in your modelled present day hydrology and provide reasons (1 (low) – 5 (high)	3 = Medium to low confidence.
Are there major differences between observed hydrology & modelled present hydrology? Why? If present hydrology reflects recent changes, provide info. If changes have been gradual, note that.	Yes. The completion of the Inyaka Dam in 2000 will definitely have changed the flow regime at EWR 5.
LOW Have base flows changed from natural? (in volume,	Significant reduction in baseflow due to afforestation

	and/or time and/or distribution)	and the Inyaka Dam.
	Are the changes an increase or decrease?	Decrease.
	Are the changes continuous through the year or only in specific seasons/months?	Continuous.
	Have the natural seasonal distribution changed and if yes, how and why?	The seasonal distribution has only been slightly changed.
	Why has the base flow changed, i.e. what is the water being used for.	Afforestation, Inyaka Dam.
	What (in m^3/s) is the natural range of baseflows (lowest to highest). If possible, provide for the wet season, and dry season.	
	What (in m^3/s) is the present day range of baseflows (lowest to highest). If possible, provide for the wet season, and dry season.	
MODERATE FLOODS (HIGH FLOWS)	Has the frequency of floods changed from natural?	Yes.
	Are the changes an increase or a decrease? If an increase, is it due to dam releases, urban runoff, or something else	Decrease in flood peaks and frequency due to Inyaka Dam and to a lesser extent due to afforestation.
	Are there any changes in seasonality of the floods? And if yes, how.	Yes.
	Why has the flooding regime changed?	See above.
LARGE FLOODS (HIGH FLOWS)	Has the frequency of floods changed from natural?	Yes.
	Are the changes an increase or a decrease? If an increase, is it due to dam releases, urban runoff, or something else.	Slight decrease in flood peaks due to Inyaka Dam and to a lesser extent due to afforestation.
	Are there any changes in seasonality of the floods? And if yes, how.	No.
	Why have the flooding changed?	
Have any frequency analysis of floods been undertaken and if so, what are the flood peaks (in m^3/s). E.g. 1:2 = X m^3/s etc.		No.
Any general comments or anything else one should take note of?		

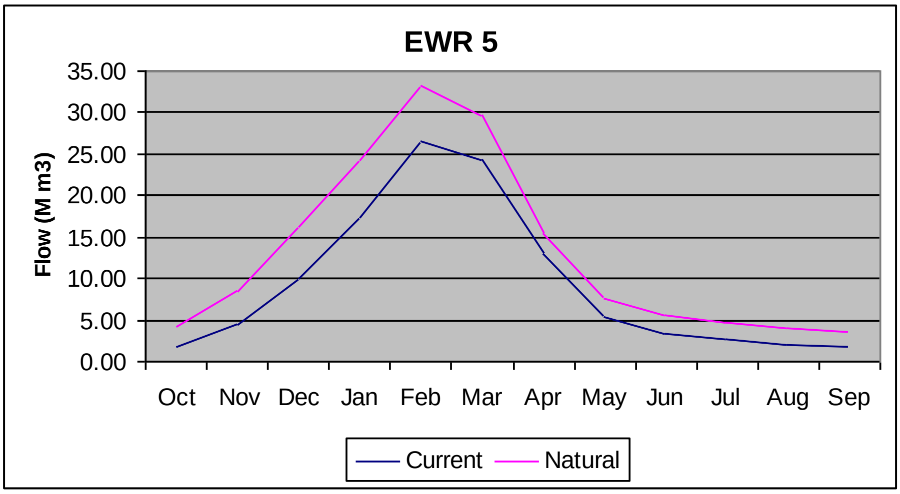

Figure A41 Flow duration curve for EWR 5

Table A28 EWR 6: Mutlumuvi (Mutlumuvi River)

EWR 6: Mutlumuvi (Mutlumuvi River)		
	Are there reliable gauges near to the site?	No. The only gauge is the Sand River gauge X3H008 which is remote from the EWR6 site.
	How long a record is available?	
	Does it measure low flows accurately?	Yes.
	Will it record zero flows accurately?	Probably.
	What are the highest flows it can record before it drowns out?	Not stated.
	Rate your confidence in your modelled naturalised hydrology and provide reasons (1 (low) – 5 (high)	1.5 - Low confidence.
	Rate your confidence in your modelled present day hydrology and provide reasons (1 (low) – 5 (high)	1.5 = Low confidence.
	Are there major differences between observed hydrology & modelled present hydrology? Why? If present hydrology reflects recent changes, provide info. If changes have been gradual, note that.	Yes. For a few years water from the Inyaka Dam was discharged into a tributary of the Mutlumuvi River. Also, abstraction that used to take place upstream of the EWR site for domestic purposed have probably now ceased since these users are now supplied from Inyaka Dam. Return flows from these domestic users should be on the increase.
BASE (LOW) FLOWS	Have base flows changed from natural? (in volume, and/or time and/or distribution)	Yes. Before domestic users were supplied from the Inyaka Dam it is likely that base flows were reduced to zero during dry months and still drops very low.
	Are the changes an increase or decrease?	Decrease.
	Are the changes continuous through the year or only in specific seasons/months?	Continuous but more noticeable during late winter and early spring.
	Have the natural seasonal distribution changed and if yes, how and why?	No.
	Why has the base flow changed, i.e. what is the water being used for.	See above.
	What (in m^3/s) is the natural range of baseflows (lowest to highest). If possible, provide for the wet season, and dry season.	
	What (in m^3/s) is the present day range of baseflows (lowest to highest). If possible, provide for the wet season, and dry season.	
MODERATE FLOODS (HIGH FLOWS)	Has the frequency of floods changed from natural?	No.
	Are the changes an increase or a decrease? If an increase, is it due to dam releases, urban runoff, or something else	
	Are there any changes in seasonality of the floods? And if yes, how.	
	Why has the flooding regime changed?	
LARGE FLOODS (HIGH FLOWS)	Has the frequency of floods changed from natural?	No.
	Are the changes an increase or a decrease? If an increase, is it due to dam releases, urban runoff, or something else.	
	Are there any changes in seasonality of the floods? And if yes, how.	No.
	Why have the flooding changed?	
	Have any frequency analysis of floods been undertaken and if so, what are the flood peaks (in m^3/s). E.g. 1:2 = X m^3/s etc.	No.
	Any general comments or anything else one should take note of?	

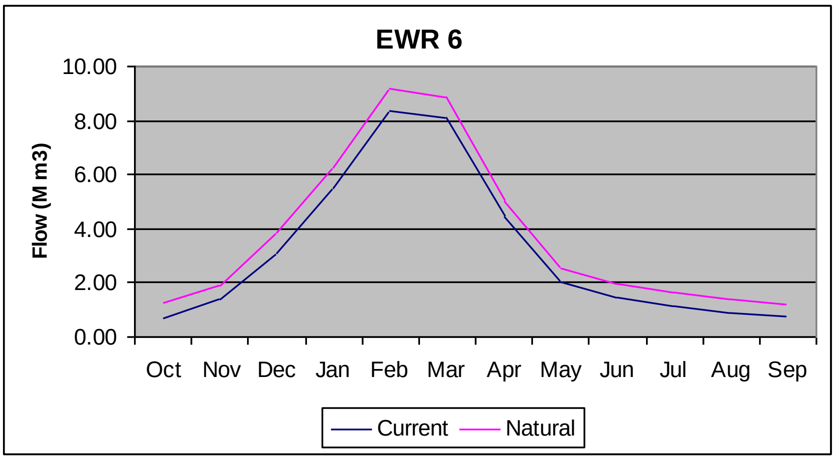

Figure A42 Flow duration curve for EWR 6

Table A29 EWR 7: Tlulandziteka (Tlulandziteka River)

EWR 7: Tlulandziteka River		
Are there reliable gauges near to the site?		No. The only gauge is the Sand River gauge X3H008 which is remote from the EWR 6 site.
How long a record is available?		
Does it measure low flows accurately?		Yes.
Will it record zero flows accurately?		Probably.
What are the highest flows it can record before it drowns out?		Not stated.
Rate your confidence in your modelled naturalised hydrology and provide reasons (1 (low) – 5 (high)		1.5 - Low confidence.
Rate your confidence in your modelled present day hydrology and provide reasons (1 (low) – 5 (high)		1.5 = Low confidence.
Are there major differences between observed hydrology & modelled present hydrology? Why? If present hydrology reflects recent changes, provide info. If changes have been gradual, note that.		No.
BASE (LOW) FLOWS	Have base flows changed from natural? (in volume, and/or time and/or distribution)	Yes. There are two small upstream dams and a diversion works 5 km upstream of site which diverts all the low flows. This does result in the river almost stop flowing in the dry season. There are no major changes from natural conditions except for a decrease in base flows as there is some irrigation upstream of the EWR site.
	Are the changes an increase or decrease?	Decrease.
	Are the changes continuous through the year or only in specific seasons/months?	Continuous but more noticeable during late winter and early spring.
	Have the natural seasonal distribution changed and if yes, how and why?	No.
	Why has the base flow changed, i.e. what is the water being used for.	See above.
	What (in m^3/s) is the natural range of baseflows (lowest to highest). If possible, provide for the wet season, and dry season.	
	What (in m^3/s) is the present day range of baseflows (lowest to highest). If possible, provide for the wet season, and dry season.	
MODERATE FLOODS (HIGH FLOWS)	Has the frequency of floods changed from natural?	No.
	Are the changes an increase or a decrease? If an increase, is it due to dam releases, urban runoff, or something else	
	Are there any changes in seasonality of the floods? And if yes, how.	
	Why has the flooding regime changed?	
OODS	Has the frequency of floods changed from natural?	No.

	Are the changes an increase or a decrease? If an increase, is it due to dam releases, urban runoff, or something else.	
	Are there any changes in seasonality of the floods? And if yes, how.	No.
	Why have the flooding changed?	
Have any frequency analysis of floods been undertaken and if so, what are the flood peaks (in m^3/s). E.g. 1:2 = X m^3/s etc		No.
Any general comments or anything else one should take note of?		

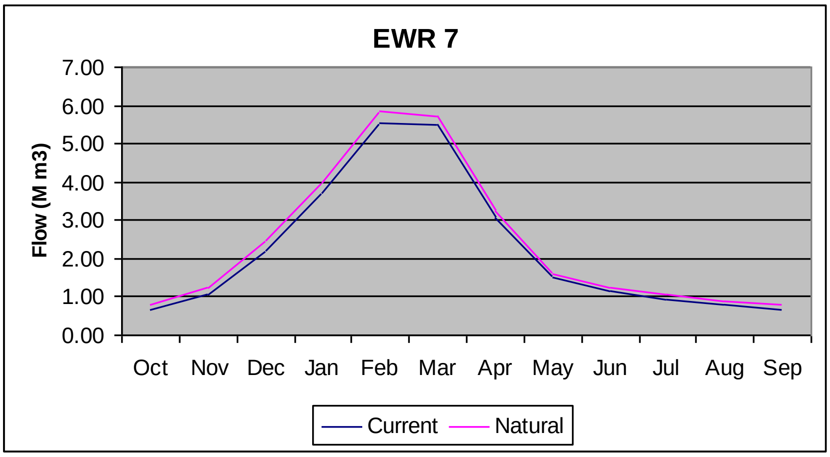

Figure A43 Flow duration curve for EWR 7

Table A30 EWR 8: Sand (Sand River)

EWR 8: Sand (Sand River)		
Are there reliable gauges near to the site?		No. Although the only gauge in the Sand River X3H008 is located near the EWR site, this gauge is not reliable.
How long a record is available?		1967 to present.
Does it measure low flows accurately?		
Will it record zero flows accurately?		Probably.
What are the highest flows it can record before it drowns out?		Not stated.
Rate your confidence in your modelled naturalised hydrology and provide reasons (1 (low) – 5 (high)		1.5 - Low confidence.
Rate your confidence in your modelled present day hydrology and provide reasons (1 (low) – 5 (high)		1.5 = Low confidence.
Are there major differences between observed hydrology & modelled present hydrology? Why? If present hydrology reflects recent changes, provide info. If changes have been gradual, note that.		Possibly. Afforestation has recently been removed from the catchment which should result in increased runoff.
BASE (LOW) FLOWS	Have base flows changed from natural? (in volume, and/or time and/or distribution)	Yes. There is some irrigation upstream of the EWR site.
	Are the changes an increase or decrease?	Decrease
	Are the changes continuous through the year or only in specific seasons/months?	Continuous but more noticeable during late winter and early spring.
	Have the natural seasonal distribution changed and if yes, how and why?	No.
	Why has the base flow changed, i.e. what is the water being used for.	See above.
	What (in m^3/s) is the natural range of baseflows (lowest to highest). If possible, provide for the wet season, and dry season.	
	What (in m^3/s) is the present day range of baseflows (lowest to highest). If possible, provide for the wet season, and dry season.	

EWR 8: Sand (Sand River)		
MODERATE FLOODS (HIGH FLOWS)	Has the frequency of floods changed from natural?	No.
	Are the changes an increase or a decrease? If an increase, is it due to dam releases, urban runoff, or something else	
	Are there any changes in seasonality of the floods? And if yes, how.	
	Why has the flooding regime changed?	
LARGE FLOODS (HIGH FLOWS)	Has the frequency of floods changed from natural?	No.
	Are the changes an increase or a decrease? If an increase, is it due to dam releases, urban runoff, or something else.	
	Are there any changes in seasonality of the floods? And if yes, how.	No.
	Why have the flooding changed?	
Have any frequency analysis of floods been undertaken and if so, what are the flood peaks (in m^3/s). E.g. 1:2 = X m^3/s etc		No.
Any general comments or anything else one should take note of?		

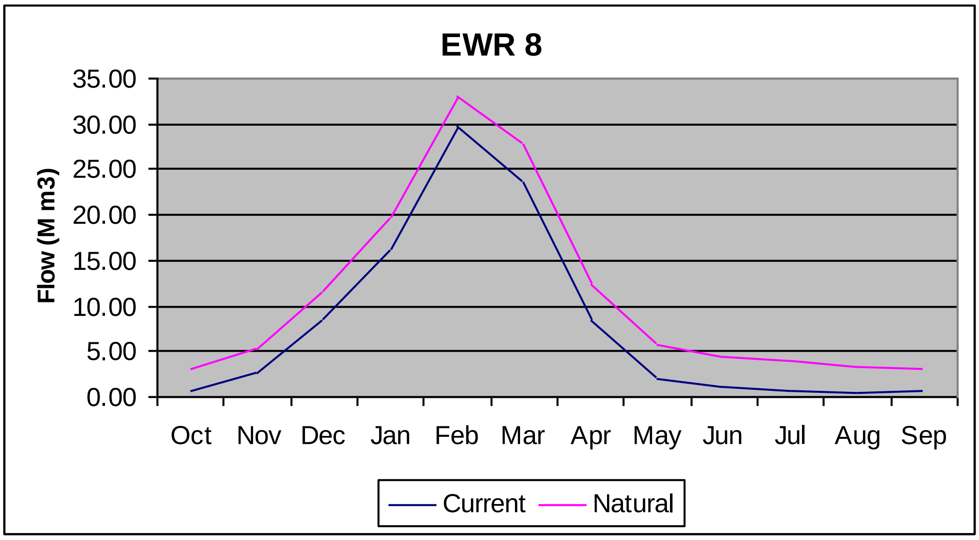

Figure A44 Flow duration curve for EWR 8

A3 HYDROLOGICAL CAUSES AND SOURCES UPSTREAM OF EWR SITES IN THE CROCOCILE AND SABIE SYSTEM

The information below is based on the hydrology generated through the Inkomati WAAS study. This has been refined in some instances in the WAAS study. Local knowledge was also used in this document, and to refine the HAI which is based purely on a comparison of present and virgin hydrology provided and no analysis of the accuracy of the hydrological data (*Pers comm*., Denis Hughes). This data was compiled during December 2007 and updated in March 2009.

Problems identified in the hydrology during this assessment are indicated in the site by site description below for the Crocodile River system (Table 1.1) and the Sabie-Sand River system (Table 1.2).

Table A31 Summary of hydrology for the Crocodile River system

EWR site	Virgin MAR (MCM)	Present Day (PD) MAR (MCM)	Impacts
EWR 1	15.04	14.37	Trout farming and small dams in tributaries. Dullstroom: 0.6 MCM use from a little dam which only affects low flows. Other tourism activities.
EWR 2	46.57	45.54	Irrigation use: 0.8 MCM Forestry use: 1 MCM EWR1: includes effects as upstream from EWR 1.
EWR 3	191.12	164.85[1]	Kwena Dam: Constant (i.e. not flood) release unless rivers are flowing high. Size of release is based on demand and varies from month to month. Higher than natural in dry and late dry season. Will impact on moderate floods but the tributaries and spilling mitigate to small extent the impact. Between the dam and site: Some irrigation, forestry
EWR 4	776.41	537.75	Elands River provides more natural diversity of flow and mitigates to some extent the impact of Kwena Dam. Forestry upstream of Nelspruit. Irrigation from Elands River confluence downstream of Nelspruit abstracts water immediately above the town in a canal. Also present a hydro power plant which diverts water from and then back to the river. In between Nelspruit off take and the hydropower returns, the river very dry. Upstream of site: Large abstractions for Kanyamazane. Water quality problems from Nelspruit. Wit River: Over utilised especially for irrigation. Related water quality problems. NB: Kwena releases: The biggest demand is below EWR 4 and Kwena Dam is operated to supply users all the way to Komatipoort. Change in smaller floods: Due to cumulative effects from abstraction and forestry. Large floods: Frequency changes due to the Kwena Dam. All impacts above EWR 3 also included.
EWR 5	1045.89	584.96	Downstream of EWR 4: Large scale irrigation for sugar cane. Kaap River contributes but is also impacted on by large scale irrigation. Malelane has very small water usage. Matsulu township (border of KNP), also extract water at an off take. Phola township: Abstracted from the Sabie River, and then return flows enter the Nsikasi (tributary) – water quality problems. Offtake DS of site : To canal, for mill, Malelane town and mostly irrigation. Kaap River: Irrigation and forestry. All impacts upstream of EWR 4 included.
EWR 6	1089.67	507.95	Mostly large scale irrigation.

			International water use must also flow past this site. All impacts upstream from EWR 5.
EWR 7	179.25	84.6	Forestry and irrigation. River stops flowing (verified from observed record – perhaps less often than what has been modelled in the WAAS study.

1 PD flows include increased low flows during certain months, i.e. the relationship between virgin and PD flows does not reflect the change in hydrology.

Table A32 Summary of hydrology for the Sabie-Sand River sy

EWR site	Virgin MAR (MCM)	Present Day (PD) MAR (MCM)	Impacts
EWR 1	140.18	108.9	Forestry is a large impact: Approx. 30 MCM. Sabie town urban requirements: 1.3 MCM Water quality – return flows from Sabie and possibly old mines.
EWR 2	262.11	194.52	Sabaan tributary enters Sabie River between EWR 1 and 2. Forestry starts to make place to irrigation. All impacts upstream of EWR 1 and from the Mac Mac River included.
EWR 3	494.18	303.68	Hazyiew abstracts from Sabie River. Irrigation. Abstraction for Phola in the Crocodile catchment. All upstream impacts of EWR 1, 2, 4, 5 included.
EWR 4	65.78	51.84	Upper catchment 100% forestry.
EWR 5	157.09	89.48	Inyaka Dam upstream. Releases to Sabie probably higher than virgin during some months. Steady release.
EWR 6	44.99	28.73	Abstraction for both domestic use and irrigation. Domestic use abstractions now ceased as these are supplied from the Bushbuckridge transfer pipeline. Irrigation abstraction at the New Forest weir divert all the low flow resulting in very low flow at EWR6 during the dry winter months.
EWR 7	28.79	12.09	Water is diverted at two weirs upstream of the site (Champagne and Dingleydale). During low flow conditions almost all the flow is diverted resulting in very low flow at EWR7. In addition, the small Acornhoek and Kasteel Dams are upstream of this site with added negative impacts.
EWR 8	133.46	91.08	In addition to the abstractions referred to upstream of EWR 6 and 7, there is also a diversion weir which diverts flow into the Edinburgh Dam. The combined effect of all these diversions is that during dry winter months there is little or no flow at EWR 8. There are also net evaporative losses in the lower reaches of the Sand River which will result in low flows which escape abstraction works evaporating before reaching EWR 8.

APPENDIX B: INSTREAM AND RIPARIAN HABITAT INTEGRITY

Ms MD Louw, Water for Africa

B1 SABIE-SAND AND CROCODILE SYSTEMS IHI

The Instream Index of Habitat Integrity (IIHI) and the Riparian Index of Habitat Integrity (RIHI) is based on the methods outlined in Kleynhans *et al*., 2008.

B1.1 DATA AVAILABILITY

The IHI undertaken was ground-based. No recent or good quality Instream Habitat Integrity (IHI) DVDs were available. The following data was used to assess the IHI:

- Personal groundbased observations.
- Local knowledge.
- Hydrological assessments.
- Water quality assessments.
- Land cover assessments (Department of Water Affairs and Forestry (DWAF)).
- Google Earth (mostly high resolution).
- Various maps.

Confidence of Data: 4. The confidence in the data is high due to the systems being reasonably assessment and the high quality of Google Earth available for large sections of the study area.

B1.2 REFERENCE CONDITION

Reference conditions are not explicitly described in the IHI at this stage. The model is based on an evaluation of impacts (scale and severity) and this forms the basis of the ratings supplied which measure change from natural.

B2 CROCODILE RIVER IHI

B2.1 MRU CROC A: EWR 1 AND 2

The Instream and Riparian IHI results are illustrated in Figure B1 and summarised in Table B1.

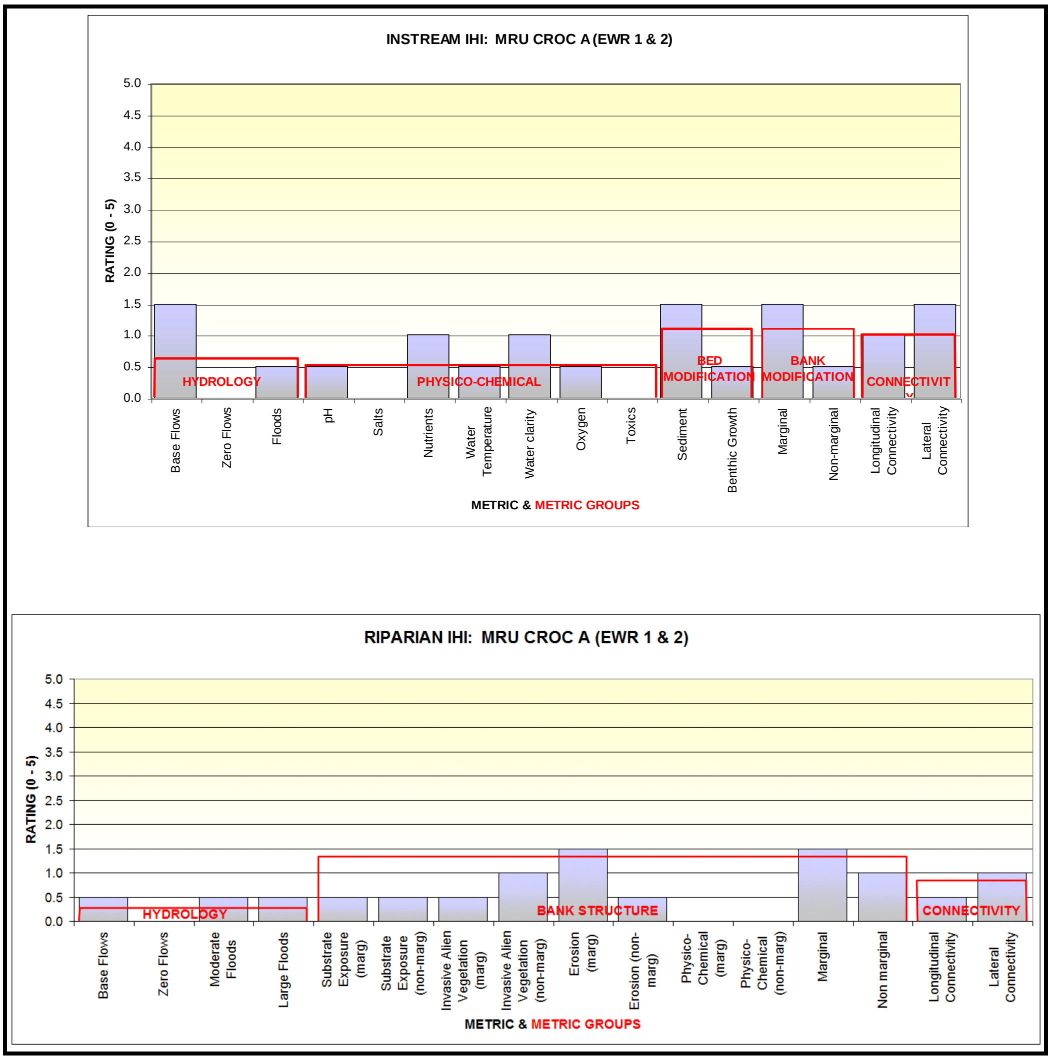

Figure B1 MRU Croc A: Instream and Riparian IHI

Table B1 Summary of the causes and sources for the change in reference condition for EWR 1

PES	Causes	Sources	F[1]/NF[2]	Conf
INSTREAM				
B	Change in base flows.	Abstractions.	F	3.6
	Increase in sediment (bed modification).	Land use.	NF and F	
	Change in bank structure of the marginal zone (Incision).	Erosion and channel incision – land use.	NF	
	Change in lateral connectivity – floodplain connection.	Incision of channel (change in sediment transport).	NF and F	
RIPARIAN				
B	Erosion.	Land use.	NF	3.9

1 Flow related 2 Non flow related

B2.2 MRU CROC B: EWR 3

The Instream and Riparian IHI results are illustrated in Figure B2 and summarised in Table B2.

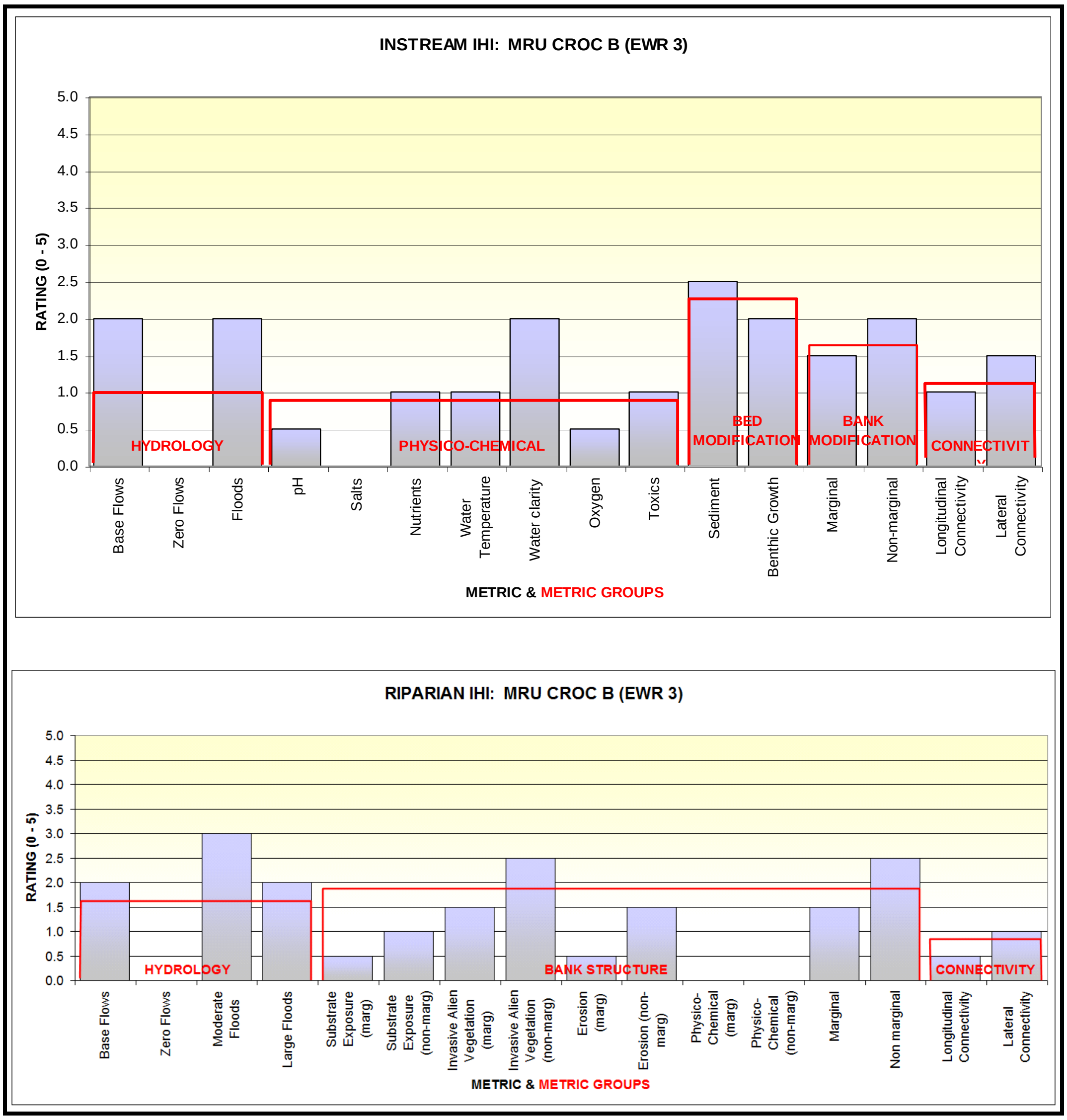

Figure B2 MRU Croc B: Instream and Riparian IHI

Table B2 Summary of the causes and sources for the change in reference condition for EWR 3

PES	Causes	Sources	F/NF	Conf
INSTREAM				
C	Change in base flows and floods.	Kwena Dam and releases.	F	3.5
	Water clarity.	Flow and land use.	F and NF	
	Sedimentation resulting in bed modification.	Change in flow regime and Kwena Dam.	F	
	Bank Modification.	Non marginal zone – landuse and agriculture.	NF	
RIPARIAN				
C	Change in base flows and floods.	Kwena Dam and releases.	F	4
	Alien vegetation especially in the non-marginal zone.	Alien infestation and land use.	F and NF	

B2.3 MRU CROC RAU D.1: EWR 4

The Instream and Riparian IHI results are illustrated in Figure B3 and summarised in Table B3.

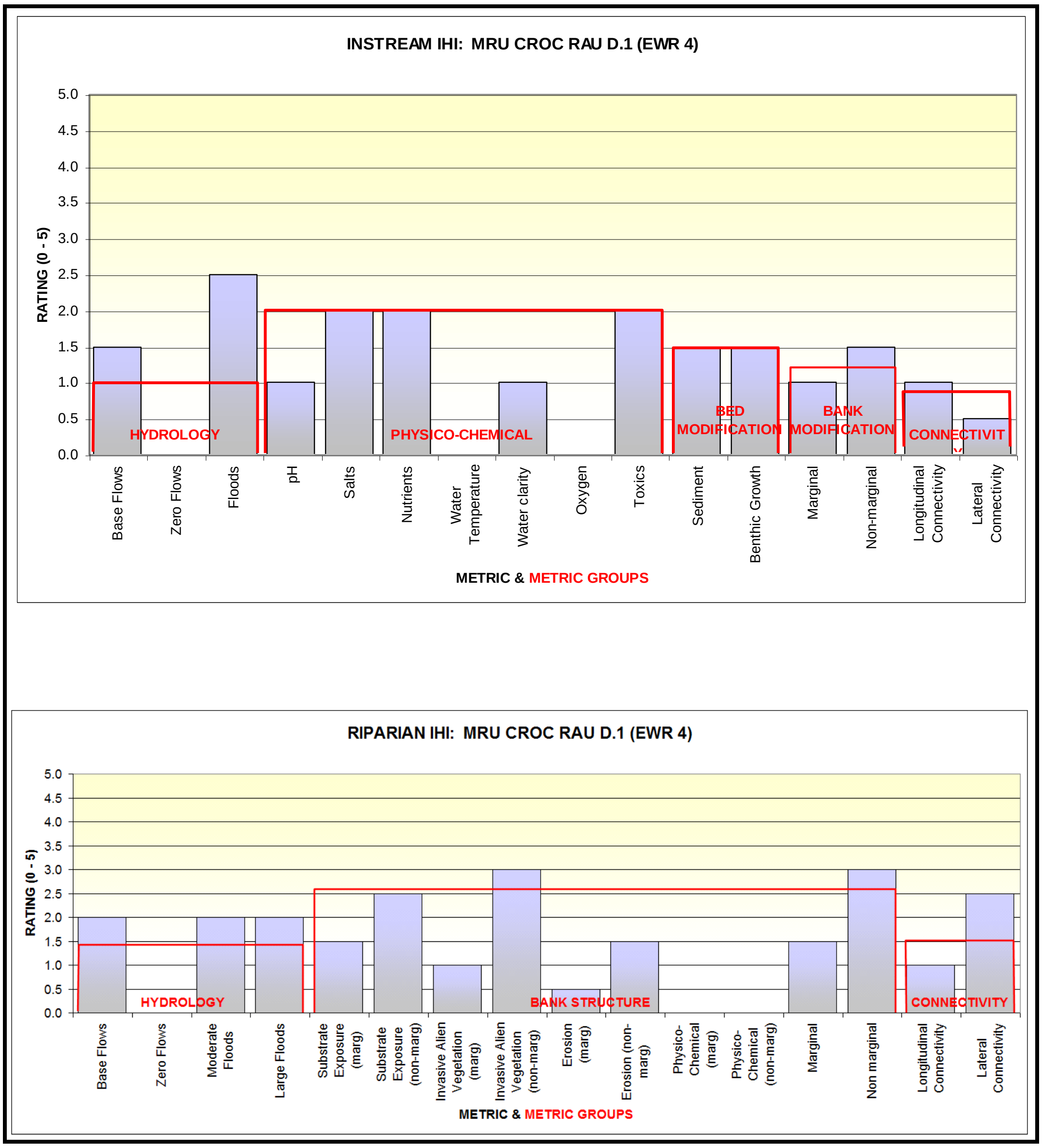

Figure B3 MRU Croc RAUD: Instream and Riparian IHI

Table B3 Summary of the causes and sources for the change in reference condition for EWR 4

PES	Causes	Sources	F/NF	Conf
INSTREAM				
C	Change in base flows and especially floods.	Kwena Dam and releases and abstractions.	F	3.3
	Salts, nutrients and toxics.	Land use.	NF	
	Bed and bank modification due to scouring, erosion and roads.	Constant releases from the dam, land use.	F & NF	
RIPARIAN				
C	Invasive and alien vegetation in non-marginal zone.	Land use and increase in flow.	F & NF	3.25

PES	Causes	Sources	F/NF	Conf
	Lateral connectivity.	Extensive roads adjacent to river.	NF	

B2.4 MRU CROC E: EWR 5

The Instream and Riparian IHI results are illustrated in Figure B4 and summarised in Table B4.

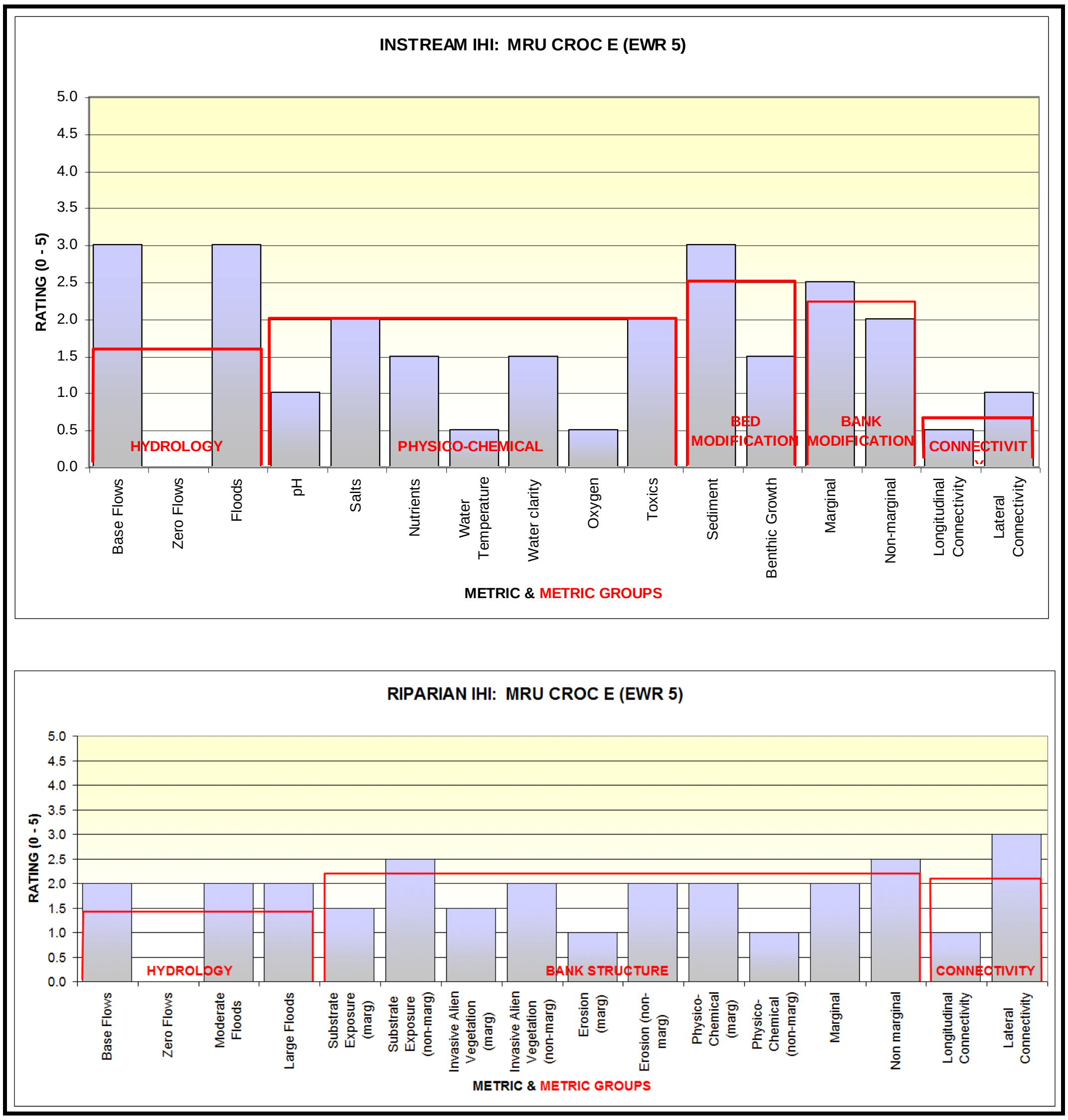

Figure B4 MRU Croc E: Instream and Riparian IHI

Table B4 Summary of the causes and sources for the change in reference condition for EWR 5

PES	Causes	Sources	F/NF	Conf
INSTREAM				
C	Change in base flows and especially floods.	Abstractions for irrigation (sugar cane and orchards).	F	3.3
	Salts, nutrients and toxics.	Land use.	NF	
	Bed and bank modification due to scouring, erosion and roads.	Constant releases from the dam, land use.	F & NF	
RIPARIAN				

PES	Causes	Sources	F/NF	Conf
C	Substrate exposure, erosion.	Land use.	NF	3.2
	Lateral connectivity.	Roads and lands.		

B2.5 MRU CROC E: EWR 6

The Instream and Riparian IHI results are illustrated in Figure B5 and summarised in Table B5.

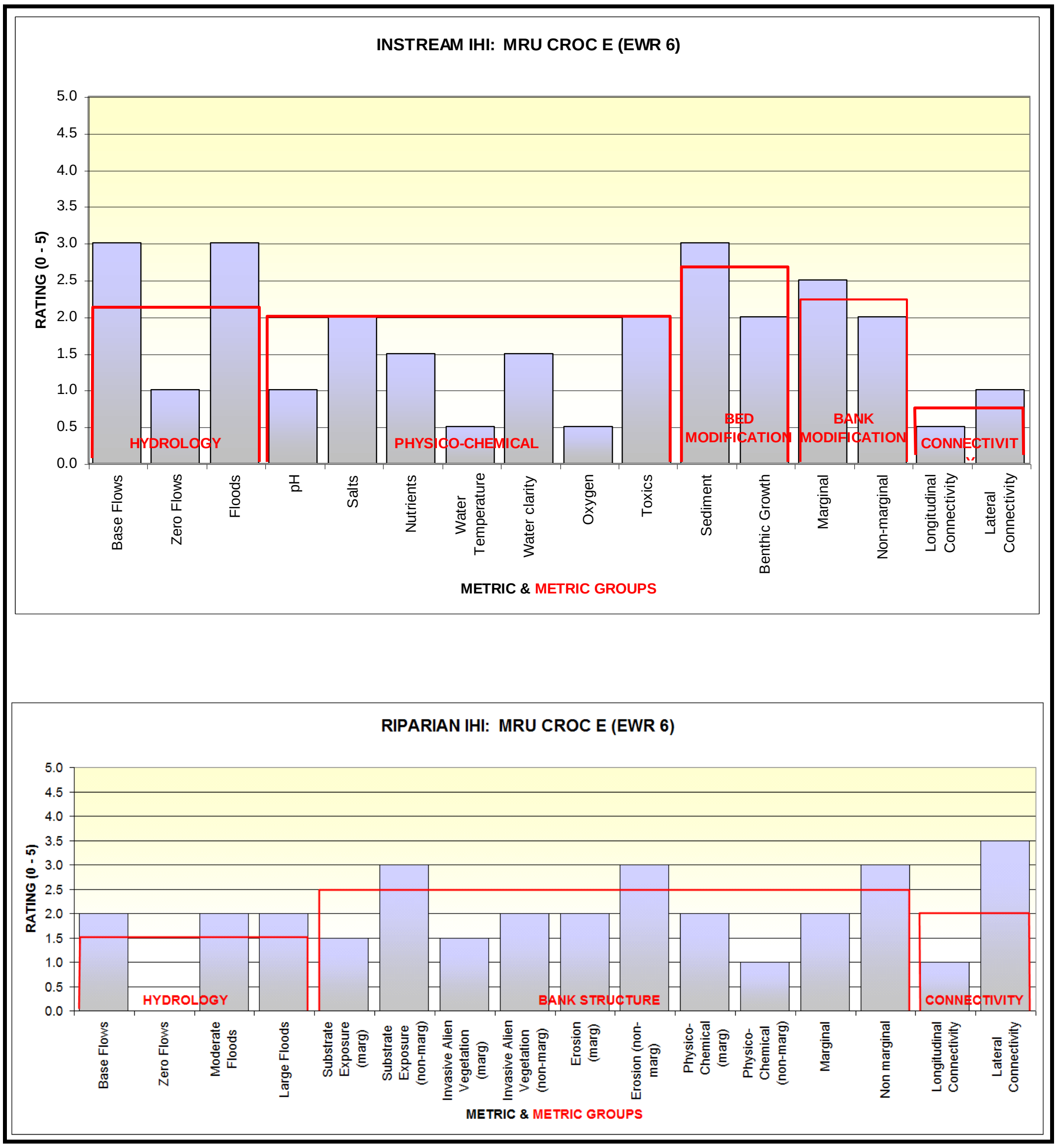

Figure B5 MRU Croc E: Instream and Riparian IHI

Table B5 Summary of the causes and sources for the change in reference condition for EWR 6

PES	Causes	Sources	F/NF	Conf
INSTREAM				
C/D	Change in base flows and especially floods.	Abstractions for irrigation (sugar cane and orchards).	F	3.4
	Salts, nutrients and toxics.	Land use.	NF	
	Bed and bank modification due to scouring, erosion sedimentation, sugar cane and veg removal on banks.	Land use, decreased flows.	F & NF	
RIPARIAN				
C/D	Substrate exposure, erosion.	Land use.	NF	3.2
	Lateral connectivity.	Roads and lands.		

B2.6 MRU KAAP RAU A.1: EWR 7

The Instream and Riparian IHI results are illustrated in Figure B6 and summarised in Table B6.

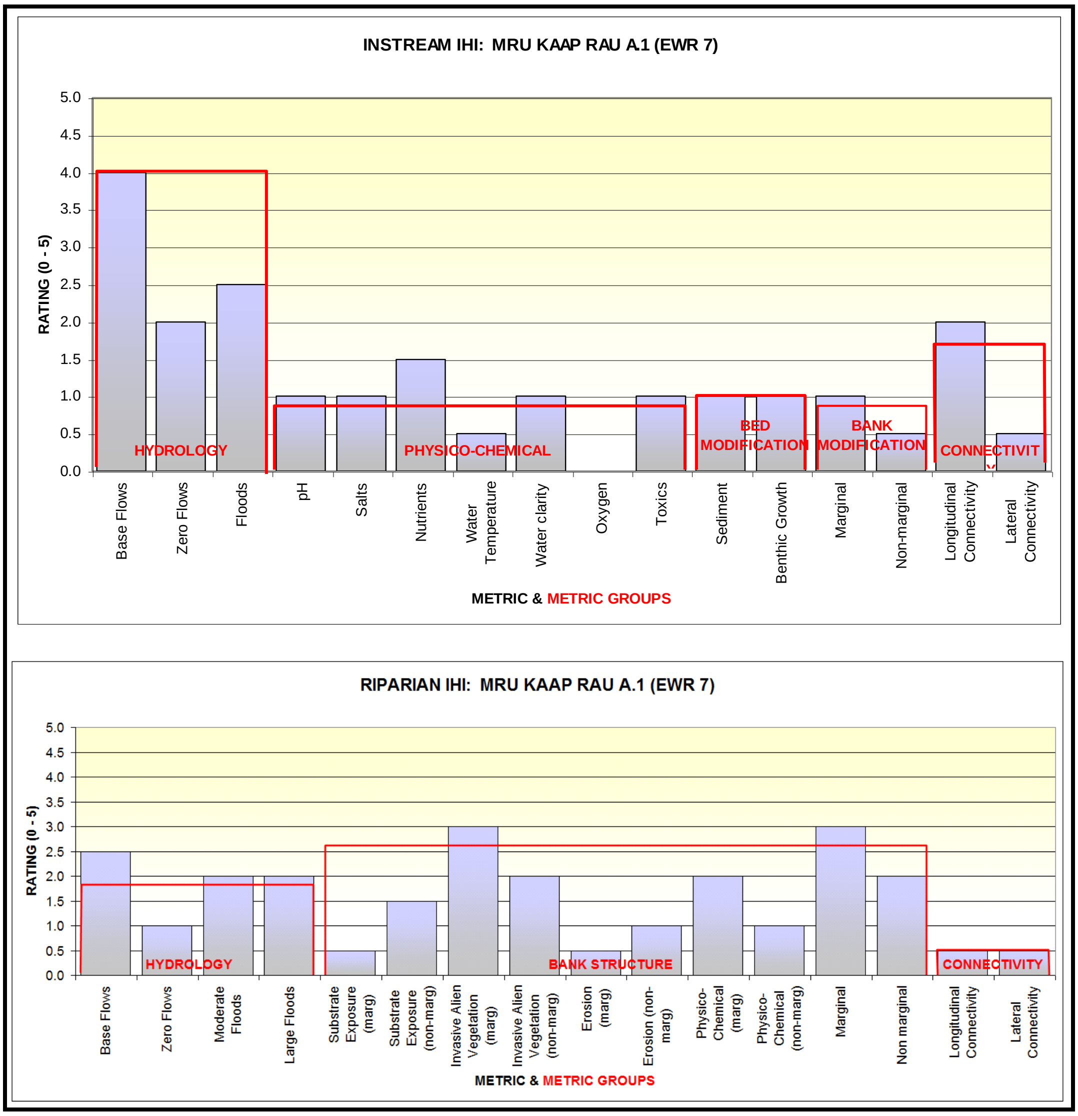

Figure B6 MRU Kaap RAU A.1: Instream and Riparian IHI

Table B6 Summary of the causes and sources for the change in reference condition for EWR 7

PES	Causes	Sources	F/NF	Conf
INSTREAM				
C	Change in hydrology (decreased flows).	Abstractions.	F	3
	Longitudinal connectivity due to change in hydrology.	Abstractions and zero flows.		
RIPARIAN				
C	Decreased base flows and zero flows.	Abstractions.	F	2.8
	Alien vegetation.	Land use.	NF	

B2.7 CROCODILE RIVER INSTREAM IHI SUMMARY

The results are compared in the following tables and graphics.

Table B7 Ratings for the each MRU and EWR site – Crocodile system

INSTREAM IHI	MRU Croc A	MRU Croc B	MRU Croc RAU D1	MRU Croc E (EWR 5)	MRU Croc E (EWR 6)	MRU Kaap RAU A1
Base Flows	-1.5	2.0	-1.5	-3.0	-3.0	-4.0
Zero Flows	0.0	0.0	0.0	0.0	1.0	-2.0
Floods	-0.5	-2.0	-2.5	-3.0	-3.0	-2.5
HYDROLOGY RATING	**0.6**	**1.0**	**1.0**	**1.6**	**2.1**	**4.0**
pH	0.5	0.5	2.0	2.0	2.0	1.0
Salts	0.0	0.0	2.0	2.0	2.0	1.0
Nutrients	1.0	1.0	2.0	2.0	2.0	1.5
Water Temperature	0.5	1.0	2.0	2.0	2.0	0.5
Water clarity	1.0	2.0	2.0	2.0	2.0	1.0
Oxygen	0.5	0.5	2.0	2.0	2.0	0.0
Toxics	0.0	1.0	2.0	2.0	2.0	1.0
PC RATING	**0.5**	**0.9**	**2.0**	**2.0**	**2.0**	**0.8**
Sediment	1.5	2.5	1.5	3.0	3.0	1.0
Benthic Growth	0.5	2.0	1.5	1.5	2.0	1.0
BED RATING	**1.1**	**2.3**	**1.5**	**2.5**	**2.6**	**1.0**
Marginal	1.5	1.5	1.0	2.5	2.5	1.0
Non-marginal	0.5	2.0	1.5	2.0	2.0	0.5
BANK RATING	**1.1**	**1.7**	**1.2**	**2.3**	**2.3**	**0.8**
Longitudinal Connectivity	-1.0	-1.0	1.0	0.5	0.5	2.0
Lateral Connectivity	-1.5	-1.5	0.5	1.0	1.0	0.5
CONNECTIVITY RATING	**1.0**	**1.1**	**0.9**	**0.6**	**0.7**	**1.7**
INSTREAM IHI %	**84.0**	**72.6**	**73.1**	**64.1**	**60.9**	**69.7**
INSTREAM IHI EC	**B**	**C**	**C**	**C**	**C/D**	**C**
INSTREAM CONFIDENCE	**3.6**	**3.5**	**3.3**	**3.3**	**3.4**	**3.0**

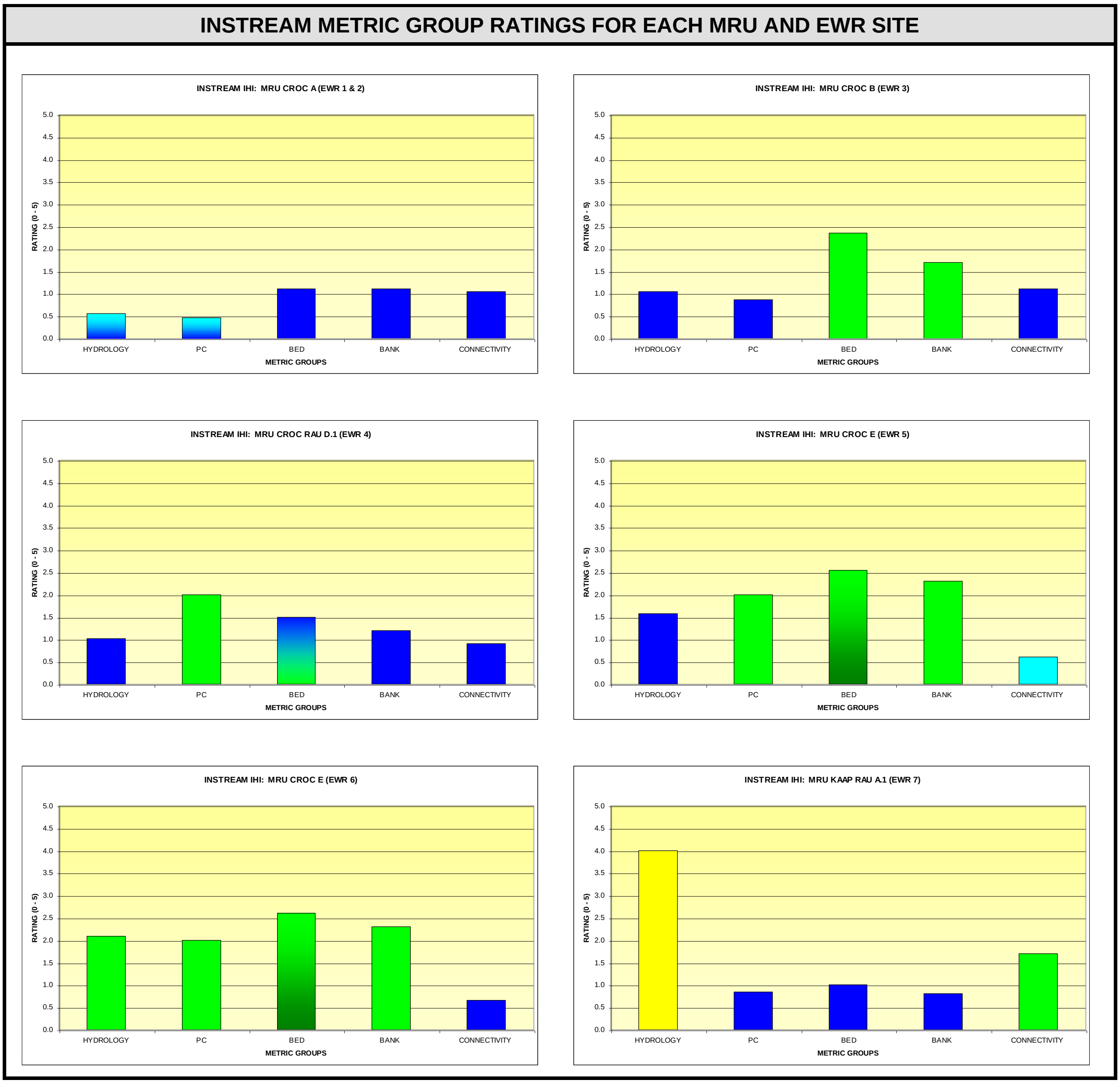

Figure B7 Instream Metric group ratings for each MRU and EWR site – Crocodile system

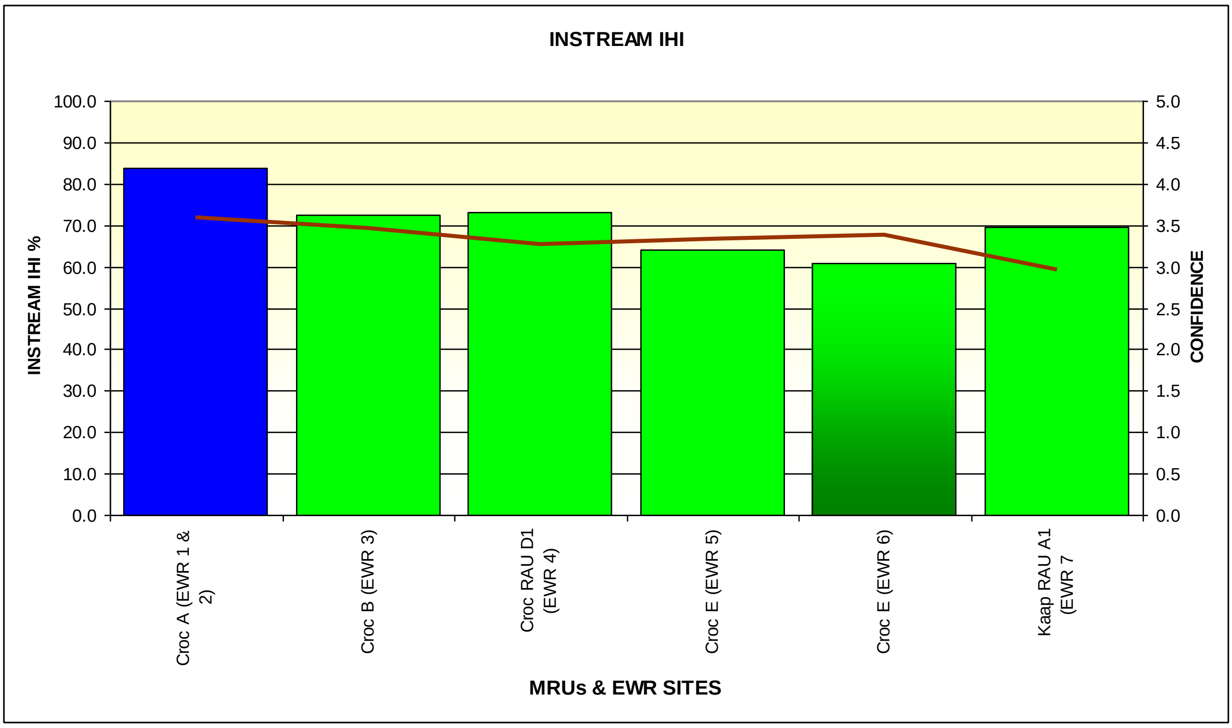

Figure B8 Summary of IHI Instream categories – Crocodile system

B2.8 CROCODILE RIVER RIPARIAN IHI SUMMARY

The results are compared in the following tables and graphics.

Table B8 Ratings for the each MRU and EWR site – Crocodile system

	MRU	MRU	MRU	MRU	MRU	MRU
RIPARIAN IHI	Croc A	Croc B	Croc RAU D1	Croc E (EWR 5)	Croc E (EWR 6)	Kaap RAU A1
Base Flows	-0.5	2.0	2.0	2.0	2.0	-2.5
Zero Flows	0.0	0.0	0.0	0.0	0.0	-1.0
Moderate Floods	-0.5	3.0	2.0	-2.0	-2.0	2.0
Large Floods	-0.5	-2.0	-2.0	-2.0	-2.0	-2.0
HYDROLOGY RATING	**0.3**	**1.6**	**1.4**	**1.4**	**1.5**	**1.8**
Substrate Exposure (marg)	0.5	0.5	1.5	1.5	1.5	0.5
Substrate Exposure (non-marg)	0.5	1.0	2.5	2.5	3.0	1.5
Invasive Alien Vegetation (marg)	0.5	1.5	1.0	1.5	1.5	3.0
Invasive Alien Vegetation (non-marg)	1.0	2.5	3.0	2.0	2.0	2.0
Erosion (marg)	1.5	0.5	0.5	1.0	2.0	0.5
Erosion (non-marg)	0.5	1.5	1.5	2.0	3.0	1.0
Physico-Chemical (marg)	0.0	0.0	0.0	2.0	2.0	2.0
Physico-Chemical (non-marg)	0.0	0.0	0.0	1.0	1.0	1.0
Marginal	1.5	1.5	1.5	2.0	2.0	3.0
Non marginal	1.0	2.5	3.0	2.5	3.0	2.0
BANK STRUCTURE RATING	**1.4**	**1.9**	**2.1**	**2.2**	**2.5**	**2.6**
Longitudinal Connectivity	-0.5	-0.5	-1.0	-1.0	-1.0	-0.5
Lateral Connectivity	-1.0	-1.0	-2.5	-3.0	-3.5	-0.5
CONNECTIVITY RATING	**0.7**	**0.7**	**1.5**	**1.6**	**2.0**	**0.5**
RIPARIAN IHI %	**82.4**	**69.3**	**65.5**	**63.9**	**59.1**	**62.6**
RIPARIAN IHI EC	**B**	**C**	**C**	**C**	**C/D**	**C**
RIPARIAN CONFIDENCE	**3.9**	**4.0**	**3.3**	**3.2**	**3.2**	**2.8**

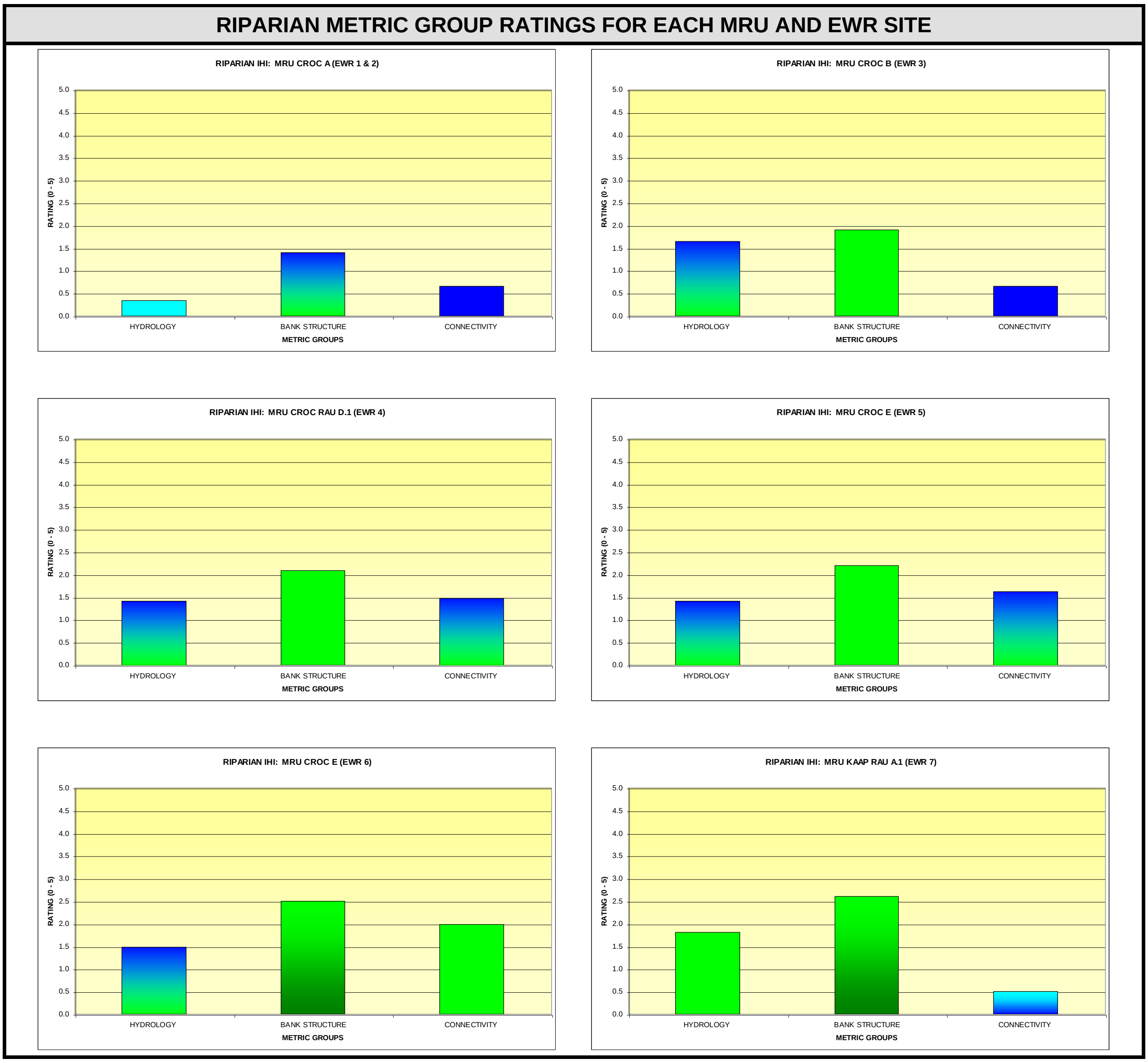

Figure B9 Riparian Metric group ratings for each MRU and EWR site – Crocodile system

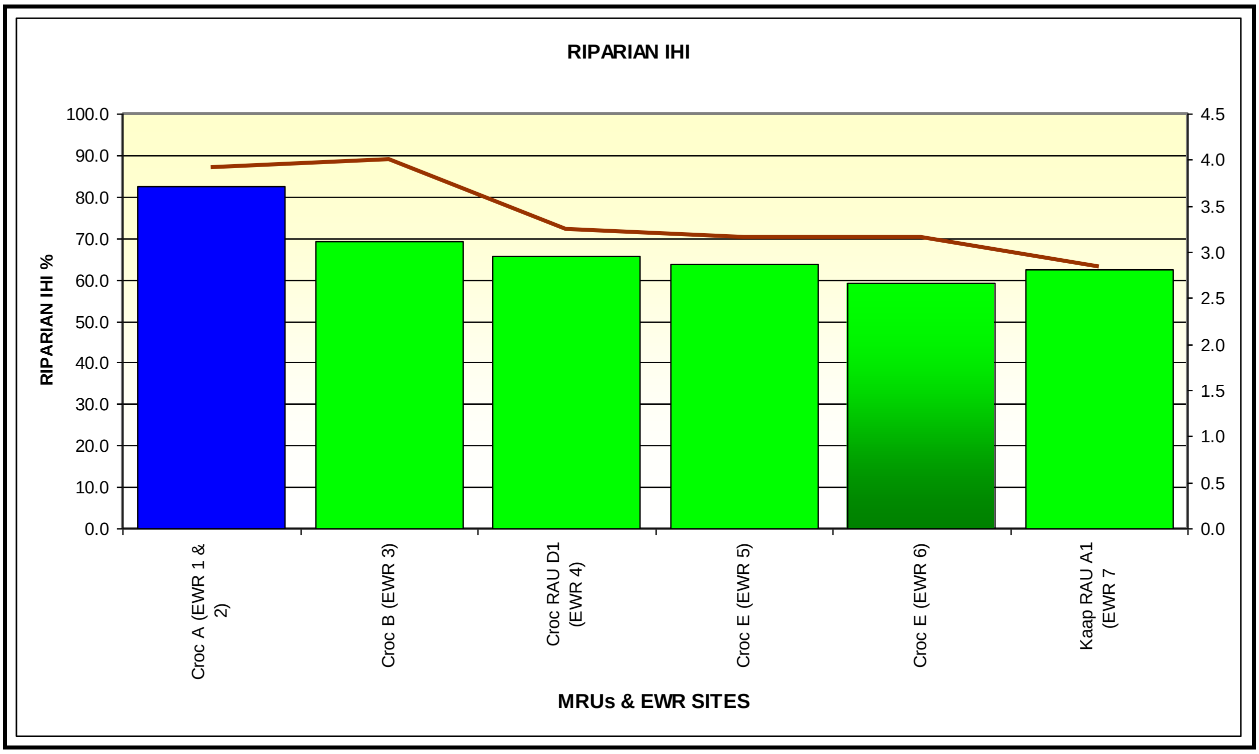

Figure B10 Summary of IHI Riparian categories – Crocodile system

B3 SABIE – SAND RIVER IHI

B3.1 MRU SABIE A: EWR 1

The Instream and Riparian IHI results are illustrated in Figure B11 and summarised in Table B9.

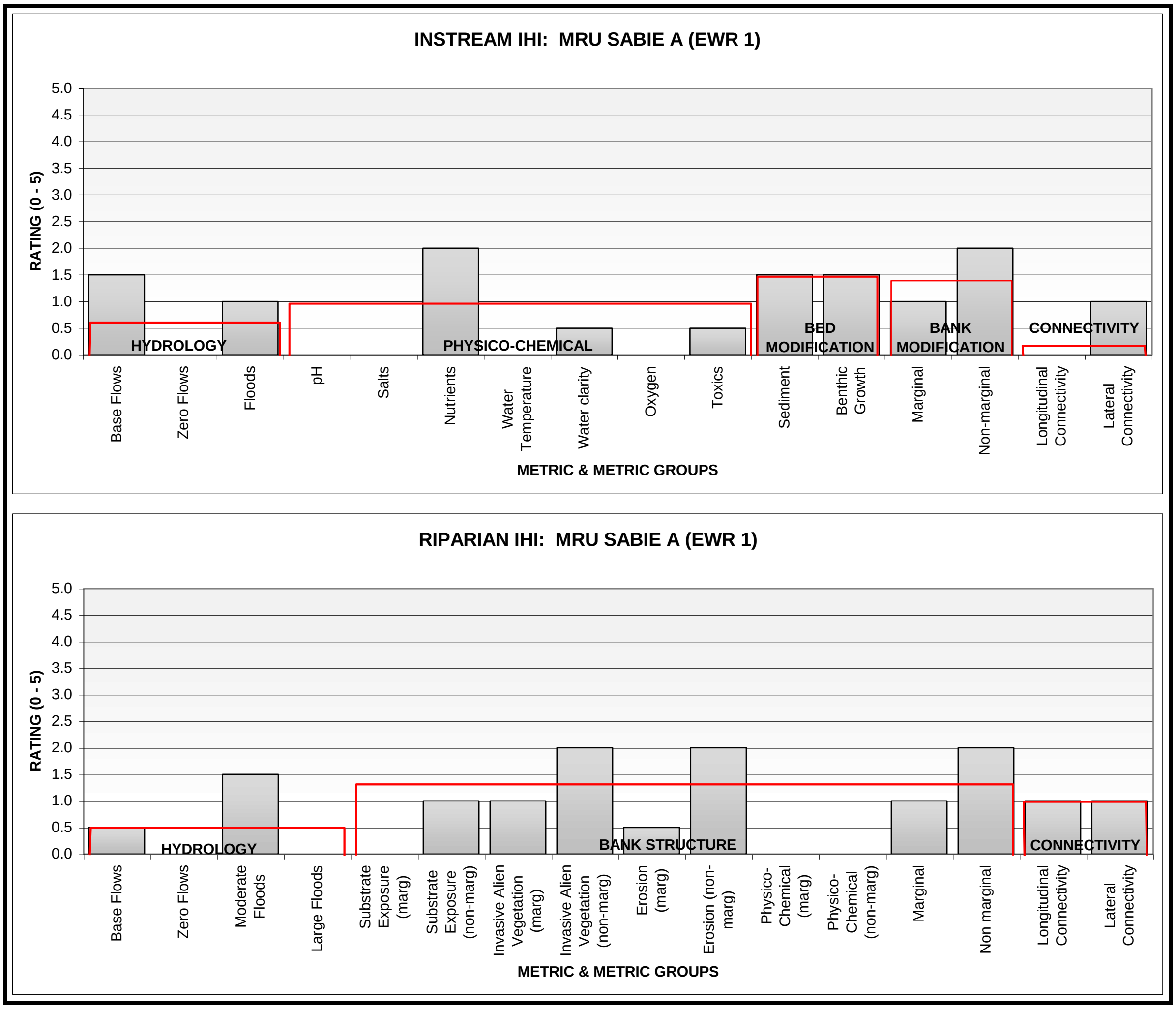

Figure B11 MRU Sabie A: Instream and Riparian IHI

Table B9 Summary of the causes and sources for the change in reference condition for MRU Sabie A EWR 1

PES	Causes	Sources	F/NF	Conf
INSTREAM				
B/C	Reduction in flow.	Forestry, small abstractions for Sabie.	F	3.2
	Nutrients.	Pollution possibly from Sabie and forestry.	NF	
	Non-marginal bank modification (erosion).	Forestry.		
RIPARIAN				
B/C	Reduction in floods.	Forestry.	F	3.1
	Bank structure modification (erosion).	Aliens and forestry.	NF	

B3.2 MRU SABIE RAU A.2: EWR 2

The Instream and Riparian IHI results are illustrated in Figure B12 and summarised in Table B10.

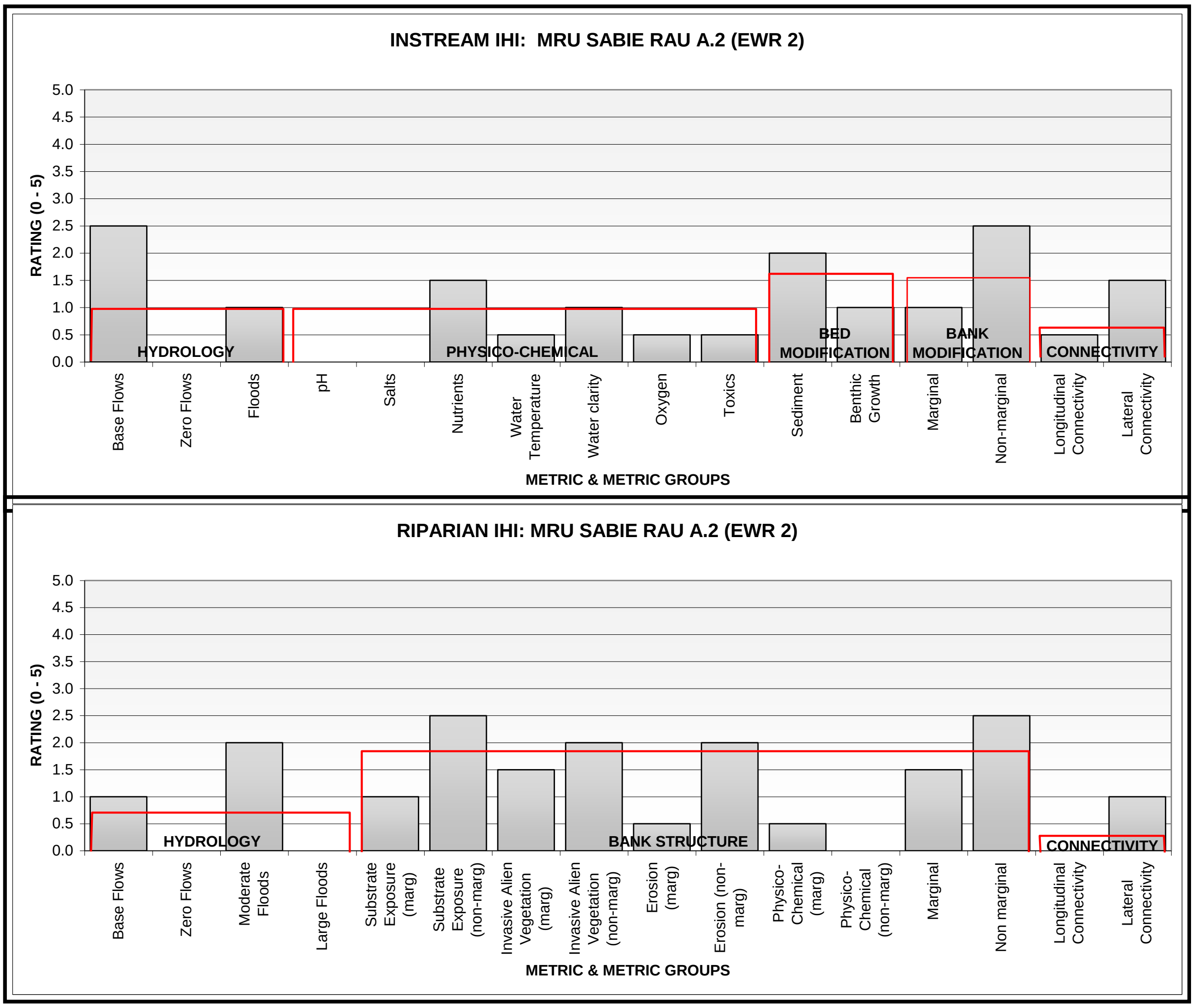

Figure B12 MRU Sabie RAU A2: Instream and Riparian IHI

Table B10 Summary of the causes and sources for the change in reference condition for MRU Sabie RAU A2

PES	Causes	Sources	F/NF	Conf
INSTREAM				
C	Base flow decrease.	Forestry, irrigation.	F	2.9
	Bed modification (increased sedimentation).	Forestry, roads, irrigation.	NF	
	Bank modification in the non-marginal zone.	Roads, forestry, lands, recreational areas, housing.		
RIPARIAN				
C	Decrease in floods.	Forestry and abstractions.	F	3.2
	Substrate exposure (mostly in non-marginal zone).	Forestry, lands, recreational areas.	NF	
	Invasive alien veg (mostly in non-marginal zone).			
	Erosion (mostly in non-marginal zone).			

B3.3 MRU SABIE RAU B.1: EWR 3

The Instream and Riparian IHI results are illustrated in Figure B13 and summarised in Table B11.

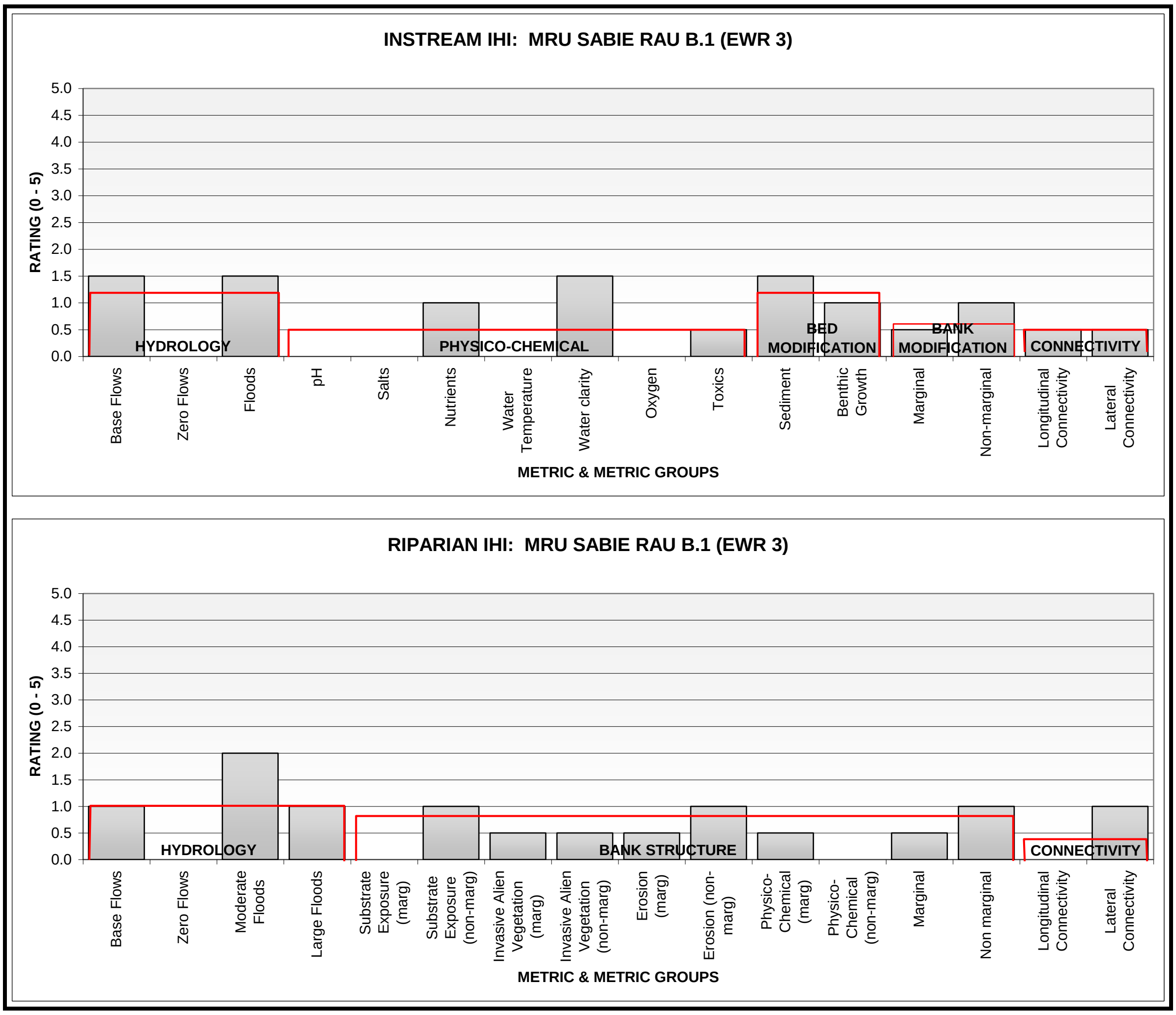

Figure B13 MRU Sabie RAU B.1: Instream and Riparian IHI

Table B11 Summary of the causes and sources for the change in reference condition for MRU Sabie RUA B.1

PES	Causes	Sources	F/NF	Conf
INSTREAM				
B	Reduction in flows.	Upstream abstraction.	F	3.1
	Water clarity.	Land use.	NF	
	Sedimentation.			
RIPARIAN				
B	Change in moderate floods.	Forestry and abstraction, Inyaka Dam in Marite.	F	3.2
	Erosion and substrate exposure in non-marginal zone.	Upstream land use.	NF	

B3.4 MRU MACMAC: EWR 4

The Instream and Riparian IHI results are illustrated in Figure B14 and summarised in Table B12.

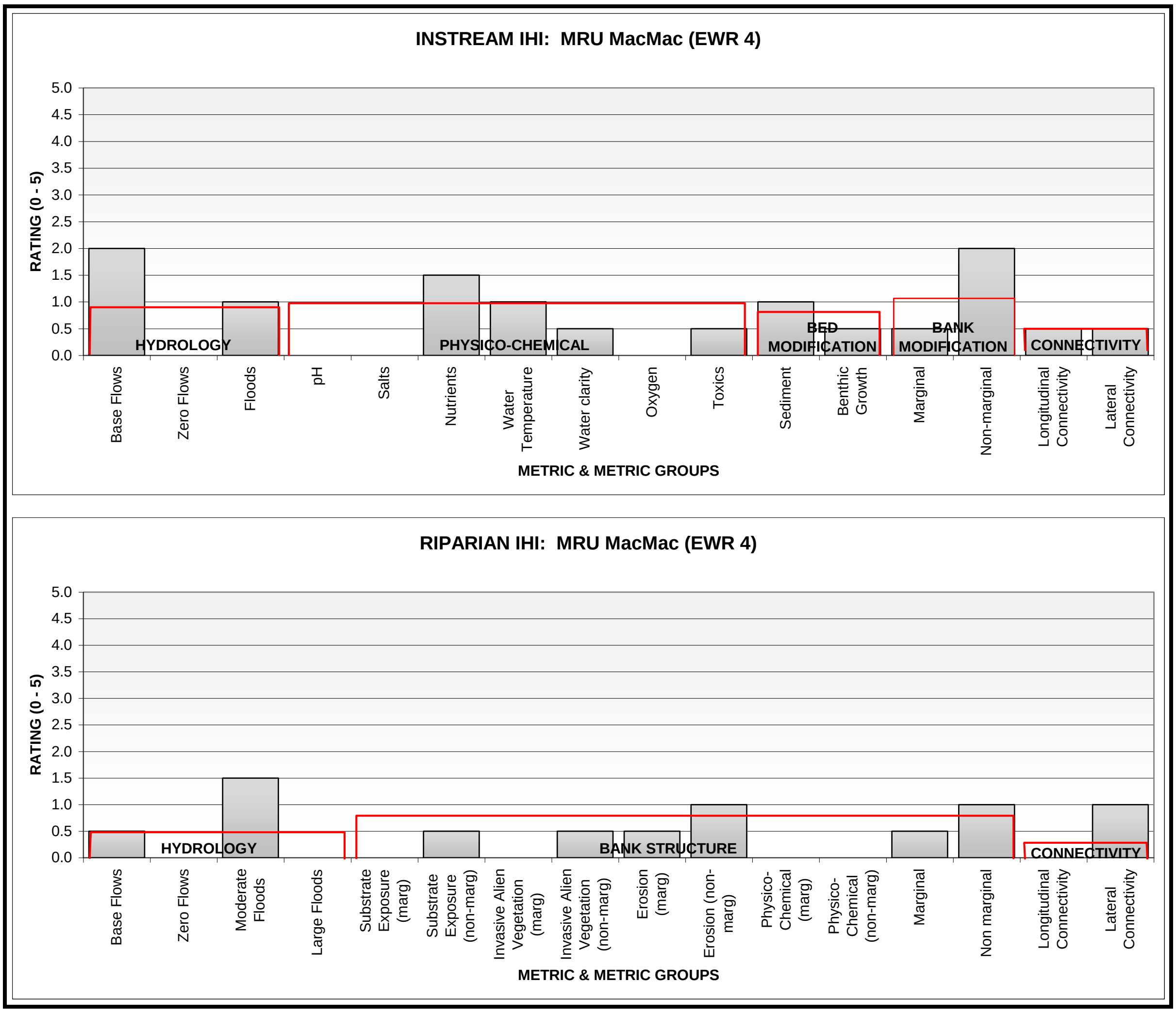

Figure B14 MRU MacMac: Instream and Riparian IHI

Table B12 Summary of the causes and sources for the change in reference condition for MRU MacMac

PES	Causes	Sources	F/NF	Conf
INSTREAM				
B	Decrease in base flows.	Forestry.	F	3.5
	Nutrients increase.	Forestry, Graskop sewage.	NF	
	Non-marginal bank modification.	Forestry.		
RIPARIAN				
A/B	Moderate floods decrease.	Forestry	NF	3.2
	Erosion (bank structure modification).			

B3.5 MRU MARITE: EWR 5

The Instream and Riparian IHI results are illustrated in Figure B15 and summarised in Table B13.

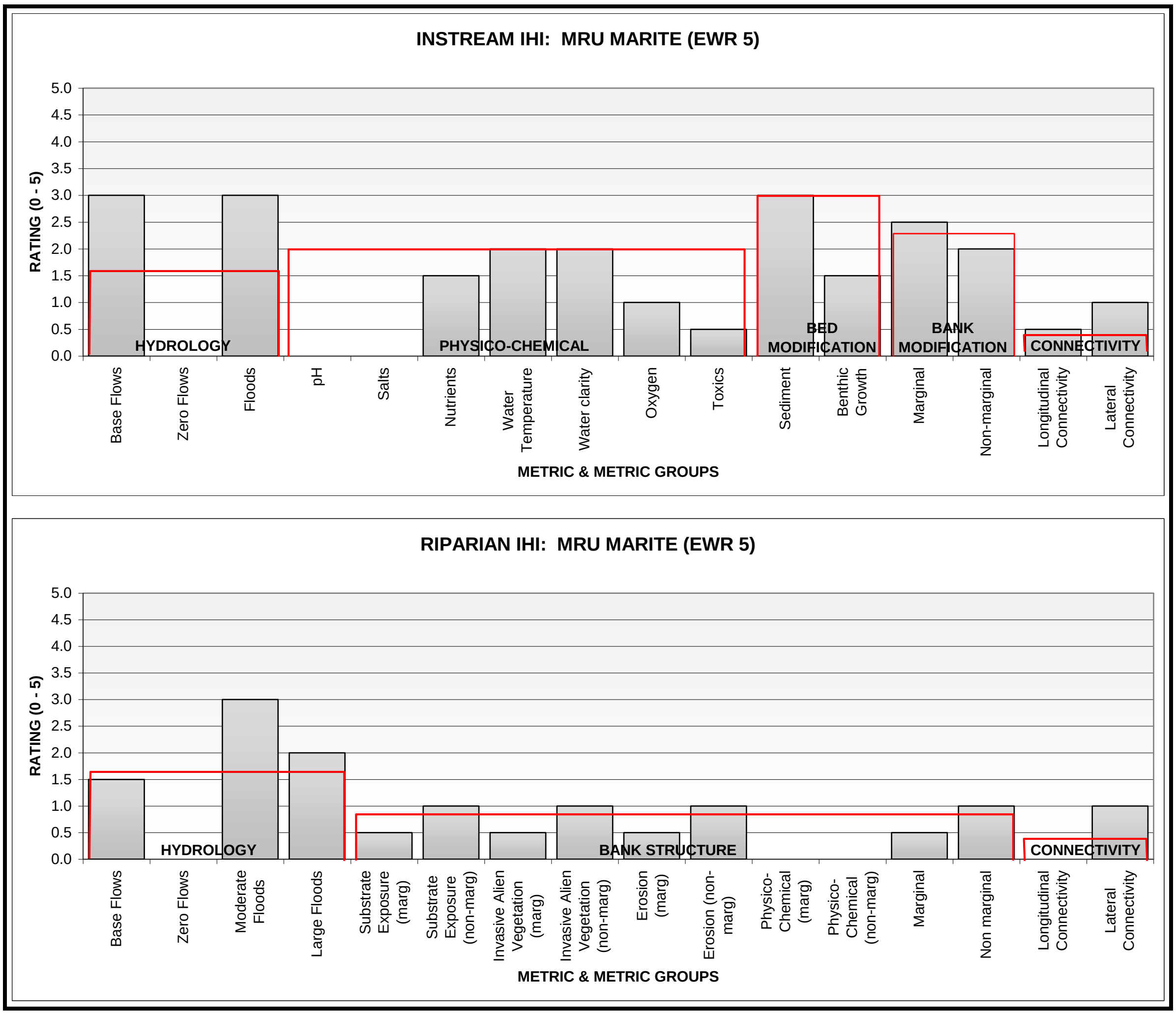

Figure B15 MRU Marite: Instream and Riparian IHI

Table B13 Summary of the causes and sources for the change in reference condition for MRU Marite

PES	Causes	Sources	F/NF	Conf
INSTREAM				
C	Increase in base flows at some stages.	Releases down river from Inyaka Dam.	F	3
	Decrease in floods.	Inyaka Dam.		
	Water temperature and clarity.	Inyaka Dam and releases.		
	Sedimentation.	Inyaka Dam.		
	Bank modification, marginal and non-marginal. Changes in floods.	Veg structure changes - Inyaka Dam.		
RIPARIAN				
B/C	Decrease in floods.	Inyaka Dam.	F	3.2
	Vegetation removal and subsistence agriculture, housing.	Land use.	NF	

B3.6 MRU MUTLUMUVI: EWR 6

The Instream and Riparian IHI results are illustrated in Figure B16 and summarised in Table B14.

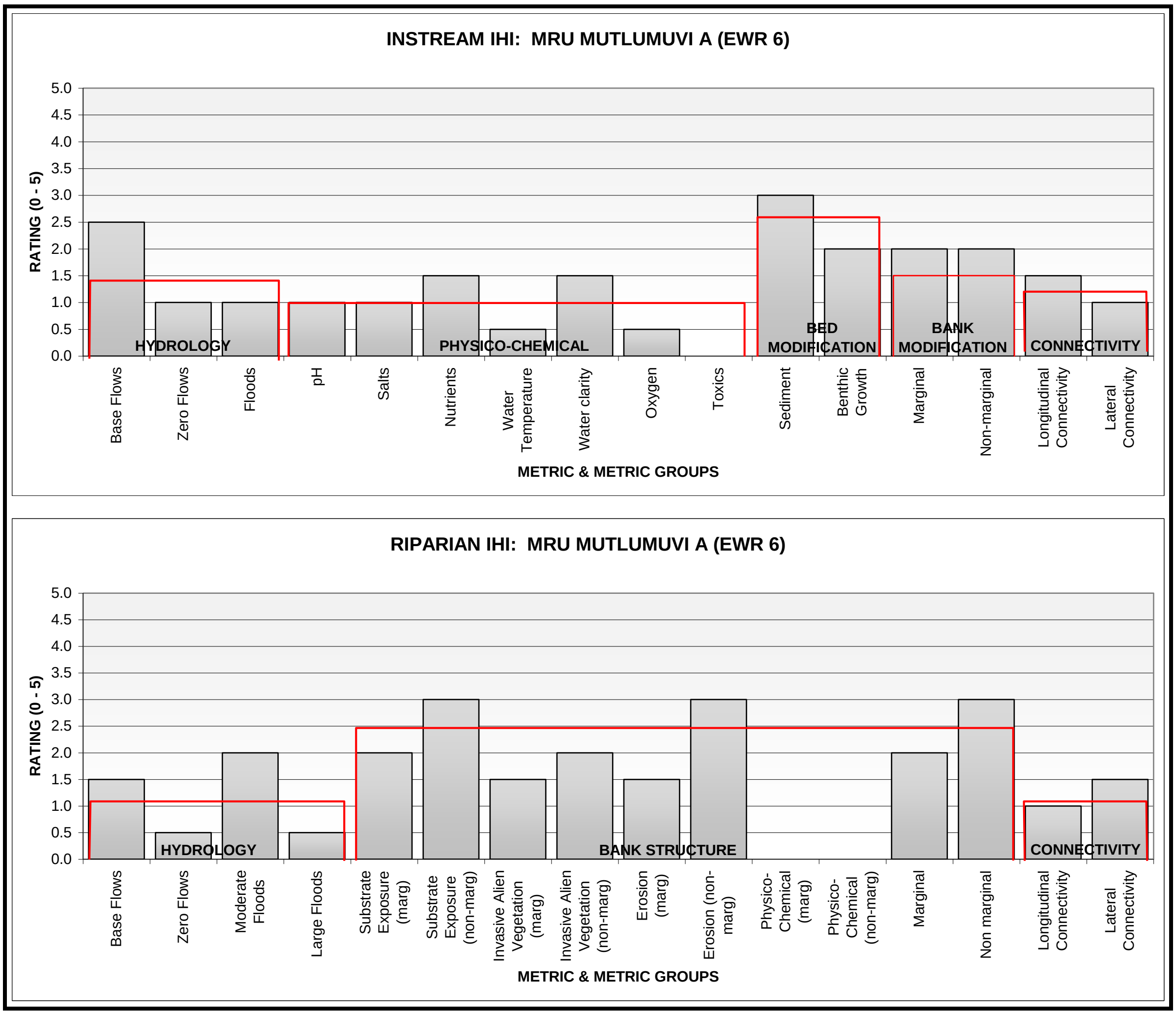

Figure B16 MRU Mutlumuvi: Instream and Riparian IHI

Table B14 Summary of the causes and sources for the change in reference condition for EWR 6

PES	Causes	Sources	F/NF	Conf
INSTREAM				
C	Decrease in low flows.	Abstraction.	F	2.7
	Bed modification.	Land use (over grazing, trampling, veg removal etc).	NF	
	Bank modification.	See above.		
RIPARIAN				
C	Substrate exposure and erosion in the non-marginal zone.	Land use (over grazing, trampling, veg removal etc).	NF	3

B3.7 MRU TLULANDIZEKA A: EWR 7

The Instream and Riparian IHI results are illustrated in Figure B17 and summarised in Table B15.

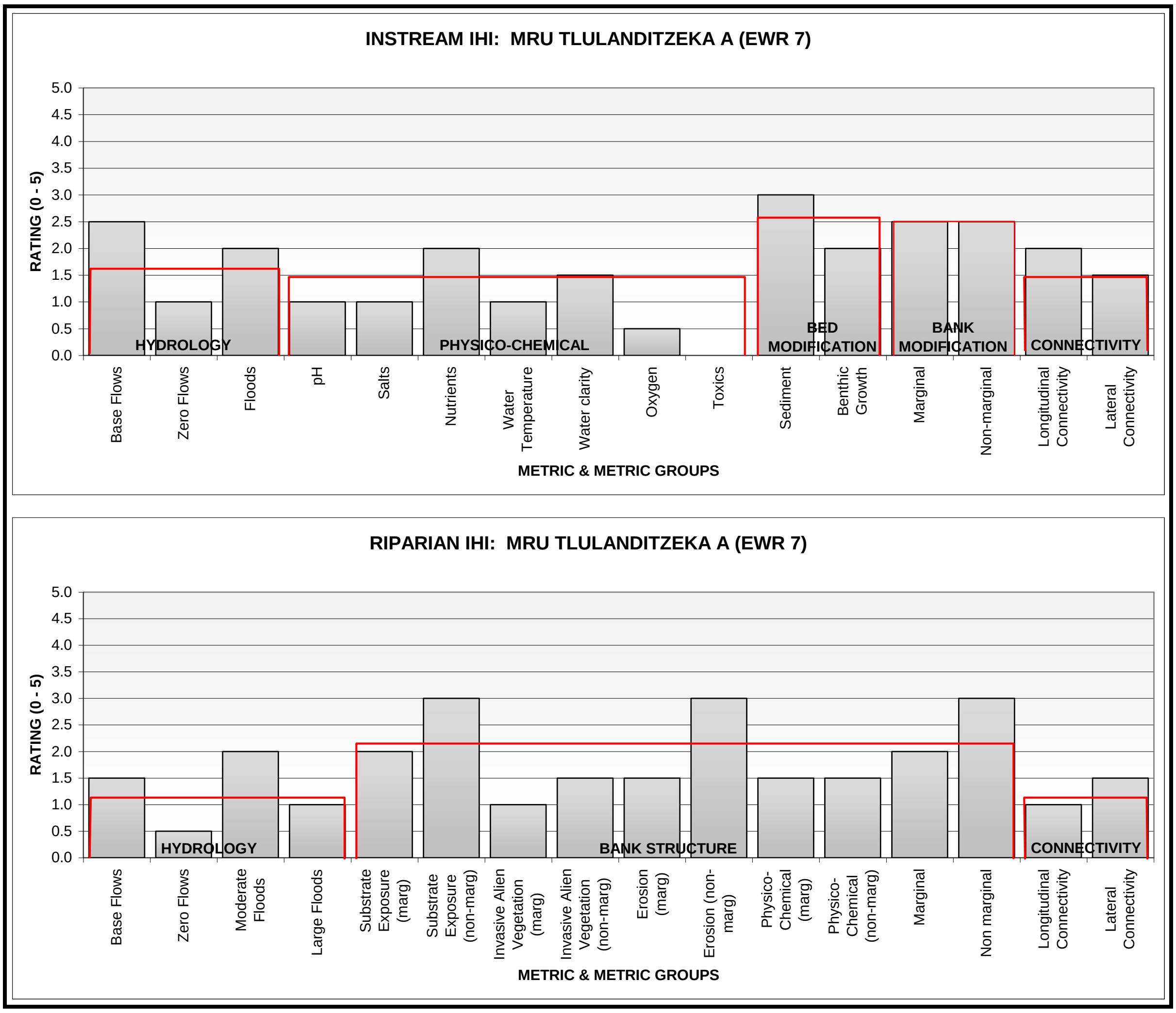

Figure B17 MRU Tlulandizeka A: Instream and Riparian IHI

Table B15 Summary of the causes and sources for the change in reference condition for MRU Thulandizeka A (EWR 7)

PES	Causes	Sources	F/NF	Conf
INSTREAM				
C/D	Decrease in low flows.	Abstraction.	F	2.7
	Bed modification.	Land use (over grazing, trampling, veg removal etc.).	NF	
	Bank modification.	See above.		
	Nutrients.	Peri-urban land use.		
RIPARIAN				
C	Substrate exposure and erosion in the non - marginal zone.	Land use (over grazing, trampling, veg removal etc.).	NF	3.2

B3.8 MRU SAND RAU B.1: EWR 8

The Instream and Riparian IHI results are illustrated in Figure B18 and summarised in Table B16.

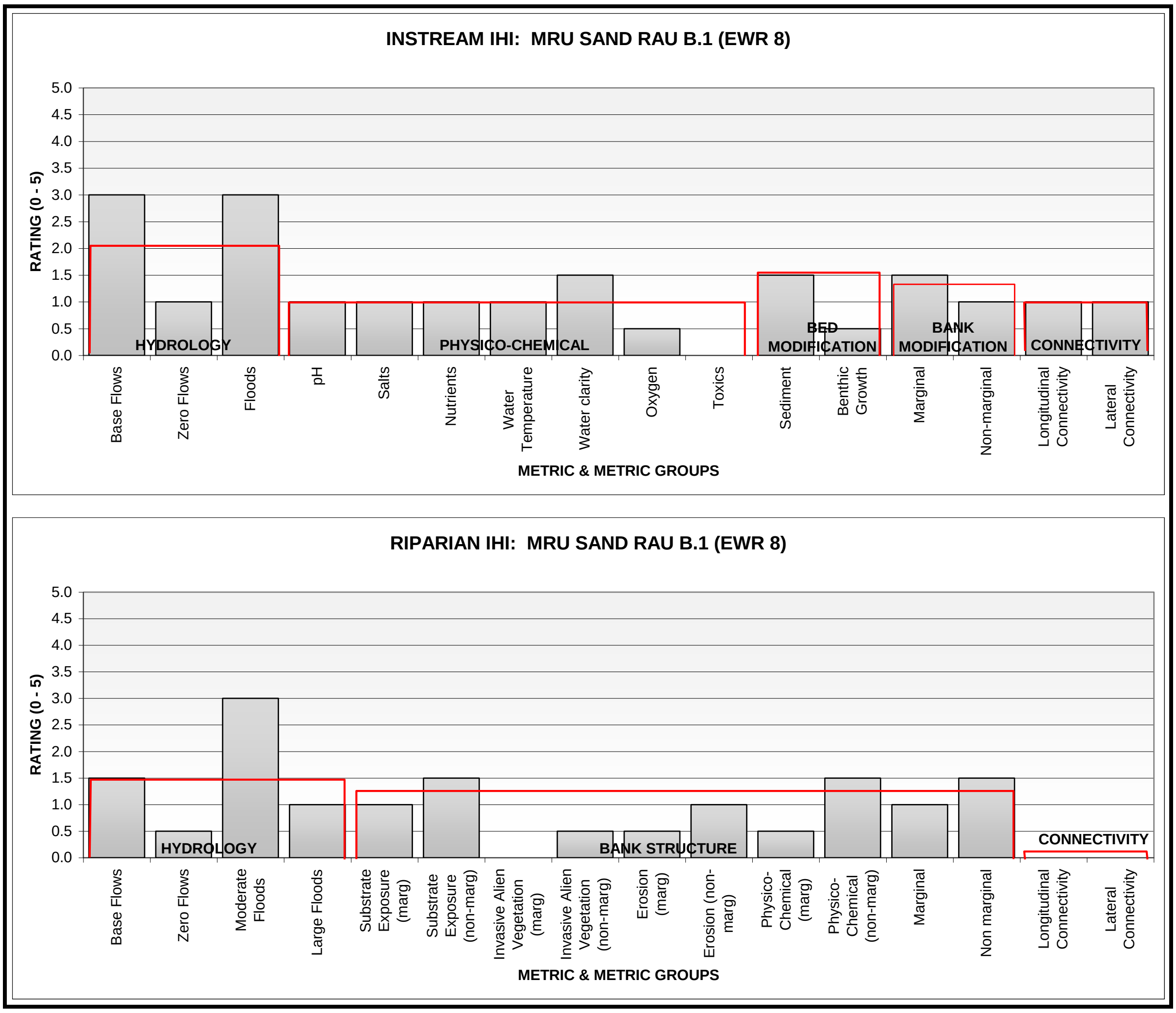

Figure B18 MRU Sand RAU B.1: Instream and Riparian IHI

Table B16 Summary of the causes and sources for the change in reference condition for MRU Sand RAU B.1

PES	Causes	Sources	F/NF	Conf
INSTREAM				
C	Decrease in flows.	Abstraction.	F	2.9
RIPARIAN				
B/C	Decrease in moderate floods.	Abstraction, weirs, small dams.	F	2.8

B3.9 SABIE – SAND INSTREAM IHI SUMMARY

The results are compared in the following tables and graphics.

Table B17 Ratings for the each MRU and EWR site –Sabie - Sand system

	MRU	MRU	MRU	MRU	MRU	MRU	MRU	MRU
INSTREAM IHI	Sabie A (EWR 1)	Sabie RAU A.2 (EWR 2)	Sabie RAU B.1 (EWR 3)	MacMac (EWR 4)	Marite (EWR 5)	Multumuvi A (EWR 6)	Upper Sand A (EWR 7)	Sand RUA B.1 (EWR 8)
Base Flows	-1.5	-2.5	-1.5	-2.0	-3.0	-2.5	-2.5	3.0
Zero Flows	0.0	0.0	0.0	0.0	0.0	-1.0	-1.0	1.0
Floods	-1.0	-1.0	-1.5	-1.0	-3.0	-1.0	-2.0	-3.0
HYDROLOGY RATING	**0.7**	**1.0**	**0.8**	**0.8**	**1.6**	**1.4**	**1.7**	**2.1**
pH	0.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0
Salts	0.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0
Nutrients	2.0	1.5	1.0	1.5	1.5	1.5	2.0	1.0
Water Temperature	0.0	0.5	0.0	1.0	2.0	0.5	1.0	1.0
Water clarity	0.5	1.0	1.5	0.5	2.0	1.5	1.5	1.5
Oxygen	0.0	0.5	0.0	0.0	1.0	0.5	0.5	0.5
Toxics	0.5	0.5	0.5	0.5	0.5			
PC RATING	**1.0**	**1.0**	**0.5**	**1.0**	**2.0**	**1.0**	**1.5**	**1.0**
Sediment	1.5	2.0	1.5	1.0	3.0	3.0	3.0	1.5
Benthic Growth	1.5	1.0	1.0	0.5	1.5	2.0	2.0	0.5
BED RATING	**1.5**	**1.7**	**1.3**	**0.8**	**2.5**	**2.6**	**2.6**	**1.1**
Marginal	1.0	1.0	0.5	0.5	2.5	2.0	2.5	1.5
Non-marginal	2.0	2.5	1.0	2.0	2.0	2.0	2.5	1.0
BANK RATING	**1.4**	**1.6**	**0.7**	**1.1**	**2.3**	**2.0**	**2.5**	**1.3**
Longitudinal Connectivity	0.0	0.5	0.5	0.5	0.5	1.5	2.0	1.0
Lateral Connectivity	1.0	1.5	0.5	0.5	1.0	1.0	1.5	1.0
CONNECTIVITY RATING	**0.2**	**0.7**	**0.5**	**0.5**	**0.6**	**1.3**	**2.0**	**1.0**
INSTREAM IHI %	**81.5**	**76.9**	**84.4**	**83.2**	**64.1**	**67.4**	**60.5**	**73.0**
INSTREAM IHI EC	**B/C**	**C**	**B**	**B**	**C**	**C**	**C/D**	**C**
INSTREAM CONFIDENCE	**3.3**	**2.9**	**3.1**	**3.5**	**3.3**	**2.7**	**2.7**	**2.9**

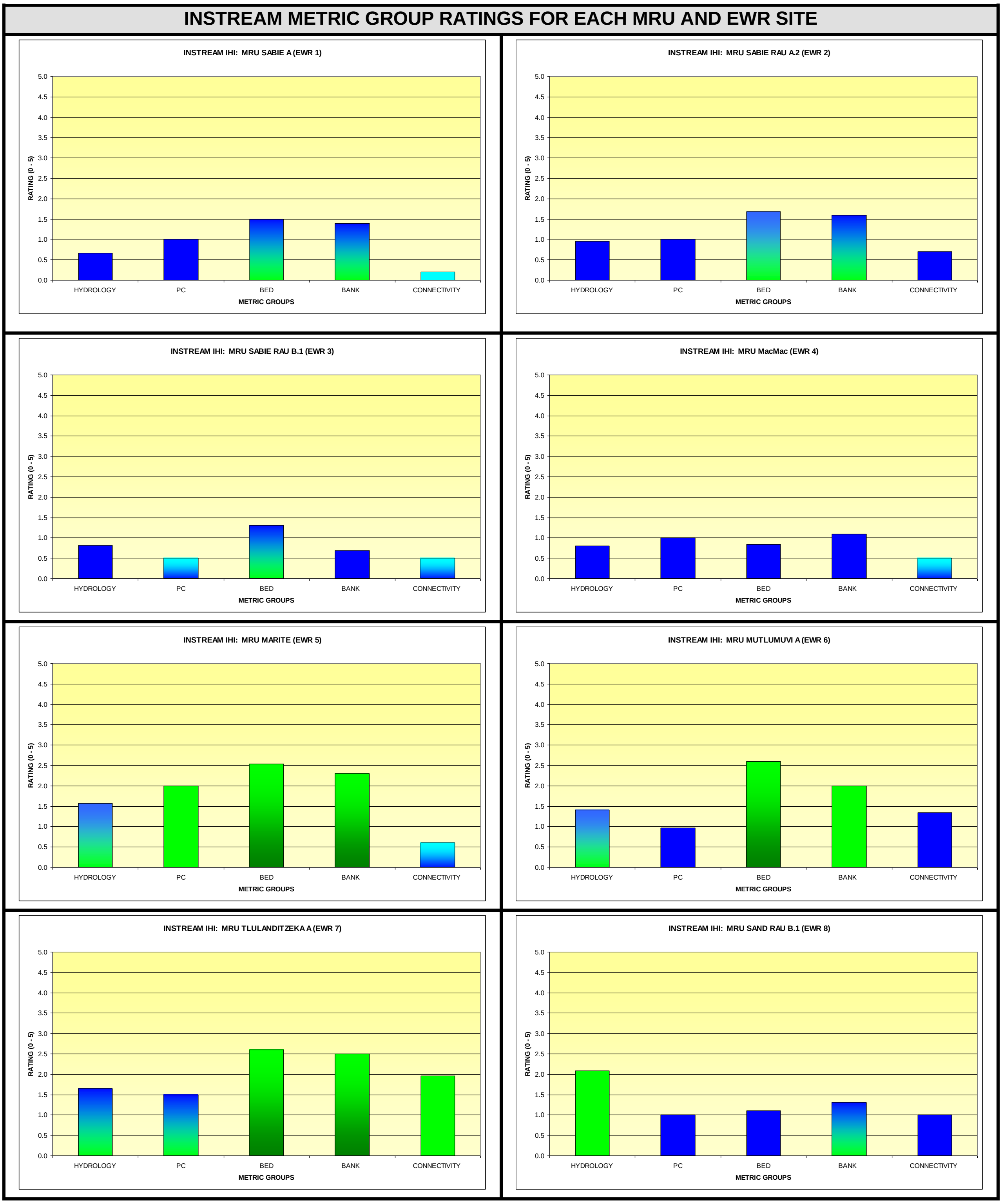

Figure B19 Instream Metric group ratings for each MRU and EWR site – Sabie – Sand system

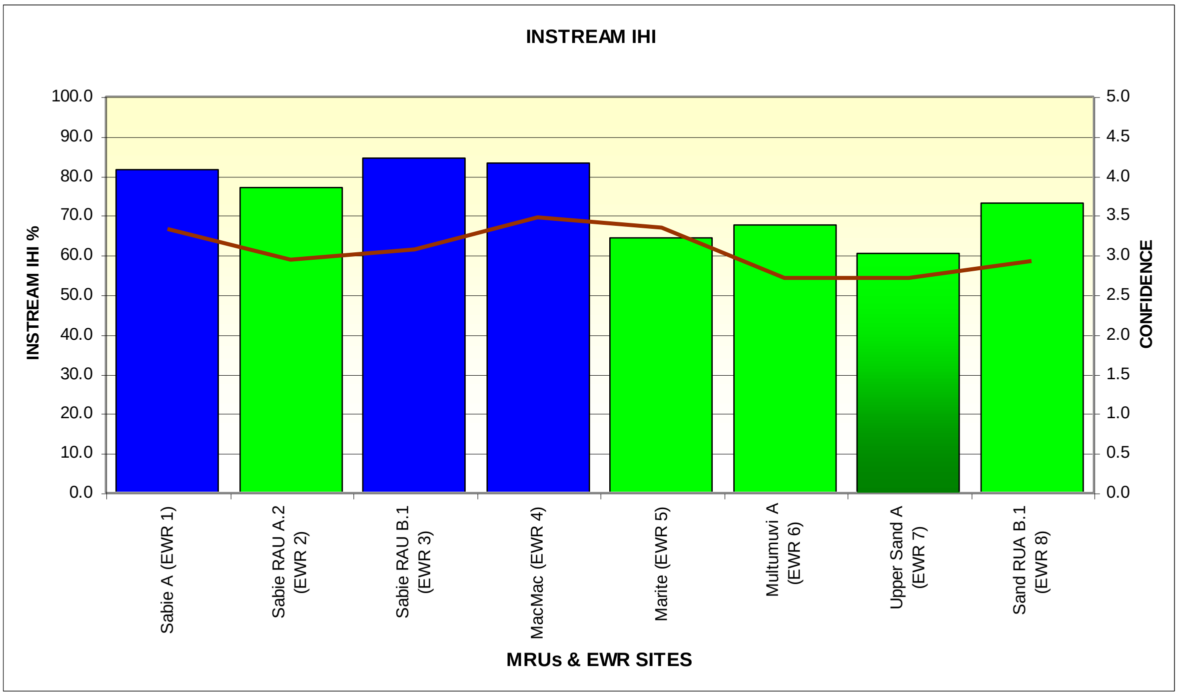

Figure B20 Summary of IHI Instream categories – Sabie – Sand system

B3.10 SABIE - SAND RIPARIAN IHI SUMMARY

The results are compared in the following tables and graphics.

Table B18 Ratings for the each MRU and EWR site –Sabie - Sand system

	MRU	MRU	MRU	MRU	MRU	MRU	MRU	MRU
RIPARIAN IHI	Sabie A (EWR 1)	Sabie RAU A.2 (EWR 2)	Sabie RAU B.1 (EWR 3)	MacMac (EWR 4)	Marite (EWR 5)	Multumuvi A (EWR 6)	Upper Sand A (EWR 7)	Sand RUA B.1 (EWR 8)
Base Flows	-0.5	-1.0	1.0	-0.5	1.5	-1.5	-1.5	1.5
Zero Flows	0.0	0.0	0.0	0.0	0.0	-0.5	-0.5	0.5
Moderate Floods	-1.5	-2.0	-2.0	-1.5	-3.0	-2.0	-2.0	-3.0
Large Floods	0.0	0.0	-1.0	0.0	-2.0	-0.5	-1.0	-1.0
HYDROLOGY RATING	**0.5**	**0.7**	**1.0**	**0.5**	**1.6**	**1.1**	**1.2**	**1.5**
Substrate Exposure (marg)	0.0	1.0	0.0	0.0	0.5	2.0	2.0	1.0
Substrate Exposure (non-marg)	1.0	2.5	1.0	0.5	1.0	3.0	3.0	1.5
Invasive Alien Vegetation (marg)	1.0	1.5	0.5	0.0	0.5	1.5	1.0	0.0
Invasive Alien Vegetation (non-marg)	2.0	2.0	0.5	0.5	1.0	2.0	1.5	0.5
Erosion (marg)	0.5	0.5	0.5	0.5	0.5	1.5	1.5	0.5
Erosion (non-marg)	2.0	2.0	1.0	1.0	1.0	3.0	3.0	1.0
Physico-Chemical (marg)	0.0	0.5	0.5	0.0	0.0	0.0	1.5	0.5
Physico-Chemical (non-marg)	0.0	0.0	0.0	0.0	0.0	0.0	1.5	1.5
Marginal	1.0	1.5	0.5	0.5	0.5	2.0	2.0	1.0
Non marginal	2.0	2.5	1.0	1.0	1.0	3.0	3.0	1.5
BANK STRUCTURE RATING	**1.4**	**1.9**	**0.8**	**0.7**	**0.8**	**2.5**	**2.2**	**1.3**
Longitudinal Connectivity	-1.0	0.0	0.0	0.0	0.0	-1.0	-1.0	0.0
Lateral Connectivity	-1.0	-1.0	-1.0	-1.0	-1.0	-1.5	-1.5	0.0
CONNECTIVITY RATING	**1.0**	**0.3**	**0.4**	**0.3**	**0.4**	**1.2**	**1.2**	**0.0**
RIPARIAN IHI %	**80.1**	**77.2**	**85.0**	**89.3**	**80.8**	**65.3**	**67.3**	**79.1**
RIPARIAN IHI EC	**B/C**	**C**	**B**	**A/B**	**B/C**	**C**	**C**	**B/C**
RIPARIAN CONFIDENCE	**3.1**	**3.2**	**3.2**	**3.2**	**3.2**	**3.0**	**3.0**	**2.8**

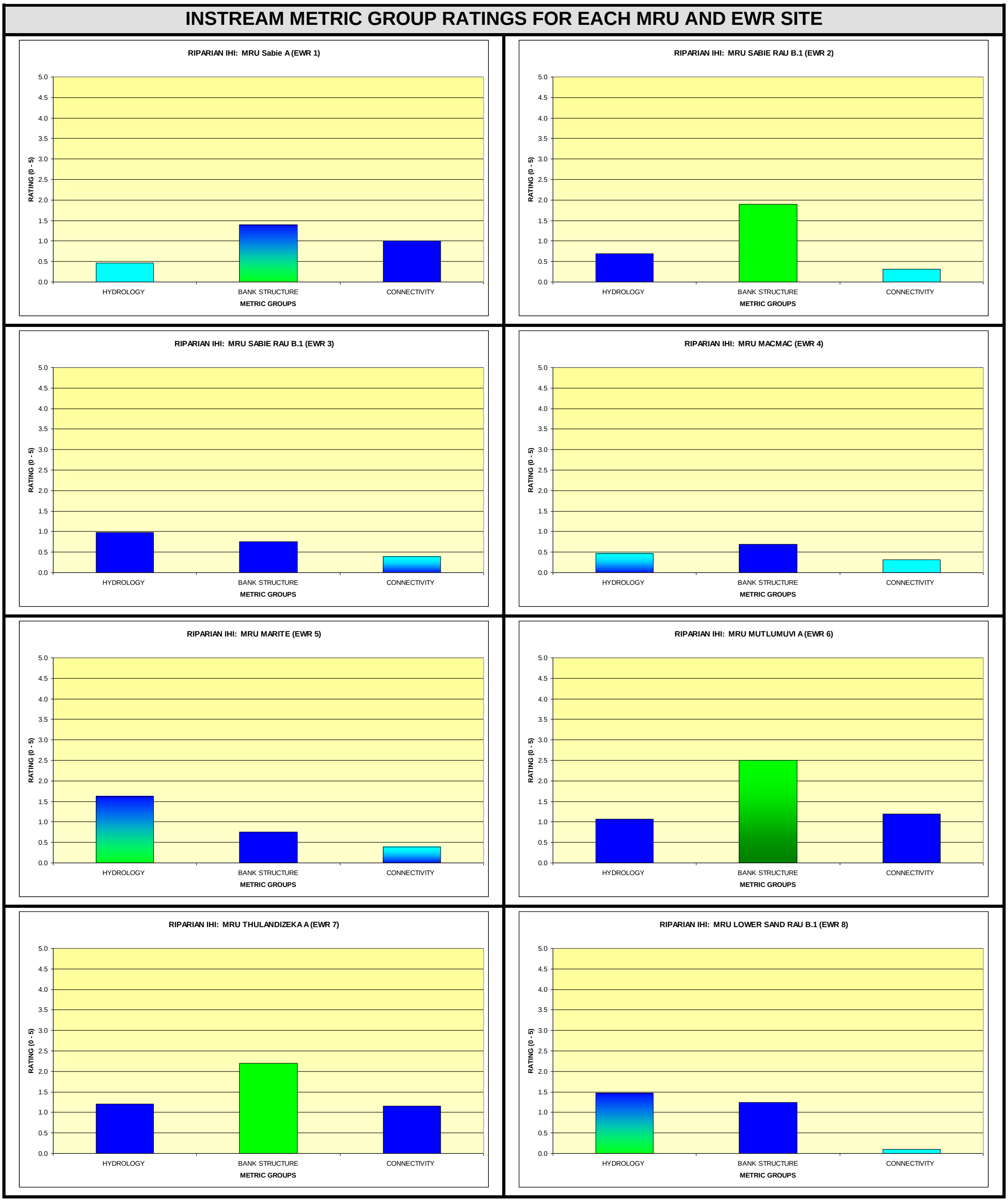

Figure B21 Riparian Metric group ratings for each MRU and EWR site – Sabie – Sand system

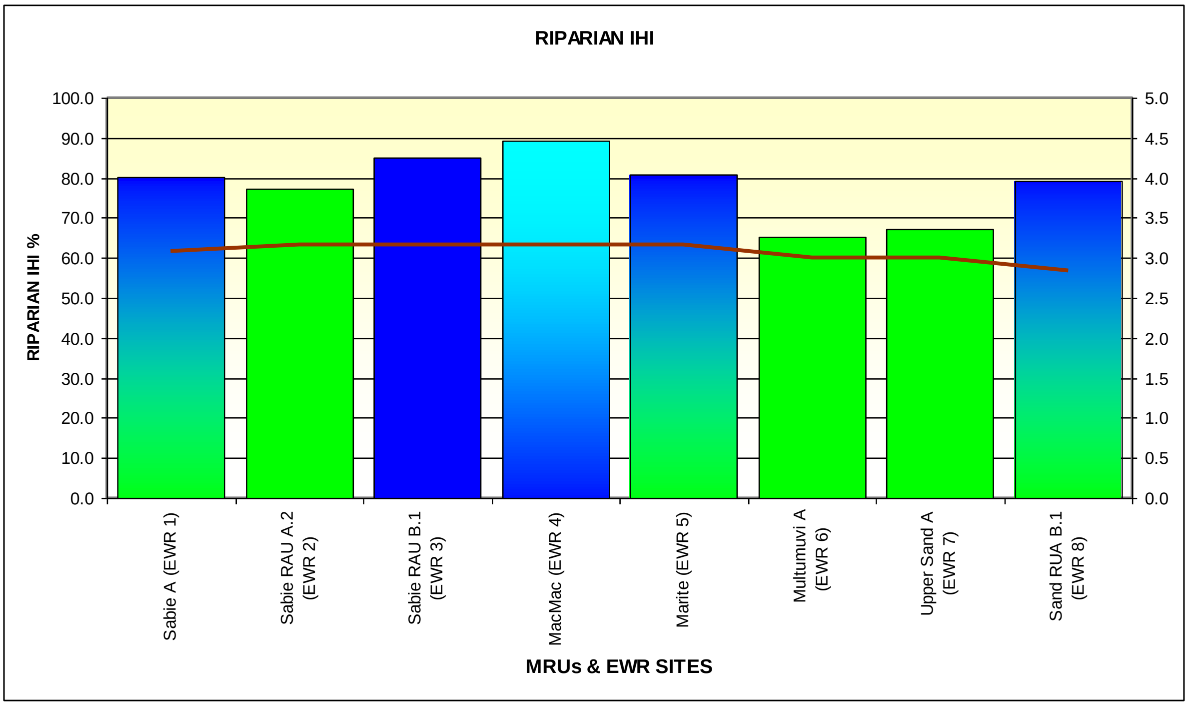

Figure B22 Summary of IHI Riparian categories – Sabie – Sand system

B4 REFERENCES

Kleynhans, C.J., Louw, M.D., and Graham, M. 2008. Module G: EcoClassification and EcoStatus determination in River EcoClassification: Index of Habitat Integrity (Section 1, Technical manual) Joint Water Research Commission and Department of Water Affairs and Forestry report. WRC Report No. TT 377-08.

APPENDIX D: PHYSICO-CHEMICAL VARIABLES

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C1 INTRODUCTION

C1.1 CATCHMENT CONTEXT

The Internal Strategic Perspective (ISP) produced for the Inkomati Water Management Area (WMA) (DWAF, 2004a), concluded that the quality of the water in the Crocodile/Sabie sub-area (Figure C1) is currently good, but is threatened by a number of activities, e.g. mining activities. Land-use in the Inkomati WMA mainly consists of urban and semi-urban populations, with associated activities. A large number of rural settlements exist in the Mhala, Mapulanneng, Nsikazi, Nkomati and Mswati regions. Important urban centres in the WMA are Nelspruit, White River, Komatipoort, Carolina, Badplaas, Barberton, Sabie, Bushbuckridge, KaNyamazane and Matsulu. Although future growth in the population is expected to be moderate and to be concentrated in the urban areas, with a decline in some rural areas (DWAF, 2004a), this growth will result in deteriorating water quality conditions if not associated with adequate sanitation facilities properly managed.

C1.1.1 Crocodile River sub-area

The Crocodile River catchment is dominated by irrigation and forestry, with it being one of the most densely forested catchments in the country. There is an estimated 42 300 ha of irrigation in the catchment and an estimated 1 775 km^2 of exotic forests (DWAF, 2004a). These two activities are also the major users of water in the catchments. Industrial water use in the catchment is limited and consists mostly of the Sappi paper mill at Ngodwana and the sugar mills at Malelane and Komatipoort. The water requirements of the Ngodwana paper mill are supplied from the Ngodwana Dam, which is situated in the Elands catchment, while the water requirements of the Malelane sugar mill are abstracted from the Crocodile River. A large number of manufacturing activities are situated in and around Nelspruit and industrial development is expanding rapidly. Development opportunities have been identified especially in the steel, chemicals, food, wood products, paper and pulp industries. Activities in the area have lead to a number of research projects, particularly focusing on the impacts of the Ngodwana paper mill on the aquatic ecosystem, and on the rivers of the Kruger National Park. The urban requirements of the Crocodile sub-area are also mostly supplied from direct abstractions from the Crocodile River.

The catchments are not well developed from a water resources point of view, with only one major dam, the Kwena Dam, in the upper catchment. There are a number of smaller dams (e.g. Witklip, Ngodwana, Klipkoppie and Longmere dams) in the central portion of the catchment, with two additional dam options (i.e. Mountain View Dam on the Kaap River and Montrose Dam at the confluence of the Elands and Crocodile rivers) are being considered. The water requirements exceed the available resource, and the catchment is considered to be highly stressed, particularly considering the sub-area's potential for economic growth (DWAF, 2004a). Management will have to be effective to achieve the potential of this area (e.g. the removal of invasive alien parts in the catchment), while still meeting the allocations for Ecological Water Requirements (EWR) and international treaties (i.e. the IncoMaputo Water Use agreement).

The water resources in the area are derived mostly from run-of-river flows but are augmented by the Kwena Dam which supplements the run-of-river abstractions during periods of low flow. Smaller dams in the area contribute significantly to the yield (DWAF, 2004a).

The overall ecological status of the Crocodile River in this ecoregions is Good to Fair, with most of the impacts occurring in the riparian zone (River Health Programme, 2001). According to the 2004 ISP, the water quality in the Crocodile sub-area is generally good although some deterioration of the quality in the lower Kaap River (often high levels of arsenic) and lower Crocodile River is observed. This is due to return flows from upstream users including irrigation, urban areas and old gold mining activities. Irrigation return seepage is noticeable during periods of low flow. The potential water quality problems emanating from the SAPPI paper mill at Ngodwana is probably the most serious water quality problem in the catchments. Effluent has been disposed of through irrigation for a number of years but the soil has become saturated with salts (especially chlorine) and these leach out into the Elands River and then enter the Crocodile River (DWAF, 2004a).

C1.1.2 Sabie River sub-area

The Sabie River sub-catchment is dominated by irrigation and forestry, although urban, peri-urban and rural requirements and activities are becoming increasingly significant. The Kruger National Park is positioned at the lower end of the catchment before the river flows into Mozambique.

The surface water quality in the Sabie River sub-catchment is generally Good with no immediate threats (DWAF, 2004a), although polluted water entering the Kruger National Park is a major concern. Return flows in the Sabie sub-catchment are limited, and are derived primarily from irrigation.

Water use along this river system is diverse. The Sabie River within the KNP has previously been described as the most pristine system within South Africa with much of its 110 km remaining free from any direct alteration (Moon *et al*., 1997). However, it was only in the 1940's that action was taken by the Mining Department against pollution and the river recovered to become the most biologically diverse in South Africa, due to recolonisation from the tributaries which were unaffected by gold mining (Pienaar, 1985).

A variety of different activities affects and takes place along this river system. The upper catchment area has already been exploited as far as possible due to commercial forestry plantations of exotic tree species, especially *Pinus* and *Eucalyptus* species. In 1990 more than 71 100 ha (16%) of the total catchment area was afforested, whilst 11 300 ha (1.8%) consisted of irrigated crops. The principal crops grown particularly in the lower catchment are bananas, avocados, citrus, paw paws and vegetables (Chunnett, Fourie and Partners, 1990).

Water quality monitoring for the past ten years has shown that the waters are suitable for irrigation, livestock watering and domestic consumption (Weeks *et al*., 1996). An analysis by Van Veelen (1991) concluded that the Sabie River is the least mineralized of the rivers in the KNP. It was also found that the pH was below 7.0 for a considerable part of the year thus causing the system to be poorly buffered. These facts coupled together with observed low Total Dissolved Solids (TDS) concentrations make this a stable but sensitive system, should changes occur in the catchment area.

C1.1.3 Sand River sub-area

The water resources of the Sand River sub-catchment are limited to the run-of-river yield and the yield of the few farm dams in the catchment. The rainfall in the Sand River sub-catchment is lower than in the Sabie River sub-catchment and the runoff, even under natural conditions, is low by comparison (DWAF, 2004a).

The major water requirements in the Sand River sub-catchment are the irrigation and urban sectors, making up an estimated 44% and 36% of the total water requirement in this sub-catchment respectively. The afforested area in the Sand River sub-catchment is estimated to be 75 km^2, while the irrigation requirements are based on an irrigated area of 26 km^2 (DWAF, 2004a).

Irrigation is the largest user of water in the Sand River sub-catchments. Irrigators mostly access the water in the catchment as run-of-river, diverting it via small weirs into canals. A few significant farm dams, such as the Edinburgh, Champagne and Orinoco dams add to the yield of the system. The main irrigation schemes are the Dingleydale/New Forest scheme, the Champagne Citrus Estate and Allandale Citrus.

The surface water quality in the Sand River sub-catchment is not as good as in the Sabie River sub-catchment due to over-abstraction which reduces the natural assimilative capacity of the river. Occasional elevated levels of nutrients in the Sand River are noted, with informal housing developments a suspected cause. The large number of rural settlements which rely on pit latrines is cause for concern as far as ground-water pollution goes but to date there have been no reported incidences of groundwater pollution (DWAF, 2004a). The Sand River sub-catchment is a relatively dry catchment with limited water resources but a large semi-urban population. The water requirements in the catchment are mostly for domestic use and irrigation. The water resources of the catchment are not sufficient to meet the requirements, even without taking the ecological Reserve into account, and irrigators in this catchment have experienced serious deficits in the past. With the support that is now available from the Inyaka Dam, this catchment is now theoretically in balance, with shortages being supplied from the Inyaka Dam. In practice however, the transfer capacity is currently insufficient and the distribution of the transferred water inadequate. A lot of infrastructure development is therefore still required to relieve water shortages in this catchment.

There is a limited amount of afforestation in the catchment (75 km^2, with afforestation being converted back to natural vegetation for conservation, which should have a positive impact on the riverine environment through increased river flow. The Sand River is also crucial to the viability of some of the commercial wildlife ventures in the Sabi-Sand Reserve, which is the most downstream recipient of the Sand River (DWAF, 2004a).

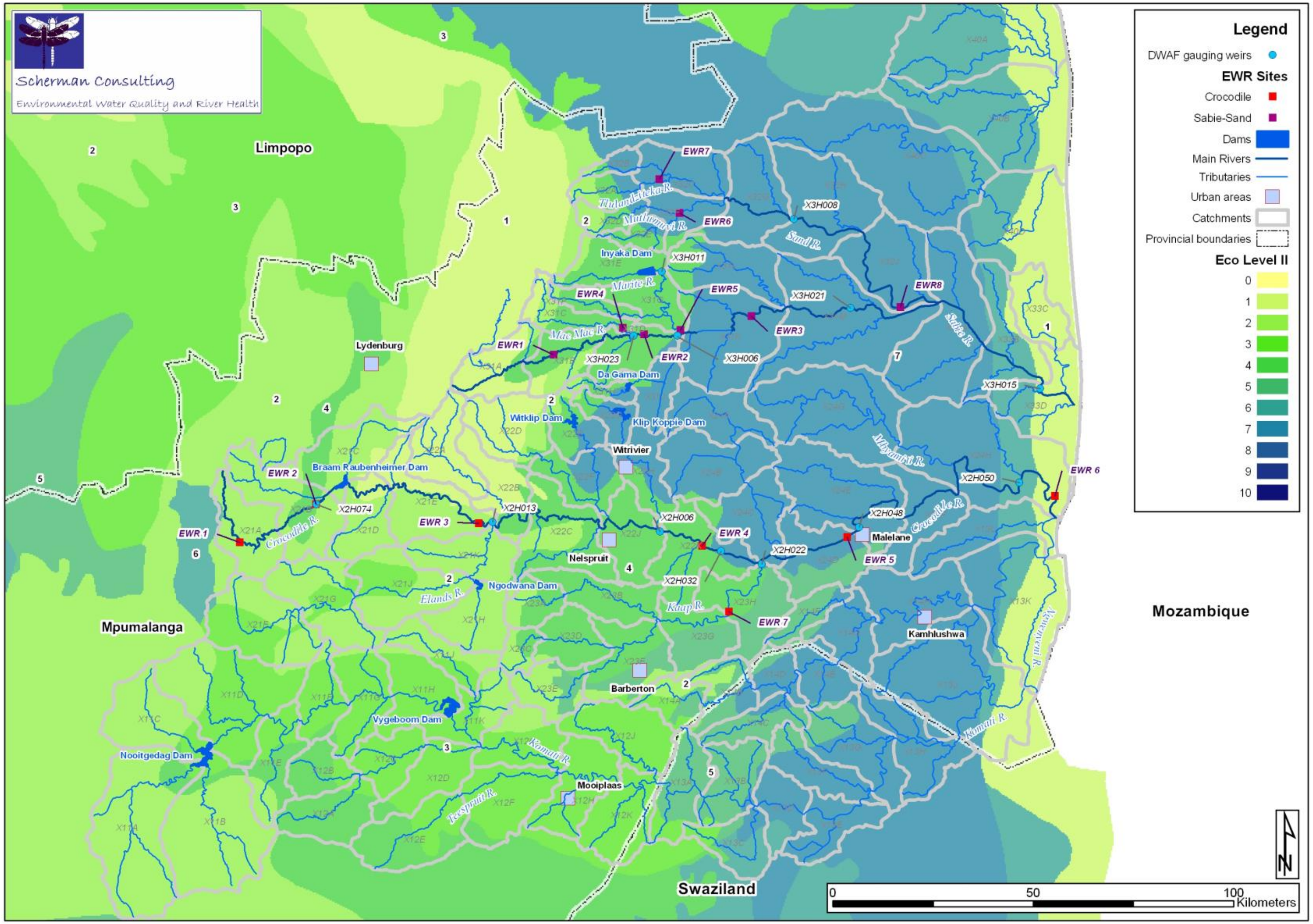

Figure C1 Locality map showing the position of the EWR sites, additional water quality sites and gauging weirs

C2 METHODS AND APPROACH

C2.1 DATA SELECTION

Gauging weirs available in the study area are shown in the Tables C1 to C3 below; data record refers to either hydrological or water quality data records. Data was evaluated and the data suitable for the study selected and shown in Table C4 per EWR site. The position of gauging weirs is shown in Figure C1.

Table C1 Inkomati gauging weirs: Crocodile River system

Station	Place	Latitude	Longitude	Data record
X2H003	Krokodil River @ Broedersvrede	25 29 17.1	31 09 29.2	
X2H004	Krokodil River @ Nelspruit	25 27 02.2	30 57 52.2	1923-10-09 to 1928-12-31
X2H006	Krokodil River @ Karino	25 28 11.2	31 05 17.3	1929-10-02 to 2007-05-17
X2H013	Krokodil River @ Montrose	25 26 55.1	30 42 42.4	1959-01-21 to 2007-07-13
X2H016	Krokodil River @ Tenbosch	25 21 49.9	31 57 20.6	1960-08-24 to 2007-05-23
X2H017	Krokodil River @ Kruger National Park	25 26 18.2	31 38 04.3	1959-08-28 to 1998-09-01
X2H032	Krokodil River @ Weltevrede	25 30 51.1	31 13 28.3	1968-09-15 to 2007-07-16
X2H033	Krokodil River @ Sterkdoorn	25 22 38.2	30 26 46.2	1970-07-06 to 1992-05-15
X2H048	Krokodil River @ Kruger National Park	25 27 37.2	31 32 07.3	
X2H049	Krokodil River @ Kruger National Park	25 20 02.2	31 48 52.3	
X2H050	Krokodil River @ Kruger National Park	25 21 39.2	31 53 39.3	
X2H074	Krokodil River @ Goedehoop	25 24 32.2	30 18 59.1	
X2H075	Krokodil River @ Sterkspruit	25 26 32.2	30 53 14.2	
X2H076	Krokodil River @ Lions Club	25 27 47.1	30 59 54.2	
X2H077	Krokodil River @ Krokodilpoort	25 29 52.1	31 10 44.2	
X2H078	Krokodil River @ Kaapmuiden	25 32 17.1	31 18 39.3	
X2H091	Krokodil River@At Rivulet @ Barclays Vale	25 25 18.2	30 45 24.2	
X2H092	Krokodil River @ Boschrand	25 26 52.2	30 57 03.2	
X2H093	Krokodil River @ Boschrand	25 27 42.1	30 57 13.2	
X2H094	Krokodil River @ Friedenheim	25 27 23.2	31 00 47.2	
X2H095	Krokodil River @ Boschrand	25 27 41.1	30 57 54.2	
X2H096	Crocodile at Montrose	25 07 18.2	30 43 33.4	2004-09-15 to 2007-07-13
X2H097	Crocodile River at Esselen	25 29 52.3	31 28 33.9	

Table C2 Inkomati gauging weirs: Kaap River system

Station	Place	Latitude	Longitude	Data record
X2H007	Kaap River @ Dolton	25 32 30.1	31 18 59.3	1930-06-25 to 1947-12-01
X2H022	Kaap River @ Dolton	25 32 35.6	31 19 00.1	1960-08-31 to 2007-07-16
X2H024	Suidkaap River @ Glenthorpe	25 42 42.6	30 50 06.0	1964-09-25 to 2007-07-11
X2H031	Suidkaap River @ Bornmans Drift	25 43 48.9	30 58 42.2	1966-06-23 to 2007-07-11
X2H083	South Kaap River @ Dixie	25 42 54.1	31 03 26.2	
X2H084	South Kaap River @ Dixie	25 42 46.1	31 03 32.2	
X2H085	Kaap River @ Italian Farm	25 40 04.1	31 07 52.2	
X2H086	Kaap River @ Bon Accord	25 40 25.1	31 10 12.2	
X2H087	Kaap River @ Bon Accord	25 40 49.1	31 10 54.2	
X2H088	Kaap River @ Lovedale	25 38 57.1	31 14 32.2	
X2H089	Kaap River @ Caraceto (Tonetti)	25 34 49.1	31 18 24.3	
X2H080	North Kaap River @ Segalla	25 39 10.1	31 03 37.2	

Table C3 Inkomati gauging weirs: Sabie-Sand River system

Station	Place	Latitude	Longitude	Data record
X2H068	Sand River @ Witklip Forest Res.	25 14 16.2	30 53 58.2	1969-10-20 to 2007-07-11
X3H006	Sabie River @ Perry's Farm	25 01 50.3	31 07 35.2	1958-09-04 to 2000-01-19
X3H008	Sand River @ Exeter	24 46 12.1	31 23 19.0	1967-09-01 to 2007-03-27
X3H012	Sabie River @ Kruger National Park	25 01 07.3	31 14 59.3	
X3H013	Sabie River @ Kruger National Park	24 59 02.3	31 35 14.3	
X3H014	Sabie River @ Kruger National Park	24 57 20.3	31 43 01.3	
X3H015	Sabie River @ Lower Sabie Rest Camp	25 08 58.3	31 56 26.4	1986-12-09 to 2007-03-27
X3H021	Sabie River @ Kruger Gate	24 58 06.5	31 30 55.5	1990-11-15 to 2007-05-23

Table C4 Water quality data used for the EWR assessment

EWR site	Station	RC	PES	Frequency of monitoring
Sabie – Sand system				
EWR 1	X3H001Q01	n = 82 (1977 - 1979)	n = 42 (2004 - 2007)	Monthly
EWR 2	X3H006Q01	n = 149 (1976 - 1979)	n = 77 (2004 - 2007)	Bi - monthly
EWR 3	X3H006Q01: RC X3H013Q01: PES	X3H006Q01 n = 149 (1976 - 1979)	X3H013Q01 n = 39 (1991 - 1999)	Bi - monthly Bi - monthly
EWR 4, Mac Mac	X3H003Q01	n = 48 (1977 - 1979)	n = 56 (2004 - 2007)	Monthly
EWR 5, Marite	X3H011Q01	n = 84 (1979 - 1981)	n = 129 (2004 - 2007)	Weekly
EWR 6, Mutlumuvi	Extrapolated from EWR 8 and used on - site data.			
EWR 7, Tlulandziteka				
EWR 8, Sand	X3H008Q01	n = 50 (1977 - 1979)	n = 44 (2003 - 2006)	Monthly
Crocodile – Kaap system				
EWR 1	Extrapolated from EWR 2 and used on - site data			
EWR 2	X2H074Q01: PES only	Default benchmark tables	n = 9 (1992 - 1994)	Monthly, but intermittent
EWR 3	X2H013Q01	n = 170 (1977 - 1980)	n = 79 (2004 - 2007)	Bi - monthly
EWR 4	X2H032Q01	n = 88 (1977 - 1980)	n = 108 (2004 - 2007)	Weekly
EWR 5	X2H017Q01	n = 125 (1977 - 1980)	n = 114 (2004 - 2007)	Weekly
EWR 6	X2H016Q01	n = 163 (1977 - 1980)	n = 119 (2004 - 2007)	Weekly
EWR 7	X2H022Q01	n = 96 (1977 - 1981)	n = 174 (2004 - 2007)	Bi - monthly

C2.2 WATER QUALITY ASSESSMENT

C2.2.1 Methods

Standard methods were used for this assessment, as outlined in the following publications:

- Methods manual of 2002 (DWAF, 2002).
- Methods updated from the DWAF (2002) document, and previously housed on the Ninham Shand web - site (http://projects.shands.co.za/Hydro/hydro/WQReserve/main.htm) and based on a workshop held in Grahamstown in 2003.
- EcoClassification Manual, version 1 (Kleynhans *et al*., 2005), which includes the Physico - chemical driver Assessment Index (PAI) model, and instructions for the water quality assessment and completion of the PAI.
- TEACHA (Tool for Ecological Aquatic Chemical Habitat Assessment) programme version 1_32 and notes (prepared by S Jooste, DWAF: RQS) of April 2007.

- Palmer *et al*. (2004), which summarized available methods as at 2003/2004.
- Document by Palmer and colleagues on including Electrical Conductivity in Reserve assessments (DWAF, 2004b).

All methods (including the use of TEACHA as a data manipulation tool) are currently being compiled into a single document by Scherman Consulting (DWAF, *in press*.).

TEACHA is an instrument to support decision - making in the Reserve process, and is a data manipulation tool. The primary output is the recommended water quality component of the Ecological Reserve with corresponding ion data to use in the setting of resource quality objectives. The use of this software presupposes that information is available and reliable. It is not an expert system and requires the availability of expertise to check that the outcome is correct and scientifically valid. It also has strict data input requirements, e.g. all salt ions have to be input or the model will not run. TEACHA was used for this assessment where possible, with data extracted from DWAF's Water Management System (WMS). The alternative approach to using TEACHA for data manipulation is to use a standard statistical package, such as Excel or Statistica, to produce summary statistics (e.g. median, 5^{th} percentile, 95^{th} percentile). Results produced by either method is input into the PAI model as ratings of 0 - 5 per metric, i.e. pH, Dissolved Oxygen (DO), salts, turbidity, toxics and nutrients. The relationship between the ratings of 0 - 5 and ecological categories A - F are shown in Table C5 below. The rank and weighting input to the PAI model is provided by the ecologist, as this assessment is linked to the type of river being assessed and the reaction of the biota in this system.

Table C5 Relationship between categories and ratings (Kleynhans *et al*., 2005)

Rating	Deviation from reference conditions	A - F Categories
0	No change.	A
1	Small change.	B
2	Moderate change.	C
3	Large change.	D
4	Serious change.	E
5	Extreme change.	F

The following variables were used for the assessment of water quality, according to the required methods:

Inorganic salts

- Sodium chloride (NaCl)
- Sodium sulphate (Na_2SO_4)
- Magnesium chloride ($MgCl_2$)
- Magnesium sulphate ($MgSO_4$)
- Calcium chloride ($CaCl_2$)
- Calcium sulphate ($CaSO_4$)
- Electrical Conductivity – used as a surrogate for aggregated salts when all ionic data are not available and TEACHA could not be used.

Note that salt ionic data, i.e. Ca, Na, Mg, Cl, SO_4, is run through TEACHA to generate aggregated salts. TEACHA has strict data input requirements, e.g. all salt ionic data is needed to generate aggregated salts. This data is normally sourced from the DWAF water quality monitoring points and available on DWAF's Water Management System (WMS).

Nutrients

- Total inorganic nitrogen or TIN (i.e. the N portion of all nitrogen sources, e.g. NO_2+NO_3+NH_4 - N)
- Phosphate ($PO_4{}^{3-}$ - P)

Systems variables

- pH
- Temperature: Although temperature is considered particularly important in the instances of thermal impacts, e.g. outlet of high - temperature effluent from the TSB sugar mill between EWR 4 and 5 on the Crocodile River, it is also important to consider if the EWR site is located below a dam, or if changes in flow would result in extreme temperature changes in rivers.
- Dissolved oxygen.
- Turbidity.

As quantitative data (other than that measured in the field) were not available for DO, temperature and turbidity, a qualitative assessment was conducted for these variables (as outlined in the EcoStatus manual of Kleynhans *et al*. (2005). Data from previous Reserve studies (i.e. Claassen *et al*. (2002) for the Crocodile system, and Pegram and Palmer (1996) for the Sabie - Sand system) were also extensively used.

Toxic substances

- Those listed in the South African Water Quality Guidelines for Aquatic Ecosystems (DWAF, 1996), which includes toxic metal ions, toxic organic substances, and/or substances selected from the chemical inventory of an effluent/discharge. The rating tables in Kleynhans *et al*. (2005) provide values for selected toxics. Information on the geology of the area, as outlined in Claassen *et al*. (2002) was also used to provide the background template of naturally elevated metals.

C2.2.2 Data sources

A number of data sources were used for this assessment, as follows:

- Literature regarding water quality issues in the catchments, e.g. RHP (2001), DWAF (2004a), Claassen *et al*. (2002), Pegram and Palmer (1996) (Section C1 of this report).
- The perusal of 1: 50 000, and 1: 250 000 maps of the study area, depicting land use activities, point and diffuse sources of pollution, and catchment characteristics such as towns, tributaries, gauging weirs, etc.
- Maps of land cover classes.
- A field survey of the study area undertaken in November 2007/8. Water quality measurements were taken at specific points, including the EWR sites (Table C6). Samples were also taken for diatom analysis at Potchefstroom University (Appendix K; Table C8), phytoplankton analysis at the University of Johannesburg (Table C7), and periphyton samples for chlorophyll - a analysis by Prof Froneman of Rhodes University (Table C7).

- A meeting with representatives of DWAF regional offices (Stanford Macavele, Kenneth Masindi, Vincent Leshabane), to access information about point and diffuse sources of pollution and available water quality data.
- Regional water quality data from the DWAF office in Nelspruit (contact: Stanford Macavele).
- Information from additional sources, e.g. personal communication with Jonathan Swart of the Sabi - Sand Wildtuin, and Andrew Deacon of the KNP.
- Liaison with the national DWAF office and obtaining available water quality information from the DWAF - WMS (Water Management System) database.
- Water quality on CD (version 1.0); produced by the CSIR in 1999.
- Water quality information on the Sabie - Sand system from Water Research Commission (WRC) reports produced by Weeks *et al*. (1995).
- Information on the geology of the area to provide the background template of naturally elevated metals (Claassen *et al*., 2002).
- Data produced by post - graduate students of the University of Johannesburg (contact: Prof Victor Wepener).

Table C6 On - site water quality data collected during the 2007 field survey

Site	NO_3 (mg/l - N)	NO_2 (mg/l - N)	NH_4 (mg/l - N)	PO4 (mg/l - P)	pH	Temp °C	DO (mg/l)	DO (% sat)	Conductivity (µS/cm)
Crocodile River system									
EWR 1	0.593	<0.01	0.037	<0.02	7.46	20.4	6.94	95.6	1741
EWR 2	0.633	<0.01	0.043	<0.02	7.47	25.2	6.35	92.1	157
EWR 3	1.430	<0.01	0.047	<0.02	7.32	22.4	5.62	71.5	94
WQ 1	0.617	<0.01	0.037	<0.02	7.66	22.1	7.72	96.2	171
EWR 4	1.437	0.03	0.083	0.203	7.55	25.3	7.4	94.6	187
EWR 6	1.267	0.01	0.060	0.037	7.64	28.5	7.64	95.3	395
EWR 7	0.697	<0.01	0.040	0.020	8.02	24.7	7.69	96.4	385
Sabie - Sand River system									
EWR 1s	1.060	0.02	0.073	0.020	7.34	23	7.33	92.3	84
EWR 4s	0.583	<0.01	0.037	0.030	7.61	24.1	7.5	95.1	80
EWR 5s	1.487	<0.01	0.063	0.020	6.64	25.3	8.03	103.5	1414
EWR 6s	1.743	0.04	0.150	<0.02	7.28	27.1	6.59	98.7	187
EWR 7s	0.490	<0.01	0.077	0.060	7.22	27.5	6.82	92.6	89

Table C7 Chlorophyll - a analysis for samples collected from the Inkomati study area (Froneman, 2007: periphyton; University of Johannesburg: phytoplankton analysis)

Site	Phytoplankton biomass (µg chl - a per litre)	Periphyton biomass (mg chl - a m^{-2})
Crocodile River system		
EWR 1, Krokodilspruit	2.76	20.52 (SD: 13.67)
EWR 2, Goedehoop	3.44	47.63 (SD: 13.43)
EWR 3, Poplar Creek	8.87	29.81 (SD: 9.36)
WQ 1 at Rivulets	4.00	25.28 (SD: 9.03)
EWR 6	3.32	
EWR 7, Kaap River	8.66	31.42 (SD: 16.74)
Sabie – Sand River system		
EWR 1	4.89	
EWR 2, Aan de Vliet		32.97 (SD: 18.28)

Site	Phytoplankton biomass (µg chl - a per litre)	Periphyton biomass (mg chl - a m $^{-2}$)
EWR 4, Mac Mac River	1.36	68.51 (SD: 27.36)
EWR 5, Marite River	1.57	57.85 (SD: 19.32)
EWR 6, Mutlumuvi River	0.35	
EWR 7, Tlulandziteka River	1.59	54.05 (SD: 25.03)

Table C8 Diatom assessment for the Inkomati study area (from Appendix D)

EWR site	Site name	River	No of species	Specific Pollution sensitivity Index (SPI)	Class	Category
EWR 1	Valyspruit	Crocodile	35	16.5	Good quality	B
EWR 2	Goedehoop	Crocodile	37	15.3	Good quality	B
EWR 3	Poplar Creek	Crocodile	28	14.6	Good quality	B
EWR 4	KaNyamazane	Crocodile	46	9.7	Moderate quality	C
EWR 5	Malelane	Crocodile	26	13.2	Moderate quality	B/C
EWR 6	Nkongoma	Crocodile	36	13.1	Moderate quality	B/C
EWR 7	Honeybird	Kaap	33	15.8	Good quality	B
EWR 1	Upper Sabie	Sabie	51	13.1	Moderate quality	B/C
EWR 2	Aan de Vliet	Sabie	31	15.3	Good quality	B
EWR 3	Kidney	Sabie	24	14.5	Good quality	B
EWR 4	MacMac	MacMac	46	14.0	Good quality	B
EWR 5	Marite	Marite	18	19.4	High quality	A
EWR 6	Mutlumuvi	Mutlumuvi	31	15.6	Good quality	B
EWR 7	Tlulandziteka	Tlulandziteka (Sand)	37	12.8	Moderate quality	B/C
EWR 8	Sand	Sand	51	13.1	Moderate quality	B/C

C3 EWR 1: VALEYSPRUIT (CROCODILE RIVER)

C3.1 DATA AVAILABILITY

Data availability	Conf
No DWAF monitoring data was available, and information was extrapolated from EWR 2. Limited phytoplankton, periphyton and diatom data available (no of data sets (n) = 1). A very poor data set exists for this site, so expert judgement and knowledge of the area was relied on.	2

C3.2 REFERENCE CONDITIONS

Reference conditions	Conf
Benchmark tables from Kleynhans *et al*. (2005).	1

Water Quality Constituents		Value: RC
Inorganic salts (mg/L)	No data available.	
Nutrients (mg/L)	Soluble Reactive Phosphate (SRP)	< 0.005
	Total Inorganic Nitrogen (TIN)	< 0.25
Physical variables	pH ($5^{th}+95^{th}$ percentiles)	6.5 + 8.0
	Electrical conductivity (mS/m)	≤ 30 mS/m
	Turbidity (NTU)	Pristine river, no known man-made modifications of the catchment, and no known concerns about turbidity. Changes in turbidity appear to be natural and related to natural catchment processes such as rainfall runoff.

C3.3 PRESENT ECOLOGICAL STATE

The PAI and water quality tables, which are completed as part of the assessment and assigns the EcoStatus rating for water quality, are shown below as Tables C9 and C10.

Table C9 Water quality table for EWR 1

RIVER	Crocodile River		**Water Quality Monitoring Points**	
WQSU	1		**RC**	Extrapolate from EWR 2, as no data
EWR SITE	1		**PES**	
Confidence assessment	Confidence in the assessment is **low**, as little useful data and no DO, temp., turbidity or metal data. Also no TIN or salts data.			
Water Quality Constituents		**Value**	**Category (Rating) / Comment**	
Inorganic salts (mg/L)	$MgSO_4$	-	No data for assessment	
	Na_2SO_4	-		
	$MgCl_2$	-		
	$CaCl_2$	-		
	NaCl	-		
	$CaSO_4$	-		
Nutrients (mg/L)	SRP	0.09	B (1)	
	TIN	-		
Physical variables	pH ($5^{th}-95^{th}$ percentiles)	-		
	Temperature	-	Site not downstream of a dam, so temperature and oxygen fluctuations not expected. Some sensitivity to changing flows expected.	
	Dissolved oxygen	-		
	Turbidity (NTU)	95^{th} percentile: 19.4		
	Electrical conductivity (mS/m)	-		
Response variable	Chl-a: periphyton	20.52	C (2) (n = 1)	
	Chl-a: phytoplankton	2.76	A (0) (n = 1)	
	Biotic community composition: macroinvertebrate (ASPT) score	6.3		

	Diatoms	SPI = 16.5	B (1) (n = 1)
OVERALL SITE CLASSIFICATION (from PAI)		**A (93.09)**	

The present state of the water quality at EWR 1 is scored as an **A category** (see Table C10). Due to the data available, the assessment is of **low** confidence.

Table C10 EWR 1: PAI

Physico-chemical Metrics	Rank	%wt	Rating	Conf
pH	5	50	0.50	4.00
SALTS	4	70	0.00	4.00
NUTRIENTS	4	70	0.50	3.00
TEMPERATURE	2	90	0.50	3.00
TURBIDITY	3	80	0.50	4.00
OXYGEN	2	90	0.50	4.00
TOXICS	1	100	0.00	5.00
PHYSICO-CHEMICAL PERCENTAGE SCORE	**93.09**			
PHYSICO-CHEMICAL CATEGORY	**A**			
BOUNDARY CATEGORY				

Notes

- Nutrients: Farming and urban activities in area, resulting in slight nutrient elevations as shown by periphyton, phytoplankton and diatoms (n = 1 for all indicators).
- Flows: Abstractions result in slight fluctuations in oxygen and temperature.

C3.3.1 PES causes and sources

PES	Causes	Sources	F/NF	Conf
A	Elevated nutrients. Lower flows result in fluctuations in oxygen and temperature.	Farming activities. Dullstroom town.	NF	2

C3.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
A	Stable	A		N/A	2

C3.5 ALTERNATIVE ECOLOGICAL CATEGORY (AEC): B/C

PES	AEC	Comments	Conf
A	B	Overall nutrient levels and toxics would increase.	2

C4 EWR 2: GOEDEHOOP (CROCODILE RIVER)

C4.1 DATA AVAILABILITY

Data availability	Conf
Little DWAF monitoring data (PES; n = 9). Limited phytoplankton, periphyton and diatoms (n = 1). Very poor data set for this site, so expert judgement and knowledge of the area used extensively.	2

C4.2 REFERENCE CONDITIONS

Reference conditions	Conf
Benchmark tables were used according to Kleynhans *et al.,* 2005.	1

C4.3 RESULTS

The PAI and water quality tables, which are completed as part of the assessment and assigns the EcoStatus rating for water quality, are shown below as Tables C11 and C12.

Table C11 Water quality table for EWR 2

RIVER	Crocodile River	**Water Quality Monitoring Points**	
WQSU	2	**RC**	Benchmark tables
EWR SITE	2	**PES**	X2H074Q01, '92-'94, n=9
Confidence assessment	Confidence in the assessment is **low**, as little useful data and no DO, temp., turbidity or metal data. Also no TIN or salts data.		
Water Quality Constituents		**Value**	**Category (Rating) / Comment**
Inorganic salts (mg/L)	$MgSO_4$	-	No data for assessment
	Na_2SO_4	-	
	$MgCl_2$	-	
	$CaCl_2$	-	
	NaCl	-	
	$CaSO_4$	-	
Nutrients (mg/L)	SRP	0.09	B (1)
	TIN	-	
Physical variables	pH (5th-95th percentiles)	-	
	Temperature	-	Site not downstream of a dam, so temperature and oxygen fluctuations not expected.
	Dissolved oxygen	-	
	Turbidity (NTU)	95th percentile: 19.4	
	Electrical conductivity (mS/m)	-	
Response variable	Chl-a: periphyton	20.52	C (2) (n=1)
	Chl-a: phytoplankton	3.44	A (0) (n=1)
	Biotic community composition: macroinvertebrate (ASPT) score	5.9	
	Diatoms	SPI=15.3	B (1) (n=1)
OVERALL SITE CLASSIFICATION (from PAI)		**B (87.37)**	

The present state of the water quality at EWR 2 is scored as a **B category** (see Table C12). Due to the data available, the assessment is of **low** confidence.

Table C12 EWR 2: PAI

Physico-chemical Metrics	Rank	%wt	Rating	Conf
pH	5	50	0.50	4.00
SALTS	4	70	0.50	4.00
NUTRIENTS	4	70	1.00	3.00
TEMPERATURE	1	100	0.50	3.00
TURBIDITY	3	80	1.00	4.00
OXYGEN	1	100	0.50	4.00
TOXICS	1	100	0.50	5.00
PHYSICO-CHEMICAL PERCENTAGE SCORE	**87.37**			
PHYSICO-CHEMICAL CATEGORY	**B**			
BOUNDARY CATEGORY				

Notes

- Nutrients: Farming and urban activities in area, resulting in slight nutrient elevations as shown by periphyton, phytoplankton and diatoms (n = 1 for all indicators).
- Diatoms indicate some salination, possibly irrigation return flows.
- Flows: Abstractions result in slight fluctuations in oxygen and temperature.

C4.3.1 PES causes and sources

PES	Causes	Sources	F/NF	Conf
B	Elevated nutrients.	Farming activities.	NF	2
	Lower flows result in fluctuations in oxygen and temperature. Turbidity from farming activities. Slight elevation in toxics is expected.	Land use activities - site is below Dullstroom town.		

C4.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
Upper B	Slow, but downward	Lower B	5 yrs	The presence of highly pollution tolerant diatom species (*S. seminulum*, *N. palea*, *N. tenelloides*, *N. gregaria*, *N. capitatoradiata*), although in small numbers, indicate that the pollution levels are higher than at EWR 1 and this could indicate a negative trend.	2

C4.5 AEC: C

PES	AEC	Comments	Conf
A	B	A drop in flows will result in an increase in nutrient levels, salinity and toxics. More frequent and lower low flows will also affect oxygen and temperature levels.	2

C5 EWR 3: POPLAR CREEK (CROCODILE RIVER)

C5.1 DATA AVAILABILITY

Data availability	Conf
DWAF monitoring data for RC and PES. Limited phytoplankton, periphyton and diatoms (n = 1). No temperature, DO or turbidity data. Little metal data. EC and aggregated salts (as TEACHA used).	3

C5.2 REFERENCE CONDITIONS

Reference conditions	Conf
DWAF monitoring data: X3H006Q01; n = 149, 1976 – 1979.	3

Water Quality Constituents		Value: RC
Inorganic salts (mg/L)	$MgSO_4$	5.314
	Na_2SO_4	1.191
	$MgCl_2$	1.104
	$CaCl_2$	2.315
	NaCl	6.238
	$CaSO_4$	0.460
Nutrients (mg/L)	Soluble Reactive Phosphate (SRP)	0.007
	Total Inorganic Nitrogen (TIN)	0.090
Physical variables	pH (5^{th}+95^{th} percentiles)	6.5 + 7.7
	Electrical conductivity (mS/m)	17.00

C5.3 RESULTS

The PAI and water quality tables, which are completed as part of the assessment and assigns the EcoStatus rating for water quality, are shown below as Tables C13 and C14

Table C13 Water quality table for EWR 3

RIVER	Crocodile River	**Water Quality Monitoring Points**	
WQSU	3	**RC**	X2H013Q01, ’77-’80, n=170
EWR SITE	3	**PES**	X2H013Q01, ’04-’07, n=79
Confidence assessment	Confidence in the assessment is **moderate**, as little DO, temp., turbidity or metal data.		
Water Quality Constituents		**Value**	**Category (Rating) / Comment**
Inorganic salts (mg/L)	$MgSO_4$	8	A (0) (TEACHA output)
	Na_2SO_4	0	
	$MgCl_2$	3	
	$CaCl_2$	3	
	NaCl	9	
	$CaSO_4$	0	
Nutrients (mg/L)	SRP	0.018	B (1) (TEACHA output)
	TIN	0.125	
Physical	pH (5^{th}-95^{th} percentiles)	7.3-8.04	B (1) (TEACHA output)

variables	Temperature	-	Site downstream of Kwena Dam so high flows affected. Although flow is not constant and bottom level release, flows are normally high.
	Dissolved oxygen	-	
	Turbidity (NTU)	-	
	Electrical conductivity (mS/m)	15.82	A (0)
Response variable	Chl-a: periphyton	29.81	D (3) (n=1)
	Chl-a: phytoplankton	8.87	A (0) (n=1)
	Biotic community composition: macroinvertebrate (ASPT) score	6.8	
	Diatoms	SPI=14.6	B (1) (n=1)
OVERALL SITE CLASSIFICATION (from PAI)		**C (74.73)**	

The present state of the water quality at EWR 3 is scored as a **C category** (see Table C14). Due to the data available, the assessment is of **moderate** confidence.

Table C14 EWR 3: PAI

Physico-chemical Metrics	Rank	%wt	Rating	Conf
pH	4	50	0.50	4.00
SALTS	3	60	0.00	4.00
NUTRIENTS	3	60	1.00	3.00
TEMPERATURE	1	100	1.50	4.00
TURBIDITY	2	80	2.00	3.00
OXYGEN	1	100	2.00	4.00
TOXICS	1	100	1.00	5.00
PHYSICO-CHEMICAL PERCENTAGE SCORE	**74.73**			
PHYSICO-CHEMICAL CATEGORY	**C**			
BOUNDARY CATEGORY				

Notes

- Nutrients: Phytoplankton, periphyton and diatoms (n = 1 for both indicators) indicate some pollution.
- Turbidity: Some turbidity expected due to catchment activities and land use.
- Toxics: Most metal data indicates good quality (except for Zn), but pesticide use practiced in area.
- Temperature and oxygen: Site downstream of Kwena Dam, with resulting changes in oxygen and temperatures, particularly at low flows.

C5.3.1 PES causes and sources

PES	Causes	Sources	F/NF	Conf
C	Slightly elevated nutrients.	Agricultural activities.	NF	3
	Temperature changes (releases and very low flows in wet season). Elevated turbidity levels. Slight elevation in toxics expected.	Operation of Kwena Dam.		

C5.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
Upper C	Negative	(Possibly move to a Lower C)	5 yrs	The present state is dependent on the operation of the dam, e.g. temperature and oxygen state is dependent on flow releases. So, although the water quality will move within the category, it may be better or worse depending on how and when water is released from Kwena Dam.	3

C5.5 RECOMMENDED ECOLOGICAL CATEGORY (REC): B

PES	REC	Comments	Conf
C	B/C	Maintain the current EC. There will however be a slight improvement in oxygen and temperature.	3

C5.6 AEC: C/D

PES	AEC	Comments	Conf
C	C/D	Lower flows in both the dry and wet seasons, with associated temperature and oxygen changes. Lower flows therefore less dilution of toxics in the system.	3

C6 EWR 4: KANYAMAZANE (CROCODILE RIVER)

C6.1 DATA AVAILABILITY

Data availability	Conf
DWAF monitoring data for RC and PES. Limited phytoplankton, periphyton + diatoms (n = 1). No temperature, DO or turbidity data. Little metal data. EC and aggregated salts (as TEACHA used).	3

C6.2 REFERENCE CONDITIONS

Reference conditions	Conf
DWAF monitoring data: X2H032Q01; n = 882, 1977 – 1980.	3

Water Quality Constituents		Value: RC
Inorganic salts (mg/L)	$MgSO_4$	11.450
	Na_2SO_4	2.160
	$MgCl_2$	1.057
	$CaCl_2$	1.283
	NaCl	11.070
	$CaSO_4$	0.501
Nutrients (mg/L)	Soluble Reactive Phosphate (SRP)	0.014
	Total Inorganic Nitrogen (TIN)	0.270
Physical variables	pH (5^{th}+95^{th} percentiles)	6.33 + 7.22
	Electrical conductivity (mS/m)	18.53

C6.3 RESULTS

The PAI and water quality tables, which are completed as part of the assessment and assigns the EcoStatus rating for water quality, are shown below as Tables C15 and C16.

Table C15 Water quality table for EWR 4

RIVER	Crocodile River	**Water Quality Monitoring Points**	
WQSU	4	**RC**	X2H032Q01, ’77-’80, n=88
EWR SITE	4	**PES**	X2H032Q01, ’04-’07, n=108
Confidence assessment	Confidence in the assessment is **moderate**, as little DO, temp., turbidity or metal data.		
Water Quality Constituents		**Value**	**Category (Rating) / Comment**
Inorganic salts (mg/L)	$MgSO_4$	36	E (4) (TEACHA output). Rating modified due to the over-estimation of $MgSO_4$ by TEACHA. See EC value.
	Na_2SO_4	5	
	$MgCl_2$	5	
	$CaCl_2$	16	
	NaCl	68	
	$CaSO_4$	0	
Nutrients (mg/L)	SRP	0.072	B (1) (TEACHA output)
	TIN	0.881	

Physical variables	pH (5th-95th percentiles)	7-7.9	A (0) as natural category was re-benchmarked
	Temperature	-	Stream fast-flowing, but periods of low flows will exacerbate temperature + oxygen fluctuations.
	Dissolved oxygen	-	
	Turbidity (NTU)	-	
	Electrical conductivity (mS/m)	43.3	B (1)
Response variable	Chl-a: periphyton	-	
	Chl-a: phytoplankton	3.35	A (0) (n=1)
	Biotic community composition: macroinvertebrate (ASPT) score	5.4 (RHP: 5.9)	
	Diatoms	SPI=9.7	C (0) (n=3)
OVERALL SITE CLASSIFICATION (from PAI)		**C (76.73)**	

The present state of the water quality at EWR 4 is scored as a **C category** (see Table C16). Due to the data available, the assessment is of **moderate** confidence.

Table C16 EWR 4: PAI

Physico-chemical Metrics	Rank	%wt	Rating	Conf
pH	4	50	1.00	3.00
SALTS	3	60	2.00	3.00
NUTRIENTS	2	80	2.00	4.00
TEMPERATURE	1	100	0.00	4.00
TURBIDITY	3	60	1.00	4.00
OXYGEN	1	100	0.50	4.00
TOXICS	1	100	2.00	5.00
PHYSICO-CHEMICAL PERCENTAGE SCORE	**76.73**			
PHYSICO-CHEMICAL CATEGORY	**C**			
BOUNDARY CATEGORY				

Notes

- Nutrients: Periphyton + diatoms (n = 1 for both indicators) indicate pollution.
- Turbidity: Some turbidity expected due to catchment activities.
- Toxics: catchment activities (including extensive urban and per-urban areas and agricultural activities, e.g. pesticide use), including input of the Elands River.

C6.3.1 PES causes and sources

PES	Causes	Sources	F/NF	Conf
C	Elevated nutrients and toxics. Temperature, turbidity and oxygen fluctuations	Extensive cultivation, urban / peri-urban areas. Poor land management – return flows.	NF	3

C6.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
C	Stable	C		Although water quality conditions are poor, it is stable due to the constant high flow, particularly high base flows.	3

C6.5 REC: B

PES	REC	Comments	Conf
C	B	Nutrient levels and toxics would decrease due to flow improvement.	3

C6.6 AEC: C/D

PES	AEC	Comments	Conf
C	C	Increased sedimentation, with a resulting change within the C EC.	N/A

C7 EWR 5: MALALANE (CROCODILE RIVER)

C7.1 DATA AVAILABILITY

Data availability	Conf
DWAF monitoring data for RC and PES. Limited diatom data (n = 1). No temperature, DO or turbidity data. Little metal data. Aggregated salts available as TEACHA used.	3

C7.2 REFERENCE CONDITIONS

Reference conditions	Conf
DWAF monitoring data: X2H017Q01; n = 125, 1977 – 1980.	3.5

Water Quality Constituents		Value: RC
Inorganic salts (mg/L)	$MgSO_4$	16.63
	Na_2SO_4	11.07
	$MgCl_2$	0
	$CaCl_2$	0
	NaCl	32.72
	$CaSO_4$	0.55
Nutrients (mg/L)	Soluble Reactive Phosphate (SRP)	0.014
	Total Inorganic Nitrogen (TIN)	0.37
Physical variables	pH (5^{th}+95^{th} percentiles)	6.7+ 7.9
	Electrical conductivity (mS/m)	58.86

C7.3 RESULTS

The PAI and water quality tables, which are completed as part of the assessment and assigns the EcoStatus rating for water quality, are shown below as Tables C17 and C18.

Table C17 Water quality table for EWR 5

RIVER	Crocodile River	**Water Quality Monitoring Points**	
WQSU	6	**RC**	X2H017Q01, ’77-’80, n=125
EWR SITE	5	**PES**	X2H017Q01, ’04-’07, n=114
Confidence assessment	Confidence in the assessment is **moderate**, as little DO, temp., turbidity or metal data.		
Water Quality Constituents		**Value**	**Category (Rating) / Comment**
Inorganic salts (mg/L)	$MgSO_4$	52 (F category)	E (4) (TEACHA output), but modified despite presence of indicator diatoms
	Na_2SO_4	5	
	$MgCl_2$	6	
	$CaCl_2$	12	
	NaCl	1	
	$CaSO_4$	0	
Nutrients (mg/L)	SRP	0.041	B (1)
	TIN	0.684	B (1)
Physical	pH (5^{th}-95^{th} percentiles)	7.51-8.4	B (1)

variables	Temperature	-	Although not downstream of a dam, alluvial bottom will result in temperature and oxygen fluctuations at low flows. There are many abstractions in this WQSU
	Dissolved oxygen	-	
	Turbidity (NTU)	-	
	Electrical conductivity (mS/m)	57.75	A (0), as benchmark table re-calibrated
Response variable	Chl-a: periphyton	-	
	Chl-a: phytoplankton	-	
	Biotic community composition: macroinvertebrate (ASPT) score	5.1	
	Diatoms	SPI=13.2	B/C (1.5) (n=1)
OVERALL SITE CLASSIFICATION (from PAI)		**C (67.21)**	

The present state of the water quality at EWR 5 is scored as a **C category** (see Table C18). Due to the data available, the assessment is of **moderate** confidence.

Table C18 EWR 5: PAI

Physico-chemical Metrics	Rank	%wt	Rating	Conf
pH	4	50	1.00	5.00
SALTS	3	70	2.00	3.00
NUTRIENTS	2	85	2.00	4.00
TEMPERATURE	1	100	2.00	3.00
TURBIDITY	4	50	2.00	4.00
OXYGEN	1	100	1.00	3.00
TOXICS	1	100	1.50	5.00
PHYSICO-CHEMICAL PERCENTAGE SCORE	**67.21**			
PHYSICO-CHEMICAL CATEGORY	**C**			
BOUNDARY CATEGORY				

Notes

- Nutrients: Chl-a samples and diatoms (n = 1 for both indicators) indicate some pollution.
- Turbidity: Elevated turbidity expected due to catchment activities; including suspended solid loads from TSB sugar mill effluents.
- Toxics: Many impacting activities in the area, e.g. sugar cane plantations and processing, citrus plantations and processing, urban areas, agricultural activities.
- Temperature and oxygen: Alluvial system, with high temperature effluents from TSB sugar mill resulting in localized fish kills.
- Elevated salts.

C7.3.1 PES causes and sources

PES	Causes	Sources	F/NF	Conf
C	All variables are elevated including oxygen and temperature. Alkaline conditions.	Agricultural and urban activities, including extensive sugar cane and citrus plantations and land management on right bank, causing abnormal low flows. Return flows from sugar mill. Abstraction.	F	3

C7.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
C	Negative	C/D	5 yrs	Poor water quality state exacerbated by extensive abstractions in this stretch of river.	3

C7.5 REC: B

PES	REC	Comments	Conf
C	B	Increased flows, particularly low flows, will improve the water quality state by dilution. It is assumed that enough water will be provided at the right time to reduce the toxics by a category.	3

C7.6 AEC: D

PES	AEC	Comments	Conf
C	D	Lower flows will result in a poorer water quality state, with elevations in nutrients, salts and toxics. Increases in temperatures and drops in oxygen level will also be seen.	4

C8 EWR 6: NKONGOMA (CROCODILE RIVER)

C8.1 DATA AVAILABILITY

Data availability	Conf
DWAF monitoring data for RC and PES. Limited phytoplankton and diatoms (n = 1). No temperature, DO or turbidity data. Little metal data. Aggregated salts as TEACHA.	3

C8.2 REFERENCE CONDITIONS

Reference conditions	Conf
DWAF monitoring data: X2H016Q01; n = 163, 1977 – 1980.	3

Water Quality Constituents		Value: RC
Inorganic salts (mg/L)	$MgSO_4$	17
	Na_2SO_4	10.54
	$MgCl_2$	4.48
	$CaCl_2$	8.26
	NaCl	50.4
	$CaSO_4$	0.63
Nutrients (mg/L)	Soluble Reactive Phosphate (SRP)	0.007
	Total Inorganic Nitrogen (TIN)	0.33
Physical variables	pH (5th+95th percentiles)	6.71 + 8.02
	Electrical conductivity (mS/m)	69.36

C8.3 RESULTS

The PAI and water quality tables, which are completed as part of the assessment and assigns the EcoStatus rating for water quality, are shown below as Tables C19 and C20.

Table C19 Water quality table for EWR 6

RIVER	Crocodile River	**Water Quality Monitoring Points**	
WQSU	6	**RC**	X2H016Q01, '77-'80, n=163
EWR SITE	6	**PES**	X2H016Q01, '04-'07, n=119
Confidence assessment	Confidence in the assessment is **moderate**, as little DO, temp., turbidity or metal data.		
Water Quality Constituents		**Value**	**Category (Rating) / Comment**
Inorganic salts (mg/L)	$MgSO_4$	50 (rating=5)	E (4) (TEACHA output), but modified despite presence of indicator diatoms
	Na_2SO_4	8	
	$MgCl_2$	17 (rating=1)	
	$CaCl_2$	33 (rating=1)	
	NaCl	2.1	
	$CaSO_4$	0	
Nutrients (mg/L)	SRP	0.031	B (1)
	TIN	0.341	B (1)

Physical variables	pH (5^{th}-95^{th} percentiles)	7.78-8.5	B (1)
	Temperature	-	Although not downstream of a dam, alluvial bottom will result in temperature and oxygen fluctuations at low flows.
	Dissolved oxygen	-	
	Turbidity (NTU)	-	
	Electrical conductivity (mS/m)	86.08	B (1). System naturally saline and benchmark category re-calibrated
Response variable	Chl-a: periphyton	-	
	Chl-a: phytoplankton	3.32	A (0) (n=1)
	Biotic community composition: macroinvertebrate (ASPT) score	5.9	
	Diatoms	SPI=13.1	B/C (1.5) (n=1)
OVERALL SITE CLASSIFICATION (from PAI)		**C (67.48)**	

The present state of the water quality at EWR 6 is scored as a **C category** (see Table C20). Due to the data available, the assessment is of **moderate** confidence.

Table C20 EWR 6: PAI

Physico-chemical Metrics	Rank	%wt	Rating	Conf
pH	4	50	1.00	5.00
SALTS	3	70	2.00	3.00
NUTRIENTS	2	85	2.50	4.00
TEMPERATURE	1	100	1.50	3.00
TURBIDITY	4	50	1.00	4.00
OXYGEN	1	100	1.00	3.00
TOXICS	1	100	2.00	5.00
PHYSICO-CHEMICAL PERCENTAGE SCORE	**67.48**			
PHYSICO-CHEMICAL CATEGORY	**C**			
BOUNDARY CATEGORY				

Notes

- Nutrients: Nutrient levels are elevated. Filamentous algal sheets are evident at low flows.
- Turbidity: Some turbidity expected due to catchment activities. Suspended solids are present in the sugar mill effluent.
- Toxics: Toxicant use expected due to sugarcane and citrus plantations. Elevated Cd levels. Downstream of impacts from sugar mill + citrus processing.
- Temperature and oxygen: Temperature levels increase and oxygen levels drop at low flows.

C8.3.1 PES causes and sources

PES	Causes	Sources	F/NF	Conf
C	Elevated nutrients, salinity, toxics and temperatures.	Agricultural activities. Downstream of sugar mill and citrus processing.	NF	3
	Reduced oxygen levels.	Low flows exacerbate temperature and oxygen levels.		

C8.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
C	Negative	C/D	5 yrs	Poor water quality state is exacerbated by low flows.	3

C8.5 REC: B

PES	REC	Comments	Conf
C	B	Improved operation of low flows will result in an improvement of the water quality state due to increased dilution.	3

C8.6 AEC: D

PES	AEC	Comments	Conf
C	D	Decreased low flows and periods of zero flows in some stretches of the river will result in associated water quality changes, e.g. increases in nutrient levels, toxics, salinity levels and temperature. Oxygen levels will drop under these conditions.	4

C9 EWR 7: (KAAP RIVER) – HONEYBIRD

C9.1 DATA AVAILABILITY

Data availability	Conf
DWAF monitoring data for RC and PES. Limited phytoplankton, periphyton + diatoms (n = 1). No temperature, DO or turbidity data. Little metal data. EC used instead of aggregated salts (as TEACHA could not be used).	3

C9.2 REFERENCE CONDITIONS

Reference conditions	Conf
DWAF monitoring data: X2H022Q01, 1977 - 1981, n = 96.	3

Water Quality Constituents		Value: RC
Inorganic salts (mg/L)	No available data.	
Nutrients (mg/L)	Soluble Reactive Phosphate (SRP)	0.027
	Total Inorganic Nitrogen (TIN)	0.44
Physical variables	pH (5^{th}+95^{th} percentiles)	6.96 + 8.18
	Electrical conductivity (mS/m)	70.15

C9.3 RESULTS

The PAI and water quality tables, which are completed as part of the assessment and assigns the EcoStatus rating for water quality, are shown below as Tables C21 and C22.

Table C21 Water quality table for EWR 7

RIVER	Kaap River	**Water Quality Monitoring Points**	
WQSU	7	**RC**	X2H022Q01, ’77-’81, n=96
EWR SITE	7	**PES**	X2H022Q01, ’04-’07, n=174
Confidence assessment	Confidence in the assessment is **moderate**, as little DO, temp., turbidity or metal data.		
Water Quality Constituents		**Value**	**Category (Rating) / Comment**
Inorganic salts (mg/L)	$MgSO_4$	-	TEACHA could not be used and EC used as surrogate.
	Na_2SO_4	-	
	$MgCl_2$	-	
	$CaCl_2$	-	
	NaCl	-	
	$CaSO_4$	-	
Nutrients (mg/L)	SRP	0.032	B (1). System is naturally eutrophic.
	TIN	0.72	B (1). System is naturally eutrophic.
Physical variables	pH (5^{th}-95^{th} percentiles)	7.96 + 8.53	B (1): natural category was re-benchmarked
	Temperature	-	River fast-flowing, although low flows will result in temperature + oxygen fluctuations
	Dissolved oxygen	-	
	Turbidity (NTU)	-	

	Electrical conductivity (mS/m)	90.8	A (0). System seems naturally saline (RC – EC=70.15)
Response variable	Chl-a: periphyton	31.42	E (4) (n=1)
	Chl-a: phytoplankton	8.66	A (0) (n=1)
	Biotic community composition: macroinvertebrate (ASPT) score	6 (RHP: 7.3)	
	Diatoms	SPI=15.8	B (1) (n=1)
OVERALL SITE CLASSIFICATION (from PAI)		**B (85.36)**	

The present state of the water quality at EWR 1 is scored as a **B category** (see Table C22). Due to the data available, the assessment is of **moderate** confidence.

Table C22 EWR 7: PAI

Physico-chemical Metrics	Rank	%wt	Rating	Conf
pH	3	50	1.00	5.00
SALTS	3	50	1.00	3.00
NUTRIENTS	2	80	1.50	3.00
TEMPERATURE	1	100	0.50	3.00
TURBIDITY	2	80	0.50	4.00
OXYGEN	1	100	0.00	3.00
TOXICS	1	100	1.00	5.00
PHYSICO-CHEMICAL PERCENTAGE SCORE	**85.36**			
PHYSICO-CHEMICAL CATEGORY	**B**			
BOUNDARY CATEGORY				

Notes

- Nutrients: Periphyton + diatoms (n = 1 for both indicators) indicate some pollution.
- Turbidity: Some turbidity expected due to catchment activities.
- Toxics: Extensive upstream mining activities (primarily along the Noord and Suid-Kaap and around Barbeton; and irrigation return flows from irrigation in the middle of the catchments. Although elevated arsenic has been reported in the area, no arsenic was seen in recent (2006 - 2007) DWAF regional office monitoring data; although peaks of elevated Fe were evident in the 1990s).
- Temperature and oxygen: Bedrock-dominated system so temperature fluctuations expected.

C9.3.1 PES causes and sources

PES	Causes	Sources	F/NF	Conf
B	Elevated nutrients and salts. Slightly alkaline waters. Slightly elevated turbidity and toxics.	Mining activities in the upper catchment. Agricultural and other activities (e.g. pole treating) in the catchment immediately above the site.	NF	3

C9.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
B	Stable	B		Water quality conditions stable, although there is evidence of pollutant tolerant diatom species at low levels.	2

C9.5 REC: B

PES	REC	Comments	Conf
B	B	Improved flows would only improve turbidity levels. Other water quality issues would have to be improved at the source.	N/A

C9.6 AEC: D

PES	AEC	Comments	Conf
B	C	Mining effluents will probably be caught in the dam. Flushing below the dam will be reduced, resulting in some elevation of nutrient levels due to agricultural activities upstream of the site and below the dam. Note that turbidity levels will drop, having a negative effect on a river that seems naturally slightly turbid due to possible build-up of periphyton.	3

C10 EWR 1: UPPER SABIE (SABIE RIVER)

C10.1 DATA AVAILABILITY

Data availability	Conf
DWAF monitoring data for RC and PES. Limited phytoplankton, periphyton + diatoms (n = 1). No temperature, DO or turbidity data. Little metal data. EC used instead of aggregated salts (as TEACHA could not be used).	3

C10.2 REFERENCE CONDITIONS

Reference conditions	Conf
DWAF monitoring data was available. Water quality station X3H001Q01 was used to set reference conditions with n = 82, and data available from 1977 – 1979.	3

Water Quality Constituents		Value: RC
Inorganic salts (mg/L)	No data available.	
Nutrients (mg/L)	Soluble Reactive Phosphate (SRP)	0.018
	Total Inorganic Nitrogen (TIN)	0.20
Physical variables	pH (5th+95th percentiles)	6.46+7.30
	Electrical conductivity (mS/m)	12.21

C10.3 RESULTS

The PAI and water quality tables, which are completed as part of the assessment and assigns the EcoStatus rating for water quality, are shown below as Tables C23 and C24.

Table C23 Water quality table for EWR 1

RIVER	Sabie River	**Water Quality Monitoring Points**	
WQSU	2	**RC**	X3H001Q01, ’77-’79, n=82
EWR SITE	1	**PES**	X3H001Q01, ’91-’99, n=42
Confidence assessment	Confidence in the assessment is **moderate**, as little DO, temp., turbidity or metal data.		

Water Quality Constituents		**Value**	**Category (Rating) / Comment**
Inorganic salts (mg/L)	$MgSO_4$	-	TEACHA could not be used and EC used as surrogate.
	Na_2SO_4	-	
	$MgCl_2$	-	
	$CaCl_2$	-	
	NaCl	-	
	$CaSO_4$	-	
Nutrients (mg/L)	SRP	0.02	A (0) as natural category was re-benchmarked
	TIN	0.45	B (1)
Physical variables	pH (5th-95th percentile)	7.37-7.87	A (0)
	Temperature	-	Not considered a problem as there are no thermal impacts and not downstream of a dam. Some turbidity due to catchment activities.
	Dissolved oxygen	-	
	Turbidity (NTU)	-	
	Electrical conductivity (mS/m)	15.58	A (0)

Response variable	Chl-a: periphyton	-	
	Chl-a: phytoplankton	4.89	A (0) (n=1)
	Biotic community composition: macroinvertebrate (ASPT) score	6.3 7.54	this study RHP surveys
	Diatoms	SPI=13.1	B/C (1.5) (n=1)
OVERALL SITE CLASSIFICATION (from PAI)		**A/B (92.43)**	

The present state of the water quality at EWR 1 is scored as an **A/B category** (see Table C24). Due to the data available, the assessment is of **moderate** confidence.

Table C24 EWR 1: PAI

Physico-chemical Metrics	Rank	%wt	Rating	Conf
pH	5	50	0.00	4.00
SALTS	5	50	0.00	4.00
NUTRIENTS	3	80	1.50	3.00
TEMPERATURE	2	95	0.00	3.00
TURBIDITY	3	80	0.50	3.00
OXYGEN	1	100	0.00	4.00
TOXICS	1	100	0.50	5.00
PHYSICO-CHEMICAL PERCENTAGE SCORE	**92.43**			
PHYSICO-CHEMICAL CATEGORY	**A**			
BOUNDARY CATEGORY				

Notes

- Nutrients: Periphyton + diatoms (n = 1 for both indicators) indicate some pollution.
- Turbidity: Some turbidity expected due to catchment activities.
- Toxics: Return flows from old mines expected.

C10.3.1 PES causes and sources

PES	Causes	Sources	F/NF	Conf
A/B	Elevated nutrients from urban activities in Sabie and surrounding areas.	Urban and per-urban fringe, with related impacts such as uncompliant releases from Sewage Treatment Works (STW).	NF	3
	Elevated turbidity levels.	Forestry.		
	Return flows.	Old mines.		

C10.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
A/B	Stable	A/B		N/A	2

C10.5 REC: B

PES	REC	Comments	Conf
A/B	A/B	No change.	N/A

C10.6 AEC: C/D

PES	AEC	Comments	Conf
A/B	B/C	This scenario will cause an overall deterioration in the current EC.	4

C11 EWR 2: AAN DE VLIET (SABIE RIVER)

C11.1 DATA AVAILABILITY

Data availability	Conf
DWAF monitoring data for RC and PES. Limited phytoplankton, periphyton + diatoms (n = 1). No DO data. Limited temperature and turbidity data from Week *et al*. (1995). Little metal data. EC used instead of aggregated salts (as TEACHA could not be used).	3

C11.2 REFERENCE CONDITIONS

Reference conditions	Conf
DWAF monitoring data was available. Water quality station X3H006Q01 was used to set reference conditions with n = 149, and data available from 1976 – 1979.	3

Water Quality Constituents		Value: RC
Inorganic salts (mg/L)	$MgSO_4$	9.37
	Na_2SO_4	1.19
	$MgCl_2$	0.82
	$CaCl_2$	2.04
	NaCl	6.72
	$CaSO_4$	0.45
Nutrients (mg/L)	SRP	0.007
	TIN	0.12
Physical variables	pH (5^{th}+95^{th} percentiles)	6.46+7.54
	Electrical conductivity (mS/m)	13.16

C11.3 RESULTS

The PAI and water quality tables, which are completed as part of the assessment and assigns the EcoStatus rating for water quality, are shown below as Tables C25 and C26.

Table C25 Water quality table for EWR 2

RIVER	Sabie River	**Water Quality Monitoring Points**	
WQSU	3	**RC**	X3H006Q01, '76-'79, n=149
EWR SITE	2	**PES**	X3H006Q01, '04-'07, n=77
Confidence assessment	Confidence in the assessment is **moderate**, as no DO, temp. or turbidity data, and little metal data.		
Water Quality Constituents		**Value**	**Category (Rating) / Comment**
Inorganic salts (mg/L)	$MgSO_4$	11	A (0)
	Na_2SO_4	0	A (0)
	$MgCl_2$	10	A (0)
	$CaCl_2$	9	A (0)
	NaCl	56	B (1)
	$CaSO_4$	0	A (0)
Nutrients	SRP	0.02	C (3)

(mg/L)	TIN	0.214	A (0)
Physical variables	pH (5th-95th percentile)	7.23-7.99	B (1)
	Temperature	-	Not considered a problem as there are no thermal impacts and not downstream of a dam. However, bedrock-dominated so temperatures may increase + lower altitude.
	Dissolved oxygen	-	
	Turbidity (NTU)	Mean: 4 NTU Maximum value: 25 NTU (Weeks et al., 1995)	
	Electrical conductivity (mS/m)	15.7	A (0)
Response variable	Chl-a: periphyton	32.97	
	Chl-a: phytoplankton	-	
	Biotic community composition: macroinvertebrate (ASPT) score	7	
	Diatoms	SPI=15.3	B (1) (n=1)
OVERALL SITE CLASSIFICATION (from PAI)		**B (87.48)**	

The present state of the water quality at EWR 2 is scored as a **B category** (see Table C26). Due to the data available, the assessment is of **moderate** confidence.

Table C26 EWR 2: PAI

Physico-chemical Metrics	Rank	%wt	Rating	Conf
pH	5	50	0.00	4.00
SALTS	5	50	0.00	4.00
NUTRIENTS	3	80	1.50	3.00
TEMPERATURE	2	95	0.50	3.00
TURBIDITY	3	80	1.00	3.00
OXYGEN	1	100	0.50	4.00
TOXICS	1	100	0.50	5.00
PHYSICO-CHEMICAL PERCENTAGE SCORE	**87.48**			
PHYSICO-CHEMICAL CATEGORY	**B**			
BOUNDARY CATEGORY				

Notes

- Nutrients: Periphyton + diatoms (n = 1 for both indicators) indicate some pollution.
- Temperature: Bedrock-dominated system so temperature increases expected at low flows.
- Toxics: Pesticide use anticipated as extensive farming in the area.
- Diatoms show deteriorating conditions (under low flow conditions) as there are pollution tolerant diatoms present in the population (see Appendix K for more detail).

C11.3.1 PES causes and sources

PES	Causes	Sources	F/NF	Conf
B	Elevated nutrient levels and toxicants.	Forestry and Sabie town and small scale irrigation.	NF	3

C11.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
A/B	Stable	A/B		N/A	2

C11.5 REC: B

PES	REC	Comments	Conf
B	A/B	An improvement in land use, will improve the nutrient status which will result in an overall improvement to an A/B EC.	3

C11.6 AEC: C/D

PES	AEC	Comments	Conf
B	C	Increased pesticide use due to farming activities will lead to elevated nutrient levels and toxics. Due to reduced flows and increased sediment load, an increase in temperature and decrease in oxygen is expected.	4

C12 EWR 3: KIDNEY (SABIE RIVER)

C12.1 DATA AVAILABILITY

Data availability	Conf
DWAF monitoring data for RC and PES, although data only until 1999 for present state. No phytoplankton and periphyton + diatoms (n = 1). No temperature, DO or turbidity data. Little metal data. EC used instead of aggregated salts (as TEACHA could not be used).	2.5

C12.2 REFERENCE CONDITIONS

Reference conditions	Conf
DWAF station X3H006Q01 was used; n = 149, 1976 – 1979.	3

Water Quality Constituents		Value: RC
Inorganic salts (mg/L)	$MgSO_4$	9.37
	Na_2SO_4	1.19
	$MgCl_2$	0.82
	$CaCl_2$	2.04
	NaCl	6.72
	$CaSO_4$	0.45
Nutrients (mg/L)	SRP	0.007
	TIN	0.12
Physical variables	pH (5^{th}+95^{th} percentiles)	6.46+7.54
	Turbidity (NTU)	-
	Electrical conductivity (mS/m)	13.16

C12.3 RESULTS

The PAI and water quality tables, which are completed as part of the assessment and assigns the EcoStatus rating for water quality, are shown below as Tables C27 and C28.

Table C27 Water quality table for EWR 3

RIVER	Sabie River	**Water Quality Monitoring Points**	
WQSU	5	**RC**	X3H006Q01, ’76-’79, n=149
EWR SITE	3	**PES**	X3H013Q01, ’91-’99, n=39 (Data record for X3H021Q01 not used as n=5)
Confidence assessment	Confidence in the assessment is **low-moderate**, as little DO, temp., turbidity or metal data. No recent data record is available for this site.		
Water Quality Constituents		**Value**	**Category (Rating) / Comment**
Inorganic salts (mg/L)	$MgSO_4$	-	TEACHA could not be used and EC used as surrogate.
	Na_2SO_4	-	
	$MgCl_2$	-	
	$CaCl_2$	-	
	NaCl	-	
	$CaSO_4$	-	

Nutrients (mg/L)	SRP	0.01	B (1)
	TIN	0.175	A (0)
Physical variables	pH (5th-95th percentile)	7.11-8.44	B (1)
	Temperature	-	Not considered a problem as there are no thermal impacts and not downstream of a dam, although low flows exacerbate temperature + oxygen changes. Turbidity peaks experienced – exacerbated by poor land management.
	Dissolved oxygen	-	
	Turbidity (NTU)	Mean: 12.5 NTU 95th percentile: 53 NTU (WMS data)	
	Electrical conductivity (mS/m)	14.71	A (0)
Response variable	Chl-a: periphyton	-	
	Chl-a: phytoplankton	-	
	Biotic community composition: macroinvertebrate (ASPT) score	6.3	
	Diatoms	SPI=14.5	B (1) (n=1)
OVERALL SITE CLASSIFICATION (from PAI)		**B (84.91)**	

The present state of the water quality at EWR 1 is scored as a **B category** (see Table C 28). Due to the data available, the assessment is of **low-moderate** confidence (largely due to present state data from X3H013Q01 only up until 1999).

Table C28 EWR 3: PAI

Physico-chemical Metrics	Rank	%wt	Rating	Conf
pH	4	40	0.00	4.00
SALTS	3	50	0.50	4.00
NUTRIENTS	2	80	1.50	3.00
TEMPERATURE	1	100	0.50	5.00
TURBIDITY	2	80	1.50	3.00
OXYGEN	1	100	0.50	4.00
TOXICS	1	100	0.50	5.00
PHYSICO-CHEMICAL PERCENTAGE SCORE	**84.91**			
PHYSICO-CHEMICAL CATEGORY	**B**			
BOUNDARY CATEGORY				

Notes

- Nutrients: All indicators (n = 1 for diatoms) indicate some enrichment and pollution upstream of the KNP.
- Turbidity: Elevated turbidities expected due to catchment activities.
- Toxics: Land-use is conservation, although extensive citrus cultivation + urban activities upstream.
- Temperature and oxygen: Low flows result in changes to temperature and oxygen.

C12.3.1 PES causes and sources

PES	Causes	Sources	F/NF	Conf
B	Elevated nutrient levels, turbidity and temperatures. Drop in oxygen levels.	Poor land management outside the KNP. Urban and rural activities outside the KNP. Changes in flow.	NF	4

C12.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
High B	Negative	Low B	5 yrs	The presence of pollutant tolerant species e.g. *E. minima*, *N. frustulum*, *N. capitatoradiata* and *S. seminulum* indicate pollution problems and the Mkuhlu township upstream from this site may be the main source of these pollutants. This is supported by the presence of *A. minutissima var. saprophila* which indicates enrichment and favours eutrophic water. However, the overall water quality seems stable, depending on the periods of low flows not increasing in frequency.	3

C12.5 AEC: B/C

PES	AEC	Comments	Conf
B	C	Decreased flows will cause an increase in oxygen and temperature. Poor land management outside the KNP will lead to higher nutrient and turbidity levels.	4

C13 EWR 4: MAC MAC (MAC MAC RIVER)

C13.1 DATA AVAILABILITY

Data availability	Conf
DWAF monitoring data for RC and PES. Limited phytoplankton, periphyton + diatoms (n = 1). No temperature, DO or turbidity data. Little metal data. EC used instead of aggregated salts (as TEACHA could not be used).	3

C13.2 REFERENCE CONDITIONS

Reference conditions	Conf
DWAF monitoring data: X3H003Q01; n = 48, 1977 – 1979.	2.5

Water Quality Constituents		Value: RC
Inorganic salts (mg/L)	No data available.	
Nutrients (mg/L)	Soluble Reactive Phosphate (SRP)	0.011
	Total Inorganic Nitrogen (TIN)	0.25
Physical variables	pH (5^{th}+95^{th} percentiles)	6.5+7.5
	Electrical conductivity (mS/m)	14.5

C13.3 RESULTS

The PAI and water quality tables, which are completed as part of the assessment and assigns the EcoStatus rating for water quality, are shown below as Tables C29 and C30.

Table C29 Water quality table for EWR 4

RIVER	Mac Mac River	**Water Quality Monitoring Points**	
WQSU	1, Mac Mac River	**RC**	X3H003Q01, ’77-’79, n=48
EWR SITE	4	**PES**	X3H003Q01, ’04-’07, n=56
Confidence assessment	Confidence in the assessment is **moderate**, as little DO, temp., turbidity or metal data.		

Water Quality Constituents		Value	Category (Rating) / Comment
Inorganic salts (mg/L)	$MgSO_4$	-	TEACHA could not be used and EC used as surrogate.
	Na_2SO_4	-	
	$MgCl_2$	-	
	$CaCl_2$	-	
	NaCl	-	
	$CaSO_4$	-	
Nutrients (mg/L)	SRP	0.013	B (1)
	TIN	0.28	B (1)
Physical variables	pH (5^{th}-95^{th} percentile)	7.2-7.9	A (0)
	Temperature	-	Not considered a problem as there are no thermal impacts and not downstream of a dam. Temperature levels may increase due to boulder- and bedrock-dominated and altitude. Some turbidity due to surrounding forestry-related activities.
	Dissolved oxygen	-	
	Turbidity (NTU)	-	

	Electrical conductivity (mS/m)	15.43	A (0)
Response variable	Chl-a: periphyton	57.85	D (3) (n=1)
	Chl-a: phytoplankton	1.36	A (0) (n=1)
	Biotic community composition: macroinvertebrate (ASPT) score	6.4	
	Diatoms	SPI=14	B (1) (n=1)
OVERALL SITE CLASSIFICATION (from PAI)		**A/B (89.32)**	

The present state of the water quality at EWR 4 is scored as an **A / B category** (see Table C30). Due to the data available, the assessment is of **moderate** confidence.

Table C30 EWR 4: PAI

Physico-chemical Metrics	Rank	%wt	Rating	Conf
pH	4	60	0.00	4.00
SALTS	4	60	0.00	3.00
NUTRIENTS	2	90	1.50	3.00
TEMPERATURE	1	100	1.00	4.00
TURBIDITY	3	80	1.00	3.00
OXYGEN	1	100	0.00	5.00
TOXICS	1	100	0.00	5.00
PHYSICO-CHEMICAL PERCENTAGE SCORE	**89.32**			
PHYSICO-CHEMICAL CATEGORY	**A/B**			
BOUNDARY CATEGORY				

Notes

- Nutrients: Periphyton + diatoms (n = 1 for both indicators) indicate some pollution, probably due to the output from Graskop Sewage Treatment Works (STW).
- Temperature: Boulder-bedrock system so elevated temperatures expected, although most of the channel is well-shaded.
- Toxics: Venus sawmill not expected to contribute much to toxicity. Physical impacts of wood-chips layering the streambed should be guarded against.

C13.3.1 PES causes and sources

PES	Causes	Sources	F/NF	Conf
A/B	Elevated nutrients.	Wastewater input to the river, e.g. Graskop WWTW which disposes to the Mac Mac River.	NF	3

C13.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
A/B	Negative	B	5 yrs	The diatom community shows traces of the onset of severe water quality impacts with the presence of *E. minima*, *N. veneta*, *N. tenelloides*, *N. frustulum* and *N. palea*. Graskop WWTW may be exacerbating conditions at the site.	3

C13.5 REC: A/B

PES	REC	Comments	Conf
A/B	A	Improve nutrient levels and reduce temperature increases with more flow.	3

C13.6 AEC: C

PES	AEC	Comments	Conf
A/B	B/C	Increased nutrient loads from Graskop WWTW at lower flows will exacerbate problems relating to Temp, DO and nutrient input and lead to a drop in EC.	4

C14 EWR 5: MARITE (MARITE RIVER)

C14.1 DATA AVAILABILITY

Data availability	Conf
DWAF monitoring data for RC and PES. Limited phytoplankton, periphyton + diatoms (n = 1). No DO data. Limited temperature and turbidity data from Week *et al*. (1995). Use of Water Quality on CD to provide information for some variables. EC used instead of aggregated salts (as TEACHA could not be used).	3

C14.2 REFERENCE CONDITIONS

Reference conditions	Conf
DWAF monitoring data: X3H011Q01; n=84, 1979 - 1981.	3

Water Quality Constituents		Value: RC
Inorganic salts (mg/L)	No data available.	
Nutrients (mg/L)	Soluble Reactive Phosphate (SRP)	0.005
	Total Inorganic Nitrogen (TIN)	0.08
Physical variables	pH (5^{th}+95^{th} percentiles)	6.2+7.4
	Turbidity (NTU)	-
	Electrical conductivity (mS/m)	25.6

C14.3 RESULTS

The PAI and water quality tables, which are completed as part of the assessment and assigns the EcoStatus rating for water quality, are shown below as Tables C31 and C32.

Table C31 Water quality table for EWR 5

RIVER	Marite River	**Water Quality Monitoring Points**	
WQSU	2, Marite River	**RC**	X3H011Q01, ’79-’81, n=84
EWR SITE	5	**PES**	X3H011Q01, ’04-’07, n=129
Confidence assessment	Confidence in the assessment is **moderate-high**, as little DO, temp., turbidity or metal data.		
Water Quality Constituents		**Value**	**Category (Rating) / Comment**
Inorganic salts (mg/L)	$MgSO_4$	-	TEACHA could not be used and EC used as surrogate.
	Na_2SO_4	-	
	$MgCl_2$	-	
	$CaCl_2$	-	
	NaCl	-	
	$CaSO_4$	-	
Nutrients (mg/L)	SRP	0.013	B (1)
	TIN	0.28	B (1)
Physical variables	pH (5^{th}-95^{th} percentile)	7-7.9	A (0) as natural category was re-benchmarked
	Temperature	-	Some temperature data from Weeks et al.

	Dissolved oxygen	-	('95). Site downstream of Inyaka Dam. (assumed constant release from multi-level outlets. Dam completed 1999)
	Turbidity (NTU)	Mean: 12 NTU Maximum value: 30 NTU (Weeks et al., 1995)	Due to constant release, turbidity levels now low most of the time.
	Electrical conductivity (mS/m)	8.9	A (0)
Response variable	Chl-a: periphyton	57.85	D (3) (n=1)
	Chl-a: phytoplankton	1.57	A (0) (n=1)
	Biotic community composition: macroinvertebrate (ASPT) score	6.4	
	Diatoms	SPI=19.4	A (0) (n=1)
OVERALL SITE CLASSIFICATION (from PAI)		**B (84.44)**	

The present state of the water quality at EWR 5 is scored as a **B category** (see Table C32). Due to the data available, the assessment is of **moderate-high** confidence.

Table C32 EWR 5: PAI

Physico-chemical Metrics	Rank	%wt	Rating	Conf
pH	4	50	0.00	4.00
SALTS	4	50	0.00	4.00
NUTRIENTS	3	60	1.50	4.00
TEMPERATURE	1	100	1.00	4.00
TURBIDITY	2	80	1.00	3.00
OXYGEN	1	100	1.00	4.00
TOXICS	1	100	0.50	5.00
PHYSICO-CHEMICAL PERCENTAGE SCORE	**84.44**			
PHYSICO-CHEMICAL CATEGORY	**B**			
BOUNDARY CATEGORY				

Notes

- Nutrients: Periphyton + diatoms (n = 1 for both indicators) indicate some pollution.
- Turbidity: Disturbed catchment downstream of Inyaka Dam, with extensive clearing for subsistence use, but due to constant releases from Inyaka Dam, turbidity levels stay low.
- Toxics: Extensive citrus cultivation in the area, so some toxics expected.
- Temperature and oxygen: Site downstream of Inyaka Dam, although a constant release from the dam.

C14.3.1 PES causes and sources

PES	Causes	Sources	F/NF	Conf
B	Increased suspended solids loads. Elevated nutrients and toxics. Temperature and oxygen fluctuations at low flows.	Extensive citrus cultivation in the area. Clearing for subsistence farming. The diatom *A. minutissimum* indicates anthropogenic disturbances and the presence of diffuse pollutants (upstream citrus farming).	NF	3

C14.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
B	Stable	B		Although extensive activities in the area, the water quality status seem stable.	3

C14.5 REC: B

PES	REC	Comments	Conf
B	B	No changes are expected under this scenario.	N/A

C14.6 AEC: C/D

PES	AEC	Comments	Conf
B	C	No EWR release and fewer floods would result in less dilution of toxics, higher build-up of nutrients and an expected small increase in turbidity levels.	4

C15 EWR 6: MUTLUMUVI (MUTLUMUVI RIVER)

C15.1 DATA AVAILABILITY

Data availability	Conf
DWAF monitoring data for RC and PES at X3H008Q01 used, and present state extrapolated from EWR8. Limited phytoplankton + diatoms (n = 1). No temperature, DO or turbidity data. Little metal data. EC used instead of aggregated salts (as TEACHA could not be used).	2

C15.2 REFERENCE CONDITIONS

Reference conditions	Conf
DWAF monitoring data: X3H011Q01; n = 84, 1979 – 1981.	3

Water Quality Constituents		Value: RC
Inorganic salts (mg/L)	No data available.	
Nutrients (mg/L)	Soluble Reactive Phosphate (SRP)	0.025
	Total Inorganic Nitrogen (TIN)	0.081
Physical variables	pH (5th+95th percentiles)	6.83+7.70
	Electrical conductivity (mS/m)	12.48

C15.3 RESULTS

The PAI and water quality tables, which are completed as part of the assessment and assigns the EcoStatus rating for water quality, are shown below as Tables C33 and C34.

Table C33 Water quality table for EWR 6

RIVER	Mutlumuvi River	**Water Quality Monitoring Points**	
WQSU	1, Sand River	**RC**	X3H008Q01, '77-'79, n=50
EWR SITE	6	**PES**	X3H008Q01, '03-'06, n=44
Confidence assessment	Confidence in the assessment is **low**, as little DO, temp., turbidity or metal data. Data only available to 2006. Extrapolating from X3H008Q01 on the Sand River + using on-site data.		

Water Quality Constituents		Value	Category (Rating) / Comment
Inorganic salts (mg/L)	$MgSO_4$	-	TEACHA could not be used and EC used as surrogate.
	Na_2SO_4	-	
	$MgCl_2$	-	
	$CaCl_2$	-	
	NaCl	-	
	$CaSO_4$	-	
Nutrients (mg/L)	SRP	0.032 (<0.02: on-site, Nov 07)	B (1) as natural category was re-benchmarked. System seems naturally eutrophic.
	TIN	0.45 (1.933: on-site, Nov 07)	B (1)
Physical variables	pH (5th-95th percentile)	7.46-8.12	B (1)
	Temperature	-	Temperature not considered a problem

	Dissolved oxygen	-	as there are no thermal impacts and not downstream of a dam. However the river is alluvial in places, which would exacerbate temperature and oxygen fluctuations. Poor land management results in elevated turbidity levels.
	Turbidity (NTU)	-	
	Electrical conductivity (mS/m)	35.1 (18.7: on-site, Nov 07)	B (1)
Response variable	Chl-a: periphyton	-	
	Chl-a: phytoplankton	0.35	A (0) (n=1)
	Biotic community composition: macroinvertebrate (ASPT) score	5.9	
	Diatoms	SPI=15.6	B (1) (n=1)
OVERALL SITE CLASSIFICATION (from PAI)		**B/C (80.92)**	

The present state of the water quality at EWR 6 is scored as a **B / C category** (see Table C34). Due to the data available, the assessment is of **low** confidence.

Table C34 EWR 6: PAI

Physico-chemical Metrics	Rank	%wt	Rating	Conf
pH	4	50	1.00	4.00
SALTS	4	50	1.00	4.00
NUTRIENTS	3	80	1.50	3.00
TEMPERATURE	2	95	1.00	3.00
TURBIDITY	4	70	1.50	3.00
OXYGEN	1	100	1.00	4.00
TOXICS	1	100	0.00	5.00
PHYSICO-CHEMICAL PERCENTAGE SCORE	**80.92**			
PHYSICO-CHEMICAL CATEGORY	**B/C**			
BOUNDARY CATEGORY				

Notes

- Nutrients: Indicators (n = 1) indicate some pollution.
- Turbidity: Some turbidity expected due to catchment activities.
- Temperature and oxygen: As the river stops flowing, temperature and oxygen fluctuations will take place.

C15.3.1 PES causes and sources

PES	Causes	Sources	F/NF	Conf
B/C	Elevated nutrient levels. Elevated turbidity and temperature. Reduced oxygen levels.	Subsistence farming and extensive urban/rural settlements. Some forestry activities.	NF	2

C15.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
B/C	Stable	B/C	Short term	The presence of pollution tolerant diatom species, although in very small numbers, indicates that upstream anthropogenic activities may be impacting slightly on this EWR site.	2

C15.5 REC: B

PES	REC	Comments	Conf
B/C	B/C	This scenario will maintain the current EC.	N/A

C15.6 AEC: C/D

PES	AEC	Comments	Conf
B/C	C/D	A deterioration in land management will result in higher nutrient and turbidity levels. Use of fertilizers and pesticides will lead to the presence of toxics in the system. Interruptions in flow will result in oxygen and temperature fluctuations.	3

C16 EWR 7: TLULANDZITEKA (TLULANDZITEKA RIVER)

C16.1 DATA AVAILABILITY

Data availability	Conf
DWAF monitoring data for RC and PES at X3H008Q01 used, and present state extrapolated from EWR8. Limited phytoplankton, periphyton + diatoms (n = 1). No temperature, DO or turbidity data. Little metal data. EC used instead of aggregated salts (as TEACHA could not be used).	2

C16.2 REFERENCE CONDITIONS

Reference conditions	Conf
DWAF monitoring data: X3H008Q01; n = 82, 1977 – 1979.	2

Water Quality Constituents		Value: RC
Inorganic salts (mg/L)	No data available.	
Nutrients (mg/L)	Soluble Reactive Phosphate (SRP)	0.025
	Total Inorganic Nitrogen (TIN)	0.081
Physical variables	pH (5^{th}+95^{th} percentiles)	6.83+7.70
	Electrical conductivity (mS/m)	12.48

C16.3 RESULTS

The PAI and water quality tables, which are completed as part of the assessment and assigns the EcoStatus rating for water quality, are shown below as Tables C35 and C36.

Table C35 Water quality table for EWR 7

RIVER	Tlulandziteka River	**Water Quality Monitoring Points**	
WQSU	2, Sand River	**RC**	X3H008Q01, ’77-’79, n=50
EWR SITE	7	**PES**	X3H008Q01, ’03-’06, n=44
Confidence assessment	Confidence in the assessment is **low**, as little DO, temp., turbidity or metal data. Data only available to 2006. Extrapolating from X3H008Q01 on the Sand River + using on-site data.		
Water Quality Constituents		**Value**	**Category (Rating) / Comment**
Inorganic salts (mg/L)	$MgSO_4$	-	TEACHA could not be used and EC used as surrogate.
	Na_2SO_4	-	
	$MgCl_2$	-	
	$CaCl_2$	-	
	NaCl	-	
	$CaSO_4$	-	
Nutrients (mg/L)	SRP	0.032	B (1) as natural category was re-benchmarked. System seems naturally eutrophic.
	TIN	0.45 (0.57: on-site, Nov 07)	B (1)
Physical variables	pH (5^{th}-95^{th} percentile)	7.46-8.12	B (1)
	Temperature	-	Site is downstream of Kasteel Dam on a

	Dissolved oxygen	-	tributary. Temperature and oxygen fluctuations fluctuations expected due to changes in flow.
	Turbidity (NTU)	-	
	Electrical conductivity (mS/m)	35.1 (8.9: on-site, Nov 07)	B (1)
Response variable	Chl-a: periphyton	54.05	D (3) (n=1)
	Chl-a: phytoplankton	1.59	A (0) (n=1)
	Biotic community composition: macroinvertebrate (ASPT) score	6.2	
	Diatoms	SPI=12.8	B/C (1.5) (n=1)
OVERALL SITE CLASSIFICATION (from PAI)		**C (76.6)**	

The present state of the water quality at EWR 7 is scored as a **C category** (see Table C36). Due to the data available, the assessment is of **low** confidence.

Table C36 EWR 7: PAI

Physico-chemical Metrics	Rank	%wt	Rating	Conf
pH	5	50	1.00	4.00
SALTS	5	50	1.00	4.00
NUTRIENTS	4	60	2.00	3.00
TEMPERATURE	2	90	1.00	3.00
TURBIDITY	3	80	2.00	3.00
OXYGEN	1	100	1.00	4.00
TOXICS	1	100	0.50	5.00
PHYSICO-CHEMICAL PERCENTAGE SCORE	**76.60**			
PHYSICO-CHEMICAL CATEGORY	**C**			
BOUNDARY CATEGORY				

Notes

- Nutrients: Periphyton + diatoms (n = 1 for both indicators) indicate some pollution.
- Turbidity: Poor land management results in elevated turbidities.
- Toxics: Agricultural and forestry activities will probably result in an increase in toxics.
- Impacts on temperature and oxygen seen due to fluctuating flows.

C16.3.1 PES causes and sources

PES	Causes	Sources	F/NF	Conf
C	Elevated nutrients and turbidity levels. Low flows impact on oxygen and temperature levels.	Poor land management in the catchment. No releases from upstream dam.	NF	2

C16.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
Upper C	Negative	Lower C	5 yrs	Diatom indicators suggest natural/anthropogenic disturbances and indicate the presence of diffuse pollutants at the site.	2

C16.5 AEC: B

PES	AEC	Comments	Conf
C	B	Improved flows will assist in reducing nutrient levels, and reduce fluctuations in temperature and oxygen. Improved land management will drop turbidity levels.	2

C16.6 AEC: D

PES	AEC	COMMENTS	CONF
C	D	These changes would result in elevated nutrients, toxics and turbidity levels; and greater fluctuations in temperature and oxygen levels. Under these conditions of less dilution, salt levels are also expected to increase.	2

C17 EWR 8: LOWER SAND (SAND RIVER)

C17.1 DATA AVAILABILITY

Data availability	Conf
DWAF monitoring data for RC and PES, but present state data only until 2006. Limited diatom data (n = 1); no peri - or phytoplankton data. No DO and metal data. Limited temperature and turbidity data from Week *et al*. (1995). EC used instead of aggregated salts (as TEACHA could not be used).	3

C17.2 REFERENCE CONDITIONS

Reference conditions	Conf
DWAF monitoring data: X3H008Q01; n = 82, 1977 – 1979. .	3

Water Quality Constituents		Value: RC
Inorganic salts (mg/L)	No data available.	
Nutrients (mg/L)	Soluble Reactive Phosphate (SRP)	0.025
	Total Inorganic Nitrogen (TIN)	0.081
Physical variables	pH (5^{th}+95^{th} percentiles)	6.83+7.70
	Turbidity (NTU)	-
	Electrical conductivity (mS/m)	12.48

C17.3 RESULTS

The PAI and water quality tables, which are completed as part of the assessment and assigns the EcoStatus rating for water quality, are shown below as Tables C37 and C38.

Table C37 Water quality table for EWR 8

RIVER	Sand River	**Water Quality Monitoring Points**	
WQSU	4, Sand River	**RC**	X3H008Q01, ’77-’79, n=50
EWR SITE	8	**PES**	X3H008Q01, ’03-’06, n=44
Confidence assessment	Confidence in the assessment is **moderate**, as little DO, temp., turbidity or metal data. Data only available to 2006.		

Water Quality Constituents		Value	Category (Rating) / Comment
Inorganic salts (mg/L)	$MgSO_4$	-	TEACHA could not be used and EC used as surrogate.
	Na_2SO_4	-	
	$MgCl_2$	-	
	$CaCl_2$	-	
	NaCl	-	
	$CaSO_4$	-	
Nutrients (mg/L)	SRP	0.032	B (1) as natural category was re-benchmarked. System seems naturally eutrophic.
	TIN	0.45	B (1)
Physical variables	pH (5^{th}-95^{th} percentile)	7.46-8.12	B (1)
	Temperature	-	Temperature not considered a problem as there are no thermal impacts and not
	Dissolved oxygen	-	

	Turbidity (NTU)	Mean: 27 NTU Maximum value: 70 NTU (Weeks et al., 1995)	downstream of a dam. However the river is alluvial and experiences low flows, which would exacerbate temperature and oxygen fluctuations.
	Electrical conductivity (mS/m)	35.1	B (1)
Response variable	Chl-a: periphyton	-	
	Chl-a: phytoplankton	-	
	Biotic community composition: macroinvertebrate (ASPT) score	5.3	
	Diatoms	SPI=13.4	B (1) (n=1)
OVERALL SITE CLASSIFICATION (from PAI)		**B (84.48)**	

The present state of the water quality at EWR 1 is scored as a **B category** (see Table C38). Due to the data available, the assessment is of **moderate** confidence, although no present state data exists for 2007. Data from DWAF's Water Management System (WMS) has been checked against SabiSand Wildtuin on-site data collection (contact: Jonathan Swart).

Table C38 EWR 8: PAI

Physico-chemical Metrics	Rank	%wt	Rating	Conf
pH	6	40	1.00	4.00
SALTS	5	50	1.00	4.00
NUTRIENTS	3	80	1.00	3.00
TEMPERATURE	1	100	1.00	5.00
TURBIDITY	4	60	1.50	4.00
OXYGEN	2	95	0.50	4.00
TOXICS	1	100	0.00	5.00
PHYSICO-CHEMICAL PERCENTAGE SCORE	**84.48**			
PHYSICO-CHEMICAL CATEGORY	**B**			
BOUNDARY CATEGORY				

Notes

- Nutrients: Diatoms indicate some pollution due to upstream catchment activities.
- Turbidity: Some turbidity expected due to catchment activities. Pools have filled up due to sedimentation (Kleynhans and Swart, pers. comm.).
- Temperature and oxygen: Fluctuations expected due to low flows in winter.

C17.3.1 PES causes and sources

PES	Causes	Sources	F/NF	Conf
B	Elevated nutrients, turbidity levels and temperatures at low flows. Oxygen levels drop at low flows.	Although this site is in a conservation area (the KNP), poor land management upstream is affecting the site.	NF	3

C17.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
B	Stable	B		N/A	3

C17.5 AEC: C

PES	AEC	Comments	Conf
B	C	Lower and longer low flow periods, resulting in more extreme temperature and oxygen fluctuations, and higher nutrient loadings.	3

C18 REFERENCES

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APPENDIX D: DIATOM ANALYSIS AS AN ADDITIONAL PHYSICO-CHEMICAL RESPONS VARIABLE

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D1 BACKGROUND AND TERMINOLOGY

D1.1 BACKGROUND

Koekemoer Aquatic Services was approached by WFA to analyse diatom samples taken at the 15 EWR sites as part of the Comprehensive Reserve determination study for the Incomati river system during September and October 2007. The diatom assessment was conducted following a baseline aquatic health assessment in the area, which focused on fish and invertebrates. The aim of the diatom study is to provide additional information concerning the aquatic health and functioning of the River systems, as an extra biomonitoring tool.

Diatoms are of great ecological importance because of their role as primary producers, and form the base of the aquatic food web. They usually account for the highest number of species among the primary producers in aquatic systems (Leira, 2005). Diatoms are photosynthetic unicellular organisms and are found in almost all aquatic and semi-aquatic habitats.

Diatoms are a siliceous class (*Bacilariophyceae* of the phylum *Bacilariophyt*a) of algae. A remarkable aspect of diatoms is their silicon dioxide cell walls. The cell walls are perforated and ornamented with many holes, which are arranged in defined and unique patterns. Identification is based on the nature of these perforations as well as their orientation and densities.

Recent studies, as well as studies in progress, have identified diatoms as useful organisms to include in the suite of biomonitoring tools currently used in South Africa (Bate *et al*., 2002, De la Rey *et al*., 2004, Taylor, 2004) both for assessments of current water quality and for establishing historical conditions in rivers in South Africa (Taylor *et al*., 2005a).

Diatoms have been shown to be reliable indicators of specific water quality problems such as organic pollution, eutrophication, acidification and metal pollution (Rott 1991, Tilman *et al*., 1982, Dixit *et al*., 1992, Cattaneo *et al.,* 2004), as well as for general water quality (AFNOR, 2000). The reasons why diatoms are useful tools for biomonitoring are listed by Round (1993):

- Diatoms have a universal occurrence throughout all rivers;
- Field sampling is rapid and easy;
- Cell cycle is rapid and they react quickly to perturbation;
- Diatoms are relatively insensitive to physical features in the environment;
- Cell counting by microscopic techniques is rapid and accurate;
- Cell numbers per unit area of substratum are enormous, making random counts excellent assessments of diatoms;
- The ecological requirements of diatoms are in many cases better known than those of any other group of riverine organisms;
- Permanent records can be made from every sample;
- Diatoms do not have specific food requirements, specialised habitat niches, and are not governed to a major extent by stream flow.

The specific water quality tolerances of diatoms have been resolved into different diatom-based water quality indices, used around the world. In general, each diatom species used in the calculation of the index is assigned two values; the first value reflects the tolerance or affinity of the particular diatom species to a certain water quality (good or bad) while the second value indicates how strong (or weak) the relationship is. These values are then weighted by the abundance of the particular diatom species in the sample. The diatom index used in the present study is known as the Specific Pollution sensitivity Index (SPI; (Coste in CEMAGREF, 1982), one of the most extensively tested indices in Europe.

Diatom-based water quality indices have recently been evaluated and implemented in South Africa (Taylor 2004, River Health Programme, 2005). De la Rey *et al*. (2004) and Taylor (2004) showed that diatom-based pollution indices may be good bio-indicators of water quality in aquatic ecosystems in South Africa by demonstrating a measurable relationship between water quality variables such as pH, electrical conductivity, phosphorus and nitrogen, and the structure of diatom communities as reflected by diatom index scores.

The close association between diatom community composition and water quality allows for inferences to be drawn about water quality.

D1.2 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)

D2 METHODS

D2.1 SAMPLING

Epilithic diatom samples were taken at EWR 1, 2, 3, 5, and 7 (Crocodile system), and EWR 1 - 6 (Sabie system) from submerged rocks on the riverbed. Epiphytic diatom samples were taken at EWR 4 and 6 due to high flows (EWR 4) and the absence of rocks at EWR 6 for the Crocodile system and at EWR 7 and 8 on the Sabie system due the absence of rocks.

Epilithon and Epiphyton were sampled as outlined Taylor *et al*., 2005b and Taylor *et al*., 2007a. These methods were designed and refined as part of the Diatom Assessment Protocol (DAP), a Water Research Commission (WRC) initiative. Taylor *et al.,* 2007a, have based the method manual on several key documents including Kelly *et al.* (1998), CEN (2003), DARES (2004) and Taylor *et al.,* 2005b. Diatom samples were taken at each site by scrubbing the substrate with a small brush and rinsing both the brush and the substrate with distilled water. Samples were taken from five or more cobbles (diameter > 64, ≤ 265 mm).

D2.2 ANALYSIS

Preparation of diatom slides followed the Hot HCl and $KMnO_4$ method as outlined in Taylor *et al.,* 2005b. Counts of diatom valves on slides were made using a Zeiss microscope with phase contrast optics (1000x). The aim of the data analysis was to count diatom valves to produce semi-quantitative data from which ecological conclusions can be drawn (Taylor *et al*., 2007a). Schoeman, (1973) and Battarbee (1986) concluded that a count of 400 valves per slide is satisfactory for the calculation of relative abundance of diatom species and this range is supported by Prygiel *et al.* (2002), according to Taylor *et al*. (2007a). Therefore a count of 400 valves per sample or more was counted and the nomenclature followed Krammer and Lange-Bertalot (1986 - 91). Diatom index values were calculated in the database programme OMNIDIA (Lecointe *et al.*, 1993) for epilithon and epiphyton data in order to generate index scores to general water quality variables.

D2.3 DIATOM BASED WATER QUALITY SCORES

The European numerical diatom index, the Specific Pollution sensitivity Index (SPI) was used to interpret results. De la Rey *et al.*, 2004, concluded that the SPI reflects certain elements of water quality with a high degree of accuracy due to the broad species base of the SPI. The Prygiel and Coste (2000) class boundaries were adapted for the Reserve studies to accommodate boundary ECs and applied during the interpretation of the results. The interpretation of the SPI scores is given in Table D1.

Table D1 Adjusted class limit boundaries for the SPI index applied in this study

SPI score	Class	Ecological Category
>17.3	HIGH QUALITY	A
16.8 – 17.2		A/B
13.3 – 16.7	GOOD QUALITY	B
12.9 – 13.2		B/C
9.2 – 12.8	MODERATE QUALITY	C
8.9 – 9.1		C/D
5.3 – 8.8	POOR QUALITY	D
4.8 – 5.2		D/E
< 4.8	BAD QUALITY	E

D3 RESULTS: CROCODILE RIVER SYSTEM

D3.1 SAMPLING SITES

Details of the sampling sites are given in Table D2.

Table D2 Diatom sampling sites

Sample number	Site	River	Co-ordinates		Resource Unit	Water Quality Sub Unit
			South	East		
618	EWR 1	Crocodile River	S25 29.647	E30 08.656	MRU A	WQSU2
619	EWR 2	Crocodile River	S25 24.555	E30 18.955	MRU A	WQSU2
620	EWR 3	Crocodile River	S25 27.127	E30 40.865	MRU B	WQSU3
621	EWR 4	Crocodile River	S25 30.146	E31 10.919	MRU D	WQSU4
622	EWR 5	Crocodile River	S25 28.972	E31 30.464	MRU E	WQSU6
623	EWR 6	Crocodile River	S25 23.430	E31 58.467	MRU E	WQSU6
624	EWR 7	Kaap River	S25 38.968	E31 14.572	MRU A	WQSU7

The main land use activities in the different Resource Units are given in Table D3.

Table D3 Main land use activities in the Resource Units

Resource Unit	Land use activities[1]
MRU A	Land-cover is largely grassland with some agricultural, forestry and urban activities, e.g. trout-farming around Dullstroom.
MRU B	Land-cover is farming (largely citrus), with alien vegetation, plantations and urban settlements present. Sappi Ngodwana is located on the Elands River system, with associated pollution problems.
MRU D	Land-cover is farming (largely citrus), with extensive alien vegetation, plantations and urban settlements and associated activities present, i.e. Nelspruit and KaNyamazane. A number of hazardous waste sites, mines and processing plants are found in the area. The polluted Wit River enters the Crocodile River in this WQSU.
MRU E	Land-cover is urban areas and associated impacts, extensive irrigation of sugar-cane, Selati sugar mill, forestry, agriculture e.g. banana and citrus plantations, citrus processing, conservation activities i.e. KNP, recreation i.e. lodges.
MRU A (Kaap River)	Land-cover is farming (e.g. paw-paws, bananas, sugar cane), sawmill and pole treating in the vicinity and mining upstream. Pollution sources from upstream users include irrigation, urban areas and old gold mining activities.

1 Information obtained from DWAF 2008, Appendix C (This report).

D3.2 DIATOM ASSEMBLAGE

The diatom abundances of the different EWR sites are given in Table D4.

Table D4 Diatom species assemblage and abundances of samples for each EWR site

Species	Site and sample number						
	EWR 1	EWR 2	EWR 3	EWR 4	EWR 5	EWR 6	EWR 7
	618	619	620	621	622	623	624
Achnanthes crassa Hustedt	7	13	5			1	
Achnanthes lanceolata (Breb.) Grun. *ssp. frequentissima* Lange-Bertalot		1				3	
Achnanthes minutissima Kutzing *v.minutissima* Kutzing (Achnanthidium)	140*	151	9	2	4	34	186
Achnanthes minutissima Kutzing *.saprophila* Kobayasi et Mayama	20	52	40	7	4		51
Achnanthes standerii Cholnoky	88	1					
Achnanthes subaffinis Cholnoky	15	23	6			3	
Achnanthidium affine (Grun) Czarnecki						12	16
Achnanthidium exiguum (Grunow) Czarnecki	1					3	
Amphora normanii Rabenhorst						2	
Amphora pediculus (Kutzing) Grunow							7
Aulacoseira granulata (Ehr.) Simonsen					7		
Aulacoseira granulata (Ehr.) Simonsen *.angustissima* (O.M.)Simonsen					20		
Craticula molestiformis (Hustedt) Lange-Bertalot		3	2	3	1	2	1
Cocconeis pediculus Ehrenberg			36	8	1	15	44
Cocconeis placentula Ehrenberg *placentula*		3	149	92	5	194	16
Cocconeis placentula Ehrenberg *pseudolineata* Geitler		2	1	3			
Cocconeis placentula Ehrenberg *euglypta* (Ehr.)Grunow			4	35			
Craticula halophila (Grunow ex Van Heurck) Mann						1	
Craticula vixnegligenda Lange-Bertalot	8	5					
Cyclostephanos dubius (Fricke) Round					27		
Cyclostephanos invisitatus (Hohn & Hellerman)Theriot Stoermer & Hakansson				1	53		1
Cyclotella ocellata Pantocsek			4	1	1		
Cymatopleura solea (Brebisson) W.Smith var.solea		1					
Cymbella affinis Kutzing var.affinis	1	4				3	1
Cymbella aspera (Ehrenberg) H.Peragallo		1					
Cymbella kappii (Cholnoky) Cholnoky							2
Cymbella minuta Hilse ex Rabenhorst (Encyonema)	1	2					
Cymbella simonsenii Krammer	1						
Cymbella symbiformis							2
Cymbella tumida (Brebisson)Van Heurck				1	1		1
Cymbella ventricosa Agardh			3				
Denticula kuetzingii Grunow var.kuetzingii		42					8
Diadesmis confervacea Kützing				2			
Diatoma vulgaris Bory 1824				3	196		
Diploneis puella (Schumann) Cleve		1					
Diploneis smithii (Brebisson) Cleve var. smithii	2						
Encyonopsis leei Krammer var. sinensis Metzeltin & Krammer	28	7	57				
Encyonopsis microcephala (Grunow) Krammer		5					
Encyonopsis subminuta Krammer & Reichardt	30	15	1				1
Eolimna minima (Grunow) Lange-Bertalot	4		7	6			4
Eolimna subminuscula (Manguin) Moser Lange-Bertalot & Metzeltin			1	47		3	4
Epithemia adnata (Kutzing) Brebisson			7				
Eunotia minor (Kutzing) Grunow in Van Heurck		4		3	1		
Fallacia monoculata (Hustedt) D.G. Mann						2	1
Fistulifera saprophila (Lange-Bertalot & Bonik) Lange-Bertalot				53		7	
Fragilaria biceps (Kutzing) Lange-Bertalot						11	
Fragilaria brevistriata Grunow (Pseudostaurosira)	2						
Fragilaria capucina Desmazieres *vaucheriae* (Kutzing)Lange-Bertalot	13				8		

Species	Site and sample number						
	EWR 1	EWR 2	EWR 3	EWR 4	EWR 5	EWR 6	EWR 7
	618	619	620	621	622	623	624
Fragilaria fasciculata (C.A. Agardh) Lange-Bertalot sensu lato	2						
Fragilaria pinnata Ehrenberg *pinnata* (Staurosirella)	1						
Fragilaria tenera (W.Smith) Lange-Bertalot		4			1		
Fragilaria ulna (Nitzsch.) Lange-Bertalot var. ulna		1					
Frustulia vulgaris (Thwaites) De Toni	2						
Frustulia weinholdii Hustedt		1					
Gomphonema affine Kutzing						6	
Gomphonema minutum (Ag.) Agardh *f. minutum*		2	3			24	
Gomphonema parvulum (Kützing) Kützing *parvulum f. parvulum*		2		7	2	5	3
Gomphonema parvulum var.lagenula (Kutz.) Frenguelli				1		1	
Gomphonema parvulum var.parvulius Lange-Bertalot & Reichardt	1						
Gomphonema parvulum parvulum f.saprophilum Lange-Bert.&Reichardt				3			
Gomphonema pumilum (Grunow) Reichardt & Lange-Bertalot				1		3	5
Gomphonema species		12	15	3		13	8
Gomphonema ventricosum Gregory						5	
Gomphonema venusta Passy. Kociolek & Lowe	4		21	1			1
Melosira varians Agardh				1	5		
Navicula antonii Lange-Bertalot				1			
Navicula arvensis Hustedt *maior* Lange-Bertalot	2						
Navicula capitatoradiata Germain	1	4	3	7	1	1	
Navicula cryptocephala Kutzing	3		1		1	3	
Navicula cryptotenella Lange-Bertalot		1					
Navicula dutoitana			5				
Navicula gregaria Donkin		2		2			
Navicula microcari Lange-Bertalot						1	
Navicula radiosa Kützing							2
Navicula recens (Lange-Bertalot) Lange-Bertalot						3	
Navicula schroeteri Meister *schroeteri*						2	
Navicula schroeteri Meister *symmetrica* (Patrick) Lange-Bertalot			4	6			2
Navicula tenelloides Hustedt		5					
Navicula tripunctata (O.F.Müller) Bory					5		
Navicula trivialis Lange-Bertalot var. trivialis		1					
Navicula veneta Kutzing	2			2		17	1
Navicula viridula (Kutzing) Ehrenberg				7			
Navicula zanoni Hustedt				2	4		3
Nitzschia acicularis (Kutzing) W.M.Smith	3	4					
Nitzschia agnita Hustedt	1						
Nitzschia amphibia Grunow *f.amphibia*			1	8		4	1
Nitzschia aurariae Cholnoky				1			
Nitzschia capitellata Hustedt in A.Schmidt & al.				2			
Nitzschia communis Rabenhorst	1						
Nitzschia dissipata (Kutzing) Grunow *media* (Hantzsch.) Grunow	2						
Nitzschia dissipata (Kutzing)Grunow *dissipata*	3	5	18	4	13		1
Nitzschia etoshensis Cholnoky				1			
Nitzschia filiformis (W.M.Smith) Van Heurck *filiformis*				2			
Nitzschia frustulum (Kutzing) Grunow *frustulum*			1	1		3	
Nitzschia gracilis Hantzsch	1						
Nitzschia heufleriana Grunow							4
Nitzschia intermedia Hantzsch ex Cleve & Grunow				1			
Nitzschia liebetruthii Rabenhorst *liebetruthii*			2	3	1	1	
Nitzschia linearis (Agardh) W.M.Smith *linearis*	1	4					

Species	Site and sample number						
	EWR 1	EWR 2	EWR 3	EWR 4	EWR 5	EWR 6	EWR 7
	618	619	620	621	622	623	624
Nitzschia linearis (Agardh) W.M.Smith *subtilis* (Grunow) Hustedt	4						
Nitzschia obtusa W.M.Smith *kurzii* (Rabenhorst) Grunow						4	
Nitzschia palea (Kutzing) W.Smith		5					
Nitzschia perspicua Cholnoky				6			
Nitzschia pusilla (Kutzing) Grunow	1					4	6
Nitzschia recta Hantzsch in Rabenhorst		4					
Nitzschia species	4	4		12	1	2	2
Nitzschia valdecostata Lange-Bertalot et Simonsen				1			
Placoneis dicephala (W.Smith) Mereschkowsky		1	1				
Reimeria uniseriata Sala Guerrero & Ferrario						2	
Rhoicosphenia curvata (Kutzing) Grunow				1			14
Rhopalodia gibba (Ehr.) O.Muller var.gibba						1	
Sellaphora pupula (Kutzing) Mereschkowksy	3		1	1			
Sellaphora seminulum (Grunow) D.G. Mann	1	3		1			
Stephanodiscus agassizensis Hakansson & Kling					22		
Stephanodiscus hantzschii Grunow in Cl. & Grun. 1880					16		
Surirella angusta Kutzing				1			
Tryblionella apiculata Gregory							1
Total count	**404**	**401**	**408**	**357**	**401**	**401**	**400**

- Shaded blocks indicate dominant species per sample

D3.3 SPI SCORES

The European numerical diatom index, the Specific Pollution sensitivity Index (SPI) was used to interpret results. De la Rey *et al.*, 2004, concluded that the SPI reflects certain elements of water quality with a high degree of accuracy due to the broad species base of the SPI.

The SPI for the samples is given in Table D5 and the diatom based ecological classification for water quality is given in Table D6.

Table D5 SPI scores for the different samples

EWR site	Site name	River	No species	Specific Pollution sensitivity Index (SPI)	Class	Category
EWR 1	Valyspruit	Crocodile	35	16.5	Good quality	B
EWR 2	Goedenhoop	Crocodile	37	15.3	Good quality	B
EWR 3	Poplar Creek	Crocodile	28	14.6	Good quality	B
EWR 4	KaNyamazane	Crocodile	46	9.7	Moderate quality	C
EWR 5	Malelane	Crocodile	26	13.2	Moderate quality	B/C
EWR 6	Nkongoma	Crocodile	36	13.1	Moderate quality	B/C
EWR 7	Honeybird	Kaap	33	15.8	Good quality	B

Table D6 Generic diatom based ecological classification

Diatom based ecological classification						
Site	**pH**	**Salinity**	**Organic nitrogen**	**Oxygen levels**	**Pollution levels**	**Trophic status**
EWR 1	Circumneutral	Fresh brackish (Cond <139 mS/m)	Slightly elevated concentrations of organically bound nitrogen.	Continuously high saturation (~100%)	Slightly polluted	Oligo - Eutrophic
EWR 2	Circumneutral	Fresh brackish (Cond <139 mS/m)	Slightly elevated concentrations of organically bound nitrogen.	Continuously high saturation (~100%)	Slightly polluted	Oligo - Eutrophic
EWR 3	Alkaline	Fresh brackish (Cond <139 mS/m)	Slightly elevated concentrations of organically bound nitrogen.	Low saturation (>30%)	Slightly to moderately polluted	Eutrophic
EWR 4	Circumneutral	Fresh brackish (Cond <139 mS/m)	Slightly elevated concentrations of organically bound nitrogen.	Low saturation (>30%)	Moderately polluted	Eutrophic
EWR 5	Alkalibiontic	Fresh (<.2% salinity)	Slightly elevated concentrations of organically bound nitrogen.	Moderate saturation (>50%)	Moderately polluted	Mesotrophic
EWR 6	Alkaline	Fresh brackish (Cond <139 mS/m)	Slightly elevated concentrations of organically bound nitrogen.	Low saturation (>30%)	Moderately polluted	Eutrophic
EWR 7	Circumneutral	Fresh brackish (Cond <139 mS/m)	Slightly elevated concentrations of organically bound nitrogen.	Continuously high saturation (~100%)	Moderately polluted	Oligo - Eutrophic

D3.4 DISCUSSION

The dominant species in the diatom samples for the EWR sites are given and the diatom assemblages are discussed. Note: Species contributing 5% or more to the total count were classified as dominant species.

D3.4.1 EWR 1: Valyspruit

Site	Dominant species	Species contribution to sample (%)
EWR 1	*Achnanthidium minutissimum*	35
	Encyonopsis subminuta	8
	Encyonopsis leei sinensis	7
	Acnanthidium saprophilum	5
	Achnanthes standerii	5

EWR 1 lies within MRU A and WQSU 1. Land-cover is largely grassland with some agricultural, forestry and urban activities, e.g. trout farming around Dullstroom. The site is a single thread, sinuous alluvial channel. Cobbles dominate the bed. Transport capacity has been reduced due to the upstream impoundments as well as irrigation and timber plantations upstream of the site. Cut banks and erosion are extensive at this site (Appendix C, this report).

A. *minutissima* was the dominant species in this sample and favours well oxygenated clean fresh water (Taylor *et al.*, 2007b). *A. minutissima* is an indicator of natural/anthropogenic disturbances and indicates the presence of diffuse pollutants (Kovács, 2007). According to Ács *et al*. (2004), *A. minutissimum* indicates low levels of disturbance at this site with 35% dominance. The presence of pollution tolerant species, although in very small numbers, indicates that upstream anthropogenic activities may be impacting slightly on this EWR site and may be the source of slightly elevated concentrations of organically bound nitrogen. This is supported by the presence of *Acnanthidium saprophilum* which favours organically enriched eutrophic waters (Taylor *et al.*, 2007b).

The endemic *A. standerii* requires high water quality as well as oxygenated water (Taylor *et al.*, 2007b). This species is an indicator of circumneutral to slightly acidic water. *E. leei sinensis* made up 7% of the count and *E. subminuta* accounts for 8% of the population. *E. subminuta* occurs in well oxygenated waters and *E. leei sinensis* occurs in slightly acidic waters with a low to moderate electrolyte content.

The SPI indicates good water quality (16.5) at this site and the diatom based ecological classification indicates well oxygenated circumneutral water. The database programme OMNIDA ver. 3 does not include SA endemics in index calculations and this may influence the pH variable to some extent (more acidic). Due to the presence of *A. standerii*, *E. leei sinensis,* and a few other species (*Navicula cryptocephala*, *Nitzschia acicularis*) there is a general indication the water is rather slightly acidic than circumneutral. Overall the diatom water quality is in a B category. The current trend should be stable for this site if current conditions prevail.

D3.4.2 EWR 2: Goedehoop

Site	Dominant species	Species contribution to sample (%)
EWR 2	*Achnanthidium minutissimum*	38
	Denticula kuetzingii	10.4
	Acnanthidium saprophilum	13
	Acnanthes subaffinis	5.7

EWR 2 lies within MRU A and WQSU 1. Land cover is largely grassland with some agricultural, forestry and urban activities, e.g. trout farming. The site is a single thread, sinuous alluvial channel. Gravel dominates the bed. Transport capacity has been reduced due to the upstream impoundments as well as irrigation and timber plantations upstream of the site. Cut banks and erosion are extensive at this site (Appendix C, this report).

As with EWR 1 the dominant species at EWR 2 was A. *minutissima* which indicates well oxygenated circumneutral water. According to Ács *et al*. (2004), *A. minutissimum* indicates low levels of disturbance at this site with 38% dominance. Anthropogenic activities upstream of this site may have a bigger impact on this site and the source of slightly more elevated concentrations of organically bound nitrogen. The presence of *A. saprophilum* which indicates enrichment and favours eutrophic water (Taylor *et al.*, 2007b) and the presence of highly pollutant tolerant species (*S. seminulum*, *N. palea*, *N. tenelloides*, *N. gregaria*, *N. capitatoradiata*), although in small numbers indicate that the pollution levels are higher at this site than at EWR 1. The presence of *D. kuetzingii*, which favours high content electrolyte waters (Taylor *et al.*, 2007b) along with *S. seminulum*, *N. palea*, *N. capitatoradiata, N. gregaria*, and *N. acicularis* indicates that salinity may be an increasing problem at this site.

The SPI indicates good water quality (15.3) at this site and the diatom based ecological classification indicates well oxygenated circumneutral water. Overall the diatom water quality is in a B category but the site is more impacted on than EWR 1. The trend for this site should be stable except for an increase in salinity if there is a reduction in flow.

D3.4.3 EWR 3: Poplar Creek

Site	Dominant species	Species contribution to sample (%)
EWR 3	*Cocconeis placentula*	37
	Encyonopsis leei sinensis	14
	Achnanthidium saprophilum	9.8
	Cocconeis pediculus	8.8
	Gomphonema venusta	5.1

EWR 3 lies within MRU B and WQSU 3. Land cover is farming (largely citrus), with alien vegetation, plantations and urban settlements present. Sappi Ngodwana is located on the Elands River system, with associated pollution problems. The site is a single thread, sinuous alluvial channel. Cobble dominates the bed (Appendix C, this report).

The dominant *C. placentula* has a broad ecological range and is found in most running waters except where nutrients are low or acidic conditions prevail (Taylor *et al.*, 2007b). It is tolerant of moderate organic pollution and also extends into brackish waters (Kelly *et al*., 2001). According to Fore and Grafe (2002), *C. placentula* and *C. pediculus* prefer alkaline eutrophic conditions. The presence of *A. saprophilum* (9.8% abundance) indicates enrichment and favours eutrophic water (Taylor *et al.*, 2007b). Although not dominant, *N. dissipata* is a good indicator of hard water (calcium based salinity) and favours alkaline conditions (Taylor, *pers comm*.).

The SPI indicates good water quality (14.6), although this falls within the lower ranges of the classification and the diatom based ecological classification indicates low oxygen saturation and alkaline conditions. Overall the diatom water quality is in a B category but the high flows (1 m^3/s on day of sampling) may have had a dilution effect (agricultural runoff) as there are species present that are very pollution tolerant and indicators of eutrophic conditions. The presence of *E. adnata* is an indication of elevated temperatures and turbidity at this site (Kwena dam) and this along with the nutrient load from agricultural run off may be the source of low oxygen saturation. The trend for this site is negative, in terms of water quality, as the observed flow has had a dilution effect. Present diatoms indicate increased eutrophication and increased salinity at lower flows, although the constant releases from Kwena dam would indicate a stable trend for water quality during dry seasons.

D3.4.4 EWR 4: KaNyamazane

Site	Dominant species	Species contribution to sample (%)
EWR 4	*Cocconeis placentula placentula*	26
	Fistulifera saprophila	15
	Eolimna subminuscula	13
	Cocconeis placentula euglypta	10

EWR 4 lies within MRU D and WQSU 4. Land-cover is farming (largely citrus), with extensive alien vegetation, plantations and urban settlements and associated activities present, i.e. Nelspruit and KaNyamazane. A number of hazardous waste sites, mines and processing plants are found in the area. The polluted Wit River enters the Crocodile River in this WQSU. The site is a single thread, sinuous alluvial channel and cobble dominates the bed (Appendix C, this report).

The dominant species at this site is *C placentula*, and its ecological preferences are discussed in section 2.4.2. EWR 4 is situated downstream from Nelspruit and KaNyamazane and it is expected that the SPI score would be much lower than 9.7 due to urban run off and industrial impacts. During sampling the flow was 7.5 m^3/s, and these conditions definitely had a dilution effect of the water quality related impacts. This is evident in the species composition of the diatom sample.

E. subminiscula, a cosmopolitan species common in electrolyte rich, strongly polluted rivers and flowing waters while *F. saprophila* (a cosmopolitan species found in highly eutrophic, anthropogenically impacted, highly polluted waters and one of the most resistant species of all) (Taylor *et al.*, 2007b) are present in high abundances at this site. Of the 46 species present, 14 species (e.g. *G. parvulum*, *N. capitellata* and *N. capitatoradiata*) are tolerant to critical levels of pollution and although they are present in small numbers their presence indicates that this site was highly polluted before the high flow event.

The SPI index indicates moderate water quality (9.7), although this falls within the lower ranges of the classification and the diatom based ecological classification indicates low oxygen saturation and circumneutral water. This is not a true reflection of the conditions at this site due to elevated flows (7 m^3/s). It is expected that the water quality will deteriorate drastically with low flows and that the electrolyte content could increase due to the presence of saline tolerant species (*N. perspicua*, and *N. etoshensis*). It is envisaged that bicarbonates and sulphides will increase during low flows due to the presence of *N. valdecostata* while the presence of *N. veneta* indicates the presence of industrial effluent. The trend is stable if current conditions prevail.

D3.4.5 EWR 5: Malelane

Site	Dominant species	Species contribution to sample (%)
EWR 5	*Diatoma vulgaris*	49
	Cyclostephanos invisitatus	13
	Cyclostephanos dubius	7
	Aulacoseira granulata var.angustissima	5
	Stephanodiscus agassizensis	5

EWR 5 is situated within MRU E and WQSU 6. Land cover is urban areas and associated impacts, extensive irrigation of sugar-cane, Selati sugar mill, forestry, agriculture e.g. banana and citrus plantations, citrus processing, conservation activities i.e. KNP, recreation i.e. lodges. The site is a single thread, sinuous alluvial channel and sand dominates the bed (Appendix C, this report).

EWR 5 is dominated by *D. vulgaris* and is generally found in mesotrophic to eutrophic waters with average electrolyte content and prefers alkaline conditions (Taylor *et al.*, 2007b and Fore and Grafe, 2002). This species does however grow well under higher concentrations of eutrophication (Kelly *et al*., 2001) which may explain the lower level of oxygen saturation and indicate that run off from farming activities are causing increased eutrophication at this site. This stretch of the river has not been flowing for some time and the sample was taken after good rain. The dominance of *D. vulgaris* along with *S. agassizensis* and *A. granulata angustissima* indicates an accumulative effect of eutrophication caused by agricultural activities and urbanization upstream of the site.

The presence of *S. agassizensis*, which prefers turbidity, *C. invisitatus* and *S. hantzschii* indicate elevated electrolyte concentrations while *C. dubius* indicates elevated chloride concentration as well as calcareous, alkaline waters (Taylor *et al.*, 2007b). Although not dominant, *N. dissipata* is a good indicator of hard water (calcium based salinity) and favours alkaline conditions (Taylor, *pers comm*.).

The SPI index indicates moderate water quality (13.2), although this falls within the lower ranges of the classification and the diatom based ecological classification indicates moderate oxygen saturation and alkalibontic water. The diatom water quality is in a B/C category but due to the presence of pollution tolerant species and species favouring elevated electrolyte levels, the trend for this site is negative.

D3.4.6 EWR 6: Nkongoma

Site	Dominant species	Species contribution to sample (%)
EWR 6	*Cocconeis placentula placentula*	48
	Achnanthidium minutissimum	8
	Gomphonema minutum	5

EWR 6 is situated within the same MRU and WQSU than EWR 5. The site is a single thread, straight bedrock dominated channel and sand dominates the bed (Appendix C, this report). The dominant species at this site is *C placentula*, and its ecological preferences are discussed in section D3.4.2. Although the other dominant species indicate well oxygenated water (*A. minutissimum*) and tolerance to moderate pollution levels (*G. minutum*) the rest of the community composition indicates that critical levels of pollution were present before elevated flows occurred (*F. saprophila, E. subminiscula, N. cryptocephala, N. recens, N. capitatoradiata)*. Of concern is the presence of *N. veneta* that is found in industrial effluent and *A. exigua* that occurs in industrial and other waste water. It is also able to grow under very low light and can tolerate temperatures of up to 40 ºC (Taylor *et al.*, 2007b). Komati sugar mill upstream of this site may be the source of pollution.

The SPI index indicates moderate water quality (13.1), although this falls within the lower ranges of the classification and the diatom based ecological classification indicates low oxygen saturation and alkaline water. The diatom water quality is in a B/C category but the trend for this site is negative as an increase in nutrient loading is expected during low flows and an increase in pollution levels and electrolyte levels.

D3.4.7 EWR 7: Honeybird

Site	Dominant species	Species contribution to sample (%)
EWR 7	*Achnanthidium minutissimum*	46
	Acnanthidium saprophilum	12
	Cocconeis pediculus	11

EWR 7 is situated in MRU A and WQSU 7. Land-cover is farming (e.g. paw-paws, bananas, sugar cane), sawmill and pole treating in the vicinity and mining upstream. Pollution sources from upstream users include irrigation, urban areas and old gold mining activities. The site is a single thread, straight bedrock dominated channel and sand dominates the bed (Appendix C, this report).

A minutissimum was the dominant species at this site, favouring well oxygenated clean fresh water (Taylor *et al.*, 2007b). *A. minutissimum* is an indicator of natural/anthropogenic disturbances and indicates the presence of diffuse pollutants (Kovács, 2007). According to Ács *et al*., 2004, *A. minutissimum* indicates low levels of disturbance at this site with 46% dominance. The presence of pollution tolerant species, although in very small numbers, indicates that upstream anthropogenic activities may be impacting slightly on this EWR site and may be the source of slightly elevated concentrations of organically bound nitrogen. This is supported by the presence of *A. saprophilum* which favours organically enriched eutrophic waters (Taylor *et al.*, 2007b). The dominance of *A. minutissima* and *C. pendiculus* as well as the presence of *D. kuetzingii* indicates elevated electrolyte conditions.

Overall the water quality is in a B category with a SPI score of 15.8. There are pollutant tolerant species present although in lower levels, but pollution may be on the increase due to species present that are tolerant to high levels of pollution (e.g. *E. subminuscula*, *G. parvulum, G. parvulum f saprophilum*). The trend for this site is stable if present conditions prevail.

D4 RESULTS: SABIE – SAND RIVER SYSTEM

D4.1 SAMPLING SITES

Details of the sampling sites are given in Table D7.

Table D7 Diatom sampling sites

Sample number	Site	River	Co-ordinates		Resource Unit	Water Quality Sub Unit
			South	East		
610	**EWR 1**	Sabie River	S25 04.424	E30 50.924	MRU A	WQSU2
614	**EWR 2**	Sabie River	S25 01.675	E31 03.099	MRU A	WQSU3
612	**EWR 3**	Sabie River	S24 59.256	E31 17.572	MRU C	WQSU5
611	**EWR 4**	Mac Mac River	S25 00.800	E31 00.243	Mac Mac	WQSU 1 (Mac Mac)
617	**EWR 5**	Marite River	S25 01.077	E31 07.997	Marite	WQSU 2 (Marite)
615	**EWR 6**	Mutlumuvi River	S24 45.352	E31 07.923	Mutlumuvi	WQSU 1 (Mut)
616	**EWR 7**	Tlulandziteka River	S24 40.829	E31 05.188	Tlulandziteka	WQSU 2 (Sand)
613	**EWR 8**	Sand River	S24 58.045	E31 37.641	MRU B	WQSU 4 (Sand)

The main land use activities in the different Resource Units are given in Table D8.

Table D1 Main land use activities in the Resource Units

Resource Unit	Land use activities[1]
MRU A	Land-cover is forestry, plantations, irrigation of crops, urban settlements (e.g. Sabie town) and associated activities, including possible return flows from old mines.
MRU C	Conservation (KNP).
Mac Mac	Forestry, including commercial plantations and Venus sawmill.
Marite	Land-cover is extensive urban/rural settlements with associated activities, irrigation of crops, particularly extensive citrus cultivation.
Mutlumuvi	Land-cover is forestry, extensive urban/rural settlements, and subsistence farming.
Tlulandziteka	Land-cover is extensive urban/rural settlements, forestry, subsistence farming and agriculture. Site is downstream of an instream dam.
MRU B	Conservation (KNP).

1 Information obtained from Appendix C, this report.

D4.2 DIATOM ASSEMBLAGE

The diatom abundances of the different EWR sites are given in Table D9.

Table D2 Diatom species assemblage and abundances of samples for each EWR site

Species	EWR 1	EWR 2	EWR 3	EWR 4	EWR 5	EWR 6	EWR 7	EWR 8
	610	614	612	611	617	615	613	615
Achnanthes crassa Hustedt	3				133		3	
Achnanthes lanceolata (Breb.) Grun. *ssp. frequentissima* Lange-Bertalot		2	2			5	3	4
Achnanthes lanceolata(Breb.) Grunow *lanceolata* Grunow	12		2	14				
Achnanthes linearis (W.Sm.) Grunow		48			22	1		
Achnanthes minutissima Kutzing *v.minutissima* Kutzing (Achnanthidium)	61	17	40	105	19	189	32	106
Achnanthes minutissima Kutzing *saprophila* Kobayasi et Mayama	4	18	4	2	6	4	9	

Species	EWR 1	EWR 2	EWR 3	EWR 4	EWR 5	EWR 6	EWR 7	EWR 8
Achnanthes standerii Cholnoky	5		4		159			9
Achnanthes subaffinis Cholnoky					26		5	
Amphipleura pellucida Kutzing				1				
Amphora pediculus (Kutzing) Grunow	1			1				18
Amphora veneta Kutzing	1							
Asterionella formosa Hassall	1							
Aulacoseira ambigua (Grun.) Simonsen	1							
Aulacoseira granulata (Ehr.) Simonsen	1			1				
Craticula molestiformis (Hustedt) Lange-Bertalot	3	2		1			1	1
Cocconeis pediculus Ehrenberg	1	17	13	4				
Cocconeis placentula Ehrenberg *placentula*	7	159	247	13	2	13	89	1
Cocconeis placentula Ehrenberg *pseudolineata* Geitler					3			
Cocconeis placentula Ehrenberg *euglypta* (Ehr.) Grunow	2		5	2			1	
Cocconeis placentula Ehrenberg *lineata* (Ehr.) Van Heurck					1		4	
Craticula buderi (Hustedt) Lange-Bertalot						1		
Craticula vixnegligenda Lange-Bertalot		1				2		
Cyclotella ocellata Pantocsek								3
Cyclotella radiosa (Grunow) Lemmermann								4
Cymbella affinis Kutzing *affinis*		5			2	4		
Cymbella minuta Hilse ex Rabenhorst (Encyonema)			9			1		
Cymbella tumida (Brebisson) Van Heurck	10	2	1	6	2	1		
Cymbella turgidula Grunow 1875 in A.Schmidt & al. *turgidula*		2	6		2			
Diatoma vulgaris Bory 1824	21			16				
Diploneis puella (Schumann) Cleve				1				
Encyonema minutum (Hilse in Rabh.) D.G. Mann	1							
Encyonopsis leei Krammer *sinensis* Metzeltin & Krammer	1	32	8	1	5		9	
Encyonopsis microcephala (Grunow) Krammer							11	4
Eolimna minima (Grunow) Lange-Bertalot	3	15	24	10	1	13	14	16
Eolimna subminuscula (Manguin) Moser Lange-Bertalot & Metzeltin	1	1	2					1
Epithemia adnata (Kutzing) Brebisson						7	28	
Epithemia sorex Kutzing								24
Eunotia minor (Kutzing) Grunow in Van Heurck	2							2
Fragilaria biceps (Kutzing) Lange-Bertalot	8			1				
Fragilaria brevistriata Grunow (Pseudostaurosira)	1							
Fragilaria capucina Desmazieres *capucina*	6							
Fragilaria capucina Desmazieres var.vaucheriae(Kutzing)Lange-Bertalot				9				
Fragilaria elliptica Schumann (Staurosira)								4
Fragilaria pinnata Ehrenberg *pinnata* (Staurosirella)			1					
Fragilaria ulna (Nitzsch.) Lange-Bertalot *ulna*	2							
Fragilaria ulna (Nitzsch.)Lange-Bertalot *acus* (Kutz.) Lange-Bertalot			1	2				
Gomphonema acuminatum Ehrenberg	1	2		1				9
Gomphonema angustatum (Kutzing) Rabenhorst		3		8			3	1
Gomphonema clavatum Ehr.						4	1	
Gomphonema insigne Gregory						4		
Gomphonema lagenula Kützing	1							
Gomphonema minutum (Ag.) Agardh f. *minutum*	22	6		20		9		
Gomphonema parvulius Lange-Bertalot & Reichardt						6		
Gomphonema parvulum (Kützing) Kützing *parvulum f. parvulum*	61			64		31		1
Gomphonema parvulum parvulum f.saprophilum Lange-Bert.&Reichardt						21	2	
Gomphonema pumilum (Grunow) Reichardt & Lange-Bertalot	8			2		15	4	
Gomphonema species	8				3	29	20	

Species	EWR 1	EWR 2	EWR 3	EWR 4	EWR 5	EWR 6	EWR 7	EWR 8
Gomphonema truncatum Ehr.	1							
Gomphonema venusta Passy. Kociolek & Lowe		8	2	2	4	22	85	
Luticola mutica (Kützing) D.G. Mann							1	
Mastogloia smithii Thwaites								12
Mayamaea atomus (Kutzing) Lange-Bertalot							2	
Mayamaea atomuspermitis (Hustedt) Lange-Bertalot	2						1	
Melosira varians Agardh		1		1				4
Navicula antonii Lange-Bertalot	7			2				29
Navicula arvensis Hustedt				1			1	
Navicula capitata Ehrenberg (=Hippodonta)							6	
Navicula capitatoradiata Germain		5	6	5				13
Navicula cryptocephala Kutzing	4	15	1	2	3	1	2	
Navicula cryptotenella Lange-Bertalot			1		4			11
Navicula dicephala Ehrenberg				1				
Navicula erifuga Lange-Bertalot								2
Navicula gregaria Donkin		8					2	5
Navicula heimansioides Lange-Bertalot					2			
Navicula longicephala Hustedt var.longicephala								8
Navicula microcephala Grunow							5	
Navicula molestiformis Hustedt				1				
Navicula radiosa Kützing					1	2		
Navicula recens (Lange-Bertalot) Lange-Bertalot	4							
Navicula reichardtiana Lange-Bertalot *reichardtiana*		8						11
Navicula schroeteri Meister var. schroeteri		1		2				9
Navicula schroeteri Meister *symmetrica* (Patrick) Lange-Bertalot	4							
Navicula tenelloides Hustedt				6			2	
Navicula tripunctata (O.F.Müller) Bory		1		1				
Navicula vandamii Schoeman & Archibald *vandamii*		2						
Navicula veneta Kutzing		3		1				3
Navicula viridula (Kutz.) Ehr. *rostellata* (Kutz.) Cleve				4				
Navicula viridula (Kutzing) Ehrenberg	2							
Navicula zanoni Hustedt		5						
Nitzschia acicularis(Kutzing) W.M.Smith							5	
Nitzschia amphibia Grunow f.amphibia						2		1
Nitzschia aurariae Cholnoky								2
Nitzschia dissipata (Kutzing) Grunow var.dissipata	59		1	60		4	3	17
Nitzschia elegantula Grunow						1	10	
Nitzschia filiformis (W.M.Smith) Van Heurck var. filiformis	1						1	3
Nitzschia fonticola Grunow in Cleve et Möller	3			1				3
Nitzschia frustulum (Kutzing) Grunow var.frustulum	3		9	5				12
Nitzschia irremissa Cholnoky	5						3	
Nitzschia liebetruthii Rabenhorst var.liebetruthii								12
Nitzschia linearis (Agardh) W.M.Smith var.linearis	4			1				
Nitzschia linearis (Agardh) W.M.Smith var.subtilis(Grunow) Hustedt	2							
Nitzschia palea (Kutzing) W.Smith	6			5		1		
Nitzschia paleacea (Grunow) Grunow in van Heurck						2		
Nitzschia paleaeformis Hustedt								7
Nitzschia pusilla (Kutzing) Grunow							8	
Nitzschia sigma (Kutzing) W.M.Smith								2
Nitzschia species	9			3			8	
Nitzschia supralitorea Lange-Bertalot				11				
Nitzschia valdecostata Lange-Bertalot et Simonsen			4					17
Placoneis dicephala (W.Smith) Mereschkowsky		6						

Species	EWR 1	EWR 2	EWR 3	EWR 4	EWR 5	EWR 6	EWR 7	EWR 8
Reimeria uniseriata Sala Guerrero & Ferrario			5					
Rhoicosphenia curvata (Kutzing) Grunow		4						
Rhopalodia gibba (Ehr.) O.Muller var.gibba						2		
Sellaphora pupula (Kutzing) Mereschkowksy	11			2				1
Sellaphora seminulum (Grunow) D.G. Mann	3		7				1	8
Simonsenia delognei Lange-Bertalot						1		
Stauroneis gracilior (Rabenhorst) Reichardt		1						
Surirella angusta Kutzing	1			1		2		
Tabularia fasciculata (Agardh)Williams et Round	8							
Thalassiosira pseudonana Hasle et Heimdal							7	
Tryblionella apiculata Gregory	1			1				5
Tryblionella gracilis W. Smith								1
Total Count	**400**	**400**	**405**	**404**	**400**	**400**	**392**	**406**

* Shaded blocks indicate dominant species per sample

D4.3 SPI SCORES

The European numerical diatom index, the Specific Pollution sensitivity Index (SPI) was used to interpret results. De la Rey *et al.*, 2004, concluded that the SPI reflects certain elements of water quality with a high degree of accuracy due to the broad species base of the SPI.

The SPI for the samples is given in Table D10 and the interpretation of the SPI scores is given in Table D11.

Table D3 SPI scores for the different samples

EWR site	Site name	River	No species	Specific Pollution sensitivity Index (SPI)	Class	Category
EWR 1	Upper Sabie	Sabie	51	13.1	Moderate quality	B/C
EWR 2	Sabie Aan de Vliet	Sabie	31	15.3	Good quality	B
EWR 3	Kidney	Sabie	24	14.5	Good quality	B
EWR 4	MacMac	MacMac	46	14.0	Good quality	B
EWR 5	Marite	Marite	18	19.4	High quality	A
EWR 6	Mutlumuvi	Mutlumuvi	31	15.6	Good quality	B
EWR 7	Tlulandziteka	Tlulandziteka	37	12.8	Moderate quality	B/C
EWR 8	Upper Sand	Sand	51	13.1	Moderate quality	B/C

Table D4 Generic diatom based ecological classification

Diatom based ecological classification						
Site	**pH**	**Salinity**	**Organic nitrogen**	**Oxygen levels**	**Pollution levels**	**Trophic status**
EWR 1	Circumneutral	Fresh brackish (Cond <139 mS/m)	Slightly elevated concentrations of organically bound nitrogen.	Fairly high (>75% saturation)	Moderately polluted	Eutrophic
EWR 2	Alkaline	Fresh brackish (Cond <139 mS/m)	Slightly elevated concentrations of organically bound nitrogen.	Low saturation (>30%)	Slightly polluted	Eutrophic
EWR 3	Alkaline	Fresh brackish (Cond <139 mS/m)	Slightly elevated concentrations of organically bound nitrogen.	Low saturation (>30%)	Slightly to moderately polluted	Eutrophic

Diatom based ecological classification						
Site	**pH**	**Salinity**	**Organic nitrogen**	**Oxygen levels**	**Pollution levels**	**Trophic status**
EWR 4	Circumneutral	Fresh brackish (Cond <139 mS/m)	Slightly elevated concentrations of organically bound nitrogen.	Continuously high saturation (~100%)	Slightly to moderately polluted	Eutrophic
EWR 5	Circumneutral	Fresh (<.2% salinity)	Slightly elevated concentrations of organically bound nitrogen.	Continuously high saturation (~100%)	Slightly polluted	Oligo - Eutrophic
EWR 6	Circumneutral	Fresh brackish (Cond <139 mS/m)	Slightly elevated concentrations of organically bound nitrogen.	Continuously high saturation (~100%)	Slightly polluted	Oligo - Eutrophic
EWR 7	Alkaline	Fresh brackish (Cond <139 mS/m)	Slightly elevated concentrations of organically bound nitrogen.	Low saturation (>30%)	Moderately polluted	Eutrophic
EWR 8	Alkaline	Fresh brackish (Cond <139 mS/m)	Slightly elevated concentrations of organically bound nitrogen.	Continuously high saturation (~100%)	Slightly to moderately polluted	Eutrophic

D4.4 DISCUSSION

The dominant species in the diatom samples for the EWR sites are given and the diatom assemblages are discussed. Note: Species contributing 5% or more to the total count were classified as dominant species.

D4.4.1 EWR 1: Upper Sabie

Site	Dominant species	Species contribution to sample (%)
EWR 1	*Achnanthidium minutissimum*	15
	Gomphonema parvulum	15
	Nitzschia dissipata	15
	Gomphonema minutum	5
	Diatoma vulgaris	5

EWR 1 lies within MRU A and WQSU 2. Land-cover includes forestry, plantations, irrigation of crops, urban settlements (e.g. Sabie town) and associated activities, including possible return flows from old mines. This site is a single thread straight channel, with sand dominating the bed (Appendix C, this report).

A. *minutissimum* was the dominant species in this sample and favours well oxygenated clean fresh water (Taylor *et al.*, 2007b). *A. minutissimum* is an indicator of natural/anthropogenic disturbances and indicates the presence of diffuse pollutants (Kovács, 2007). *D. vulgaris* is generally found in mesotrophic to eutrophic waters with average electrolyte content and prefers alkaline conditions (Taylor *et al.*, 2007b and Fore and Grafe, 2002). The presence of species tolerant to moderate to heavy pollution (*G. minutum*, *G. pumilum* and *G. parvulum*), indicates that upstream anthropogenic activities may be impacting on this EWR site and may be the source of slightly elevated concentrations of organically bound nitrogen. The presence of *N. dissipata* in high abundance indicates calcium based salinity (Taylor, *pers comm*.).

The SPI indicates good water quality (13.1) although this falls within the lower ranges of the classification. Overall the diatom water quality is in a B/C category. The trend is stable and the community indicates increased salinity and eutrophication.

D4.4.2 EWR 2: Aan de Vliet

Site	Dominant species	Species contribution to sample (%)
EWR 2	*Cocconeis pediculus*	40
	Achnanthes linearis	12
	Encyonopsis leei var. sinensis	8
	Diatoma vulgaris	5

EWR 2 lies within MRU A and WQSU 3. Land-cover is agriculture (irrigation), forestry, rural and urban settlements (e.g. Hazyview) and associated activities. The site is a single thread, sinuous bedrock dominated channel (Appendix C, this report).

The dominant *C. pediculus* favours moderate to high electrolyte, brackish waters (Taylor *et al.*, 2007b). The presence of *A. linearis* and *E. leei sinensis* indicates a systematic increase in acidic conditions.

The SPI score for this site is 15.3 (Good water quality) and current conditions are alkaline eutrophic waters with low oxygen saturation. It is expected that the water quality will deteriorate as the effect of upstream land use on this site includes industrial effluent (presence of *N. veneta*) and very high levels of pollution (*N. gregaria*, *N. capitatoradiata*, *N. reichardtiana*, and *E. minima*). Community composition indicates increased eutrophication and a general increase in electrolyte content if conditions persist.

D4.4.3 EWR 3: Kidney

Site	Dominant species	Species contribution to sample (%)
EWR 3	*Cocconeis placentula*	60
	Achnanthidium minutissimum	10
	Eolimna minima	5

EWR 3 lies within MRU C and WQSU 5. This site falls within the Kruger National Park. The site is a multi thread, straight channel, bedrock dominated with a sand bed (Appendix C, this report).

The dominant *C. placentula* has a broad ecological range and is found in most running waters except where nutrients are low or acidic conditions prevail (Taylor *et al.*, 2007b). It is tolerant of moderate organic pollution and also extends into brackish waters (Kelly *et al*., 2001). According to Fore and Grafe, 2002, *C. placentula* and *C. pediculus* prefer alkaline eutrophic conditions. The presence of *A. minutissimum* indicates oxygenated, fresh waters (Taylor *et al.*, 2007b). This species also indicates indicate the presence of diffuse pollutants. The presence of pollutant tolerant species e.g. *E. minima*, *N. frustulum*, *N. capitatoradiata* and *S. seminulum* indicate pollution problems and the Mkuhlu township upstream from this site may be the main source of these pollutants. This is supported by the presence of A. *saprophilum* which indicates enrichment and favours eutrophic water (Taylor *et al.*, 2007b).

The SPI indicates good water quality (14.5), although this falls within the lower ranges of the classification and the diatom based ecological classification indicates low oxygen saturation and alkaline conditions. Overall the diatom water quality is in a B category but the high flows (1.3 m^3/s on day of sampling) may have had a dilution effect as there are species present that are very pollution tolerant and indicators of eutrophic conditions (*A. saprophilum*). The presence of *N. valdecostata* is an indication of elevated bicarbonates and sulphides at this site and this along with the nutrient load from anthropogenic activities may be the source of low oxygen saturation. The trend for this site is negative, in terms of water quality, as the observed flow has had a dilution effect. Present diatoms indicate increased eutrophication and increased salinity at lower flows. The sample indicated that the valves of the *Cocconeis* genus were deformed which could be an indication of metal contamination.

D4.4.4 EWR 4: Mac Mac

Site	Dominant Species	Species contribution to sample (%)
EWR 4	*Achnanthidium minutissimum*	26
	Gomphonema parvulum	16
	Nitzschia dissipata	15
	Gomphonema minutum	5

EWR 4 lies within MRU Mac Mac and WQSU 1. Forestry, including commercial plantations and Venus sawmill. The site is a single thread, straight alluvial channel and cobble dominates the bed (Appendix C, this report).

The dominant species at this site indicates fast flowing, well oxygenated water. *G. parvulum* and *G. minutum* are very pollution tolerant and its dominance indicates increased pollution levels which may be caused by the sawmill or graskop STW upstream of the site. The presence of *N. dissipata* in high abundance indicates calcium based salinity (Taylor, *pers comm*.) and it seems the site is impacted by the upstream activities due to species present with a preference for moderate to high electrolyte waters. The diatom community shows traces of the onset of severe water quality impacts with the presence of *E. minima*, *N. veneta*, *N. tenelloides*, *N. frustulum* and *N. palea*).

The SPI index indicates moderate water quality (14), with well oxygenated slightly to moderate polluted eutrophic water. The general trend for this site is negative under these low flow conditions due to increased pollution and eutrophication. It is however expected that with higher flows the water quality could improve due to dilution of pollutants.

D4.4.5 EWR 5: Marite

Site	Dominant species	Species contribution to sample (%)
EWR 5	*Achnanthes standerii*	40
	Achnanthes crassa	33
	Achnanthes subaffinis	6
	Achnanthes linearis	6
	Achnanthidium minutissimum	5

EWR 5 is situated within MRU Marite and WQSU 2. Land-cover is extensive urban/rural settlements with associated activities, irrigation of crops, particularly extensive citrus cultivation. The site is a single thread, straight channel and sand dominates the bed (Appendix C, this report).

EWR 5 is dominated by the endemic *A. standerii* which requires high water quality as well as oxygenated water (Taylor *et al.*, 2007b). This species is an indicator of circumneutral to slightly acidic water. All dominants present indicate clean, flowing well oxygenated water. The database programme OMNIDA ver. 3 does not include SA endemics in index calculations and this may influence the pH variable to some extent (slightly more acidic).

Due to the elevated flows (0.5 m^3/s) present on the day of sampling this diatom community may not be a true reflection of water quality. Although *A. minutissimum* indicates anthropogenic disturbances and the presence of diffuse pollutants (upstream citrus farming), the community does not show serious impacts at the moment.

The SPI indicates high quality (19.4), well oxygenated circumneutral water. It is recommended that another sample is taken at lower flows to get a true reflection of community composition and possible water quality related impacts. The trend for this site is stable. Although the current conditions cannot prevail there is no indication at this moment that there are serious water quality related impacts.

D4.4.6 EWR 6: Mutlumuvi

Site	Dominant species	Species contribution to sample (%)
EWR 6	*Achnanthidium minutissimum*	47
	Gomphonema parvulum	7
	Gomphonema venusta	6
	Gomphonema parvulum var.parvulum f.saprophilum	5

EWR 6 is situated within MRU Mutlumuvi within WQSU 1. Land-cover is forestry, extensive urban/rural settlements, and subsistence farming. The site is a multi-thread, sinuous bedrock dominated channel and sand dominates the bed (Appendix C, this report).

A. minutissima was the dominant species in this sample and favours well oxygenated clean fresh water (Taylor *et al.*, 2007b). *A. minutissima* is an indicator of natural/anthropogenic disturbances and indicates the presence of diffuse pollutants (Kovács, 2007). According to Ács *et al*. (2004), *A. minutissimum* indicates low levels of disturbance at this site with 47% dominance. The presence of pollution tolerant species, although in very small numbers, indicates that upstream anthropogenic activities may be impacting slightly on this EWR site and may be the source of slightly elevated concentrations of organically bound nitrogen.

The dominance of G. parvulum and G. *parvulum parvulum f. saprophilum* indicates pollution input from upstream anthropogenic activities as these species are extremely pollution tolerant. As the river had very little to no flow on the day of sampling elevated temperatures could have occurred and is substantiated by the presence of *E. adnata* as this species occurs in waters with elevated temperatures and nutrient load and *R. gibba* which occurs in standing water (Taylor *et al.*, 2007b).

The SPI index indicates moderate water quality (15.6), with well oxygenated circumneutral waters. The diatom water quality is in a B category but the trend for this site is stable to positive as an increase in flows will have a dilution effect on nutrient loading and possible electrolyte increases due to upstream anthropogenic activities.

D4.4.7 EWR 7: Tlulandziteka

Site	Dominant Species	Species contribution to sample (%)
EWR 7	*Cocconeis pediculus*	22
	Gomphonema venusta	22
	Achnanthidium minutissimum	8
	Epithemia adnata	7

EWR 7 is situated in MRU A and WQSU 7. Land cover is extensive urban/rural settlements, forestry, subsistence farming and agriculture. Site is downstream of an instream dam. The site is a single thread, sinuous bedrock dominated channel and sand dominates the bed (Appendix C, this report).

The dominant *C. pediculus* has a broad ecological range and is found in most running waters except where nutrients are low or acidic conditions prevail (Taylor *et al.*, 2007b). It is tolerant of moderate organic pollution and also extends into brackish waters (Kelly *et al*., 2001). According to Fore and Grafe (2002), *C. pediculus* prefer alkaline eutrophic conditions. *A. minutissima*, according to Ács *et al*. (2004), indicates low levels of disturbance at this site with 22% dominance. The presence of *E. adnata* indicates elevated temperatures and nutrient load. The presence of pollution tolerant species, although in very small numbers, indicates that upstream anthropogenic activities may be impacting moderately on this EWR site and may be the source of slightly elevated concentrations of organically bound nitrogen. This is supported by the presence of *N. capitata*, *N. gregaria*, *N. acicularis* and *N. irremissa*.

Overall the water quality is in a B/C category with a SPI score of 12.8 although this falls within the lower ranges of the classification and the diatom based ecological classification indicates low oxygen saturation and alkaline conditions. There are pollutant tolerant species present although in lower levels, but pollution may be on the increase due to species present that are tolerant to high levels of pollution. The trend for this site is stable if present conditions prevail although it is foreseen that water quality will deteriorate rapidly under reduced flow.

D4.4.8 EWR 8: Sand

Site	Dominant Species	Species contribution to sample (%)
EWR 8	*Achnanthidium minutissimum*	26
	Navicula antonii	7
	Epithemia sorex	6

EWR 8 is situated in MRU B and WQSU 4. This site falls within the Kruger National Park. The site is a single thread, sinuous channel, bedrock dominated with a sand bed (Appendix C, this report).

As with EWR 6 the dominant species is *A. minutissimum* and indicates well oxygenated waters and point source pollutants. The presence of *N. antonii* indicates that the upstream anthropogenic impacts are affecting this site with regard to nutrient load and pollutants. *E. sorex* favours waters with moderate to high electrolyte content.

Bicarbonates and sulphides are a factor at this site due to the presence of the *N. valdecostata* and the presence of *N. dissipata* is a good indicator of hard water (calcium based salinity) and favours alkaline conditions (Taylor, *pers comm*.). It seems that upstream anthropogenic activities (army base and abattoir) are impacting on this site.

The SPI score for this site is 13.2 (B category) although this falls within the lower ranges of the categorization. It seems that the trend for this site is negative as the majority of species present at this site is tolerant to high and extreme levels of pollution. Enrichment will increase in the long run and oxygen will be depleted from the system, unless high flow dilutes the water quality related impacts at this site.

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APPENDIX E: GEOMORPHOLOGY

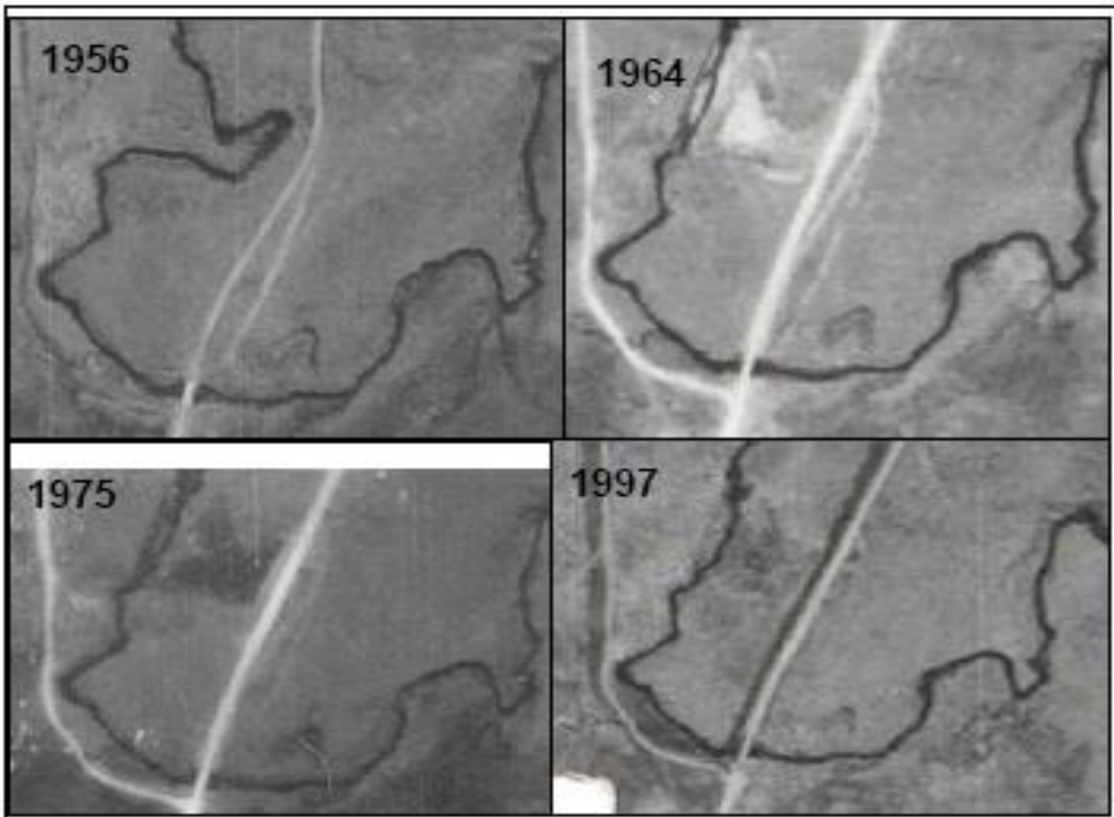
M Rountree, Fluvius Environmental Consultants

E1 EWR 1: VALEYSPRUIT (CROCODILE RIVER)

E1.1 DATA AVAILABILITY

Data availability	Conf
Historical aerial photography (1944, 1956, 1965, 1997). Hydrology records. Sediment transport analysis (adapted from Dollar and Biker, Geomorphology Specialist report for the Ecological Reserve of the Crocodile River catchment; 2002). Site survey information.	3

E1.2 REFERENCE CONDITIONS

Reference conditions	Conf
 Croc EWR Site 1: No directional changes for EWR Site 1 could be observed from the aerial photographs due to the large scale of the photographs and the narrow channel. The channel appears to have been straightened upstream (on the left) of the site between 1956 and 1964 upstream of the site; probably associated with the agricultural activities which are evident at this time. The site has typical meandering floodplain with ox-bow features on the floodplain. The floodplain consists of cut banks, advancing point bars and cut-off meanders. This site is classified as an alluvial meandering channel type and is representative of the macro-reach; being typical of eastern-draining rivers above the escarpment. Small wetlands are present on the floodplain.	3

E1.3 PRESENT ECOLOGICAL STATE

E1.3.1 Site suitability

This provides an assessment of the suitability of the site for EWR determination studies	SCORES: 5	2	1	SCORE	Notes
Representivity of the site for the reach				**3.8**	Morphology representative, and impacts at site (grazing, roads) representative of the catchment.
How well does the *morphology* of the site represent that of the reach?	Very well	Don't know	Poorly	4.0	
To what extent is the *condition* of the site representative of the general condition of the reach?	Representative	Don't know	Very different	3.5	
Morphological Cues				**3.7**	Alluvial (meandering floodplain) site with bedrock control downstream. Levees and cut off meanders are present. However not easy to relate these cues to flows on a cross section
Is the site a bedrock or alluvial dominated section?	Alluvial	Mixed	Bedrock	5.0	
Are there good morphological clues that can be related to flood levels?	Very good	Don't know	Bad	3.0	
If these are present, are the terraces paired?	Yes	Don't know	No	3.0	
Sediment Transport Modelling				**4.0**	This is predominantly a bedload system and PBMT modelling is therefore appropriate and has already beed conducted in a previous study. Will use these results for this study.
Is the river a bedload dominated system (i.e. is potential bed material tranpsort modelling suitable)	Yes	Don't know	No	4.0	
Is potential bed material transport modelling going to be undertaken at this site?	Yes	Don't know	No	4.0	
OVERALL SCORE:				**3.8**	

Site description			
Morphology of the site	No good quality Google Earth imagery was available. The site is a typical meandering floodplain with ox-bow features on the floodplain. The floodplain consists of cut banks, advancing point bars and cut-off meanders. An oxbow lake is evident on the eastern flank of the floodplain. Aerial photograph analysis indicates that this predates 1956. No directional changes could be observed from the aerial photographs due to the large scale of the photographs and the narrow channel. The channel appears to have been straightened upstream of the site between 1956 and 1964. These changes are associated with agricultural activities which are evident at this time. Other localised impacts have arisen from the roads.		
PES	B (85.3%)	**Confidence**	3

E1.3.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
B	Channel incision/confinement and straightening.	Land-use impacts from agriculture and roads.	NF	3

E1.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
B	Stable	B		The current impacts are relatively small and the present state of the system is stable under these conditions.	3

E1.5 REC: A/B

PES	REC	Comments	Conf
B	B	Maintain the current EC.	3

E1.6 AEC: B/C

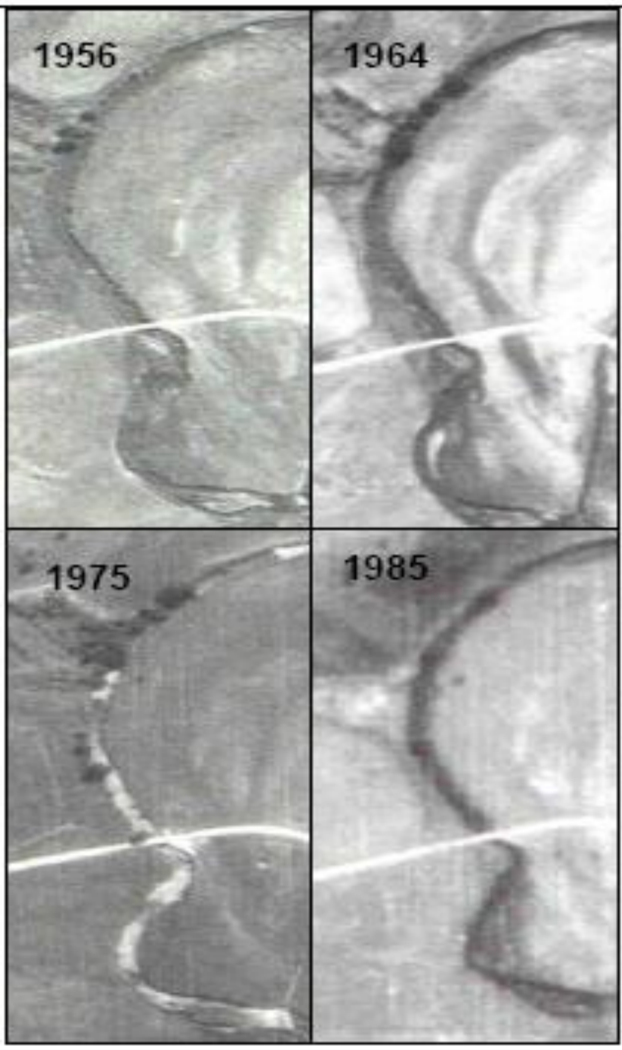
PES	AEC	Comments	Conf
B	C	A reduction in the moderate floods. This would result in less frequent and shorter duration overtopping floods, which would result in partial desiccation of the floodplains and associated wetlands.	2

E2 EWR 2: GOEDEHOOP (CROCODILE RIVER)

E2.1 DATA AVAILABILITY

Data availability	Conf
Historical aerial photography (1956, 1964, 1975, 1985). Hydrology records. Sediment transport analysis (adapted from Dollar and Biker, Geomorphology Specialist report for the Ecological Reserve of the Crocodile River catchment; 2002). Site survey information.	3

E2.2 REFERENCE CONDITIONS

Reference conditions	Conf
 Croc EWR Site 2: Few directional channel changes at EWR Site 2 could be observed due to the large scale of the photographs and the small channel. However the active channel appears to have narrowed in places and there has also been an increase in woody riparian species on the riverbanks occurred for the period 1956 to 1975.	2.5
The reference state is similar to the current condition, although the river may have been slightly wider and perhaps less deeply incised.	

E2.3 PRESENT ECOLOGICAL STATE

E2.3.1 Site suitability

This provides an assessment of the suitability of the site for EWR determination studies	SCORES: 5	2	1	SCORE	Notes
Representivity of the site for the reach				**3.3**	
How well does the *morphology* of the site represent that of the reach?	Very well	Don't know	Poorly	4.0	Morphology representative, and impacts at site (grazing, roads, incision) generally representative of the catchment.
To what extent is the *condition* of the site representative of the general condition of the reach?	Representative	Don't know	Very different	2.5	
Morphological Cues				**3.3**	Alluvial (meandering floodplain) site with bedrock control downstream. Levees and cut off meanders are present. However not easy to relate these cues to flows on a cross section
Is the site a bedrock or alluvial dominated section?	Alluvial	Mixed	Bedrock	5.0	
Are there good morphological clues that can be related to flood levels?	Very good	Don't know	Bad	2.0	
If these are present, are the terraces paired?	Yes	Don't know	No	3.0	
Sediment Transport Modelling				**4.0**	This is predominantly a bedload system and PBMT modelling is therefore appropriate and has already beed conducted in a previous study. Will use these results for this study.
Is the river a bedload dominated system (i.e. is potential bed material tranpsort modelling suitable)	Yes	Don't know	No	4.0	
Is potential bed material transport modelling going to be undertaken at this site?	Yes	Don't know	No	4.0	
OVERALL SCORE:				**3.5**	

Site description	 Alluvial river incised into the floodplain. Banks are well vegetated.		
Morphology of the site	The EWR site is within a meandering alluvial river section. Within the channel there are small riffles and long runs/pools. There is erosion on both banks (i.e. both banks are cut) suggesting a possible incision problem, but this is likely to be a localised impact associated with flow confinements under the bridge crossing. Riparian vegetation plays an important role in stabilizing the banks.		
PES	B (85.1%)	**Confidence**	2.5

E2.3.2 PES: Causes and sources

PES	Causes	Sources	F/NF	Conf
B	Channel incision/confinement and straightening.	Land use impacts from agriculture and roads.	NF	3
	Some slight changes to sediment supply.	Land use activities (agriculture).		

E2.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
B	Stable	B		The current impacts are relatively small and the present state of the system is stable under these conditions.	2.5

E2.5 REC: B

PES	REC	Comments	Conf
B	B	Maintain the current EC.	3

E2.6 AEC: C

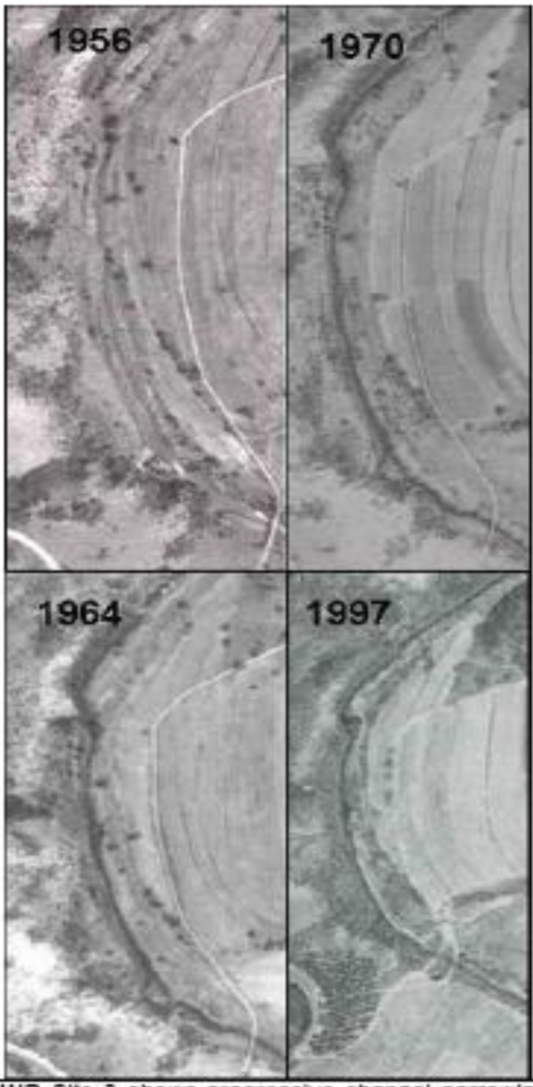
PES	AEC	Comments	Conf
B	C	It would be expected that there would be a reduction in the moderate floods. This would result in less frequent and shorter duration overtopping floods, which would result in partial desiccation of the floodplains and associated wetlands.	2

E3 EWR 3: POPLAR CREEK (CROCODILE RIVER)

E3.1 DATA AVAILABILITY

Data availability	Conf
Historical aerial photography (1956, 1964, 1975, 1985). Hydrology records. Sediment transport analysis (adapted from Dollar and Biker, Geomorphology Specialist report for the Ecological Reserve of the Crocodile River catchment; 2002). Site survey information.	3

E3.2 REFERENCE CONDITIONS

Reference conditions	Conf
 Croc EWR Site 3: EWR Site 3 shows progressive channel narrowing since 1956 with an increase in woody riparian vegetation. Site 3 is below the large Kwena Dam.	3.5
The reference state would have been a pool-riffle channel types with (relative to current conditions) a wider channel experiencing more frequent floods; finer bed and gentler sloping banks with well-vegetated marginal zones. This would have been a lower energy channel with more fines and gravels. Possibly a bit of a sinuous channel; with some in-channel vegetated bars and more marginal vegetation.	

E3.3 PRESENT ECOLOGICAL STATE

E3.3.1 Site suitability

This provides an assessment of the suitability of the site for EWR determination studies	SCORES: 5	2	1	SCORE	Notes
Representivity of the site for the reach				**3.8**	Morphology representative, and impacts at site (cut banks, incision and erosion) are generally representative of the catchment. Vegetation might be slightly better than average
How well does the *morphology* of the site represent that of the reach?	Very well	Don't know	Poorly	4.0	
To what extent is the *condition* of the site representative of the general condition of the reach?	Representative	Don't know	Very different	3.5	
Morphological Cues				**3.7**	Alluvial with limited bedrock and boulders present. Narrow floodplain and terraces are present.
Is the site a bedrock or alluvial dominated section?	Alluvial	Mixed	Bedrock	4.0	
Are there good morphological clues that can be related to flood levels?	Very good	Don't know	Bad	3.5	
If these are present, are the terraces paired?	Yes	Don't know	No	3.5	
Sediment Transport Modelling				**4.0**	This is predominantly a bedload system and PBMT modelling is therefore appropriate and has already beed conducted in a previous study. Will use these results for this study.
Is the river a bedload dominated system (i.e. is potential bed material tranpsort modelling suitable)	Yes	Don't know	No	4.0	
Is potential bed material transport modelling going to be undertaken at this site?	Yes	Don't know	No	4.0	
OVERALL SCORE:				**3.8**	

Site description	 		
Morphology of the site	Cut banks are present on both banks (water is very turbid), and channel narrowing is evident from the aerial photographs. The channel in this pool riffle site is incising in response to the clean water releases, as well as the prolonged elevated base flows which are being released from Kwena Dam. The active channel is composed of loose cobbles with some gravels and occasional fixed boulders. There are no fines anywhere along the reach in the channel and very few gravels (extremely coarse) are present.		
PES	C (62.4%)	**Confidence**	3

E3.3.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
C	Channel incision – cut banks on both banks.	Kwena Dam upstream is the source of reduced floods, elevated low and base flows.	F	3.5

E3.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
C	Slow negative	D	5 years	Continued altered flow releases will erode banks, and reduced flooding is desiccating the upper terraces/floodplain.	2.5

E3.5 REC: B

PES	REC	Comments	Conf
C	C	It is not possible to improve the condition of the geomorphology. Although the loss of the moderate floods is a problem, due to the clean water being released from Kwena Dam the reinstatement of these large flows (from the dam) would actually increase the rate of erosion and channel incision in this reach.	3

E3.6 AEC: C/D

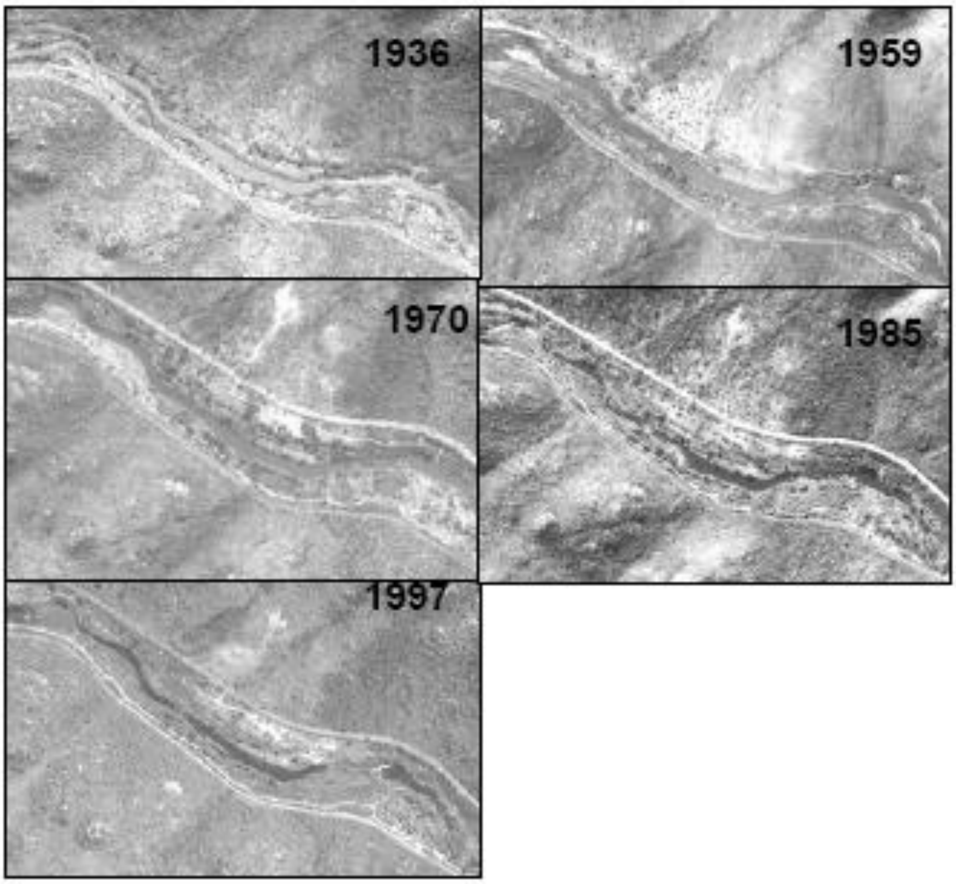
PES	AEC	Comments	Conf
C	C	There is unlikely to be any adjustment to the EC of the geomorphology.	N/A

E4 EWR 4: KANYAMAZANE (CROCODILE RIVER)

E4.1 DATA AVAILABILITY

Data availability	Conf
Historical aerial photography (1936, 1959, 1970, 1985, 1997). Sediment transport analysis (adapted from Dollar and Biker, Geomorphology Specialist report for the Ecological Reserve of the Crocodile River catchment; 2002). Hydrology records. Site survey information.	3

E4.2 REFERENCE CONDITIONS

Reference conditions	Conf
 **Croc EWR Site 4:** EWR Site 4 shows progressive channel narrowing since 1936. Channel narrowing is most prominent riffle sections (located at the active channel meander bends) and is coincidental with an increase in vegetation establishment.	3.5
The site is close to the reference state (mixed pool-riffle).	

E4.3 PRESENT ECOLOGICAL STATE

E4.3.1 Site suitability

This provides an assessment of the suitability of the site for EWR determination studies	SCORES: 5	2	1	SCORE	Notes
Representivity of the site for the reach				**3.8**	Morphology representative, and impacts at site (grazing, limited wood harvesting) are generally representative of the catchment.
How well does the *morphology* of the site represent that of the reach?	Very well	Don't know	Poorly	4.0	
To what extent is the *condition* of the site representative of the general condition of the reach?	Representative	Don't know	Very different	3.5	
Morphological Cues				**3.0**	Alluvial with large bedrock boulders are present. Extensive terraces are present on one bank; other bank is highly disturbed.
Is the site a bedrock or alluvial dominated section?	Alluvial	Mixed	Bedrock	3.5	
Are there good morphological clues that can be related to flood levels?	Very good	Don't know	Bad	3.5	
If these are present, are the terraces paired?	Yes	Don't know	No	2.0	
Sediment Transport Modelling				**4.0**	This is predominantly a bedload system and PBMT modelling is therefore appropriate and has already beed conducted in a previous study. Will use these results for this study.
Is the river a bedload dominated system (i.e. is potential bed material tranpsort modelling suitable)	Yes	Don't know	No	4.0	
Is potential bed material transport modelling going to be undertaken at this site?	Yes	Don't know	No	4.0	
OVERALL SCORE:				**3.6**	

Site description	  The reach is in a generally very good condition.		
Morphology of the site	EWR 4 is classified as a mixed pool-rapid channel type and is representative of the macro-reach. The channel consists of an active channel inset into a wider macro-channel. There is strong bedrock influence, extensive lateral bars and well-developed terraces at the site. Riparian trees have been removed, probably through a combination of fire, grazing and direct curio/firewood harvesting. This will have an impact on back stabilisation and sedimentation. There has been some slight channel narrowing, possibly as a result of increased sediment loads (due to land degradation in the Lowveld) and associated vegetation encroachment. These factors have resulted in some degradation of the riparian, marginal and instream habitat conditions.		
PES	B/C (81.6%)	**Confidence**	3

E4.3.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
B/C	Reduced sediment transport capacity.	Reduced flood flows from the Kwena Dam and abstraction from Nelspruit.	F	3
	Increased sediment supply.	Agriculture and some informal settlement areas.	NF	

E4.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
B/C	Stable	B/C		In the medium term, current scenarios would be unlikely to cause a change in the Geomorphology EC.	2.5

E4.5 REC: B

PES	REC	Comments	Conf
B/C	B	More effective scouring of sediment resulting in an improved EC.	3

E4.6 AEC: C/D

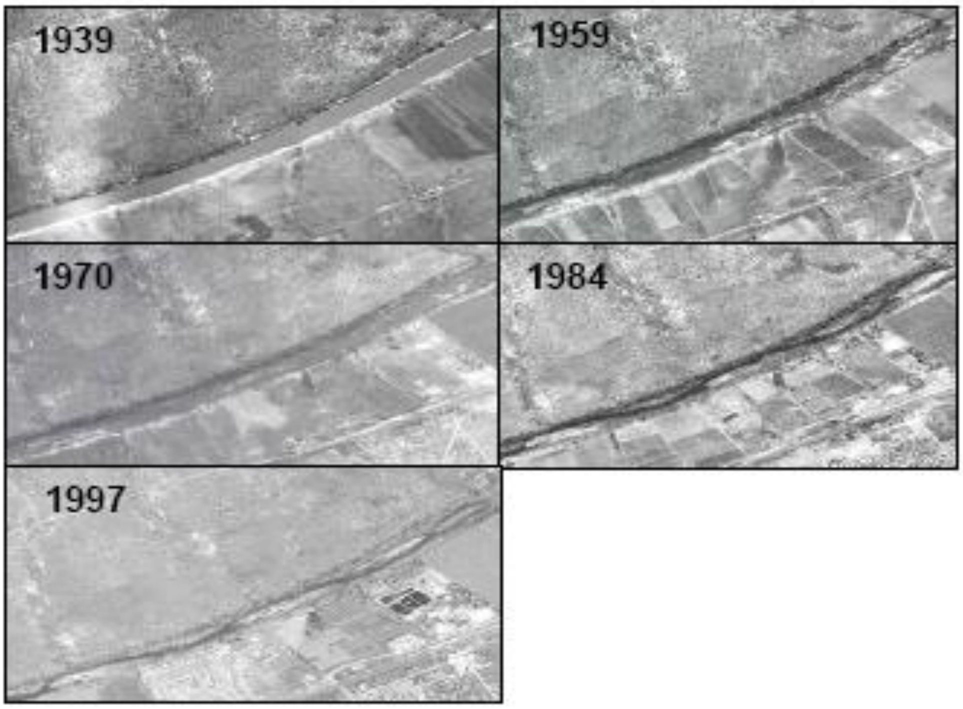
PES	AEC	Comments	Conf
B/C	C	More rapid sedimentation of the pools and active channels.	2.5

E5 EWR 5: MALALANE (CROCODILE RIVER)

E5.1 DATA AVAILABILITY

Data availability	Conf
Historical aerial photography (1936, 1959, 1970, 1984, 1997). Hydrology records. Sediment transport analysis (adapted from Dollar and Biker, Geomorphology Specialist report for the Ecological Reserve of the Crocodile River catchment; 2002). Site survey information.	3

E5.2 REFERENCE CONDITIONS

Reference conditions	Conf
 **Croc EWR Site 5** EWR Site 5 shows progressive channel narrowing since 1939, and a general increase in depositional features is evident. Aerial photographs indicate an increase in mid-channel bars and lateral bars, coincidental with colonisation by vegetation. This would suggest a directional change towards more stable, vegetated morphological features and subsequent reduced floodplain conveyance.	3
A very wide, sandy bed river system. Vegetation was restricted to the macro-channel banks (and encroachment prevented by bank to bank seasonal flows and large flood flows which scoured sediment from the channel). This combination of factors maintained a mobile sand bed which further inhibited vegetation establishment and stabilisation of sediment.	

E5.3 PRESENT ECOLOGICAL STATE

E5.3.1 Site suitability

This provides an assessment of the suitability of the site for EWR determination studies	SCORES: 5	2	1	SCORE	Notes
Representivity of the site for the reach				**3.8**	Morphology representative, and impacts at site (bank disturbance outside KNP) are generally representative of the catchment; although possibly slightly better at this site
How well does the *morphology* of the site represent that of the reach?	Very well	Don't know	Poorly	4.0	
To what extent is the *condition* of the site representative of the general condition of the reach?	Representative	Don't know	Very different	3.5	
Morphological Cues				**2.2**	Macro-channel with alluvial dominated active channel. No clear terraces are present.
Is the site a bedrock or alluvial dominated section?	Alluvial	Mixed	Bedrock	3.5	
Are there good morphological clues that can be related to flood levels?	Very good	Don't know	Bad	2.0	
If these are present, are the terraces paired?	Yes	Don't know	No	1.0	
Sediment Transport Modelling				**4.3**	This is a bedload system and PBMT modelling is therefore appropriate and has already beed conducted in a previous study. Will use these results for this study.
Is the river a bedload dominated system (i.e. is potential bed material tranpsort modelling suitable)	Yes	Don't know	No	5.0	
Is potential bed material transport modelling going to be undertaken at this site?	Yes	Don't know	No	4.0	
OVERALL SCORE:				**3.4**	

<table>
<tr><td>Site description</td><td colspan="3">

EWR 5 is classified as an alluvial braided channel type and is representative of the macro-reach. The channel consists of an active channel inset into a wider macro-channel. The channel is alluvial, with sand dominating the bed. The bed is mobile, even under the lowest flow conditions. The channel morphology is currently characterised by vegetated mid-channel bar, lateral bars, in-channel benches and terraces. Riparian and in-channel vegetation (particularly reeds) play an important role in stabilizing the channel banks, and have an important effect on the sedimentation processes in the active channel.</td></tr>
<tr><td>Morphology of the site</td><td colspan="3">The current state of the river is markedly different from the reference state – reduced flows and increased sediment loads from the upstream catchment has caused a smaller active channel to develop - the morphology is now represented by an active channel inset into a wider macro-channel. Subsequent encroachment of vegetation has allowed for the development of vegetated mid-channel bars, lateral bars and in-channel benches inside the former larger channel. The now smaller inset channel meanders between these increasingly vegetated, stabilised sedimentary bars on the macro-channel floor. The macro channel floor is dominated by sand, with limited bedrock exposure/influence.</td></tr>
<tr><td>PES</td><td>C/D (60.1%)</td><td>Confidence</td><td>3.5</td></tr>
</table>

E5.3.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
C/D	Reduced sediment transport capacity (leading to increased deposition and vegetation encroachment).	Reduced flood flows from upstream dams and very reduced/regulated low flows, abstraction from Nelspruit and large irrigation abstractions.	F	3
	Increased stabilization and vegetation of banks and bars.	Altered hydrological regime.		
	Increased sediment supply.	Erosion from agricultural and informal settlement areas.	NF	

E5.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
C/D	Negative	D	5 years	The aerial photographic record demonstrates a strong directional change from a wide, dynamic channel to a much smaller, narrower active channel. The bars and banks have become more vegetated and stabilised.	3

E5.5 REC: B

PES	REC	Comments	Conf
C/D	C	Improved low flow conditions would slightly improve the stabilisation and deepening of the channel, and result in a small increase in the active channel and a small reduction in the extent of bars.	3

E5.6 AEC: D

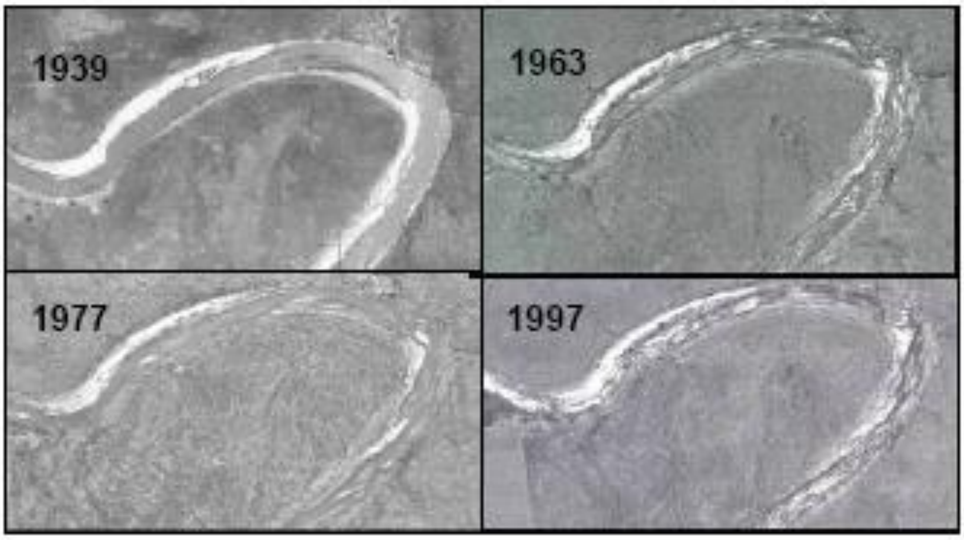
PES	AEC	Comments	Conf
C/D	D	Further reduced flows (and possible very low/no flow periods) would result in further degradation of the EC. The channel would continue to become shallower and sandier.	3.5

E6 EWR 6: NKONGOMA (CROCODILE RIVER)

D5.1 DATA AVAILABILITY

Data availability	Conf
Historical aerial photography (1939, 1963, 1977, 1997). Hydrology records. Sediment transport analysis (adapted from Dollar and Biker, Geomorphology Specialist report for the Ecological Reserve of the Crocodile River catchment; 2002). Site survey information.	3

E6.1 REFERENCE CONDITIONS

Reference conditions	Conf
 **Croc EWR Site 6** As with EWR Sites 4 and 5, aerial photographs indicate an increase in mid-channel bars and lateral bars, coincidental with colonisation by vegetation, suggesting a directional change towards more stable, vegetated morphological features. This is probably due to reduced floods. The reference state is a more open wider active channel, larger (wider) rapids and smaller bar areas.	3

E6.2 PRESENT ECOLOGICAL STATE

E6.2.1 Site suitability

This provides an assessment of the suitability of the site for EWR determination studies	SCORES: 5	2	1	SCORE	Notes
Representivity of the site for the reach				**3.8**	Morphology representative, and impacts at site (limited vegetation disturbance on the bank outside KNP) are generally representative of the catchment; although possibly slightly better at this site.
How well does the *morphology* of the site represent that of the reach?	Very well	Don't know	Poorly	4.0	
To what extent is the *condition* of the site representative of the general condition of the reach?	Representative	Don't know	Very different	3.5	
Morphological Cues				**1.7**	Bedrock dominated section of the river, with alluvial deposits in the channel. No clear terraces are present.
Is the site a bedrock or alluvial dominated section?	Alluvial	Mixed	Bedrock	2.0	
Are there good morphological clues that can be related to flood levels?	Very good	Don't know	Bad	2.0	
If these are present, are the terraces paired?	Yes	Don't know	No	1.0	
Sediment Transport Modelling				**4.3**	This is a bedload system and PBMT modelling is therefore appropriate and has already been conducted in a previous study. Will use these results for this study.
Is the river a bedload dominated system (i.e. is potential bed material tranpsort modelling suitable)	Yes	Don't know	No	5.0	
Is potential bed material transport modelling going to be undertaken at this site?	Yes	Don't know	No	4.0	
OVERALL SCORE:				**3.3**	

Site description	 		
Morphology of the site	EWR 6 is a mixed anastomosing channel type and is representative of the macro-reach. The site runs across a bedrock rapid area. Downstream there is a deep pool. The channel consists of a number of active channels inset into a wider macro-channel. There is strong bedrock influence. A relatively thin, mostly sandy veneer of alluvium overlies the dominant bedrock. The bed is mobile, even under the lowest flow conditions. The aerial photographic record demonstrates a strong directional change from a wide channel to a few much smaller, narrower active channel, probably due to reduced floods and flows generally. The bars and banks have become more vegetated and stabilised.		
PES	C (66.6%)	**Confidence**	3

E6.2.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
C	Reduced sediment transport capacity.	Reduced flows from the Kwena Dam; abstraction from towns; extensive irrigation abstractions.	F	3
	Increased sediment supply.	Primarily agriculture, but also sediment introduction due to erosion in informal settlement areas.	NF	

E6.3 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
C	Negative	C/D	10 years	The aerial photographic record demonstrates a strong directional change from a wide channel to a few much smaller, narrower active channel probably due to reduced floods and flows generally. The bars and banks have become more vegetated and stabilised.	3

E6.4 REC: B

PES	REC	Comments	Conf
C	C	The pools have filled in extensively due to a combination of reduced flows and increased erosion in the catchment and it will therefore not be possible to improve the geomorphology beyond the C EC.	3

E6.5 AEC: D

PES	AEC	Comments	Conf
C	C/D	Reduced floods and reduced low/base flows will exacerbate the sedimentation of the pools in this area.	2.5

E7 EWR 7: HONEYBIRD (KAAP RIVER)

E7.1 DATA AVAILABILITY

Data availability	Conf
Historical aerial photography (1936, 1959, 1970, 1984, 1997). Hydrology records. Sediment transport analysis (adapted from Dollar and Biker, Geomorphology Specialist report for the Ecological Reserve of the Crocodile River catchment; 2002). Site survey information.	3

E7.2 REFERENCE CONDITIONS

Reference conditions	Conf
 **Croc EWR Site 7:** EWR Site 7 is bedrock gorge channel type with strong bedrock influence. Upstream of the bridge there has been an increase in bars followed by vegetation colonisation and stabilisation, leading to a reduction in active channel width.	2.5
The current state is close to the reference condition.	

E7.3 PRESENT ECOLOGICAL STATE

E7.3.1 Site suitability

This provides an assessment of the suitability of the site for EWR determination studies	SCORES: 5	2	1	SCORE	Notes
Representivity of the site for the reach				**2.8**	Morphology representative, but impacts (alien vegetation, bank disturbance) at site are possibly slightly worse at this site due to historic disturbance along and near the road crossing. Bridge will have backup effect at high flows
How well does the *morphology* of the site represent that of the reach?	Very well	Don't know	Poorly	3.0	
To what extent is the *condition* of the site representative of the general condition of the reach?	Representative	Don't know	Very different	2.5	
Morphological Cues				**2.0**	Bedrock dominated section of the river, with lateral alluvial deposits. Terrace may be an artefact of backup effects and old bank disturbance.
Is the site a bedrock or alluvial dominated section?	Alluvial	Mixed	Bedrock	3.0	
Are there good morphological clues that can be related to flood levels?	Very good	Don't know	Bad	2.0	
If these are present, are the terraces paired?	Yes	Don't know	No	1.0	
Sediment Transport Modelling				**4.3**	This is a bedload system and PBMT modelling is therefore appropriate and has already been conducted in a previous study. Will use these results for this study.
Is the river a bedload dominated system (i.e. is potential bed material tranpsort modelling suitable)	Yes	Don't know	No	5.0	
Is potential bed material transport modelling going to be undertaken at this site?	Yes	Don't know	No	4.0	
OVERALL SCORE:				**3.0**	

<table>
<tr><td>Site description</td><td colspan="3">
</td></tr>
<tr><td>Morphology of the site</td><td colspan="3">EWR 7 is classified as a bedrock gorge channel type and is representative of the Kaap River. The cross-section traverses a riffle. The strong bedrock influence means that the site is highly resistant to change so that little morphological adjustment is likely to occur in response to flow regulation. The bed material is predominantly cobble and boulder with very little sand and gravel. It is possible that upstream of the bridge there has been some enhanced sediment deposition at high flows due to flow constrictions through the narrow bridge crossing, and also associated with disturbance on the banks.</td></tr>
<tr><td>PES</td><td>B (86.1%)</td><td>Confidence</td><td>2.5</td></tr>
</table>

E7.3.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
B	Reduced sediment transport capacity.	Reduced flows from abstraction, forestry etc.	F	3
	Increased sediment supply.	Primarily agriculture, but also sediment introduction due to erosion in informal settlement areas.	NF	

E7.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
B	Negative	B/C	10 years	The aerial photos demonstrate a directional change towards a narrower, less dynamic river channel.	3

E7.5 REC: B

PES	REC	Comments	Conf
B	B	Maintain the current EC, but address the negative trend. This will require the provision of adequate moderate floods to scour the channel and prevent narrowing and encroachment. An improvement in EC is not possible.	N/A

E7.6 AEC: D

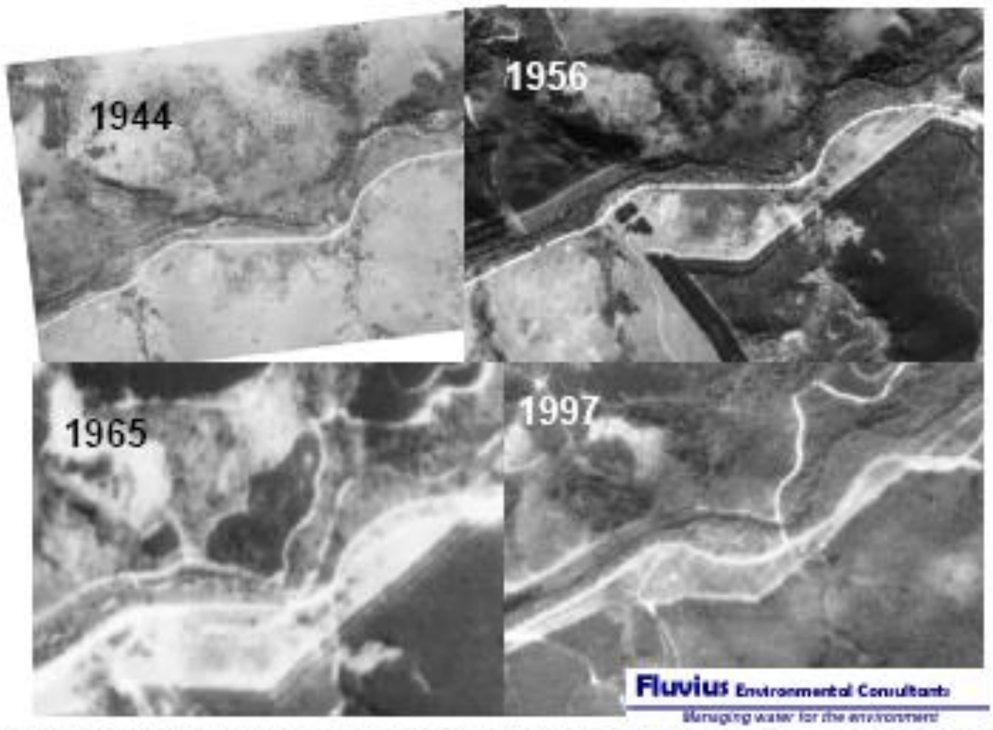
PES	AEC	Comments	Conf
B	C	The proposed Mountain View Dam in this upper catchment would reduce the flooding frequency and size of floods.	2

E8 EWR 1: UPPER SABIE (SABIE RIVER)

E8.1 DATA AVAILABILITY

Data availability	Conf
Historical aerial photography (1944, 1956, 1965, 1997). Sediment transport modelling and analysis undertaken for this study. Hydrology records. Site survey information at time of study.	3

E8.2 REFERENCE CONDITIONS

Reference conditions	Conf
 **Sabie EWR Site 1**: An increase in woody vegetation is evident from the aerial photographs. The small size of the channel and poor quality of the aerial photography preclude any detailed analysis of inchannel features. The reference condition is a pool-riffle system, with a boulder/cobble bed with gravels. The valley is confined, and thus whilst there is a large flood terrace on one bank, the opposite bank is a steep cut bank. Woody cover under natural condition probably less than present.	3

E8.3 PRESENT ECOLOGICAL STATE

E8.3.1 Site suitability

This provides an assessment of the suitability of the site for EWR determination studies	SCORES: 5	2	1	SCORE	Notes
Representivity of the site for the reach				**3.5**	
How well does the *morphology* of the site represent that of the reach?	Very well	Don't know	Poorly	4.0	Morphology representative, but condition may be poor due to recent extensive fires and excessive sediment input from foresty, and burnt, areas
To what extent is the *condition* of the site representative of the general condition of the reach?	Representative	Don't know	Very different	3.0	
Morphological Cues				**2.3**	
Is the site a bedrock or alluvial dominated section?	Alluvial	Mixed	Bedrock	2.0	Mixed bedrock/alluvial site. Teraces on the one bank, the other bank is a steep cut bank with bedrock influence. Terraces are not paired.
Are there good morphological clues that can be related to flood levels?	Very good	Don't know	Bad	3.0	
If these are present, are the terraces paired?	Yes	Don't know	No	2.0	
Sediment Transport Modelling				**2.3**	This is a bedload system and PBMT modelling would be appropriate, but the budget only allows for priority sites to be modelled in this way. Priority is likely to lie further down the catchment (i.e. near or inside the Kruger National Park).
Is the river a bedload dominated system (i.e. is potential bed material tranpsort modelling suitable)	Yes	Don't know	No	5.0	
Is potential bed material transport modelling going to be undertaken at this site?	Yes	Don't know	No	1.0	
OVERALL SCORE:				**2.7**	

<table>
<tr><td>Site description</td><td colspan="3">

Upstream impacts upon the site include:
Forestry;
A few, small weirs and illegal abstraction, and
Return sewage flows from Sabie town.
Virgin MAR: 152 MCM; Present MAR: 115 MCM</td></tr>
<tr><td>Morphology of the site</td><td colspan="3">The site is a pool-riffle system with a boulder/cobble bed and gravel and large sand component. It is possible that the sand component has increased due to upstream forestry activities and has led to a reduction in channel size. Aerial photos indicate an increase in woody vegetation cover. The riparian zone is heavily infested with exotic vegetation and has recently burnt prior to the site visit. The flood terraces are composed of fine sands and not paired, as one bank is a steep cut bank.</td></tr>
<tr><td>PES</td><td>B (83.3%)</td><td>Confidence</td><td>3.5</td></tr>
</table>

E8.3.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
B	Small changes to the sediment supply.	Forestry activities.	NF	3.5
	Decreased flows due to a reduction in size of the active channel.		F	
	Forestry and abstraction.	Flow reduction.	F	

E8.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
B	Stable	B			3

E8.5 REC: B

PES	REC	Comments	Conf
B	B	The current scenario will not result in an improvement of the EC.	N/A

E8.6 AEC: C/D

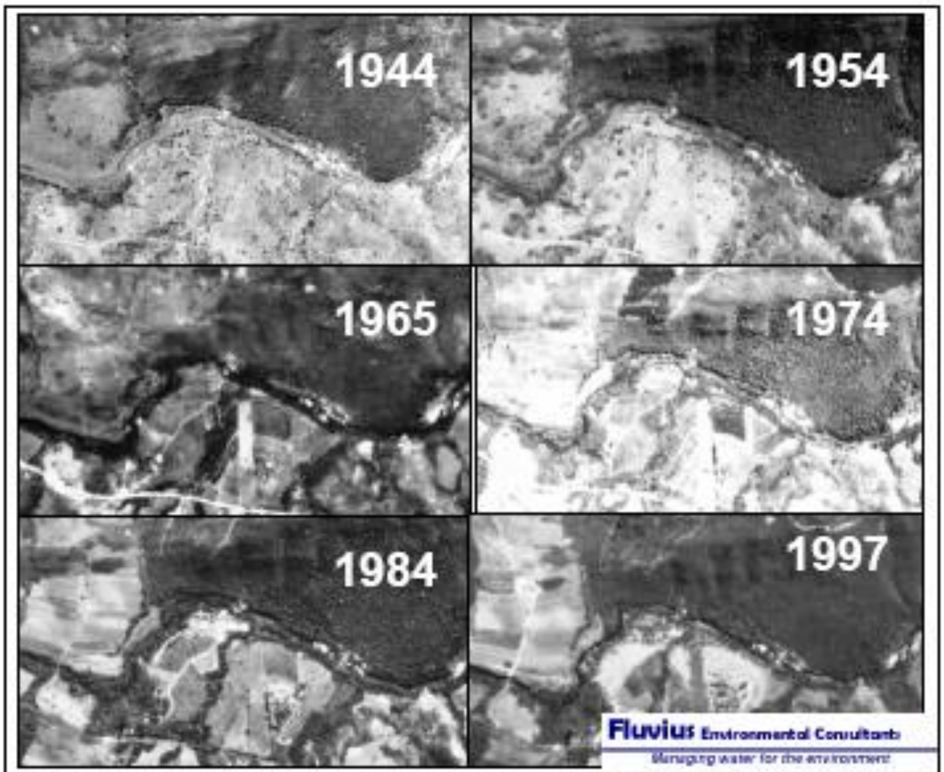
PES	AEC	Comments	Conf
B	C	Increased sediment load due to poor land management in forestry and other upstream landuse activities will result in a C EC due to serious changes in channel morphology and increased bars. Vertical and horizontal channel connectivity will be impacted due to more weirs.	2.5

E9 EWR 2: AAN DE VLIET (SABIE RIVER)

E9.1 DATA AVAILABILITY

Data availability	Conf
Historical aerial photography (1944, 1954, 1965, 1974, 1984, 1997). Sediment transport modelling and analysis undertaken for this study. Hydrology records. Site survey information at time of study.	3

E9.2 REFERENCE CONDITIONS

<table>
<tr><th>Reference conditions</th><th>Conf</th></tr>
<tr><td>


Sabie EWR Site 2: An increase in woody vegetation is evident from the aerial photographs. The small size of the channel and poor quality of the aerial photography preclude any detailed analysis of inchannel features. The small bedrock anastomosing section is stable.

The 1940's condition of the river (prior to any intensive catchment development) is assumed to represent a component of the natural (reference state) dynamics of the site. At this site, the reference condition would thus range from the current well-wooded banks and bars with associated narrow channel across a range of morphologies which would also include a slightly wider active channel and more open (i.e. less well wooded) channel banks and bars. The larger bedrock exposures downstream would not be covered with sediment. Thus the current condition of the river currently is close to natural. The only anticipated changes from reference state are probably a higher component of fines in the bed material and slightly infilled pools (both due to higher sediment loads from forestry and other disturbed areas in the catchment).
</td><td>3</td></tr>
</table>

E9.3 PRESENT ECOLOGICAL STATE

E9.3.1 Site suitability

This provides an assessment of the suitability of the site for EWR determination studies	SCORES: 5	2	1	SCORE	Notes
Representivity of the site for the reach				**3.0**	Morphology not very representative (wide floodplain is atypical), and condition may be poorer due to bank modification and vegetation removal assocaited with resort.
How well does the *morphology* of the site represent that of the reach?	Very well	Don't know	Poorly	3.0	
To what extent is the *condition* of the site representative of the general condition of the reach?	Representative	Don't know	Very different	3.0	
Morphological Cues				**2.5**	Mixed bedrock/alluvial site. Floodplain on the one bank, other bank is steep cut bank. Terraces are not paired.
Is the site a bedrock or alluvial dominated section?	Alluvial	Mixed	Bedrock	3.0	
Are there good morphological clues that can be related to flood levels?	Very good	Don't know	Bad	2.5	
If these are present, are the terraces paired?	Yes	Don't know	No	2.0	
Sediment Transport Modelling				**2.3**	This is a bedload system and PBMT modelling would be appropriate, but the budget only allows for priority sites to be modelled in this way. Priority is likely to lie further down the catchment (i.e. near or inside the Kruger National Park).
Is the river a bedload dominated system (i.e. is potential bed material tranpsort modelling suitable)	Yes	Don't know	No	5.0	
Is potential bed material transport modelling going to be undertaken at this site?	Yes	Don't know	No	1.0	
OVERALL SCORE:				**2.6**	

Site description			
Morphology of the site	Although the site where the cross-section is located is pool riffle, the reach has numerous bedrock anastomosing sections. The site has riffles, vegetated banks and islands, pools and runs, and an extensive floodplain area. A wide floodplain pocket occurs on the southern bank, and thus the site may not be typical of the reach MRU Sabie A as this very wide floodplain section is somewhat atypical. Landscaping/disturbance of the banks have occurred for garden/park creation, and placement of chalets along the river banks. The northern bank is eroding, and the southern bank has likely been engineered, and small scale sand mining has occurred here. The active channel at the site has shrunk, and the riparian zone has become more well-wooded. It is likely that the bed material has similarly fined.		
PES	B (85.3%)	**Confidence**	3.5

E9.3.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
B	Channel incision/confinement and straightening.	Landscaping/disturbance of the RB has occurred for garden/park creation, and placement of chalets along the river banks and impacts on the floodplain to some extent.	NF	3
	Some slight changes to sediment supply.	Landuse activities (agriculture).		

E9.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
B	Stable	B			3

E9.5 REC: B

PES	REC	Comments	Conf
B	B	Maintain the current EC.	N/A

E9.6 AEC: C/D

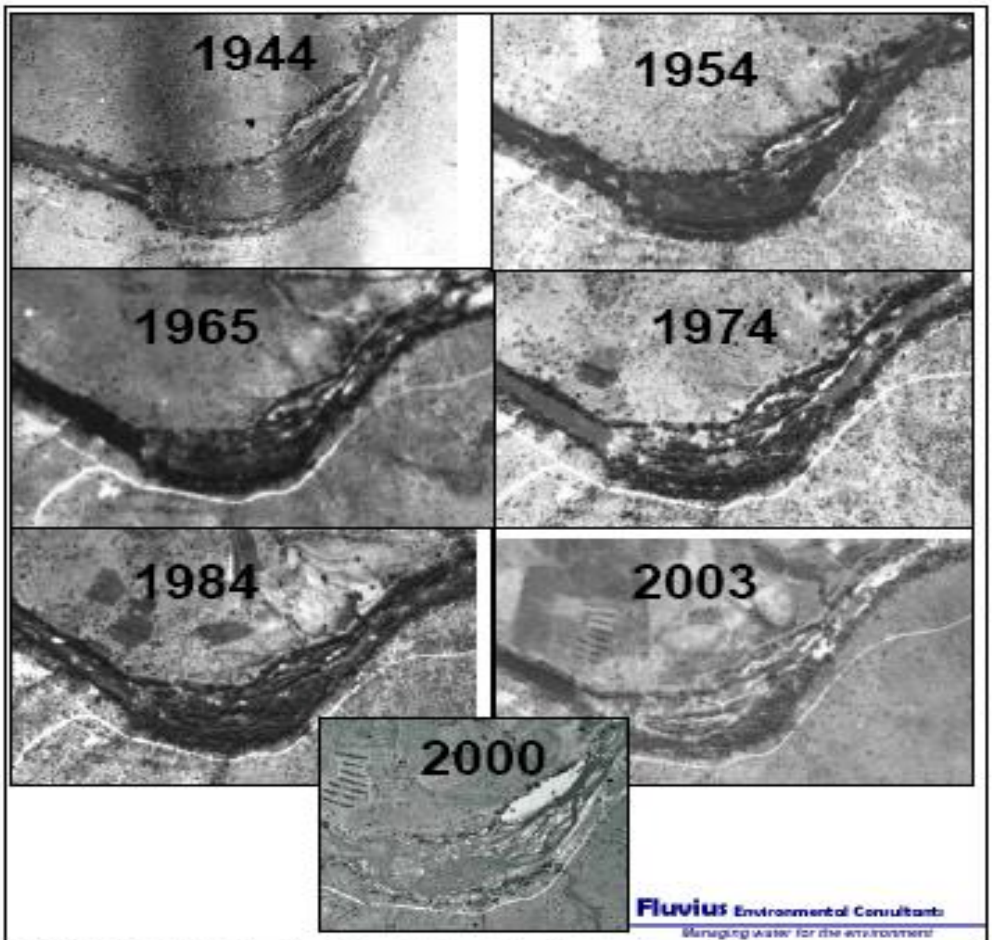
PES	AEC	Comments	Conf
B	C	Sedimentation would increase and flood frequency will be reduced due to increased abstraction.	2

E10 EWR 3: KIDNEY (SABIE RIVER)

E10.1 DATA AVAILABILITY

Data availability	Conf
Historical aerial photography (1956, 1964, 1970, 1997). Sediment transport modelling and analysis undertaken for this study. Hydrology records. Site survey information at time of study, and previous cross-sectional surveys over the last 15 years (from unpublished PhD research and KNP River Research Programme).	5

E10.2 REFERENCE CONDITIONS

Reference conditions	Conf
 **Sabie EWR Site 3**: This site displays the typical cyclical patterns of sediment deposition and vegetation establishment (1944-1984) interrupted by large infrequent floods which scour the system (as in 1921 and 2000). Over the long term, the site is stable. This is a very well-studied site within the Kruger National Park. The site has representative sections of the bedrock anastomosing channel type. Although from 1944 until 1984, there was a very strong trend of increasing extent of woody vegetation, this trend was reversed following an extreme flood in February 2000. Thus the post – 2000 imagery appears very similar to the earliest 1944 imagery – the system has been "reset" by the 2000 flood, as has the 1944 image following the similarly large 1921 flood. The degrees of changes recorded by this sequence of aerial photography record a commonly identified pattern of sediment storage within Southern African eastern seaboard river (Rountree *et al*., 2000; Rountree *et al*., 2001; Rountree and Rogers, 2004). Sediment (and vegetation) accumulates in river systems over a period of decades and then this is removed when large infrequent flood events occur.	4

E10.3 PRESENT ECOLOGICAL STATE

E10.3.1 Site suitability

This provides an assessment of the suitability of the site for EWR determination studies	SCORES: 5	2	1	SCORE	Notes
Representivity of the site for the reach				**4.0**	Sit is Within a BA channel segment, although at the cross-section there is extensive alluvial influence (almost MA in character). Typical of these types of reaches.
How well does the *morphology* of the site represent that of the reach?	Very well	Don't know	Poorly	4.0	
To what extent is the *condition* of the site representative of the general condition of the reach?	Representative	Don't know	Very different	4.0	
Morphological Cues				**1.2**	No true morphological cues. The "terrace" at the site could be an old BCB now forming part of a lateral bar. It is unlikely that the seasonal channel on the far edge of the floodplain is contemporary - the Breonadia are more than 1.5m in diameter and very far from the channel. Probably tapping in to subsurface flows along the old seasonal channel pathway?
Is the site a bedrock or alluvial dominated section?	Alluvial	Mixed	Bedrock	1.5	
Are there good morphological clues that can be related to flood levels?	Very good	Don't know	Bad	1.0	
If these are present, are the terraces paired?	Yes	Don't know	No	1.0	
Sediment Transport Modelling				**5.0**	Excellent candidate for PBMT modelling - bedload(sand,gravel,cobbles)system. PBMT to be undertaken at this site due to its high priority status (low in the catchment to assess flood requirements;sedim entation in the Sabie a longstanding concern and sit within the KNP).
Is the river a bedload dominated system (i.e. is potential bed material tranpsort modelling suitable)	Yes	Don't know	No	5.0	
Is potential bed material transport modelling going to be undertaken at this site?	Yes	Don't know	No	5.0	
OVERALL SCORE:				**3.4**	

<table>
<tr><td>Site description</td><td colspan="3">
</td></tr>
<tr><td>Morphology of the site</td><td colspan="3">The site is a bedrock anastomosing channel form type with steep slopes; multiple channels with high bedrock influence and large mixed alluvial and bedrock core bars in between the several active channels. The channels are diverse, having bedrock, boulder, cobbles, gravels and sandy sections. The bedrock core bars (usually dominated by B. salicina) separate the channels. At the downstream end of this section there are large sandy lateral bars. These are high elevation, stable macro-channel features.

The site is located downstream of Hazyview, and this section of the river forms on border of the Kruger National Park. There is one dam upstream, but floods are only moderately affected.

Although the site is in a B category, the reach is likely to be in a lower (lower B or B/C) category. This is because the bedrock anastomosing channel type (in which this EWR site is located) is the least sensitive of all channel types to sedimentation. Sedimentation is the primary problem in this section of the river, due to the increased erosion and decreased flows arising from upstream.

It is in the narrow sections of the river, characterised by braided and pool-rapid channel types, where sediment is preferentially deposited and stored. This increase in sediment storage results in the loss of exposed bedrock areas and riffles, as well as deep pools, causing a decrease in the instream habitat diversity as the sites all tend towards sandy shallow systems. Therefore the confidence in the PES assessment is a 4.</td></tr>
<tr><td>PES</td><td>B (84.6%)</td><td>Confidence</td><td>4</td></tr>
</table>

E10.3.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
B	Increased sediment supply – increased fines and deposition, loss of pools.	Intensive settlement (extensive peri-urban areas with large bare areas) and heavy grazing pressures. Extensive forestry and poor landuse in lower catchment as well as erosion.	NF	3
	Decreased flows – reduced sediment transport potential.	Forestry; irrigation, and abstraction.	F	

E10.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
B	Negative	B/C	10 years	Increased sediment and decreased transport capacity will continue to cause aggradation and loss of bedrock influence. Although this particular site is not very sensitive to sedimentation, other sections of the river (immediately up- and downstream) would show the effects of sedimentation, and loss of habitat diversity, more quickly.	3.5

E10.5 AEC: B/C

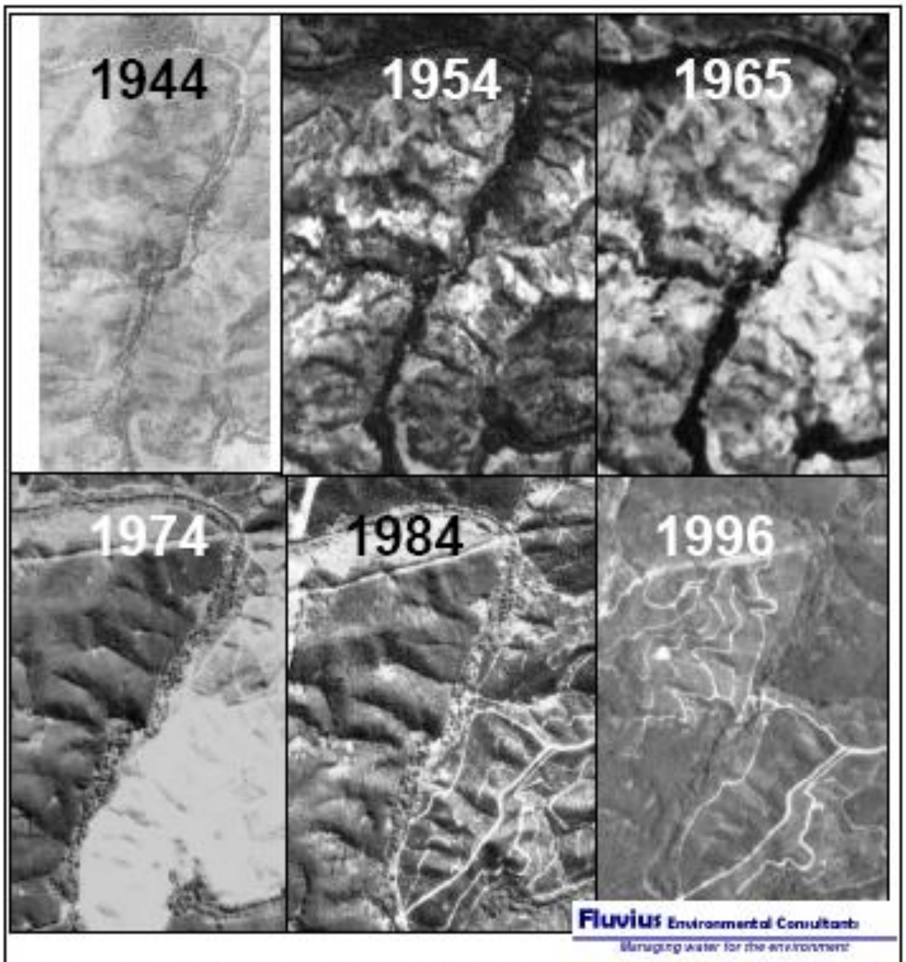
PES	AEC	Comments	Conf
B	C	Increased sedimentation, particularly in the braided and pool-rapid channel type sections of this reach. Habitat changes will include more extensive reeds, shallower channels and a loss of deep pools and bedrock rapids and riffles.	3

E11 EWR 4: MAC MAC (MAC MAC RIVER)

E11.1 DATA AVAILABILITY

Data availability	Conf
Historical aerial photography (1944, 1954, 1965, 1974, 1984, 1996). Site survey information at time of study. Daily flow data is required to undertake sediment (potential bed material) transport modelling so that effective discharge classes can be determined. At this site, no daily hydrological data were available – the nearest flow gauge is too far away to be used with any confidence to represent the flows at this site.	3

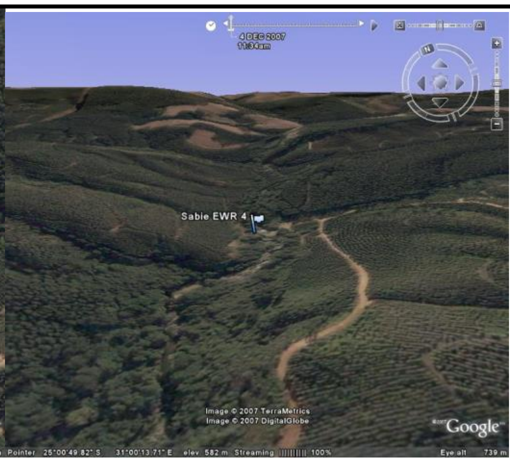
E11.2 REFERENCE CONDITIONS

Reference conditions	Conf
 **Sable EWR Site 4**: There seems to be an increase in woody vegetation. The small size of the channel and poor quality of the aerial photography preclude any detailed analysis of inchannel features. From the aerial photographs, there appears to have been an increase in woody vegetation. The channel and areas of exposed bedrock which were evident in 1944 are again evident in the 2006/7 Google Earth imagery (which represents the site post the large floods in 2000). Overall, however, the site is very close to the natural condition.	3.5

E11.3 PRESENT ECOLOGICAL STATE

E11.3.1 Site suitability

This provides an assessment of the suitability of the site for EWR determination studies	SCORES: 5	2	1	SCORE	Notes
Representivity of the site for the reach				**3.8**	
How well does the *morphology* of the site represent that of the reach?	Very well	Don't know	Poorly	3.5	In terms of condition, the site is likely to be representative - few impacts are evident along this river.
To what extent is the *condition* of the site representative of the general condition of the reach?	Representative	Don't know	Very different	4.0	
Morphological Cues				**1.7**	No true morphological cues. The "terrace" at the site could be an old BCB now forming part of a lateral bar. It is unlikely that the seasonal channel on the far edge of the floodplain is contemporary - the Breonadia are more than 1.5m in diameter and very far from the channel. Probably tapping in to subsurface flows along the old seasonal channel pathway.
Is the site a bedrock or alluvial dominated section?	Alluvial	Mixed	Bedrock	1.5	
Are there good morphological clues that can be related to flood levels?	Very good	Don't know	Bad	2.5	
If these are present, are the terraces paired?	Yes	Don't know	No	1.0	
Sediment Transport Modelling				**2.3**	Excellent candidate for PBMT modelling - bedload(sand,gravel,cobbles)system. However budget limitations prevent PBMT from being undertaken at this site. Only priority (probably KNP) site/s to have sed transport modelling done.
Is the river a bedload dominated system (i.e. is potential bed material tranpsort modelling suitable)	Yes	Don't know	No	5.0	
Is potential bed material transport modelling going to be undertaken at this site?	Yes	Don't know	No	1.0	
OVERALL SCORE:				**2.6**	

Site description	 		
Morphology of the site	The site is a pool-rapid section with boulder, cobble covered bed, with extensive bedrock exposure. Very large *B. salicina* trees are located in the upper terrace of this site (which appears to follow an old seasonal or backwater channel at the edge of the macro-channel). No paired terraces are present and the terrace upon which the *B. salicina* are currently growing may be an old bedrock core bar which has become bank-attached. The site is close to natural.		
PES	A (93.1%)	**Confidence**	3

E11.3.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
A	Small changes to the sediment supply due to forestry, but steep river precludes any morphological adjustment.	Extensive Forestry.	NF	3.5
	Decreased low flows and lower fines transport.		F	

E11.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
A	Stable	A		Extensive forestry and associated increased sediment runoff may increase the sediment load, but this steep bedrock river section is not sensitive to such small changes.	2.5

E11.5 AEC: C

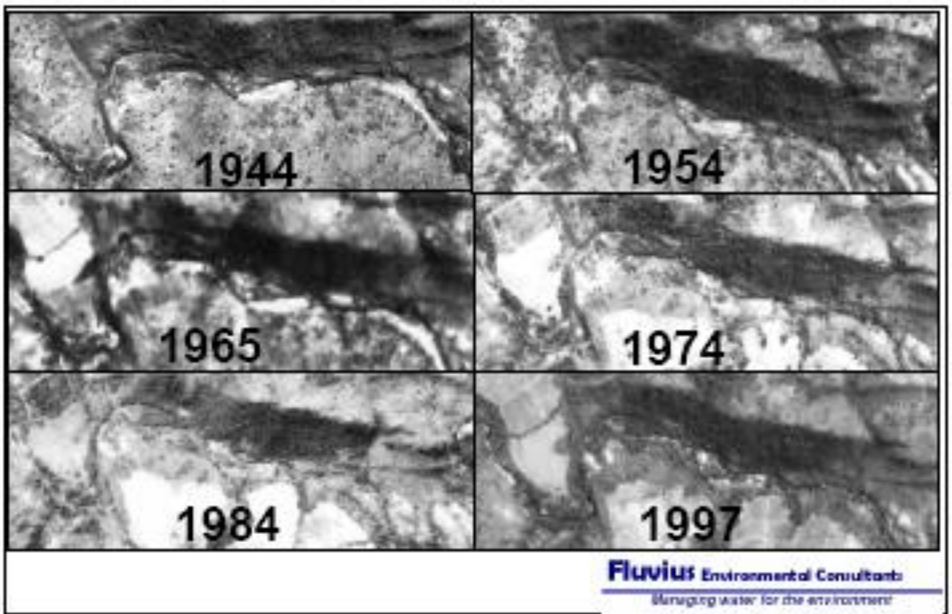
PES	AEC	Comments	Conf
A	B	Channel connectivity will decrease due to more weirs in the system. Increased sediment loads will occur due to increased hillslope erosion and more weirs.	2

E12 EWR 5: MARITE (MARITE RIVER)

E12.1 DATA AVAILABILITY

Data availability	Conf
Historical aerial photography (1944, 1954, 1965, 1974, 1984, 1997). Sediment transport modelling and analysis undertaken for this study. Hydrology records. Site survey information at time of study. Previous 1996 IFR study.	3

E12.2 REFERENCE CONDITIONS

Reference conditions	Conf
 Sable EWR Site 5: The active channel has narrowed in the 1944 to 1984 period, and woody vegetation along the banks increased. The small size of the channel and poor quality of the aerial photography preclude any other detailed analysis of in-channel features. Reference condition is a more open, dynamic channel. The scale of photography and size of channel makes it difficult to confidently assess the (likely) sedimentation issues. It is suspected that this is a sensitive reach for sedimentation and instream habitat changes, but there is not enough data availably for a higher confidence rating.	3

E12.3 PRESENT ECOLOGICAL STATE

E12.3.1 Site suitability

This provides an assessment of the suitability of the site for EWR determination studies	SCORES: 5	2	1	SCORE	Notes
Representivity of the site for the reach				**4.0**	Morphologically representative. In terms of condition, the site appears to be representative (from Google Earth imagery) - few impacts are evident along this river.
How well does the *morphology* of the site represent that of the reach?	Very well	Don't know	Poorly	4.0	
To what extent is the *condition* of the site representative of the general condition of the reach?	Representative	Don't know	Very different	4.0	
Morphological Cues				**1.7**	No true morphological cues - upstream of the site there are apparent terraces, but these are not paired and seem to be composed of sand waves - not really reflecting long term flood histories.
Is the site a bedrock or alluvial dominated section?	Alluvial	Mixed	Bedrock	1.5	
Are there good morphological clues that can be related to flood levels?	Very good	Don't know	Bad	2.5	
If these are present, are the terraces paired?	Yes	Don't know	No	1.0	
Sediment Transport Modelling				**4.3**	Good candidate for PBMT modelling - bedload(sand,gravel) system.Must undertak PBMT from being undertaken at this site as there are no morphological cues to use assess flood requirements.
Is the river a bedload dominated system (i.e. is potential bed material tranpsort modelling suitable)	Yes	Don't know	No	5.0	
Is potential bed material transport modelling going to be undertaken at this site?	Yes	Don't know	No	4.0	
OVERALL SCORE:				**3.3**	

Site description			
Morphology of the site	The river is sandy and boulder dominated. Riffles and deep pools are present with sandy runs upstream. The site has shown progressively more stabilisation and vegetation encroachment of the bars since the 1980's, and there has been little removal of this vegetation from the extreme 2000 floods. The scale of photography and size of the channel makes it difficult to confidently assess the (likely) sedimentation issues at the site and hence ascribe the "natural" flux of the system to determine PES with high accuracy.		
PES	C (65.23%)	**Confidence**	2.5

E12.3.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
C	Changes to the sediment supply - the size of the active channel is reduced; larger component of fines on the bed.	Reduced flows from Inyaka Dam.	F	3.5
	Decreased flows - the size of the active channel is reduced; woody vegetation encroachment and stabilisation of the bed.	Inyaka Dam is upstream – reduced flows and floods.		

E12.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
C	Negative	D	10 years	The dam is relatively new and the channel will continue to adjust to the new flows.	3

E12.5 REC: B

PES	REC	Comments	Conf
C	C	Given the relatively recent completion of the large dam upstream of the site, it would be difficult to improve the condition of the Geomorphology of the areas downstream of the dam (such as at our site) One option would be to release at least some of the high flows, as this may halt the negative trajectory and maintain the current EC. However restoration of some flows is insufficient to counteract the catchment-wide degradation, and thus this action would only result in an improvement within the EC.	3

E12.6 AEC: C/D

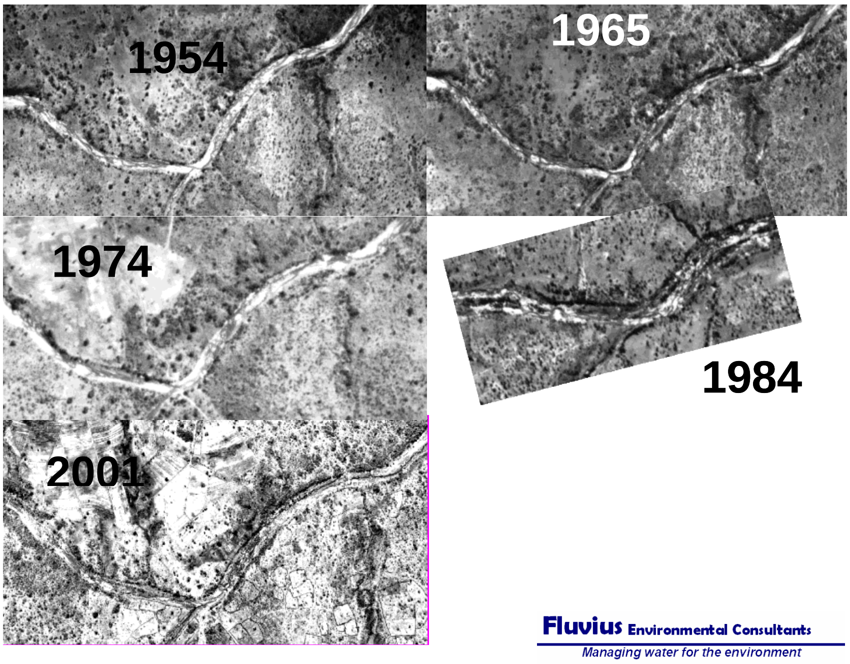
PES	AEC	Comments	Conf
C	D	Continuing erosion in the lower catchment would cause an increase in sediment storage in the channel (sediment production remains high, but the ability of the river to remove/transport it is reduced as a result of reduced flows). This will result in a sandier river, some riffles and bedrock areas in the reach will be lost, vegetation encroachment on bars and banks will take place and cobbles will be embedded.	2

E13 EWR 6: MUTLUMUVI (MUTLUMUVI RIVER)

E13.1 DATA AVAILABILITY

Data availability	Conf
Historical aerial photography (1954, 1965, 1974, 1984, 2001). Site survey information at time of study. 1996 IFR site information (Godfrey, 2002). Daily flow data is required to undertake sediment (potential bed material) transport modelling so that effective discharge classes can be determined. At this site, no daily hydrological data were available – the nearest flow gauge is too far away to be used with any confidence to represent the flows at our site.	3

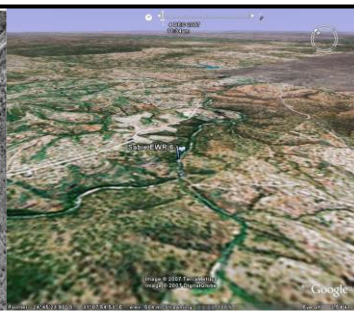
E13.2 REFERENCE CONDITIONS

Reference conditions	Conf
 **Sabie EWR Site 6**: There has been a net increase in vegetation on the macro-channel floor, suggesting increased stabilisation of the sediment. Reference state is a sandy, wide channel with bedrock outcrops and large boulders in the channel. The macro-channel floor is moderately vegetated.	3

E13.3 PRESENT ECOLOGICAL STATE

E13.3.1 Site suitability

This provides an assessment of the suitability of the site for EWR determination studies	SCORES: 5	2	1	SCORE	Notes
Representivity of the site for the reach				**4.0**	Morphologically representative. In terms of condition, the site appears to be representative (from Google Earth imagery) - few impacts are evident along this river.
How well does the *morphology* of the site represent that of the reach?	Very well	Don't know	Poorly	4.0	
To what extent is the *condition* of the site representative of the general condition of the reach?	Representative	Don't know	Very different	4.0	
Morphological Cues				**1.5**	One possible terrace on one bank, but not paired. The site is strongly bedrock influenced.
Is the site a bedrock or alluvial dominated section?	Alluvial	Mixed	Bedrock	2.0	
Are there good morphological clues that can be related to flood levels?	Very good	Don't know	Bad	1.5	
If these are present, are the terraces paired?	Yes	Don't know	No	1.0	
Sediment Transport Modelling				**3.8**	Good candidate for PBMT modelling - bedload(sand,gravel) system.Must undertak PBMT from being undertaken at this site as there are no morphological cues to use assess flood requirements.
Is the river a bedload dominated system (i.e. is potential bed material tranpsort modelling suitable)	Yes	Don't know	No	3.5	
Is potential bed material transport modelling going to be undertaken at this site?	Yes	Don't know	No	4.0	
OVERALL SCORE:				**3.1**	

Site description	 		
Morphology of the site	The site is a multi-channel, bedrock to mixed anastomosing channel type; strongly bedrock controlled. The macro-channel floor has become more stabilised through larger, increasingly vegetated bars and sediment loads from the upstream catchment areas have increased significantly due to poor land management. Some (small-scale) sand mining within the macro-channel is occurring along the reach (MRU). There are no morphological cues, so Potential Bed Material Transport (PBMT, or bedload sediment) modelling is essential at this site. Possibly a terrace occurs, but is not paired. The general absence of fine sediment in the channels indicates a typically high energy environment.		
PES	C (71.0%)	**Confidence**	3

E13.3.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
C	The channel banks and bed have become more stable.	Reduced flows.	F	3
	Reduced size of the active channel.	Sediment as a result of poor land use management in lower areas.	NF	

E13.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
C	Stable	C		No large scale impacts, and the higher sediment yields from the catchment should be consistent in future.	2.5

E13.5 REC: B

PES	REC	Comments	Conf
C	C	Flows alone will not lead to an improvement. Primarily the river is responding to poor landuse activities and associated increased erosion and sedimentation in the river.	N/A

E13.6 AEC: C/D

PES	AEC	Comments	Conf
C	D	This scenario assumes that a large dam in the upper catchment is removing many of the flood flows, as well as deteriorated landuse management practices.	2

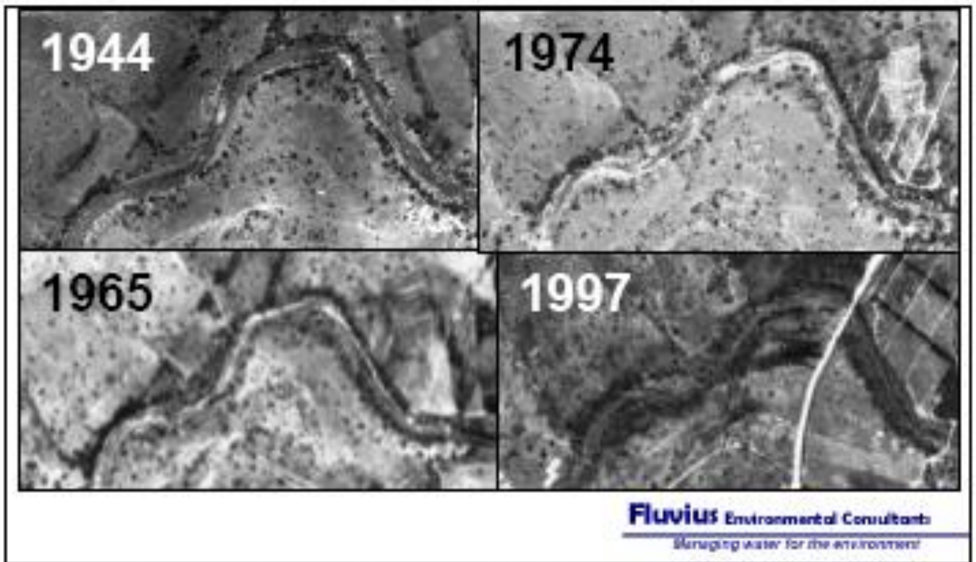
E14 EWR 7: TLULANDZITEKA (TLULANDZITEKA RIVER)

E14.1 DATA AVAILABILITY

Data availability	Conf
Historical aerial photography (1944, 1965, 1974, 1997). Site survey information.	2

E14.2 REFERENCE CONDITIONS

<table>
<tr><th>Reference conditions</th><th>Conf</th></tr>
<tr><td>



Sable EWR Site 7: The active channel width has reduced significantly and there has been a net increase in vegetation on the macro-channel floor, suggesting a reduction in flood flows and a stabilisation of the sediment.

Historically had a much wider active channel and more open macro-channel (i.e. less woody vegetation).
</td><td>3</td></tr>
</table>

E14.3 PRESENT ECOLOGICAL STATE

E14.3.1 Site suitability

This provides an assessment of the suitability of the site for EWR determination studies					Notes
	SCORES: 5	2	1	SCORE	
Representivity of the site for the reach				**4.0**	Upstream of the site the river is predominantly undisturbed. Downstream of the site there is encroachment from farming along the banks. At thesite site the effects of the road and bridge have impacted the river.
How well does the *morphology* of the site represent that of the reach?	Very well	Don't know	Poorly	4.0	
To what extent is the *condition* of the site representative of the general condition of the reach?	Representative	Don't know	Very different	4.0	
Morphological Cues				**1.5**	Cut bank on the left; terrace on the right bank which becomes paired going upstream away from the bridge.
Is the site a bedrock or alluvial dominated section?	Alluvial	Mixed	Bedrock	2.0	
Are there good morphological clues that can be related to flood levels?	Very good	Don't know	Bad	1.5	
If these are present, are the terraces paired?	Yes	Don't know	No	1.0	
Sediment Transport Modelling				**4.0**	An good candidate for PBMT modelling - bedload(sand,gravel) system, although site is upstream of a bridge and downstream the sediments are slightly coarser downstream.
Is the river a bedload dominated system (i.e. is potential bed material tranpsort modelling suitable)	Yes	Don't know	No	4.0	
Is potential bed material transport modelling going to be undertaken at this site?	Yes	Don't know	No	4.0	
OVERALL SCORE:				**3.2**	

Site description			
Morphology of the site	The active channel width has reduced significantly and there has been a net increase of vegetation on the active channel floor, suggesting a reduction in flood flows and stabilization of the sediment. A combination of reduced floods and possible increased nutrients and sediment derived from the catchment activities may have promoted the expansion of the reeds in the channel. The banks and bars are highly stabilised by the dense reedbeds, and these reedbeds are likely to persist through most management scenarios since reeds are very robust and difficult to reduce.		
PES	C/D (61.44%)	**Confidence**	2.5

E14.3.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
C	Small changes to the sediment supply.	Few dams, roads, extensive grazing.	NF	3.5
	Decreased flows - the size of the active channel is reduced.	Abstraction, forestry, dam upstream.	F	

E14.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
C/D	Stable	C/D		No further changes expected as reeds have dominated the channel bed and therefore it is unlikely that they would be removed. Additional vertical increases in the reedbeds (due to flood deposition) may occur, but this is not likely to result in a channel morphology change.	2.5

E14.5 AEC: B

PES	AEC	Comments	Conf
C/D	C	Reduction in sediment delivery to channel and reduced erosion. Sufficient high flows are provided by overtopping of the dam.	3

E14.6 AEC: D

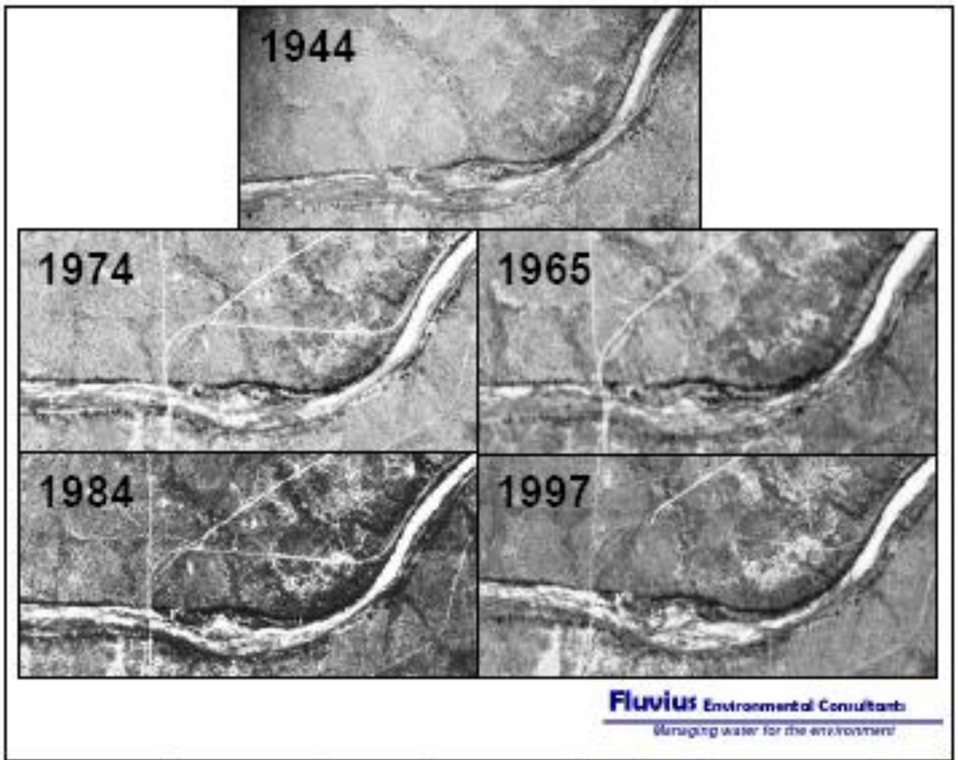
PES	AEC	Comments	Conf
C/D	D	The geomorphological consequences will be an increase in bed height, more subsurface flows and sediment with resulting decrease in riffles and shallower pools.	3

E15 EWR 8: LOWER SAND (SAND RIVER)

E15.1 DATA AVAILABILITY

Data availability	Conf
Historical aerial photography (1944, 1965, 1974, 1984, 1997). Sediment transport modelling and analysis undertaken for this study. Hydrology records. Site survey information at time of study.	3.5

E15.2 REFERENCE CONDITIONS

Reference conditions	Conf
 **Sable EWR Site 8**: There is little perceptible change, although the active channel width may have narrowed, and the macro-channel floor appears increasingly stabilised. This suggests a small reduction in flood flows and possible stabilisation of the sediment. Reference condition includes a wide active channel with a less stable macro channel floor.	3.5

E15.3 PRESENT ECOLOGICAL STATE

E15.3.1 Site suitability

This provides an assessment of the suitability of the site for EWR determination studies	SCORES: 5	2	1	SCORE	Notes
Representivity of the site for the reach				**4.5**	
How well does the *morphology* of the site represent that of the reach?	Very well	Don't know	Poorly	4.5	Site is representative of the reach - largely undisturbed, sandy system with bedrock outcorps.
To what extent is the *condition* of the site representative of the general condition of the reach?	Representative	Don't know	Very different	4.5	
Morphological Cues				**2.2**	
Is the site a bedrock or alluvial dominated section?	Alluvial	Mixed	Bedrock	3.5	Cues are not paired or clear - multiple channel site.
Are there good morphological clues that can be related to flood levels?	Very good	Don't know	Bad	2.0	
If these are present, are the terraces paired?	Yes	Don't know	No	1.0	
Sediment Transport Modelling				**4.7**	
Is the river a bedload dominated system (i.e. is potential bed material tranpsort modelling suitable)	Yes	Don't know	No	4.0	An excellent candidate for PBMT modelling - priority because it is low down in the catchment.
Is potential bed material transport modelling going to be undertaken at this site?	Yes	Don't know	No	5.0	
OVERALL SCORE:				**3.8**	

Site description			
Morphology of the site	This section is a mixed anastomosing channel type section and consists of multiple mixed (sandy with bedrock influence) channels across the macro-channel floor. There are sandy areas with large bedrock outcrops, extensive reed vegetation across the macro channel floor, and large sandy lateral bars in places. The increased sediment loads from the degrading catchment have likely caused an increase in sediment storage and likely reduction in instream habitat diversity, depth of channel and volume of instream habitat. This has been verified by independent unpublished rapid assessments of the condition of bedrock sections of the Sand River (Rountree, unpublished report for the Kruger National Park).		
PES	C (71.82%)	**Confidence**	3

E15.3.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
C	Increased sediment supply - the size of the active channel has probably reduced, macro-channel floor is stabilizing.	Landuse practices.	NF	3
	Decreased flows - the size of the active channel is reduced.	Extensive Forestry; irrigation, abstraction.	F	

E15.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
C	Negative	C/D	10 years	The sandy nature of the river means that this reach is relatively resilient to moderate flow reductions and sediment increases. However the high sediment loads derived from this catchment are reducing in-channel bedrock influence (Rountree, unpublished report) and filling in	2.5

PES	Trend	Trend PES	Time	Reasons	Conf
				pools (Kleynhans, *pers comm*.).	

E15.5 AEC: C

PES	AEC	Comments	Conf
C	C	This will cause a slight reduction in the EC but will not be enough to cause a change in category.	2

E16 REFERENCES

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Rountree, M.W., Rogers, K.H. and Heritage, G.L. 2000. Landscape state change in the semi-arid Sabie River, Kruger National Park, in Response to Flood and Drought. *South African Geographical Journal* 82: 173-181.

APPENDIX F: FISH

P Kotze, Clean Stream Biological Services

F1 EWR 1: VALEYSPRUIT (CROCODILE RIVER)

F1.1 DATA AVAILABILITY

Data availability	Conf
Single site visit and fish sampling during October 2007. Kleynhans *et al.* (2002): *Ecological importance and sensitivity, fish integrity and indicators of fish ecological reserve requirements.* Rivers Database (2007): *Database on fish distribution in South African Rivers*. WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.* Regional specialist input (Dr. J. Engelbrecht)	4

F1.2 REFERENCE CONDITIONS

F1.2.1 Summary of reference conditions

Information on the expected reference conditions for fish at NRHP site X2CROC-VALYS, according to Kleynhans *et al*. (2007) was used to determine the expected reference conditions. This reference condition for fish should be valid for the entire Natural Resource Unit (NRU) Croc A and the stretch of the Crocodile within EcoRegion 9.02. Only one indigenous fish species, namely *Barbus anoplus* (Chubbyhead barb) is expected at this site under reference conditions. This species is expected at more than 75% of sites in a reach and should be present in moderate abundance (Table F1).

Table F1 EWR 1: Reference fish species

Expected Reference and Habitat derived Frequency of Occurrence (FROC) of fish at EWR 1 (Values used in FRAI) Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Barbus anoplus	Chubbyhead barb	BANO	5	5
FROC ratings: 0 = absent 1 = present at very few sites (<10%) 2 = present at few sites (>10 - 25%)	3 = present at about >25 - 50% of sites 4 = present at most sites (>50 - 75%) 5 = present at almost all sites (>75%)			

F1.3 PRESENT ECOLOGICAL STATE

F1.3.1 Site suitability

Site suitability in terms of assessment index	The optimally preferred habitat for the only expected fish species , namely semi-rheophilic *B. anoplus* very well represented at site. As only one fish species, and it being only semi-rheophilic, fish weighting of fish in EWR process may have to be lower than other biotic components. Fish habitats (velocity-depth categories and associated cover) at site highly similar to expected habitats of the RAU. Limiting factor for FRAI application may be presence of single expected fish species.		
	EWR suitability = 2.5 Site FRAI suitability = 4.5	**Confidence**	4

The PES for fish should be valid for the entire reach of the Crocodile River within NRU Croc A, and thus within EcoRegion 9.02. Special emphasis was placed on the section from Dullstroom to the end of EcoRegion 9.02.

PES description	The fish population is still close to natural. Some stressors are present in low intensity, such as habitat alteration due to sedimentation and bank erosion, and the presence of the alien predatory rainbow trout (*Oncorhynchus mykiss*).		
	A (92.6%)	**Confidence**	5

F1.3.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
A	Sedimentation of substrates.	Increased erosion, grazing and bank instability.	NF	3.5
	Loss of overhanging vegetation as cover.	Bank erosion and instability.		
	Pressure on fish assemblage/predation.	Aliens (Trout).		

F1.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
A	Stable	A		The fish assemblage in this section of the Crocodile River have adapted to the slightly altered water quality and flows, as well as the presence of alien rainbow trout for many years, and should remain fairly stable over the long term should current conditions prevail.	4

F1.5 AEC: B/C

PES	AEC	Comments	Conf
A	B/C	Decreased flows and some moderate events will result in decreased flushing of sediment from the substrate, the primary cover available for *B. anoplus* (in the absence of overhanging vegetation as result of steep banks). The above mentioned scenario is therefore expected to decrease the FROC of *B. anoplus*.	4

F2 EWR 2: GOEDEHOOP (CROCODILE RIVER)

F2.1 DATA AVAILABILITY

Data availability	Conf
Single site visit and fish sampling during October 2007. Kleynhans *et al.* (2002): *Ecological importance and sensitivity, fish integrity and indicators of fish ecological reserve requirements.* Rivers Database (2007): *Database on fish distribution in South African Rivers*. WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.* Regional specialist input (Dr. J. Engelbrecht).	4

F2.2 REFERENCE CONDITIONS

Information on the expected fish reference conditions at the NRHP site X2CROC-UKWEN, as cited in Kleynhans *et al*. (2007) was used to determine the expected fish reference conditions. This fish reference condition should be valid for the Crocodile River stretch within NRU Croc A that falls within EcoRegion 9.04. Ten indigenous fish species are expected under reference conditions. Most species are expected to have frequent occurrence within their optimal habitats at the site under reference conditions. Reference species detail is listed in Table F2.

Table F2 EWR 2: Reference fish species

Expected Reference and Habitat derived Frequency of Occurrence (FROC) of fish at EWR 2 (Values used in FRAI) Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Amphilius natalensis	Natal mountain catfish	ANAT	4	3
Amphilius uranoscopus	Mountain catfish	AURA	5	2
Barbus anoplus	Chubbyhead barb	BANO	5	4
Barbus argenteus	Rosefin barb	BARG	5	1
Barbus neefi	Sidespot barb	BNEE	5	5
Chiloglanis bifurcus	Incomati suckermouth	CBIF	3	0
Chiloglanis pretoriae	Shortspine suckermouth	CPRE	5	3
Kneria auriculata	Southern kneria	KAUR	5	3
Pseudocrenilabrus philander	Southern mouthbrooder	PPHI	5	5
Tilapia sparmanii	Banded tilapia	TSPA	4	4
FROC ratings: 0 = absent 1 = present at very few sites (<10%) 2 = present at few sites (>10 - 25%)	3 = present at about >25 - 50% of sites 4 = present at most sites (>50 - 75%) 5 = present at almost all sites (>75%)			

F2.3 PRESENT ECOLOGICAL STATE

F2.3.1 Site suitability

Site suitability in terms of assessment index	Habitat for small rheophilic species very well represented at EWR site. Fish habitats (velocity-depth categories and associated cover) at site highly similar to expected habitats of the RAU.		
	EWR suitability = 4 Site FRAI suitability = 4	**Confidence**	4

This PES for fish was determined for the stretch of the Crocodile River for NRU Croc A that falls within Ecoregion 9.04, within which site EWR 2 is situated.

PES description	The PES reflects slightly deteriorated ecological integrity, primarily attributed to altered low flows and increased sedimentation and slightly altered water quality. Most of the expected fish species are however still present in this reach, although in reduced abundance and spatial distribution.		
	B (82.4%)	**Confidence**	4

F2.3.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
B	Sedimentation of substrates.	Increased erosion, grazing and bank instability.	NF	3
	Loss of overhanging vegetation as cover.	Bank erosion and instability.		
	Pressure on fish assemblage/predation.	Aliens (rainbow trout).	F	
	Slightly reduced habitat diversity and availability.	Decreased flows related to abstraction.		

F2.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
B	Stable	B		The fish assemblage has adapted to the slightly altered water quality and flows, as well as the presence of alien rainbow trout for many years, and should remain fairly stable over the long term.	3

F2.5 AEC: C

PES	AEC	Comments	Conf
A	B/C	Altered flow regime (increase low flows) will negatively impact on the FROC of species that are intolerant to no flow conditions and prefer fast habitats (*A. natalensis, A. uranoscopus, B. argenteus, C. bifurcus* and *C. pretoriae*). Altered flows (decreases) may even result in the loss of the critically endangered *C. bifurcus* from this reach.	4

F3 EWR 3: POPLAR CREEK (CROCODILE RIVER)

F3.1 DATA AVAILABILITY

Data availability	Conf
Single site visit and fish sampling during October 2007. Kleynhans et al. (2002): *Ecological importance and sensitivity, fish integrity and indicators of fish ecological reserve requirements.* Rivers Database (2007): *Database on fish distribution in South African Rivers*. WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.* Regional specialist input (Dr. J. Engelbrecht).	4

F3.2 REFERENCE CONDITIONS

Information on the expected fish reference conditions at the NRHP site X2CROC-DKWEN, as cited in Kleynhans *et al*. (2007) was used to determine the expected reference conditions. This fish reference condition should be valid for the Crocodile River stretch within NRU Croc D and E (EcoRegions 10.01 and 10.02). Seven indigenous fish species are expected under reference conditions. Most species are expected to have frequent occurrence within their optimal habitats at the site under reference conditions. Reference species detail is listed in Table F3.

Table F3 EWR 3: Reference fish species

Expected Reference and Habitat derived Frequency of Occurrence (FROC) of fish at EWR 3 (Values used in FRAI) Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Anguilla mossambica	Longfin eel	AMOS	4	3
Amphilius uranoscopus	Mountain catfish	AURA	5	5
Barbus argenteus	Rosefin barb	BARG	5	4
Chiloglanis bifurcus	Incomati suckermouth	CBIF	3	3
Chiloglanis pretoriae	Shortspine suckermouth	CPRE	5	5
Pseudocrenilabrus philander	Southern mouthbrooder	PPHI	3	3
Tilapia sparmanii	Banded tilapia	TSPA	3	1
FROC ratings: 0 = absent 1 = present at very few sites (<10%) 2 = present at few sites (>10 - 25%)	3 = present at about >25 - 50% of sites 4 = present at most sites (>50 - 75%) 5 = present at almost all sites (>75%)			

F3.3 PRESENT ECOLOGICAL STATE

F3.3.1 Site suitability

Site suitability in terms of assessment index	Habitat for small rheophilic species very well represented at site. Fish habitats (velocity-depth categories and associated cover) at site highly similar to expected habitats of the RAU.		
	EWR suitability = 4.5 Site FRAI suitability = 4.0	**Confidence**	4

This PES for fish was determined for the stretch of the Crocodile River for MRU Croc B within which site EWR 3 is situated.

PES description	The PES reflects slightly deteriorated ecological integrity, based on the fish assemblage, primarily attributed to an altered low flow regime (Kwena Dam), increased sedimentation and slightly altered water quality. Most of the expected fish species are however still present in this reach, although be it in reduced abundance and spatial distribution. Species preferring fast habitats have been favoured and species with requirement for slower habitats have been impacted by the

	flow modification.		
	B (84.7%)	**Confidence**	4

F3.3.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
B	Sedimentation of substrates.	Increased erosion related to agriculture, forestry, grazing and bank instability.	NF	3
	Loss of overhanging vegetation as cover.	Bank erosion and instability.		
	Pressure on fish assemblage/Predation.	Introduced/translocated indigenous species (*Clarias gariepinus*).		
	Loss in habitat diversity.	Altered hydrological regime (Kwena Dam releases).	F	
	Reduced migration success as a result of migration barriers and altered migratory cues.	Migration barriers (especially Kwena dam, but also smaller weirs) impede natural migration. Altered hydrological events delay/prevent natural migratory cues (controlled releases from Kwena Dam).		

F3.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
B	Stable	B		The fish assemblage has adapted to the slightly altered water quality and flows, as well as the presence of alien rainbow trout for many years, and should remain fairly stable over the long term .	3

F3.5 REC: B

PES	REC	Comments	Conf
B	B	Maintain the current EC.	4

F3.6 AEC: C/D

PES	AEC	Comments	Conf
B	C	Increased duration of low flows, with lower water level will reduce the availability of riffle/rapid/run habitats (Fast Deep (FD)/Fast shallow (FS)), which will decrease the FROC of rheophilic and semi-rheophilic species (*A. uranoscopus, C. bifurcus* and *C. pretoriae*). Decreased low flows will further reduce the availability of overhanging vegetation as cover, which will also affect the FROC of species such as *P. philander* and *also T. sparmanii*. Decreased flows will also increase the availability of the preferred habitats (slow) of the introduced *C. gariepinus* with resultant increased abundance of this species that may increase the predation pressure on the indigenous fish species.	4

F4 EWR 4: KANYAMAZANE (CROCODILE RIVER)

F4.1 DATA AVAILABILITY

Data availability	Conf
Single site visit and fish sampling during October 2007. Kleynhans *et al*. (2002): *Ecological importance and sensitivity, fish integrity and indicators of fish ecological reserve requirements.* Rivers Database (2007): *Database on fish distribution in South African Rivers*. WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.* Regional specialist input (Dr. J. Engelbrecht)	4

F4.2 REFERENCE CONDITIONS

Information on the expected fish reference conditions at the NHRP site X2CROC-DNELS, as cited in Kleynhans *et al*. (2007), was used to determine the expected reference conditions. Two species, namely *Barbus paludinosus* (BPAU) and *Micralestes acutidens* (MACU) was sampled during the current study and was therefore added to the expected fish species list. The fish reference condition set should be valid for the Crocodile River stretch within NRU Croc F lying downstream of Nelspruit. Twenty indigenous fish species are expected under reference conditions. Reference species are listed in Table F4.

Table F4 EWR 4: Reference fish species

Expected Reference and Habitat derived Frequency of Occurrence (FROC) of fish at EWR 4 (Values used in FRAI) Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Anguilla mossambica	Longfin eel	AMOS	3	2
Amphilius uranoscopus	Stargazer, mountain catfish	AURA	2	1
Barbus eutaenia	Orangefin barb	BEUT	4	3
Labeobarbus marequensis	Largescale yellowfish	BMAR	5	5
Barbus paludinosus	Goldie barb	BPAL	3	3
Barbus trimaculatus	Threespot barb	BTRI	4	3
Barbus unitaeniatus	Longbeard barb	BUNI	4	3
Barbus viviparous	Bowstripe barb	BVIV	4	3
Clarias gariepinus	Sharptooth catfish	CGAR	4	4
Chiloglanus pretotiae	Shortspine suckermouth (Rock catlet)	CPRE	5	5
Labeo cylindricus	Redeye labeo	LCYL	5	5
Labeo molybdinus	Leaden labeo	LMOL	5	5
Micralestis acutidens	Silver robber	MACU	3	3
Marcusenius macrolepidotus	Bulldog	MMAC	4	3
Oreochromus mossambicus	Mozambique tilapia	OMOS	4	4
Opsaridium peringueyi	Southern barred minnow	OPER	5	4
Petrocephalus wesselsi	Southern churchill	PCAT	3	2
Pseudocrenilabrus philander	Southern mouthbrooder	PPHI	4	4
Tilapia rendalli	Redbreast tilapia	TREN	3	3
Tilapia sparmanii	Banded tilapia	TSPA	3	3
FROC ratings: 0 = absent 1 = present at very few sites (<10%) 2 = present at few sites (>10 - 25%)	3 = present at about >25 - 50% of sites 4 = present at most sites (>50 - 75%) 5 = present at almost all sites (>75%)			

F4.3 PRESENT ECOLOGICAL STATE

F4.3.1 Site suitability

Site suitability in terms of assessment index	Habitat for small rheophilic species very well represented at site. Fish habitats (velocity-depth categories and associated cover) at site highly similar to expected habitats of the RAU.		
	EWR suitability = 4.0 Site FRAI suitability = 4.0	**Confidence**	4

This PES for fish was determined for the stretch of the Crocodile River for NRU Croc F which equates to MRU Croc C downstream of Nelspruit.

PES description	The PES reflects slightly deteriorated ecological integrity, based on the fish assemblage, primarily attributed to an altered low flow regime (Kwena Dam and small farm dams), increased sedimentation and altered water quality (including impacts from town of Nelspruit). Most of the expected fish species are however still present in this reach, although their relative abundance and spatial distribution have been altered. Species with a preference for fast habitats have been favoured as a result of flow modification (constant releases) and species with requirement for slower habitats have been negatively impacted as a result of this.		
	B (84.2%)	**Confidence**	4

F4.3.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
B	Altered fish assemblage (loss in abundance, breeding and feeding success).	Altered water quality (Nelspruit municipal area, White river municipal area, industrial runoff).	NF	3
	Altered fish assemblage (loss in abundance, breeding and feeding success).			
	Reduced migration success as a result of migration barriers and altered migratory cues.	Migration barriers (especially Kwena dam, but also smaller weirs) impede natural migration. Altered hydrological events delay/prevent natural migratory cues.	F	

F4.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
B	Stable	B		The fish assemblage has adapted to the altered flow regime and modified water quality and should remain fairly stable over the long term.	3

F4.5 REC: B

PES	REC	Comments	Conf
B	B	A higher category is unlikely to be attainable.	3

F4.6 AEC: C/D

PES	AEC	Comments	Conf
B	C	Sedimentation of riffle/rapid areas will deteriorate conditions for species which have preference for substrate of good quality (AURA, CPRE, BEUT, LCYL, LMOL, OPER and BMAR). This scenario will also result in decreased availability of pools (slow habitats) and overhanging vegetation (albeit temporary) and may lead to decreased FROC for fish with preference for slower habitats and this cover type (especially BPAU, BVIV, MACU, MMAC, PWES, PPHI and TSPA).	4

F5 EWR 5: MALALANE (CROCODILE RIVER)

F5.1 DATA AVAILABILITY

Data availability	Conf
Single site visit and fish sampling during October 2007. Kleynhans *et al*. (2002): *Ecological importance and sensitivity, fish integrity and indicators of fish ecological reserve requirements.* Rivers Database (2007): *Database on fish distribution in South African Rivers*. WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.* Regional specialist input (Dr. A Deacon).	4

F5.2 REFERENCE CONDITIONS

Information on the expected reference conditions at the NRHP site X2CROC-MALEL (EWR 5), as cited in Kleynhans *et al*. (2007) was used. The fish reference condition set should be valid for the Crocodile River stretch within NRU Croc G. Thirty-five indigenous fish species are expected under reference conditions. Reference species are listed in Table F5.

Table F5 EWR 5: Reference fish species

Expected Reference and Habitat derived Frequency of Occurrence (FROC) of fish at EWR 5 (Values used in FRAI) Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Anguilla marmorata	Giant mottled eel	AMAR	1	1
Anguilla mossambica	Longfin eel	AMOS	1	1
Barbus annectens	Broadstriped barb	BANN	3	1
Barbus eutaenia	Orangefin barb	BEUT	3	2
Barbus afrohamiltoni	Hamilton's barb	BAFR	1	1
Brycinus imberi	Imberi	BIMB	4	3
Labeobarbus marequensis	Largescale yellowfish	BMAR	5	5
Barbus paludinosus	Goldie barb	BPAL	3	2
Barbus radiatus	Beira barb	BRAD	4	3
Barbus toppini		BTOP	3	2
Barbus trimaculatus	Threespot barb	BTRI	5	4
Barbus unitaeniatus	Longbeard barb	BUNI	4	4
Barbus viviparous	Bowstripe barb	BVIV	5	5
Clarias gariepinus	Sharptooth catfish	CGAR	5	5
Chiloglanus paratus	Sawfin suckermouth (Rock catlet)	CPAR	5	3
Chiloglanus pretotiae	Shortspine suckermouth (Rock catlet)	CPRE	4	2
Chiloglanus swierstrai	Lowveld suckermouth (Rock catlet)	CSWI	3	2
Glossogobius giurus	Tank goby	GGIU	3	2
Hydrocynus vittatus	Tigerfish	HVIT	2	2
Labeo congoro	Purple labeo	LCON	4	2
Labeo cylindricus	Redeye labeo	LCYL	5	3
Labeo molybdinus	Leaden labeo	LMOL	5	4
Labeo rosae	Rednose labeo	LROS	3	2
Labeo ruddi	Silver labeo	LRUD	1	1
Micralestis acutidens	Silver robber	MACU	4	3
Mesobola brevianalis	River sardine	MBRE	4	3

Expected Reference and Habitat derived Frequency of Occurrence (FROC) of fish at EWR 5 (Values used in FRAI) Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Marcusenius macrolepidotus	Bulldog	MMAC	3	2
Oreochromus mossambicus	Mozambique tilapia	OMOS	5	5
Opsaridium peringueyi	Southern barred minnow	OPER	4	2
Petrocephalus wesselsi	Southern churchill	PWES	3	1
Pseudocrenilabrus philander	Southern mouthbrooder	PPHI	3	3
Schilbe intermedius	Silver catfish	SINT	3	2
Synodontis zambezensis	Brown squeaker	SZAM	2	1
Tilapia rendalli	Redbreast tilapia	TREN	4	4
Tilapia sparmanii	Banded tilapia	TSPA	1	1

FROC ratings:
0 = absent
1 = present at very few sites (<10%)
2 = present at few sites (>10 - 25%)
3 = present at about >25 - 50% of sites
4 = present at most sites (>50 - 75%)
5 = present at almost all sites (>75%)

F5.3 PRESENT ECOLOGICAL STATE

F5.3.1 Site suitability

Site suitability in terms of assessment index	Habitat for small rheophilic species in adequate abundance at site. Fish habitats (velocity-depth categories and associated cover) at site fairly similar to expected habitats of the RAU. Estimated that the site have slightly more fast-shallow and less slow-deep than RAU, which should be considered in FRAI application.		
	EWR suitability = 3.5 Site FRAI suitability = 3.0	**Confidence**	4.5

This PES for fish was determined for the stretch of the Crocodile River for NRU Croc G (MRU D and part of E within Ecoregion 3.07).

PES description	The PES reflects moderately deteriorated ecological integrity, primarily attributed to an altered low flow regime, increased sedimentation, increased benthic algal growth and altered water quality. Most of the expected fish species are however still present in this reach, although be it in reduced abundance and spatial distribution. The presence of large part of this stretch and most of the left bank and local catchment falling within conservation area (KNP) contribute somewhat to preservation of the overall ecological integrity of this section.		
	C (66.1%)	**Confidence**	4

F5.3.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
C	Sedimentation of substrates.	Increased erosion related to agriculture, grazing and bank instability.	NF	3.5
	Altered fish assemblage (loss in abundance, breeding and feeding success).	Altered water quality especially increased nutrients related to seepage from sugarcane/agriculture).		
	Loss in natural habitat diversity (loss of deep pools due to sedimentation, loss of overhanging vegetation and undercut banks due to reduced flows).	Altered hydrological regime (especially as a result of abstraction for irrigation – primarily sugarcane).	F	
	Reduced migration success as a result of migration barriers and altered migratory cues.	Migration barriers (small weirs) impede on natural migration. Altered hydrological events delay/prevent natural migratory cues.		

F5.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
C	Stable	C		The fish assemblage in this section of the Crocodile River have adapted to the altered flow regime and modified water quality and should remain fairly stable over the long term should current conditions prevail.	3

F5.5 REC: B

PES	REC	Comments	Conf
C	B	Improved flows (higher low flows, less regulated flows) will improve quality and abundance of FS and FD habitats, with a positive impact on the FROC of some species with high preference for these habitats (especially CPAR, CPRE, LCON, LCYL, LMOL and OPER). Improved flows will inundate more reeds and more overhanging vegetation will become available, which will benefit species with a preference for this habitat type, with a possible improvement in the FROC of these species (BPAU, BRAD and BTRI).	4

F5.6 AEC: D

PES	AEC	Comments	Conf
B	D	Decreased low flows and periods of zero flow in some stretches will have a radical impact on flow dependant species (BEUT, CPRE, CSWI, OPER) and most probably also on species moderately intolerant to no flow conditions (BMAR, CPAR, LCON, LCYL, LMOL and MACU- and probably also HVIT). Loss of deep channels, becoming sandier shallow channel will affect especially species like HVIT and LCON negatively. Increased nutrients will further degrade the available substrate through excessive algal growth, affecting species with a preference for substrate of good quality. A further decrease in the FROC of BEUT, BMAR, CPAR, CPRE, MACI and OPER can therefore be expected. Increased algal growth may benefit some a species like LCON. Further deterioration in water quality will result in decreased FROC and even absence of species intolerant to water quality alterations (MMAC, and possible loss of OPER).	4

F6 EWR 6: NKONGOMA (CROCODILE RIVER)

F6.1 DATA AVAILABILITY

Data availability	Conf
Single site visit and fish sampling during October 2007. Kleynhans *et al*. (2002): *Ecological importance and sensitivity, fish integrity and indicators of fish ecological reserve requirements.* Rivers Database (2007): *Database on fish distribution in South African Rivers*. WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.* Regional specialist input (Dr. A Deacon).	4

F6.2 REFERENCE CONDITIONS

Information on the expected reference conditions at the NRHP site X2CROC-NKONG (EWR 6), as cited in Kleynhans *et al.* (2007) was used. The fish reference condition set should be valid for the Crocodile River stretch within NRU Croc I. Thirty four indigenous fish species are expected under reference conditions. Reference species detail is listed in Table F6.

Table F6 EWR 6: Reference fish species

Expected Reference and Habitat derived Frequency of Occurrence (FROC) of fish at EWR 6 (Values used in FRAI) Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Acanthopagrus berda	Riverbream	ABER	2	1
Anguilla bengalensis labiata	African mottled eel	ALAB	1	1
Anguilla marmorata	Giant mottled eel	AMAR	2	1
Anguilla mossambica	Longfin eel	AMOS	2	1
Barbus annectens	Broadstriped barb	BANN	1	1
Barbus afrohamiltoni	Hamilton's barb	BFRI	3	2
Brycinus imberi	Imberi	BIMB	5	3
Labeobarbus marequensis	Largescale yellowfish	BMAR	5	4
Barbus paludinosus	Goldie barb	BPAL	3	2
Barbus radiatus	Beira barb	BRAD	3	2
Barbus trimaculatus	Threespot barb	BTRI	4	3
Barbus unitaeniatus	Longbeard barb	BUNI	3	2
Barbus viviparous	Bowstripe barb	BVIV	5	4
Clarias gariepinus	Sharptooth catfish	CGAR	4	3
Chiloglanus paratus	Sawfin suckermouth (Rock catlet)	CPAR	5	3
Chiloglanus pretotiae	Shortspine suckermouth (Rock catlet)	CPRE	1	1
Chiloglanus swierstrai	Lowveld suckermouth (Rock catlet)	CSWI	4	3
Glossogobius callidus	River goby	GCAL	2	1
Glossogobius giurus	Tank goby	GGIU	5	4
Hydrocynus vittatus	Tigerfish	HVIT	5	3
Labeo congoro	Purple labeo	LCON	5	3
Labeo cylindricus	Redeye labeo	LCYL	5	4
Labeo molybdinus	Leaden labeo	LMOL	5	4
Labeo rosae	Rednose labeo	LROS	4	3
Labeo ruddi	Silver labeo	LRUD	1	1
Micralestis acutidens	Silver robber	MACU	5	3
Mesobola brevianalis	River sardine	MBRE	4	3

Expected Reference and Habitat derived Frequency of Occurrence (FROC) of fish at EWR 6 (Values used in FRAI) Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Marcusenius macrolepidotus	Bulldog	MMAC	4	2
Oreochromus mossambicus	Mosambique tilapia	OMOS	5	5
Petrocephalus wesselsi	Souther churchill	PWES	2	1
Pseudocrenilabrus philander	Southern mouthbrooder	PPHI	3	3
Schilbe intermedius	Silver catfish	SINT	4	2
Synodontis zambezensis	Brown squeaker	SZAM	3	1
Tilapia rendalli	Redbreast tilapia	TREN	5	5

FROC ratings:
0 = absent
1 = present at very few sites (<10%)
2 = present at few sites (>10 - 25%)
3 = present at about >25 - 50% of sites
4 = present at most sites (>50 - 75%)
5 = present at almost all sites (>75%)

F6.3 PRESENT ECOLOGICAL STATE

F6.3.1 Site suitability

Site suitability in terms of assessment index	Habitat for small rheophilic species in adequate abundance at site. Fish habitats (velocity-depth categories and associated cover) at site fairly similar to expected habitats of the RAU. Estimated that the site have slightly more fast-shallow and fast-deep and less slow-deep than RAU, which should be considered in FRAI application.		
	EWR suitability = 4.0 Site FRAI suitability = 3.0	**Confidence**	4.5

This PES for fish was determined for the stretch of the Crocodile River for NRU Croc I.

PES description	The PES indicates moderately deteriorated ecological integrity, reflective of all the impacts in the catchment upstream of this reach. Primary local impacts include increased sedimentation, increased benthic algal growth and altered water quality related to agricultural activities (mostly sugarcane). Most of the expected fish species are however still present in this reach, although be it in reduced abundance and spatial distribution. The presence the left bank and local catchment falling within the conservation area (KNP) contribute to preservation of the overall ecological integrity of this section.		
	C (65.6%)	**Confidence**	4

F6.3.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
C	Sedimentation of substrates.	Increased erosion related to agriculture, grazing and bank instability.	NF	4
	Altered fish assemblage (loss in abundance, breeding and feeding success).	Altered water quality especially increased nutrients related to seepage from sugarcane/agriculture).		
	Loss in natural habitat diversity (loss of deep pools due to sedimentation, loss of overhanging vegetation and undercut banks due to reduced flows).	Altered hydrological regime (especially as a result of abstraction for irrigation – primarily sugarcane).	F	
	Reduced migration success as a result of migration barriers and altered migratory cues.	Migration barriers (small weirs) impede on natural migration. Altered hydrological events delay/prevent natural migratory cues.		

F6.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
C	Stable	C		The fish assemblage have adapted to the altered flow regime and modified water quality and should remain fairly stable over the long term should current conditions prevail.	3

F6.5 REC: B

PES	REC	Comments	Conf
C	B	Improved flows (higher low flows, less regulated flows) will improve quality and abundance of FS and FD habitats, with a positive impact on the FROC of some species with high preference for these habitats (especially AMOS, BMAR, CPAR, CSWI, HVIT and LCON). Improved flows will inundate more reeds and more overhanging vegetation will become available, which will benefit species with a preference for this habitat type as cover, with a possible improvement in the FROC of these species (BPAU, BRAD, BVIV, MMAC and MACU).	4

F6.6 AEC: D

PES	AEC	Comments	Conf
B	D	Decreased low flows and longer periods of zero flow in some stretches will have a radical impact on flow dependant species and result in decreased FROC of species as BMAR, CPAR, HVIT, LCON, LCYL, LMOL and MACU and a possible loss of CPRE, CSWI from this stretch under extreme conditions. Loss of deep channels, becoming sandier shallow channel will affect especially species like HVIT and LCON negatively. Increased nutrients will further degrade the available substrate through excessive algal growth, affecting species with a preference for substrate of good quality. A further decrease in the FROC of BMAR, CPAR, and GGIU can therefore be expected. Increased algal growth may benefit some a species like LCON. Impact on species with preference for substrate as cover will be aggravated by increased sedimentation as a result of fewer floods. Loss of overhanging, undercut banks and aquatic vegetation as a result of the decreased water levels will also negatively impact on the FROC of species with a high preference for these cover features (BPAU, BVIV, BTRI, BUNI, BVIV and MMAC).	4

F7 EWR 7: HONEYBIRD (KAAP RIVER)

F7.1 DATA AVAILABILITY

Data availability	Conf
Single site visit and fish sampling during October 2007. Kleynhans *et al*. (2002): *Ecological importance and sensitivity, fish integrity and indicators of fish ecological reserve requirements.* Rivers Database (2007): *Database on fish distribution in South African Rivers*. WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.* Regional specialist input (Dr. J. Engelbrecht)	4

F7.2 REFERENCE CONDITIONS

Information on the expected fish reference conditions at site X2KAAP-HONEY, as cited in Kleynhans *et al.* (2007) was used to determine the expected reference conditions. The fish reference condition set should be valid for the Kaap River stretch within NRU Kaap A. Seventeen indigenous fish species are expected under reference condition. Reference species detail is listed in Table F7.

Table F7 EWR 7: Reference fish species

Expected Reference and Habitat derived Frequency of Occurrence (FROC) of fish at EWR 7 (Values used in FRAI) Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Anguilla mossambica	Longfin eel	AMOS	3	2
Barbus eutaenia	Orangefin barb	BEUT	5	4
Labeobarbus marequensis	Largescale yellowfish	BMAR	5	5
Barbus trimaculatus	Threespot barb	BTRI	5	5
Barbus unitaeniatus	Longbeard barb	BUNI	5	5
Barbus viviparous	Bowstripe barb	BVIV	5	5
Clarias gariepinus	Sharptooth catfish	CGAR	3	3
Chiloglanus paratus	Sawfin suckermouth (Rock catlet)	CPAR	4	4
Chiloglanus pretoriae	Shortspine suckermouth (Rock catlet)	CPRE	5	4
Chiloglanus swierstrai	Lowveld suckermouth (Rock catlet)	CSWI	3	2
Labeo cylindricus	Redeye labeo	LCYL	4	4
Labeo molybdinus	Leaden labeo	LMOL	4	4
Labeo rosae	Rednose labeo	LROS	2	1
Micralestis acutidens	Silver robber	MACU	3	3
Opsaridium peringueyi	Southern barred minnow	OPER	3	2
Pseudocrenilabrus philander	Southern mouthbrooder	PPHI	4	3
Tilapia rendalli	Redbreast tilapia	TREN	3	2

FROC ratings:
0 = absent
1 = present at very few sites (<10%)
2 = present at few sites (>10 - 25%)
3 = present at about >25 - 50% of sites
4 = present at most sites (>50 - 75%)
5 = present at almost all sites (>75%)

F7.3 PRESENT ECOLOGICAL STATE

F7.3.1 Site suitability

Site suitability in terms of assessment index	Habitat for small rheophilic species very well represented at site. Fish habitats (velocity-depth categories and associated cover) at site expected to be similar to estimated habitats of the RAU.		
	EWR suitability = 4.5 Site FRAI suitability = 4.0	**Confidence**	4

This PES for fish was determined for the stretch of the Kaap River stretch within NRU Kaap A.

PES description	The PES reflects moderately deteriorated ecological integrity, related to impacts such altered flow regimes, forestry and agriculture. Most of the expected fish species are however still present in this reach, although be it in reduced abundance and spatial distribution.		
	C (76.8%)	**Confidence**	3.5

F7.3.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
C	Loss in natural habitat diversity.	Altered hydrological regime.	F	3.5
	Reduced migration success as a result of migration barriers and altered migratory cues.	Migration barriers (small weirs) impede on natural migration. Altered hydrological events delay/prevent natural migratory cues.	NF	

F7.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
C	Stable	C		The fish assemblage in this section of the Crocodile River have adapted to the altered flow regime and modified water quality and should remain fairly stable over the long term should current conditions prevail.	3

F7.5 REC: B

PES	REC	Comments	Conf
C	B	This scenario may result in improved FROC on a variety of species, including species with requirement for FS and FD habitats and those that are intolerant to no flow conditions (OPER, CPAR and BMAR). This may also lead to the more tolerant species utilising this section optimally, with their FROC returning close to natural state (BTRI, BUNI, and BVIV).	3

F7.6 AEC: D

PES	AEC	Comments	Conf
C	D	Altered hydrological regime, with much less flows (lower base flows) will lead to reduced riffle/rapid/run habitats, with reduced FROC of species with preference for FD and FS habitats (BEUT, BMAR, CPAR, CPRE, CSWI, LCYL, LMOL, MACU and OPER). This may even lead to the total loss of OPER from this section. With fewer floods the riffles will become sandier and negatively impact some species with a high preference for substrate of good quality (especially BEUT, CPRE). Degradation of overhanging vegetation will also result in decreased FROC of species with a preference for this cover type, i.e. BTRI, BUNI, BVIV and PPHI.	3

F8 EWR 1: UPPER SABIE (SABIE RIVER)

F8.1 DATA AVAILABILITY

Data availability	Conf
Single site visit and fish sampling during September 2007. Rivers Database (2007): *Database on fish distribution in South African Rivers*. Weeks *et al*. (1996): *A Pre-impoundment Study of the Sabie-Sand River System, Mpumalanga with special reference to predicted impacts on the Kruger National Park.* WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.*	3

F8.2 REFERENCE CONDITIONS

No specific fish reference condition information is available for the reach of the Sabie River where EWR 1 is situated. The closest site available with a defined reference condition is X3-Sabi-Brand (downstream of Mac-Mac River confluence), which was primarily used to derive the expected reference conditions and is valid for the Sabie River stretching from below the Sabie falls (downstream of Sabie town) to the confluence with the Mac-Mac River. Seven fish species are expected in this section of the Sabie River with all species expected to be naturally present at more than 50% of sites sampled in a reach. These species are listed in Table F8.

Table F8 EWR 1: Reference fish species

Expected Reference and Habitat derived Frequency of Occurrence (FROC) of fish at EWR 1 (Values used in FRAI) Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Anguilla mossambica	Longfin eel	AMOS	4	2
Amphilius uranoscopus	Stargazer, mountain catfish	AURA	4	3
Barbus anoplus	Chubbyhead barb	BANO	4	3
Barbus brevipinnis	Shortfin barb	BBRE	4	3
Chiloglanis anoterus	Rock catlet	CANO	5	5
Tilapia sparrmanii	Banded tilapia	TSPA	4	3
Varicorhinus nelspruitensis	Incomati chiselmouth	VNEL	5	5
FROC ratings: 0 = absent 1 = present at very few sites (<10%) 2 = present at few sites (>10 - 25%)		3 = present at about >25 - 50% of sites 4 = present at most sites (>50 - 75%) 5 = present at almost all sites (>75%)		

F8.3 PRESENT ECOLOGICAL STATE

F8.3.1 Site suitability

Site suitability in terms of assessment index	Habitat for large rheophilic (VNEL), as well as small rheophilic, semi-rheophilic and limnophilic species. Limiting factor may be extensive forestry activities and aggravated algal growth which limits sampling success. Fish habitats (velocity-depth categories and associated cover) at site highly similar to expected habitats of the RAU. Limiting factor is slightly less slow habitats and slightly more fast habits at EWR site in comparison to RAU.		
	EWR suitability = 4.5 Site FRAI suitability = 4	**Confidence**	4

The PES was calculating for the section of Sabie River secondary NRU Sabie B.1 downstream of the Sabie falls (equates to WQSU 2).

PES description	The main changes to the reference fish assemblage can primarily be attributed to the reduced flows and increased sedimentation. Most of the expected fish species are however still present in this reach, although at reduced abundance and spatial distribution.		
	B/C (78.3%)	**Confidence**	4

F8.3.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
B/C	Abstraction	Forestry and Sabie town and small scale irrigation.	F	3
	Loss of habitat (decreased fast habitats and overhanging vegetation) diversity as a result of decreased base flows.	Alien vegetation encroachment.	NF	
	Increased sedimentation resulting in deterioration of substrate as habitat (clogging interstitial spaces, loss of important spawning habitats, etc.).	Hillslope erosion related to afforestation.		

F8.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
B/C	Stable	B/C		The fish assemblage in this section have adapted to the altered water quality and flows and should remain fairly stable over the long term should current conditions prevail.	4

F8.5 REC: B

PES	REC	Comments	Conf
B/C	B	Improvement of cover in the form of overhanging vegetation and undercut banks (overall riparian condition, decreased alien vegetation) and improved habitat for species preferring slow habitats will result in an improvement of the EC.	4

F8.6 AEC: C/D

PES	AEC	Comments	Conf
B/C	C/D	Decreased low flows will result in reduced fast habitats (riffles, rapids, runs) with a resultant loss or decreased FROC of rheophilic and semi-rheophilic species (VNEL, AURA, CANO, BBRI). Increased sediments and nutrients will reduce quality of habitat in especially riffles and rapids (interstitial spaces) with negative impact on above-mentioned species. Increased temperatures may also affect FROC of species such as TSPA, VNEL, BBRI and BANO. Increased toxins will also have a significant impact as a large proportion of species is intolerant to modified water quality.	4

F9 EWR 2: AAN DE VLIET (SABIE RIVER)

F9.1 DATA AVAILABILITY

Data availability	Conf
Single site visit and fish sampling during September 2007. This site is a provincial RHP site with adequate historic and present data available. Weeks *et al*. (1996): *A Pre-impoundment Study of the Sabie-Sand River System, Mpumalanga with special reference to predicted impacts on the Kruger National Park.* Rivers Database (2007): *Database on fish distribution in South African Rivers*. WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.*	4

F9.2 REFERENCE CONDITIONS

No specific fish reference information is available for the EWR site or other site in this section of the Sabie River (Kleynhans *et al.,* 2007). The closest site with reference condition is the NHRP site, X3-Sabi-Brand, which was primarily used to derive the expected reference conditions for fish of EWR 1, higher up in the Sabie River. *Barbus argenteus* was added as this species was previously sampled in this reach (Kleynhans, 1997). The reference condition set for EWR 2 is valid for the Sabie River stretching from below the confluence with the Mac-Mac River to the confluence with the Marite River. This equates to secondary natural resource unit (S NRU) Sabie B.2 downstream of the of Sabie falls. Twenty-two fish species are expected in this section of the Sabie River and are listed in Table F9.

Table F9 EWR 2: Reference fish species

Expected Reference and Habitat derived Frequency of Occurrence (FROC) of fish at EWR 2 (Values used in FRAI) Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Anguilla mossambica	Longfin eel	AMOS	4	2
Amphilius uranoscopus	Stargazer, mountain catfish	AURA	4	4
Barbus argenteus	Rosefin barb	BARG	3	2
Barbus brevipinnis	Shortfin barb	BBRE	4	1
Barbus eutaenia	Orangefin barb	BEUT	5	5
Labeobarbus marequensis	Largescale yellowfish	BMAR	5	4
Labeobarbus polylepis	Smallscale yellowfish	BPOL	5	4
Barbus trimaculatus	Threespot barb	BTRI	5	3
Barbus unitaeniatus	Longbeard barb	BUNI	4	2
Chiloglanis anoterus	Rock catlet	CANO	5	5
Clarias gariepinus	Sharptooth catfish	CGAR	4	4
Chiloglanis paratus	Sawfin suckermouth	CPAR	3	2
Chiloglanis swierstrai	Lowveld suckermouth	CSWI	4	4
Labeo cylindricus	Redeye labeo	LCYL	4	2
Labeo molybdinus	Leaden labeo	LMOL	4	2
Micralestis acutidens	Silver robber	MACU	4	3
Marcusenius macrolepidotus	Bulldog	MMAC	4	3
Opsaridium peringueyi	Southern barred minnow	OPER	5	5
Petrocephalus wesselsi	Southern churchill	PWES	4	2
Pseudocrenilabrus philander	Southern mouthbrooder	PPHI	4	3
Tilapia sparrmanii	Banded tilapia	TSPA	4	3

Expected Reference and Habitat derived Frequency of Occurrence (FROC) of fish at EWR 2 (Values used in FRAI) Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Varicorhinus nelspruitensis	Incomati chiselmouth	VNEL	5	5

FROC ratings:
0 = absent
1 = present at very few sites (<10%)
2 = present at few sites (>10 - 25%)
3 = present at about >25 - 50% of sites
4 = present at most sites (>50 - 75%)
5 = present at almost all sites (>75%)

F9.3 PRESENT ECOLOGICAL STATE

F9.3.1 Site suitability

Site suitability in terms of assessment index	Habitat for large rheophilic (VNEL), as well as small rheophilic, semi-rheophilic and limnophilic species. Limiting factor is some vegetation removal on right bank for recreation purposes. Fish habitats (velocity-depth categories and associated cover) at site highly similar to expected habitats of the RAU. Limiting factor is slightly less slow habitats and slightly more fast habits at EWR site in comparison to RAU.		
	EWR suitability = 4.5 Site FRAI suitability = 3.5	**Confidence**	4

The PES was calculating for the section of Sabie River secondary NRU Sabie B.2.

PES description	The PES reflects slightly reduced conditions in terms of habitat and substrate. This is primarily attributed to the reduced flows and increased sedimentation. Most of the expected fish species are however still present in this reach, although in reduced abundance and spatial distribution.		
	B/C (78.6%)	**Confidence**	4

F9.3.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
B/C	Abstraction.	Forestry and Sabie town and small scale irrigation.	F	3
	Loss of habitat (decreased fast habitats and overhanging vegetation) diversity as a result of decreased base flows.	Alien vegetation encroachment.	NF	
	Reduced migration success as a result of alteration of natural cues for migration and migration barriers.	Migration barriers (especially Corumanu dam, but also smaller weirs).		
	Potential water quality deterioration at times (diatoms indicate possible pollution events)	Agriculture and lodges.	NF	
	Increased sedimentation result in deterioration of substrate as habitat.	Hillslope erosion related to afforestation.		

F9.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
B/C	Stable	B/C		The fish assemblage in this section have adapted to the altered water quality and flows and should remain fairly stable over the long term should current conditions prevail.	4

F9.5 REC: B

PES	REC	Comments	Conf
B/C	B	Improved riparian zone (marginal) conditions with adequate natural overhanging vegetation will improve conditions for species with high requirement for this habitat (slow shallow and deep with overhanging vegetation) such as BBRI, BTRI and BUNI.	4

F9.6 AEC: C/D

PES	AEC	Comments	Conf
B/C	C/D	Deteriorated water quality will result in decreased FROC of species with requirement for high water quality, such as AURA, BARG, BEUT, CANO, and OPER. Decreased low flows (lower water levels) will lead to a loss in habitat diversity during these periods (reduction in riffle/rapid areas, decreased overhanging vegetation as cover as a result of decreased water level not reaching the edge of stream) with a resultant decrease in FROC for species preferring riffle/rapid/run (fast) habitats (AURA, BARG, BEUT, BMAR, BPOL, CANO, CPAR, OPER, and VNEL) and with high requirement for overhanging vegetation (BEUT, MMAC, PPHI, and TSPA).	4

F10 EWR 3: KIDNEY (SABIE RIVER)

F10.1 DATA AVAILABILITY

Data availability	Conf
Single site visit and fish sampling during September 2007. Rivers Database (2007): *Database on fish distribution in South African Rivers*. Weeks *et al*. (1996): *A Pre-impoundment Study of the Sabie-Sand River System, Mpumalanga with special reference to predicted impacts on the Kruger National Park.* WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.* 1996 IFR site information (Godfrey, 2002).	4

F10.2 REFERENCE CONDITIONS

The fish reference condition information, as set for the NRHP site X3-SABI-SEKUR (Kleynhans *et al*., 2007) is directly applicable to EWR 3. The reference condition set, in the context of this study, is valid for the Sabie River within secondary NRU Sabie C.1. Thirty five fish species can be expected in this section of the Sabie River under natural conditions. Expected species are listed in Table F10.

Table F10 EWR 3: Reference fish species

Expected Reference and Habitat derived Frequency of Occurrence (FROC) of fish at EWR 3 (Values used in FRAI) Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Anguilla mossambica	Longfin eel	AMOS	2	1
Amphilius uranoscopus	Stargazer, mountain catfish	AURA	1	1
Barbus annectens	Broadstriped barb	BANN	3	3
Barbus argenteus	Rosefin barb	BARG	1	0
Barbus eutaenia	Orangefin barb	BEUT	4	4
Barbus afrohamiltoni	Hamilton's barb	BFRI	1	1
Brycinus imberi	Imberi	BIMB	1	1
Labeobarbus marequensis	Largescale yellowfish	BMAR	5	5
Barbus paludinosus	Goldie barb	BPAU	2	2
Barbus radiatus	Beira barb	BRAD	3	3
Barbus toppini		BTOP	1	1
Barbus trimaculatus	Threespot barb	BTRI	4	4
Barbus unitaeniatus	Longbeard barb	BUNI	4	4
Barbus viviparous	Bowstripe barb	BVIV	5	5
Chiloglanis anoterus	Rock catlet	CANO	4	4
Clarias gariepinus	Sharptooth catfish	CGAR	4	4
Chiloglanis paratus	Sawfin suckermouth	CPAR	4	3
Chiloglanis swierstrai	Lowveld suckermouth	CSWI	4	4
Hydrocynus vittatus	Tigerfish	HVIT	1	1
Labeo congoro	Purple labeo	LCON	2	2
Labeo cylindricus	Redeye labeo	LCYL	5	5
Labeo molybdinus	Leaden labeo	LMOL	5	5
Labeo rosae	Rednose labeo	LROS	4	4
Micralestis acutidens	Silver robber	MACU	5	5
Mesobola brevianalis	River sardine	MBRE	5	5
Marcusenius macrolepidotus	Bulldog	MMAC	4	3

Expected Reference and Habitat derived Frequency of Occurrence (FROC) of fish at EWR 3 (Values used in FRAI) Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Oreochromus mossambicus	Mozambique tilapia	OMOS	5	5
Opsaridium peringueyi	Southern barred minnow	OPER	5	4
Petrocephalus wesselsi	Southern churchill	PCAT	2	1
Pseudocrenilabrus philander	Southern mouthbrooder	PPHI	4	4
Schilbe intermedius	Silver catfish	SINT	4	3
Serranochromus meridianus	Lowveld largemouth	SMER	5	4
Synodontis zambezensis	Brown squeaker	SZAM	1	1
Tilapia rendalli	Redbreast tilapia	TREN	5	5
Tilapia sparrmanii	Banded tilapia	TSPA	2	2

FROC ratings:
0 = absent
1 = present at very few sites (<10%)
2 = present at few sites (>10 - 25%)
3 = present at about >25 - 50% of sites
4 = present at most sites (>50 - 75%)
5 = present at almost all sites (>75%)

F10.3 PRESENT ECOLOGICAL STATE

F10.3.1 Site suitability

Site suitability in terms of assessment index	Habitat for small rheophilic species well represented at site. Fish habitats (velocity-depth categories and associated cover) at site slightly different from RAU, and should be considered during application of results to FRAI.		
	EWR suitability = 4.5 Site FRAI suitability = 2.5	**Confidence**	4

The PES was calculating for the section of Sabie River within secondary natural resource unit (NRU) Sabie C.1 (MRU B.1).

PES description	The PES reflects slightly reduced conditions, primarily attributed to the reduced flows, increased sedimentation and increased algal growth. Most of the expected fish species are however still present in this reach, although in reduced abundance and spatial distribution. The presence of a conservation area (KNP) improves the ecological integrity of this section and limits local catchment impacts.		
	B (85.6%)	**Confidence**	4

F10.3.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
B	Abstraction.	Forestry and Sabie town and small scale irrigation.	F	3
	Reduced migration success as a result of alteration of natural cues for migration and presence of migration barriers.	Migration barriers (especially Corumanu Dam, but also smaller weirs, up- and downstream and within the reach).		
	Loss of habitat (decreased fast habitats and overhanging vegetation) diversity as a result of decreased base flows.	Alien vegetation encroachment.	NF	
	Increased sedimentation and excessive algal growth result in deterioration of substrate as habitat and loss of deep habitats.	Hillslope erosion related, especially attributed to small-scale farming on one bank and increased nutrients.		

F10.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
B	Stable	B		The fish assemblage in this section have adapted to the altered	4

				water quality and flows and should remain fairly stable over the long term should current conditions prevail.	

F10.5 AEC: B/C

PES	AEC	Comments	Conf
B	C	Rheophilic and semi rheophilic species, with a preference for FS and FD habitats and species that are intolerant to no flow conditions (BEUT, BMAR, CANO, CSWI, LCYL and OPER) will be affected. Decreased water quality will further affect species intolerant to water quality change (e.g. BEUT, CANO, OPER, MACU and MMAC). Deterioration of substrates (increased sediment) will further decrease FROC of species with high preference for this habitat (BMAR, CANO, and CPAR). Loss of SD habitats will decrease FROC of LCON and SINT.	3

F11 EWR 4: MAC MAC (MAC MAC RIVER)

F11.1 DATA AVAILABILITY

Data availability	Conf
Single site visit and fish sampling during September 2007. Rivers Database (2007): *Database on fish distribution in South African Rivers*. Weeks *et al*. (1996): *A Pre-impoundment Study of the Sabie-Sand River System, Mpumalanga with special reference to predicted impacts on the Kruger National Park.* WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.*	3

F11.2 REFERENCE CONDITIONS

No specific fish reference condition information is available for the EWR 4 (Kleynhans *et al*., 2007). The closest site with reference condition information is site X3MACM-BRAND closer to the confluence of the Mac Mac and Sabie River. This reference condition was primarily used to derive the expected reference conditions for fish with emphasis being placed on the fish species that can be expected in habitat compositions in the vicinity of site EWR 4. The reference NRHP site X3MACM-BRAN is very close to the confluence of the Sabie River and may be influenced by some fish species from the Sabie River that frequent the lower reaches of the Mac Mac river from time to time, but does not necessarily utilise the entire reach (within EcoRegion 4.04) of the Mac-Mac River. The reference condition set, is valid for the Mac-Mac River falling within EcoRegion 4.04. Twelve fish species are expected to have inhabited this section of the river under natural condition and are listed in Table F11.

Table F11 EWR 4: Reference fish species

Expected Reference and Habitat derived Frequency of Occurrence (FROC) of fish at EWR 4 (Values used in FRAI) Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Anguilla mossambica	Longfin eel	AMOS	4	2
Amphilius natalensis	Natal mountain catfish	ANAT	1	1
Amphilius uranoscopus	Stargazer, mountain catfish	AURA	4	4
Barbus brevipinnis	Shortfin barb	BBRI	4	2
Barbus eutaenia	Orangefin barb	BEUT	5	4
Labeobarbus polylepis	Smallscale yellowfish	BPOL	1	1
Chiloglanis anoterus	Rock catlet	CANO	5	5
Clarias gariepinus	Sharptooth catfish	CGAR	4	4
Opsaridium peringueyi	Southern barred minnow	OPER	5	3
Pseudocrenilabrus philander	Southern mouthbrooder	PPHI	4	3
Tilapia sparrmanii	Banded tilapia	TSPA	4	3
Varicorhinus nelspruitensis	Incomati chiselmouth	VNEL	5	5

FROC ratings:
0 = absent
1 = present at very few sites (<10%)
2 = present at few sites (>10 - 25%)
3 = present at about >25 - 50% of sites
4 = present at most sites (>50 - 75%)
5 = present at almost all sites (>75%)

F11.3 PRESENT ECOLOGICAL STATE

F11.3.1 Site suitability

Site suitability in terms of assessment index	Habitat for large rheophilic (VNEL), as well as small rheophilic, well represented at site. Limiting factor may be extensive forestry activities. Fish habitats (velocity-depth categories and associated cover) at site highly similar to expected habitats of the RAU. Limiting factor may be slightly less deep habitats and vegetation as cover.		
	EWR suitability = 4.5 Site FRAI suitability = 4.0	**Confidence**	4

The PES was calculating for the section of Mac-Mac River falling within ecoregion 4.04.

PES description	The PES reflects slightly deteriorated ecological integrity, primarily attributed to the reduced flows and increased sedimentation, the primary source of deterioration being forestry. Most of the expected fish species are however still present in this reach, although in reduced abundance and spatial distribution.		
	B/C (80.4%)	**Confidence**	4

F11.3.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
B/C	Loss of fish habitat diversity (decreases fast habitats, overhanging vegetation and undercut banks) as a result of decreased base flows.	Primarily afforestation.	F	3
	Reduced migration success as a result of migration barriers (primarily downstream).	Migration barriers (especially Corumanu dam, but also smaller weirs).	NF	
	Increased sedimentation result in deterioration of substrate as habitat and loss of deep habitats.	Hillslope erosion related to afforestation.		

F11.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
B/C	Stable	B/C		The fish assemblage in this section have adapted to the altered water quality and flows and should remain fairly stable over the long term should current conditions prevail.	4

F11.5 REC: A/B

PES	REC	Comments	Conf
B/C	B	Improved water quality should result in improved frequency of occurrence of species with requirement for high water quality, namely BBRI and OPER, species currently present in reduced frequency of occurrence.	4

F11.6 AEC: C

PES	AEC	Comments	Conf
B/C	C/D	Decreased low flows will result in reduced fast habitats (riffles, rapids, runs) with a resultant loss or decreased FROC of rheophilic and semi-rheophilic species (VNEL, BEUT, AURA, CANO, and OPER). Embeddedness of cobbles and nutrient increases will reduce quality of habitat especially in riffles and rapids (interstitial spaces) with negative impact on above-mentioned species. Increased temperatures and resultant decreased oxygen will also affect FROC of above mentioned species. Increased alien vegetation will reduce bank stability and decrease overhanging vegetation, impacting on species with high requirement for this cover type, i.e. BBRI, BEUT, TSPA and PPHI.	4

F12 EWR 5: MARITE (MARITE RIVER)

F12.1 DATA AVAILABILITY

Data availability	Conf
Single site visit and fish sampling during September 2007. Rivers Database (2007): *Database on fish distribution in South African Rivers*. Weeks *et al*. (1996): *A Pre-impoundment Study of the Sabie-Sand River System, Mpumalanga with special reference to predicted impacts on the Kruger National Park.* WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.*	4

F12.2 REFERENCE CONDITIONS

The reference condition as set for the NRHP site X3-MARI-SANDF (Kleynhans *et al*., 2007) is directly applicable to site EWR 5. One fish species, namely *Barbus brevipinnis* (BBRI) was added to the list of fish species expected under natural conditions, as this species was sampled at this site during 1997 (Kleynhans Fish Database). The reference condition is, in the context of this study, valid for the section of the Marite River within EcoRegion 4.04. Twenty three fish species can be expected in this section and are listed in Table F12.

Table F12 EWR 5: Reference fish species

Expected Reference and Habitat derived Frequency of Occurrence (FROC) of fish at EWR 5 (Values used in FRAI) Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Anguilla marmorata	Giant mottled eel	AMAR	2	1
Anguilla mossambica	Longfin eel	AMOS	3	2
Amphilius natalensis	Natal mountain catfish	ANAT	3	1
Amphilius uranoscopus	Stargazer, mountain catfish	AURA	4	4
Barbus brevipinnis	Shortfin barb	BBRI	1	1
Barbus eutaenia	Orangefin barb	BEUT	4	4
Labeobarbus marequensis	Largescale yellowfish	BMAR	5	4
Barbus trimaculatus	Threespot barb	BTRI	4	3
Barbus unitaeniatus	Longbeard barb	BUNI	4	2
Chiloglanis anoterus	Rock catlet	CANO	5	5
Clarias gariepinus	Sharptooth catfish	CGAR	4	4
Chiloglanis paratus	Sawfin suckermouth	CPAR	3	2
Chiloglanis swierstrai	Lowveld suckermouth	CSWI	2	2
Labeo cylindricus	Redeye labeo	LCYL	1	1
Labeo molybdinus	Leaden labeo	LMOL	3	3
Micralestis acutidens	Silver robber	MACU	3	2
Marcusenius macrolepidotus	Bulldog	MMAC	4	4
Oreochromus mossambicus	Mozambique tilapia	OMOS	3	2
Opsaridium peringueyi	Southern barred minnow	OPER	4	3
Petrocephalus wesselsi	Southern churchill	PCAT	3	1
Pseudocrenilabrus philander	Southern mouthbrooder	PPHI	4	4
Tilapia sparrmanii	Banded tilapia	TSPA	4	4
Varicorhinus nelspruitensis	Incomati chiselmouth	VNEL	4	2

FROC ratings:
0 = absent
1 = present at very few sites (<10%)
3 = present at about >25 - 50% of sites
4 = present at most sites (>50 - 75%)

Expected Reference and Habitat derived Frequency of Occurrence (FROC) of fish at EWR 5 (Values used in FRAI) Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
2 = present at few sites (>10 - 25%)	5 present at almost all sites (>75%)			

F12.3 PRESENT ECOLOGICAL STATE

F12.3.1 Site suitability

Site suitability in terms of assessment index	Habitat for large rheophilic (VNEL), as well as small rheophilic, well represented at site. Limiting factor may be livestock farming activities impacting on fish habitat. Fish habitats (velocity-depth categories and associated cover) at site very similar to expected habitats of the RAU.		
	EWR suitability = 4.0 Site FRAI suitability = 3.5	**Confidence**	4

The PES was calculating for the section of Marite River within Ecoregion 4.04 lying downstream of the Inyaka dam.

PES description	The PES reflects deteriorated ecological integrity primarily attributed to the altered hydrological regime, (operation of Inyaka Dam), increased sedimentation (overgrazing, rural areas) and slight deterioration in water quality. Most of the expected fish species are however still present in this reach, although be it in reduced abundance and spatial distribution.		
	B/C (77.9%)	**Confidence**	4

F12.3.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
B/C	Increased sedimentation result in deterioration of substrate as habitat and loss of deep habitats.	Increased sedimentation from hillslope erosion related to rural areas (over grazing, small-scare agriculture, and informal settlements) as well as changed flow regime	NF/F	3
	Loss of fish habitat diversity	Flow modification related to Inyaka Dam.	F	
	Reduced migration success as a result of migration barriers and altered migratory cues.	Migration barriers (especially Corumanu and Inyaka Dam, but also smaller weirs) impede natural migration. Altered moderate and large hydrological events as result of Inyaka dam can delay/prevent natural migratory cues).		

F12.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
B/C	Negative	C	Long term	It can be expected that the fish assemblage is still adapting to the major alteration in hydrological regimes brought about by the construction of the Inyaka Dam.	3

F12.5 REC: B

PES	REC	Comments	Conf
B/C	B	An improved flow regime (close to natural regime) will improve habitat diversity and abundance, with a resultant improved FROC of species such as ANAT, BUNI and VNEL.	4

F12.6 AEC: C/D

PES	AEC	Comments	Conf
B/C	C/D	Water quality deterioration (more nutrients, toxics, less dilution) will lead to decreased FROC of water quality intolerant and moderately intolerant species (AURA, BEUT, CANO, CSWI, LMOL, MMAC, and OPER). No releases for the EWR will result in loss of habitat diversity, reflected by reduced FROC of most expected species. It will also affect the migratory cues, impacting negatively on species migrating between reaches (especially BMAR, CGAR, TSPAR, and VNEL). Increased sediment will reduce the quality of substrate as habitat through embeddedness, impacting on species with high preference for substrates (BEUT, CPAR and LMOL). Reduced marginal vegetation related to riparian zone degradation will result in decreased FROC of species with high requirements for overhanging vegetation (BEUT, BTRI, BUNI, MMAC, and PPHI).	4

F13 EWR 6: MUTLUMUVI (MUTLUMUVI RIVER)

F13.1 DATA AVAILABILITY

Data availability	Conf
Single site visit and fish sampling during September 2007. Angliss and Rodgers, 2002: *Sand River Catchment Biomonitoring Report.* Rivers Database (2007): *Database on fish distribution in South African Rivers*. Weeks *et al*. (1996): *A Pre-impoundment Study of the Sabie-Sand River System, Mpumalanga with special reference to predicted impacts on the Kruger National Park.* WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.* Regional specialist input (Mr. M. Angliss)	3

F13.2 REFERENCE CONDITIONS

The reference condition as set for the NHRP site X3MUTL-THULA (Kleynhans *et al*., 2007) was applied for the determination of the reference condition. AMOS was added to the list of fish species expected under natural conditions, as this species was sampled at this site during 1997 (Kleynhans Fish Database). The reference condition set is, in the context of this study, valid for the section of the Mutlumuvi River within EcoRegion 3.07, which equates secondary natural resource unit MUT A.3. Twenty nine fish species can be expected in this section and are listed in Table F13.

Table F13 EWR 6: Reference fish species

Expected Reference and Habitat derived Frequency of Occurrence (FROC) of fish at EWR 6 (Values used in FRAI) Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Anguilla mossambica	Longfin eel	AMOS	1	1
Barbus annectens	Broadstriped barb	BANN	4	3
Barbus eutaenia	Orangefin barb	BEUT	4	3
Barbus afrohamiltoni	Hamilton's barb	BFRI	3	1
Labeobarbus marequensis	Largescale yellowfish	BMAR	5	4
Barbus paludinosus	Goldie barb	BPAU	4	2
Barbus radiatus	Beira barb	BRAD	4	2
Barbus toppini		BTOP	4	2
Barbus trimaculatus	Threespot barb	BTRI	5	4
Barbus unitaeniatus	Longbeard barb	BUNI	5	3
Barbus viviparous	Bowstripe barb	BVIV	5	4
Chiloglanis anoterus	Rock catlet	CANO	5	4
Clarias gariepinus	Sharptooth catfish	CGAR	4	4
Chiloglanis paratus	Sawfin suckermouth	CPAR	5	4
Chiloglanis swierstrai	Lowveld suckermouth	CSWI	5	3
Glossogobius callidus	River goby	GCAL	3	2
Glossogobius giurus	Tank goby	GGIU	5	3
Labeo cylindricus	Redeye labeo	LCYL	5	3
Labeo molybdinus	Leaden labeo	LMOL	5	4
Micralestis acutidens	Silver robber	MACU	5	4
Mesobola brevianalis	River sardine	MBRE	5	4
Marcusenius macrolepidotus	Bulldog	MMAC	4	3
Oreochromus mossambicus	Mozambique tilapia	OMOS	5	5

Expected Reference and Habitat derived Frequency of Occurrence (FROC) of fish at EWR 6 (Values used in FRAI) Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Opsaridium peringueyi	Southern barred minnow	OPER	4	1
Petrocephalus wesselsi	Southern churchill	PCAT	4	2
Pseudocrenilabrus philander	Southern mouthbrooder	PPHI	4	4
Schilbe intermedius	Silver catfish	SINT	3	2
Serranochromus meridianus	Lowveld largemouth	SMER	3	2
Tilapia rendalli	Redbreast tilapia	TREN	4	4
FROC ratings: 0 = absent 1 = present at very few sites (<10%) 2 = present at few sites (>10 - 25%)		3 = present at about >25 - 50% of sites 4 = present at most sites (>50 - 75%) 5 = present at almost all sites (>75%)		

F13.3 PRESENT ECOLOGICAL STATE

F13.3.1 Site suitability

Site suitability in terms of assessment index	Habitat for small rheophilic species and some semi-rheophilic species well represented at site. Fish habitats (velocity-depth categories and associated cover) at site expected to be similar to expected habitats of the RAU.		
	EWR suitability = 3.0 Site FRAI suitability = 3.5	**Confidence**	4

The PES was calculating for the section of Mutlumuvi River within ecoregion 3.08.

PES description	The PES reflects deteriorated ecological integrity, primarily attributed to the altered hydrological regime (serious increase in zero flow duration, large change in low flows and small alteration in moderate events), extensive sedimentation (overgrazing, rural areas) and deterioration in water quality. Most of the expected fish species are however still present in this reach, although in reduced abundance and spatial distribution. Rheophilic and semi-rheophilic species have been affected negatively.		
	C (69.2%)	**Confidence**	4

F13.3.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
C	Reduced migration success as a result of migration barriers and altered migratory cues.	Migration barriers (especially Corumanu Dam, but also smaller weirs) impede natural migration. Altered hydrological events delay/prevent natural migratory cues.	NF	
	Loss of fish habitat diversity (especially FS and FD habitat).	Flow modification and abstraction.	F	
	Increased sedimentation and benthic growth result in deterioration of substrate as habitat.	Hillslope erosion related to rural areas (over grazing, small-scare agriculture, informal settlements). Increased nutrients result in aggregated benthic growth.	NF	
	Increased pressure on fish assemblage.	Large scale harvesting take place with use of nets.		
	Local fish habitats are altered and deteriorated.	Solid waste disposal.		

F13.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
C	Stable	C		The fish assemblage in this section have adapted to the altered water quality and flows and should remain fairly stable over the long	3

				term should current conditions prevail.	

F13.5 REC: B

PES	REC	Comments	Conf
C	B	Improved flow management (release of EWR, increased low flows, decreased zero flows) will improve the FROC of at least some species with preference of FS and FD, as well as species intolerant to no flow (e.g. BEUT, BMAR, CSWI, LCYL, and OPER). Improved substrate condition (reduced sedimentation) will further improve the habitat quality of the above mentioned species.	3

F13.6 AEC: C/D

PES	AEC	Comments	Conf
C	D	Deteriorated flow management will decrease the FROC of at least some species with preference of FS and FD, as well as species intolerant to no flow (e.g. BEUT, BMAR, CSWI, and LCYL). Flow intolerant species such as OPER may even be lost under such conditions, although they may recolonise from downstream section during favourable conditions. Deteriorated substrate condition (increased sedimentation and excessive algal growth) will further contribute to the loss or decreased FROC of the above mentioned species.	3

F14 EWR 7: TLULANDZITEKA (TLULANDZITEKA RIVER)

F14.1 DATA AVAILABILITY

Data availability	Conf
Single site visit and fish sampling during September 2007. Angliss and Rodgers, 2002: *Sand River Catchment Biomonitoring Report.* Weeks *et al*. (1996): *A Pre-impoundment Study of the Sabie-Sand River System, Mpumalanga with special reference to predicted impacts on the Kruger National Park.* WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.* Regional specialist input (Mr. M. Angliss)	3

F14.2 REFERENCE CONDITIONS

The fish reference condition information as set for NHRP site X3Mutl-Thula (Kleynhans *et al*., 2007) was applied for the determination of the reference condition. One fish species, namely *Anguilla mossambica* (AMOS) was added to the list of fish species expected under natural conditions, as this species was sampled at this site during 1997 (Kleynhans Fish Database). The reference condition set, is in the context of this study, valid for the section of the Tlulandziteka River within EcoRegion 3.07, which equates secondary NRU Thul A.3. Twenty-eight fish species can be expected in this section of the Tlulandziteka River under natural conditions and is listed in Table F14.

Table F 14 EWR 7: Reference fish species

Expected Reference and Habitat derived Frequency of Occurrence (FROC) of fish at EWR 7 (Values used in FRAI) Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Anguilla mossambica	Longfin eel	AMOS	2	1
Barbus annectens	Broadstriped barb	BANN	4	2
Barbus anoplus	Chubbyhead barb	BANO	3	2
Barbus brevipinnis	Shortfin barb	BBRI	3	1
Barbus eutaenia	Orangefin barb	BEUT	4	3
Labeobarbus marequensis	Largescale yellowfish	BMAR	5	4
Barbus neefi	Sidespot barb	BNEE	3	2
Barbus paludinosus	Goldie barb	BPAU	4	3
Barbus radiatus	Beira barb	BRAD	4	3
Barbus trimaculatus	Threespot barb	BTRI	5	4
Barbus unitaeniatus	Longbeard barb	BUNI	5	4
Barbus viviparous	Bowstripe barb	BVIV	5	4
Chiloglanis anoterus	Rock catlet	CANO	5	4
Clarias gariepinus	Sharptooth catfish	CGAR	4	4
Chiloglanis paratus	Sawfin suckermouth	CPAR	5	3
Chiloglanis swierstrai	Lowveld suckermouth	CSWI	5	2
Labeo cylindricus	Redeye labeo	LCYL	5	2
Labeo molybdinus	Leaden labeo	LMOL	5	3
Micralestis acutidens	Silver robber	MACU	5	3
Mesobola brevianalis	River sardine	MBRE	5	3
Marcusenius macrolepidotus	Bulldog	MMAC	4	2
Oreochromus mossambicus	Mozambique tilapia	OMOS	5	5

Expected Reference and Habitat derived Frequency of Occurrence (FROC) of fish at EWR 7 (Values used in FRAI) Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Opsaridium peringueyi	Southern barred minnow	OPER	4	2
Petrocephalus wesselsi	Southern churchill	PCAT	4	1
Pseudocrenilabrus philander	Southern mouthbrooder	PPHI	4	3
Schilbe intermedius	Silver catfish	SINT	3	1
Serranochromus meridianus	Lowveld largemouth	SMER	3	2
Tilapia rendalli	Redbreast tilapia	TREN	4	3

FROC ratings:
0 = absent
1 = present at very few sites (<10%)
2 = present at few sites (>10 - 25%)
3 = present at about >25 - 50% of sites
4 = present at most sites (>50 - 75%)
5 = present at almost all sites (>75%)

F14.3 PRESENT ECOLOGICAL STATE

F14.3.1 Site suitability

Site suitability in terms of assessment index	Habitat for small rheophilic species and some semi-rheophilic species well represented at site. Fish habitats (velocity-depth categories and associated cover) at site expected to be similar to expected habitats of the RAU.		
	EWR suitability = 3.0 Site FRAI suitability = 3.5	**Confidence**	4

The PES was calculating for the section of Tlulandziteka River within ecoregion 3.08.

PES description	The PES reflects deteriorated ecological integrity, based on the fish assemblage, primarily attributed to the altered hydrological regime (serious increase in zero flow duration, large change in low flows and small alteration in moderate events), extensive sedimentation (overgrazing, rural areas) and deterioration in water quality. Most of the expected fish species are however still present in this reach, although be it in reduced abundance and spatial distribution. Rheophilic and semi-rheophilic species have been affected negatively.		
	C (65.4%)	**Confidence**	3

F14.3.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
C	Loss of fish habitat diversity (especially FS and FD).	Flow modification and abstraction.	F	3
	Reduced migration success as a result of migration barriers and altered migratory cues.	Migration barriers (especially Corumanu dam, but also smaller weirs) impede natural migration. Altered hydrological events delay/prevent natural migratory cues.		
	Increased sedimentation and benthic growth result in deterioration of substrate as habitat.	Hillslope erosion related to rural areas (over grazing, small-scare agriculture, informal settlements). Increased nutrients result in aggregated benthic growth.	NF	
	Increased pressure on fish assemblage, especially if large scale harvesting takes place.	Fishing (with nets).		
	Local fish habitats are altered and deteriorate.	Solid waste disposal.		

F14.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
C	Stable	C		The fish assemblage in this section has adapted to the altered water quality and flows and should remain fairly stable over the long term.	3

F14.5 AEC: B

PES	AEC	Comments	Conf
C	B	Improved flows will result in more FD and FS habitats, improving the current FROC of species with preference for fast habitats (CPAR, CSWI, LCYL, LMOL, and OPER). This will also improve conditions for species sensitive to no flows, such as BBRI and CSWI. Improved water quality will be reflected by improved FROC of BEUT, CANO, MACU, MMAC and PCAT. General improvement in the riparian zone condition should result in improved overhanging vegetation as cover with a resultant increase in the FROC of species such as BBIV.	3

F14.6 AEC: D

PES	AEC	Comments	Conf
C	D	Reduced flows and increased zero flows will reduce FS and FD habitat and also lead to loss of flow intolerant and moderately flow intolerant species (BEUT, BMAR, CANO, CPAR, CSWI, LCYL, and LMOL) and probably the complete eradication of OPER. Reduced water quality will lead to further pressure on the water quality intolerant species. Deterioration in substrates as a result of sedimentation and benthic algae will lead to decreased FROC of BNEE, BEUT, BMAR, *Chiloglanis* and *Labeo* spp. Deterioration in riparian zone with decreased overhanging vegetation will be reflected by decreased FROC of species such as BANO, BNEE, BPAU, BRAD, BTRI, BUNI and BVIV.	3

F15 EWR 8: LOWER SAND (SAND RIVER)

F15.1 DATA AVAILABILITY

Data availability	Conf
Single site visit and fish sampling during September 2007. Angliss and Rodgers, 2002: *Sand River Catchment Biomonitoring Report.* Rivers Database (2007): *Database on fish distribution in South African Rivers*. Weeks *et al*. (1996): *A Pre-impoundment Study of the Sabie-Sand River System, Mpumalanga with special reference to predicted impacts on the Kruger National Park.* WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.* Deacon (2007): *Fish Database of Kruger National Park Rivers (1960 to present).*	4

F15.2 REFERENCE CONDITIONS

The reference as set for NRHP site X3SAND-SKUKU (Kleynhans *et al*., 2007) was directly applicable as reference condition for EWR 8. GCAL was added to the list of fish species expected under natural conditions, as this species was sampled at this site during 1997 (Kleynhans Fish Database). The reference condition set is, in the context of this study, valid for the section of the Sand River within RAU S and B.1. Thirty fish species can be expected in this section and are listed in Table F15.

Table F 15 EWR 8: Reference fish species

Expected Reference and Habitat derived Frequency of Occurrence (FROC) of fish at EWR 8 (Values used in FRAI) Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Anguilla marmorata	Giant mottled eel	AMAR	1	1
Anguilla mossambica	Longfin eel	AMOS	1	1
Barbus annectens	Broadstriped barb	BANN	4	3
Barbus afrohamiltoni	Hamilton's barb	BFRI	3	3
Brycinus imberi	Imberi	BIMB	4	3
Labeobarbus marequensis	Largescale yellowfish	BMAR	5	5
Barbus radiatus	Beira barb	BRAD	3	3
Barbus toppini		BTOP	3	3
Barbus trimaculatus	Threespot barb	BTRI	5	5
Barbus unitaeniatus	Longbeard barb	BUNI	3	3
Barbus viviparous	Bowstripe barb	BVIV	5	5
Chiloglanis anoterus	Rock catlet	CANO	2	1
Clarias gariepinus	Sharptooth catfish	CGAR	4	4
Chiloglanis paratus	Sawfin suckermouth	CPAR	4	2
Chiloglanis swierstrai	Lowveld suckermouth	CSWI	4	2
Glossogobius callidus	River goby	GCAL	2	2
Glossogobius giurus	Tank goby	GGIU	3	2
Labeo cylindricus	Redeye labeo	LCYL	5	4
Labeo molybdinus	Leaden labeo	LMOL	5	4
Labeo rosae	Rednose labeo	LROS	3	3
Micralestis acutidens	Silver robber	MACU	4	4
Mesobola brevianalis	River sardine	MBRE	3	3
Marcusenius macrolepidotus	Bulldog	MMAC	4	3
Oreochromus mossambicus	Mozambique tilapia	OMOS	5	5

Expected Reference and Habitat derived Frequency of Occurrence (FROC) of fish at EWR 8 (Values used in FRAI) Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Opsaridium peringueyi	Southern barred minnow	OPER	2	1
Petrocephalus wesselsi	Southern churchill	PCAT	2	1
Pseudocrenilabrus philander	Southern mouthbrooder	PPHI	4	4
Schilbe intermedius	Silver catfish	SINT	3	3
Serranochromus meridianus	Lowveld largemouth	SMER	3	3
Tilapia rendalli	Redbreast tilapia	TREN	5	5

FROC ratings:
0 = absent
1 = present at very few sites (<10%)
2 = present at few sites (>10 - 25%)
3 = present at about >25 - 50% of sites
4 = present at most sites (>50 - 75%)
5 = present at almost all sites (>75%)

F15.3 PRESENT ECOLOGICAL STATE

F15.3.1 Site suitability

Site suitability in terms of assessment index	During flowing conditions, habitat for small rheophilic species will be present at site. Fish habitats (velocity-depth categories and associated cover) at site expected to be similar to expected habitats of the RAU.		
	EWR suitability = 2.5 Site FRAI suitability = 3.0	**Confidence**	4

The PES was calculating for the section of the Sand River within resource assessment unit (RAU) Sand B.1.

PES description	The PES reflects slightly deteriorated ecological integrity, based on the fish assemblage, primarily attributed to the slightly altered hydrological regime (low flows), some increased sedimentation (overgrazing in rural areas of upper catchment) and slight deterioration in water quality. Most of the expected fish species are however still present in this reach, although in reduced abundance and spatial distribution. The majority of this reach lies within conservation areas, which contributed to general good ecological integrity.		
	B (86.8%)	**Confidence**	4

F15.3.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
B	Slightly altered low flows reduce FS habitats.	Abstraction, livestock watering.	F	4.5
	Reduced migration success as a result of migration barriers. and	Migration barriers (especially Corumanu dam, but also smaller weirs) impede natural migration.	NF	
	Altered migratory cues.	Altered hydrological events delay/prevent natural migratory cue.	F	
	Increased sedimentation and benthic growth result in deterioration of substrate as habitat. Sedimentation transforms deep habitats to shallow habitats.	Hillslope erosion in catchment (over grazing, small-scare agriculture, informal settlements). Increased nutrients result in slightly aggregated benthic growth.	NF	

F15.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
B	Stable	B		The fish assemblage in this section has adapted to the altered water quality and flows and should remain fairly stable.	3

F15.5 AEC: C

PES	AEC	Comments	Conf
B	C	The scenario will result in decreased FROC of species with preference for FS and FD habitats (BMAR, CPAR, LCYL, LMOL, and MACU), and a complete loss in species intolerant to no flow conditions (CANO, CSWI, OPER, and HVIT).	4

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APPENDIX G: MACROINVERTEBRATES

C Thirion and C Todd, DWAF: RQS
AC Uys, Laughing Waters
P Vos, Jeffares and Green

G1 EWR 1: VALEYSPRUIT (CROCODILE RIVER)

G1.1 DATA AVAILABILITY

Data availability	Conf
Invertebrate data and analysis from a single sampling trip to the site on 5 October 2007 (two sets of samples). Historical Invertebrate data from the Rivers Database for sites X2LUNS-KRUIS. X2CROC-VALYS (the EWR site), X2CROC-DONKE. Personal communications and assistance with data from Christa Thirion and Colleen Todd (DWAF: RQS). Preliminary maps and information on the catchment as supplied by Delana Louw, Water for Africa. Specialist assessments for this study. • Hydrological assessment (HAI) by Prof Denis Hughes • IHI assessment by Delana Louw • Diatom Assessment by Shael Koekemoer • Geomorphological Assessment Index by Mark Rountree • Vegetation Assessment Index by James McKenzie Kleynhans *et al.* (2005): *A Level 1 Ecosystem Classification System for South Africa, Lesotho and Swaziland*. Kleynhans *et al.* (2007): *A Level 2 Ecosystem Classification System for South Africa, Lesotho and Swaziland*. Dallas (2007): *River Health Programme: SASS5 Data Interpretation Guidelines.*	4

G1.2 REFERENCE CONDITIONS

Reference conditions	Conf
The reference total SASS 5 score is 240, with more than 35 taxa and an ASPT of 7.5.	3

G1.3 PRESENT ECOLOGICAL STATE

PES description	SASS5 score: 215 No of Taxa: 34 ASPT: 6.3 The macroinvertebrate assemblage reflects slightly deteriorated ecological integrity, attributed primarily to land use activities resulting in decreased low flows and sedimentation of instream habitats with coinciding water quality problems. This can be seen most clearly in the disappearance of the stoneflies (Perlidae) and the cobble dwelling Chlorocyphid mayflies. Many sensitive flow dependent taxa were collected in stones-in-current (SIC), stones-out-of-current (SOOC) and gravel-sand-mud (GSM) habitats, while vegetation harboured the more resilient taxa. High scoring taxa in the former biotopes include Heptageniidae, Polymitarcydae, Prosopistomatidae, Psephenidae, and Athericidae.		
	B (87.1%)	**Confidence**	4

G1.3.1 PES causes and sources

PES	Causes	Sources	F/NF	Conf
B	Alteration of low flows.	Abstraction.	F	2.5
	Increased sedimentation of instream habitat.	Land use.	NF	

G1.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
B	Stable	B		The macroinvertebrates have already reacted to the current conditions.	2

G1.5 AEC: B/C

PES	AEC	Comments	Conf
B	B/C	An increase in sedimentation and nutrient loading could be aggravated by a reduction in flow. The cumulative effect of these factors could reduce the quality of the cobble habitat due to increased sedimentation and increased algal growth, as well as the vegetation habitat due to reduced	3

PES	AEC	Comments	Conf
		inundation. The fast flow and moderate flow habitats will also be affected. It is anticipated that the changes in habitat and flow will reduce the abundance and/or frequency of occurrence of rheophilics and taxa requiring inundated vegetation. Possible increased nutrients could increase the abundances and frequency of occurrences of more tolerant taxa.	

G2 EWR 2: GOEDEHOOP (CROCODILE RIVER)

G2.1 DATA AVAILABILITY

Data availability	Conf
Invertebrate data and analysis from a single sampling trip to the site on 5th October 2007 (two sets of samples). Historical Invertebrate data from the Rivers Database' for site X2CROC-GOEDE (the EWR site). Preliminary maps and information on the catchment as supplied by Delana Louw, Water for Africa. Personal communications and assistance with data from Christa Thirion and Colleen Todd (DWAF: RQS). Specialist assessments for this study: • Hydrological assessment by Prof Denis Hughes. • IHI assessment by Delana Louw. • Diatom Assessment by Shael Koekemoer. • Geomorphological Assessment Index by Mark Rountree. • Vegetation Assessment Index by James McKenzie. Kleynhans *et al.* (2005): *A Level 1 Ecosystem Classification System for South Africa, Lesotho and Swaziland*. Kleynhans *et al.* (2007): *A Level 2 Ecosystem Classification System for South Africa, Lesotho and Swaziland*. Dallas (2007): *River Health Programme: SASS5 Data Interpretation Guidelines.*	4

G2.2 REFERENCE CONDITIONS

Reference conditions	Conf
The reference total SASS 5 score is 260 and an ASPT of 7 and 59 taxa expected.	3

G2.3 PRESENT ECOLOGICAL STATE

PES description	SASS5 score: 228 No of Taxa: 36 ASPT: 6.4 This slight decrease in the PES is due to water quality modification as a result of numerous instream trout dams in the upper catchment. Problems associated with this include nutrient enrichment of the water, which results in algal growth on instream habitat, effectively decreasing the availability of habitat for macroinvertebrate colonization. Flow modification and sedimentation are also having a negative impact on the instream habitat and resultant macroinvertebrate colonization. Flow sensitive taxa that were sampled included Perlidae, Prosopistomatidae, Heptageniidae, Tricorythidae. High scoring taxa included Prosopistomatidae, Heptageniidae and Perlidae. The burrowing mayfly, Polymitarcydae, was also sampled at the site.		
	B (84.4%)	**Confidence**	4

G2.3.1 PES causes and sources

PES	Causes	Sources	F/NF	Conf
B	Alteration of low flows.	Many small instream trout dams, abstraction.	F	3
	Increased sedimentation of instream habitat.	Land use.	NF	

G2.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
B	Negative	B/C	5 year	Land use and resulting erosion and sedimentation, abstraction, and water quality maintained at same levels. There have been a number of recent developments in the upper Crocodile catchment, including the Highland Gate development in the Kareekraal Spruit. The invertebrates have not yet adapted to these changes.	2

G2.5 AEC: C

PES	AEC	Comments	Conf

PES	AEC	Comments	Conf
B	C	A decrease in the quality of the instream habitat, with resultant algal growth and accumulation of fines in the stones in current habitat will occur. Less marginal vegetation will be available for colonization by macroinvertebrates. Increased alien vegetation may result in bank destabilization which will increase sedimentation affecting instream habitat. These changes to the system will reduce the abundance and/or frequency of occurrence of rheophilic taxa as well as taxa utilizing the marginal vegetation. Those taxa requiring good quality cobble habitat, will be negatively impacted by the increased sedimentation and algal growth on the cobbles. Certain tolerant taxa may increase in abundance with increased nutrients in the system.	2.5

G3 EWR 3: POPLAR CREEK (CROCODILE RIVER)

G3.1 DATA AVAILABILITY

Data availability	Conf
Invertebrate data and analysis from a single sampling trip to the site on 5th October 2007 (two sets of samples); Invertebrate data from the Rivers Database for site X2CROC-INDEM; Personal communications and assistance with data from Christa Thirion and Colleen Todd (DWAF: RQS). Preliminary maps and information on the catchment as supplied by Delana Louw, Water for Africa. Specialist assessments for this study: • Hydrological assessment by Prof Denis Hughes. • IHI assessment by Delana Louw. • Diatom Assessment by Shael Koekemoer. • Geomorphological Assessment Index by Mark Rountree. • Vegetation Assessment Index by James McKenzie. Kleynhans *et al.* (2005): *A Level 1 Ecosystem Classification System for South Africa, Lesotho and Swaziland*. Kleynhans *et al.* (2007): *A Level 2 Ecosystem Classification System for South Africa, Lesotho and Swaziland*. Dallas (2007): *River Health Programme: SASS5 Data Interpretation Guidelines.*	4

G3.2 REFERENCE CONDITIONS

Reference conditions	Conf
The reference total SASS 5 score is 240 with >35 taxa and an ASPT of 7.5.	3.5

G3.3 PRESENT ECOLOGICAL STATE

G3.3.1 Site suitability

Site suitability in terms of assessment index	Reasonable diversity of hydraulic habitats. MV comprises largely woody vegetation and is not optimal or SASS 5 sampling. Water quality compromised and suspended sediment load is likely to alter habitat quality throughout.		
	3	**Confidence**	2

PES description	SASS5 score: 218 No of Taxa: 32 ASPT: 6.8 The PES of the invertebrate assemblage reflects moderately deteriorated ecological integrity, attributed primarily to the upstream Kwena Dam and land use activities.and modified flow conditions. The unseasonal high releases from the Kwena Dam. The MIRAI indicates that the main reasons for the deterioration in the macroinvertebrate assemblage are related to the change in habitat (scouring due to high velocities) and connectivity and seasonality. The main reason can be regarded as the unseasonal high flows during the winter months. No specific group of macroinvertebrates have been affected by the condition in this stretch of the Crocodile River. The MIRAI indicates that the invertebrates are affected by all aspects of the river condition but that the physico-chemical deterioration had the greatest impact.		
	C (74.5%)	**Confidence**	4

G3.3.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
C	Reduced low flows.	Operation of Kwena Dam.	F	2.5
	Alteration in moderate floods.			
	Increased sediment loading (high turbidity).	Kwena dam, altered flow regime.	NF	
	Bed and bank modified (sedimentation).	Land use in catchment.		

G3.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
C	Negative	C/D	5 years	The operation of Kwena Dam has resulted in a severe change of seasonal flows, with high constant releases made during the dry season. Due to these constant releases sampling at this site is very difficult. Due to the development in the catchment the invertebrates have not yet adapted to the reduced low flows, altered flood regime and higher turbidity.	2.5

G3.5 REC: B

PES	REC	Comments	Conf
C	B	A number of taxa preferring slower water speeds are expected to occur more frequently and some of the molluscs and dipterans are expected to recolonise.	2.5

G3.6 AEC: C/D

PES	AEC	Comments	Conf
C	C/D	Deteriorating catchment condition will result in an increase in sedimentation and resultant loss of habitat. The deteriorating catchment condition is also likely to result in worsening water quality, thus resulting in the more sensitive invertebrate taxa occurring less frequently and even disappearing.	3

G4 EWR 4: KANYAMAZANE (CROCODILE RIVER)

G4.1 DATA AVAILABILITY

Data availability	Conf
Invertebrate data and analysis from a single sampling trip to the site on 5th October 2007 (two sets of samples). Macroinvertebrate data from the National Rivers Database for additional sites in the reach. Preliminary maps and information on the catchment as supplied by Delana Louw, Water for Africa. Personal communications and assistance with data from Christa Thirion and Colleen Todd (DWAF: RQS). Specialist assessments for this study: • Hydrological assessment by Prof Denis Hughes. • IHI assessment by Delana Louw. • Diatom Assessment by Shael Koekemoer. • Geomorphological Assessment Index by Mark Rountree. • Vegetation Assessment Index by James McKenzie. Kleynhans *et al.* (2005): *A Level 1 Ecosystem Classification System for South Africa, Lesotho and Swaziland*. Kleynhans *et al.* (2007): *A Level 2 Ecosystem Classification System for South Africa, Lesotho and Swaziland*. Dallas (2007): *River Health Programme: SASS5 Data Interpretation Guidelines.*	3

G4.2 REFERENCE CONDITIONS

Reference conditions	Conf
The reference total SASS 5 is 270, with over 35 taxa and an ASPT of >7.	3.5

G4.3 PRESENT ECOLOGICAL STATE

G4.3.1 Site suitability

Site suitability in terms of assessment index	A range of the preferred hydraulic habitats are present, with the exception of sand and mud. The marginal vegetation is not optimal, in the sense that it comprises largely *Phragmites* and the alien invasive *Eichornia crassipes*. Water is turbid, possibly as a result of sedimentation. The turbidity and any effects thereof (e.g. fines) has an effect on the quality of all invertebrate habitats.		
	3	**Confidence**	3

PES description	SASS5 score: 153 No of Taxa: 26 ASPT: 5.9 The PES of the macroinvertebrate assemblage reflects moderately deteriorated ecological integrity, attributed primarily to the upstream land use activities and modified flow conditions. No specific group of macroinvertebrates have been affected by the condition in this stretch of the Crocodile River. The MIRAI indicates that the macroinvertebrates are affected by all aspects of the river condition but that the physico-chemical deterioration had the greatest impact.		
	C (75.9%)	**Confidence**	4

G4.3.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
C	Significant alterations to low flows and floods.	Abstraction (irrigation) and Kwena Dam operation	F	3
	Increased salts, nutrients and toxics; decreased water clarity.	Irrigation return flows; other land-use practices.	NF	
	Increased sediment loading (related to erosion of banks as a result of clearing of crops e.g. sugarcane).	Land-use		

G4.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
C	Stable	C		The macroinvertebrates have already reacted to the current conditions.	3

G4.5 REC: B

PES	REC	Comments	Conf
C	B	Improved catchment management will reduce the sediment loading and improve water quality. The improved conditions will lead to more sensitive taxa occurring more frequently and some moderately sensitive taxa such as Polymitarcyidae, Athericidae and Chlorocyphidae recolonising the river.	3

G4.6 AEC: C/D

PES	AEC	Comments	Conf
C	D	Increased return flow and worsening water quality. Increased industrial activities in Nelspruit could also result in higher levels of toxics occurring more frequently. The scenario will lead a more sensitive invertebrates occurring less frequently and even disappearing from this section of the river. It is expected that the Stonefly Perlidae will disappear as well as the more sensitive species of the Baetidae and Hydropsychidae.	3

G5 EWR 5: MALALANE (CROCODILE RIVER)

G5.1 DATA AVAILABILITY

Data availability	Conf
Invertebrate data and analysis from a single sampling trip to the site on 5th October 2007 (two sets of samples). Invertebrate data from the Rivers database. Preliminary maps and information on the catchment as supplied by Delana Louw, Water for Africa. Personal communications and assistance with data from Christa Thirion and Colleen Todd (DWAF: RQS). Specialist assessments for this study: Hydrological assessment by Prof Denis Hughes. IHI assessment by Delana Louw. Diatom Assessment by Shael Koekemoer. Geomorphological Assessment Index by Mark Rountree. Vegetation Assessment Index by James McKenzie. Kleynhans *et al.* (2005): *A Level 1 Ecosystem Classification System for South Africa, Lesotho and Swaziland*. Kleynhans *et al.* (2007): *A Level 2 Ecosystem Classification System for South Africa, Lesotho and Swaziland*. Dallas (2007): *River Health Programme: SASS5 Data Interpretation Guidelines.*	4

G5.2 REFERENCE CONDITIONS

Reference conditions	Conf
The reference total SASS 5 score is 180, with over 30 taxa and an ASPT of >6.	3

G5.3 PRESENT ECOLOGICAL STATE

G5.3.1 Site suitability

Site suitability in terms of assessment index	Site highly disturbed. Water quality compromised. SIC and MV present although not optimal. SOOC and GSM absent. This means that a full SASS 5 sample is not possible. *Eichornia crassipes* abundant and further proliferation could result in loss of SIC and MV habitat area, shading, and eventual de-oxygenation of the water.		
	3	**Confidence**	3.5

PES description	SASS5 score: 161 No of Taxa: 32 ASPT: 5 The PES of the macroinvertebrate assemblage reflects moderately deteriorated ecological integrity, attributed primarily to land use activities resulting in decreased low flows and coinciding water quality problems. MIRAI indicates that the main reasons for the impaired state of the macroinvertebrate assemblage are due to connectivity and Sensitivity (69.7) and Water quality (73.6) problems.		
	C (76.9%)	**Confidence**	4

G5.3.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
C	Significant alteration to low flows and floods.	Abstractions for irrigation.	F	3
	Water quality issues including increased salts, nutrients, toxics, decreased water clarity.	Land use (return flows, etc.).	NF	
	Bed modified as a result of sedimentation.	Releases from the dam, land use.		

G5.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
C	Stable	C		The invertebrates have already reacted to the changes in the	2.5

				river.	

G5.5 REC: B

PES	REC	Comments	Conf
C	B	Improved flow regime and catchment management can lead to reduced return flows and less sedimentation in the river. The gastropod snails will occur less frequently and a number of moderately sensitive taxa such as Polymitarcyidae and Corduliidae will recolonise the river.	3

G5.6 AEC: D

PES	AEC	Comments	Conf
C	D	Decreased low flows: increased return flows: Lead to worse water quality and increased sedimentation due to further bank erosion. This will result in less available habitat and the disappearance of a number of the more sensitive invertebrates (e.g. Perlidae and the more sensitive species of the Baetidae) while others will occur less frequently.	3

G6 EWR 6: NKONGOMA (CROCODILE RIVER)

G6.1 DATA AVAILABILITY

Data availability	Conf
Invertebrate data and analysis from a single sampling trip to the site on 5th October 2007 (two sets of samples). Invertebrate data from the River Health Program 'Rivers Client' for sites X2CROC_NGONG. Preliminary maps and information on the catchment as supplied by Delana Louw, Water for Africa. Personal communications and assistance with data from Christa Thirion and Colleen Todd (DWAF: RQS). Specialist assessments for this study: • Hydrological assessment by Prof Denis Hughes. • IHI assessment by Delana Louw. • Diatom Assessment by Shael Koekemoer. • Geomorphological Assessment Index by Mark Rountree. • Vegetation Assessment Index by James McKenzie. Kleynhans *et al.* (2005): *A Level 1 Ecosystem Classification System for South Africa, Lesotho and Swaziland*. Kleynhans *et al.* (2007): *A Level 2 Ecosystem Classification System for South Africa, Lesotho and Swaziland*. Dallas (2007): *River Health Programme: SASS5 Data Interpretation Guidelines.*	4

G6.2 REFERENCE CONDITIONS

Reference conditions	Conf
The reference total SASS 5 score is 230, with over 32 taxa and an ASPT of >6.	3.5

G6.3 PRESENT ECOLOGICAL STATE

G6.3.1 Site suitability

Site suitability in terms of assessment index	Scarce FCS and MV habitat. Bedrock and GSM are plentiful. Site thus limited in terms of availability of the critical habitat types for macroinvertebrate EWR assessment.		
	2.5	**Confidence**	2.5

PES description	SASS5 score: 121 No of Taxa: 25 ASPT: 4.8 The PES of the macroinvertebrate assemblage reflects moderately deteriorated ecological integrity, attributed primarily to land use activities resulting in decreased low flows and sedimentation of instream habitats with coinciding water quality problems. This can be seen most clearly in the disappearance of the taxa preferring cobbles as well as surface dwelling macroinvertebrates. MIRAI indicates that the main reasons for the deterioration in the macroinvertebrates are due to water quality (62.2%) and connectivity and seasonality (58.9%) problems.		
	C (74.9%)	**Confidence**	4

G6.3.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
C	Significant variation in low flows and floods.	Abstraction for irrigation.	F	3
	Zero flows.			
	Water quality deterioration (particularly salts, toxics and nutrients).	Land use.	NF	
	Instream and bank modification through sedimentation (resulting from erosion).	Clearing of sugarcane and orchards, overall land use.		

G6.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
C	Stable	C		Invertebrates already adapted to changes	2.5

G6.5 REC: B

PES	REC	Comments	Conf
C	B	Improved land management related to irrigation practices will lead to improved flow conditions, less erosion and therefore less sedimentation. Reduced return flows from agriculture will improve the water quality. These improvements will lead to a more natural invertebrate assemblage with the return of some moderately sensitive taxa such as Heptageniidae, Aeshnidae and Athericidae.	3

G6.6 AEC: D

PES	AEC	Comments	Conf
C	C/D	A larger area of irrigated sugarcane will result in increased periods of low flow and poorer water quality due to increased return flow. The poor land use practices will also result in greater erosion and sedimentation in the river. Because these activities are restricted to one bank only, the invertebrates will only go down to a C/D EC. As a result of the changed conditions a number of the more sensitive invertebrates (Tricorythidae and the more sensitive species of Baetidae) will disappear from the system, while others will occur less frequently and in lower abundances.	3

G7 EWR 7: HONEYBIRD (KAAP RIVER)

G7.1 DATA AVAILABILITY

Data availability	Conf
Invertebrate data and analysis from a single sampling trip to the site on 5th October 2007 (two sets of samples); Invertebrate data from the Rivers database'; Preliminary maps and information on the catchment as supplied by Delana Louw, Water for Africa. Personal communications and assistance with data from Christa Thirion and Colleen Todd (DWAF: RQS). Specialist assessments for this study: • Hydrological assessment by Prof Denis Hughes. • IHI assessment by Delana Louw. • Diatom Assessment by Shael Koekemoer. • Geomorphological Assessment Index by Mark Rountree. • Vegetation Assessment Index by James McKenzie. Kleynhans *et al.* (2005): *A Level 1 Ecosystem Classification System for South Africa, Lesotho and Swaziland*. Kleynhans *et al.* (2007): *A Level 2 Ecosystem Classification System for South Africa, Lesotho and Swaziland*. Dallas (2007): *River Health Programme: SASS5 Data Interpretation Guidelines.*	4

G7.2 REFERENCE CONDITIONS

Reference conditions	Conf
The reference total SASS 5 score is 250, with over 5 taxa and an ASPT of >7.	3.5

G7.3 PRESENT ECOLOGICAL STATE

PES description	SASS5 score: 194 No of Taxa: 34 ASPT: 5.7 The PES of the macroinvertebrate assemblage reflects slightly deteriorated ecological integrity, attributed primarily to land use activities resulting in decreased low flows and coinciding water quality problems. The MIRAI indicates that the water quality (77.9%) is the main reason for the deterioration in water quality.		
	B (83.6%)	**Confidence**	3

G7.3.1 PES causes and sources

PES	Causes	Sources	F/NF	Conf
B	Reduced base flows and zero flow.	Abstraction for irrigation.	F	3
	Water quality deterioration.	Land use.	NF	

G7.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
B	Stable	B		The macroinvertebrates have already adapted to the changes in the system.	2.5

G7.5 REC: B

PES	REC	Comments	Conf
B	B	Maintain the current EC.	N/A

G7.6 AEC: D

PES	AEC	Comments	Conf
B	C	Increased abstraction from the Kaap River will result in a decrease in available habitat for the invertebrates. Decreased water quality will result from increased irrigation return flow. The decreased flow and water quality will cause higher temperatures and more algal growth reducing the available cobble habitat. As a result some of the more sensitive species of the Baetidae and Hydropsychidae will disappear while others (e.g. Perlidae, Heptageniidae and Chlorocyphidae) will occur less frequently.	3

G8 EWR 1: UPPER SABIE (SABIE RIVER)

G8.1 DATA AVAILABILITY

Data availability	Conf
Invertebrate data and analysis from a single sampling trip during September, 2007. Invertebrate data from the River Health Program for sites X3KSAB-TWEEF. Maps of study area and catchment information. Personal communications and assistance with data from Christa Thirion and Colleen Todd (DWAF: RQS). Specialist assessments for this study: • Hydrological assessment by Prof Denis Hughes. • IHI assessment by Delana Louw. • Diatom Assessment by Shael Koekemoer. • Geomorphological Assessment Index by Mark Rountree. • Vegetation Assessment Index by James McKenzie. Kleynhans *et al.* (2005): *A Level 1 Ecosystem Classification System for South Africa, Lesotho and Swaziland*. Kleynhans *et al.* (2007): *A Level 2 Ecosystem Classification System for South Africa, Lesotho and Swaziland*. Dallas (2007): *River Health Programme: SASS5 Data Interpretation Guidelines.*	3

G8.2 REFERENCE CONDITIONS

Reference conditions	Conf
The reference total SASS 5 score is 220, with >30 taxa and an ASPT of 7.5.	3

G8.3 PRESENT ECOLOGICAL STATE

G8.3.1 Site suitability

Site suitability in terms of assessment index	High due to high habitat diversity at all flows, good water quality, plentiful inundated marginal vegetation, presence of indigenous riparian vegetation on left bank.		
	5	**Confidence**	3.5

PES description	SASS5 score: 170 No of Taxa: 27 ASPT: 6.3 Habitat diversity was high and a number of sensitive flow dependent taxa were collected including Baetidae (>2spp); Perlidae, Heptageniidae, and Athericidae. The PES of the invertebrate assemblage reflects slightly deteriorated ecological integrity, attributed primarily to land use activities resulting in decreased low flows and sedimentation of instream habitats with coinciding water quality problems. This can be seen most clearly in the disappearance of the stoneflies (Perlidae) and the cobble dwelling Chlorocyphid mayflies. According to Dallas (2007), this SASS score equates to an A for this ecoregion (North Eastern Highlands lower zone).		
	B (82.1%)	**Confidence**	4

G8.3.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
B	Nutrient enrichment and increased turbidity.	Minor return flows from Sabie town and forestry in catchment. Large sawmill and Plywood factory upstream of Sabie town.	NF	3
	Flow reduction.	Abstraction (forestry and Sabie town), small scale irrigation.	F	

G8.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
B	Stable	B		Macroinvertebrates have adapted to current altered flow and water quality conditions.	2

G8.5 REC: B

PES	REC	Comments	Conf
B	A/B	Improving the condition of the marginal zone of the riparian vegetation will provide more habitat for vegetation dwelling invertebrates.	3

G8.6 AEC: C/D

PES	AEC	Comments	Conf
B	C	Increased nutrient enrichment will result in a decrease in the quality of the instream habitat, with potential resultant algal growth and accumulation of fines in the stones in current habitat impacting taxa requiring good quality cobble habitat. Less marginal vegetation will be available for colonization by macroinvertebrates due to lower flows. These changes to the system will reduce the abundance and/or FROC of rheophilic taxa as well as taxa utilizing the marginal vegetation. Certain tolerant taxa may increase in abundance with increased nutrients in the system.	3

G9 EWR 2: AAN DE VLIET (SABIE RIVER)

G9.1 DATA AVAILABILITY

Data availability	Conf
Invertebrate data and analysis from a single sampling trip to the site on 5 September 2007. Personal communications and assistance with data from Christa Thirion and Colleen Todd (DWAF: RQS). Macroinvertebrate data from the Rivers Database. Specialist assessments for this study: • Hydrological assessment by Prof Denis Hughes. • IHI assessment by Delana Louw. • Diatom Assessment by Shael Koekemoer. • Geomorphological Assessment Index by Mark Rountree. • Vegetation Assessment Index by James McKenzie. Kleynhans *et al.* (2005): *A Level 1 Ecosystem Classification System for South Africa, Lesotho and Swaziland*. Kleynhans *et al.* (2007): *A Level 2 Ecosystem Classification System for South Africa, Lesotho and Swaziland*. Dallas (2007): *River Health Programme: SASS5 Data Interpretation Guidelines.*	4

G9.2 REFERENCE CONDITIONS

Reference conditions	Conf
The reference SASS 5 score is 220, with over 30 taxa present and an ASPT of > 7.5.	3

G9.3 PRESENT ECOLOGICAL STATE

G9.3.1 Site suitability

Site suitability in terms of assessment index	High diversity of flow and non-flow habitats in good condition, adequate depth, good water quality, indigenous riparian vegetation on the left bank.		
	4	**Confidence**	4

PES description	SASS5 score: 167 No of Taxa: 24 ASPT: 7 This slight decrease in the PES is due to water quality modification as a result of numerous instream trout dams in the upper catchment. Problems associated with this include nutrient enrichment of the water, which results in algal growth on instream habitat, effectively decreasing the availability of habitat for macroinvertebrate colonization. Flow modification and sedimentation are also having a negative impact on the instream habitat and resultant macroinvertebrate colonization. Sensitive flow dependent taxa collected include >2 spp Baetidae, Perlidae, and Athericidae. The majority of taxa were collected in the stones-in-current (SIC) habitat, followed by the marginal vegetation habitat. Stones-out-of-current (SOOC) and gravel, sand, mud (GSM) biotopes were sampled in the pool areas. According to Dallas (2007), this SASS score equates to a B category for this EcoRegion (Lowveld Upper).		
	B/C (79.5%)	**Confidence**	4

G9.3.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
C	Reduction in base flows.	Forestry and irrigation.	F	3
	Change in bed morphology.	Roads, forestry and irrigation.		
	Clearing of right bank and associated erosion.	Roads, forestry and irrigation. Resort activities.	NF	

G9.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf

B	Stable	B		Macroinvertebrates have adapted to current altered flow and water quality conditions.	2

G9.5 REC: B

PES	REC	Comments	Conf
B/C	B	Improving the condition of the marginal zone of the riparian vegetation will provide more habitat for vegetation dwelling invertebrates resulting in the return of a number of molluscs as well as Aeshnidae and Atyidae.	3

G9.6 AEC: C/D

PES	AEC	Comments	Conf
B/C	C	Increased sedimentation will result in a decrease in the quality and quantity of the cobble habitat. Decreased flows will result in less available vegetation habitat. As a result of these changes the more sensitive taxa inhabiting these biotopes will occur less frequently.	3

G10 EWR 3: KIDNEY (SABIE RIVER)

G10.1 DATA AVAILABILITY

<table>
<tr><th>Data availability</th><th>Conf</th></tr>
<tr><td>Invertebrate data and analysis from a single sampling trip during September, 2007.
Maps of study area and catchment information.
Personal communications and assistance with data from Christa Thirion and Colleen Todd (DWAF: RQS).
1996 IFR site information (Godfrey, 2002).
Specialist assessments for this study:
• Hydrological assessment by Prof Denis Hughes.
• IHI assessment by Delana Louw.
• Diatom Assessment by Shael Koekemoer.
• Geomorphological Assessment Index by Mark Rountree.
• Vegetation Assessment Index by James McKenzie.
Kleynhans et al. (2005): A Level 1 Ecosystem Classification System for South Africa, Lesotho and Swaziland.
Kleynhans et al. (2007): A Level 2 Ecosystem Classification System for South Africa, Lesotho and Swaziland.
Dallas (2007): River Health Programme: SASS5 Data Interpretation Guidelines.</td><td>4</td></tr>
</table>

G10.2 REFERENCE CONDITIONS

Reference conditions	Conf
The reference total SASS 5 score is 220, with over 32 taxa and an ASPT of >7.	3

G10.3 PRESENT ECOLOGICAL STATE

G10.3.1 Site suitability

<table>
<tr><td rowspan="2">Site suitability in terms of assessment index</td><td colspan="3">Difficult site to sample as a result of the multiple channels. The channel on the roadward side had reasonably diverse habitat present, with plentiful flow habitat. Bed substrates were unsilted and no algae were present.</td></tr>
<tr><td>3.5</td><td>Confidence</td><td>3</td></tr>
</table>

<table>
<tr><td rowspan="2">PES description</td><td colspan="3">SASS5 score: 203 No of Taxa: 32 ASPT: 6.3
The PES of the macroinvertebrate assemblage reflects slightly deteriorated ecological integrity, attributed primarily to land use activities resulting in decreased low flows and sedimentation of instream habitats with coinciding water quality problems. This can be seen most clearly in the disappearance of cobble dwelling taxa preferring faster velocities such as the Tricorythid mayflies. MIRAI indicates that the main reasons for the altered macroinvertebrate conditions are changes in seasonality and connectivity (74.1%) and to a lesser degree deterioration in water quality (88.4%). Habitat diversity was high and a suite of sensitive flow dependent taxa were collected in SIC, MV and SOOC habitat which included Athericidae, Helodidae, Pyralidae, Chlorocyphidae, Heptageniidae, Perlidae and Hydracarina. According to Dallas (2007), this SASS score equates to an A for this EcoRegion (Lowveld lower zone).</td></tr>
<tr><td>B (86.9%)</td><td>Confidence</td><td>4</td></tr>
</table>

G10.3.2 PES causes and sources

<table>
<tr><th>PES</th><th>Causes</th><th>Sources</th><th>F/NF</th><th>Conf</th></tr>
<tr><td rowspan="4">B</td><td>Increased turbidity.</td><td rowspan="2">Land-use.</td><td rowspan="2">NF</td><td rowspan="4">3</td></tr>
<tr><td>Sedimentation.</td></tr>
<tr><td>Reduction in flow.</td><td>Upstream abstractions, Inyaka Dam.</td><td rowspan="2">F</td></tr>
<tr><td>Altered high flows (moderate floods).</td><td>Forestry, abstraction, Inyaka Dam.</td></tr>
</table>

G10.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
B	Stable	B		Invertebrate community composition and abundance suggests that the taxa present have adjusted to current conditions in the catchment and the reduction in flows.	3

G10.5 AEC: B/C

PES	AEC	Comments	Conf
B	C	Increased sedimentation will lead to cobbles becoming more embedded, resulting in decreased habitat availability. The lower flows and increased return flows are likely to lead to higher nutrient levels and increased temperatures which will result in increased algal growth reducing available habitat even further. A number of the more sensitive taxa such as Helodidae, Pyralidae and the more sensitive species of Baetidae and Hydropsychidae will disappear and other less sensitive cobble dwelling taxa will occur less frequently.	3

G11 EWR 4: MAC MAC (MAC MAC RIVER)

G11.1 DATA AVAILABILITY

Data availability	Conf
Invertebrate data and analysis from a single sampling trip during September, 2007. Maps of study area and catchment information. Personal communications and assistance with data from Christa Thirion and Colleen Todd (DWAF: RQS). Specialist assessments for this study: • Hydrological assessment by Prof Denis Hughes. • IHI assessment by Delana Louw. • Diatom Assessment by Shael Koekemoer. • Geomorphological Assessment Index by Mark Rountree. • Vegetation Assessment Index by James McKenzie. Kleynhans *et al.* (2005): *A Level 1 Ecosystem Classification System for South Africa, Lesotho and Swaziland*. Kleynhans *et al.* (2007): *A Level 2 Ecosystem Classification System for South Africa, Lesotho and Swaziland*. Dallas (2007): *River Health Programme: SASS5 Data Interpretation Guidelines.*	3

G11.2 REFERENCE CONDITIONS

Reference conditions	Conf
The reference range for the site is SASS 5 scores of 270, with >35 taxa and an ASPT of > 7.3.	3

G11.3 PRESENT ECOLOGICAL STATE

G11.3.1 Site suitability

Site suitability in terms of assessment index	Habitat diversity is high, with plentiful hydraulic habitats which will largely remain with increases and reductions in flow. Adequate marginal vegetation. Majority of the riparian zone is indigenous vegetation.		
	5	**Confidence**	3

PES description	SASS5 score: 225 No of Taxa: 35 ASPT: 6.4 The PES of the macroinvertebrate assemblage reflects slightly deteriorated ecological integrity, attributed primarily to land use activities resulting in decreased low flows and sedimentation of instream habitats. This can be seen most clearly in the disappearance of cobble dwelling taxa preferring faster velocities such as the Tricorythid mayflies. MIRAI indicates that the main reason for the altered macroinvertebrate conditions are changes in seasonality and connectivity (80.0%) and to a far lesser degree a slight deterioration in water quality (89.7%). Diverse communities of invertebrates were collected in all habitats, with the sensitive (mostly flow dependent) element comprised of Dixidae, Philopotamidae, Hydropsychidae, Chlorocyphidae, Heptageniidae, and Baetidae >2spp. According to Dallas (2007) this SASS score and ASPT equates to an A category within this EcoRegion (NE Highlands, lower zone).		
	A/B (88.2%)	**Confidence**	3

G11.3.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
A/B	Slight eutrophication.	Input from upstream wastewater treatment works, forestry.	NF	2.5
	Altered flooding regime (moderate and high floods).	Forestry.		
	Reduced low flows.	Forestry.	F	

G11.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
A/B	Stable	A/B		Scores approximate reference, with the forestry already established in the catchment. It is likely that the community will remain stable.	2.5

G11.5 AEC: C

PES	AEC	Comments	Conf
A/B	B/C	Higher temperatures and lower oxygen concentrations will occur. An increase in the road networks and poorly maintained stream crossings will lead to increased sedimentation and corresponding decrease in available habitat quality. This decreased habitat will lead to cobble dwelling taxa occurring less frequently.	3

G12 EWR 5: MARITE (MARITE RIVER)

G12.1 DATA AVAILABILITY

Data availability	Conf
Invertebrate data and analysis from a single sampling trip to the site on 3 September 2007. Maps of study area and catchment information. Personal communications and assistance with data from Christa Thirion and Colleen Todd (DWAF: RQS). Specialist assessments for this study: • Hydrological assessment by Prof Denis Hughes. • IHI assessment by Delana Louw. • Diatom Assessment by Shael Koekemoer. • Geomorphological Assessment Index by Mark Rountree. • Vegetation Assessment Index by James McKenzie. Kleynhans *et al.* (2005): *A Level 1 Ecosystem Classification System for South Africa, Lesotho and Swaziland*. Kleynhans *et al.* (2007): *A Level 2 Ecosystem Classification System for South Africa, Lesotho and Swaziland*. Dallas (2007): *River Health Programme: SASS5 Data Interpretation Guidelines.*	3

G12.2 REFERENCE CONDITIONS

Reference conditions	Conf
The range of scores for the reference is set at 240, with >34 taxa and an ASPT of > 7.	3

G12.3 PRESENT ECOLOGICAL STATE

G12.3.1 Site suitability

Site suitability in terms of assessment index	Abundant habitat in all flow classes including very fast flow. Plentiful marginal vegetation. Water quality good and flow at the time of sample created both shallow and deep habitat. There is a slight disadvantage in that the river is braided at this site.		
	4	**Confidence**	3

PES description	SASS5 score: 231 No of Taxa: 36 ASPT: 6.4 The PES of the macroinvertebrate assemblage reflects moderately deteriorated ecological integrity, attributed primarily to land use activities resulting in decreased low flows and the altered flow regime resulting from the operation of Inyaka Dam. This can be seen most clearly in the disappearance of cobble dwelling taxa preferring faster velocities such as the Tricorythid mayflies and Philopotamid caddisflies. MIRAI indicates that the main reason for the altered macroinvertebrate conditions are changes in seasonality and connectivity (66.1%) and to a far lesser degree a slight deterioration in water quality (80.7%). According to the Dallas (2007) banding for this EcoRegion (North eastern Highlands, upper zone), this site would be categorised as an A.		
	B/C (80.5%).	**Confidence**	2.5

G12.3.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
B/C	Increase in low flows. Reduction in floods. Altered water temperature and clarity. Change in sedimentation. Change in bank structure.	Releases from Inyaka Dam.	F	3

G12.3.3 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
B/C	Stable	B/C		The invertebrate community has a reasonably high sensitivity and appears to have adjusted to current flow conditions, despite their difference from natural state.	2

G12.4 REC: B

PES	REC	Comments	Conf
B/C	B	An improved flow regime (close to natural regime) will improve habitat and slower water velocities should result in slightly more sediments in the system. This will result in a number of the taxa preferring slower water (e.g. gastropods) returning.	2.5

G12.5 AEC: C/D

PES	AEC	Comments	Conf
B/C	C	The lower flows, smaller floods, more sandy habitat and increased nutrient concentrations will result in a decrease in cobble dwelling habitat as a result of less and poorer habitat as well as an increase in the more tolerant taxa depending on the water column and GSM. The decrease in vegetation will also result in a depauperate vegetation dwelling assemblage.	3

G13 EWR 6: MUTLUMUVI (MUTLUMUVI RIVER)

G13.1 DATA AVAILABILITY

Data availability	Conf
Invertebrate data and analysis from a single sampling trip during September, 2007. Information from RHP site X3MUTL-NEWFO. Maps of study area and catchment information. 1996 IFR site information (Godfrey, 2002). Rivers database. Personal communications and assistance with data from Christa Thirion and Colleen Todd (DWAF: RQS). Specialist assessments for this study: • Hydrological assessment by Prof Denis Hughes. • IHI assessment by Delana Louw. • Diatom Assessment by Shael Koekemoer. • Geomorphological Assessment Index by Mark Rountree. • Vegetation Assessment Index by James McKenzie. Kleynhans *et al.* (2005): *A Level 1 Ecosystem Classification System for South Africa, Lesotho and Swaziland*. Kleynhans *et al.* (2007): *A Level 2 Ecosystem Classification System for South Africa, Lesotho and Swaziland*. Dallas (2007): *River Health Programme: SASS5 Data Interpretation Guidelines.*	3

G13.2 REFERENCE CONDITIONS

Reference conditions	Conf
The reference total SASS 5 score is 270, with over 35 taxa and an ASPT of > 7.5.	3

G13.3 PRESENT ECOLOGICAL STATE

G13.3.1 Site suitability

Site suitability in terms of assessment index	Adequate and diverse invertebrate habitat despite low flows.		
	4	**Confidence**	3

PES description	SASS5 score: 189 No of Taxa: 32 ASPT: 5.9 The PES of the macroinvertebrate assemblage reflects moderately deteriorated ecological integrity, attributed primarily to land use activities resulting in decreased low flows and zero flow duration and altered beds and banks. This can be seen most clearly in the disappearance of cobble dwelling taxa preferring faster velocities such as the Tricorythid mayflies and Philopotamid caddisflies. MIRAI indicates that the main reason for the altered macroinvertebrate conditions are changes in seasonality and connectivity (68.6%) and to a far lesser degree a moderate deterioration in water quality (77.4%). Despite the lack of substantial flow habitat and depth at the site at the time of sampling, a number of more sensitive invertebrates were collected in SIC, GSM and MV. These include Heptageniidae, Baetidae (>2spp), Perlidae, Chlorocyphidae, Atyidae, and Athericidae. The Dallas (2007) banding for this EcoRegion (Lowveld upper) sets this site as an A.		
	B/C (77.7%)	**Confidence**	3.5

G13.3.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
B/C	Substantially reduced low flows.	Abstraction.	F	2.5
	Increase in zero flow duration.			
	Alteration of flood regime.	Land use.		
	Bed and bank modification.			

G13.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
B/C	Negative	C	Short term	The invertebrate community will undergo further changes over a five year period. This relates to loss of connectivity and increase in sedimentation.	3

G13.5 REC: B

PES	REC	Comments	Conf
B/C	B	Flow sensitive taxa will increase and sensitive taxa e.g. Oligoneuridae and the more sensitive species of Baetidae and Hydropsychidae will return. The increased low flows and shorter periods of lno flow will also result in more frequent inundation of marginal vegetation. The improved habitat in the marginal vegetation will result in a return of some of the vegetation dwelling taxa such as Pleidae and Aeshnidae.	3

G13.6 AEC: C/D

PES	AEC	Comments	Conf
B/C	C	This scenario will lead to a decrease of the available vegetation and consequently in a decrease in the frequency of occurrence of a number of taxa.	3

G14 EWR 7: TLULANDZITEKA (TLULANDZITEKA RIVER)

G14.1 DATA AVAILABILITY

Data availability	Conf
Invertebrate data and analysis from a single sampling trip to the site on 6TH September 2007. Maps of study area and catchment information. Personal communications and assistance with data from Christa Thirion and Colleen Todd (DWAF: RQS). Rivers Database. Specialist assessments for this study: • Hydrological assessment by Prof Denis Hughes. • IHI assessment by Delana Louw. • Diatom Assessment by Shael Koekemoer. • Geomorphological Assessment Index by Mark Rountree. • Vegetation Assessment Index by James McKenzie. Kleynhans *et al.* (2005): *A Level 1 Ecosystem Classification System for South Africa, Lesotho and Swaziland*. Kleynhans *et al.* (2007): *A Level 2 Ecosystem Classification System for South Africa, Lesotho and Swaziland*. Dallas (2007): *River Health Programme: SASS5 Data Interpretation Guidelines.*	3

G14.2 REFERENCE CONDITIONS

Reference conditions	Conf
The reference SASS 5 score range is >250, with >35 taxa and ASPT of >7	2.5

G14.3 PRESENT ECOLOGICAL STATE

G14.3.1 Site suitability

Site suitability in terms of assessment index	Site significantly disturbed. Habitat diversity is restricted by increasing sedimentation. Poor MV. The bed and banks are significantly modified, and sedimentation has compromised instream SIC and SOC habitats.		
	2.5	**Confidence**	2.5

PES description	SASS5 score: 197 No of Taxa: 32 ASPT: 6.2 Instream habitat at this site has been altered by sediment loading, flow alteration and deterioration in water quality. There is also encroachment of *Phragmites sp*. into the channel. There is plentiful coarse substrate, creating a 'flow over coarse substrate' hydraulic habitat. This is currently largely mobile, but is becoming armoured by the additional sediment loading. Despite the alteration to instream habitat and banks at this site, a number of more sensitive invertebrates were collected in SIC, GSM and MV. These include Heptageniidae, Baetidae (>2spp), Perlidae, Chlorocyphidae, Hydropsychidae (>2sp), Helodidae, and Athericidae. Despite the alteration to instream habitat and banks at this site, a number of more sensitive invertebrates were collected in SIC, GSM and MV. These include Heptageniidae, Baetidae (> 2 spp), Perlidae, Chlorocyphidae, Hydropsychidae (> 2 sp), Helodidae, and Athericidae. The Dallas (2007) banding for this EcoRegion (Lowveld upper) sets this site as an A.		
	B/C (78.1%)	**Confidence**	2

G14.3.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
B/C	Low flow reductions.	Abstraction.	F	2
	Bed and bank modification.	Landuse in catchment (cattle, roads etc.).	NF	
	Nutrient enrichment.			
	Erosion in the riparian zone.			

G14.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
B/C	Negative	C/D	5 years	It is likely that the invertebrate community has already 'reset' itself following disturbance to the bed through vegetation encroachment and subsequent sedimentation (road building etc.). However the likely continuation of the increasing sediment loading will gradually decrease all flow habitats and further deterioration in the invertebrate community is inevitable.	2.5

G14.5 AEC: B

PES	AEC	Comments	Conf
B/C	B	Improved land use such as less grazing and trampling in the riparian zone will reduce the erosion and thus also the sedimentation. This will improve the cobble and vegetation habitat for the invertebrates increasing the frequency at which a number of the taxa occur as well as the return of the sensitive mayfly family Tricorythidae.	2

G14.6 AEC: D

PES	AEC	Comments	Conf
B/C	C/D	This scenario will result in sedimentation of the river bed, decreasing the interstitial spaces and therefore the available habitat for cobble dwelling invertebrates. The decreased flows and resulting increased temperatures and decreased oxygen concentrations will also affect the more sensitive taxa. A number of the less sensitive taxa will occur less frequently, while some of the more sensitive taxa (Athericidae, Leptophlebiidae, Chlorocyphidae, Perlidae etc.) will disappear from the river reach.	2

G15 EWR 8: LOWER SAND (SAND RIVER)

G15.1 DATA AVAILABILITY

Data availability	Conf
Invertebrate data and analysis from a single sampling trip to the site on 5 September 2008. Maps of study area and catchment information. Personal communications and assistance with data from Christa Thirion and Colleen Todd (DWAF: RQS). Specialist assessments for this study: • Hydrological assessment by Prof Denis Hughes. • IHI assessment by Delana Louw. • Diatom Assessment by Shael Koekemoer. • Geomorphological Assessment Index by Mark Rountree. • Vegetation Assessment Index by James McKenzie. Kleynhans *et al.* (2005): *A Level 1 Ecosystem Classification System for South Africa, Lesotho and Swaziland*. Kleynhans *et al.* (2007): *A Level 2 Ecosystem Classification System for South Africa, Lesotho and Swaziland*. Dallas (2007): *River Health Programme: SASS5 Data Interpretation Guidelines.*	3

G15.2 REFERENCE CONDITIONS

Reference conditions	Conf
The reference total SASS 5 score is >235, with over 30 taxa and an ASPT of >7.	3

G15.3 PRESENT ECOLOGICAL STATE

G15.3.1 Site suitability

Site suitability in terms of assessment index	At the time of sampling the site was a series of small disconnected pools in a sand bed channel dominated by *Phragmites* reeds. The habitat is restricted to GSM and MV, with no flow habitats at all. The sample is skewed by this low variability both in physical and hydraulic habitat.		
	2.5	**Confidence**	1

PES description	SASS5 score: 105 No of Taxa: 20 ASPT: 5.3 The habitat at this site is dominated by coarse mobile sands and *Phragmites sp.* reeds. Standing water habitats only were present during the field visit. Water temperatures in pools were high due to the lack of flow and shading. The macroinvertebrate fauna collected were, as expected under such conditions, predominantly resilient, low-scoring taxa, which occur in these types of habitats. The only higher scoring taxon collected were Heptageniid mayflies. The balance of the fauna is typical of a temporary sand-dominated system with a marginal vegetation component. According to the Dallas (2007) banding, the system would be categorised as a D class. This is under review.		
	C (68.8%)	**Confidence**	3.5

G15.3.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
C	Reduction in low flows.	Abstraction.	F	2
	Modified water quality.	Land-use upstream.	NF	

G15.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
C	Negative	C/D	5 years	Maintenance of current abstraction will have the effect of reducing the already low overall sensitivity of the invertebrate community. There is little habitat to buffer this change.	2

G15.5 REC: B

PES	REC	Comments	Conf
C	B	With improved low flows and possibly small to moderate floods (due to improved catchment management) habitat quality will improve, with a subsequent increase in overall macroinvertebrate diversity and abundance. More sensitive taxa are likely to increase in abundance and the number of high scoring taxa could increase.	3

G15.6 AEC: C

PES	AEC	Comments	Conf
C	C/D	Further loss of low flows and alteration of flood regime will lead to further impairments in water quality, proliferation of algae, deposition of fines, and overall degradation of instream habitat. The hydraulic habitat; Fast over Coarse Sediment (FCS) and Marginal Vegetation In Current (MVIC), both of which harbour the more sensitive elements of the invertebrate community, are likely to be most compromised both in terms of quality and quantity.	2.5

G16 REFERENCES

Dallas, H. 2007. River Health Programme: SASS5 Data Interpretation Guidelines. Document prepared for Institute for Natural Resources, and Department of Water Affairs and Forestry.

Godfrey, L. (Ed), 2002. Ecological Reserve Determination for the Crocodile River Catchment, Incomati System, Mpumalanga. Technical Report for the Department of Water Affairs and Forestry, by the Division of Water Environment and Forestry Technology, CSIR, Pretoria. Report No. ENV-P-C 2001. iii + 70 pp.

Kleynhans, C.J., Thirion, C. and Moolman, J. 2005. A Level I River Ecoregion classification System for South Africa, Lesotho and Swaziland. Report No. N/0000/00/REQ0104. Resource Quality Services, Department of Water Affairs and Forestry, Pretoria, South Africa.

Kleynhans, C.J., Thirion, C., Moolman, J. and Gaulana, L. 2007. A Level II River Ecoregion classification System for South Africa, Lesotho and Swaziland. Report No. N/0000/00/REQ0104. Resource Quality Services, Department of Water Affairs and Forestry, Pretoria, South Africa.

APPENDIX H: RIPARIAN VEGETATION

J Mackenzie, BioRiver Solutions

H1 EWR 1: VALEYSPRUIT (CROCODILE RIVER)

H1.1 DATA AVAILABILITY

Data availability	Conf
Satellite images (Google earth) of the respective reach. Hydraulic cross-section (profile) at the site together with surveyed key vegetation points. Data collected from field assessment in October 2007. Previous VEGRAI training site Historical aerial photography (1944, 1956, 1965, 1997). Biomes of South Africa: Grasslands (Rutherford & Westfall, 1986); Grasslands (bushveld) (van Wyk & van Wyk, 1997) Grasslands (Mucina & Rutherford, 2006) Bioregions of South Africa: Mesic Highveld Grasslands (Gm 6) (Mucina & Rutherford, 2006) Vegetation Type: Undifferentiated bushveld and woodland (van Wyk & van Wyk, 1997) Vegetation Units: Lydenburg Montane Grassland (Gm 18), (Mucina & Rutherford, 2006) Principle region of plant diversity and Endemism: Maputaland-Pondoland Region (van Wyk & van Wyk, 1997). Water Research Commission (WRC) (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.*	3.5

H1.2 REFERENCE CONDITIONS

The site occurs in the Lydenburg Montane Grassland in the Grassland biome. The marginal zone will be incised into the grassland floodplain with meandering channels and backwater/oxbow lake non-woody plants. Non-woody vegetation dominate both on the marginal and non-marginal zones as well as the floodplains (*Miscanthus* is dominant), with a minor woody presence (*Cliffortia* and *Leucosidea* spp. mainly).

Confidence: 4

H1.3 PRESENT ECOLOGICAL STATE

H1.3.1 Site suitability

Site Suitability for the Assessment of Environmental Flows		
Habitat availability	**Rate**	**Motivation where applicable**
Presence/absence of the marginal zone.	1	Marginal zone predominantly present localized bank cutting (steep) with no marginal zone.
Proportion of marginal zone that is able to be sampled.	0	Entire marginal zone was sampled.
Channel morphology		
Channel bank stabilization.	2	Approx 40 – 60% of marginal zone undercut, frequently with overhanging root.
Channel manipulation.	1	Unmanipulated.
Profile distance too long to effectively conduct VEGRAI.	1	Entire profile assessed.
Vegetation		
Occurrence of obligate, marginal zone riparian species.	2	Obligate riparian species sufficient in marginal zone.
Occurrence of obligate, non-marginal zone riparian species.	2	Obligate riparian species sufficient in non-marginal zone.
Occurrence of species that are (regional) indicators of the riparian zone, or wetness.		Obligates present, so unrated.
Recent fire/s at site.	1	Localized, recent remnant.
Exotic species at the site.	1	Present, but < 10 on all zones.
Left and right-hand banks have riparian vegetation in similar condition.	0	Similar banks into vegetation.
Able to obtain sufficient survey points of indicator species for flow requirements.	1	Up to 7 points per bank.

Plant species easily identifiable i.e. leaves or flowers present at time of site visit.	1	Some annuals not in flower, some fire damage with coppice only.
Hydraulic control		
Unnatural up/downstream control affecting site.	1	Upstream effect of bridge minimal localized deposition.
Overall Site Suitability Rating	**1.1**	
Suitability rating: 0 - Suite highly suitable 3 - Site unsuitable	1 - Site suitable 4 - Site extremely unsuitable	2 - Site moderately suitable 5 - Site not to be used

PES description	Marginal zone: This zone is most important for year-round refuge habitat, and overhanging vegetation is important for habitat creation/variability. Lower zone: Has high seasonal importance for breeding habitat, and shading of aquatic habitats. Upper zone: Is not directly important for instream habitat, but bank stability is indirectly important as it provides possible shading. The site is very close to reference conditions, with minor impacts of exotics on the non marginal zone and some bank slumping caused by livestock trampling.		
	A (92.5%)	**Confidence**	4.1

H1.3.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
A	Some reduction in non-woody cover and abundance in marginal and non-marginal zones.	Small amount of exotics on non-marginal zone, and some trampling which has caused bank destabilization (slumping has occurred).	NF	4

H1.3.3 Profile

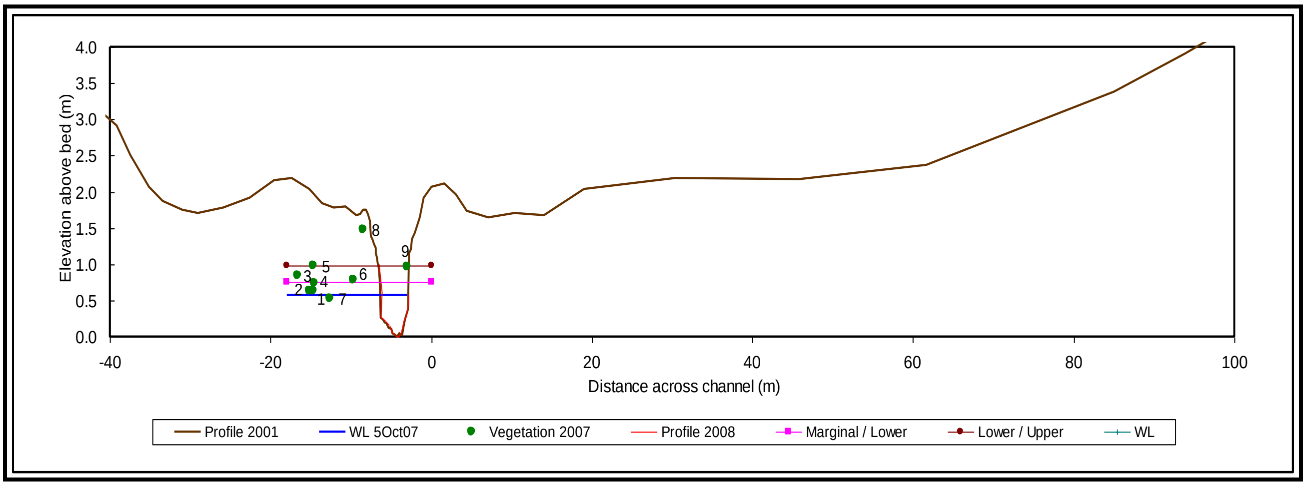

Figure H1 EWR 1: Riparian vegetation survey points used to assess flow requirements

Key:

1: *Juncus lomatophyllus* (Lower limit)
2: *Setaria spachelata* (Lower limit)
3: *Setaria spachelata* (Upper limit)
4: *Miscanthus junceus* (Lower limit)
5: *Cliffortia* (Lower limit)
6: *Juncus lomatophyllus* (Upper limit)
7: *Juncus lomatophyllus* (Lower limit)
8: *Leucosidea sericea* (Upper limit)
9: *Leucosidea sericea* (Lower limit)

H1.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
A	Stable	A		Low impact of exotics, are unlikely to increase. Existing trampling pressure unlikely to cause a trend.	2

H1.5 AEC: B/C

PES	AEC	Comments	Conf
A	B	Increased trampling pressure will cause bank destabilization (slumping) and the subsequent change of marginal zone vegetation with a reduction in non-woody cover and abundance. This will allow exotics to increase on the non-marginal zone, but the impact will remain low.	2.1

H2 EWR 2: GOEDEHOOP (CROCODILE RIVER)

H2.1 DATA AVAILABILITY

Data availability	Conf
Satellite images (Google earth) of the respective reach. Hydraulic cross-section (profile) at the site with surveyed key vegetation points. Geomorphological, Index of Habitat Integrity (IHI), EcoRegion and associated information. Data collected from field assessment during October 2007. Aerial photos of site - 1956, 1964, 1975, 1985. Biomes of South Africa: Grasslands (Rutherford & Westfall, 1986); Grasslands (bushveld) (van Wyk & van Wyk, 1997) Grasslands (Mucina & Rutherford, 2006) Bioregions of South Africa: Mesic Highveld Grasslands (Gm 6) (Mucina & Rutherford, 2006) Vegetation Type: Undifferentiated bushveld and woodland (van Wyk & van Wyk, 1997) Vegetation Units: Lydenburg Thornveld (Gm 21), (Mucina & Rutherford, 2006) Principle region of plant diversity and Endemism: Maputaland-Pondoland Region (van Wyk & van Wyk, 1997). WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.*	3.5

H2.2 REFERENCE CONDITIONS

The site occurs in Lydenburg Thornveld in the Grassland biome. The marginal zone will be incised into the grassland floodplain with meandering channels and floodplain. Non-woody vegetation dominate both the marginal and non-marginal zones mostly, as well as the floodplains (*Miscanthus* spp. is dominant), with a minor woody presence (*Cliffortia*, *Combretum* and *Leucosidea* spp. mainly).

Confidence: 3.5

H2.3 PRESENT ECOLOGICAL STATE

H2.3.1 Site suitability

Site Suitability for the Assessment of Environmental Flows		
Habitat availability	**Rate**	**Motivation where applicable**
Presence/absence of the marginal zone.	1	Marginal zone predominantly present localized bank cutting (steep) with no marginal zone.
Proportion of marginal zone that is able to be sampled.	0	Entire marginal zone was sampled.
Channel morphology		
Channel bank stabilization.	2	Approx 40 – 60% of marginal zone undercut, frequently with overhanging root.
Channel manipulation.	1	Unmanipulated.
Profile distance too long to effectively conduct VEGRAI.	0	Entire profile assessed.
Vegetation		
Occurrence of obligate, marginal zone riparian species.	2	Obligate riparian species sufficient in marginal zone.
Occurrence of obligate, non-marginal zone riparian species.	2	Obligate riparian species sufficient in non-marginal zone.
Occurrence of species that are (regional) indicators of the riparian zone, or wetness.		Obligates present, so unrated.
Recent fire/s at site.	0	None.
Exotic species at the site.	1	Present, but < 10% on all zones.
Left and right-hand banks have riparian vegetation in similar condition.	0	Similar banks into vegetation.
Able to obtain sufficient survey points of indicator species for flow requirements.	2	Up to 4 points per bank.
Plant species easily identifiable i.e. leaves or flowers present at time of site visit.	0	Identification of indicators was possible.
Hydraulic control		

Unnatural up/downstream control affecting site.	1	Upstream effect of bridge minimal localized deposition.
Overall Site Suitability Rating	**0.9**	
Suitability rating: 0 - Suite highly suitable 3 - Site unsuitable	1 - Site suitable 4 - Site extremely unsuitable	2 - Site moderately suitable 5 - Site not to be used

PES description	Marginal zone: This zone is most important for year-round refuge habitat, and overhanging vegetation is important for habitat creation/variability. Lower zone: Has high seasonal importance for breeding habitat, and shading of aquatic habitats. Upper zone: Is not directly important for instream habitat, but bank stability is indirectly important as it provides possible shading. The site is very close to reference condition, with minor impact of exotics on the marginal and non-marginal zones, and some bank slumping caused by livestock trampling.		
	A/B (89.9%)	**Confidence**	3.7

H2.3.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
A/B	Some reduction in non-woody cover and abundance in marginal and non-marginal zones.	Small amount of exotics and some trampling which has caused bank destabilization (slumping has occurred) on marginal and marginal zones.	NF	4

H2.3.3 Profile

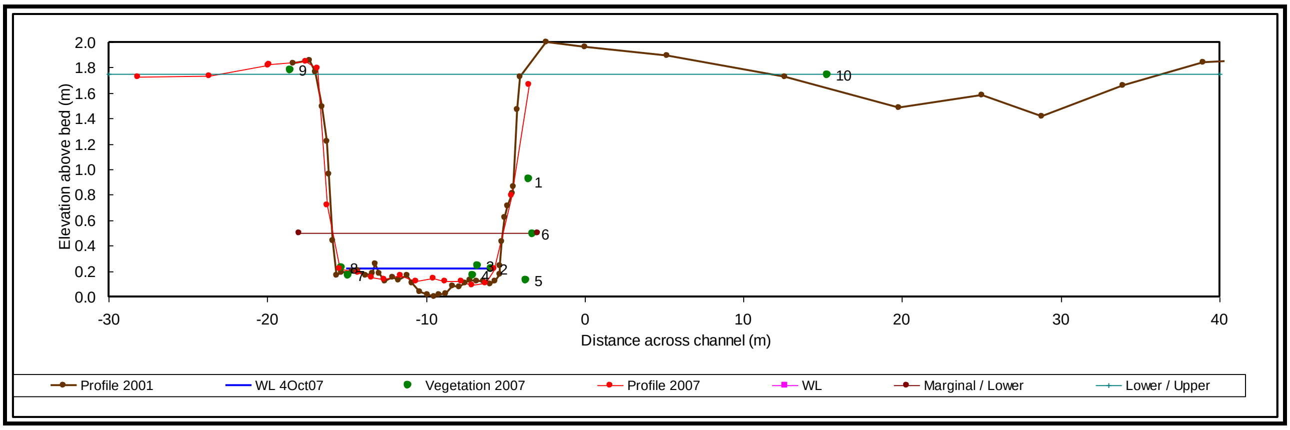

Figure H2: EWR 2: Riparian vegetation survey points used to assess flow requirements

Key:

1: *Combretum* (Upper limit)
2: *Miscanthus* (lower limit)
3: *Phragmites* (lower limit)
4: *Juncus* (lower limit)
5: *Juncus* (lower limit)
6: *Juncus* (Upper limit)
7: *Phragmites* (lower limit)
8: *Miscanthus* (lower limit)
9: *Miscanthus* (Upper limit)
10: *Miscanthus* (Upper limit)

H2.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
A/B	Negative	B	10 years	There is a low impact of exotics, but if left unchecked will increase at the expense of indigenous species (some aggressive aliens present such as *Moris*, *Sesbania* and *Gleiditsia* spp.). Existing trampling pressure is also likely to cause additional bank slumping.	3

H2.5 AEC: C

PES	AEC	Comments	Conf
A	B	Reduced low and moderate flows will likely reduce the success of woody recruitment on marginal and non-marginal zones. Non-woody cover will increase as the as marginal zone follows the narrowing channel.	2.8

H3 EWR 3: POPLAR CREEK (CROCODILE RIVER)

H3.1 DATA AVAILABILITY

Data availability	Conf
Satellite images (Google earth) of the respective reach. Hydraulic cross-section (profile) at the site with surveyed key vegetation points. Previous VEGRAI training site. Aerial photos of site - 1956, 1964, 1970, 1997. Biomes of South Africa: Savanna (Rutherford & Westfall, 1986); Savanna (bushveld) (van Wyk & van Wyk, 1997) Savanna biome (Mucina & Rutherford, 2006). Bioregions of South Africa: Lowveld (SVI 7) (Mucina & Rutherford, 2006). Vegetation Type: Undifferentiated bushveld and woodland (van Wyk & van Wyk, 1997). Vegetation Units: Legogote Sour Bushveld (SVI 9), (Mucina & Rutherford, 2006). Principle region of plant diversity and Endemism: Maputaland-Pondoland Region (van Wyk & van Wyk, 1997). WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.* Data collected from field assessment in 2007.	4

H3.2 REFERENCE CONDITIONS

This site occurs in the Lowveld bioregion of the Savanna biome in the Legogote Sour Bushveld. The site occurs on a stretch of river which cuts through high ground. As a result a mixed vegetation is expected, but one predominated by woody vegetation. Marginal zone species would typically be *Syzigium* species, *Cliffortia sp* and *Breonadia salicina*, with *Combretum erythrophyllum* and *Acacia robusta* and *gerardii* on the lower and upper zones. Marginal zone would typically be a narrow band with some sedge and hydrophilic grasses.

Confidence: 3.5

H3.3 PRESENT ECOLOGICAL STATE

H3.3.1 Site suitability

Site Suitability for the Assessment of Environmental Flows		
Habitat availability	**Rate**	**Motivation where applicable**
Presence/absence of the marginal zone.	1	Marginal zone slightly inundated, but present.
Proportion of marginal zone that is able to be sampled.	0	Entire marginal zone was sampled.
Channel morphology		
Channel bank stabilization.	0	Banks stable.
Channel manipulation.	1	Road through LB and agricultural disturbance to within upper zone.
Profile distance too long to effectively conduct VEGRAI.	1	Entire profile assessed.
Vegetation		
Occurrence of obligate, marginal zone riparian species.	2	Obligate riparian species sufficient in marginal zone.
Occurrence of obligate, non-marginal zone riparian species.	1	Obligate riparian species more than sufficient in non-marginal zone.
Occurrence of species that are (regional) indicators of the riparian zone, or wetness.		Obligates present, so unrated.
Recent fire/s at site.	0	None.
Exotic species at the site.	2	< 10% in marginal zone, but high (up to 40%) in lower and upper zone woody.
Left and right-hand banks have riparian vegetation in similar condition.	1	Similar banks into vegetation.
Able to obtain sufficient survey points of indicator species for flow requirements.	1	Up to 7 points per bank.
Plant species easily identifiable i.e. leaves or flowers	0	Identification of indicators was possible.

present at time of site visit.		
Hydraulic control		
Unnatural up/downstream control affecting site.	0	No localized effect.
Overall Site Suitability Rating	**0.8**	

Suitability rating:

0 - Suite highly suitable	1 - Site suitable	2 - Site moderately suitable
3 - Site unsuitable	4 - Site extremely unsuitable	5 - Site not to be used

PES description	This site has all the necessary elements of the reference condition, but is highly disturbed and has a high proportion of exotic species. Marginal zone: Is a mix of woody (*Cliffortia, Breonadia, Syzigium)* and grass (*Setaria sphacelata*). Lower and upper zones: Dominated by woody species with terrestrial grass understorey. Terrestrial species also indicate high levels of disturbance.		
	B (77.3%)	**Confidence**	3.7

H3.3.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
B	Loss of species composition and indigenous riparian species cover.	High level of invasion by exotic species	NF	4.5
	Reduced woody cover and abundance.	Extensive disturbance at the site, agricultural activities, roads within the riparian zone and targeted woody species removal.		

H3.3.3 Profile

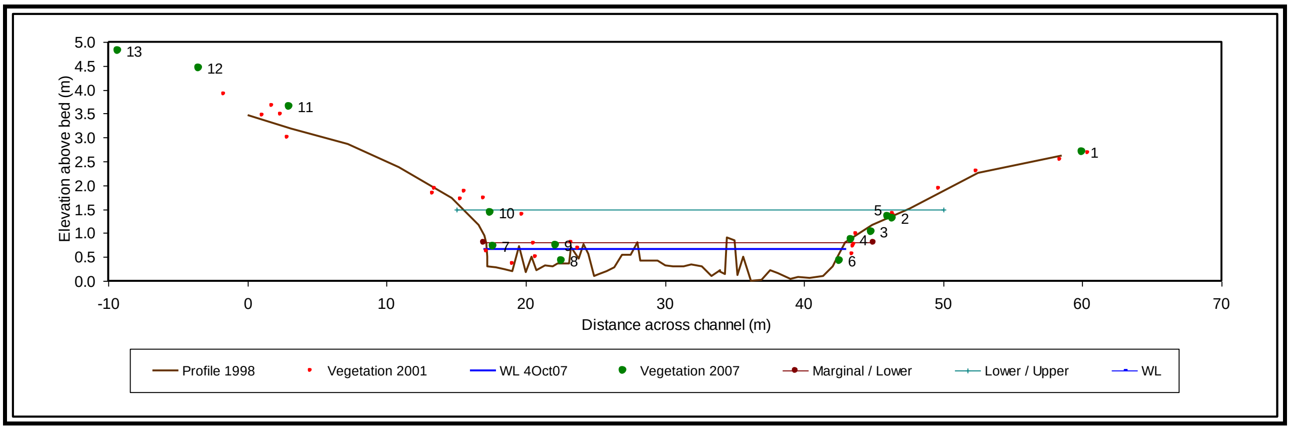

Figure H3 EWR 3: Riparian vegetation survey points used to assess flow requirements

Key:

1: *Combretum* (upper limit)
2: *Combretum* (lower limit)
3: *Gleditsia* (lower limit)
4: *Salix mucronata* (upper limit)
5: *Cliffortia* (upper limit)
6: *Salix mucronata* (lower limit)
7: *Phragmites/Cyperus* ()
8: *Phragmites/Salix* (lower limit)
9: *Salix mucronata* (upper limit)
10: *Combretum* (lower limit)
11: *Celtis africana* (lower limit)
12: *Celtis africana* (upper limit)
13: *Acacia karoo/gerardii*.

H3.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
C	Negative	D	5-10 years	Exotic invasion is high (up to 40% in places) and if left unchecked will increase in proportion at the expense of indigenous riparian vegetation.	3.5

H3.5 REC: B

PES	REC	Comments	Conf
C	B	More natural flows will facilitate non-woody establishment in the marginal zone, and will also facilitate *Cliffortia* spp. recruitment (presently absent). Flow manipulation will not improve the vegetation component on its own. In addition some woody exotics removal on the lower and upper zones will increase indigenous species cover and abundance, and improve species proportions which will improve species composition.	2.8

H3.6 AEC: C/D

PES	AEC	Comments	Conf
C	D	**Marginal zone** Existing *Cliffortia* and *Salix* adults are likely to survive, but most recruitment will be reduced. Some recruitment will still take place, but the marginal zone will migrate towards a narrowing channel. For non-woody species, initially a reduction in cover and abundance will occur, followed by marginal zone migration. Lower zone species are likely to colonize "old marginal" zone areas, also potentially changing species composition. **Lower zone** Lower flows will facilitate improved conditions for aliens and terrestrial species in the lower zone. Indigenous cover and abundance will reduce accordingly, species composition will be negatively impacted and exotics will prevent indigenous riparian recruitment. Reduced recruitment will also alter population structures to deviate more from expected.	3

H4 EWR 4: KANYAMAZANE (CROCODILE RIVER)

H4.1 DATA AVAILABILITY

Data availability	Conf
Satellite images (Google earth) of the respective reach. Hydraulic cross-section (profile) at the site with surveyed key vegetation points. Data collected from field assessment in 2007. Previous VEGRAI training site Aerial photos of site - 1936, 1959, 1970, 1985, 1997. Biomes of South Africa: Savanna (Rutherford & Westfall, 1986); Savanna (bushveld) (van Wyk & van Wyk, 1997) Savanna biome (Mucina & Rutherford, 2006). Bioregions of South Africa: Lowveld (SVI 7) (Mucina & Rutherford, 2006). Vegetation Type: Undifferentiated bushveld and woodland (van Wyk & van Wyk, 1997). Vegetation Units: Pretoriuskop Sour Bushveld (SVI 10), (Mucina & Rutherford, 2006). Principle region of plant diversity and Endemism: Maputaland-Pondoland Region (van Wyk & van Wyk, 1997. WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.*	4

H4.2 REFERENCE CONDITIONS

This site occurs in the Lowveld bioregion of the Savanna biome in the Pretoriuskop Sour Bushveld. The site occurs on a stretch of river which cuts through a gorge, but is still quite wide. As a result, a mixed vegetation is expected, but one predominated by woody vegetation. The site is also predominantly exposed bedrock and cobble/boulder. Marginal zone species would typically be *Syzigium* species, *Cliffortia sp* and *Breonadia salicina*, with *Combretum erythrophyllum, Ficus sycomorus* and *Acacia robusta* and *gerardii* on the lower and upper zones. Less *Phragmites mauritianus* expected than what is currently at the site. The marginal zone would typically be a narrow band with some sedge and hydrophilic grasses in between *Breonadia.*

Confidence: 3.5

H4.3 PRESENT ECOLOGICAL STATE

H4.3.1 Site suitability

Site Suitability for the Assessment of Environmental Flows		
Habitat availability	**Rate**	**Motivation where applicable**
Presence/absence of the marginal zone.	1	Marginal zone slightly inundated, but present.
Proportion of marginal zone that is able to be sampled.	0	Entire marginal zone was sampled.
Channel morphology		
Channel bank stabilization.	0	Banks stable, some slumping due to trampling and cobble/sand mining (small-scale).
Channel manipulation.	1	Rail along RB.
Profile distance too long to effectively conduct VEGRAI.	1	Entire profile assessed.
Vegetation		
Occurrence of obligate, marginal zone riparian species.	1	Obligate riparian species more than sufficient in marginal zone.
Occurrence of obligate, non-marginal zone riparian species.	1	Obligate riparian species more than sufficient in non-marginal zone.
Occurrence of species that are (regional) indicators of the riparian zone, or wetness.		Obligates present, so unrated.
Recent fire/s at site.	2	LB 60% recent burns.
Exotic species at the site.	2	Up to 40% exotics, all zones.
Left and right-hand banks have riparian vegetation in similar condition.	2	Probably due to fires and livestock on LB and not RB.

Able to obtain sufficient survey points of indicator species for flow requirements.	0	8 or more points per bank.
Plant species easily identifiable i.e. leaves or flowers present at time of site visit.	0	Identification of indicators was possible.
Hydraulic control		
Unnatural up/downstream control affecting site.	0	No localized effect.
Overall Site Suitability Rating	**0.8**	
Suitability rating: 0 - Suite highly suitable 3 - Site unsuitable	1 - Site suitable 4 - Site extremely unsuitable	2 - Site moderately suitable 5 - Site not to be used

PES description	The site is heavily impacted with a high (20 - 40%) proportion of exotic species present. Flow reduction has resulted in channel narrowing and expansion of *Phragmites mauritianus* and disturbance includes wood removal, cobble harvesting, road and rail disturbance, grazing and trampling and soil erosion. Marginal zone: Dominated by *Phragmites mauritianus (*with some *Breonadia salicina*). Lower and upper zones: Dominated by a mix of woody species (*Combretum erythrophyllum* and *Ficus sycomorus* mainly) and grasses, but the woody canopy is sparse due to removal and loss of recruitment from grazing.		
	C (64.7%)	**Confidence**	3.6

H4.3.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
C	Increased reed cover.	Reduced flows with expansion of marginal zone.	F	4
	Change in species composition.	Exotic species invasion.	NF	
	Reduced woody cover and abundance and increased cover by grasses and open sand.	Vegetation removal, grazing & trampling and frequent fires.		

H4.3.3 Profile

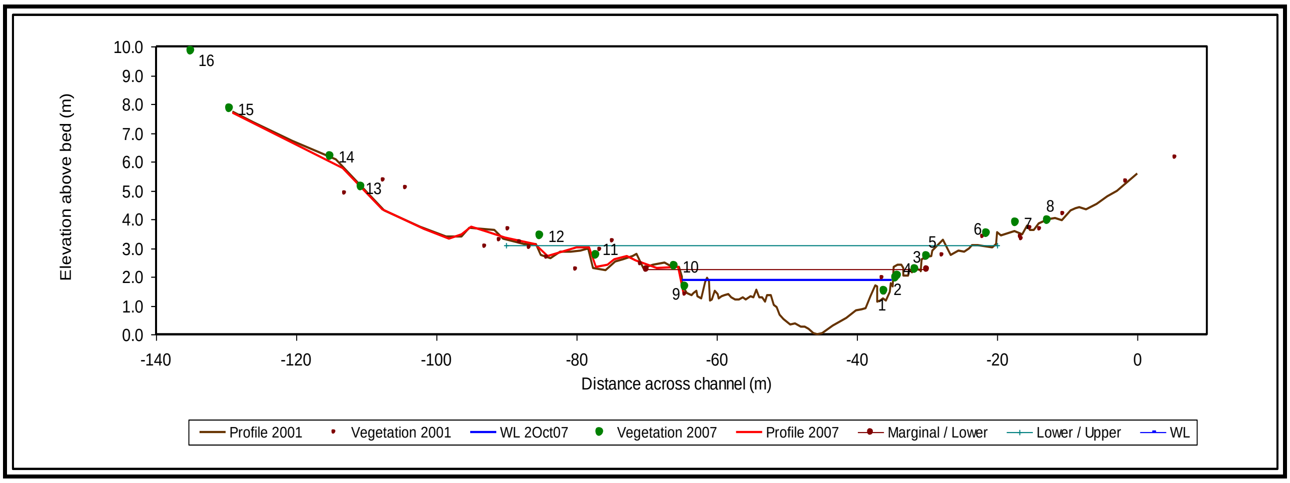

Figure H4 EWR 4: Riparian vegetation survey points used to assess flow requirements

Key:

1: *Berulla/C. dives/Persecaria* (lower limit)
2: *Ludwigia octovalvis* (lower limit)
3: *Ludwigia octovalvis* (upper limit)
4: *C. dives/Myriophyllum*
5: *Breonadia salicina*
6: *Nuxia oppositifolia*
7: *Trichilia emetica/Ficus sur* (lower limit)
8: *Lonchocarpus capassa* (lower limit)
9: *Phragmites mauritianus* (lower limit)
10: *Phragmites mauritianus* (levee)
11: *Phragmites mauritianus* (upper limit)
12: *Combretum erythrophyllum* (lower limit)

13: *Combretum erythrophyllum* (upper limit)
14: *Terminalia sericea*
15: *Acacia robusta* (lower limit)
16: *Acacia robusta* (upper limit)

H4.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
C	Negative	D	10 years	Targeted wood removal, trampling and grazing, cobble collecting and road and rail disturbance Exotic invasion high (up to 20 - 40%) and if left unchecked will increase in proportion at the expense of indigenous riparian vegetation. Reduced moderate flows have favoured an increase in woody vegetation on the lower zone.	3

H4.5 REC: B

PES	REC	Comments	Conf
C	B	Non-woody cover, abundance and species composition will improve on the marginal zone with reduced grazing/trampling pressure. Woody cover, abundance and species composition will improve on lower and upper zones with reduced wood removal and exotic removal, recruitment will improve with reduced grazing/trampling pressure and exotic removal (this will improve population structure).	2.7

H4.6 AEC: C/D

PES	AEC	Comments	Conf
C	D	Increased sedimentation will result in loss of exposed bedrock habitat which *B. salicina* requires for recruitment and establishment. Cover, abundance and recruitment of *B. salicina* will therefore reduce, and population structure will change over time . Reduced flooding and increased sedimentation will also cause reeds to increase, marginal zone migration will occur as sediment is colonised, and a change in species composition will occur i.e. initial loss of other non-woody marginal zone species.	2.8

H5 EWR 5: MALALANE (CROCODILE RIVER)

H5.1 DATA AVAILABILITY

Data availability	Conf
Satellite images (Google earth) of the respective reach. Hydraulic cross-section (profile) at the site together with surveyed key vegetation points for setting flows. Data collected from field assessment in 2007. Previous VEGRAI training site Aerial photos of site - 1936, 1959, 1970, 1984, 1997. Biomes of South Africa: Savanna (Rutherford & Westfall, 1986); Savanna (bushveld) (van Wyk & van Wyk, 1997) Savanna biome (Mucina & Rutherford, 2006). Bioregions of South Africa: Lowveld (SVI 7) (Mucina & Rutherford, 2006). Vegetation Type: Undifferentiated bushveld and woodland (van Wyk & van Wyk, 1997). Vegetation Units: Granite Lowveld (SVI 3), (Mucina & Rutherford, 2006). Principle region of plant diversity and Endemism: Maputaland-Pondoland Region (van Wyk & van Wyk, 1997). WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.*	4.5

H5.2 REFERENCE CONDITIONS

This site occurs in the Lowveld bioregion of the Savanna biome in the Granite Lowveld vegetation unit. Mixed vegetation is expected, but one predominated by woody vegetation on the lower and upper zones (although historically more open than closed canopy). The site is predominantly alluvial and *Phragmites mauritianus* is expected to line the active channel with a mostly narrow (under natural flows) band. Marginal zone species would typically be *Phragmites mauritianus*, with *Combretum erythrophyllum, Ficus sycomorus* and *Diospyros mespiliformisi* on the lower and upper zones. Less *Phragmites mauritianus* expected than what is currently at the site.

Confidence: 3.5

H5.3 PRESENT ECOLOGICAL STATE

H5.3.1 Site suitability

Site Suitability for the Assessment of Environmental Flows		
Habitat availability	**Rate**	**Motivation where applicable**
Presence/absence of the marginal zone.	1	Marginal zone fairly inundated, but present.
Proportion of marginal zone that is able to be sampled.	0	About 10% not sampled due to deep water.
Channel morphology		
Channel bank stabilization.	0	Banks stable.
Channel manipulation.	1	RB with constructed homes, decks and walls.
Profile distance too long to effectively conduct VEGRAI.	2	RB marginal zone too deep to survey.
Vegetation		
Occurrence of obligate, marginal zone riparian species.	1	Obligate riparian species more than sufficient in marginal zone.
Occurrence of obligate, non-marginal zone riparian species.	1	Obligate riparian species more than sufficient in non-marginal zone.
Occurrence of species that are (regional) indicators of the riparian zone, or wetness.		Obligates present, so unrated.
Recent fire/s at site.	0	None.
Exotic species at the site.	2	Up to 40% exotics in marginal zone, lower and upper zones less.
Left and right-hand banks have riparian vegetation in similar condition.	1	Similar.
Able to obtain sufficient survey points of indicator species for flow requirements.	2	Up o 5 points per bank and instream features.

Plant species easily identifiable i.e. leaves or flowers present at time of site visit.	0	Identification of indicators was possible.
Hydraulic control		
Unnatural up/downstream control affecting site.	0	No localized effect.
Overall Site Suitability Rating	**0.8**	
Suitability rating: 0 - Suite highly suitable 3 - Site unsuitable	1 - Site suitable 4 - Site extremely unsuitable	2 - Site moderately suitable 5 - Site not to be used

PES description	The landuse differs for the left and right banks. The left bank (LB) is within KNP and right bank (RB) is impacted by recreational facilities/fencing. Marginal zone: Has migrated and expanded towards the active channel as flows have been reduced and sediments have accumulated, and consists mainly of reedbeds (*Phragmites mauritianus*) and open sand with some *Cyperus sp*. Lower zone: Mainly a mix of reeds and shrubs (*Gymnosporia senegalensis* and *Grewia* spp.) mainly, while the upper zone is a mix of sparce shub/tree and open/grassed areas.		
	C (76.3%)	**Confidence**	3.4

H5.3.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
C	Change to species composition.	Exotic vegetation high in the marginal zone (mainly non-woody aquatics).	NF	4
	Reduced vegetation cover in upper zone.	Clearing for recreation on RB.		
	Expansion of marginal zone reeds.	As channel narrows due to reduced flows.	F	

H5.3.3 Profile

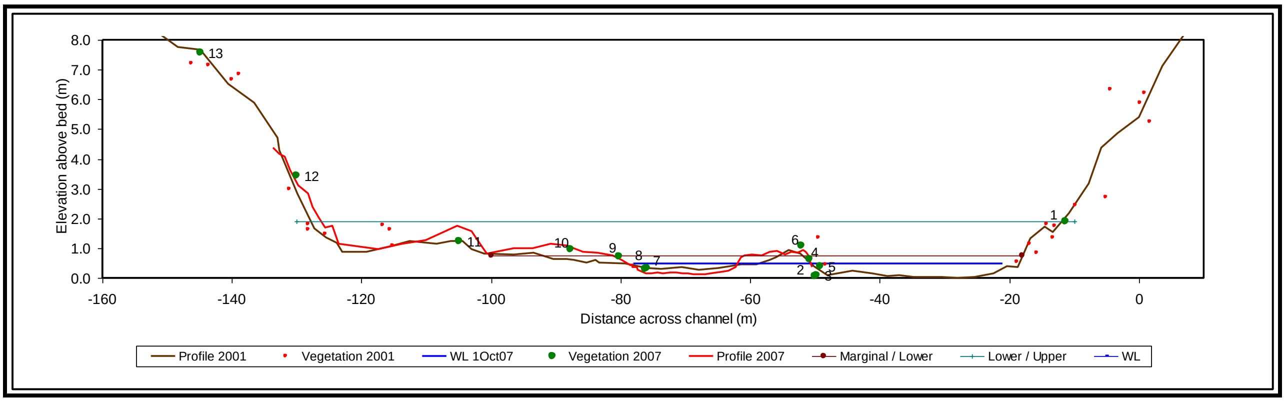

Figure H5 EWR 5: Riparian vegetation survey points used to assess flow requirements

Key:

1: *Phragmites* (upper limit)
3: *Persecaria* (lower limit)
4: *Cyperus/Juncus* (upper limit)
5: *Cyperus/Juncus* (lower limit)
6: *Phragmites* (upper limit)
7: *Phragmites* (lower limit)
8: *Cynodon* (lower limit)
9: *Persecaria* (upper limit)
10: *Cynodon* (upper limit)
11: *Phragmites* (upper limit)
12: *Phragmites* (lower limit)
13: *Phragmites* (upper limit)

H5.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
C	Negative	C/D	10 -15 years	Exotic invasion is high (up to 20 - 40%) on the marginal zone, and if left unchecked will increase in proportion at the expense of indigenous riparian vegetation.	3

H5.5 REC: B

PES	REC	Comments	Conf
C	B	Improved low flows and more natural flow variability: Reduce reedbeds and sediment accumulation. Creates additional recruitment opportunities for woody vegetation and prevents terrestrial species colonization.	2.9

H5.6 AEC: D

PES	AEC	Comments	Conf
C	D	Reduction in base flows and small floods: Expansion of reedbeds and increased terrestrialization with reduced flood disturbance.	2.7

H6 EWR 6: NKONGOMA (CROCODILE RIVER)

H6.1 DATA AVAILABILITY

Data availability	Conf
Satellite images (Google earth) of the respective reach. Hydraulic cross-section (profile) at the site together with surveyed key vegetation points for setting flows. Aerial photos of site - 1939, 1963, 1977, 1997 Biomes of South Africa: Savanna (Rutherford & Westfall, 1986); Savanna (bushveld) (van Wyk & van Wyk, 1997) Savanna biome (Mucina & Rutherford, 2006). Bioregions of South Africa: Lowveld (SVI 7) (Mucina & Rutherford, 2006). Vegetation Type: Undifferentiated bushveld and woodland (van Wyk & van Wyk, 1997). Vegetation Units: Tshokwane-Hlane Basalt Lowveld (SVI 5), (Mucina & Rutherford, 2006). Principle region of plant diversity and Endemism: Maputaland-Pondoland Region (van Wyk & van Wyk, 1997). WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.*	4.5

H6.2 REFERENCE CONDITIONS

This site occurs in the Lowveld bioregion of the Savanna biome in the Tshokwane-Hlane Basalt Lowveld vegetation unit. Mixed vegetation is expected, but one predominated by woody vegetation on the lower and upper zones (although historically more open than closed canopy existed). The site is predominantly exposed bedrock, but is entering the gorge so alluvial deposits occur where *Phragmites mauritianus* is expected. Marginal zone species would typically be *Phragmites mauritianus*, with *Cyperus spp.* where open sand occurs. C. *erythrophyllum, Nuxia oppositifolia, F. sycomorus* and *Diospyros mespiliformisi* on the lower and upper zones, interspersed with shrubs (*Gymnosporia senegalensis* and *Grewia spp.*).

Confidence: 3.5

H6.3 PRESENT ECOLOGICAL STATE

H6.3.1 Site suitability

Site Suitability for the Assessment of Environmental Flows		
Habitat availability	**Rate**	**Motivation where applicable**
Presence/absence of the marginal zone.	1	Marginal zone fairly inundated, but present.
Proportion of marginal zone that is able to be sampled.	2	Only LB sampled by foot, RB not by access.
Channel morphology		
Channel bank stabilization.	0	Banks stable.
Channel manipulation.	0	None.
Profile distance too long to effectively conduct VEGRAI.	2	RB not sampled.
Vegetation		
Occurrence of obligate, marginal zone riparian species.	2	Obligate riparian species more than sufficient in marginal zone.
Occurrence of obligate, non-marginal zone riparian species.	2	Obligate riparian species more than sufficient in non-marginal zone.
Occurrence of species that are (regional) indicators of the riparian zone, or wetness.		Obligates present, so unrated.
Recent fire/s at site.	0	None.
Exotic species at the site.	1	Less than 10% overall.
Left and right-hand banks have riparian vegetation in similar condition.	1	Similar, LB high proportion of exposed bedrock.
Able to obtain sufficient survey points of indicator species for flow requirements.	2	> 8 points LB only.

Plant species easily identifiable i.e. leaves or flowers present at time of site visit.	0	Identification of indicators was possible.
Hydraulic control		
Unnatural up/downstream control affecting site.	0	No localized effect.
Overall Site Suitability Rating	**1.0**	
Suitability rating: 0 - Suite highly suitable 3 - Site unsuitable	1 - Site suitable 4 - Site extremely unsuitable	2 - Site moderately suitable 5 - Site not to be used

PES description	The site is fairly close to reference condition in structure and composition with the exception of low (<10%) impact of exotic vegetation. Reduced flows have however made significant changes to the marginal zone especially. Marginal zone reeds have expanded with reduced flows and *B. salicina* population shows a marked reduction to what is expected due to water stress.		
	C (76.6%)	**Confidence**	3.6

H6.3.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
C	Increased reed cover.	Reduced flows.	F	3.5
	Changes to species composition.	Exotic vegetation (<10%).	N	

H6.3.3 Profile

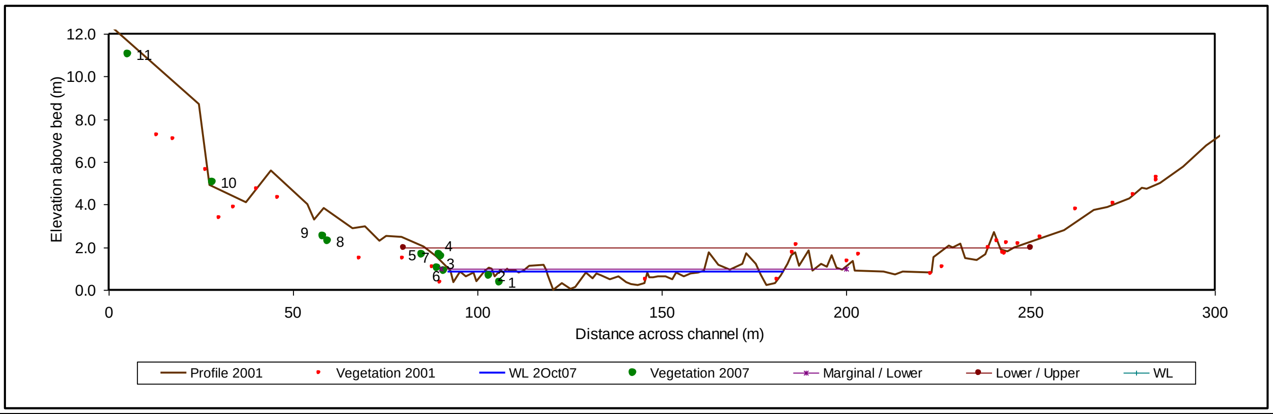

Figure H6 EWR 6: Riparian vegetation survey points used to assess flow requirements

Key:

1: *Phragmites/Ludwigia* (lower limit)
2: *C. marginata/Persecaria* (lower limit)
3: *Phragmites* (upper limit)
4: *Breonadia* (juv)
5: *Breonadia* (adult)/*Krausii*
6: *C. marginata* (upper limit)
7: *F. caprefolia* (lower limit)
8: *Phragmites* (upper limit)
9: *Flugea virrosa*
10: *D. mespiliformis*/*L. capassa* (lower limit)
11: *Schotia*/*Spirostachys*

H6.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
C	Negative	C/D	10 - 15 years	Exotic invasion low (up to 10%) on marginal zone mainly, and if left unchecked will increase in proportion at the expense of indigenous riparian vegetation.	3

H6.5 REC:B

PES	REC	Comments	Conf
C	B	Improve low flows and naturalise variability in flow. Improved recruitment opportunities for *Breonadia salicina* will increase woody cover and abundance. Increased inundation stress will also cause reeds to recede, but maintain vigour and density along the narrowed (but more natural) marginal zone.	3

H6.6 AEC: D

PES	AEC	Comments	Conf
C	D	Decrease low flows and increased zero flow periods will result in expansion of reedbeds (migration of marginal zone). Terrestrialisation of the riparian zone also likely to increase.	2.7

H7 EWR 7: HONEYBIRD (KAAP RIVER)

H7.1 DATA AVAILABILITY

Data availability	Conf
Satellite images (Google earth) of the respective reach. Hydraulic cross-section (profile) at the site together with surveyed key vegetation points for setting flows. Data collected from field assessment in 2007. Aerial photos of site - 1936, 1959, 1970, 1984, 1997. Biomes of South Africa: Savanna (Rutherford & Westfall, 1986); Savanna (bushveld) (van Wyk & van Wyk, 1997) Savanna biome (Mucina & Rutherford, 2006). Bioregions of South Africa: Lowveld (SVI 7) (Mucina & Rutherford, 2006). Vegetation Type: Undifferentiated bushveld and woodland (van Wyk & van Wyk, 1997). Vegetation Units: Granite Lowveld (SVI 3), (Mucina & Rutherford, 2006). Principle region of plant diversity and Endemism: Maputaland-Pondoland Region (van Wyk & van Wyk, 1997). WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.*	3.5

H7.2 REFERENCE CONDITIONS

This site occurs in the Lowveld bioregion of the Savanna biome in the Granite Lowveld vegetation unit. Mixed vegetation is expected with the marginal zone dominated by *B. salicina* where exposed bedrock occurs and *P. mauritianus* where alluvial deposits occur. Lower and upper zones are expected to be dominated by woody vegetation which includes *C. erythrophyllum, S. cordatum,* and *F. sycomorus* with mixed grass.

Confidence: 3.5

H7.3 PRESENT ECOLOGICAL STATE

H7.3.1 Site suitability

Site Suitability for the Assessment of Environmental Flows		
Habitat availability	**Rate**	**Motivation where applicable**
Presence/absence of the marginal zone.	1	Fair proportion of exposed, steep bedrock with no marginal zone.
Proportion of marginal zone that is able to be sampled.	0	Entire marginal zone sampled.
Channel morphology		
Channel bank stabilization.	0	Banks stable.
Channel manipulation.	1	Close proximity of road works and agricultural activities.
Profile distance too long to effectively conduct VEGRAI.	0	With difficulty due to density of exotic vegetation on LB.
Vegetation		
Occurrence of obligate, marginal zone riparian species.	2	Obligate riparian species more than sufficient in marginal zone.
Occurrence of obligate, non-marginal zone riparian species.	2	Obligate riparian species more than sufficient in non-marginal zone.
Occurrence of species that are (regional) indicators of the riparian zone, or wetness.		Obligates present, so unrated.
Recent fire/s at site.	0	None.
Exotic species at the site.	4	Up to 80% exotics on upper zone, less on lower and marginal zones, but still high proportions.
Left and right-hand banks have riparian vegetation in similar condition.	3	RB is seep zone with some wetland species, LB typically riparian, but with exotics.
Able to obtain sufficient survey points of indicator species for flow requirements.	3	RB up to 7 points, LB too dense to survey beyond marginal and lower part of lower zone.
Plant species easily identifiable i.e. leaves or flowers present at time of site visit.	0	Identification of indicators was possible.

Hydraulic control		
Unnatural up/downstream control affecting site.	0	Bedrock control interesting, but natural.
Other		
Please specify.	3	RB seep zone with wetland indicator species occurring.
Overall Site Suitability Rating	**1.4**	
Suitability rating: 0 - Suite highly suitable 1 - Site suitable 2 - Site moderately suitable 3 - Site unsuitable 4 - Site extremely unsuitable 5 - Site not to be used		

PES description	In the marginal zone it appears that *Breonadia* is "stranded" in bedrock areas due to reduced flow and water stress is high. Recruitment is absent. There is an extensive seep zone, especially the RB with typical wetland plants. The lower zone is predominantly a reed and grass mix with scattered woody individuals. Selective wood removal is apparent. The Upper zone is dominated by woody vegetation but agricultural and civil disturbance is high. The Lower and upper zone has high degree of exotic infestation, especially *Arunda spp.*		
	C/D (59.7%)	**Confidence**	3.1

H7.3.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
C/D	Reduced woody cover in marginal zone.	Reduced low flows.	F	4
	Changes to species composition.	High (60 - 80%) impact by exotic vegetation.	NF	
	Reduced woody cover.	Selected wood removal, agricultural and civil disturbance.		

H7.3.3 Profile

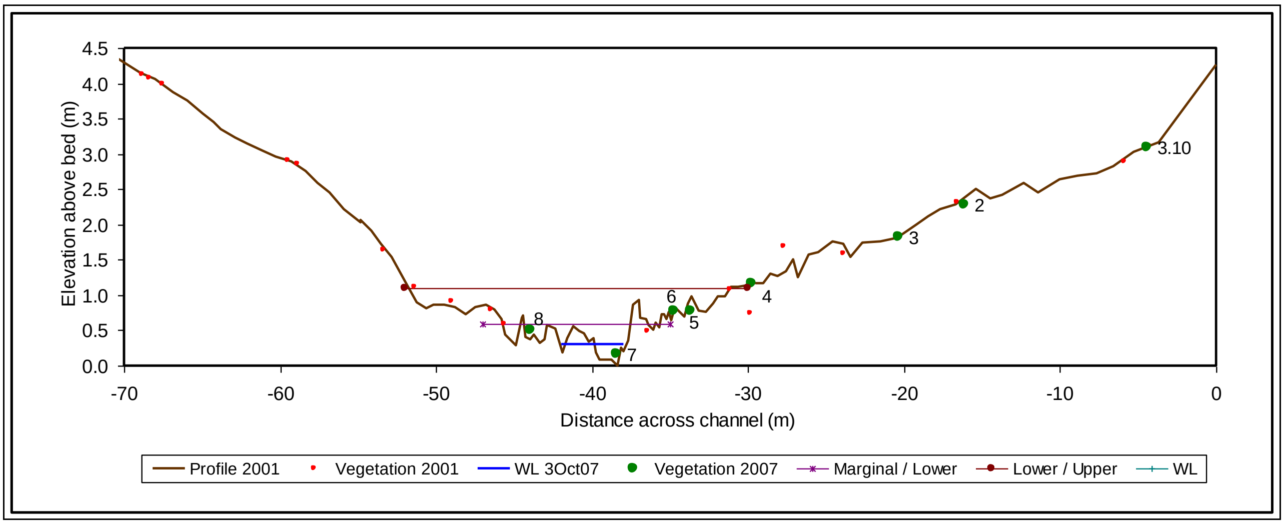

Figure H7 EWR 7: Riparian vegetation survey points used to assess flow requirements

Key:

1: Syzygium cordatum (adlt) (upper limit)
2: *A. robusta/F. sycomorus* (lower limit)
3: S. cordatum/F. Sycomorus (juvs)
4: *Ishaemum*
5: F. sycomorus/S. mucronata (lower limit/upper limit respectively)
6: Phragmites mauritianus (upper limit)
7: *Phragmites mauritianus* (lower limit)
8: *Phragmites mauritianus* (lower limit)

H7.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
C/D	Negative	D	5 years	Wood removal, earth works and roads have had high disturbance in upper and lower zone. The previous photographs of this site has shown a significant increase in exotics which will keep on increasing.	3

H7.5 REC: B

PES	REC	Comments	Conf
C/D	B/C	An improvement in the flow regime will lead to a C EC with increased *Breonadia salicina* cover and reduced *Phragmites mauritianus* cover. The removal of exotics will improve the EC to a B/C.	3

H7.6 AEC: D

PES	AEC	Comments	Conf
C/D	D	Extensive loss of woody riparian species will occur in the marginal and lower zones. Reeds are likely to reduce, depending on the severity of the scenario.	2.5

H8 EWR 1 UPPER SABIE (SABIE RIVER)

H8.1 DATA AVAILABILITY

Data availability	Conf
Satellite images (Google earth) of the respective reach. Hydraulic cross-section (profile) at the site together with surveyed key vegetation points for setting flows. Data collected from field assessment in 2007. Previous VEGRAI training site Aerial photos of site - 1944, 1956, 1965, 1997. Biomes of South Africa: Savanna (Rutherford & Westfall, 1986); Savanna (bushveld) (van Wyk & van Wyk, 1997) Savanna (Mucina & Rutherford, 2006). Bioregions of South AfricaLowveld (SVI 7) (Mucina & Rutherford, 2006). Vegetation Type: Undifferentiated bushveld and woodland (van Wyk & van Wyk, 1997). Vegetation Units: Legogote Sour Bushveld (SVI 9), (Mucina & Rutherford, 2006). Principle region of plant diversity and Endemism: Maputaland-Pondoland Region (van Wyk & van Wyk, 1997). WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.*	4

H8.2 REFERENCE CONDITIONS

Marginal zone:
Dominated by a mixture of reeds (*P. mauritianus*) and herbaceous vegetation (*Seteria megaphylla*, ferns, *Cyperus* and *Berulla* spp.; with the reed component in smaller proportions than herbs), but with fairly high influence from overhanging lower zone trees (*Sygium* spp. and *B. salicina*). Stable vegetated geomorphic features with minimal open areas exist.

Lower zone:
Tree and shrub dominated riparian vegetation is present, which is fairly dense with a high proportion of riparian obligates (*S. cordatum*, *C. erythrophyllum*, *Cliffortia* and *Euclea* spp.). High proportion of shading for both lower and marginal zones (overhang) exists.

Upper zone:
Tree and shrub dominated as with the lower zone, but with greater variability of species (no additional riparian obligates present though), and fairly dense (*Syzigium* sp., *C. erythrophyllum*, *Tremma orieltalis*, *Halleria lucida*, *Diospyros mespiliformis*, *Celtis africana*, *Euclea* spp.)

Confidence: 3.5

H8.3 PRESENT ECOLOGICAL STATE

H8.3.1 Site suitability

Site Suitability for the Assessment of Environmental Flows		
Habitat availability	**Rate**	**Motivation where applicable**
Presence/absence of the marginal zone.	1	Marginal completely present.
Proportion of marginal zone that is able to be sampled.	0	Entire marginal zone was sampled.
Channel morphology		
Channel bank stabilization.	0	Impact not observed along site.
Channel manipulation.	1	Slight manipulation towards bridge.
Profile distance too long to effectively conduct VEGRAI.	1	Entire profile assessed.
Vegetation		

Site Suitability for the Assessment of Environmental Flows		
Habitat availability	**Rate**	**Motivation where applicable**
Occurrence of obligate, marginal zone riparian species.	1	More than sufficient obligate riparian species in marginal zone.
Occurrence of obligate, non-marginal zone riparian species.	2	Sufficient obligate riparian species in non-marginal zone, although abundance affected by recent fire.
Occurrence of species that are (regional) indicators of the riparian zone, or wetness.		Obligates present, so unrated.
Recent fire/s at site.	4	Extensive recent fires on RB (which proportionally was a much larger bank than LB).
Exotic species at the site.	1	About 20% exotic overall.
Left and right-hand banks have riparian vegetation in similar condition.	2	Banks similar, but LB steep & short, RB long and gentle, therefore veg proportions are different.
Able to obtain sufficient survey points of indicator species for flow requirements.	1	6 points for each bank.
Plant species easily identifiable i.e. leaves or flowers present at time of site visit.	0	Despite fire, identification was not a problem.
Hydraulic control		
unnatural up/downstream control affecting site	1	site slightly affected by bridge supports downstream
Overall Site Suitability Rating	**1.2**	
Suitability rating: 0 - Suite highly suitable 3 - Site unsuitable	1 - Site suitable 4 - Site extremely unsuitable	2 - Site moderately suitable 5 - Site not to be used

PES description	Marginal zone: This zone is generally close to reference condition, although exotic species (>10% of the species composition) are present (*Ageratum* species mainly). *B. salicina* is present, but should be slightly better represented. The marginal zone is dominated by non-woody vegetation with high levels of overhanging and submerged vegetation. There is a low abundance of woody vegetation, which plays an important role in flood attenuation and overhang (shade and falling leaves) which is important for instream habitat. Lower zone: The vegetation type is generally as expected on the lower zone, but disturbance (non-flow related) is high (picnic areas, roads) with moderately high levels of vegetation removal. Exotic species also compose about 20% of vegetation (*Lantana camara*, and *Acacia mearnsii*). The lower zone is dominated by woody vegetation (shading) but non-woody vegetation is important for fish breeding sites during floods/higher flows. Upper zone: Similar to the lower zone, but fewer exotics are present. The upper zone is dominated by woody vegetation, but the non-woody understorey is important for bank stabilization.		
	B/C (80.1%)	**Confidence**	3.4

H8.3.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
B/C	Reduced riparian vegetation cover and abundance. Reduced recruitment which also skews population structure to "older" individuals.	Exotic species (up to 20% on lower zone), particularly *L. camara* and forest escapees utilize resource (light and space) that would otherwise be used by indigenous riparian species. Physical disturbance such as roads and vegetation removal for past picnic areas.	NF	3.3

H8.3.3 Profile

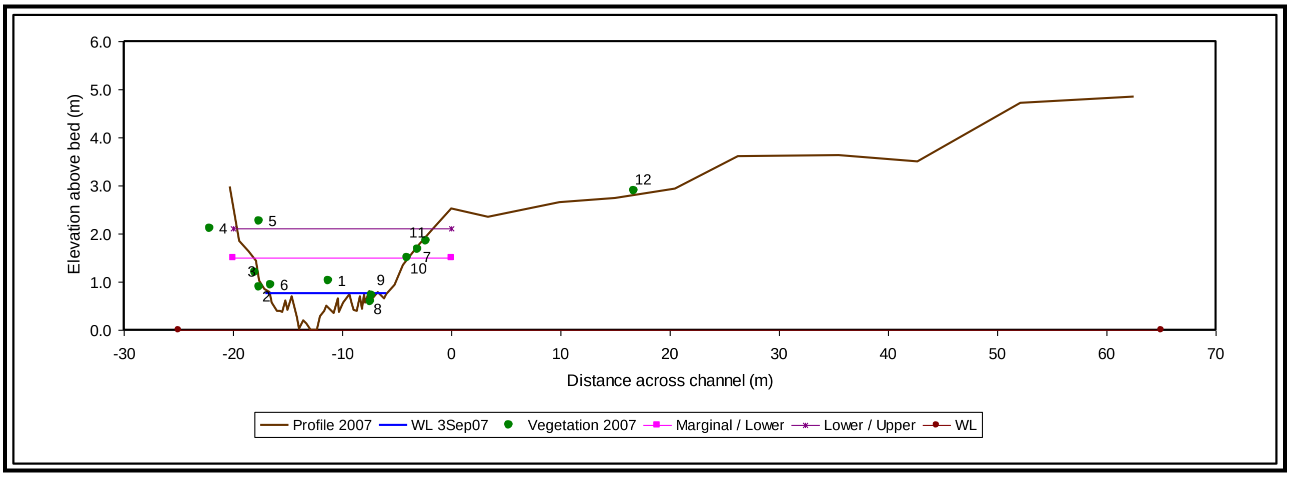

Figure H8 EWR 1: Riparian vegetation survey points used to assess flow requirements

Key:

1: *Ageratum* (lower limit)
2: Water level
3: *Ficus sur* (tree line) (lower limit)
4: Lower/Upper interface
5: *Ficus sur* recruitment
6: *Ficus sur* (root lower level) (lower limit)
7: *Tremma orientalis* (lower limit)
8: *Phragmites mauritianus* (rhizome) (lower limit)
9: *Phragmites mauritianus* (at water level) (lower limit)
10: fern species (upper limit)
11: *Syzygium cordatum* (lower limit)
12: *Combretum erythrophyllum* (terrace).

H8.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
B/C	Negative	C	5 - 10 years	Non-flow related impacts (combination of loss of recruitment and exotic invasion) likely to alter woody vegetation component for all vegetation metrics, non-woody vegetation response expected to be more stable.	2.5

H8.5 REC: B

PES	REC	Comments	Conf
B/C	B	An improved EC due to periodic removal of alien species and a cessation of picnic activities at the site.	3.3

H8.6 AEC: C/D

PES	AEC	Comments	Conf
B/C	C/D	Alien vegetation will increase substantially and the reduced flows and associated sedimentation on the channel floor will result in alluvial bars colonised by reedbeds.	2.5

H9 EWR 2: AAN DE VLIET (SABIE RIVER)

H9.1 DATA AVAILABILITY

Data availability	Conf
Historical aerial photography (1944, 1954, 1965, 1974, 1984, 1997). Satellite images (Google earth) of the respective reach. Hydraulic cross-section (profile) at the site together with surveyed key vegetation points for setting flows. Previous VEGRAI training site. Biomes of South Africa: Savanna (Rutherford & Westfall, 1986); Savanna (bushveld) (van Wyk & van Wyk, 1997) Savanna (Mucina & Rutherford, 2006). Bioregions of South Africa Lowveld (SVI 7) (Mucina & Rutherford, 2006). Vegetation Type: Undifferentiated bushveld and woodland (van Wyk & van Wyk, 1997). Vegetation Units: Pretoriuskop Sour Bushveld (SVI 10), (Mucina & Rutherford, 2006). Principle region of plant Diversity and Endemism: Maputaland-Pondoland Region (van Wyk & van Wyk, 1997). WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.*	4

H9.2 REFERENCE CONDITIONS

Marginal zone

Dominated by a mixture of reeds *(P. mauritianus*), herbaceous aquatics (ferns, *Cyperus, Persecaria* and *Ludwigia* sp.) and grasses (*Seteria megaphylla,* and *Cynodon dactylon*) (reeds in smaller proportions than herbs and grasses), with fairly high influence from overhanging lower zone trees (*Syzigium* sp and *B. salicina*). Small proportion of the marginal zone will be woody and shady (*B. salicina* and *Syzigium* spp.) mainly.

Lower zone

Tree and shrub dominated vegetation type, fairly dense and shady (*S. cordatum* and *guineense, C. erythrophyllum, F. sycomorus* mainly).

Upper zone

Also tree and shrub dominated, also fairly dense and shady (*Syzigium sp., C. erythrophyllum, T. orieltalis, D. mespiliformis, C. africana, Euclea* and *Anthocleista* species mainly).

Confidence: 3.5

H9.3 PRESENT ECOLOGICAL STATE

H9.3.1 Site suitability

Site Suitability for the Assessment of Environmental Flows		
Habitat availability	**Rate**	**Motivation where applicable**
Presence/absence of the marginal zone.	1	Marginal completely present.
Proportion of marginal zone that is able to be sampled.	0	Entire marginal zone was sampled.
Channel morphology		
Channel bank stabilization.	0	Less than 20% undercutting, and stabilized by roots.
Channel manipulation.	1	Slight, some dumping from recreational activities.
Profile distance too long to effectively conduct VEGRAI.	1	Entire profile assessed.
Vegetation		
Occurrence of obligate, marginal zone riparian species.	1	More than sufficient obligate riparian species in marginal zone.

Site Suitability for the Assessment of Environmental Flows		
Habitat availability	**Rate**	**Motivation where applicable**
Occurrence of obligate, non-marginal zone riparian species.	1	More than sufficient obligate riparian species in non-marginal zone, although structure affected by veg removal.
Occurrence of species that are (regional) indicators of the riparian zone, or wetness.		Obligates present, so unrated.
Recent fire/s at site.	1	Burns have occurred, but not recent.
Exotic species at the site.	1	About 20% or less exotic overall.
Left and right-hand banks have riparian vegetation in similar condition.	2	Banks similar, but LB steep & short, RB long and gentle, therefore veg proportions are different.
Able to obtain sufficient survey points of indicator species for flow requirements.	1	Min 6 points for each bank.
Plant species easily identifiable i.e. leaves or flowers present at time of site visit.	0	Despite fire, identification was not a problem.
Hydraulic control		
Unnatural up/downstream control affecting site.	0	Not observed.
Overall Site Suitability Rating	**0.8**	
Suitability rating: 0 - Suite highly suitable 3 - Site unsuitable	1 - Site suitable 4 - Site extremely unsuitable	2 - Site moderately suitable 5 - Site not to be used

PES description	Marginal zone: Is generally close to reference condition, with exotic species abundance 10 - 20% (*Ageratum* and *Nasturtium* mainly i.e. non-woody). *B. salicina* and *S. cordatum* is present and recruiting well in uncleared areas. The zone is dominated by non-woody vegetation with high levels of overhang and submerged vegetation. There is a low abundance of woody vegetation, which plays an important role in flood attenuation and overhang (shade and falling leaves) which is important for instream habitat. Lower zone: The vegetation type on the lower zone is generally as expected, but disturbance (non-flow related) is high (picnic areas, roads, resort activities) with high levels of vegetation removal including regular mowing. Exotic species also compose about 20% of the vegetation *(L. camara, A. mearnsii, Psidium guava, Ageratum, Canna,* and *Tichonia* spp.). The lower zone is dominated by woody vegetation (shading) but non-woody vegetation dominates a high proportion of the zone due to clearing of woody species. Upper zone: Similar to the lower zone, but with fewer exotics present. The upper zone is dominated by woody vegetation, but the non-woody understorey is important for bank stabilization. Non-woody vegetation dominates in areas that are regularly cleared/mowed.		
	C (74.3%)	**Confidence**	3.2

H9.3.2 PES causes ans sources

PES	Causes	Sources	F/NF	Conf
C	Reduced riparian vegetation cover and abundance. Reduced recruitment which also skews population structure to "older" individuals.	Presents of exotic species in the marginal and lower zone (agricultural and forestry escapees mainly). Resort activities especially on RB, and mowing.	NF	3.3

H9.3.3 Profile

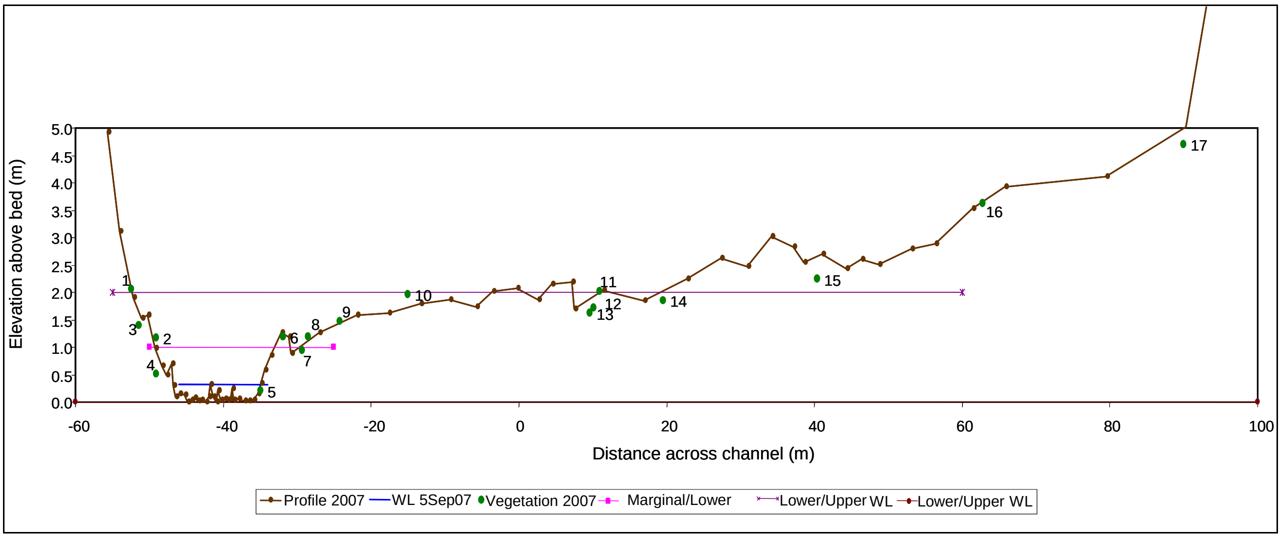

Figure H9 EWR 2: Riparian vegetation survey points used to assess flow requirements

Key:

1: *Breonadia salicina* (upper limit)
2: *Breonadia salicina* (lower limit)
3: *Anthocleista* & *Breonadia* (recruitment)
4; *Breonadia salicina* (lower limit)
5: *Phragmites mauritianus* (lower limit)
6: *Phragmites mauritianus* (upper limit)
7: *Syzygium* (recruitment)
8: *Breonadia salicina* (lower limit)
9: *Syzygium cordatum* (lower limit)
10: *Syzygium cordatum/Breonadia salicina/Anthocleista* (upper limit)
11: *Cyperus dives* (upper limit)
12: *Cyperus dives* (lower limit)
13: *Berulla* (lower limit)
14: *Typha capensis* (water level (wl))
15: *Cyperus/Phragmites mauritianus* (back channel)
16: *Anthocleista/Cyperus hexamita/S. cordatum/Ficus sur* (upper/lower/recruitment)
17: *Ficus sycomorus* (lower limit).

H9.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
C	Negative	C/D	5 - 10 years	Response due to clearing/mowing is stable since activities will not increase nor decrease, but exotics, if left unchecked will increase in proportion at the expense of indigenous riparian vegetation. Confidence is low since alien clearing activities are unknown.	2

H9.5 REC: B

PES	REC	Comments	Conf
C	B	To improve the EC, exotic vegetation must be selectively removed on the lower and upper zones. Current exotics on the marginal site are non-woody and therefore difficult to control. Vegetation removal and mowing within the riparian zone and recreational activities should be reduced in intensity but importantly also in extent i.e. areas within the riparian zone, especially on the floodplain.	2.8

H9.6 AEC: C/D

PES	AEC	Comments	Conf
C	D	Alien vegetation will increase substantially, with associated reductions in indigenous riparian species cover, abundance and recruitment. With less recruitment, over time populations will become skewed toward older individuals and proportions of species in the assemblage will change	3.1

PES	AEC	Comments	Conf
		and expected species will be less well represented.	

H10 EWR 3 KIDNEY (SABIE RIVER)

H10.1 DATA AVAILABILITY

Data availability	Conf
Satellite images (Google earth) of the respective reach. Hydraulic cross-section (profile) at the site together with surveyed key vegetation points for setting flows. Data collected from field assessment in 2007. Aerial photos of site - 1956, 1964, 1970, 1997. 1996 IFR site information (Godfrey, 2002). Biomes of South Africa: Savanna (Rutherford & Westfall, 1986); Savanna (bushveld) (van Wyk & van Wyk, 1997) Savanna (Mucina & Rutherford, 2006). Bioregions of South Africa: Lowveld (SVI 7) (Mucina & Rutherford, 2006). Vegetation Type: Undifferentiated bushveld and woodland (van Wyk & van Wyk, 1997). Vegetation Units: Gabbro Grassy Bushveld (SVI 6), (Mucina & Rutherford, 2006). Maputaland-Pondoland principle region of plant diversity (van Wyk & van Wyk, 1997). WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.* Numerous postgraduate studies on the Sabie especially inside KNP.	5

H10.2 REFERENCE CONDITIONS

Marginal zone

Sections that are characterised by unconsolidated alluvia will tend to be dominated by reedbeds (*P. mauritianus*), while sections characterised by cobble/boulder or exposed bedrock will tend to be dominated by grasses (*C. dactylon*) and herbaceous aquatics (*Cyperus* sp, *Persecaria* sp, *Ludwigia* sp). A small proportion of the marginal zone will be woody (*Breonadia* and *Syzigium* spp. mainly).

Lower zone

Mix of tree and shrub dominated vegetation (*B. salicina, S. cordatum* and *guineense, and Nuxia oppositifolia* mainly) where substrates tend to be more rocky or consolidated. Reeds/open sand (*P. mauritianus*) occurs where substrates tend to be unconsolidated.

Upper zone

Tree and shrub dominated mainly (*C. erythrophyllum, F. sycomorus,* and *D. mespiliformis* with some *Spirostachys africana* expected in localised pockets*).*

Confidence: 4

H10.3 PRESENT ECOLOGICAL STATE

H10.3.1 Site suitability

Site Suitability for the Assessment of Environmental Flows		
Habitat availability	**Rate**	**Motivation where applicable**
Presence/absence of the marginal zone.	0	Marginal completely present.
Proportion of marginal zone that is able to be sampled.	0	Entire marginal zone was sampled.
Channel morphology		
Channel bank stabilization.	0	Some (natural) undercutting, but stabilized by roots.
Channel manipulation.	0	None.
Profile distance too long to effectively conduct VEGRAI.	1	Entire profile assessed.
Vegetation		

Site Suitability for the Assessment of Environmental Flows		
Habitat availability	**Rate**	**Motivation where applicable**
Occurrence of obligate, marginal zone riparian species.	0	Obligate riparian species abundant in marginal zone.
Occurrence of obligate, non-marginal zone riparian species.	0	Obligate riparian species abundant in non-marginal zone.
Occurrence of species that are (regional) indicators of the riparian zone, or wetness.		Obligates present, so unrated.
Recent fire/s at site.	0	None.
Exotic species at the site.	1	< 10% exotic overall.
Left and right-hand banks have riparian vegetation in similar condition.	1	Similar banks into vegetation.
Able to obtain sufficient survey points of indicator species for flow requirements.	0	More than 8 points per bank and other critical areas.
Plant species easily identifiable i.e. leaves or flowers present at time of site visit.	0	Identification was not a problem.
Hydraulic control		
Unnatural up/downstream control affecting site.	0	None.
Overall Site Suitability Rating	**0.2**	
Suitability rating: 0 - Suite highly suitable 3 - Site unsuitable	1 - Site suitable 4 - Site extremely unsuitable	2 - Site moderately suitable 5 - Site not to be used

PES description	Marginal zone: The condition of this zone is close to reference condition, with exotic species present at <10% (*Ageratum* mainly i.e. non-woody). Some vegetation has been removed as a result of the small unnatural component of flooding during 2000. This zone is dominated by a non-woody component that includes a mix of reedbeds and grass/herb areas. Lower zone: Vegetation is close to expected, with < 10% exotic invasion that consists of woody (*Lantana* and *Sesbania* spp. mainly) and non-woody (*Ageratum* spp. and mexican sunflower mainly) components. The lower zone is dominated by both woody (trees) and non-woody (reeds) vegetation patches. Upper zone: The upper zone is similar to the lower zone, also with < 10% exotic invasion that consists of woody (*Lantana* and *Sesbania* spp. mainly, and some *Melia* spp.) and non-woody (*Ageratum* spp. and mexican sunflower mainly) components. The upper zone is dominated by woody vegetation, which is on the increase, a natural trajectory for this site following the large flooding disturbance during 2000.		
	A/B (89.3%)	**Confidence**	4

H10.3.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
A/B	Reduced riparian vegetation cover and abundance.	Exotic vegetation.	NF	3.5
		Small unnatural component of 2000 floods due to increased velocity volume from cleared upstream areas.	F	

H10.3.3 Profile

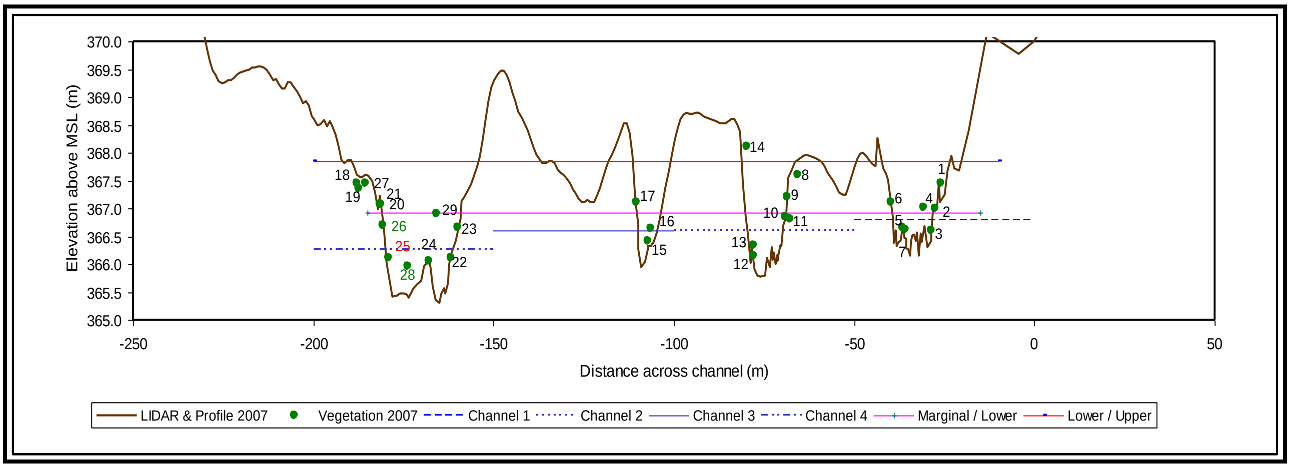

Figure H10 EWR 3: Riparian vegetation survey points used to assess flow requirements

Key:

1: *S. cordatum* (juv) (upper limit)
2: *B. salicina* (juv)/*Ludwigia* (upper limit)
3: water level
4: *B. salicina* (sub adult)/*Cyperus* (upper limit)
5: *Persecaria* (lower limit)
6: *N. oppositifolia* (lower limit)
7: *P. mauritianus* (lower limit)
8: *N. oppositifolia* (adult) (upper limit)
9: *N. oppositifolia* (adult) (lower limit)
10: *B. salicina* (lower limit)
11: *S. guineense* (lower limit)
12: *P. mauritianus* (lower limit)
13: water level
14: *P. mauritianus* (upper limit)
15: *Ludwigia* (lower limit)
16: *Schoenoplectus* (upper limit)
17: *C. dives* (upper limit)
18: *Cyperus dives* (upper limit)
19: *Ludwigia* (upper limit)
20: *Schoenoplectus* (lower limit)
21: *Cyperus dives* (lower limit)
22: *Ludwigia* (lower limit)
23: *Cyperus dives* (upper limit)
24: *Persecaria* (upper limit)
25: *B. salicina* (lower limit)
26: *P. mauritianus* (upper limit)
27: *N. oppositifolia* (lower limit)
28: *P. mauritianus* (lower limit)
29: *Cyperus dives/C. hexangularis/Syzygium* recruits (upper limit).

H10.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
A/B	Stable	A/B		Exotics, if left unchecked would increase in proportion at the expense of indigenous riparian vegetation, but the actions of Working for Water inside KNP appear to be ongoing and frequent enough to stabilise the site. Stability does however, depend on the continued action of Working for Water.	2.5

H10.5 AEC: B/C

PES	AEC	Comments	Conf
A/B	B/C	Alien vegetation will increase unabated. This will result in slightly reduced woody cover and abundance and a subsequent change in species composition. Increased sedimentation and the loss of bedrock habitat which will result in a loss of *Breonadia* recruitment and a subsequent change in population structure. Sedimentation will also facilitate reed colonisation and expansion (especially of the marginal zone), and an increase in cover and abundance on the lower zone.	3

H11 EWR 4 MAC MAC (MAC MAC RIVER)

H11.1 DATA AVAILABILITY

Data availability	Conf
Satellite images (Google earth) of the respective reach. Hydraulic cross-section (profile) at the site together with surveyed key vegetation points for setting flows. Data collected from field assessment in 2007. Aerial photos of site - 1944, 1954, 1965, 1974, 1984, 1996. Biomes of South Africa: Savanna (Rutherford & Westfall, 1986); Savanna (bushveld) (van Wyk & van Wyk, 1997) Savanna (Mucina & Rutherford, 2006). Bioregions of South Africa: Lowveld (SVI 7) (Mucina & Rutherford, 2006). Vegetation Type: Undifferentiated bushveld and woodland (van Wyk & van Wyk, 1997). Vegetation Units: Legogote Sour Bushveld (SVI 9), (Mucina & Rutherford, 2006). Principle region of plant diversity and Endemism: Maputaland-Pondoland Region (van Wyk & van Wyk, 1997). WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.*	4

H11.2 REFERENCE CONDITIONS

Marginal zone

This section of the river occurs in hilly, steep sided area. The marginal zone will therefore tend to be dominated by a mix of open rocky/cobble/boulder areas and non-woody vegetation (grasses such as *Setaria sphacelata*, and herbaceous aquatics such as *Cyperus*, *Schoenoplectus*, and *Juncus* spp.). A small proportion of the marginal zone will be woody (*Breonadia* and *Syzigium* spp. mainly), but the marginal zone will be largely shady due to extensive overhang from lower zone woody vegetation. Water will therefore have lower temperatures and high amounts of leaf litter.

Lower zone

Mix of tree and shrub dominated vegetation (*B. salicina, S. cordatum, C. africana, Anthocleista* spp. mainly) typical of kloof areas, and open exposed bedrock areas.

Upper zone

Typical kloof vegetation, tree and shrub dominated mainly *C. africana, Anthocleista, Ficus sp., Erythrina,* and *Bequaertiodendron* spp.

Confidence: 3.5

H11.3 PRESENT ECOLOGICAL STATE

H11.3.1 Site suitability

Site Suitability for the Assessment of Environmental Flows		
Habitat availability	**Rate**	**Motivation where applicable**
Presence/absence of the marginal zone.	0	Marginal completely present.
Proportion of marginal zone that is able to be sampled.	0	Entire marginal zone was sampled.
Channel morphology		
Channel bank stabilization.	0	Some (natural) undercutting, but stabilized by roots.
Channel manipulation.	1	Effects of downstream low-level bridge minimal.
Profile distance too long to effectively conduct VEGRAI.	1	Entire profile assessed.
Vegetation		
Occurrence of obligate, marginal zone riparian species.	1	Obligate riparian species more than sufficient in marginal zone.

Occurrence of obligate, non-marginal zone riparian species.	0	Obligate riparian species abundant in non-marginal zone.
Occurrence of species that are (regional) indicators of the riparian zone, or wetness.		Obligates present, so unrated.
Recent fire/s at site.	0	None.
Exotic species at the site.	1	< 10% exotic overall.
Left and right-hand banks have riparian vegetation in similar condition.	1	Similar banks into vegetation.
Able to obtain sufficient survey points of indicator species for flow requirements.	2	LB only 3 points due to short length, RB > 8 points.
Plant species easily identifiable i.e. leaves or flowers present at time of site visit.	0	Identification was not a problem.
Hydraulic control		
Unnatural up/downstream control affecting site.	1	Effects of downstream low-level bridge slight.
Overall Site Suitability Rating	**0.6**	
Suitability rating: 0 - Suite highly suitable 1 - Site suitable 2 - Site moderately suitable 3 - Site unsuitable 4 - Site extremely unsuitable 5 - Site not to be used		

PES description	Marginal zone: This zone is close to reference condition, with exotic species invasion at < 10% (small impact). Some vegetation has been removed as a result of picnic and road activities in area, but this is a small impact. Some root exposure and undercutting is evident and may be from extended lower low flows. The marginal zone is dominated by non-woody vegetation. Lower zone: This zone is close to expected, with < 10% exotic infestation (*Senna* spp. mainly). Some vegetation removal due to picnic and road activities downstream at site has occurred, as well as some targeted removal of large woodies - presumably Working For Water activity (WFW). The Lower zone is dominated by both woody (trees) and open area (exposed bedrock) patches. Upper zone: Is similar to the Lower zone, also with < 10% exotic woody species invasion (*Lantana*, *Senna* and *Ceasalpinea* spp. mainly). Some vegetation removal due to picnic and road activities downstream of site has occurred, as well as some targeted removal of large woodies - presumably WFW activity. The Upper zone is dominated by woody vegetation. Interestingly several extremely large *B. salicina* specimens occur on the upper zone and may indicate much wetter and wider active channel in the last 100 years.		
	A/B (89.9%)	**Confidence**	3.9

H11.3.2 PES causes and sources

PES	CAUSES	SOURCES	F/NF	Conf[3]
A/B	Reduced riparian vegetation cover and abundance (minimal impact).	< 10% exotics on all zones.	NF	3.5
		Some root exposure and undercutting may be from extended lower low flows.	F	

H11.3.3 Profile

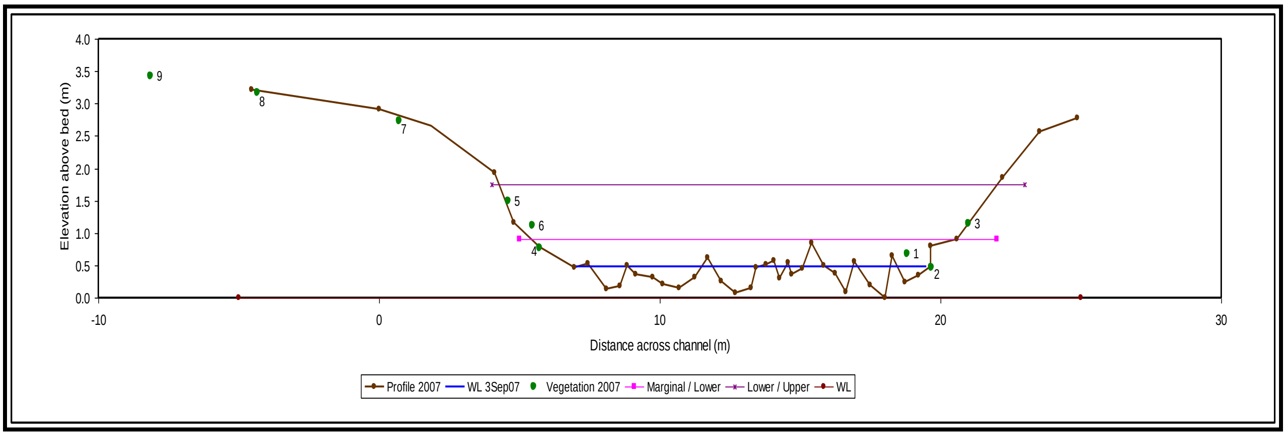

Figure H11 EWR 4: Riparian vegetation survey points used to assess flow requirements

Keys:

1: *B. salicina* recruitment (lower limit)
2: Water level
3: *B. salicina* (adult level)
4: *C. dives/S. cordatum* recruitment
5: *F. sur* (lower limit)
6: *B. salicina* adults (lower limit)
7: *B. magalismontana* (lower limit)
8: *C. africana* adult (adult level)
9: *B. salicina* adults (old channel) (adult level).

H11.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
A/B	Negative	B	10 -15 years	Exotics, if left unchecked will increase in proportion at the expense of indigenous riparian vegetation.	3

H11.5 AEC: C

PES	AEC	Comments	Conf
A/B	B/C	Aliens will increase to around 30 - 40% on all zones, especially forestry escapees and *Lantana*. Additional aliens will mean less available resource (water, light, space and nutrients) for the recruitment and survival of indigenous riparian species (both woody and non-woody). Subsequently cover and abundance will reduce, and populations will become biased toward older individuals. Species composition will also change more from reference condition since proportions of indigenous species will reduce or vanish.	2.9

H12 EWR 5 MARITE (MARITE RIVER)

H12.1 DATA AVAILABILITY

Data availability	Conf
Satellite images (Google earth) of the respective reach. Hydraulic cross-section (profile) at the site together with surveyed key vegetation points for setting flows. Data collected from field assessment in 2007. Previous VEGRAI training site Aerial photos of site - 1944, 1954, 1965, 1974, 1984, 1997. Previous IFR studies. Biomes of South Africa: Savanna (Rutherford & Westfall, 1986); Savanna (bushveld) (van Wyk & van Wyk, 1997) Savanna (Mucina & Rutherford, 2006). Bioregions of South Africa Lowveld (SVI 7) (Mucina & Rutherford, 2006). Vegetation Type: Undifferentiated bushveld and woodland (van Wyk & van Wyk, 1997). Vegetation Units: Pretoriuskop Sour Bushveld (SVI 10), (Mucina & Rutherford, 2006). Principle region of plant Diversity and Endemism: Maputaland-Pondoland Region (van Wyk & van Wyk, 1997). WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.*	4

H12.2 REFERENCE CONDITIONS

Marginal zone

Sections that are characterised by unconsolidated alluvia will tend to be dominated by reedbeds (*P. mauritianus*), while sections characterised by cobble/boulder or exposed bedrock will tend to be dominated by woody vegetation (*Breonadia* and *Syzigium* mainly), although open sandy and rocky areas are frequent within these vegetation types.

Lower zone

A mix of tree and shrub dominated vegetation (*B. salicina*, *S. cordatum* and *guineense*, *Nuxia oppositifolia* and *C. erythrophyllum* mainly) is present where substrates tend to be more rocky or consolidated and reeds/open sand is present (*P. mauritianus*) where substrates tend to be unconsolidated.

Upper zone

Tree and shrub dominate mainly (*C. erythrophyllum*, *F. sycomorus*, *D. mespiliformis*) with some *Spirostachys africana* expected in localised pockets. Some *B. salicina* expected where fragmented exposed bedrock occurs.

Confidence: 3.7

H12.3 PRESENT ECOLOGICAL STATE

H12.3.1 Site suitability

Site Suitability for the Assessment of Environmental Flows		
Habitat availability	**Rate**	**Motivation where applicable**
Presence/absence of the marginal zone.	1	Marginal completely present.
Proportion of marginal zone that is able to be sampled.	0	Entire marginal zone was sampled.
Channel morphology		
Channel bank stabilization.	1	Some undercutting, but predominantly natural and stabilized by roots.
Channel manipulation.	0	Channel banks (marginal zone) unmanipulated.
Profile distance too long to effectively conduct VEGRAI.	0	Entire profile assessed.

Site Suitability for the Assessment of Environmental Flows		
Habitat availability	**Rate**	**Motivation where applicable**
Vegetation		
Occurrence of obligate, marginal zone riparian species.	1	More than sufficient obligate riparian species in marginal zone.
Occurrence of obligate, non-marginal zone riparian species.	1	More than sufficient obligate riparian species in non-marginal zone.
Occurrence of species that are (regional) indicators of the riparian zone, or wetness.		Obligates present, so unrated.
Recent fire/s at site.	2	Approx 30% of Site (RB) recently burnt.
Exotic species at the site.	1	< 20% throughout, but > 0%.
Left and right-hand banks have riparian vegetation in similar condition.	0	Banks similar, not different in vegetation type.
Able to obtain sufficient survey points of indicator species for flow requirements.	2	Only 3 on RB, but sufficient for bank morphology.
Plant species easily identifiable i.e. leaves or flowers present at time of site visit.	0	Despite fire, identification was not a problem.
Hydraulic control		
Unnatural up/downstream control affecting site.	0	Site not affected by unnatural hydrualic controls.
Overall Site Suitability Rating	**0.7**	
Suitability rating: 0 - Suite highly suitable 3 - Site unsuitable	1 - Site suitable 4 - Site extremely unsuitable	2 - Site moderately suitable 5 - Site not to be used

PES description	Marginal zone: The marginal zone is close to reference condition, with exotic species present at less than 10%. Some vegetation has been removed as a result of livestock accessing the river and footpaths have been cut. Root exposure and undercutting may be from extended lower low flows. The marginal zone is dominated by patches of reedbeds, grassed areas and tree clumps (*Breonadia* and *Syzigium* spp.). Lower zone: Vegetation in this zone is close to expected, although there is a presence of 10 - 20% woody exotics (*Lantana, Caesalpinea, Sesbania, Psidium,* and *Senna* spp. mainly). Vegetation removal is mainly due to grazing and trampling from livestock, selected wood removal, cutting of footpaths, and recent fires. The lower zone is dominated by both woody (trees) and open area (exposed bedrock) patches. Upper Zone: Similar to the lower zone, with less then 10% woody exotic species present (*Lantana, Caesalpinea, Sesbania, Psidium,* and *Senna* spp. mainly). Vegetation removal is mainly due to grazing and trampling from livestock, selected wood removal, cutting of footpaths, and recent fires. The upper zone is dominated by woody vegetation.		
	B/C (80.4%)	**Confidence**	4

H12.3.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
B/C	Reduced riparian vegetation cover and abundance (minimal impact)	10 - 20% presence of exotic species in all vegetation zones Some vegetation removal due to grazing and trampling from livestock, selected wood removal, cutting of footpaths, and recent fires.	NF	3.7
	Expansion of marginal zone by reed colonization of sand bars over time	Increased low flows (reduced variability) due to releases from Inyaka Dam.	F	

H12.3.3 Profile

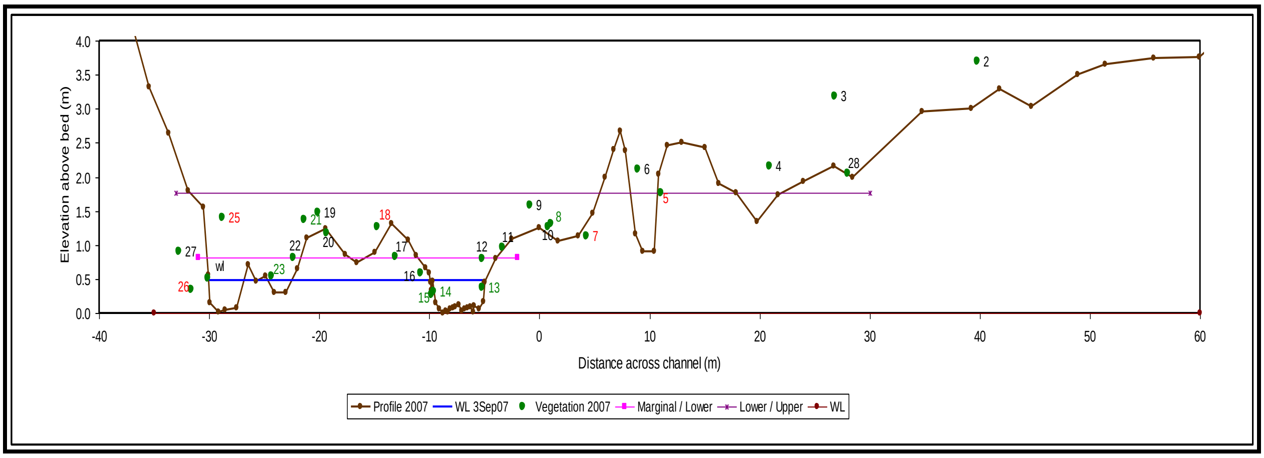

Figure H12 EWR 5: Riparian vegetation survey points used to assess flow requirements

Key:

1: *D. mespiliformis* adult tree line (lower limit) 2: *Terminalia sericea* (adults)
3: *C. erythrophyllum* 4: *N. oppositifolia*
5: *B. salicina* (upper limit) 6: *S. cordatum* (upper limit)
7: *B. salicina/S. cordatum* (upper limit) 8: *P. mauritianus* (upper limit)
9: *Setaria & Ishaemum* (upper limit) 10: *Cyperus dives* (upper limit)
11: *Syzygium* recruits 12: *Ludwigia* (upper limit)
13: *P. mauritianus* (lower limit) 14: *P. mauritianus* (lower limit)
15: *P. mauritianus* (lower limit) 16: *Setaria & Ishaemum* (lower limit)
17: *Syzygium* recruits (lower limit) 18: *B. salicina* adults (upper limit)
19: *Syzygium* recruits (upper limit) 20: *Syzygium* recruits (upper limit)
21: *P. mauritianus* (upper limit) 22: *Persecaria* (upper limit)
23: *P. mauritianus* (lower limit) 24: Water level
25: *B. salicina & N. oppositifolia* (upper limit) 26: *B. salicina* root zone (lower limit)
27: *Syzygium* recruits () 28: *S. cordatum* (upper limit).

H12.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
B/C	Negative	C/D	10 -15 years	Exotics, if left unchecked will increase in proportion at the expense of indigenous riparian vegetation.	3

H12.5 REC: B

PES	REC	Comments	Conf
B/C	B	Selective removal of exotic vegetation in the lower and upper zones will improve the EC. Current exotics present in the marginal zone are low or non-woody and therefore difficult to control. A reduction in vegetation removal, grazing and trampling will result in increased natural cover and abundance of woody and non-woody riparian vegetation.	3.3

H12.6 AEC: C/D

PES	AEC	Comments	Conf
B/C	C/D	The scenario will result in the reduction of indigenous riparian species cover, abundance and recruitment. With less recruitment, over time populations will become skewed toward older individuals and proportions of species in the assemblage will change and expected species will be less well represented.	2.7

H13 EWR 6: MUTLUMUVI (MUTLUMUVI RIVER)

H13.1 DATA AVAILABILITY

Data availability	Conf
Satellite images (Google earth) of the respective reach. Hydraulic cross-section (profile) at the site together with surveyed key vegetation points for setting flows. Data collected from field assessment in 2007. Aerial photos of site - 1954, 1965, 1974, 1984. 1996 IFR site information (Godfrey, 2002). Biomes of South Africa: Savanna (Rutherford & Westfall, 1986); Savanna (bushveld) (van Wyk & van Wyk, 1997) Savanna (Mucina & Rutherford, 2006). Bioregions of South Africa Lowveld (SVI 7) (Mucina & Rutherford, 2006). Vegetation Type: Undifferentiated bushveld and woodland (van Wyk & van Wyk, 1997). Vegetation Units: Granite Lowveld (SVI 3), (Mucina & Rutherford, 2006). Principle region of plant Diversity and Endemism: Maputaland-Pondoland Region (van Wyk & van Wyk, 1997). WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.*	4

H13.2 REFERENCE CONDITIONS

Marginal zone

Sections are characterised by unconsolidated alluvia will tend to be dominated by reedbeds (*P. mauritianus*), while sections characterised by cobble/boulder or exposed bedrock will tend to be dominated by woody vegetation (*Breonadia* and *Syzigium* spp. mainly).

Lower zone

Mix of tree and shrub dominated vegetation (*B. salicina*, *S. cordatum* and *S. guineense*, and *N. oppositifolia* mainly) where substrates tend to be more rocky or consolidated and reeds/open sand (*P. mauritianus*) where substrates tend to be unconsolidated.

Upper zone

Tree and shrub dominated with terrestrial grasses. High diverity of woody vegetation expected *(Lonchcarpus capassa*, *Ficus sycomorus* and *F. sur*, *Diospyros mespiliformis*, *Schotia brachypetala*) with some *Spirostachys africana* expected in localised pockets).

Confidence: 3.5

H13.3 PRESENT ECOLOGICAL STATE

H13.3.1 Site suitability

Site Suitability for the Assessment of Environmental Flows		
Habitat availability	**Rate**	**Motivation where applicable**
Presence/absence of the marginal zone.	0	Marginal completely present.
Proportion of marginal zone that is able to be sampled.	0	Entire marginal zone was sampled.
Channel morphology		
Channel bank stabilization.	0	No destabilization observed.
Channel manipulation.	0	None.
Profile distance too long to effectively conduct VEGRAI.	1	Entire profile assessed.
Vegetation		
Occurrence of obligate, marginal zone riparian species.	1	Obligate riparian species more than sufficient in marginal zone.

Site Suitability for the Assessment of Environmental Flows		
Habitat availability	**Rate**	**Motivation where applicable**
Occurrence of obligate, non-marginal zone riparian species.	1	Obligate riparian species more than sufficient in non-marginal zone.
Occurrence of species that are (regional) indicators of the riparian zone, or wetness.		Obligates present, so unrated.
Recent fire/s at site.	0	None.
Exotic species at the site.	1	< 20% exotic overall.
Left and right-hand banks have riparian vegetation in similar condition.	1	Similar banks into vegetation.
Able to obtain sufficient survey points of indicator species for flow requirements.	0	More than 8 points per bank and instream features.
Plant species easily identifiable i.e. leaves or flowers present at time of site visit.	0	Identification was not a problem.
Hydraulic control		
Unnatural up/downstream control affecting site.	0	None.
Overall Site Suitability Rating	**0.4**	
Suitability rating: 0 - Suite highly suitable 3 - Site unsuitable	1 - Site suitable 4 - Site extremely unsuitable	2 - Site moderately suitable 5 - Site not to be used

PES description	Marginal zone: Close to reference, but selected wood removal has reduced some of the tree species and therefore cover, abundance and recruitment has been reduced. Reeds have also expanded due to colonization of additional sediment. Lower zone: The zone has been invaded by 10 - 20%, woody exotics (*Lantana*, *Caesalpinea*, *Sesbania*, *Psidium*, and *Senna* spp. mainly). As with the marginal zone, selected wood removal has reduced some of the tree species and therefore cover, abundance and recruitment has been reduced. Reeds have also expanded due to colonization of additional sediment. Upper zone: Close to reference, but grazing and trampling has removed large proportions of understorey.		
	C (75.6%)	**Confidence**	3.8

H13.3.2 Reasons for PES

PES	Causes	Sources	F/NF	Conf
C	Reduced cover and abundance of indigenous riparian species.	High levels of alien species invasion (especially in lower and upper zones).	NF	5
	Changes to species composition and population structure of indigenous riparian species.	High levels of vegetation removal (grazing and trampling mainly) especially in lower and upper zones.		

H13.3.3 Profile

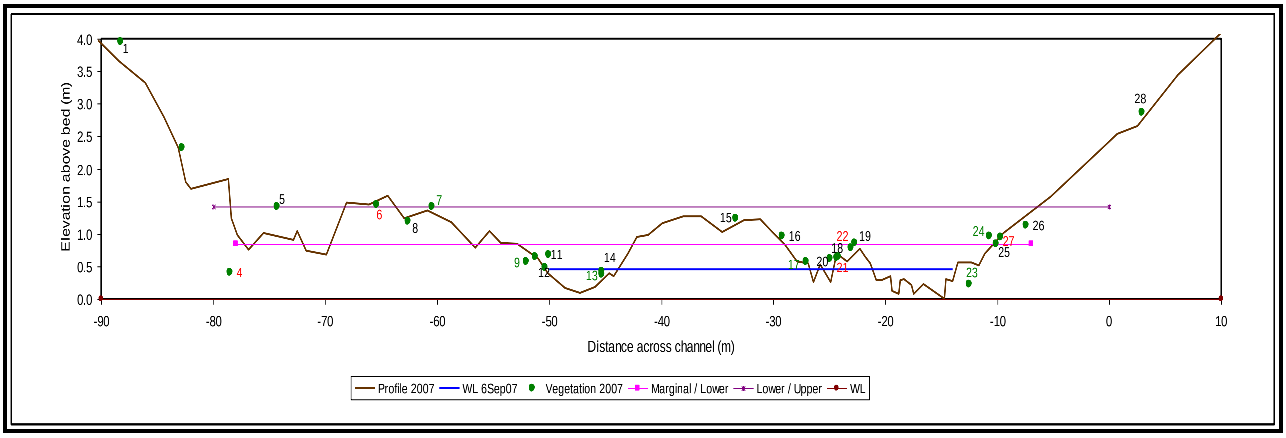

Figure H13 EWR 6: Riparian vegetation survey points used to assess flow requirements

Key:

1: *C. erythrophyllum* (Lower limit)
2: *D. mespiliformis/S. brachypetala* (Lower limit)
3: Terrace (Lower limit)
4: *B. salicina & S. cordatum* (Upper limit)
5: *S. cordatum* (Upper limit)
6: *B. salicina & Salix mucronata* (Upper limit)
7: *P. mauritianus* (Upper limit)
8: *C. dives* (Upper limit)
9: *P. mauritianus* (Lower limit)
11: *Setaria* (Upper limit)
12: *Setaria* (Lower limit)
13: *P. mauritianus* (Lower limit)
14: *S. mucronata* (Lower limit)
15: *Myrica serrata* (Upper limit)
16: *Myrica serrata* (Lower limit)
17: *P. mauritianus/Setaria* (Lower limit)
18: *Cyperus* (Lower limit)
19: *Cyperus* (Upper limit)
20: *S. mucronata* (Lower limit)
21: *B. salicina* (Lower limit)
22: *B. salicina* recruits
23: *P. mauritianus* roots (Lower limit)
24: *P. mauritianus* (Upper limit)
25: *C. dives* (Upper limit)
26: *D. mespiliformis* (Upper limit)
27: *B. salicina* recruits (Upper limit)
28: *D. mespiliformis* (Upper limit).

H13.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
C	Negative	D	10 years	Exotics, if left unchecked will increase in proportion at the expense of indigenous riparian vegetation. Grazing and trampling from livestock, wood removal (selected *Breonadia* spp., *Ficus sur, Erythrina,* and *Sprirostachys* spp.) and cutting of footpaths has high impact.	3

H13.5 REC: B

PES	REC	Comments	Conf
C	B	No change to the marginal zone. On the lower and upper zones a reduction in exotic vegetation together with marked reduction in selected wood removal was used to improve EC.	3.2

H13.6 AEC: C/D

PES	AEC	Comments	Conf
C	D	Increase selected wood removal of large trees (Breonadia mainly) from the marginal zone, as well as trampling in marginal zone. Increase grazing of lower and upper zone non-woody species as well as proportion of exotics in these zones.	2.5

H14 EWR 7 TLULANDZITEKA (TLULANDZITEKA RIVER)

H14.1 DATA AVAILABILITY

Data availability	Conf
Satellite images (Google earth) of the respective reach. Hydraulic cross-section (profile) at the site together with surveyed key vegetation points for setting flows. Data collected from field assessment in 2007. Aerial photos of site - 1944, 1965, 1974, 1997. Biomes of South Africa: Savanna (Rutherford & Westfall, 1986); Savanna (bushveld) (van Wyk & van Wyk, 1997) Savanna (Mucina & Rutherford, 2006). Bioregions of South Africa Lowveld (SVI 7) (Mucina & Rutherford, 2006). Vegetation Type: Undifferentiated bushveld and woodland (van Wyk & van Wyk, 1997). Vegetation Units: Granite Lowveld (SVI 3), (Mucina & Rutherford, 2006). Principle region of plant Diversity and Endemism: Maputaland-Pondoland Region (van Wyk & van Wyk, 1997). WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.*	2

H14.2 REFERENCE CONDITIONS

Marginal zone

Sections that are characterised by unconsolidated alluvia will tend to be dominated by reedbeds (*P. mauritianus*), while sections characterised by cobble/boulder or exposed bedrock will tend to be dominated by woody vegetation (*Breonadia* and *Syzigium* spp. mainly).

Lower zone

Mix of tree and shrub dominated vegetation (*B. salicina*, *S. cordatum* and *S. guineense*, and *N. oppositifolia* mainly) where substrates tend to be more rocky or consolidated and reeds/open sand (*P. mauritianus*) where substrates tend to be unconsolidated.

Upper zone

Tree and shrub dominated with terrestrial grasses. High diversity of woody vegetation expected. *(Lonchcarpus capassa, F. sycomorus* and *F. sur, Diospyros mespiliformis, Schotia brachypetala* with some *Spirostachys africana* expected in localised pockets*).*

Confidence: 3.5

H14.3 PRESENT ECOLOGICAL STATE

H14.3.1 Site suitability

Site Suitability for the Assessment of Environmental Flows		
Habitat availability	**Rate**	**Motivation where applicable**
Presence/absence of the marginal zone.	1	Marginal completely present, some deposition near bridge.
Proportion of marginal zone that is able to be sampled.	0	Entire marginal zone was sampled.
Channel morphology		
Channel bank stabilization.	0	Bank erosion observed, but minimal.
Channel manipulation.	1	Unmanipulated.
Profile distance too long to effectively conduct VEGRAI.	1	Entire profile assessed.
Vegetation		
Occurrence of obligate, marginal zone riparian species.	2	Obligate riparian species sufficient in marginal zone.
Occurrence of obligate, non-marginal zone riparian	2	Obligate riparian species sufficient in non-marginal zone.

Site Suitability for the Assessment of Environmental Flows		
Habitat availability	**Rate**	**Motivation where applicable**
species.		
Occurrence of species that are (regional) indicators of the riparian zone, or wetness.		Obligates present, so unrated.
Recent fire/s at site.	2	Most of RB recently burnt (high intensity fire).
Exotic species at the site.	3	60 – 80% exotics in upper zone, less in lower and marginal zones.
Left and right-hand banks have riparian vegetation in similar condition.	1	Similar banks into vegetation.
Able to obtain sufficient survey points of indicator species for flow requirements.	1	6 - 7 points per bank.
Plant species easily identifiable i.e. leaves or flowers present at time of site visit.	0	Identification was not a problem.
Hydraulic control		
Unnatural up/downstream control affecting site.	1	Downstream effect of bridge pillars increased sediment deposition slightly, but localized.
Overall Site Suitability Rating	**1.2**	
Suitability rating: 0 - Suite highly suitable 3 - Site unsuitable	1 - Site suitable 4 - Site extremely unsuitable	2 - Site moderately suitable 5 - Site not to be used

PES description	Marginal zone: This zone is reed dominated, with reduced woody component. Lower zone: Dominated by reedbeds and exotic vegetation, and largely cultivated and woody vegetation has been extensively removed. Upper zone: Close to reference, but grazing and trampling has removed large proportions of understorey and selected wood removal has reduced the woody component.		
	C (66.6%)	**Confidence**	3.7

H14.3.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
C	Reduced cover and abundance of indigenous riparian species.	High levels of alien species invasion (especially in lower and upper zones).	NF	4.5
	Changes to species composition and population structure of indigenous riparian species.	High levels of vegetation removal (grazing and trampling mainly) especially in lower and upper zones.		
	Expansion of reedbeds.	Narrowing of channel due to reduced flows.	F	

H14.3.3 Profile

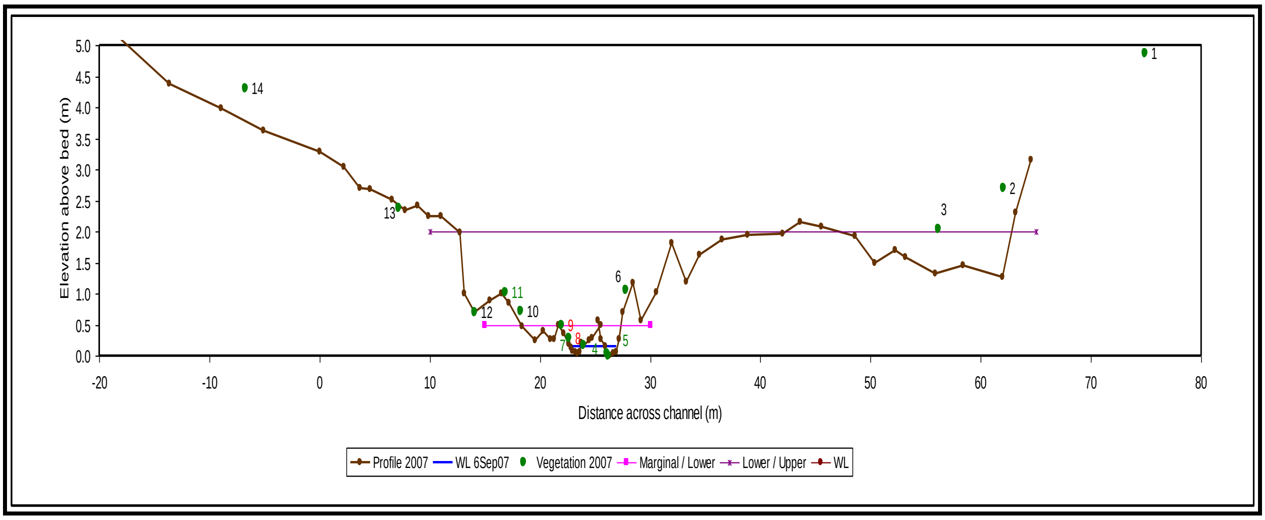

Figure H14 EWR 7: Riparian vegetation survey points used to assess flow requirements

Key:

1: *D. mespiliformis* (adults) (lower limit)
2: *A. sieberiana* (adults) (lower limit)
3: *C. erythrophyllum* (adults)
4: *P. mauritianus* (lower limit)
5: *P. mauritianus* (lower limit)
6: *A. sieberiana* (lower limit)
7: *P. mauritianus* (lower limit)
8: *S. mucronata* (lower limit)
9: *P. mauritianus & S. mucronata* (upper limit)
10: *F. sur* (lower limit)
11: *P. mauritianus* (upper limit)
12: *Cyperus* (upper limit)
13: *C. erythrophyllum* (adults)
14: *F. sur*
15: *D. mespiliformis* (upper limit)

H14.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
C	Negative	D	5 - 10 years	Presence of exotics species are high, with an occurrence of up to 40 - 60% on the Upper zone. If left unchecked will increase in proportion at the expense of indigenous riparian vegetation. Grazing and trampling from livestock, wood removal (selected *Breonadia, F. sur, Erythrina,* and *Sprirostachys* spp.) and cutting of footpaths is high. Expansion of reedbeds could continue to areas where open sand still exists.	3

H14.5 AEC: B

PES	AEC	Comments	Conf
C	D	Increased presence of exotic species will lead to a decrease in woody vegetation (especially cover and abundance). Reedbeds will increase on marginal and lower zones.	3

H14.6 AEC: D

PES	AEC	Comments	Conf
C	D	Increased presence of exotic species will lead to a decrease in woody vegetation (especially cover and abundance). Reedbeds will increase on marginal and lower zones.	3

H15 EWR 8 LOWER SAND (SAND RIVER)

H15.1 DATA AVAILABILITY

Data availability	Conf
Satellite images (Google earth) of the respective reach. Hydraulic cross-section (profile) at the site together with surveyed key vegetation points for setting flows. Data collected from field assessment in 2007. Aerial photos of site - 1944, 1965, 1974, 1984, 1997. Numerous postgraduate studies on the Sabie especially inside KNP. Previous IFR studies. Biomes of South Africa: Savanna (Rutherford & Westfall, 1986); Savanna (bushveld) (van Wyk & van Wyk, 1997) Savanna (Mucina & Rutherford, 2006). Bioregions of South Africa: Lowveld (SVl 7) (Mucina & Rutherford, 2006). Vegetation Type: Undifferentiated bushveld and woodland (van Wyk & van Wyk, 1997). Vegetation Units: Granite Lowveld (SVl 3), (Mucina & Rutherford, 2006). Maputaland-Pondoland principle region of plant diversity (van Wyk & van Wyk, 1997). WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.*	4.5

H15.2 REFERENCE CONDITIONS

Marginal zone

Sections that are characterised by unconsolidated alluvia will tend to be dominated by reedbeds (*P. mauritianus*), while sections characterised by cobble/boulder or exposed bedrock will tend to be dominated by grasses (*Cynodon dactylon*) and herbaceous aquatics (*Cyperus*, *Persecaria*, and *Ludwigia* species). Small proportion of the marginal zone will be woody (*Breonadia* and *Syzigium* species mainly).

Lower zone

Mix of tree and shrub dominated vegetation (*B. salicina*, *S. cordatum* and *S. guineense*, and *N. oppositifolia* mainly) where substrates tend to be more rocky or consolidated and reeds/open sand (*P. mauritianus*) where substrates tend to be unconsolidated.

Upper zone

Tree and shrub dominated mainly (*C. erythrophyllum*, *F. sycomorus*, *D. mespiliformis* with some *S. africana* expected in localised pockets).

Confidence: 3.5

H15.3 PRESENT ECOLOGICAL STATE

H15.3.1 Site suitability

Site Suitability for the Assessment of Environmental Flows		
Habitat availability	**Rate**	**Motivation where applicable**
Presence/absence of the marginal zone.	0	Marginal completely present.
Proportion of marginal zone that is able to be sampled.	0	Entire marginal zone was sampled.
Channel morphology		
Channel bank stabilization.	0	No destabilization noted.
Channel manipulation.	1	Unmanipulated.
Profile distance too long to effectively conduct VEGRAI.	1	Entire profile assessed.
Vegetation		

Occurrence of obligate, marginal zone riparian species.	0	Obligate riparian species abundant in marginal zone.
Occurrence of obligate, non-marginal zone riparian species.	0	Obligate riparian species abundant in non-marginal zone.
Occurrence of species that are (regional) indicators of the riparian zone, or wetness.		Obligates present, so unrated.
Recent fire/s at site.	0	No recent.
Exotic species at the site.	1	Present, but < 10% on all zones.
Left and right-hand banks have riparian vegetation in similar condition.	1	Similar banks into vegetation.
Able to obtain sufficient survey points of indicator species for flow requirements.	0	> 8 points per bank.
Plant species easily identifiable i.e. leaves or flowers present at time of site visit.	0	Identification was not a problem.
Hydraulic control		
Unnatural up/downstream control affecting site.	1	Upstream effect of low-level bridge minimal localised deposition.
Overall Site Suitability Rating	**0.4**	

Suitability rating:
0 - Suite highly suitable | 1 - Site suitable | 2 - Site moderately suitable
3 - Site unsuitable | 4 - Site extremely unsuitable | 5 - Site not to be used

PES description	Marginal zone: The zone has expanded as sedimentation occurs, since reeds have colonised and stabilised additional sand deposits. Marginal species composition is as expected, but reeds occur in greater proportions and abundance. Lower and Upper zone: These zones are close to reference condition, with low alien vegetation impact, but reedbeds are more extensive than expected i.e. a greater patchiness with reeds and open sediment was expected.		
	B (86.7%)	**Confidence**	3.7

H15.3.2 PES causes and sources

PES	Causes	Sources	F/NF	Conf
B	Reduced indigenous vegetation cover and changes to species composition.	Exotic vegetation impact low (<10%).	F	4
	Expansion of reedbeds.	Narrowing of channel due to reduced flows.	NF	

H15.3.3 Profile

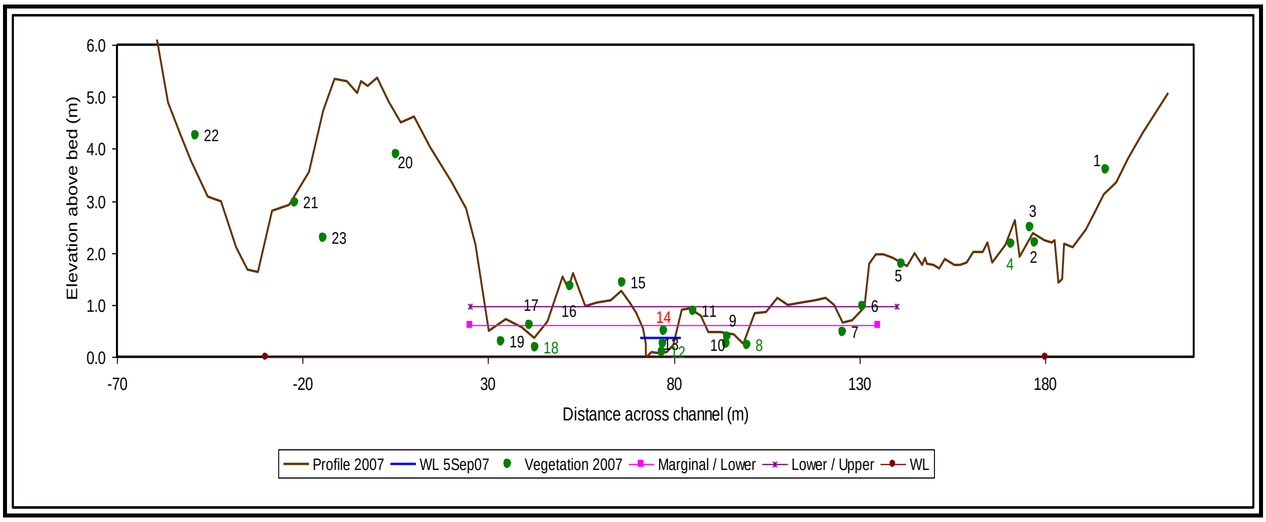

Figure H15 EWR 8: Riparian vegetation survey points used to assess flow requirements

Key:

1: *S. cordatum/D. mespiliformis* (upper limit)
2: *D. mespiliformis* (lower limit)
3: *Gymnosporia senegalensis/Phoenix reclinata* (lower limit)
4: *P. mauritianus* (upper limit)
5: *Combretum erythrophyllum*
6: Lower/upper zone interface
7: *Cyperus* sp (upper limit)
8: *P. mauritianus* (lower limit)
9: *Persecaria* (upper limit)
10: water level
12: *P. mauritianus* (lower limit)
13: water level
14: *B. salicina* (lower limit)
15: *Combretum erythrophyllum* (upper limit)
16: Periwinkle
17: *Cyperus* sp (upper limit)
18: *P. mauritianus/Schoenoplectus* (lower limit)
19: *Cyperus* sp (lower limit)
20: *C. erythrophyllum*/*A. robusta* recruits/*E. crispa* (upper limit)
21: *L. capassa* (lower limit)
22: *D. mespiliformis* (lower limit)
23: N. *oppositifolia* (upper limit).

H15.4 TREND

PES	Trend	Trend PES	Time	Reasons	Conf
B	Stable	B		Exotics, if left unchecked would increase in proportion at the expense of indigenous riparian vegetation, but the actions of WFW inside KNP appear to be ongoing and frequent enough to stabilize the site. Stability does however; depend on the continued action of Working for Water.	2.5

H15.5 AEC: C

PES	AEC	Comments	Conf
B	B/C	Reduced flows and increased sedimentation will facilitate channel narrowing and a shift in vegetation as the marginal zone migrates. Reeds will colonise new sand and further aid channel narrowing, while reeds on the lower zone will remain. Species composition is unlikely to change. It is assumed that alien vegetation is kept at bay and does not increase.	2.5

H16 REFERENCES

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

Van Wyk, B. and Van Wyk, P. 1997. *Field Guide to Trees of Southern Africa*, C. Struik Publishing, Cape Town, South Africa.