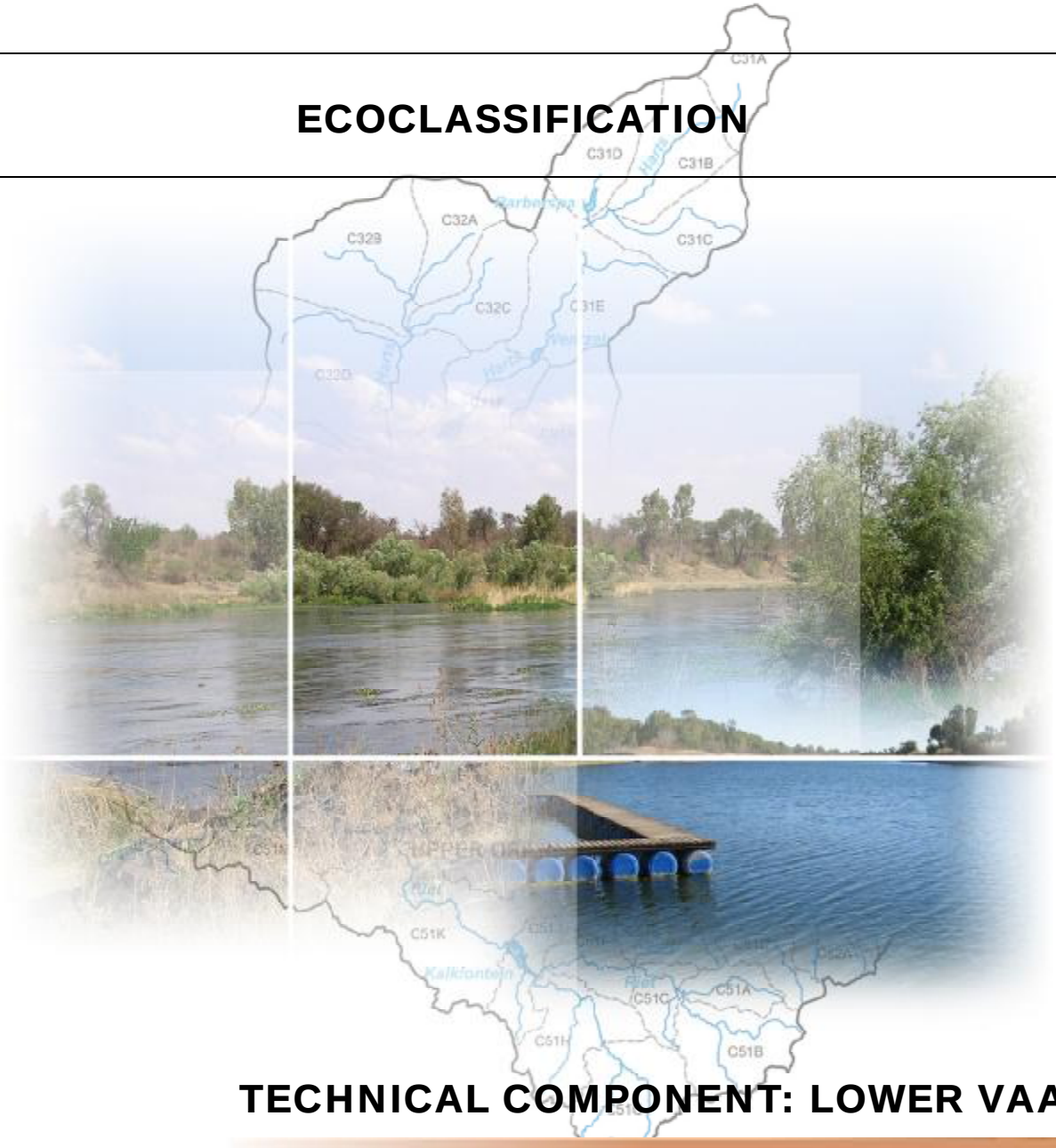
COMPREHENSIVE RESERVE DETERMINATION

INTEGRATED VAAL RIVER SYSTEM

SURFACE WATER

ECOCLASSIFICATION



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Bold type indicates this report.

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1.2	RDM/ WMA10C000/01/CON/ 0207	Lower Vaal Comprehensive Reserve determination: Surface Water Desktop EcoClassification report
1.3	RDM/ WMA10C000/ 01/CON/ 0108	Lower Vaal Comprehensive Reserve determination: Surface Water Basic Human Needs Reserve report
1.4	RDM/ WMA10C000/ 01/CON/ 0109	Lower Vaal Comprehensive Reserve determination: Surface Water Resource Units report
1.5	RDM/ WMA09/10C000/ 01/CON/ 0209	Lower and Lower Vaal Comprehensive Reserve determination: Surface Water Wetland/Pans Assessment report
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1.10	RDM/ WMA10C000/ 01/CON/ 0510	Lower Vaal Comprehensive Reserve determination: Surface Water Ecospecs and monitoring report
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1.12	RDM/ WMA10C000/01/CON/ 0710	Lower Vaal Comprehensive Reserve determination: Surface Water Electronic information

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EXECUTIVE SUMMARY

Chapter 3 of the National Water Act (NWA) (Act No. 36, 1998) provides for the protection of water resources of the country through the implementation of Resource Directed Measures (RDM), based on the guiding principles of sustainability and equity. In terms of the Act, before any authorization to utilise a particular water resource can be granted, it is necessary to determine the Reserve for the relevant ecological component of the resource that will be impacted by the proposed water use. The Reserve can be defined as, 'the quantity, quality and reliability of water needed to sustain both basic human needs and aquatic ecosystems.

The Chief Directorate: Resource Directed Measures (CD: RDM) is tasked with the responsibility of ensuring that the Reserve requirements, which have priority over other uses in terms of the Act, are determined before any new water uses are authorised. The Reserve requirements must be met, before the requirements for economic development or water uses are satisfied so as to ensure that the long-term integrity of ecosystems are not comprised or severely impacted upon'. As the Department of Water Affairs (DWA) is the custodian of the nation's water resources, it is their responsibility to ensure the adequate protection and effective management of these resources.

The CD: RDM initiated a Comprehensive Reserve Determination Study for the water resources of the Lower Vaal Water Management Area (WMA) that forms part of the overall comprehensive Reserve determination of the integrated Vaal River System. The purpose of this Reserve Determination Study is to determine the ecological and basic human needs water quantity and quality Reserve for the Lower Vaal at a comprehensive level of detail.

The study area for the Comprehensive Reserve determination is the lower Vaal River within the Lower Vaal and Upper Orange WMAs (part of WMA 10 and 13). These catchment areas form part of the integrated Vaal River System, as they fall within the C drainage region of South Africa. The Lower Vaal WMA is the last of the three cascading WMAs in the Vaal River System, which includes the drainage area of the Vaal River from its headwaters to the confluence of the Vaal and Orange Rivers.

The Lower Vaal WMA is situated in the north-western part of the country and forms part of the Orange River watercourse. It covers a catchment area of 133 354 km^2, and includes parts of the Northern Cape and North-West Provinces, and a small part of the Free State Province. The Vaal River is the only major river in the WMA, as it flows in a westerly direction from Bloemhof Dam to the confluence with the Orange River. The largest part of the WMA falls within the catchment of the Molopo River, a tributary of the Orange River. The Molopo, Nossob and Kuruman rivers drain the remainder of the WMA but due to the very low rainfall in the WMA, the contribution of flow from these rivers are insignificant. The WMA consists of the D41 (excluding D41A), parts of D42C and D42D, parts of D73A and D73C, C31, C32, C33, C91, and C92 tertiary catchments. For the purpose of this study only the C drainage region is of relevance as it forms part of the Vaal River System, which includes the Harts River catchment, the Modder/Riet catchments and the Vaal River catchment.

The Modder/Riet system forms part of the upper Orange River catchment and consists of tertiary catchments C51 and C52. The Orange River confluences with the Vaal River near the downstream outlet of the Lower Vaal WMA. The C drainage region of the Lower WMA comprises four sub-catchments and the Upper Orange.

Virtually all the surface flow of the Vaal River, the main source of water in the Lower Vaal WMA, originates from the Upper and Middle Vaal WMAs. Very little surface run-off originates within the WMA itself due to the low rainfall, flat topography and sandy soils. The groundwater resource is more substantial, supplying an estimated 128 million m^3/annum. The Vaal River is fed by the only tributary, the Harts River which drains a catchment area of 31 000km^2, with the Dry Harts being the major tributary of the Harts River joining it just downstream of Taung. The only lake and wetlands of note are at Barberspan in the Upper Harts River catchment which has been given Ramsar status as a wildlife conservation area.

The development of the surface water resources occurring in the WMA has reached its potential, however all water is not being fully utilised. The water in Taung Dam and Spitskop Dam are currently not utilised and further studies are required to determine best how to utilise the water contained in these dams. There are several large dams that have been constructed in the study area, including Bloemhof Dam, Vaalharts Weir and a number of dams on the Modder/Riet system

This report provides the results of Ecoclassification process of the Reserve determination process for the four selected Ecological Water Requirement (EWR) sites in the Lower Vaal WMA.

Specialist surveys for the macroinvertebrate, fish, riparian vegetation, water quality and hydraulics were undertaken during 2007 and 2008.

The selected Ecological Water Requirement (EWR) sites are indicated in Table A.

Table A: Selected EWR sites for the Lower Vaal catchment

EWR Site number	EWR16	EWR17	EWR18	EWR19
EWR site name	Downstream Bloemhof Dam	Lloyds weir on Harts River	Schmidtsdrift	Lilydale Lodge
River	Vaal	Harts	Vaal	Riet
National RHP site		C3HART-DELPO	C9VAAL-SCHMI	
Coordinates	S27.65541; E25.59564	S28.37694; E24.30305	S28.7048; E24.07601	S29.03842; E24.50283
Ecoregion (Level II)	11.08; 29.02	29.02; 30.01	29.02; 30.01	29.02
Geomorphic zone	E: Lower Foothills	E: Lower Foothills	E: Lower Foothills	E: Lower Foothills
Altitude (m)	1211	1114	1239	1107
RU	Vaal K	Harts C	Vaal O	Riet D
Quaternary catchment	C91A	C33C	C92B	C51L
Hydrological Gauge	C9H021	C3H016	C9H024	C5H048

Figure A summarises the Present Ecological Status (PES), Ecological Importance and Sensitivity (EIS) and Recommended Ecological Category (REC) for each EWR site in the Lower Vaal.

In summary the Ecostatus for the Lower Vaal range from an E to a C/D category and the Ecological Importance and Sensitivity is moderate for all the EWR sites except the site on the Riet River that has a high EIS. Various factors contribute to the low Ecostatus at the EWR sites, but reduced baseflows and

moderate events as well as poor water quality are the main sources. Figure 3.1 summarises the results per EWR site. The difficulty in improving the Ecostatus is due to the Vaal River system being operated as a water supply scheme for irrigation and drinking water and not for ecological sustainability purposes.

SITE 16			
Components	PES	EIS	REC
Hydrology	D	Moderate	D
Water Quality	C		C
Geomorphology	D/E		D/E
Fish	E		E
Invertebrates	C/D		C/D
Riparian Veg	F		D/E
ECOSTATUS	E		E

SITE 17			
Components	PES	EIS	REC
Hydrology	D/E	Moderate	D/E
Water Quality	D		D
Geomorphology	D		D
Fish	D		D
Invertebrates	C/D		C/D
Riparian Veg	D		D
ECOSTATUS	D		D

SITE 18			
Components	PES	EIS	REC
Hydrology	C	Moderate	C
Water Quality	C		C
Geomorphology	C/D		C/D
Fish	C		C
Invertebrates	C/D		C/D
Riparian Veg	C/D		C/D
ECOSTATUS	C/D		C/D

SITE 19			
Components	PES	EIS	REC
Hydrology	D	High	D
Water Quality	D		D
Geomorphology	C		C
Fish	D		D
Invertebrates	C		C
Riparian Veg	C/D		C/D
ECOSTATUS	D		D

Figure A Summary of PES, EIS and REC for the EWR sites in the Lower Vaal

The hydrology of the Lower Vaal WMA is impacted in the main stem of the Vaal by the Vaal Dam, Vaal Barrage (completed in 1919), Bloemhof Dam and Vaalharts Weir. The flow regime in the main stem of the Vaal is impacted by the following:

- Vaal Dam storage
- Releases from Vaal Dam to dilute salts to 600 mg/L TDS (mainly in winter)
- Releases from Vaal Dam and Vaal River Barrage to supply the Vaal Harts irrigation scheme (completed 1938)
- Vaal Harts irrigation scheme transfer (Vaalharts Weir) and return flows
- Transfer from Orange River to the lower Riet River
- Operation of the Vaal River to ensure minimum flows at Douglas Weir just upstream of the Vaal and Orange confluence.

This altered flow regime has resulted in increased winter base flows in the Lower Vaal River and smaller floods being reduced in summer.

Due to this regulation having being implemented in varying degrees for 90 years the aquatic organisms have adapted and the river banks are stable.

Alien invasive plants have changed the characteristics of large parts of the riparian zones of the Vaal, Harts and Riet Rivers. These infestations are non-flow related but due to disturbances as a result of agricultural and mining impacts on the banks. Management interventions for clearing of these plants are required to improve the overall status of the riparian zone.

In the Riet and Harts Rivers the hydrology has changed due to increased irrigation usage, upstream dams and urban requirements. These rivers have less flow in winter as well as summer due to these anthropogenic changes.

The other major driver of change in the Lower Vaal WMA is water quality. The water quality in the main stem of the Vaal River (EWR sites 16 and 18) is impacted by gold mine return flows from the Middle Vaal. The mine related water quality impacts are associated with high salts, acidity, elevated metals (iron, aluminium and manganese) and radioactivity. The other major impactor of water quality is associated with high nutrient values originating from waste water treatment works not meeting discharge standards. These elevated nutrient levels have resulted in prolific algal growth (filamentous, water hyacinth and blooms of blue green and green algae) which has resulted in a reduction in available habitat for both fish and macroinvertebrates.

The water quality in the Harts and Riet rivers are impacted by diffuse return flows from agriculture (salts and nutrients) as well as high nutrient values originating from waste water treatment works. The Vaal Hartz irrigation scheme has especially impacted the Harts River and the water quality has also impacted the aquatic ecologies PES with the smothering of available habitat for both fish and macroinvertebrates by prolific algal growth.

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APPENDIX D: MACROINVERTEBRATE ASSESSMENT

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ACRYNOMS

CD: RDM	Chief Directorate: Resource Directed Measures
D: NWRP	Directorate: National Water Resource Planning
D: RQS	Directorate: Resource Quality Services
DWAF	Department of Water Affairs and Forestry
EC	Ecological Category
EIS	Ecological Importance and Sensitivity
EWR	Ecological Water Requirements
GDP	Gross Domestic Product
GGP	Gross Geographic Product
IHI	Index of Habitat Integrity
NWA	National Water Act
PES	Present Ecological State
QHI	Quick Habitat Integrity
REC	Recommended Ecological Category
RU	Resource Unit
SCI	Socio Cultural Importance
ToR	Terms of Reference
WMA	Water Management Area

GLOSSARY

DROUGHT FLOW	The minimum flow required facilitating the survival of the riverine ecosystem in a particular condition and over short, infrequent periods, when users are subject to water restrictions. Drought flows in the Vaal River will be defined as low-flows that occur

	less than x % of the time under natural conditions for each month.
ECOLOGICAL CATEGORY	A category indicating the potential management target for a river. Values range from Category A (unmodified, natural) to Category D (largely modified). This term replaces former terms used, namely: Ecological Reserve Category (ERC), Desired Future State (DFS) and Ecological Management Class (EMC). The reasons for these changes are explained in the proceedings of a workshop to clarify the terminology used in Reserve determinations (DWAF 2003). It should be noted that a distinction is made between Management Classes, which form part of the National Classification System, and Ecological Categories, which forms part of the Ecological Water Requirement assessment.
ECOSPECS	Clear and measurable specifications of ecological attributes (e.g. water quality, flow, biological integrity) that defines the Ecological Category. The purpose of ecospecs is to establish clear goals relating to resource quality (Kleynhans 2003).
ECOSTATUS	An overall assessment of the Ecological Category (A-F), based on rule-based integration of specialist indices (water quality, fish, etc). Ecostatus refers to the totality of the features and characteristics of the river and its riparian areas that bear upon its ability to support an appropriate natural flora and fauna and its capacity to provide a variety of goods and services" (Iversen *et al.* 2000, *In* IWR Environmental 2003).
ECOLOGICAL WATER REQUIREMENTS (EWR)	The flow patterns (magnitude, timing and duration) and water quality needed to maintain a riverine ecosystem in a particular condition. This term is used to refer to both the quantity and quality components.
INSTREAM FLOW REQUIREMENTS (IFR)	The flow patterns (magnitude, timing and duration) needed to maintain a riverine ecosystem in a

	particular condition. This term is used to refer to the quantity component only of Ecological Water Requirements.
MAINTENANCE FLOW	The flow required to meet the requirements of the riverine ecosystem at a particular site and maintain the resource base in a particular condition during "normal" climatic years. The distinction between "normal" and "drought" was based on an examination of monthly flow duration curves
PRESENT ECOLOGICAL STATE (PES)	The degree to which ecological conditions of an area have been modified from natural (reference) conditions. The measure is based on water quality variables, biotic indicators and habitat information collected 1 to 3 years prior to the assessment. Results are classified on a 6-poin scale, from Category A (*Largely Natural*) to Category F (*Critically Modified*).
REFERENCE CONDITION	Natural ecological conditions, prior to human development.
RESERVE	The quantity and quality of water required (a) to satisfy basic human needs by securing a basic water supply, as prescribed under the Water Services Act, 1997 (Act No. 108 of 1997), for people who are now or who will, in the reasonably near future, be (i) relying upon; (ii) taking water from; or (iii) being supplied from, the relevant water resource; and (b) to protect aquatic ecosystems under the National Water Act, 1998 (Act No. 36 of 1998) in order to secure ecologically sustainable development and use of the relevant water resource. The Reserve refers to the modified Ecological Water Requirement, where operational limitations, and stakeholder consultation are taken into account.
RESOURCE QUALITY OBJECTIVE	Quantitative and auditable statements about water quantity, water quality, habitat integrity and biotic integrity that specify the requirements (goals) needed to ensure a particular level of resource protection. This term takes into account the management *classes* and the requirements of other users. These components are not addressed in this project

RESOURCE UNIT	Stretches of river that are sufficiently ecologically distinct to warrant their own specification of Ecological Water Requirements, and that can be practically managed as a single unit.

1 INTRODUCTION

1.1 BACKGROUND

Chapter 3 of the National Water Act (NWA) (Act No. 36, 1998) provides for the protection of water resources of the country through the implementation of Resource Directed Measures (RDM), based on the guiding principles of sustainability and equity. In terms of the Act, before any authorization to utilise a particular water resource can be granted, it is necessary to determine the Reserve for the relevant ecological component of the resource that will be impacted by the proposed water use. The Reserve can be defined as, 'the quantity, quality and reliability of water needed to sustain both basic human needs and aquatic ecosystems.

According to the Act all Reserve determinations that are currently determined and approved by the Department of Water Affairs (DWA) are preliminary Reserve determinations and the associated recommended class is a preliminary class (section 17(1)), until a system for the classifying of water resources has been prescribed.

The Chief Directorate: Resource Directed Measures (CD: RDM) is tasked with the responsibility of ensuring that the Reserve requirements, which have priority over other uses in terms of the Act, are determined before any new water uses are authorised. The Reserve requirements must be met, before the requirements for economic development or water uses are satisfied so as to ensure that the long-term integrity of ecosystems are not compromised or severely impacted upon'. As the Department of Water Affairs (DWA) is the custodian of the nation's water resources, it is their responsibility to ensure the adequate protection and effective management of these resources.

The CD: RDM initiated the Comprehensive Reserve Determination Study for selected water resources in the Lower Vaal Water Management Area (WMA) as part of the comprehensive Reserve determination study for the integrated Vaal River System. The purpose of this study for the selected water resources of the Lower Vaal WMA is to determine the ecological and basic human needs water quantity and quality Reserve at a comprehensive level of detail.

The results of the Comprehensive Reserve determination study will assist the DWA to make more informed decisions regarding the authorisation of future water uses, operation and management of the system and the evaluation of the magnitude of the impacts of the present and proposed developments.

This report provides the results of step 3 of the 8-step Reserve determination process (see Figure 1.1) on a comprehensive level of detail for the rivers of the Lower Vaal catchment area.

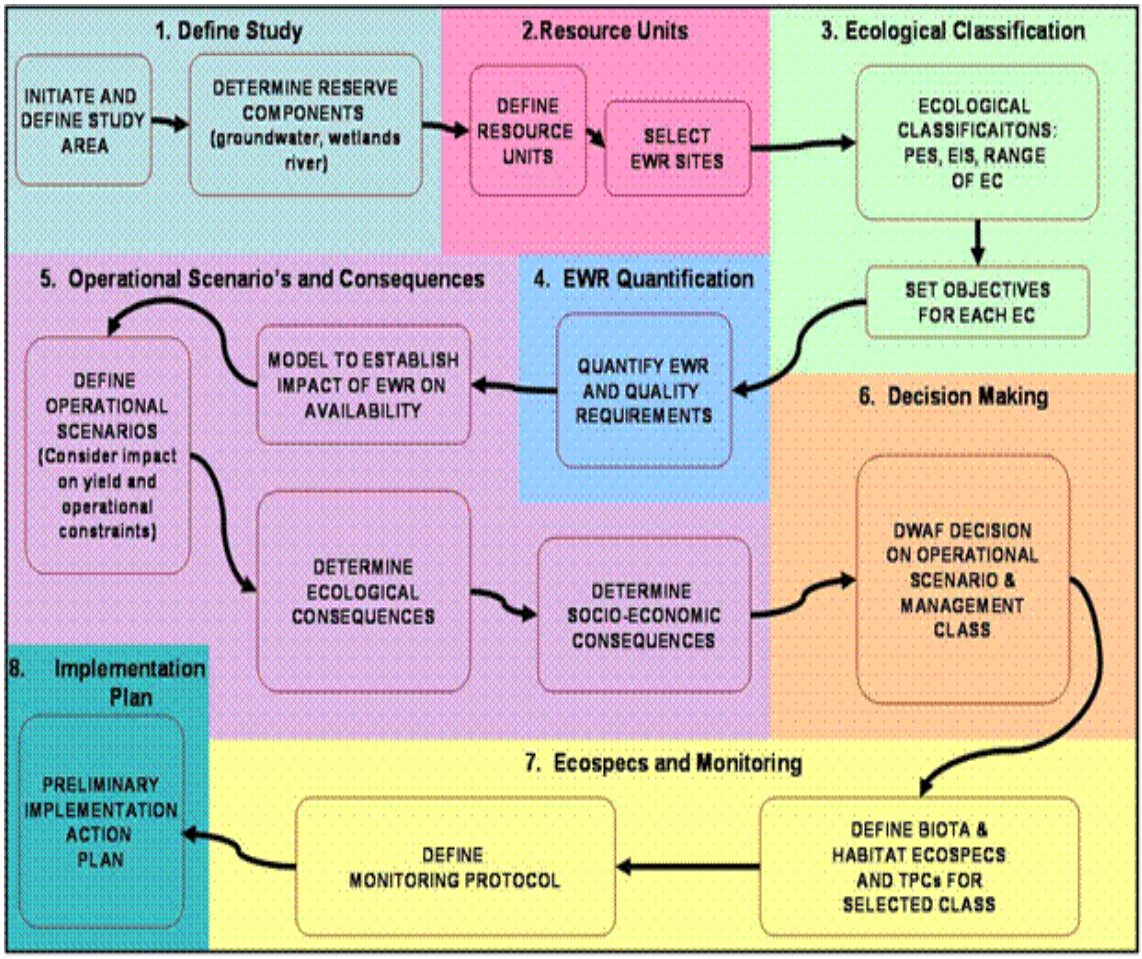

Figure 1.1: Generic procedure for the determination of the ecological Reserve

1.2 STUDY AREA

The study area for the Comprehensive Reserve determination is the lower Vaal River within the Lower Vaal and Upper Orange WMAs (part of WMA 10 and 13) (see Figure 1.2). These catchment areas form part of the integrated Vaal River System, as they fall within the C drainage region of South Africa. The Lower Vaal WMA is the last of the three cascading WMAs in the Vaal River System, which includes the drainage area of the Vaal River from its headwaters to the confluence of the Vaal and Orange Rivers.

The Lower Vaal WMA is situated in the north-western part of the country and forms part of the Orange River watercourse. It covers a catchment area of 133 354 km^2, and includes parts of the Northern Cape and North-West Provinces, and a small part of the Free State Province. The Vaal River is the only major river in the WMA, as it flows in a westerly direction from Bloemhof Dam to the confluence with the Orange River. The largest part of the WMA falls within the catchment of the Molopo River, a tributary of the Orange River. The Molopo, Nossob and Kuruman rivers drain the remainder of the WMA but due to the very low rainfall in the WMA, the contribution of flow from

these rivers are insignificant. The WMA consists of the D41 (excluding D41A), parts of D42C and D42D, parts of D73A and D73C, C31, C32, C33, C91, and C92 tertiary catchments. For the purpose of this study only the C drainage region is of relevance as it forms part of the Vaal River System, which includes the Harts River catchment, the Modder/Riet catchments and the Vaal River catchment.

The Modder/Riet system forms part of the upper Orange River catchment and consists of tertiary catchments C51 and C52. The Orange River confluences with the Vaal River near the downstream outlet of the Lower Vaal WMA. The C drainage region of the Lower WMA comprises four sub-catchments and the Upper Orange one catchment as listed in Table 1.1.

Table 1.1: Sub-catchments and related quaternary drainage regions within the C Drainage region within the Lower Vaal WMA and Upper Orange WMA (DWAF, 2006)

PRIMARY CATCHMENT	SUB-CATCHMENT	QUARTENARY CATCHMENTS	AVERAGE GROSS AREA (km^2)
C	Dry Harts	C32A-D	10 205
	Harts	C31A-F	11 023
	Vaalharts	C33A-C	9843
	Vaal downstream Bloemhof	C91A-E, C92A-C	22 427
	Modder/Riet	C51A-M, C52A-L	34 795

Virtually all the surface flow of the Vaal River, the main source of water in the Lower Vaal WMA, originates from the Upper and Middle Vaal WMAs. Very little surface run-off originates within the WMA itself due to the low rainfall, flat topography and sandy soils. The groundwater resource is more substantial, supplying an estimated 128 million m^3/annum. The Vaal River is fed by the only tributary, the Harts River which drains a catchment area of 31 000km^2, with the Dry Harts being the major tributary of the Harts River joining it just downstream of Taung. The only lake and wetlands of note are at Barberspan in the Upper Harts River catchment which has been given Ramsar status as a wildlife conservation area.

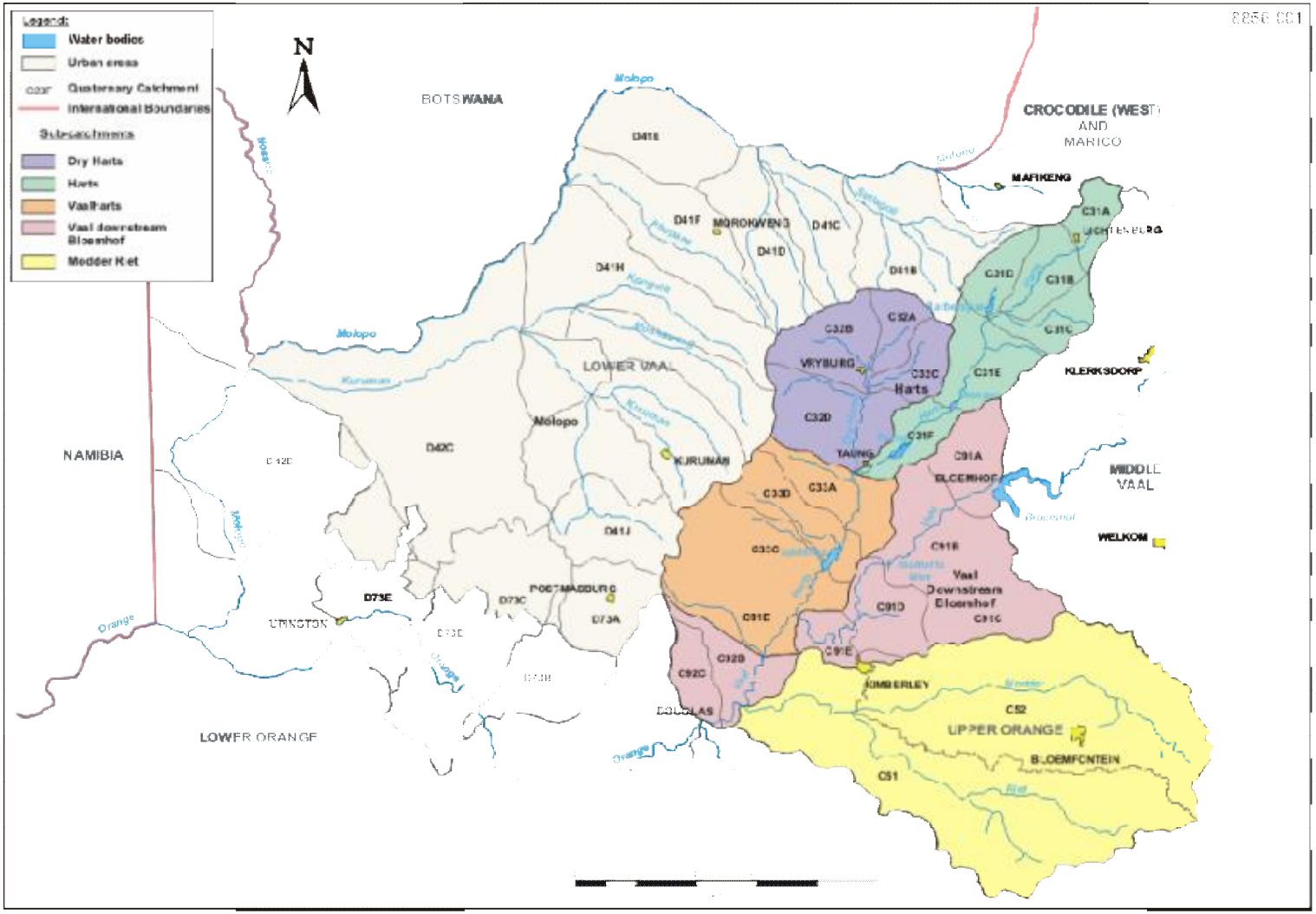

Figure 1.2: Lower Vaal River catchment areas (part of Lower Vaal and Upper Orange WMAs)

The development of the surface water resources occurring in the WMA has reached its potential, however all water is not being fully utilised. The water in Taung Dam and Spitskop Dam are currently not utilised and further studies are required to determine best how to utilise the water contained in these dams. There are several large dams that have been constructed in the study area, including Bloemhof Dam, Vaalharts Weir and a number of dams on the Modder/Riet system.

The selected Ecological Water Requirement (EWR) sites are listed in Table 1.2 and shown in Figure 1.2.

Table 1.2: Selected EWR sites for the Lower Vaal catchment

EWR Site number	EWR16	EWR17	EWR18	EWR19
EWR site name	Downstream Bloemhof Dam	Lloyds weir on Harts River	Schmidtsdrift	Lilydale Lodge
River	Vaal	Harts	Vaal	Riet
National RHP site		C3HART-DELPO	C9VAAL-SCHMI	
Coordinates	S27.65541; E25.59564	S28.37694; E24.30305	S28.7048; E24.07601	S29.03842; E24.50283
Ecoregion (Level II)	11.08; 29.02	29.02; 30.01	29.02; 30.01	29.02
Geomorphic zone	E: Lower Foothills	E: Lower Foothills	E: Lower Foothills	E: Lower Foothills
Altitude (m)	1211	1114	1239	1107
RU	Vaal K	Harts C	Vaal O	Riet D
Quaternary catchment	C91A	C33C	C92B	C51L
Hydrological Gauge	C9H021	C3H016	C9H024	C5H048

Surveys for the macroinvertebrate and fish have been undertaken during September 2007 (low flows) and April 2008 (high flows). The riparian vegetation was assessed during a field survey in June 2008.

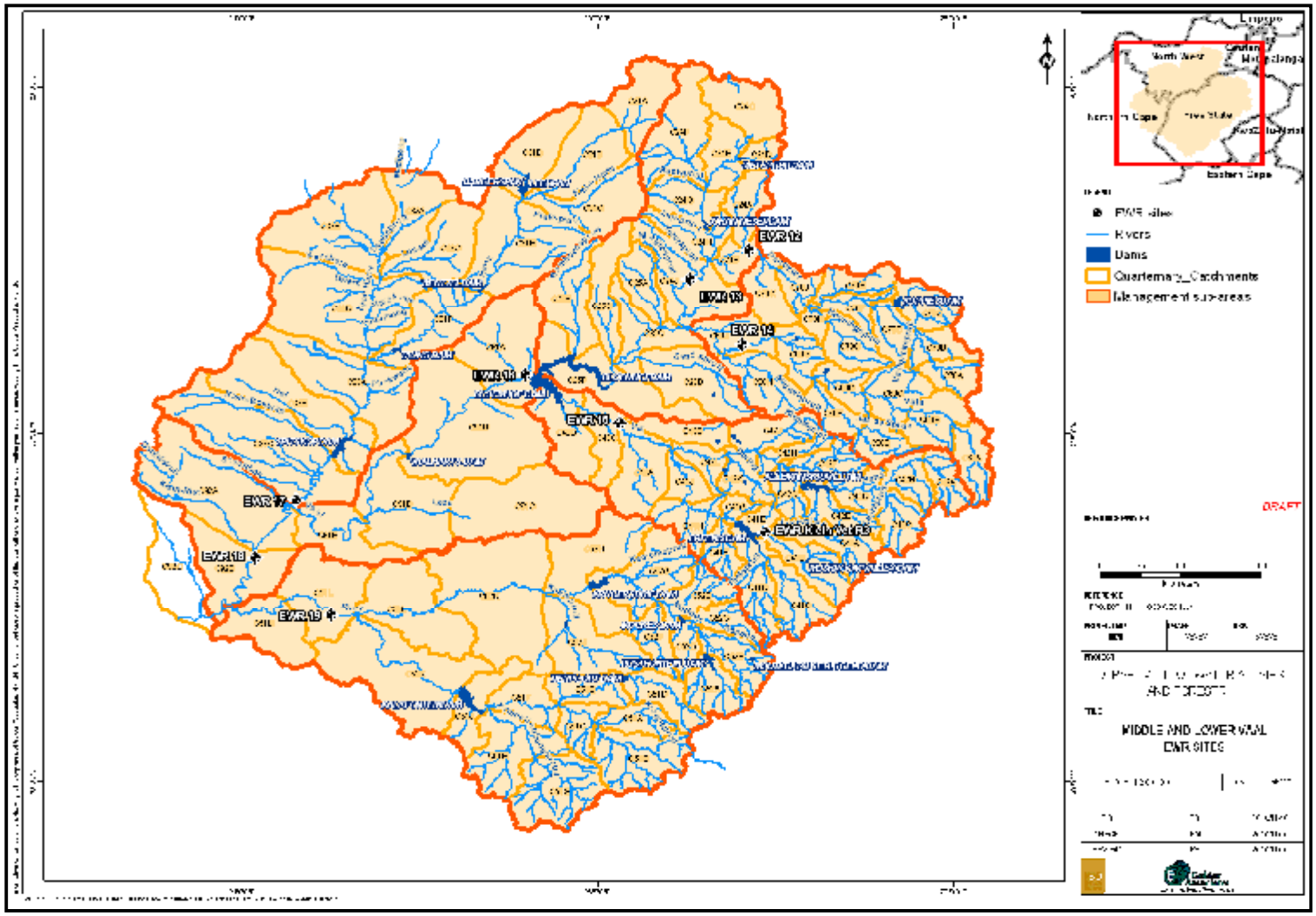

Figure 1.3: Resource Units and selected EWR sites for the Lower and Middle Vaal catchment

1.3 PURPOSE OF THIS REPORT

The activities and tasks for step 3 of the Reserve determination process were undertaken in accordance with the appropriate approaches and methodologies for rivers as prescribed by the CD: RDM of DWA, namely:

- The methodology as set out in DWAF (1999): Resource Directed Measures for Protection of Water Resources; Volume 3: River Ecosystems Version 1.0 (Revised water quality methodology, 2002).
- The revised methods as outlined in Louw and Hughes (2002), the Habitat Flow Stressor Response (HFSR) manual of IWR Source-to-Sea (2004) and the EcoClassification manual of Kleynhans *et al* (2005).
- EcoClassification and EcoStatus determination in River EcoClassification: Manual for EcoStatus Determination (version 2) of Kleynhans and Louw (2007).
- SPATSIM (Spatial and Time Series Information Modelling) (Hughes and Forsythe, 2006) was used as a framework to determine the EWR results.
- The Habitat Flow Stressor Response method (HFSR) (IWR S2S, 2004) was used to set low flows, a method adjusted from the Building Block Methodology (BBM; King and Louw, 1998).
- The approach to set high flows is a combination of the Downstream Response to Imposed Flow Transformation (DRIFT; Brown and King, 2001) approach and BBM.

This report serves to document the results of the EcoClassification process for the rivers of the Lower Vaal and the final results are provided per EWR site and include the following:

- Data availability
- Ecological Importance and Sensitivity (EIS)
- Reference conditions
- PES for each specialist component and the EcoStatus
- Trends
- Recommended Ecological category (REC) for each specialist component and the EcoStatus
- Alternative Ecological categories (AEC) for each specialist component and the EcoStatus.
- Confidence in the results
- Conclusions.

The specialist components consist of the drivers (geomorphology, physico-chemical variables and hydrology) and the response (riparian vegetation, fish and macroinvertebrates).

1.4 REPORT STRUCTURE

This report is structured into the following sections:

Section 1: Introduction and Background

Section 2: EcoClassification for the rivers of the Lower Vaal River catchment per EWR site

Section 3: Conclusions

Section 4: References.

2 ECOCLASSIFICATION OF THE RIVERS OF THE LOWER VAAL CATCHMENT

This section provides the summarised results of the EcoClassification process at the selected EWR sites of the Lower Vaal catchment. The detail analysis and rationale are provided per specialist component in the Appendices.

2.1 EWR 16: VAAL RIVER: DOWNSTREAM OF BLOEMHOF DAM

EWR site 16 is situated on the Vaal River (S27.655; E25.595) in quaternary catchment C91A. The site is at the upstream side of the Lower Vaal WMA just below Bloemhof Dam. The natural Mean Annual Runoff (MAR) at the EWR site is 3 242.5 million m^3.

Figure 2.1: View of EWR site 16 on the Vaal River

2.1.1 Data availability

The data available at EWR site 16 is summarised in Table 2.1

Table 2.1: EWR 16: Summary of data availability

Component	Data availability	Confidence
Hydrology	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. Modelled data represents the period 1920 to 1994.	3
Physico-chemical	Water quality available from C9H021Q01 1972 – 2008 (n = 2431).	4
Geomorphology	Historical aerial photographs from Land Surveyors Offices. Google Earth imagery of the site and catchment was available. Ecological reports and specialist assessments for this study.	3
Riparian vegetation	Google Earth imagery and aerial photos. Hydraulic cross-section at the EWR site together with surveyed key vegetation points for setting flows. Data collected from field assessment during 2008. Available historical data on biomes, bioregions and vegetation type etc.	4
Fish	Skelton, 2001 and expected fish species lists obtained from Neels Kleynhans at DWA, also available as a download on the DWA website.	4
Macroinvertebrates	Rivers Database 2008, and personal communication with Christa Thirion	3

2.1.2 Ecological Importance and Sensitivity

The Ecolgical Importance and Sensitivity (EIS) for this EWR site is moderate as shown in Table 2.2. *B kimberleyensis* and *A sclateri* expected in this river reach. The full suite of possible habitats is available.

Table 2.2: EWR 16: EIS results

DETERMINANTS / METRICS	PRESENT RATING (0 – 4)	COMMENTS
BIOTA (RIPARIAN & INSTREAM)		
Rare & endangered	4	*B kimberleyensis* near threatened expected and *A sclateri* expected, other fish are isolated within this reach of river due to regulations and no fish ladders
Unique (endemic, isolated, etc.)	2	*B kim, L capensis, B aeneus, L umbratus* all endemic to Orange Vaal, inverts ubiquitous at family level
Intolerant (flow & flow related water quality)	3	Fish none that are in tolerate to water quality, *A scl, B Aen, L cap, B kim* are moderately intolerant to no flow (need some flowing habitat types), flow related inverts with a high preference to flow related habitat types, A *Simullidae, Gyrinidae, Hydropsychidae, Muscidae*.
Species/taxon richness	2	15 invertebrate families. ASPT 4 6 fish recorded of 11 fish species expected.
RIPARIAN & INSTREAM HABITATS		
Diversity of types	3	Pools, riffles. Bedrock, gravel sand, boulders, cobbles - full suite of possible habitats available.
Refugia	1	Pools available, no feeder tributaries.

DETERMINANTS / METRICS	PRESENT RATING (0 – 4)	COMMENTS
Sensitivity to flow changes	2	Large system, not sensitive to flow modification, riffle and habitat across width of river
Sensitivity to flow related water quality changes	3	Water quality drives algal growth that smothers habitat, system already impacted and no assimilative capacity left.
Migration route/corridor (instream & riparian)	0	Important migratory route that is cut off by dams and weirs, highly regulated system, no feeder tributaries.
Importance of conservation & natural areas	1	Bloemhof Dam is a provincial nature reserve, yellow fish conservancies potential.
MEDIAN	2	
EIS	**MODERATE**	

2.1.3 Reference Conditions

The reference conditions for the components are summarised in Table 2.3. Additional information on fish, macroinvertebrate and riparian vegetation is provided in the specialist reports.

Table 2.3: EWR 16: Reference conditions

Component	Reference conditions	Conf
Hydrology	Natural flows at the EWR site were available for the period 1920 to 1994 and was provided by the system modellers.	3
Physico-chemical	The DWAF (2006 draft 2) study on the Integrated Water Quality Management Plan for the Vaal River System: Task 2. Water Quality Status Assessment of the Vaal River System was used as a reference guide for this water quality assessment. The water quality database was updated from DWAF up to 2008.	
Geomorphology	A single thread, straight channel within a mixed alluvial plane-bed reach. Bed material consists of silt and clay.	3
Riparian vegetation	**Marginal zone** Sedge dominated zone with minor herbaceous component. *Salix mucronata* and *Acacia karoo* could also form a minor woody component, but distribution is expected to be sparse, even in the reference condition. *Phragmites australis* is likely to occur in patches in shallower water. **Lower zone** Grass and sedge dominated zone with minor herbaceous component. *S. mucronata* and *G. virgatum* could also form a minor woody component. Grasses such as *Imperata cylindrica* will form major component as well as sedges such as *Miscanthus junceus Cyperus latifolius* and other cyperoid species) also expected to occur where lateral alluvia occur. Upper portion of lower zone expected to be colonised by terrestrial grasses (adjacent to grassland biome) such as *Themeda triandra*. **Upper zone** Grass dominated (mainly terrestrial grasses such as Themeda triandra and *Eragrostis* spp.), woody component will be sparse, if any and dominated by *Acacia* sp and *Searsia* sp.	3
Fish	Reference data obtained from Kleynhans CJ, Louw MD, Moolman J. 2007. Reference frequency of occurrence of fish species in South Africa. Report produced for the Department of Water	3.5

Component	Reference conditions	Conf
	Affairs and Forestry (Resource Quality Services) and the Water Research Commission. 11 fish species expected at the EWR site (see Appendix B or detail on reference species).	
Macroinvertebrates	The reference South African Scoring System version 5 (SASS5) score is 140 and the Average Score Per Taxon (ASPT) is 5.6. Reference data obtained from Christa Thirion. Reference taxa are listed in Appendix C.	3

2.1.4 Present Ecological State

A summary of the Present Ecological State (PES) per specialist component are provided below, with detail assessments available in the specialist reports.

Hydrology (PES = D)

Data is available from gauging weir C9H021 and shows a significant decrease from natural flows in all the flow components with the main impacts on the moderate events and floods. This is due to the operation of Bloemhof Dam just upstream of the EWR site.

Geomorphology (PES = D/E)

The site and reach are moderately bedrock influenced with a few bedrock riffles downstream and some small islands created by bedrock outcrops. Since the 1950's there has been some slight narrowing of the active channel. This reduction in channel size over the reach may be due to reduced flows, but at the site this is due to the development of a deeper, narrower channel as a result of the releases of clean, "sediment hungry" waters from the dam which cause erosion downstream.

At the site, both banks are cut – tree roots are being exposed due to the scour of the lower banks. The PES is thus in a D/E due the impacts of Bleomhof Dam on sediment availability as well as the highly altered hydrology. The channel is incising and there are no alternative opportunities for replenishment of the sediment which is trapped in the dam and thus little opportunity for improvement with flows in the zone immediately downstream of the dam.

Physico-chemical variables (PES = C)

Data is available from monitoring site C9H021 and shows low salinity (EC) and SO_4. Algal diversity is low, mainly spirogyra. Low nutrients although ammonia is high that leads to eutrophication. The fairly good water quality could be due to the variability in flow as water is released on a weekly basis for demands (mainly irrigation) downstream.

Fish (PES = E)

The Ecological Category of E can be attributed primarily to the absence of 5 of the 11 expected species and the lower than expected frequency of occurrence of certain species. Non availability of specific habitat cover and lack of upstream migration possibilities contributes to the PES of an E.

In addition to the indigenous species, four introduced fish species were recorded namely *Cyprinus carpio* (Carp), *Gambusia affinis* (Mosquitofish), *Ctenopharyngodon idella* (Grass carp) and *Oreochromis mossambicus* (Mozambique tilapia) were sampled.

Macroinvertebrates (PES = C/D)

The Ecological Category of C/D is a combination of flow and non-flow related impacts. The impacts are mostly related to changes in the flow regime due to the operation of Bloemhof Dam. The SASS5 scores were 64 and 56 respectively for the surveys undertaken in September 2007 and April 2008. Key families not sampled were: Baetidae >2spp, Ecnomidae, Elmidae, Heptageniidae, Hydropsychidae >2spp, Oligoneuridae, Perlidae, Philopotamidae and Tricorythidae.

Riparian vegetation (PES = F)

Current status: The area is currently highly degraded due to the removal of indigenous species and transformation of the riparian vegetation by the introduction of a number of exotic species. The exotic species in the area, in fact, contribute to a total of over 70% of the total number of species identified during the surveys.

Reasons for PES: The marginal zone at Site EWR 16 is dominated by graminoid and cyperoid species including , the lower non-marginal zone is dominated by exotic graminoids and herbaceous species with some woody species present and upper non-marginal zone is dominated by exotic tree species.

It is important to note that it was suggested that the river reach be used to determine the riparian vegetation status due the localised degradation at the EWR site (below Bloemhof Dam, camping and caravan park, bridges and town of Bloemhof).

2.1.5 PES causes and sources

A source is the origin of a stressor that occurs at a specific intensity, duration and frequency of exposure. This results in a change in the ecological conditions and can be defined as a cause. The PES for the various components as well as the reasons for the PES are summarised in Table 2.4.

Table 2.4: EWR 16: Causes and sources

	PES	Causes	Sources	F[1]/NF[2]
Hydrology	D	Changes in all the flow components, especially the moderate events	Bloemhof Dam just upstream of the site	F
Physico-chemical	C	Slightly increased salts	Mining upstream	F
		Eutrophication	High nutrients (although not indicated by the data) from agriculture and WWTW discharge	F
Geomor-phology	D/E	Reduced scour and thus caused fining of the channel bed and a lack of bed scour or bank inundation	Bloemhof Dam upstream of the site resulting in reduced baseflows and small floods	F

	PES	Causes	Sources	F[1]/NF[2]
Riparian Vegetation	F	Homogenisation of the riparian zone	70% alien invasive species	NF
		Excessive hyacinth and algal growth	Increased nutrients	F
Fish	E	Non availability of specific habitat cover units due to the growth of invasive aquatic macrophytes	Bloemhof Dam upstream causing altered flow regimes	F
		Lack of access to upstream river reaches for fish species with this migratory requirement	Bloemhof Dam upstream	NF
Inverts	C/D	Habitat covered in algae	Nutrient enrichment	NF
		Initial summer flush to open up the necessary habitat not available	Bloemhof dam upstream that controls releases	F

1 Flow related 2 Non Flow related

2.1.6 PES Trend

An estimate was made whether the specialist components drivers (quantity, quality and geomorphology) and responses (fish, macroinvertebrates and riparian vegetation) are stable or changing. The results are summarised in Table 2.5.

Table 2.5: EWR 16: Trend

	PES	Trend	Reasons	Confidence
Hydrology	D	Stable	Operation of Bloemhof Dam not to change in near future	3
Physico-chemical	C	Slightly negative	There is an all year release of water into the system making it highly modified, although slight increases in salts	4
Geomor-phology	D/E	Stable	Impact from Bloemhof Dam has been stabilised	3
Riparian vegetation	F	Negative	Increased encroachment of alien invasive plant in the riparian zone	4
Fish	E	Slightly negative	Observed abundances of some species lower than reference indicating that the abundances of some species may be decreasing	3
Inverts	D/C	Stable	Macroinvertebrates have adjusted to the currentl flow regime and water quality changes	3

2.1.7 PES Ecostatus

To determine the EcoStatus, the macroinvertebrates and fish results are combined to determine the instream category. The Vegetation Response Assessment Index (VEGRAI) category and confidence is then included in the assessment index (see Table 2.6) and the integrated ecostatus is calculated. The EcoStatus category for EWR site 16 on the Vaal River is a category E.

Table 2.6: EWR 16: Integrated Ecostatus

INSTREAM BIOTA	Importance Score	Weight	EC %	EC
FISH				
1.What is the natural diversity of **fish** species with different flow requirements	3	60		
2.What is the natural diversity of **fish** species with a preference for different cover types	1	100		
3.What is the natural diversity of **fish** species with a preference for different flow depth classes	2	80		
4. What is the natural diversity of **fish** species with various tolerances to modified water quality	4	30		
FISH ECOLOGICAL CATEGORY	10	270	**28**	**E**
AQUATIC INVERTEBRATES				
1. What is the natural diversity of **invertebrate** biotopes	2	80		
2. What is the natural diversity of **invertebrate** taxa with different velocity requirements	1	100		
3. What is the natural diversity of **invertebrate** taxa with different tolerances to modified water quality	4	60		
AQUATIC INVERTEBRATE ECOLOGICAL CATEGORY	**7**	240	**59.0**	**C/D**
INSTREAM ECOLOGICAL CATEGORY (No confidence)		510	**45.7**	**D**

INSTREAM ECOLOGICAL CATEGORY WITH CONFIDENCE	Confidence rating	Proportions	Modified weights
Confidence rating for **fish** information	3	0.43	12.00
Confidence rating for **macro-invertebrate** information	4	0.57	33.71
	7	1.00	45.71
INSTREAM ECOLOGICAL CATEOGORY	**EC**		**D**

RIPARIAN VEGETATION	EC %	EC
RIPARIAN VEGETATION ECOLOGICAL CATEGORY	**15.5**	**F**

ECOSTATUS	Confidence rating	Proportions	Modified weights
Confidence rating for instream biological information	3.6	0.48	21.85
Confidence rating for riparian vegetation zone information	3.9	0.52	8.09
	7.5	1.00	29.94
ECOSTATUS	**EC**		**E**

2.1.8 Recommended Ecological Category (REC) and Alternative Ecological Categories (AEC)

The REC is determined based on ecological criteria and considers the EIS, the restoration potential of the system and attainability there-of. The ecostatus is an E category mainly due to the F category for riparian vegetation as a result of non-flow related impacts. However, the instream PES is a D category with a moderate EIS. It is thus recommended that the instream PES is used as the REC for EWR site 16.

Only an AEC up was considered to assess the sensitivity of the system to flow and water quality changes.

AEC up: C/D

The following changes were considered:

Changes in hydrology

- Lower winter base flow
- Increased November flows
- Allow first-flush freshet cues in November

Water quality management

- Reduce nutrients from agricultural runoff and WWTW's
- Reduced salts due to greater flows and flushing

Riparian vegetation

- Management intervention to reduce the alien invasive plant encroachnment

Bloemhof Dam is a migratory barrier and the fish species not sampled need a migratory corridor. Unless a fishway is built there will be no changes in the fish category as they are stuck between Vaal Harts Weir and Bloemhof Dam – *Barbus anoplus*, *B. palidonosus*, and *B. Trimaculatus.* The macroinvertebrates improved slightly from a C/D to a C category and the riparian zone from an F to a D category. However, the instream PES did not change.

The REC and AEC categories per specialist and overall category are summarised in Table 2.7.

Table 2.7: EWR 16: Summary of the REC and AEC

Driver component	**PES**	**Trend**	**AEC Up (REC)**
Hydrology	D	Stable	D
Water quality	C	Slightly negative	B/C
Geomorphology	D/E	Stable	D/E
Response component			
Fish	E	Slightly negative	E
Macroinvertebrates	C/D	Stable	C
Instream EC	D	Stable	D
Riparian vegetation	F	Negative	D
Ecostatus	**E**	**Stable**	**D**
Ecological Importance and Sensitivity	**Moderate**		
Recommended Ecological Category	**D**		

2.2 EWR 17: HARTS RIVER: LLOYDS WEIR

EWR site 17 is situated on the Harts River at S28.37694; E24.30305 in quaternary catchment C33C, with a natural MAR of 147.85 million m^3.

Figure 2.2: View of EWR site 17 on the Harts River at Lloyds Weir

2.2.1 Data availability

The data available at EWR site 17 is summarised in Table 2.8.

Table 2.8: EWR 17: Summary of data availability

Component	Data availability	Confidence
Hydrology	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. Modelled data represents the period 1920 to 1994.	3
Physico-chemical	Water quality from C3H016Q01 1992 – 2008 (*n* = 268)	2
Geomorphology	Historical aerial photographs from Land Surveyors Offices. Google Earth imagery of the site and catchment was available. Ecological reports and specialist assessments for this study.	3

Component	Data availability	Confidence
Riparian vegetation	Google Earth imagery and aerial photos. Hydraulic cross-section at the EWR site together with surveyed key vegetation points for setting flows. Data collected from field assessment during 2008. Available historical data on biomes, bioregions and vegetation type etc.	3
Fish	Skelton, 2001 and expected fish species lists obtained from Neels Kleynhans at DWA, also available as a publication on the DWA website.	2
Macroinvertebrates	Rivers Database 2008, and personal communication with Christa Thirion	2

2.2.2 Ecological Importance and Sensitivity

The Ecological Importance and Sensitivity (EIS) for this site were rated as moderate with ***B kimberleyensis*** and ***A sclateri*** expected. The full suite of possible habitats is available at the site. Some macroinvertebrates intolerant to flow related changes are present.

Table 2.9: EWR 17: EIS results

DETERMINANTS / METRICS	PRESENT RATING (0 - 4)	COMMENTS
BIOTA (RIPARIAN & INSTREAM)		
Rare & endangered	4	*B kimberleyensis* near threatened expected and *A sclateri* expected. Migration stopped by Spitskop Dam.
Unique (endemic, isolated, etc.)	2	*B kim, L capensis, B aeneus, L umbratus* all endemic to Orange Vaal, inverts ubiquitous at family level.
Intolerant (flow & flow related water quality)	3	Fish none that are intolerant to water quality, *A scl, B Aen, L cap, B kim* are moderately intolerant to no flow (need some flowing habitat types), flow related inverts with a high preference to flow related habitat types, A *Simullidae, Gyrinidae, Hydropsychidae, Muscidae.*
Species/taxon richness	2	15 invertebrate families. ASPT 4 6 fish recorded of 11 fish species expected.
RIPARIAN & INSTREAM HABITATS		
Diversity of types	3	Pools, riffles. Bedrock, gravel sand, boulders, cobbles - full suite of possible habitats available
Refugia	1	Pools available, no feeder tributaries.
Sensitivity to flow changes	2	Large system, not sensitive to flow modification, riffle and habitat across width of river.

DETERMINANTS / METRICS	PRESENT RATING (0 - 4)	COMMENTS
Sensitivity to flow related water quality changes	3	Water quality drives algal growth that smothers habitat, system already impacted and no assimilative capacity left.
Migration route/corridor (instream & riparian)	0	Important migratory route that is cut off by dams and weirs, highly regulated system, no feeder tributaries.
Importance of conservation & natural areas	1	Bloemhof Dam is a provincial nature reserve, yellow fish conservancies?
MEDIAN	2	
EIS	**MODERATE**	

2.2.3 Reference Conditions

The reference conditions for the components are summarised in Table 2.10. Additional information on fish, macroinvertebrate and riparian vegetation is provided in the specialist reports.

Table 2.10: EWR 17: Reference conditions

Component	Reference conditions	Conf
Hydrology	Simulated natural flows were available from 1920 to 1994.	3
Physico-chemical	The DWAF (2006 draft 2) study on the Integrated Water Quality Management Plan for the Vaal River System: Task 2. Water Quality Status Assessment of the Vaal River System was used as a reference guide for this water quality assessment. The water quality database was updated from DWAF up to 2008.	2
Geomorphology	A sinuous, single thread channel within a mixed alluvial reach. Bed material consists mainly of silt and clay.	3
Riparian vegetation	**Marginal zone** Grass and sedge dominated zone with *Cyperus* spp, *Panicum coloratum* and *Cenchrus cilliaris* being prominent with a major herbaceous component. *Acacia karroo* may encroach on this zone in areas but very sparsely. *Phragmites australis* is likely to occur in patches in shallower water. **Lower zone** Grass dominated zone with minor woody component. *S. mucronata* and *Acacia karroo* could also form a minor to mjor woody component. Grasses (especially *Cenchrus cilliaris, Imperata cylindrica* and *Miscanthus junceus*) are also expected to occur. Upper portion of lower zone expected to be colonised by terrestrial grasses such *Chloris virgata, Aristida* spp and *Eragrostis* spp due to this area's proximity to the terrestrial system adjacent to the river. **Upper zone** Grass dominated (mainly terrestrial grasses) with a minor woody component comprised mainly of Acacia karoo and Searsia spp.	3
Fish	Reference data obtained from Kleynhans CJ, Louw MD, Moolman J. 2007. Reference frequency of occurrence of fish species in South Africa. Report produced for the Department of Water Affairs and Forestry (Resource Quality Services) and the Water Research Commission.	3

Component	Reference conditions	Conf
	11 fish species expected at the EWR site (see Appendix B or detail on reference species).	
Macroinvertebrates	The reference South African Scoring System version 5 (SASS5) score is 125 and the Average Score Per Taxon (ASPT) is 5.6. Reference data obtained from Christa Thirion. Reference taxa are listed in Appendix C.	2

2.2.4 Present Ecological State

A summary of the Present Ecological State (PES) per specialist component are provided below, with detail assessments available in the specialist reports.

Hydrology (PES = D/E)

Gauging weir C3H016 just upstream of the site was used together with the modelled natural and present day flows. Low flows, moderate events and event hydrology have been impacted by the returns flows from Vaalharts Irrigation scheme and Spitskop Dam upstream of the site. The present day low flows are higher than the natural low flows and this have a major impact on the system.

Geomorphology (PES = D)

PES is in a D category due to widespread cut banks along this reach; grazing and trampling disturbance on the upper and lower banks. Additionally, the upstream bridge has caused some localised erosion.

Physico-chemical variables (PES = D)

Data from monitoring site C3H016 was used for present day. This data shows high salt concentrations (EC and SO_4), mainly from irrigation return flows. Upstream diamond mining causes possible impacts on turbidity. The nutrients are low to moderate with moderate to high ammonia concentrations from degrading algal matter.

Fish (PES = D)

The ecological category of D recorded at this site can be attributed primarily to the absence of three expected species and the lower than reference frequency of occurrence of several observed species including *B.paludinosus*, *B.trimaculatus*, *L.umbratus* and *T.sparrmanii.* This can be ascribed to the flow modification (Spitskop Dam upstream) and the availability of cover.

In addition to the indigenous species, four introduced fish species were recorded namely *Cyprinus carpio* (Carp), *Gambusia affinis* (Mosquitofish), *Ctenopharyngodon idella* (Grass carp) and *Oreochromis mossambicus* (Mozambique tilapia) were sampled.

Macroinvertebrates (PES = C/D)

The Ecological Category of C/D is a combination of flow and non-flow related impacts. Impacts mostly related to changes in flow regime due to upstream dams and poor water quality return flows from the Vaal-Harts irrigation scheme.

Key families not sampled during the surveys were: Baetidae >2spp, Ecnomidae, Elmidae, Heptageniidae, Perlidae, Hydropsychidae >2spp, Philopotamidae and Tricorythidae.

Riparian vegetation (PES = D)

Current status: The area is currently considerably degraded due to the construction of bridges and mining activities that have disturbed much of the riparian vegetation and the introduction of a number of exotic species. The exotic species in the area contribute to a significant number of the total number of species identified during the surveys as well as a considerable percentage (approximately 30%) of the abundance recorded during the survey.

Reasons for PES: This was the first site in the study that did not fall within the Highveld Alluvial vegetation type and, in fact falls within the Upper Gariep Alluvial vegetation type. This vegetation type appears to be less impacted by the invasion of exotic species than the Highveld Alluvial vegetation type, possibly due to less agriculture in the surrounding areas. In the areas along the banks of the river the disturbed riparian vegetation has been invaded by some exotic species and pioneer grasses.

2.2.5 PES causes and sources

The PES for the various components as well as the reasons for the PES are summarised in Table 2.11.

Table 2.11: EWR 17: Causes and sources

	PES	Causes	Sources	F[1]/NF[2]
Hydrology	D/E	Reduced moderate events and event hydrology as well as increased baseflows during low flow months	Irrigation return flows from Vaalharts Irrigation Scheme and Spitskop Dam upstream	F
Physico-chemical	D	High salts	Mining impacts, agricultural return flows (salts and nutrient) and sedimentation	F/NF
		High nutrients	Same as above	F/NF
Geomorphology	D	Increased baseflows and a slight reduction in small floods which may cause reduced sediment transport, increasing deposition and decreasing flushing of fines and scour	Irrigation return flows and Spitskop Dam upstream	F
Riparian Vegetation	D	Homogenisation of riparian zone	Enchroachment of terrestrial exotic invasive species (Anthropogenic)	NF
		Aquatic exotic invasive species	Increased nutrients	F

	PES	Causes	Sources	F[1]/NF[2]
Fish	D	Non availability of specific habitat cover units due to the growth of invasive aquatic macrophytes	Nutrient enrichment due to runoff from upstream agricultural activities	NF
		Lack of access to upstream river reaches for fish species with this migratory requirement	Upstream Spitskop Dam a significant upstream migration barrier breaking the link between the Vaal and Harts River catchments	NF
Inverts	C/D	Water quality have a detrimental effect on taxa that have a high and moderate preference for good water quality	Agricultural return flows from upstream agriculture	NF
		Very high floods resulted in washing away taxa that is associated with fast flowing waters	Unnatural releases from Spitskop Dam that is upstream of the site.	F

1 Flow related 2 Non Flow related

2.2.6 PES Trend

An estimate was made whether the specialist components drivers (quantity, quality and geomorphology) and responses (fish, macroinvertebrates and riparian vegetation) are stable or changing. The results are summarised in Table 2.12.

Table 2.12: EWR 17: Trend

	PES	Trend	Reasons	Confidence
Hydrology	D/E	Stable	Existing irrigation upstream as well as Spitskop Dam not likely to change	3
Physico-chemical	D	Slightly negative	Trapped salts and nutrients in the dam sediment, agricultural return flows and increased mining impacts	2.5
Geomorphology	D	Stable	Existing irrigation upstream as well as Spitskop Dam	3
Riparian vegetation	D	Negative	Increased alien invasive plant encroachment without management intervention	4
Fish	D	Slightly negative	Observed abundances of certain species (***B.trimaculatus; B.anoplus; B.paludinosus, Tilapia sparrmanii)*** lower than expected suggesting that the abundances of these species may be decreasing	3
Inverts	C/D	Stable	Macroinvertebrates have adjusted to the current conditions (flow regime and quality)	2

2.2.7 PES EcoStatus

To determine the EcoStatus, the macroinvertebrates and fish results are combined to determine the instream category. The Vegetation Response Assessment Index (VEGRAI) category and confidence is then included in the assessment index (see Table 2.13) and the integrated EcoStatus is calculated. The EcoStatus category for EWR site 17 on the Harts River is a D category.

Table 2.13: EWR 17: Integrated EcoStatus

INSTREAM BIOTA	Importance Score	Weight	EC %	EC
FISH				
1.What is the natural diversity of **fish** species with different flow requirements	3	80		
2.What is the natural diversity of **fish** species with a preference for different cover types	4	100		
3.What is the natural diversity of **fish** species with a preference for different flow depth classes	3	60		
4. What is the natural diversity of **fish** species with various tolerances to modified water quality	2	30		
FISH ECOLOGICAL CATEGORY	12	270	**46.2**	**D**
AQUATIC INVERTEBRATES				
1. What is the natural diversity of **invertebrate** biotopes	2	80		
2. What is the natural diversity of **invertebrate** taxa with different velocity requirements	2	100		
3. What is the natural diversity of **invertebrate** taxa with different tolerances to modified water quality	2	60		
AQUATIC INVERTEBRATE ECOLOGICAL CATEGORY	**6**	240	**57.7**	**C/D**
INSTREAM ECOLOGICAL CATEGORY (No confidence)		510	**51.8**	**D**

INSTREAM ECOLOGICAL CATEGORY WITH CONFIDENCE	Confidence rating	Proportions	Modified weights
Confidence rating for **fish** information	3	0.50	23.10
Confidence rating for **macro-invertebrate** information	3	0.50	29.35
	6	1.00	52.45
INSTREAM ECOLOGICAL CATEOGORY	**EC**		**D**

RIPARIAN VEGETATION	EC %	EC
RIPARIAN VEGETATION ECOLOGICAL CATEGORY	**47.6**	**D**

ECOSTATUS	Confidence rating	Proportions	Modified weights
Confidence rating for instream biological information	3	0.44	23.14
Confidence rating for riparian vegetation zone information	3.8	0.56	26.60
	6.8	1.00	49.74
ECOSTATUS	**EC**		**D**

2.2.8 Recommended Ecological Category (REC) and Alternative Ecological Categories (AEC)

The REC is determined based on ecological criteria and considers the EIS, the restoration potential of the system and attainability there-of. The ecostatus is a D category with a moderate EIS, thus it is recommended that the PES is maintained, thus the REC is a D category at EWR site 17.

Only an AEC up has been assessed as the ecostatus is already in a D category.

AEC up: C

The following changes were considered to assess the system:

- Increased moderate events in March
- Water quality management will be slow as 70 years of soils nutrients and salts to be flushed out
- Large flood to remove instream vegetation.

Both the fish and macroinvertebrates benefit from the increased moderate events in March and the flood to clean the system and improved half a category. This resulted in the instream category to improve from a D to a C/D category. However, without clearing of the alien invasive plants, the overall ecostatus remain in a D category.

The REC and AEC categories per specialist and overall category are summarised in Table 2.14.

Table 2.14: EWR 17: Summary of the REC and AEC

Driver component	PES (REC)	Trend	AEC Up
Hydrology	D/E	Stable	D
Water quality	D	Lightly negative	D
Geomorphology	D	Stable	D
Response component			
Fish	D	Slightly negative	C/D
Macroinvertebrates	C/D	Stable	C
Instream EC	D	Stable	C/D
Riparian vegetation	D	Negative	D
Ecostatus	**D**	**Stable**	**D**
Ecological Importance and Sensitivity	**Moderate**		
Recommended Ecological Category	**D**		

2.3 EWR 18: VAAL RIVER: SCHMIDTSDRIFT

EWR site 18 (see Figure 2.3) is situated on the Vaal River at S28.705; E24.076 in quaternary catchment C29B. The natural MAR at the EWR site is 3 347.2 million m^3.

Figure 2.3: View of EWR site 18 on Vaal River at Schmidtsdrift

2.3.1 Data availability

The data available at EWR site 18 is summarised in Table 2.15.

Table 2.15: EWR 18: Summary of data availability

Component	Data availability	Confidence
Hydrology	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 Modelled data represents the period 1920 to 1994.	2.5
Physico-chemical	Limited water quality data at C9H024Q01 1995 – 2008 (n = 163)	2

Geomorphology	Historical aerial photographs from Land Surveyors Offices. Google Earth imagery of the site and catchment was available. Ecological reports and specialist assessments for this study.	3
Riparian vegetation	Google Earth imagery and aerial photos. Hydraulic cross-section at the EWR site together with surveyed key vegetation points for setting flows. Data collected from field assessment during 2008. Available historical data on biomes, bioregions and vegetation type etc.	4
Fish	Skelton, 2001 and expected fish species lists obtained from Neels Kleynhans at DWA, also available as a publication on the DWA website.	4
Macroinvertebrates	Rivers Database 2008, and personal communication with Christa Thirion	2

2.3.2 Ecological Importance and Sensitivity

The Ecological Importance and Sensitivity (EIS) for this site were rated as moderate as shown in Table 2.16. *B kimberleyensis* was sampled at the site. The species/taxon richness is high although only limited habitats were available.

Table 2.16: EWR 18: EIS results

DETERMINANTS / METRICS	PRESENT RATING (0 - 4)	COMMENTS
BIOTA (RIPARIAN & INSTREAM)		
Rare & endangered	4	*B kimberleyensis* found and near threatened expected and *A sclateri* expected. Other fish are isolated within this reach of river due to regulations and no fish ladders.
Unique (endemic, isolated, etc.)	2	*B kimberleyensis, L capensis, B aeneus, L umbratus* all endemic to Orange Vaal, inverts ubiquitous at family level.
Intolerant (flow & flow related water quality)	2	Fish none that are intolerant to water quality, *A scl, B Aen, L cap, B kim* are moderately intolerant to no flow (need some flowing habitat types), flow related inverts with a high preference to flow related habitat types, *Ceratopogonidae*.
Species/taxon richness	3	26 invertebrate families. ASPT 4.2, 8 fish recorded of 11 fish species expected.
RIPARIAN & INSTREAM HABITATS		
Diversity of types	2	Pools, sand, marginal vegetation,-limited habitats available, large mats of parrots feather
Refugia	3	Deep pools available, closely linked to Vaal as feeder tributaries.

DETERMINANTS / METRICS	PRESENT RATING (0 - 4)	COMMENTS
Sensitivity to flow changes	2	Sensitive to flow modification, less natural zero flows.
Sensitivity to flow related water quality changes	3	Water quality drives algal growth that smothers habitat, system already impacted and no assimilative capacity left.
Migration route/corridor (instream & riparian)	1	Important migratory route that is cut off by Spitskop and other dams and weirs, highly regulated system, few feeder tributaries.
Importance of conservation & natural areas	1	No longer any provincial nature reserves - now being used for diamond mine.
MEDIAN	2	
EIS	**MODERATE**	

2.3.3 Reference Conditions

The reference conditions for the components are summarised in Table 2.17. Additional information on fish, macroinvertebrate and riparian vegetation is provided in the specialist reports.

Table 2.17: EWR 18: Reference conditions

Component	Reference conditions	Conf
Hydrology	Simulated natural flows for the period 1920 to 1994 were available.	3
Physico-chemical	The DWAF (2006 draft 2) study on the Integrated Water Quality Management Plan for the Vaal River System: Task 2. Water Quality Status Assessment of the Vaal River System was used as a reference guide for this water quality assessment. The water quality database was updated from DWAF up to 2008.	3
Geomorphology	Sinuous, single thread channel within an alluvial reach. Bed material consists mainly of silt and clay.	3
Riparian vegetation	**Marginal zone** Grass and sedge dominated zone with *Cyperus* spp, *Panicum coloratum* and *Cenchrus cilliaris* being prominent with a major herbaceous component. *Acacia karroo* may encroach on this zone in areas but very sparsely. *Phragmites australis* is likely to occur in patches in shallower water and along lateral bars. **Lower zone** Grass dominated zone with minor woody component consisting mainly of *S. mucronata* and *Acacia karroo* and *Searsia* spp could also form a minor to major woody component. Grasses (especially *Cenchrus cilliaris, Imperata cylindrica* and *Miscanthus junceus*) are also expected to occur. Upper portion of lower zone expected to be colonised by terrestrial grasses such *Chloris virgata, Aristida* spp and *Eragrostis* spp due to this area's proximity to the terrestrial system adjacent to the river. **Upper zone** Grass dominated (mainly terrestrial grasses and low karroid shrubs) with a minor woody component comprised mainly of *Acacia karoo* and *Searsia* spp.	3.5

Component	Reference conditions	Conf
Fish	Reference data obtained from Kleynhans CJ, Louw MD, Moolman J. 2007. Reference frequency of occurrence of fish species in South Africa. Report produced for the Department of Water Affairs and Forestry (Resource Quality Services) and the Water Research Commission. 11 fish species expected at the EWR site (see Appendix B or detail on reference species).	3
Macroinvertebrates	The reference South African Scoring System version 5 (SASS5) score is 125 and the Average Score Per Taxon (ASPT) is 5.6. Reference data obtained from Christa Thirion. Reference taxa are listed in Appendix C.	2.5

2.3.4 Present Ecological State

A summary of the Present Ecological State (PES) per specialist component are provided below, with detail assessments available in the specialist reports.

Hydrology (PES = C)

Reduced base flows, moderate events and event hydrology occur at the EWR site. This is mainly due to the operation of the lower part of the Vaal River system to only release adequate water from Bloemhof Dam to satisfy the user needs with little or no spills at Douglas Weir to the Orange River.

Geomorphology (PES = C/D)

Flows at this site have been critically reduced relative to the natural conditions. The large reduction of flows has degraded the in-channel condition through reduced scour and bed activation events and the riparian zone due to reduced inundation events, and overall the entire river ecosystem due to the frequent extreme low flow conditions. The in-channel habitat is choked by the excessive algal growth.

Thus although the impacts of the upstream dams on sediment reduction are lessened due to the ameliorating effects of tributaries, the flow regime for this reach has changed so much that the PES is now in a C/D.

Physico-chemical variables (PES = C)

The water quality data from monitoring site C9H024 was used for the PES. The data shows high salts and low nutrients. High growth of aquatic macrophytes is present, suggesting that the ammonia is higher than the nutrients.

Fish (PES = C)

Ecological Category of C that was recorded at site EWR 18 can be attributed primarily to the absence of *Austroglanis sclateri* and *Barbus anoplus* from the observed fish assemblage and the lower than expected abundance of *Barbus paludinosus*, *Barbus trimaculatus*, and *Labeobarbus kimberleyensis.* Excessive algal growth and limited availability of cover also contributed to the PES of a C for the fish.

In addition to the indigenous species, four introduced fish species were recorded namely *Cyprinus carpio* (Carp), *Gambusia affinis* (Mosquitofish), *Ctenopharyngodon idella* (Grass carp) and *Oreochromis mossambicus* (Mozambique tilapia).

Macroinvertebrates (PES = C/D)

The Ecological Category of C/D is a combination of flow and non-flow related impacts. Impacts mostly related to changes in flow regime due to Bloemhof Dam regulating flows, and the poor water quality. This resulted in SASS5 scores of 33 (September) and 74 (April). The key families that were not sampled were: Baetidae >2spp, Ecnomidae, Elmidae, Heptageniidae, Hydropsychidae >2spp, Oligoneuridae, Perlidae and Philopotamidae.

Riparian vegetation (PES = C/D)

Current status: The area is currently considerably degraded due to the mining activities on the banks of the river resulting in an inflow of silt and the introduction of exotic species in the area. The number of exotic species occurring in the area is considerably less (20%) than many of the other sites. The exotic species that appears to be having the greatest impact on the area is the aquatic weed *Myriophyllum spicatum* which has colonised and taken over the aquatic habitat. This species, if it remains unchecked may cause considerable damage in future. Furthermore, the lack of stochastic events, such as flooding may be aiding the colonisation by this species at site EWR 18.

Reasons for PES: The area has been impacted by construction of bridges, mining activities and other infrastructure. In these areas along the banks of the river the disturbed riparian vegetation has been invaded by some exotic species and pioneer grasses.

2.3.5 PES causes and sources

The PES for the various components as well as the reasons for the PES are summarised in Table 2.18.

Table 2.18: EWR 18: Causes and sources

	PES	Causes	Sources	F[1]/NF[2]
Hydrology	C	Reduced baseflows, moderate events and event hydrology	Current operation of the lower Vaal system	F
Physico- chemical	C	High salinity	Mining impacts	F
		Nutrients (high ammonia)	Degrading algal matter visible at site	F
Geomorphology	C/D	Critically reduced baseflows and removal of almost all small and moderate floods cause reduced sediment transport resulting in deposition of fines.	Current operation of the lower Vaal system	F
Riparian Vegetation	C/D	Encroachment of terrestrial exotic invasive species	Mining activities, bridges and other infrastructure	NF
		Colonisation of aquatic exotic invasive weeds	Nutrient enrichment	NF

	PES	Causes	Sources	F[1]/NF[2]
Fish	C	Non availability of specific habitat cover units due to the growth of invasive aquatic macrophytes	Nutrient enrichment due to runoff from upstream agricultural activities	NF
		Lack of access to upstream river reaches for fish species with this migratory requirement	Upstream Vaal Harts Weir in the Vaal River, downstream Douglas weir	NF
		Presence of invasive alien fish species	Some species such as *Gambusia affinis* were introduced as mosquito control agents, other species such as *Cyprinus carpio* are introduced for sport fishing. *Oreochromis mossambicus* probably got introduced as escapees from aquaculture projects.	NF
Inverts	C/D	Unavailability of fast flowing conditions	Dams upstream and release strategy	F
		Taxa that are water quality sensitive are absent.	Poor water quality from Harts River and mining activities adjacent to the river	NF

1 Flow related 2 Non Flow related

2.3.6 PES Trend

An estimate was made whether the specialist components drivers (quantity, quality and geomorphology) and responses (fish, macroinvertebrates and riparian vegetation) are stable or changing. The results are summarised in Table 2.19.

Table 2.19: EWR 18: Trend

	PES	Trend	Reasons	Confidence
Hydrology	C	Stable	Current operation of the system not to change in near future	3
Physico-chemical	C	Slightly negative	There is high algal growth in the river	2
Geomorphology	C/D	Stable	System has adapted to the current operation	2.5
Riparian vegetation	C/D	Negative	Ongoing disturbance of mining activities results in colonisation of alien invasive plants	4
Fish	C	Negative	Observed abundances of certain species (*B.trimaculatus; B.anoplus; B.paludinosus, Tilapia sparrmanii)* lower than expected suggesting that the abundances of these species may be decreasing due to flow and quality changes	4
Inverts	C/D	Stable	Macroinvertebrates have adjusted to the changes in the flow and poor water quality	2

2.3.7 PES EcoStatus

To determine the EcoStatus, the macroinvertebrates and fish results are combined to determine the instream category. The Vegetation Response Assessment Index (VEGRAI) category and confidence is then included

in the assessment index (see Table 2.20) and the integrated EcoStatus is calculated. The EcoStatus category for EWR site 18 on the Vaal River is a category C/D.

Table 2.20: EWR 18: Integrated EcoStatus

INSTREAM BIOTA	Importance Score	Weight	EC %	EC
FISH				
1.What is the natural diversity of **fish** species with different flow requirements	3	60		
2.What is the natural diversity of **fish** species with a preference for different cover types	1	100		
3.What is the natural diversity of **fish** species with a preference for different flow depth classes	2	80		
4. What is the natural diversity of **fish** species with various tolerances to modified water quality	4	30		
FISH ECOLOGICAL CATEGORY	10	270	**63.7**	**C**
AQUATIC INVERTEBRATES				
1. What is the natural diversity of **invertebrate** biotopes	2	80		
2. What is the natural diversity of **invertebrate** taxa with different velocity requirements	1	100		
3. What is the natural diversity of **invertebrate** taxa with different tolerances to modified water quality	4	60		
AQUATIC INVERTEBRATE ECOLOGICAL CATEGORY	**7**	240	**58.0**	**C/D**
INSTREAM ECOLOGICAL CATEGORY (No confidence)		510	**60.4**	**C/D**

INSTREAM ECOLOGICAL CATEGORY WITH CONFIDENCE	Confidence rating	Proportions	Modified weights
Confidence rating for **fish** information	3	0.43	27.30
Confidence rating for **macro-invertebrate** information	4	0.57	33.14
	7	1.00	60.44
INSTREAM ECOLOGICAL CATEOGORY	**EC**		**C/D**

RIPARIAN VEGETATION	EC %	EC
RIPARIAN VEGETATION ECOLOGICAL CATEGORY	**60.3**	**C/D**

ECOSTATUS	Confidence rating	Proportions	Modified weights
Confidence rating for instream biological information	3.6	0.54	32.85
Confidence rating for riparian vegetation zone information	3.0	0.46	27.53
	6.6	1.00	60.38
ECOSTATUS	**EC**		**C/D**

2.3.8 Recommended Ecological Category (REC) and Alternative Ecological Categories (AEC)

The REC is determined based on ecological criteria and considers the EIS, the restoration potential of the system and attainability there-of. The EIS at EWR site 18 is moderate and as the potential to change the current operation of the lower Vaal is small, the REC for EWR site 18 is to maintain the PES category of a C/D.

Alternative categories up and down were assessed for the site.

AEC up: C

The following changes were considered for the improved alternative category:

Changes in hydrology

- Allow more moderate flows
- Allow freshet cues in summer in October and November

Water quality management

- Implement water quality guidelines/objectives
- Reduce nutrients in the system through increased moderate /freshets
- Reduce sediments through better management of the mining activities along the river

The above changes resulted in the improvement of the macroinvertebrates and the instream PES from a C/D to a C category. This resulted in the ecostatus (AEC) to improve to a C.

AEC down: D

The changes considered to assessed the down AEC were:

Changes in hydrology

- Reduce moderate flows
- No freshet cues in summer in October and November

Riparian vegetation

- Greater impacts of diamond mining and no rehabilitation (increased sediments)

Water quality management

- Implement water quality guidelines/objectives
- Increased salts due to less flows for dilution.

The above changes resulted in all the response components as well as the ecostatus (AEC) to deteriorate to a D category.

The REC and AEC categories per specialist and overall category are summarised in Table 2.21.

Table 2.21: EWR 18: Summary of the REC and AEC

Driver component	PES (REC)	Trend	AEC Up	AEC down
Hydrology	C	Stable	C	D
Water quality	C	Slightly negative	C	D
Geomorphology	C/D	Stable	C/D	D
Response component				
Fish	C	Negative	C	D
Macroinvertebrates	C/D	Stable	C	D
Instream EC	C/D	Stable	C	D
Riparian vegetation	C/D	Negative	C/D	D
Ecostatus	**C/D**	**Slightly negative**	**C**	**D**
Ecological Importance and Sensitivity	**Moderate**			
Recommended Ecological Category	**C/D**			

2.4 EWR 19: RIET RIVER AT LILLYDALE LODGE

EWR site 19 is situated on the Riet River (see Figure 2.4) at Lillydale Lodge (S29.038; E24.503) in quaternary catchment C51L. The natural MAR at the EWR site is 403.86 million m^3.

Figure 2.4: View of EWR site 19 on the Riet River at Lillydale Lodge

2.4.1 Data availability

The data available at EWR site 19 is summarised in Table 2.22.

Table 2.22: EWR 19: Summary of data availability

Component	Data availability	Confidence
Hydrology	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. The observed data has a number of gaps which makes it difficult to have closely comparable results. Modelled data represents the period 1920 to 1994.	2
Physico-chemical	Water quality data available from C5H048Q01 1990 – 2008 (n = 789)	2
Geomorphology	Historical aerial photographs from Land Surveyors Offices. Google Earth imagery of the site and catchment was available. Ecological reports and specialist assessments for this study.	3
Riparian vegetation	Google Earth imagery and aerial photos. Hydraulic cross-section at the EWR site together	3

Component	Data availability	Confidence
	with surveyed key vegetation points for setting flows. Data collected from field assessment during 2008. Available historical data on biomes, bioregions and vegetation type etc.	
Fish	Skelton, 2001 and expected fish species lists obtained from Neels Kleynhans at DWA, also available as a publication on the DWA website. Previous rapid Reserve study results for the Modder/Riet (Free State Regional Office)	4
Macroinvertebrates	Rivers Database 2008 and personal communication with Christa Thirion. Previous rapid Reserve study results for Modder/Riet (Free State Regional Office)	3

2.4.2 Ecological Importance and Sensitivity

The Ecological Importance and Sensitivity (EIS) for this site were rated as high due to the following:

Presence of *B kimberleyensis*, high species/taxon richness, a diversity of possible habitat types are available, especially deep pools that serves as refugia, important migration route between Vaal and the Riet River and surrounding area was recently proclaimed as a National Park.

Table 2.23: EWR 19: EIS results

DETERMINANTS / METRICS	PRESENT RATING (0 - 4)	COMMENTS
BIOTA (RIPARIAN & INSTREAM)		
Rare & endangered	4	*B kimberleyensis* found and near threatened expected and A sclateri expected, other fish are isolated within this reach of river due to regulations and no fish ladders.
Unique (endemic, isolated, etc.)	2	*B kimberleyensis, L capensis, B aeneus, L umbratus* all endemic to Orange Vaal, inverts ubiquitous at family level.
Intolerant (flow & flow related water quality)	2	Fish none that are intolerant to water quality, *A scl, B aen, L cap, B kim* are moderately intolerant to no flow (need some flowing habitat types), flow related inverts with a high preference to flow related habitat types, *Ceratopogonidae, Gyrinidae, Hydropsychidae, Muscidae, Simiuliidae. Turbellaia*.
Species/taxon richness	3	28 invertebrate families. ASPT 5.2, 5 fish recorded of 8 fish species expected.
RIPARIAN & INSTREAM HABITATS		
Diversity of types	3	Pools, sand, marginal vegetation, riffles- diverse and abundant available, algal growth in riffles.

DETERMINANTS / METRICS	PRESENT RATING (0 - 4)	COMMENTS
Refugia	3	Deep pools available; closely linked to Vaal as feeder tributaries.
Sensitivity to flow changes	2	Large river and less sensitive to flow modification.
Sensitivity to flow related water quality changes	2	Limited algal growth, system already impacted and reduced assimilative capacity.
Migration route/corridor (instream & riparian)	3	Important migratory route from Vaal to Modder & Riet, dams far upstream.
Importance of conservation & natural areas	3	National park recently proclaimed at site.
MEDIAN	3	
EIS	**HIGH**	

2.4.3 Reference Conditions

The reference conditions for the components are summarised in Table 2.24. Additional information on fish, macroinvertebrate and riparian vegetation is provided in the specialist reports.

Table 2.24: EWR 19: Reference conditions

Component	Reference conditions	Conf
Hydrology	Modelled natural flows were provided for the period 1920 to 1994	2
Physico-chemical	The DWAF (2006 draft 2) study on the Integrated Water Quality Management Plan for the Vaal River System: Task 2. Water Quality Status Assessment of the Vaal River System was used as a reference guide for this water quality assessment. The water quality database was updated from DWAF up to 2008.	3
Geomorphology	A single thread channel within a bedrock reach with pools and riffles. The bed material is mainly bed-rock with boulders	3
Riparian vegetation	Marginal zone Grass and sedge dominated zone with *Cyperus* spp, *Panicum coloratum* and *Cenchrus cilliaris* being prominent with a major herbaceous component. *Acacia karroo* may encroach on this zone in areas but very sparsely. *Phragmites australis* is likely to occur in patches in shallower water and in pools. Lower zone Grass dominated zone with minor to moderately developed woody component consisting mainly of *Acacia karroo* and *Searsia* spp. Grasses (especially *Cenchrus cilliaris, Imperata cylindrica* and *Miscanthus junceus*) are also expected to occur. Upper portion of lower zone expected to be colonised by terrestrial grasses such *Chloris virgata, Aristida* spp and *Eragrostis* spp due to this area's proximity to the terrestrial system adjacent to the river. Upper zone	3.5

Component	Reference conditions	Conf
	Grass and Karroid shrub dominated (terrestrial species) with a minor woody component comprised mainly of *Acacia karoo* and *Searsia* spp. In steeper rockier areas larger shrubs and small trees like *Diospyros lyceoides*, Ziziphus mucronata and Acacia karroo may dominate.	
Fish	Reference data obtained from Kleynhans CJ, Louw MD, Moolman J. 2007. Reference frequency of occurrence of fish species in South Africa. Report produced for the Department of Water Affairs and Forestry (Resource Quality Services) and the Water Research Commission. 8 fish species expected at the EWR site (see Appendix B or detail on reference species).	3
Macroinvertebrates	The reference South African Scoring System version 5 (SASS5) score is 160 and the Average Score Per Taxon (ASPT) is 5.6. Reference data obtained from Christa Thirion. Reference taxa are listed in Appendix C.	3

2.4.4 Present Ecological State

A summary of the Present Ecological State (PES) per specialist component are provided below, with detail assessments available in the specialist reports.

Hydrology (PES = D)

The main impacts are on the moderate events and the event hydrology with a small increase in the baseflows during winter. However, the confidence in the gauged data is very low resulting in low confidence in the simulated hydrology.

Geomorphology (PES = C)

Relative to the natural hydrology the present day flows at this site are characterised by reduced floods, reduced wet season baseflows and elevated dry season baseflows.

The EWR site is located in a steep bedrock gorge section of the river. Most of the bed of the active channel is exposed bedrock (i.e. sediment free), and there is little available sediment in the active channel due to the high energy at the site. There are large dams upstream and these would have a low impact on sediment trapping, but extreme reductions in floods were identified by the hydrologists. Thus although the morphology of the site is relatively resilient to any flow changes, PES for the reach was calculated to be a low C due to the far greater sensitivity of the up- and downstream alluvial reaches to the reduced floods.

Physico-chemical variables (PES = D)

The water quality data from monitoring site C5H048 shows extremely high salts (agricultural activity even on the river banks) and moderate to high nutrients (agricultural return flows). There are dams upstream that are used for irrigation (trapping the nutrients and salts). Most nutrients are due to diffuse pollution rather than point source.

Fish (PES = D)

Ecological Category of D that was determined for site EWR 19 can be attributed to the absence of *Austroglanis sclateri*, *Labeobarbus kimberleyensis* and *Labeo umbratus* from the observed fish assemblage.

The flow modification due to upstream use and reduction in cover were the main contributing factors to the D category for fish.

In addition to the indigenous species, four introduced fish species were recorded namely *Cyprinus carpio* (Carp), *Gambusia affinis* (Mosquitofish), *Ctenopharyngodon idella* (Grass carp) and *Oreochromis mossambicus* (Mozambique tilapia) are present in the system.

Macroinvertebrates (PES = C)

The SASS5 scores were 124 (September) and 87 (April) respectively resulting in an ecological category of C. This can be attributed to a combination of flow and non-flow related impacts. Impacts are mostly related to changes in the flow regime due to upstream dams in the Modder and Riet Rivers and the poor water quality return flows from the upstream irrigation. The available habitat was diverse.

Key families not sampled were: Baetidae >2spp, Ecnomidae, Elmidae, Heptageniidae, Hydropsychidae >2spp, Perlidae, Philopotamidae and Tricorythidae.

Riparian vegetation (PES = C/D)

Current status: The area is currently degraded due to the introduction of a number of exotic species and the previous mining and farming impacts. The exotic species in the area contribute to a total of 20% of the total number of species identified during the surveys, but do make up a considerable amount of the local biomass.

Reasons for PES: Exotic species occur especially in areas where disturbance has taken place due to agricultural activities. The area has been declared a national park but has been previously impacted by mining activities and farming activities. In these previously mined areas along the banks of the river the disturbed riparian vegetation has been invaded by some exotic species and pioneer grasses.

2.4.5 PES causes and sources

The PES for the various components as well as the reasons for the PES are summarised in Table 2.25.

Table 2.25: EWR 19: Causes and sources

	PES	Causes	Sources	F[1]/NF[2]
Hydrology	D	Increased dry season baseflows and reduction in moderate events and event hydrology	Dams upstream in the system and return flows from irrigation and possibly the transfer of water from the Orange River	F
Physico- chemical	D	High salinity	Soils sediment in dams upstream	F/NF
		Moderate nutrients	Diffuse pollution from agricultural practices. Long lead time to leach out of the soils.	F/NF
		High ammonia	Ammonia from the degrading algal matter.	F/NF

	PES	Causes	Sources	F[1]/NF[2]
Geomorphology	C	Decreased baseflows and a reduction in floods have reduced sediment transport; so flushing of fines and scour is reduced	Dams upstream in the catchment	F
Riparian Vegetation	D	Infestation of terrestrial exotic invasive species	Disturbed riparian zones due to agricultural and mining activities	NF
		Growth of aquatic exotic invasive species	Anthropogenic (increased nutrients)	F
Fish	D	Non availability of specific habitat cover units due to the growth of invasive aquatic macrophytes	Nutrient enrichment due to runoff from upstream agricultural activities	NF
		Shifts in seasonality with specific reference to the reduction in spring flushes and moderate flow events	Upstream dams and abstraction for irrigation purposes	F
		Reduction in water quality due to runoff from agriculture	Extensive agriculture in the catchment often to within the riparian zone	NF
Inverts	C	Loss of taxa that shows a high requirement for fast and moderately fast flows	Water abstraction for irrigation purposes upstream in the Riet River	F
		Loss of taxa that has a high and moderate requirement for unspoilt water quality	Agricultural runoff due to irrigation on the banks of the river	NF

1 Flow related 2 Non Flow related

2.4.6 PES Trend

An estimate was made whether the specialist components drivers (quantity, quality and geomorphology) and responses (fish, macroinvertebrates and riparian vegetation) are stable or changing. The results are summarised in Table 2.26.

Table 2.26: EWR 19: Trend

	PES	Trend	Reasons	Confidence
Hydrology	D	Stable	No change in the situation in near future due to existing dams upstream and ongoing irrigation in the catchment	2
Physico-chemical	D	Negative	Diffuse pollution, mainly from irrigation return flows	3
Geomorphology	C	Stable	System has stabilised with the current reduced moderate events and increased baseflows	2
Riparian vegetation	D	Negative	Ongoing agricultural activities on the banks will result in increased infestation of alien invasive plants	4
Fish	D	Stable	Higher than expected abundances for several fish species	3
Inverts	C	Stable	Macroinvertebrates have adjusted to the current flows and poor water quality	2

2.4.7 PES EcoStatus

To determine the EcoStatus, the macroinvertebrates and fish results are combined to determine the instream category. The Vegetation Response Assessment Index (VEGRAI) category and confidence is then included in the assessment index (see Table 2.27) and the integrated EcoStatus is calculated. The EcoStatus for EWR site 19 on the Riet River is a D category.

Table 2.27: EWR 19: Integrated EcoStatus

INSTREAM BIOTA	Importance Score	Weight	EC %	EC
FISH				
1.What is the natural diversity of **fish** species with different flow requirements	3	80		
2.What is the natural diversity of **fish** species with a preference for different cover types	4	100		
3.What is the natural diversity of **fish** species with a preference for different flow depth classes	3	60		
4. What is the natural diversity of **fish** species with various tolerances to modified water quality	2	30		
FISH ECOLOGICAL CATEGORY	12	270	**43.0**	**D**
AQUATIC INVERTEBRATES				
1. What is the natural diversity of **invertebrate** biotopes	2	80		
2. What is the natural diversity of **invertebrate** taxa with different velocity requirements	2	100		
3. What is the natural diversity of **invertebrate** taxa with different tolerances to modified water quality	2	60		
AQUATIC INVERTEBRATE ECOLOGICAL CATEGORY	**6**	240	**70.0**	**C**
INSTREAM ECOLOGICAL CATEGORY (No confidence)		510	**55.2**	**D**

INSTREAM ECOLOGICAL CATEGORY WITH CONFIDENCE	Confidence rating	Proportions	Modified weights
Confidence rating for **fish** information	3	0.5	21.50
Confidence rating for **macro-invertebrate** information	3	0.5	35.00
	6	1.0	56.50
INSTREAM ECOLOGICAL CATEOGORY	**EC**		**D**

RIPARIAN VEGETATION	EC %	EC
RIPARIAN VEGETATION ECOLOGICAL CATEGORY	**57.7**	**C/D**

ECOSTATUS	Confidence rating	Proportions	Modified weights

Confidence rating for instream biological information	3.0	0.44	24.93
Confidence rating for riparian vegetation zone information	3.8	0.56	32.24
	6.8	1.00	57.17
ECOSTATUS	**EC**		**D**

2.4.8 Recommended Ecological Category (REC) and Alternative Ecological Categories (AEC)

The REC is determined based on ecological criteria and considers the EIS, the restoration potential of the system and attainability there-of.

The EIS at EWR 19 is high due to a number of factors. This area has also been declared a National Park. However due to the current irrigation impacts at the site and the large dams in the system improvement in the short term is not foreseen. Specific management actions are required to improve the system through reduced irrigation and changes to the flow releases from the upstream dams. The REC is thus to maintain the PES of a D category. Only an up alternative category was considered for the system at the EWR site.

AEC up: C

The following changes were considered to assess the system:

Hydrology

- Releases from dams for first flushes and moderate events
- Decrease irrigation usage to change seasonality towards natural

Water Quality

- Water quality improvement – use of less fertilizers

The above changes resulted in a change of all the response components to a C category and also the overall ecostatus (AEC). The REC and AEC categories per specialist and overall category are summarised in Table 2.28.

Table 2.28: EWR 19: Summary of the REC and AEC

Driver component	**PES (REC)**	**Trend**	**AEC Up**
Hydrology	D	Stable	D
Water quality	D	Negative	C/D
Geomorphology	C	Stable	C
Response component			
Fish	D	Stable	C
Macroinvertebrates	C	Stable	C
Instream EC	D	Stable	C
Riparian vegetation	C/D	Negative	C
Ecostatus	**D**	**Stable**	**C**
Ecological Importance and Sensitivity	**High**		
Recommended Ecological Category	**D**		

3 CONCLUSIONS

In summary the Ecostatus for the Lower Vaal range from an E to a C/D category and the Ecological Importance and Sensitivity is moderate for all the EWR sites except the site on the Riet River that has a high EIS. Various factors contribute to the low ecostatus at the EWR sites, but reduced baseflows and moderate events as well as poor water quality are the main sources. Figure 3.1 summarises the results per EWR site. The difficulty in improving the ecostatus is due to the Vaal River system being operated as a water supply scheme for irrigation and drinking water and not for ecological sustainability purposes.

Vaal River at Bloemhof Dam

SITE 16			
Components	PES	EIS	REC
Hydrology	D	Moderate	D
Water Quality	C		C
Geomorphology	D/E		D/E
Fish	E		E
Invertebrates	C/D		C/D
Riparian Veg	F		D/E
ECOSTATUS	E		E

Harts River at Lloyds Weir

SITE 17			
Components	PES	EIS	REC
Hydrology	D/E	Moderate	D/E
Water Quality	D		D
Geomorphology	D		D
Fish	D		D
Invertebrates	C/D		C/D
Riparian Veg	D		D
ECOSTATUS	D		D

Vaal River at Schmidtsdrift

SITE 18			
Components	PES	EIS	REC
Hydrology	C	Moderate	C
Water Quality	C		C
Geomorphology	C/D		C/D
Fish	C		C
Invertebrates	C/D		C/D
Riparian Veg	C/D		C/D
ECOSTATUS	C/D		C/D

Riet River at Lillydale Lodge

SITE 19			
Components	PES	EIS	REC
Hydrology	D	High	D
Water Quality	D		D
Geomorphology	C		C
Fish	D		D
Invertebrates	C		C
Riparian Veg	C/D		C/D
ECOSTATUS	D		D

Figure 3.1 Summary of PES, EIS and REC for the EWR sites in the Lower Vaal

The hydrology of the Lower Vaal WMA is impacted in the main stem of the Vaal by the Vaal Dam, Vaal Barrage (completed in 1919), Bloemhof Dam and Vaalharts Weir. The flow regime in the main stem of the Vaal is impacted by the following:

- Vaal Dam storage
- Releases from Vaal Dam to dilute salts to 600 mg/L TDS (mainly in winter)
- Releases from Vaal Dam and Vaal River Barrage to supply the Vaal Harts irrigation scheme (completed 1938)
- Vaal Harts irrigation scheme transfer (Vaalharts Weir) and return flows
- Transfer from Orange River to the lower Riet River

- Operation of the Vaal River to ensure minimum flows at Douglas Weir just upstream of the Vaal and Orange confluence.

This altered flow regime has resulted in increased winter base flows in the Lower Vaal River and smaller floods being reduced in summer.

Due to this regulation having being implemented in varying degrees for 90 years the aquatic organisms have adapted and the river banks are stable.

Alien invasive plants have changed the characteristics of large parts of the riparian zones of the Vaal, Harts and Riet Rivers. These infestations are non-flow related but due to disturbances as a result of agricultural and mining impacts on the banks. Management interventions for clearing of these plants are required to improve the overall status of the riparian zone.

In the Riet and Harts Rivers the hydrology has changed due to increased irrigation usage, upstream dams and urban requirements. These rivers have less flow in winter as well as summer due to these anthropogenic changes.

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APPENDIX A
HYDROLOGY ASSESSMENT

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REPORT ON

MIDDLE AND LOWER VAAL RESERVE – HYDROLOGY SPECIALIST REPORT

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Appendix A Document Limitations

1 INTRODUCTION

The location of the EWR sites (EWR12 to EWR 19), the quaternary catchment boundaries, rivers and major urban areas of Gauteng are shown in Figure 1. Sites 1, 2 & 7 are on the Vaal River, site 3 on the Vals River, sites 4 on Vet River, site 5 downstream of Bloemhof dam, site 6 on Harts River and site 8 on Riet River.

Natural and Present Day flows were generated by WRP and used as is in this study. Observed data used included in this assessment was of stations that would best represent flows at each of the sites, therefore proximity to the site as well as availability of data in long enough period for meaningful statistical at an overview level to be determined, determined station selection. However it should be noted that observed data has its own problems, with respect to capture, accuracy and reliability of the data. These are however problems that reduce the confidence in the observed data. In the absence of any other data that can be used to assess the current hydrological situation, set aside the simulated present day flows, the observed data is to a large extent useful. Careful consideration and knowledge of the system, climate and historical events such as big floods of 1987 enable for the informed use of the observed data. To a larger extent the observed data used in this assessment at the different sites agrees with the simulated present day flows, with highs and lows as would be expected when comparing simulated flows versus observed flows. The exception is station C5H016 and C9H010 which deviate very sharply for the present day flows and this is attributed to the fact that the high flows (i.e. very wet years) were not sufficiently captured. This hydrology assessment focused on the generation for flow duration curves, monthly flow distribution and rating of the confidence we have in the hydrology in relation to low flows, zero flows, moderate flows, high flows and seasonality changes in the flows.

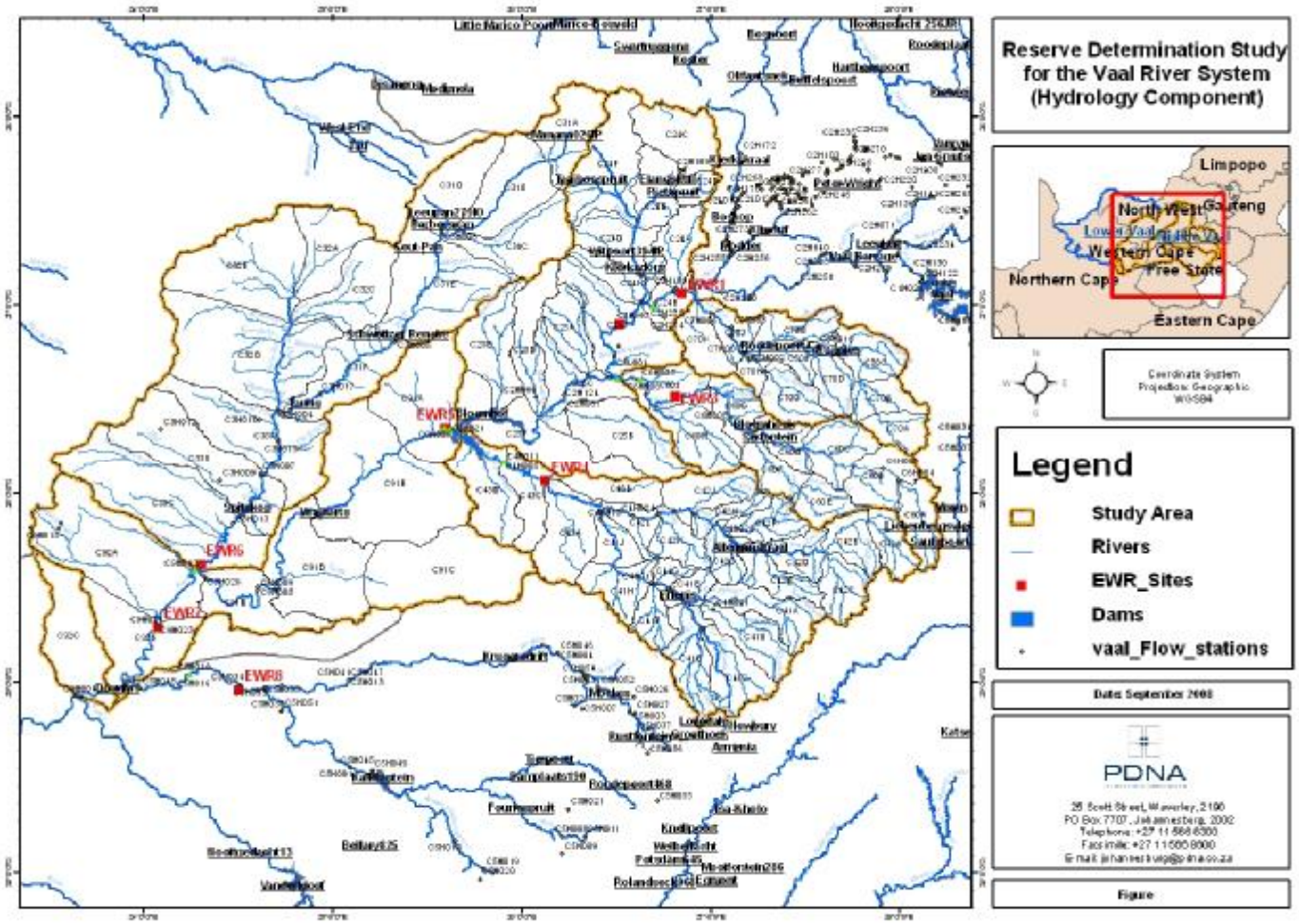


Figure 1: EWR sites and quaternary catchments (sites EWR 1 – 8 refer to sites EWR 12 – 19)

2 DWAF STREAMFLOW GAUGES

The available DWAF monthly data from stream flow gauging sites are referred to in the following sections where available and appropriate. A large number of flow gauges in the catchment have too little data or no data at all. This therefore means that the reliability of observed data has is very low as some of the selected gauges could be far of from the EWR site they being used for, the length of time series may not be long enough and gaps in the data also contributes to the reduction of confidence in the observed data. However the observed data is included in this report for information. It is also to provide for means of verification, where possible and to highlight the inadequacy of flow monitoring in the catchment.

3 PRESENT DAY HYDROLOGICAL IMPACTS

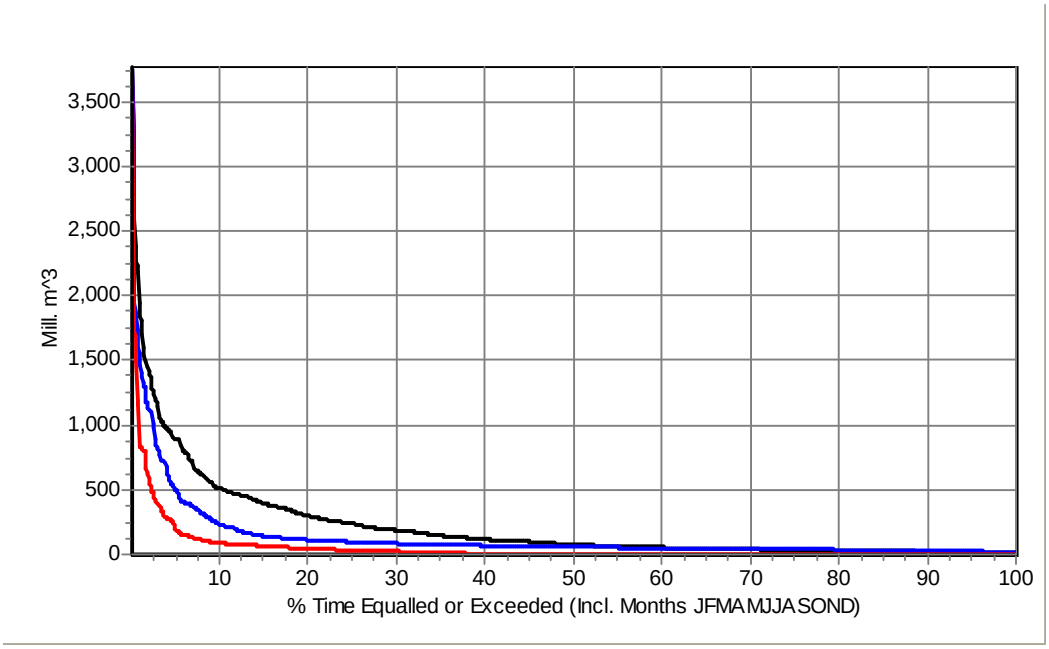
The natural and present day time series of monthly flows were provided by the systems modellers and these have been compared with the observed records as part of the assessment of the present day hydrological impacts. The observed data has lots of gaps that were left out and some of the stations which are much closer to the EWR sites are missing data, which makes it difficult to have closely comparable results. The HAI details for the sites are given in Tables 1 to 8, while flow duration curves are compared in Figures 2 to 25 to support some of the conclusions.

4 HAI FOR EWR12 – VERMAASDRIFT ON VAAL RIVER

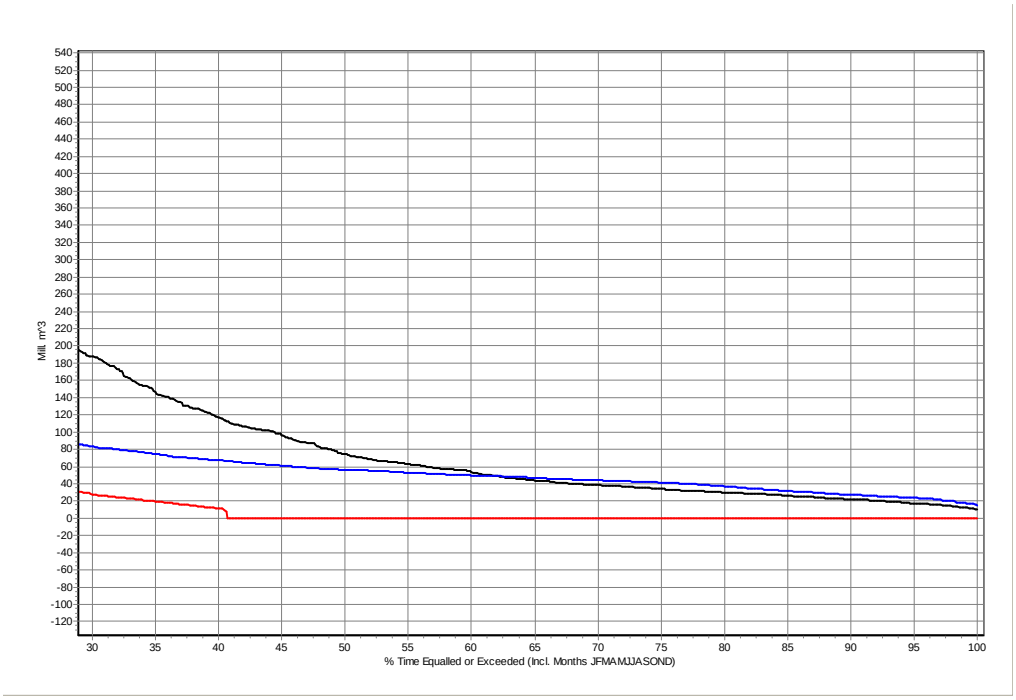
Table 1 provides the best estimates of HAI based on these data. The confidence rating is based on the interpretation of the simulated flows and not on the confidence in the simulations. The seasonality rating has been set at 0, as there is not shift in the monthly flows, as shown in Figure 3, even though the observed data seems to suggest at shift of the peak month from February to March. This is because the length of the observed as shown in Figure 4, which inevitable skews the distribution. There is a DWAF gauging station downstream of this site (C2H007, area of 63437 km^2 and data for 1938 to 2008).

Table 1: HAI details for site EWR12

HYDROLOGY DRIVER ASSESSMENT INDEX		
HYDROLOGY METRICS	**RATING**	**CONFIDENCE**
LOW FLOWS	1.00	4.00
ZERO FLOW DURATION	0.00	3.00
SEASONALITY	0.00	4.00
MODERATE EVENTS	4.00	3.00
EVENT HYDROLOGY(HIGH FLOWS-FLOODS)	4.00	3.00



(a)



(b)

Figure 2: Annual monthly flow duration curves (data 1920 to 1994 for Natural and Present Day, 1938 to 2008 for Observed) for site EWR12 (Black = Natural, Blue = Present Day, Red = Observed).

(a) Full Graph (b) Zoomed at about 30%

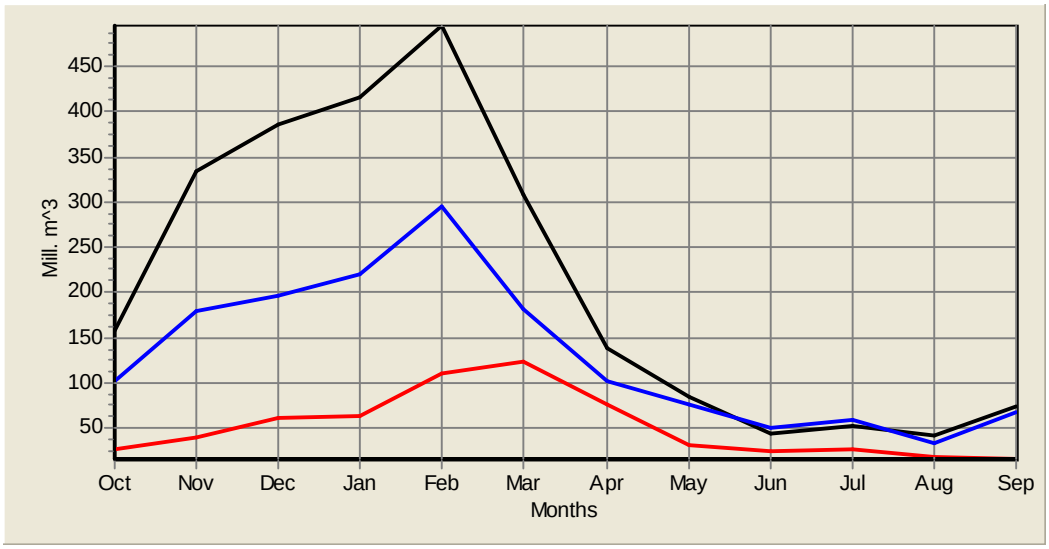


Figure 3: Seasonal distributions (data 1920 to 1994 for Natural and Present Day, 1938 to 2008 for Observed) for site EWR12 (Black = Natural, Blue = Present Day, Red = Observed).

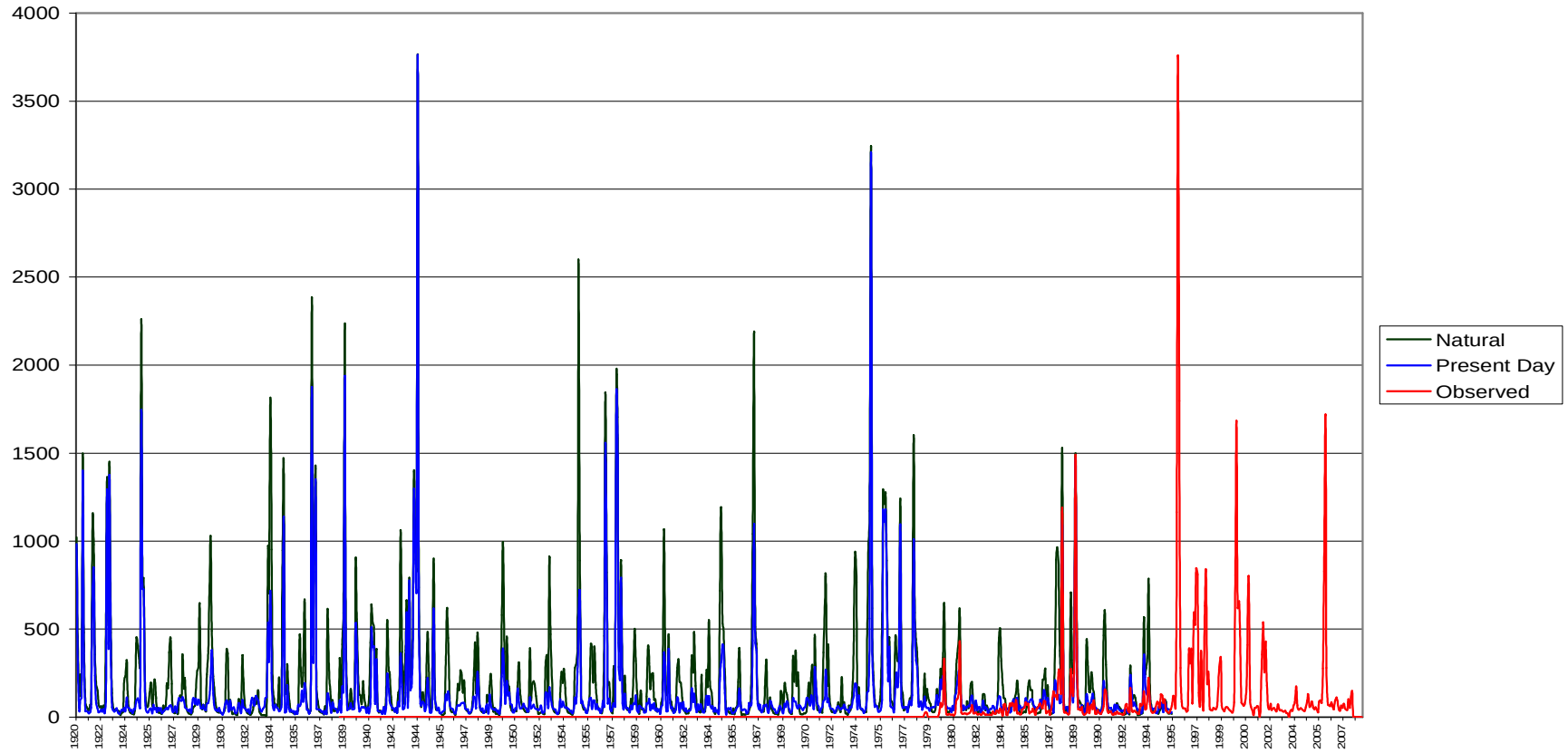


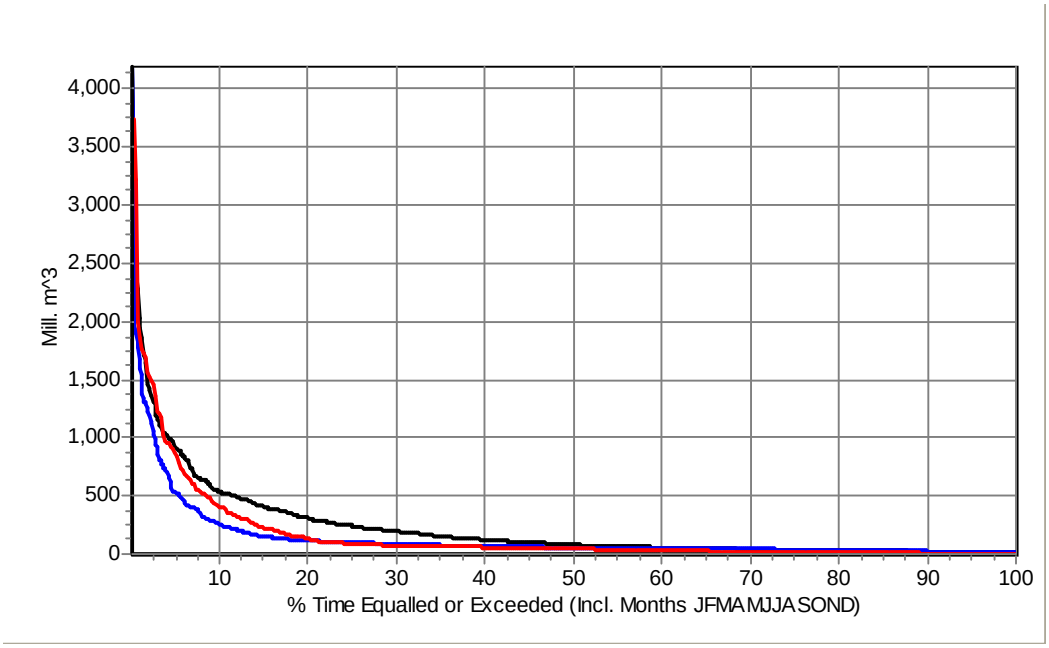
Figure 4: Time series plot (data 1920 to 1994 for Natural and Present Day, 1938 to 2008 for Observed) for site EWR12 (Black = Natural, Blue = Present Day, Red = Observed).

5 HAI FOR EWR13 – REGINA BRIDGE ON VAAL RIVER

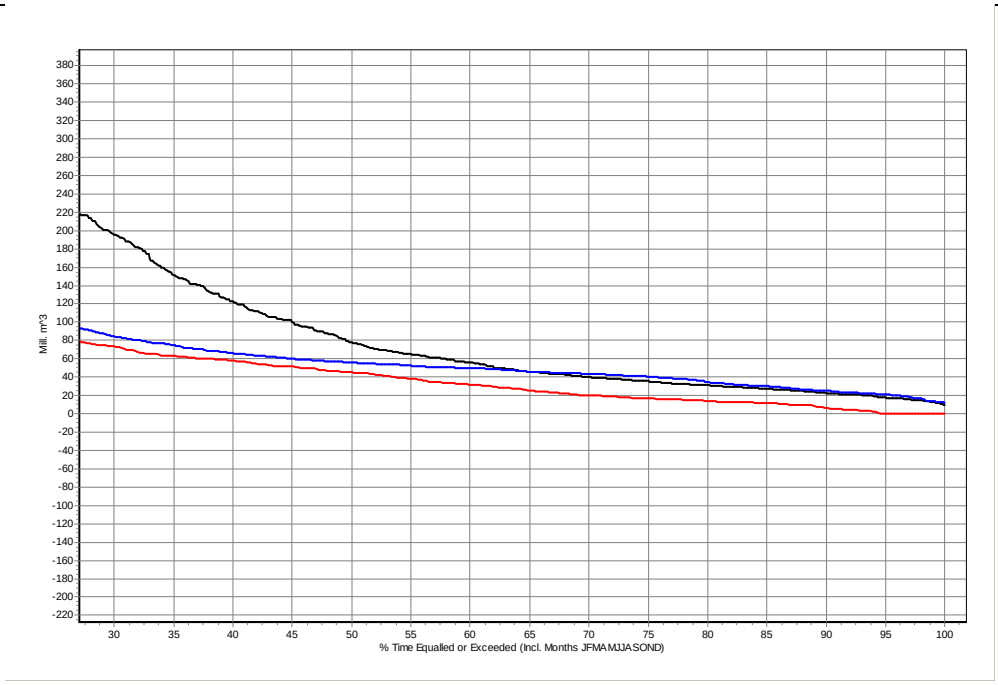
Figure 5 illustrates that the moderate to high flows are impacted at this site. There is a DWAF gauging stations at C2H061 (79903 km^2 and data from 1972 to 2007). In terms flows the observed record and the simulated present day flows are reasonably consistent. Table 2 provides the best estimates of HAI based on these data. There is no indication of seasonality shift, which is also confirmed by the observed flows, which in this case there was a reasonable long record as shown in Figure 7.

Table 2: HAI details for Site EWR13

HYDROLOGY DRIVER ASSESSMENT INDEX		
HYDROLOGY METRICS	**RATING**	**CONFIDENCE**
LOW FLOWS	1.00	4.00
ZERO FLOW DURATION	1.00	3.00
SEASONALITY	0.00	4.00
MODERATE EVENTS	4.00	3.00
EVENT HYDROLOGY(HIGH FLOWS-FLOODS)	4.00	3.00



(a)



(b)

Figure 5: Annual monthly flow duration curves (data 1920 to 1994 for Natural and Present Day, 1972 to 2007 for Observed) for site EWR13 (Black = Natural, Blue = Present Day, Red = Observed).

(a) Full Graph **(b) Zoomed at about 30%**

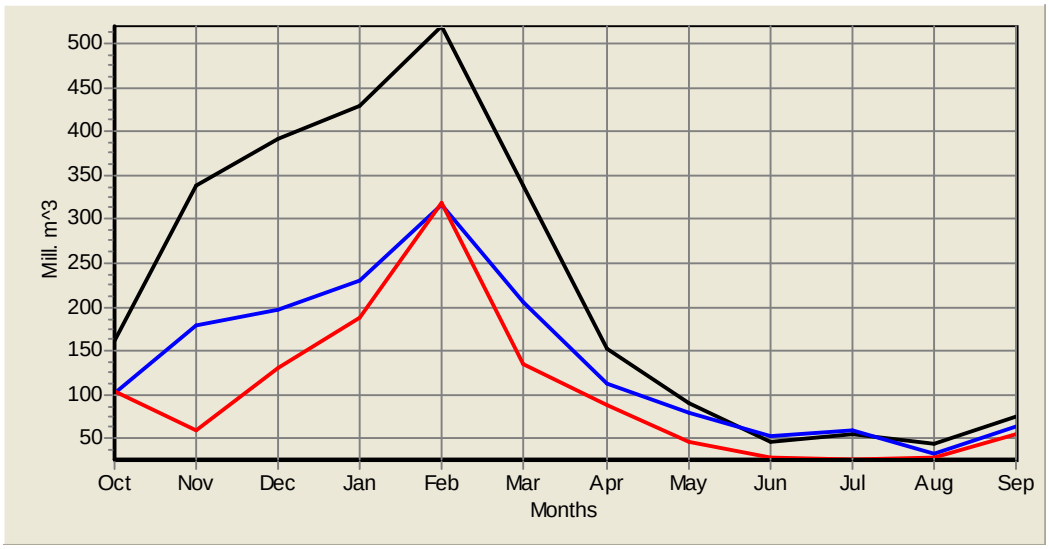


Figure 6: Seasonal distributions (data 1920 to 1994 for Natural and Present Day, 1972 to 2007 for Observed) for site EWR13 (Black = Natural, Blue = Present Day, Red = Observed).

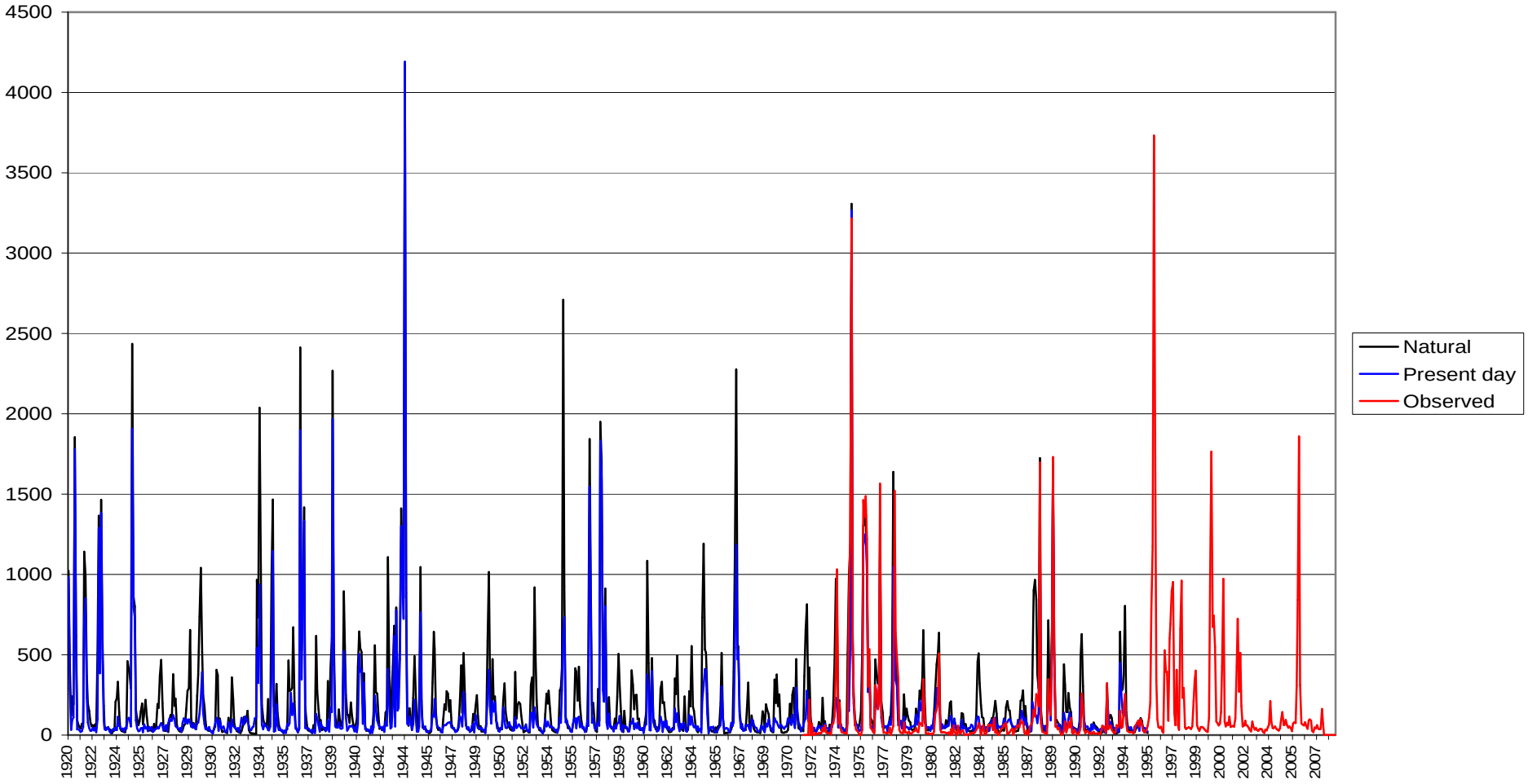


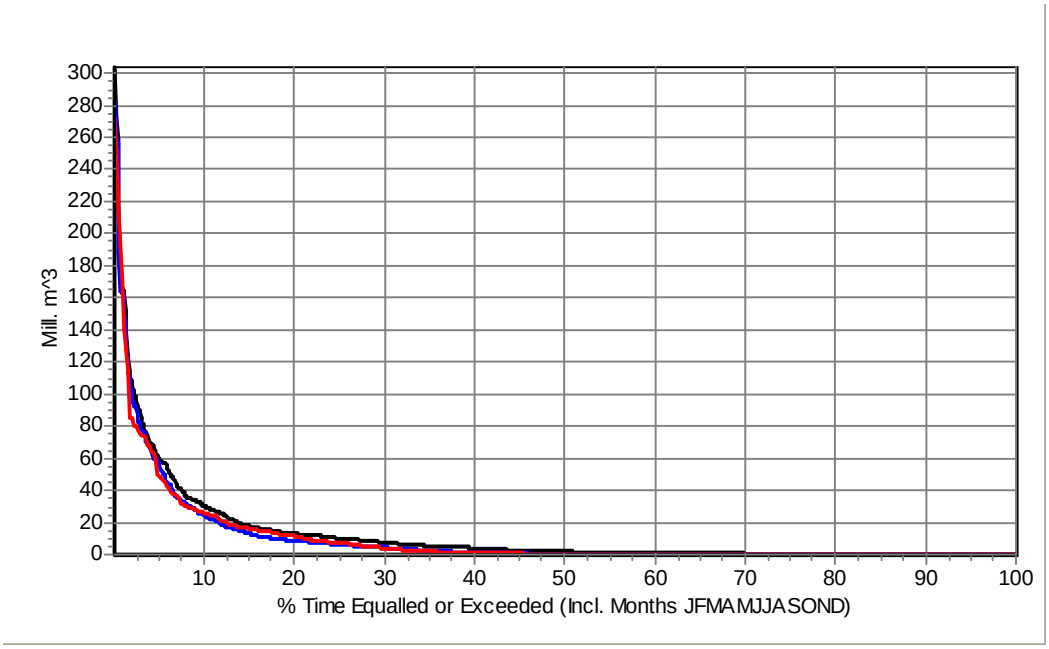
Figure 7: Time series plot (data 1920 to 1994 for Natural and Present Day, 1972 to 2007 for Observed) for site EWR13 (Black = Natural, Blue = Present Day, Red = Observed).

6 HAI FOR EWR14 – PROKLAMEERDRIFT ON VALS RIVER

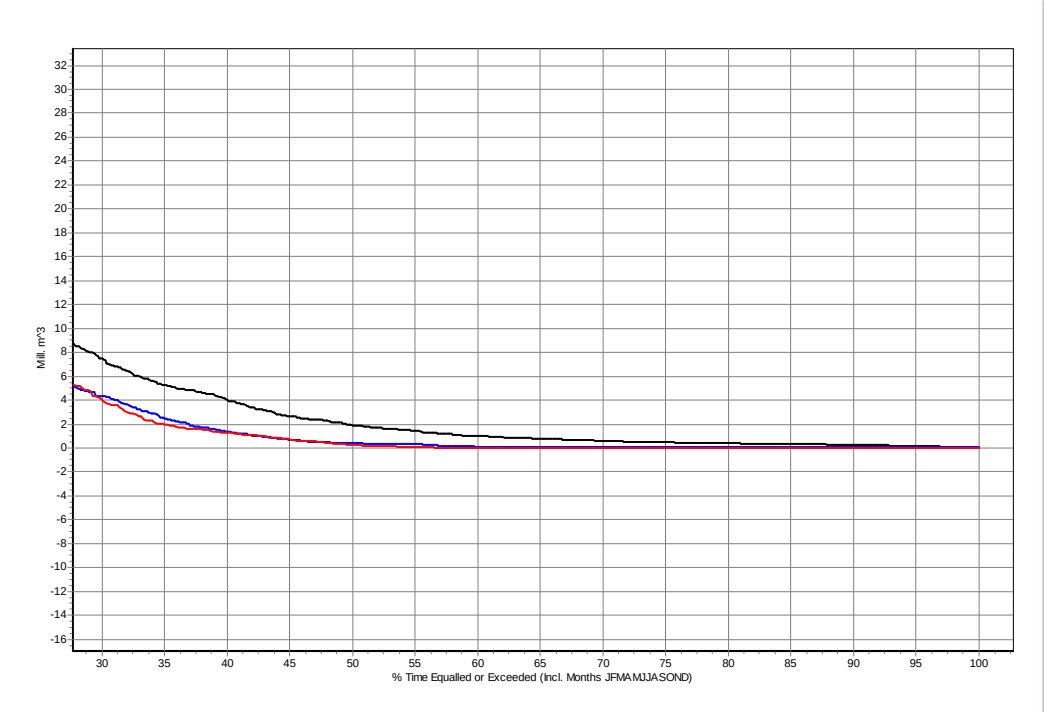
Figure 8 illustrates that the full range of flows are impacted at this site, but not as severely as at the previous sites. There is a DWAF gauge (C6H003, area of 7765 km^2, with data for 1967 to 2005) just downstream of this site. The observed data are consistent with the simulated present day flows. Table 3 provides the estimates of HAI based on the simulated data. A rating of 0 indicating no shift in the seasonality at the site was given based on the comparison between the natural and present day flows (see Figure 9).

Table 3: HAI details for Site EWR14

HYDROLOGY DRIVER ASSESSMENT INDEX		
HYDROLOGY METRICS	**RATING**	**CONFIDENCE**
LOW FLOWS	5.00	4.00
ZERO FLOW DURATION	0.00	3.00
SEASONALITY	0.00	4.00
MODERATE EVENTS	4.00	3.00
EVENT HYDROLOGY(HIGH FLOWS-FLOODS)	2.00	3.00



(a)



(b)

Figure 8: Annual monthly flow duration curves (data 1920 to 1994 for Natural and Present Day, 1967 to 2005 for Observed) for site EWR14 (Black = Natural, Blue = Present Day, Red = Observed).

(a) Full Graph **(b) Zoomed at about 30%**

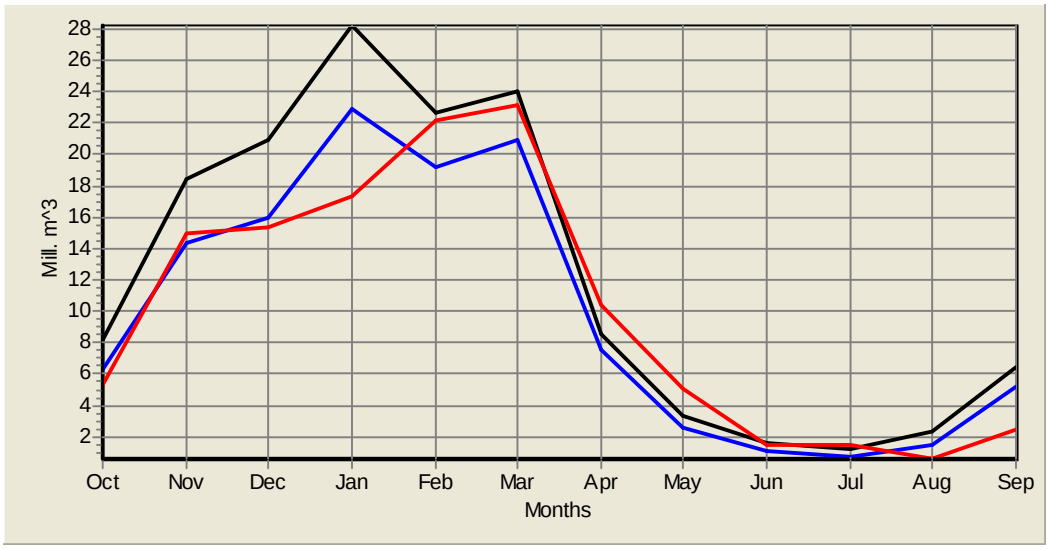


Figure 9: Seasonal distributions (data 1920 to 1994 for Natural and Present Day, 1967 to 2005 for Observed) for site EWR14 (Black = Natural, Blue = Present Day, Red = Observed).

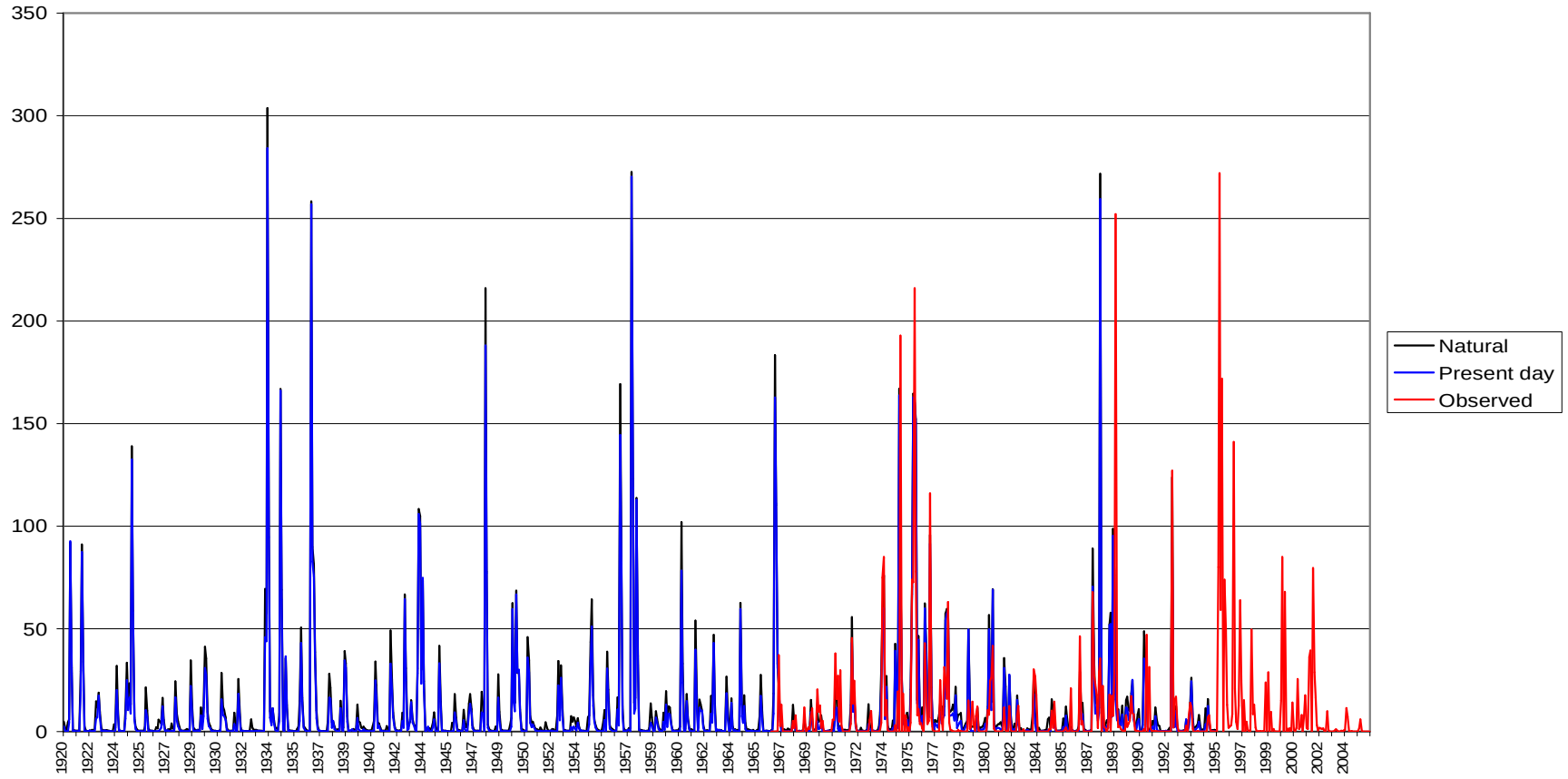


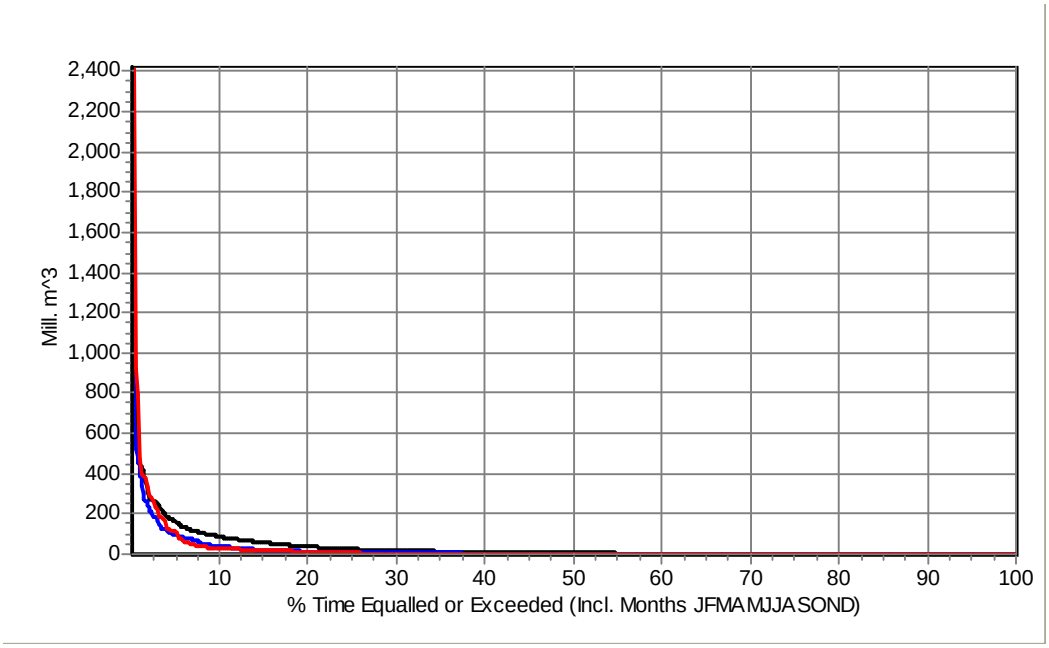
Figure 10: Time series plot (data 1920 to 1994 for Natural and Present Day, 1967 to 2005 for Observed) for site EWR14 (Black = Natural, Blue = Present Day, Red = Observed).

7 HAI FOR EWR15 – FISANTKRAAL ON VET RIVER

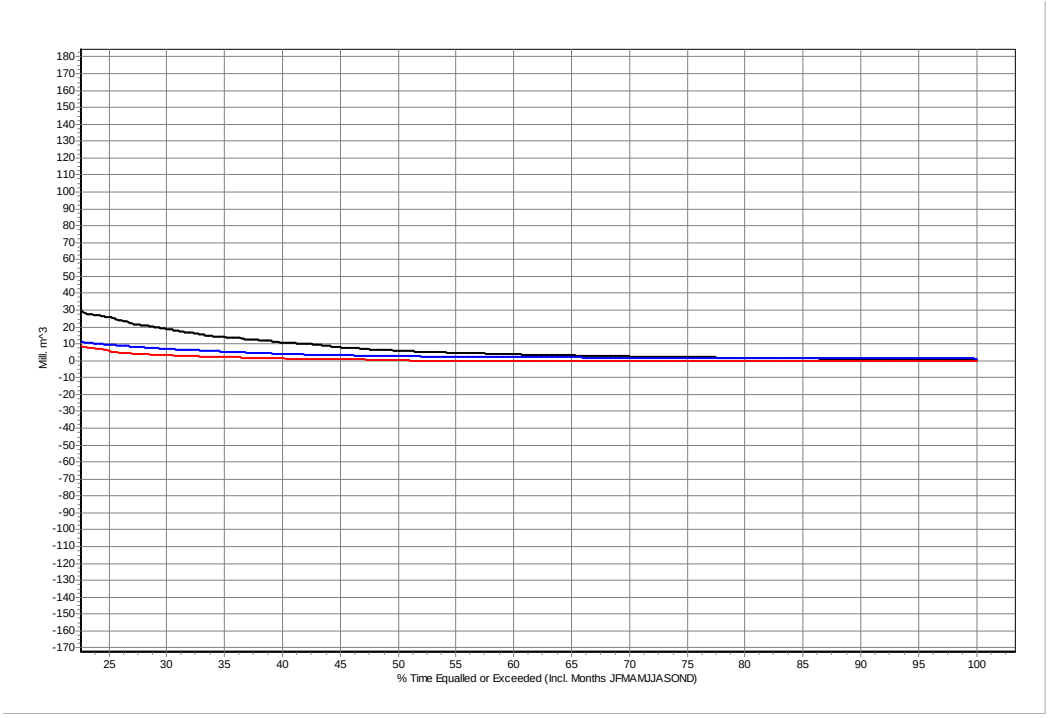
This site is located close to the gauging weir (C4H002 – 17 599 km^2 – data for 1935 to 1972). The estimates of HAI based on the simulated data are provided in Table 4. The greater part of the impact at this site is on the moderate to high flows as observed in Figure 11. The seasonality at this site also has a rating of zero when the natural and present day flows are compared. However the observed shows a peak in February compared to a peak in March for the natural and present day flows. Again the length of the observed record as shown in figure 13 reduces the confidence in this data to draw conclusion.

Table 4: HAI details for Site EWR15

HYDROLOGY DRIVER ASSESSMENT INDEX		
HYDROLOGY METRICS	**RATING**	**CONFIDENCE**
LOW FLOWS	3.00	4.00
ZERO FLOW DURATION	0.00	3.00
SEASONALITY	0.00	4.00
MODERATE EVENTS	5.00	3.00
EVENT HYDROLOGY(HIGH FLOWS-FLOODS)	4.00	3.00



(a)



(b)

Figure 11: Annual monthly flow duration curves (data 1920 to 1994 for Natural and Present Day, 1935 to 1972 for Observed) for site EWR15 (Black = Natural, Blue = Present Day, Red = Observed).

(a) Full Graph (b) Zoomed at about 30%

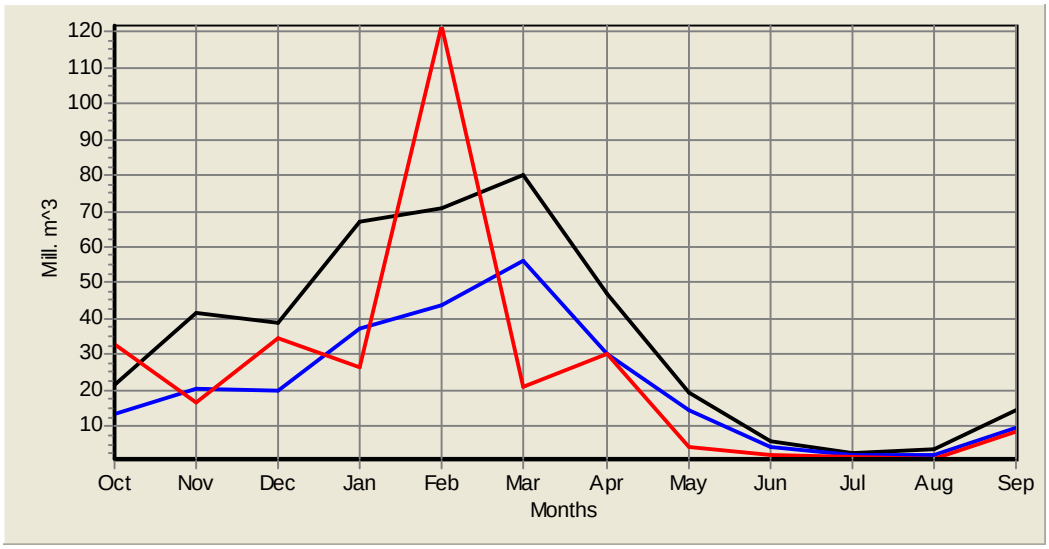


Figure 12: Seasonal distributions (data 1920 to 1994 for Natural and Present Day, 1935 to 1972 for Observed) for site EWR15 (Black = Natural, Blue = Present Day, Red = Observed).

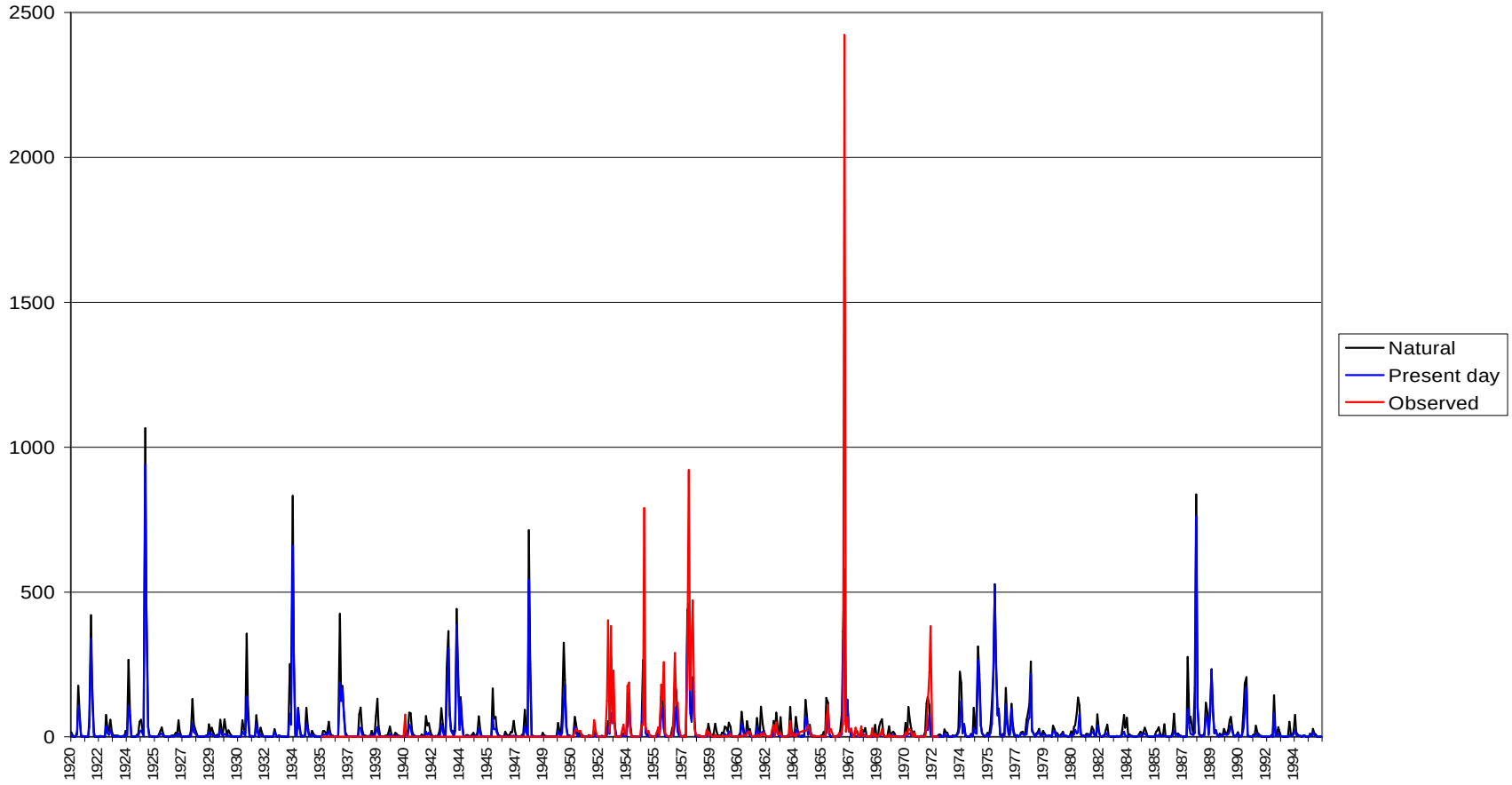


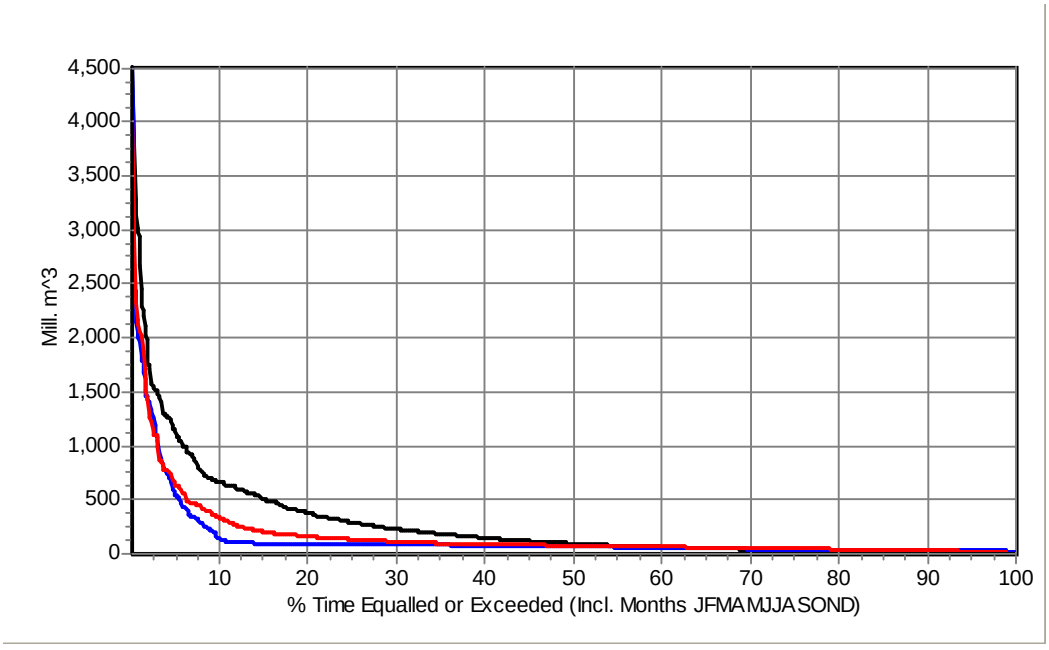
Figure 13: Time series plot (data 1920 to 1994 for Natural and Present Day, 1935 to 1972 for Observed) for site EWR15 (Black = Natural, Blue = Present Day, Red = Observed).

8 HAI FOR EWR16 – JUST DOWNSTREAM BLOEMHOF DAM

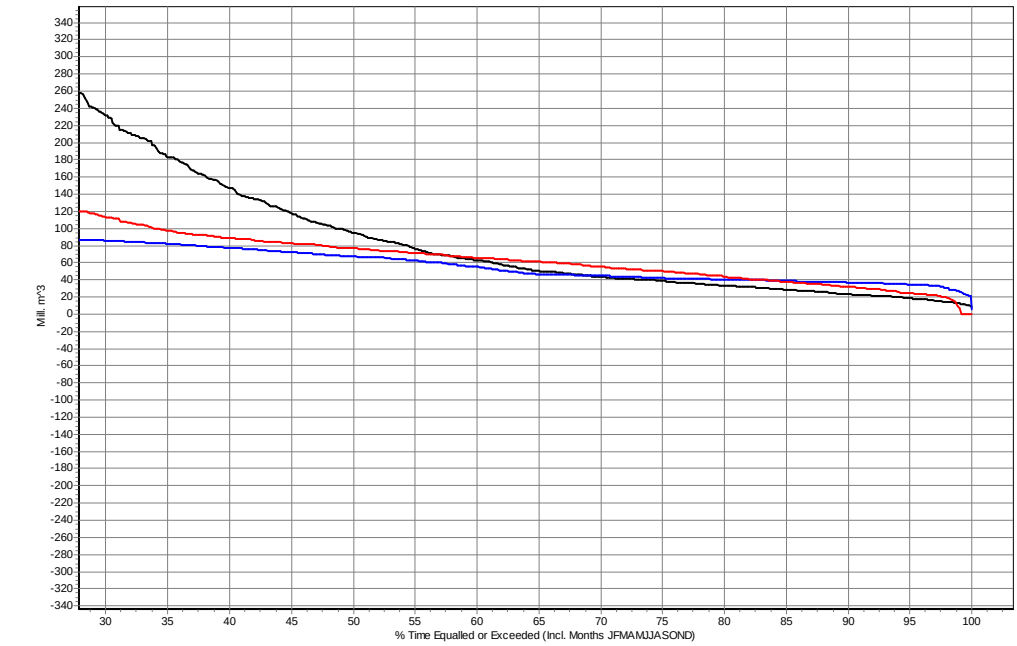
The site is located downstream of Bloemhof Dam which was constructed in 19...It is also located close to DWAF gauging weir C9H006 (108 652 km^2 – data for 1937 to 1970) and C9H021 (108 652 km² – data for 1970 to 2008). The flow duration curves for simulated natural and present day flows are illustrated in Figure 14, while the estimates of HAI based on the simulated data are provided in Table 5. There is a sufficiently long record of observed flows (see Figure 16) and even though the weir changed in 1970 the data is consistent. The observed flows are seen to be higher than the present day flows when high flows are considered (see Figure 14). The seasonality at the site has not been impacted and that is consistent even with the observed flows as shown in Figure 15.

Table 5: HAI details for Site EWR16

HYDROLOGY DRIVER ASSESSMENT INDEX		
HYDROLOGY METRICS	**RATING**	**CONFIDENCE**
LOW FLOWS	0.00	4.00
ZERO FLOW DURATION	0.00	3.00
SEASONALITY	0.00	4.00
MODERATE EVENTS	5.00	3.00
EVENT HYDROLOGY(HIGH FLOWS-FLOODS)	5.00	3.00



(a)



(b)

Figure 14: Annual monthly flow duration curves (data 1920 to 1994 for Natural and Present Day, 1937 to 1970 for Observed) for site EWR16 (Black = Natural, Blue = Present Day, Red = Observed).

(a) Full Graph (b) Zoomed at about 30%

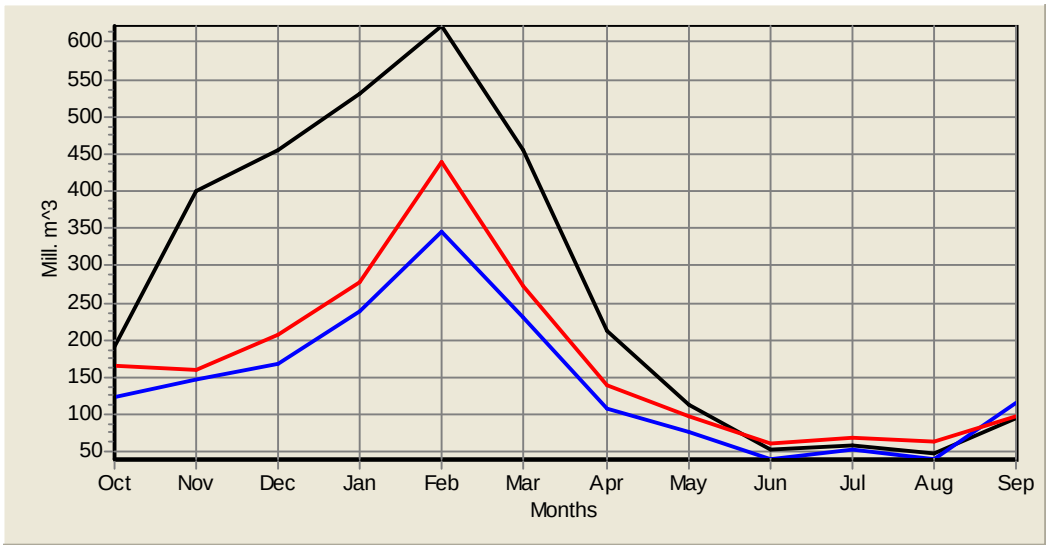


Figure 15: Seasonal distributions (data 1920 to 1994 for Natural and Present Day, 1937 to 1970 for Observed) for site EWR16 (Black = Natural, Blue = Present Day, Red = Observed).

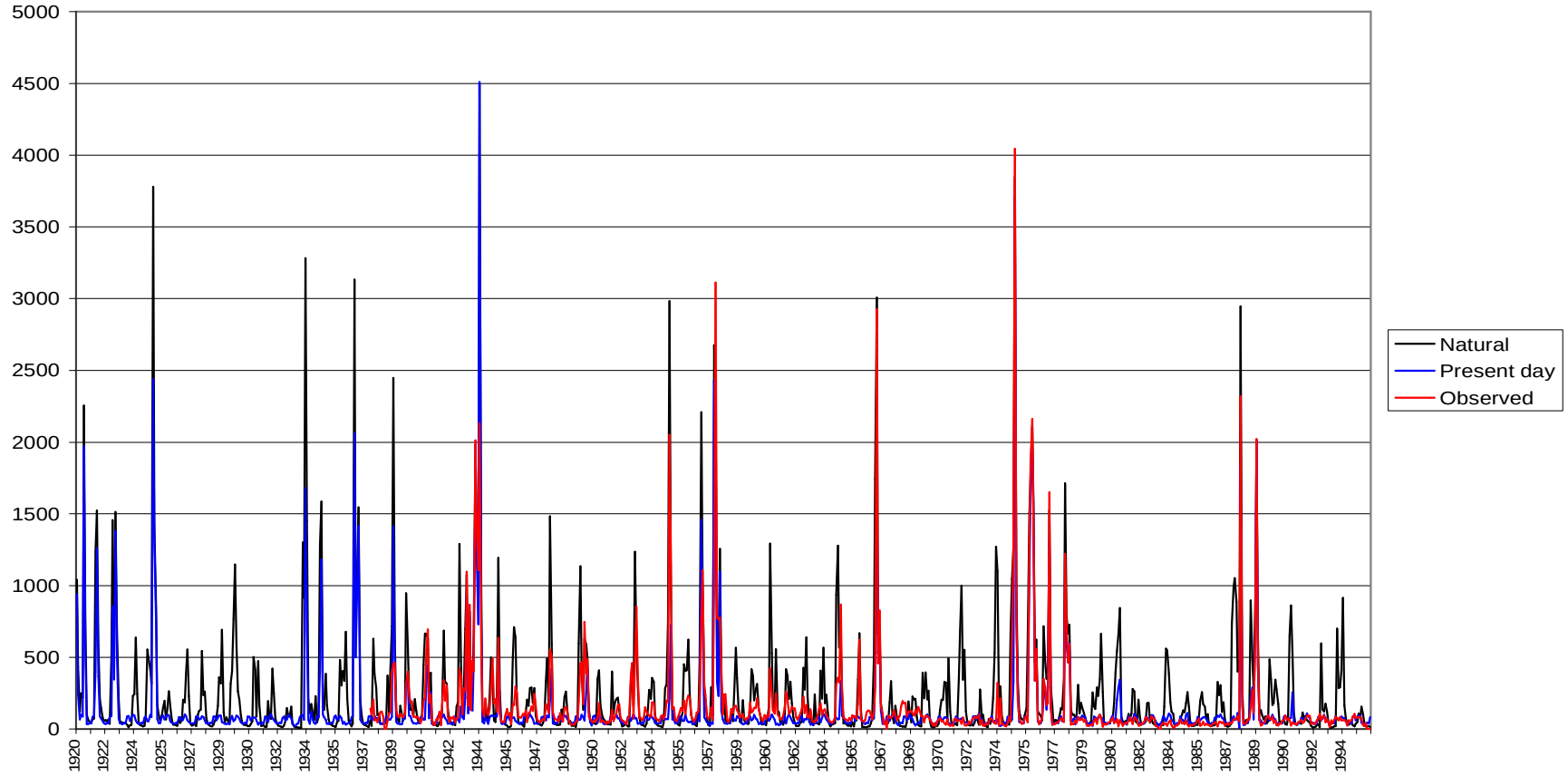


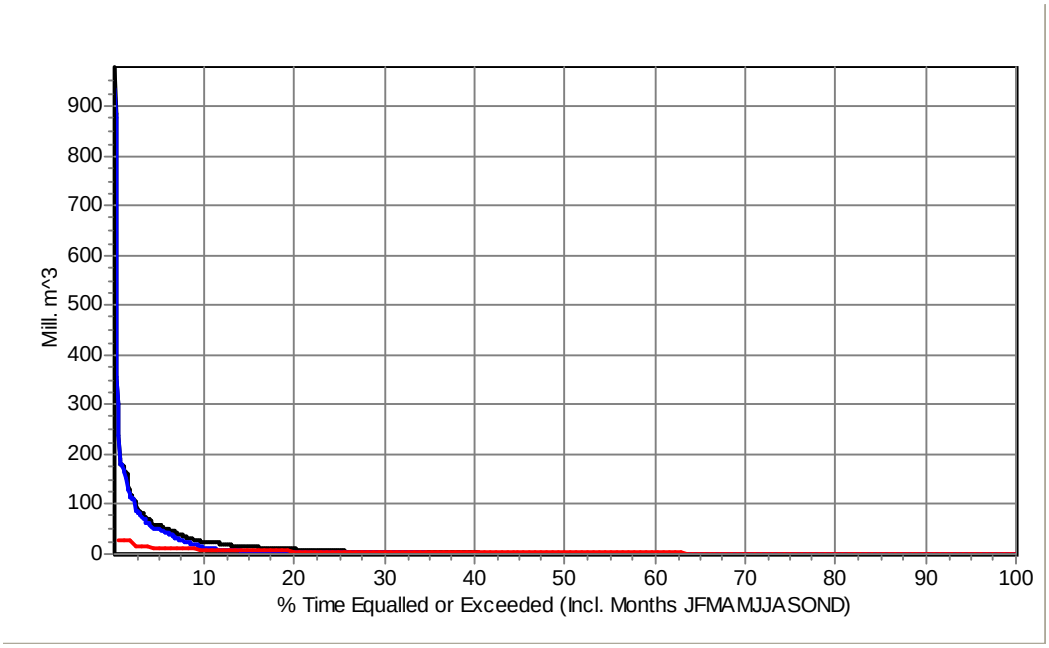
Figure 16: Time series plot (data 1920 to 1994 for Natural and Present Day, 1937 to 1970 for Observed) for site EWR16 (Black = Natural, Blue = Present Day, Red = Observed).

9 HAI FOR EWR17 – LLOYDS WEIR ON HARTS RIVER

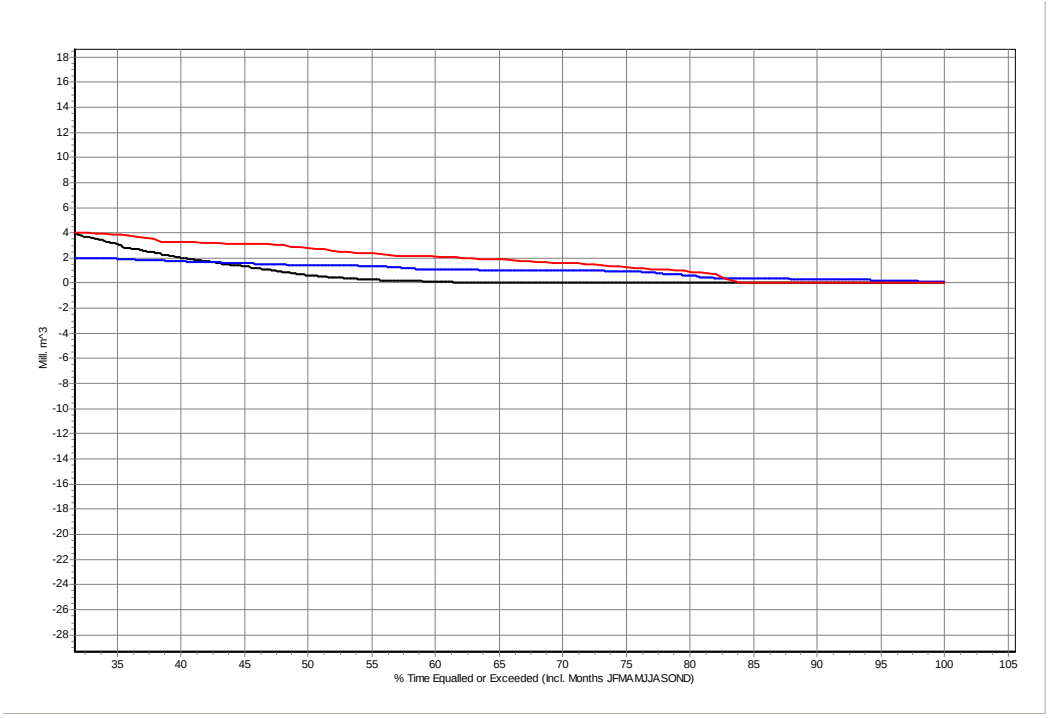
Figure 17 illustrates that the full range of flows are impacted at this site. There is a DWAF gauging station just downstream of this site, C3H016 (29 370 km² – data for 1994 to 2007). There is a remarkable consistency between the present day and observed flow as seen in Figure 17 and Figure 18The estimates of HAI based on the simulated data are provided in Table 6.

Table 6: HAI details for Site EWR17

HYDROLOGY DRIVER ASSESSMENT INDEX		
HYDROLOGY METRICS	**RATING**	**CONFIDENCE**
LOW FLOWS	5.00	4.00
ZERO FLOW DURATION	0.00	3.00
SEASONALITY	0.00	4.00
MODERATE EVENTS	4.00	3.00
EVENT HYDROLOGY(HIGH FLOWS-FLOODS)	4.00	3.00



(a)



(b)

Figure 17: Annual monthly flow duration curves (data 1920 to 1994 for Natural and Present Day, 1974 to 2007 for Observed) for site EWR17 (Black = Natural, Blue = Present Day, Red = Observed).

(a) Full Graph **(b) Zoomed at about 30%**

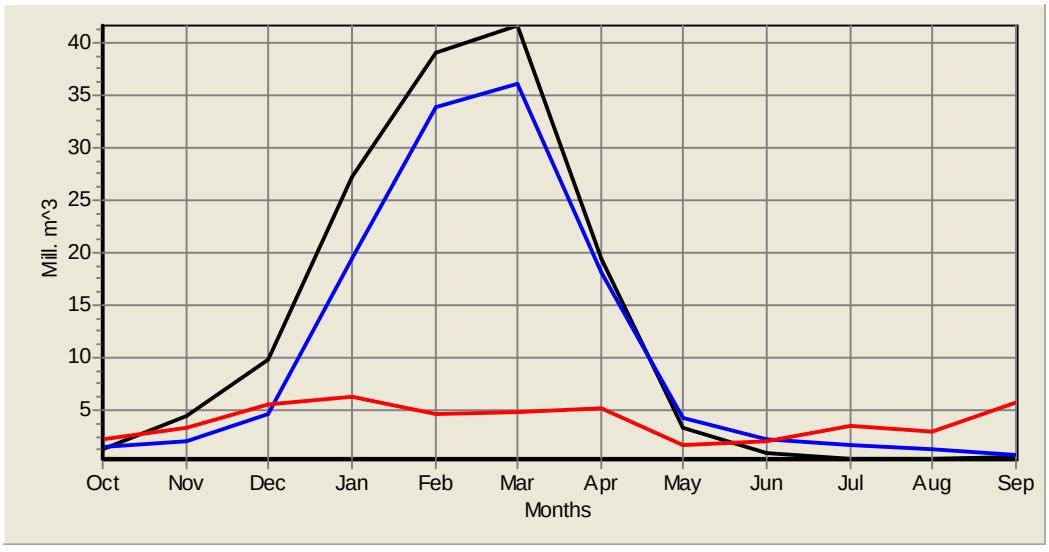


Figure 18: Seasonal distributions (data 1920 to 1994 for Natural and Present Day, 1974 to 2007 for Observed) for site EWR17 (Black = Natural, Blue = Present Day, Red = Observed).

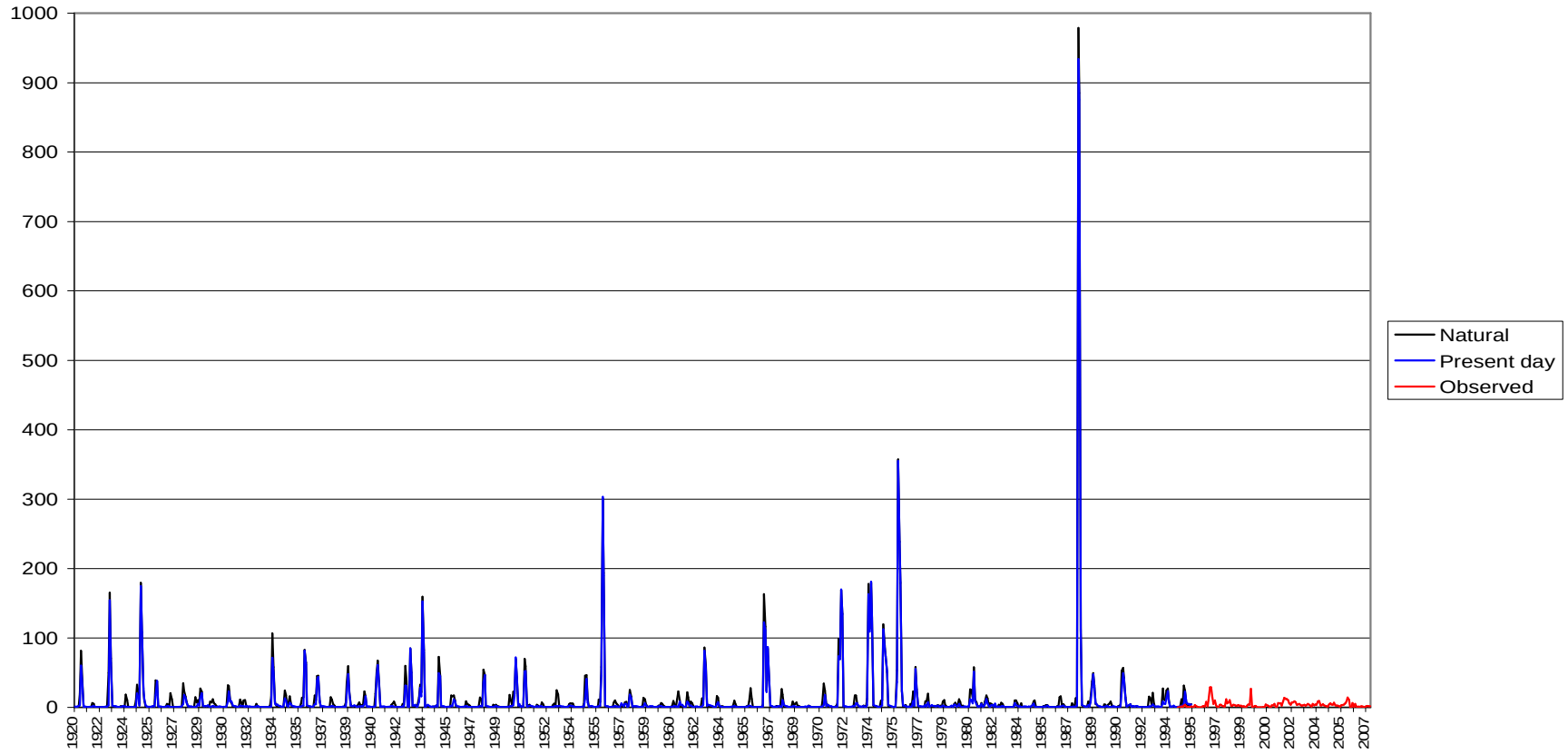


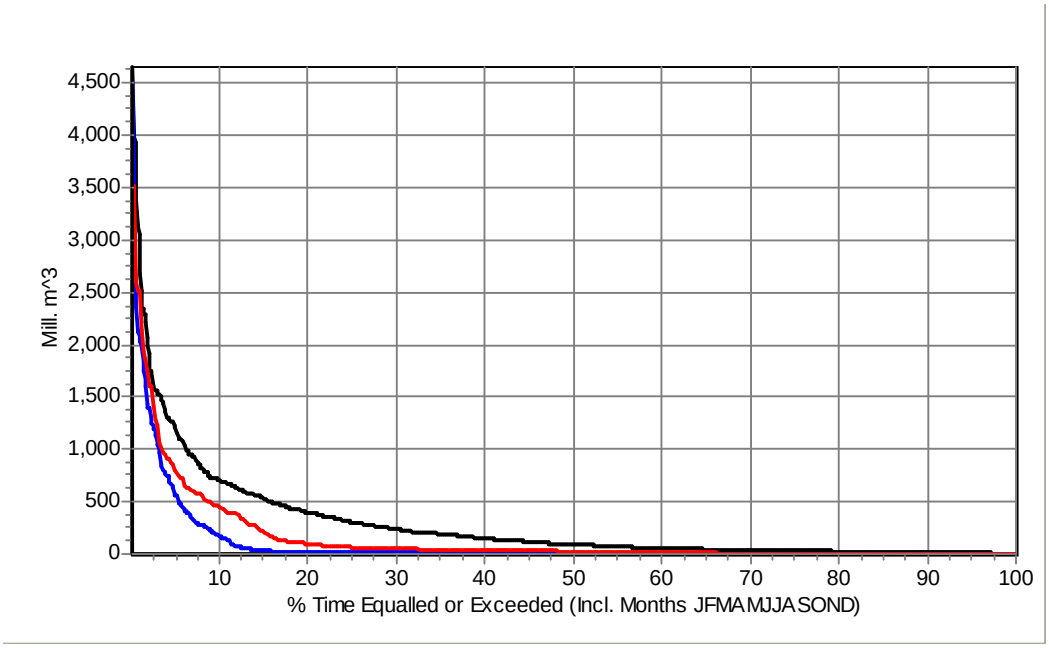
Figure 19: Time series plot (data 1920 to 1994 for Natural and Present Day, 1974 to 2007 for Observed) for site EWR17 (Black = Natural, Blue = Present Day, Red = Observed).

10 HAI FOR EWR18 – SCHMIDTSDRIFT ON VAAL RIVER

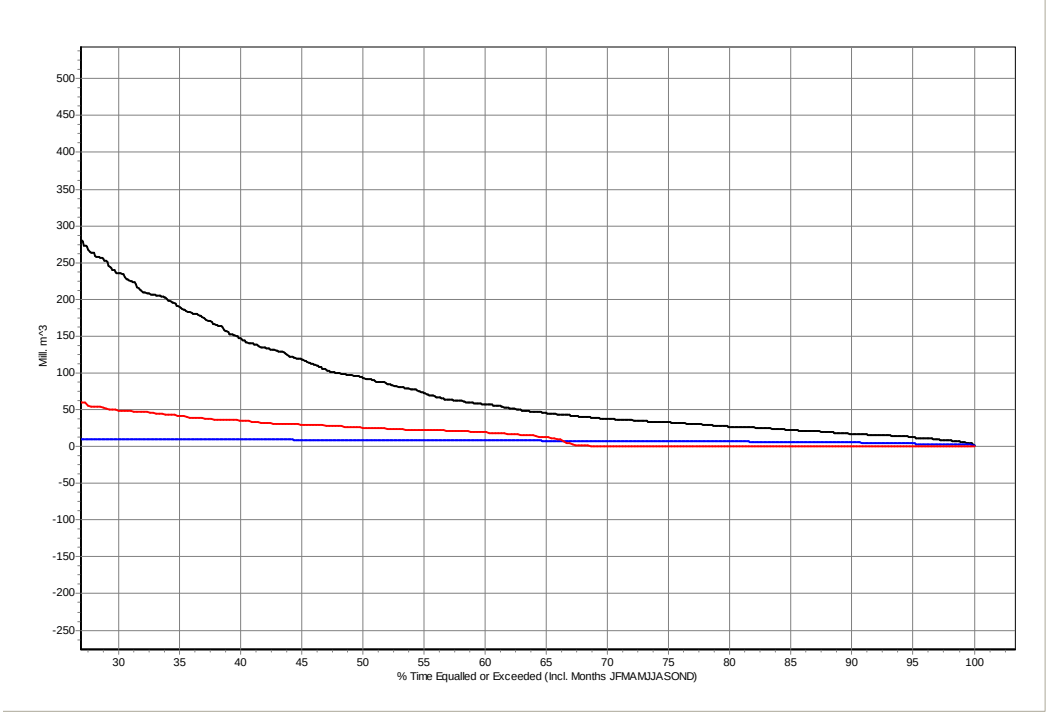
Figure 20 illustrates that the full range of flows are impacted at this site. The HAI values given in Table 7 and indicate a heavily impacted site with increased runoff, particularly in winter (dry) months. Observed data are available at C9H010 (153 093 km² data from 1974 to 2007) The seasonality rating is set at 0 as observed in Figure 21, which shows no shift in the seasonality of the flows.

Table 7: HAI details for Site EWR18

HYDROLOGY DRIVER ASSESSMENT INDEX		
HYDROLOGY METRICS	**RATING**	**CONFIDENCE**
LOW FLOWS	5.00	4.00
ZERO FLOW DURATION	0.00	3.00
SEASONALITY	0.00	4.00
MODERATE EVENTS	5.00	3.00
EVENT HYDROLOGY(HIGH FLOWS-FLOODS)	5.00	3.00



(a)



(b)

Figure 20: Annual monthly flow duration curves (data 1920 to 1995 for Natural and Present Day, 1974 to 2007 for Observed) for site EWR18 (Black = Natural).

(a) Full Graph (b) Zoomed at about 30%

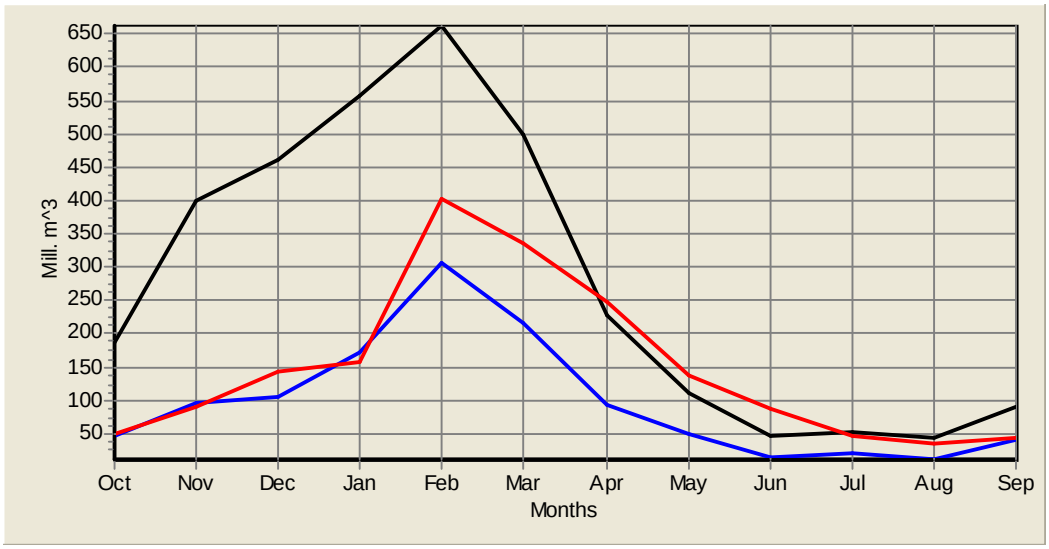


Figure 21: Seasonal distributions (data 1920 to 1994 for Natural and Present Day, 1974 to 2007 for Observed) for site EWR18 (Black = Natural, Blue = Present Day).

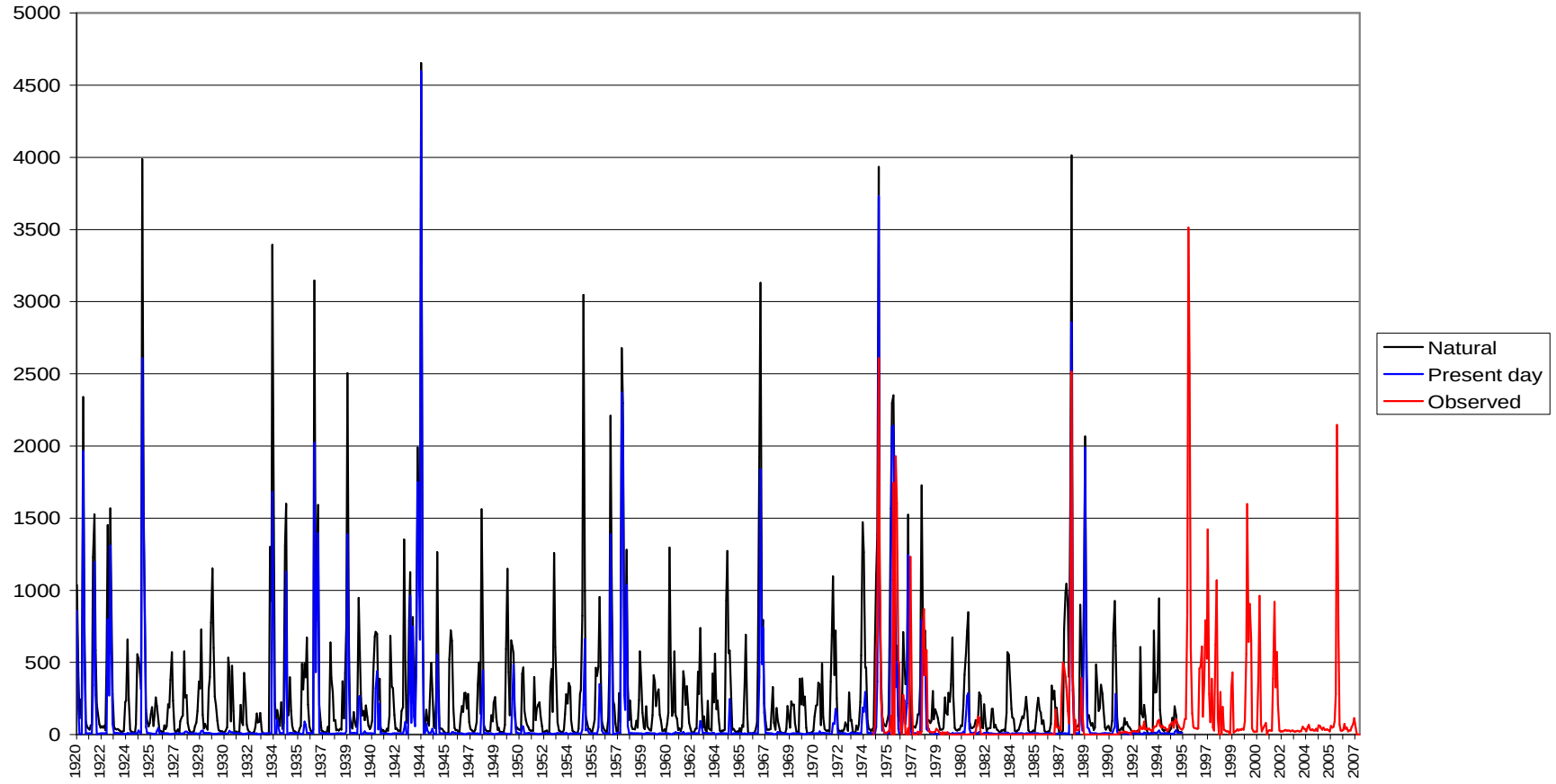


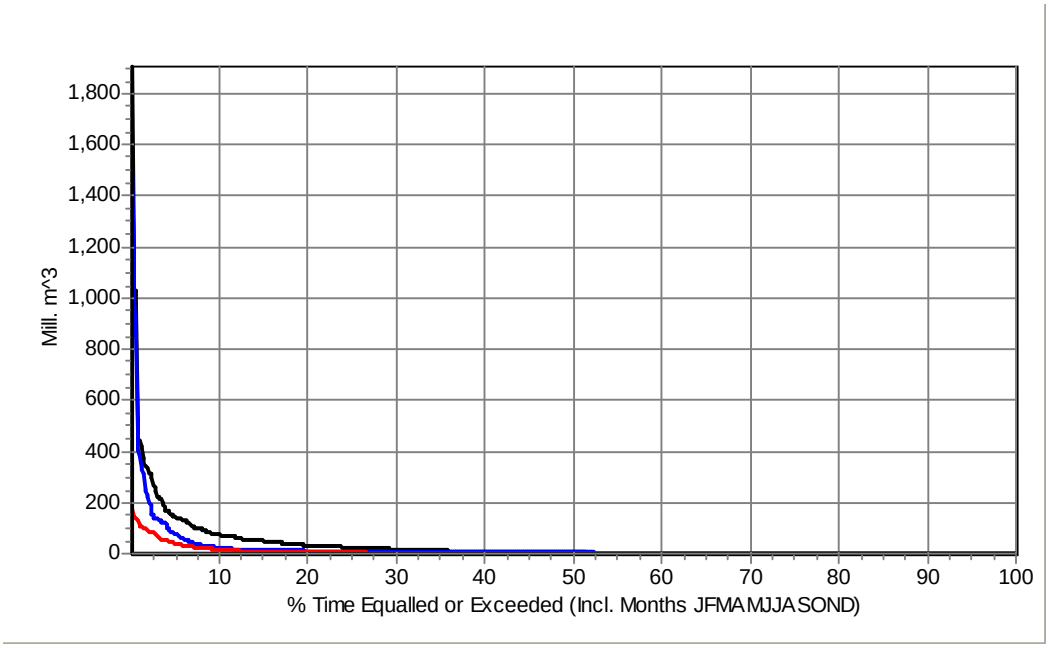
Figure 22: Time series plot (data 1920 to 1994 for Natural and Present Day, 1974 to 2007 for Observed) for site EWR18 (Black = Natural, Blue = Present Day).

11 HAI FOR EWR19 – LILYDALE LODGE? RIET RIVER

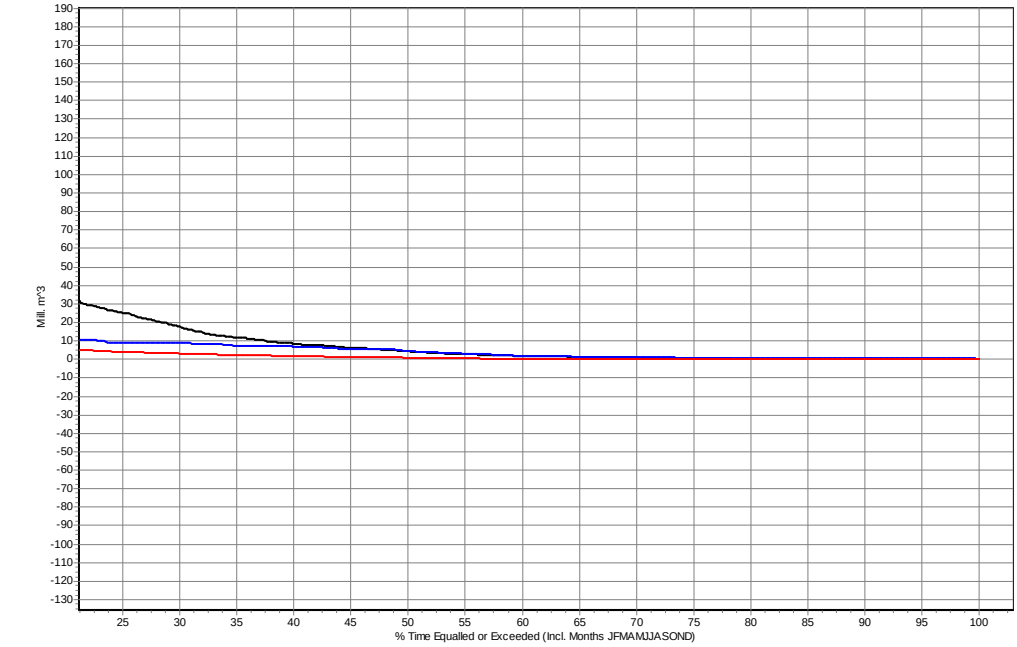
Figure 23 illustrates that the moderate to high flows are impacted at this site. There is a gauging station downstream of the site, C5H016 (33351 km² - data from 1953 to 1999), which indicates a substantial reduction in flows at the site when compared to the present day flows. The observed record is relatively long as observed in Figure 25, however the reliability of the record has not been verified and major peaks show by the present day flow seem not to have been picked up in the observed flows. The estimates of HAI based on the simulated data are provided in Table 8. As observes in Figure 24 there is no indication of a seasonality shift at the site.

Table 8: HAI details for Site EWR19

HYDROLOGY DRIVER ASSESSMENT INDEX		
HYDROLOGY METRICS	**RATING**	**CONFIDENCE**
LOW FLOWS	1.00	4.00
ZERO FLOW DURATION	0.00	3.00
SEASONALITY	0.00	4.00
MODERATE EVENTS	4.00	3.00
EVENT HYDROLOGY(HIGH FLOWS-FLOODS)	5.00	3.00



(a)



(b)

Figure 23: Annual monthly flow duration curves (data 1920 to 1995 for Natural and Present Day, 1953 to 1999 for Observed) for site EWR19 (Black = Natural, Blue = Present Day, Red = Observed).

(a) Full Graph (b) Zoomed at about 30%

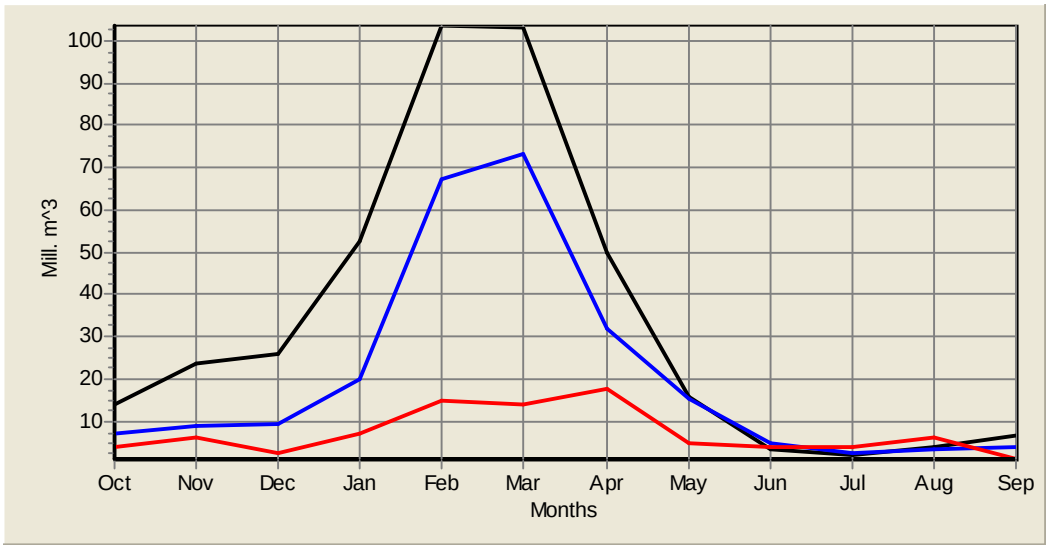


Figure 24: Seasonal distributions (data 1920 to 1995 for Natural and Present Day, 1953 to 1999 for Observed) for site EWR19 (Black = Natural, Blue = Present Day, Red = Observed).

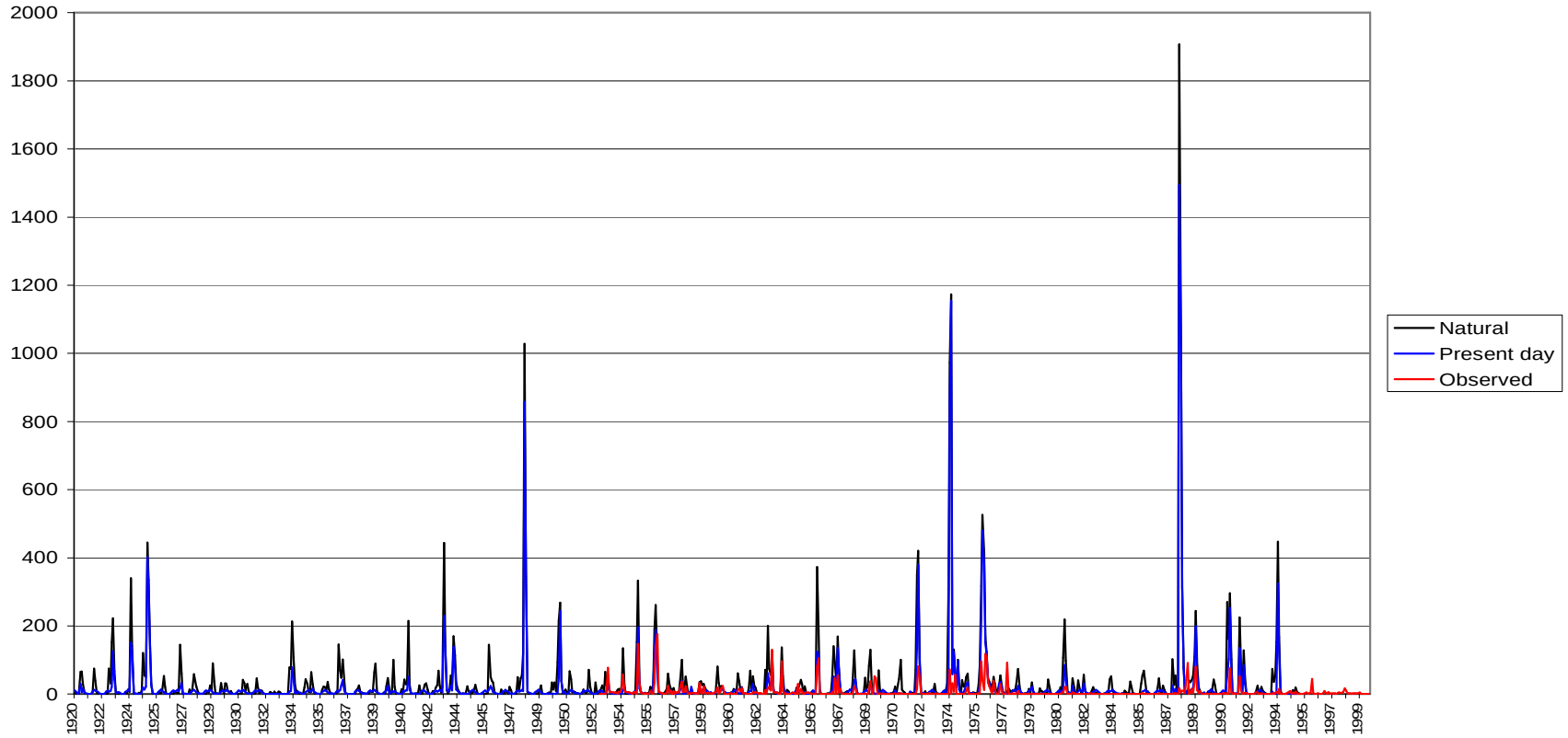


Figure 25: Time series plot (data 1920 to 1994 for Natural and Present Day, 1953 to 1999 for Observed) for site EWR19 (Black = Natural, Blue = Present Day, Red = Observed).

12 CONCLUSION

The simulation of the present day flows is based on the natural flows and therefore the accuracy thereof is dependent on that of the natural flows. The observed flows in most instances where available are consistent with the present day flows. The observed are included in this assessment as check for consistency of the simulated flow, however due to the length, gaps and reliability of some of the data the cannot be used in the analysis. Urbanization, abstraction, dam storage are some of the factors that have great deal of impact on the catchment hydrology. In some cases the present day flows exceed the natural flows, which could be attributed to increased runoff as a result of increased impervious area or artificial releases from storage.

Ralph Heath ??

GOLDER ASSOCIATES AFRICA (PTY) LTD

\\JOH1-S-FS1\GAADATA\PROJECTS\8856 - LOWER VAAL WMA\REPORTS\FINAL REPORTS DWA 2011\ECOCLASSIFICATION\APPENDIX A_HYDROLOGY REPORT.DOCX

APPENDIX A

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APPENDIX B
HYDRAULIC ASSESSMENT

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REPORT ON

HYDRAULICS FOR COMPREHENSIVE RESERVE DETERMINATION FOR LOWER VAAL

Report No : 8856-8438-3

Submitted to:

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1 INTRODUCTION

Assessment of the ecological Reserve for rivers required the determination of Environmental Water Requirements (EWR) for protection of aquatic ecosystems. EWRs tend to quantify the water needs of the various biotic components in terms of relations between flow magnitude and timing. These relations include the frequency, duration, timing and rate of change of flows, and the specification of flows for the ecological Reserve aims to replicate important aspects of the natural hydrological regime (Hirschowitz et al, 2007).

The results of hydraulic analyses and modelling form the essential link between the way in which the hydrologists, engineers and water managers express the flow of water in the river in terms of flow rate, and the way in which river ecologists express the water requirements of the river ecosystem itself in terms of variables like the flow depth and flow velocity (Birkhead, 2002).

The role of hydraulics and the procedure for generating hydraulic information has been documented for different levels of Reserve determinations (Department of Water Affairs and Forestry, 1999). A procedure for using standard hydraulic information as the basis for quantifying hydraulic habitat has been described by Jordanova et al., 2004. Further development regarding the use of hydraulic information for prediction the abundance and composition of hydraulic habitats has been carried out (Hirschowitz et al, 2007). HABitat-FLOw simulation software has been developed to provide a working model that automates the prediction of habitat-type abundance and composition for fish and macroinvertebrates (Hirschowitz et al, 2007). The model has bee used for prediction of hydraulic habitats for fish and macroinvertebrates.

This report is presenting the hydraulics assessment of the Comprehensive Reserve determination for the Lower Vaal.

2 SITE SELECTION

During the site selection trip for the Lower Vaal Reserve determination, 4 sites were selected. Coordinates of the selected EWR sites are listed in Table 1. Locations of the selected EWR sites are shown in Table 1. Photos of the EWR sites are presented in Figure 2 to Figure 5.

Table 1: Coordinates of selected EWR sites

River	Site no.	South	East
Vaal	EWR16	27.65541	25.59564
Harts	EWR17	28.37694	24.30305
Vaal	EWR18	28.7048	24.07601
Riet	EWR19	29.03842	24.50283

Advantages and disadvantages of the selected EFR sites are given in Table 2.

Table 2: Advantages and disadvantages of selected EWR sites

River	Site	Advantages	Disadvantages
Vaal	EWR16	Easy access to the site. Single channel. Gauging weir for flow records.	Vegetation on both banks influences overall flow resistance at high flows. Downstream hydraulic structures may create an additional backwater effect under high flow condition.
Harts	EWR17	Easy access to the site. Single channel. Gauging weir for flow records.	Under high flows an additional flow resistance from the confluence backwater could occur.
Vaal	EWR18	Easy access to the site. Single channel. Gauging weir for flow records.	Vegetation on both banks influences overall flow resistance at high flows. Downstream hydraulic structures may create an additional backwater effect under high flow condition.
Riet	EWR19	Gauging weir for flow records.	Hydraulics is more complex. Large scale river bad substrates result to non-uniform flow with potential for non-horizontal water profile at low flows. There are instream vegetated islands that additionally complicate hydraulic modelling.

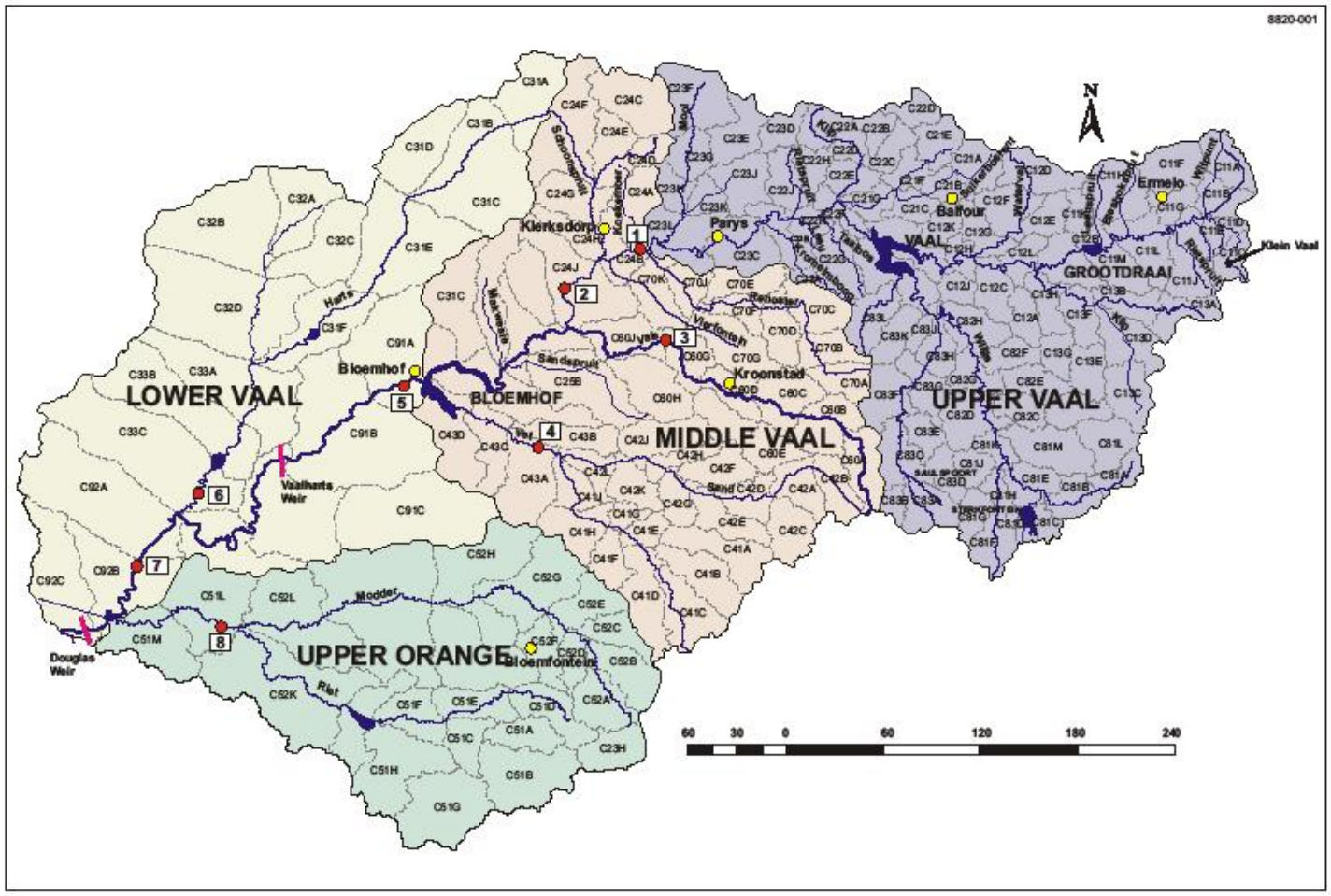

Figure 1: Location of the EWR sites (sites EWR 1 – 8 refer to sites EWR 12 – 19)

Figure 2: Vaal River EWR16 view from the right bank

Figure 3: Harts River EWR17 view from the right bank

Figure 4: Vaal River EWR18 view from the left bank

Figure 5: Riet River EWR19 view from the left bank

3 DATA COLLECTION

3.1 EWR sites survey

Survey of the selected EWR sites was performed by professional surveyors. Permanent bench marks (BM) were installed at each site and coordinates of fixed survey stations are listed in Table 3.

Table 3: Coordinates of fixed survey stations at the selected EWR sites

River	Site no.	Coordinate system	Station	Remark	Y-Coord (m)	X-Coord (m)	Z-Coord (m)
Vaal	EWR16	LO25 CAPE DATUM	DW5	IPC	-58662.46	3060111.80	1216.86
Harts	EWR17	LO25 WGS 84	DW3	IPC	68508.37	3140697.33	1008.53
Vaal	EWR18	LO25 WGS 84	DW7	IPC	90249.83	3176805.45	1009.091
Riet	EWR19	LO25 WGS 84	DW8	IPC	47508.91	3212407.83	1076.282

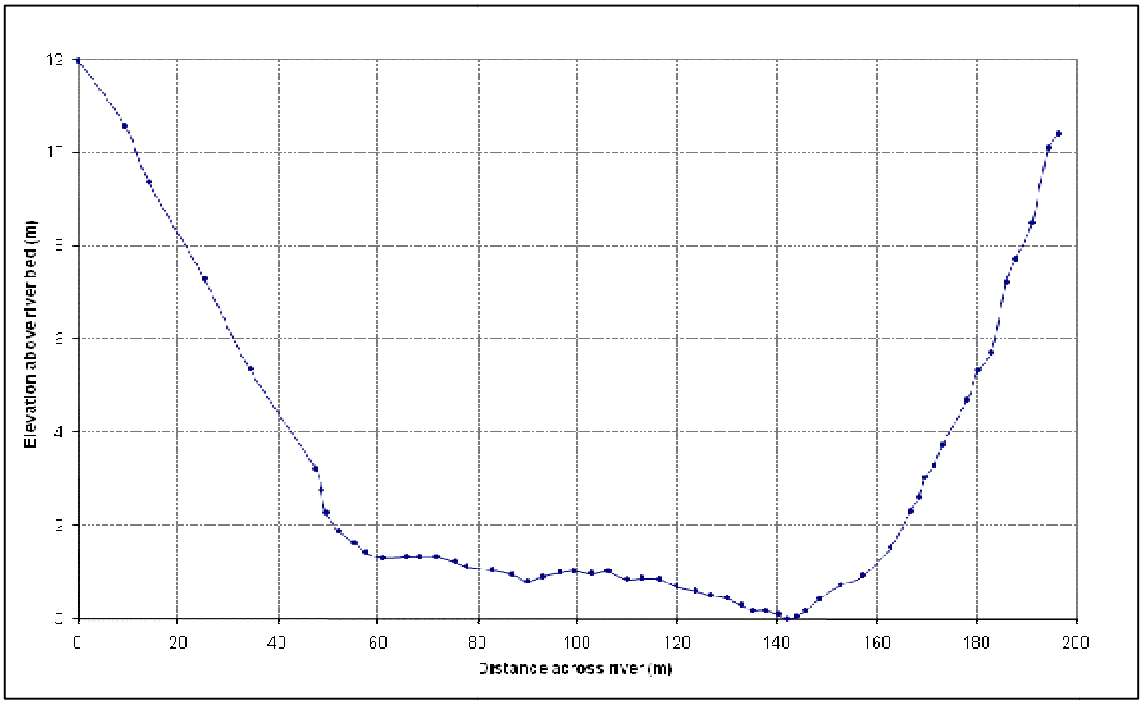

Figure 6: Cross-sectional profile for EWR16 on the Vaal River.

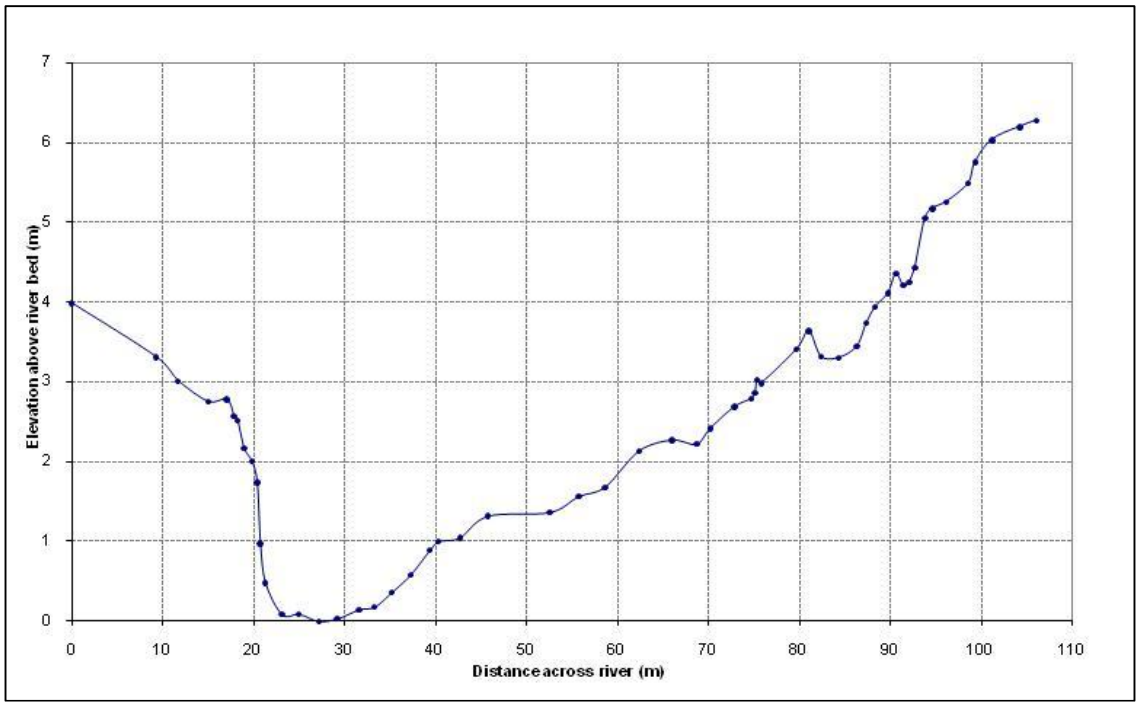

Figure 7: Cross-sectional profile for EWR17 on the Harts River

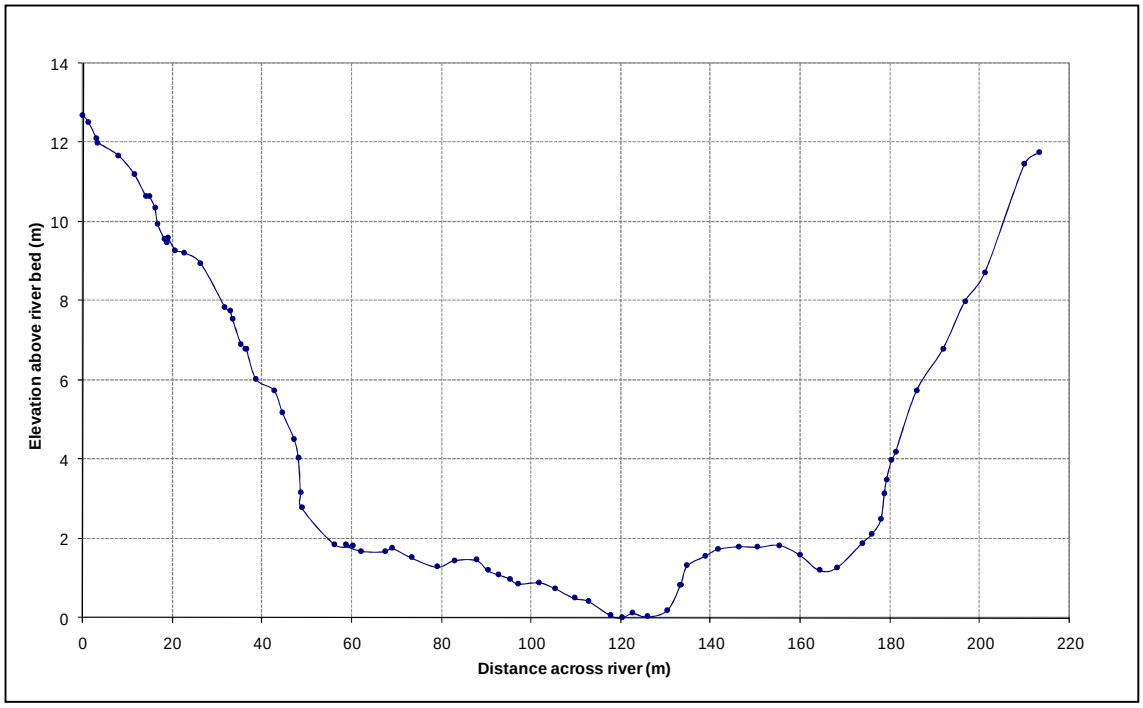

Figure 8: Cross-sectional profile for EWR18 on the Vaal River

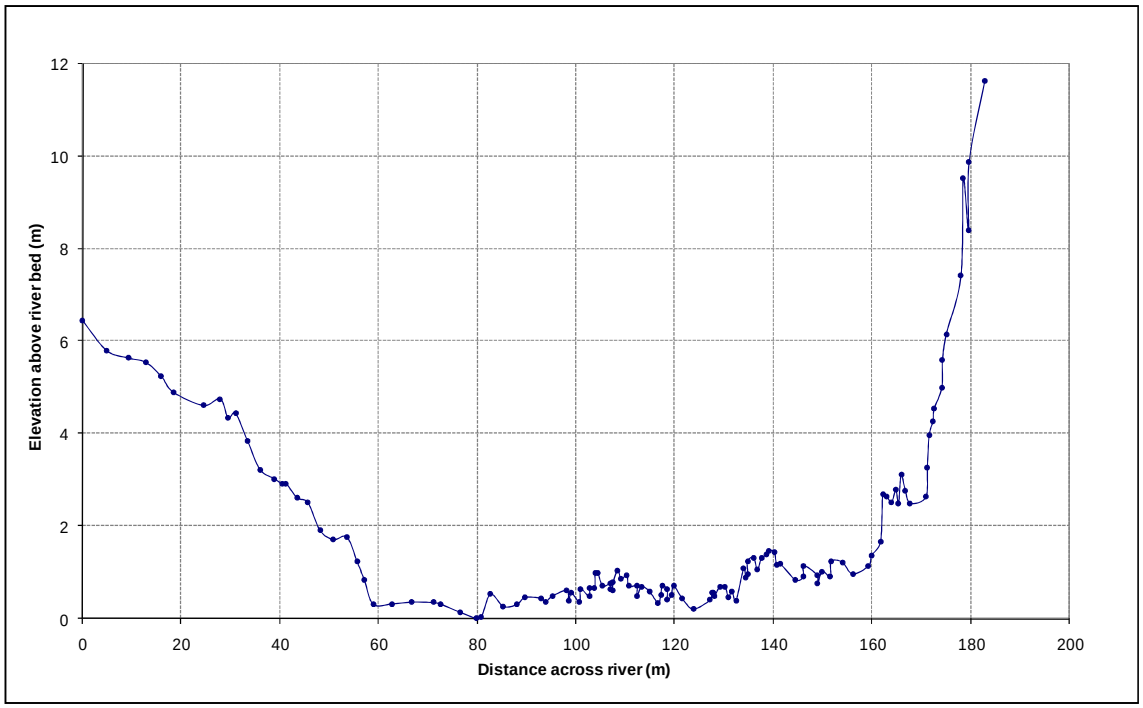

Figure 9: Cross-sectional profile for EWR19 on the Riet River

3.2 Hydraulic data collected

The stage-discharge data collected at the EWR sites together with the dates when the data were collected are provided in Table 4.

Table 4: Hydraulic data collected at EWR sites

River	Site no.	Date	Discharge Q (m^3/s)	Max. flow depth, y (m)
Vaal	EWR16	26.09.2007	40.89	2.94
		25.08.2008	55.03	2.99
Harts	EWR17	28.09.2007	1.13	1.05
		25.08.2008	0.89	0.96
Vaal	EWR18	20.06.2008	4.99	3.14
		26.08.2008	2.11	3.00
Riet	EWR19	27.09.2007	5.26	0.84
		24.06.2008	4.20	0.77
		26.08.2008	2.55	0.67

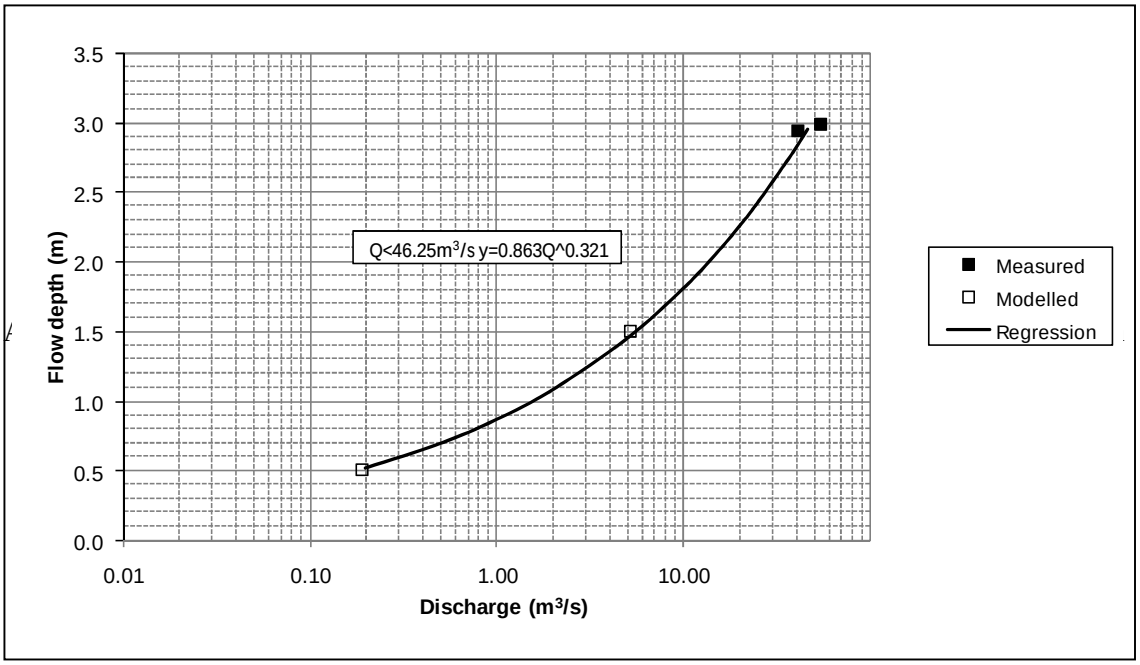

Figure 10: Measured and modelled rating relationship for Vaal River EWR16 for Q < 46.25m^3/s

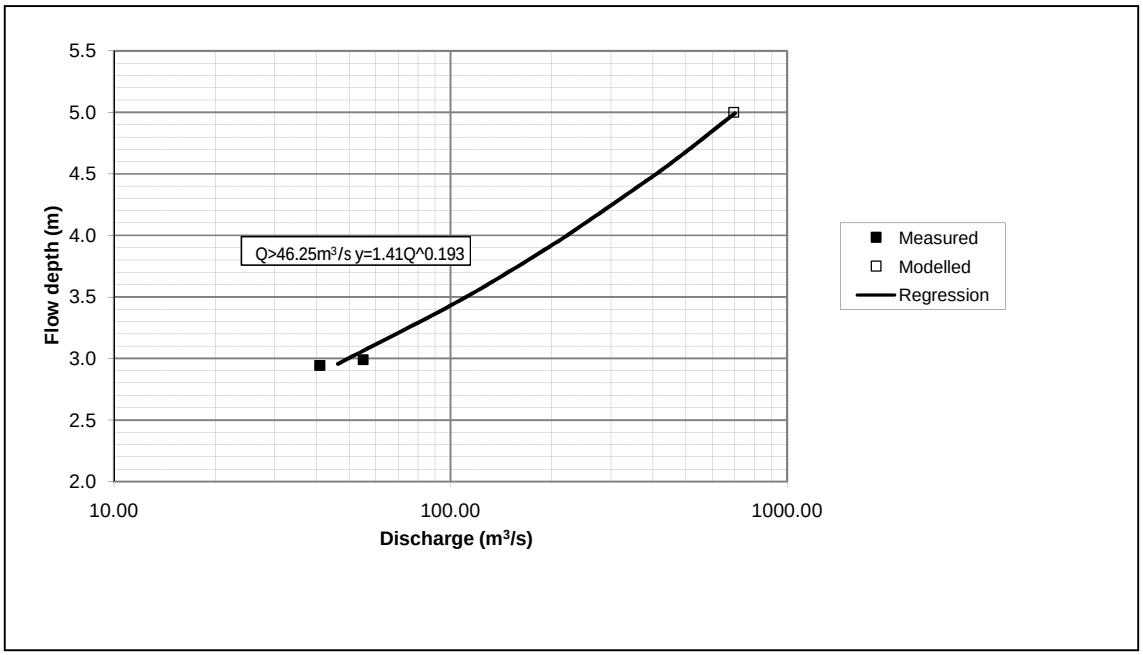

Figure 11: Measured and modelled rating relationship for Vaal River EWR16 for Q > 46.25 m^3/s

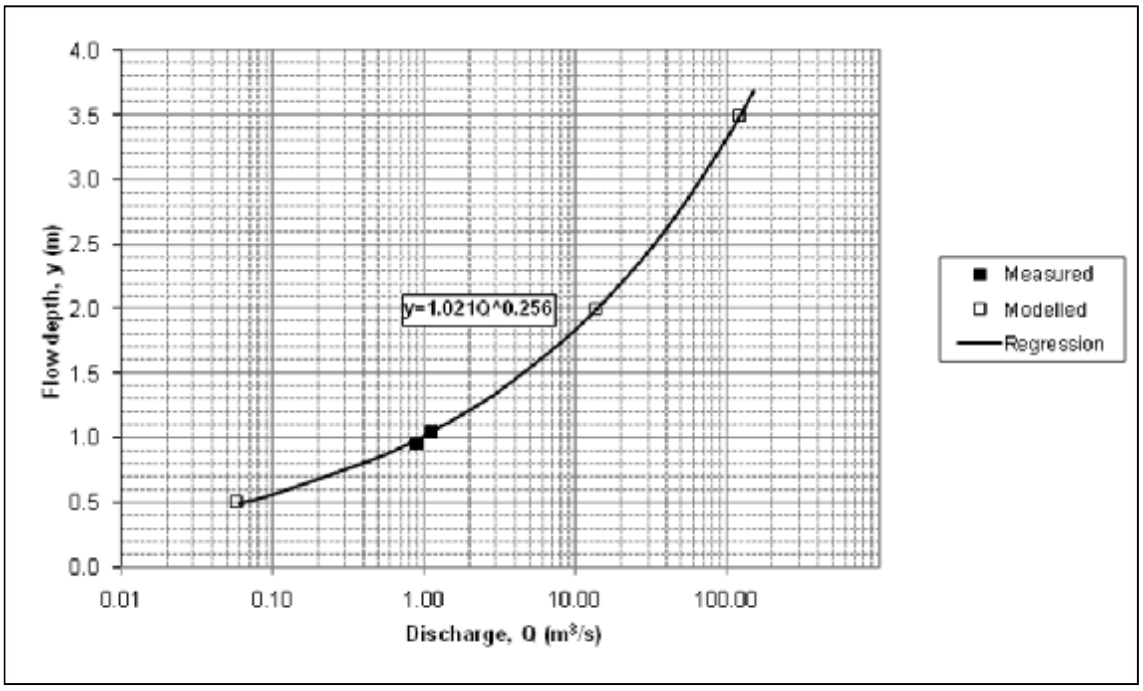

Figure 12: Measured and modelled rating relationship for Harts River EWR17

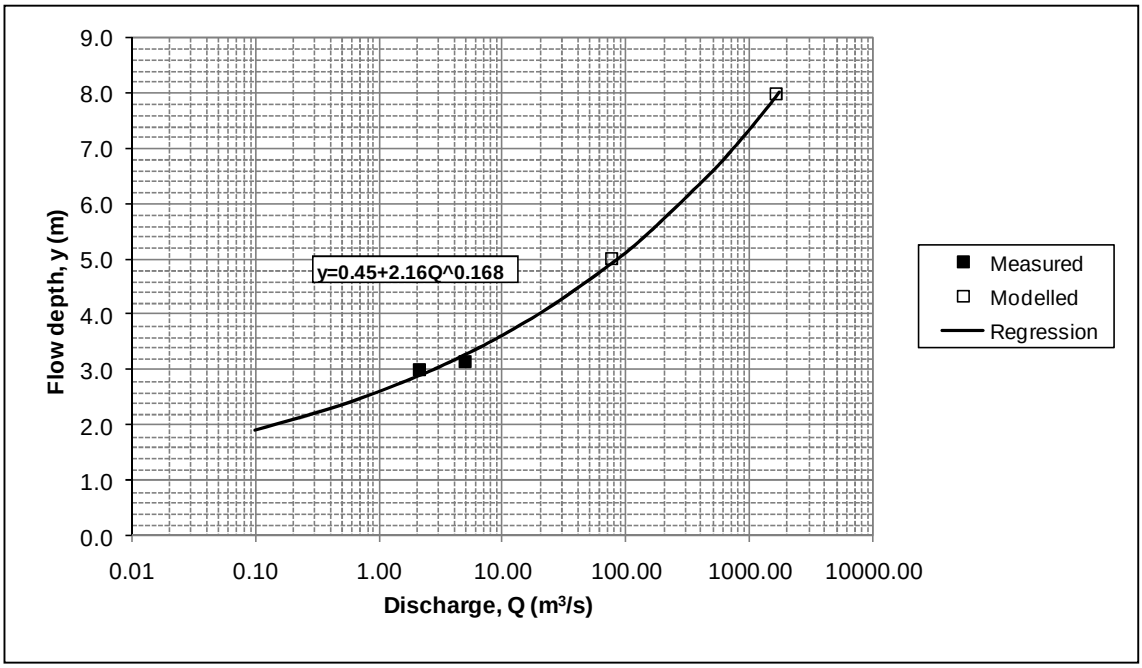

Figure 13: Measured and modelled rating relationship for Vaal River EWR18

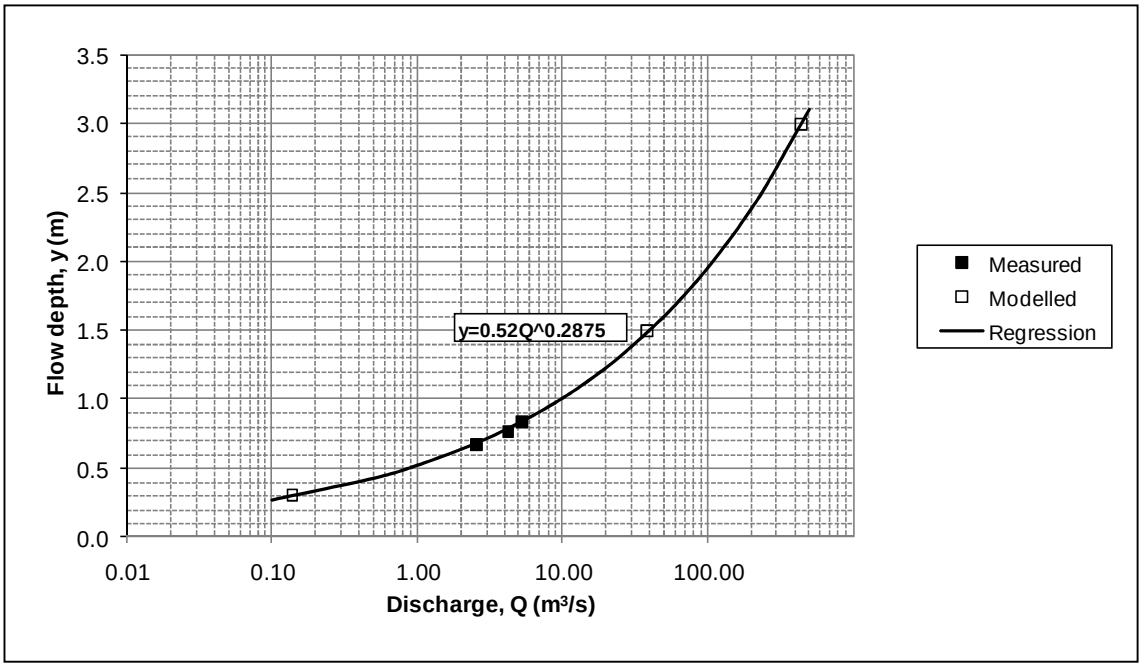

Figure 14: Measured and modelled rating relationship for Riet River EWR19

Modelled hydraulic data for the EWR sites are give in Appendix A.

3.3 Confidence in the hydraulic modelling

Confidence in the hydraulic modelling in a range of confidence of 0 to 5 is given in Table 5. The confidence in the hydraulic modelling for flows that higher and lower then were observed is low. The reason for the low confidence in the hydraulic modelling is related to too narrow range of the observed rating data.

Table 5: Confidence in the hydraulic modelling

EWRs Site	Limits of measured discharge range (m^3/s)		Confidence rating for discharge range (0=none, 1=low, 2=low/medium, 3=medium, 4=medium/high, 5=high)		
	Q_{min}	Q_{max}	$Q<Q_{min}$	$Q_{min}<Q<Q_{max}$	$Q>Q_{max}$
16	40.89	55.03	2	4	2
17	0.89	1.13	3	4	2
18	2.11	4.99	2	4	2
19	2.55	5.26	2	4	2

4 REFERENCES

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APPENDIX A

Table A-1: EWR16 Modelled hydraulics parameters in 0.05 m depth interval

Max depth	Average depth	Discharge	Width	Perimeter	Average Velocity
(m)	(m)	(m3/s)	(m)	(m)	(m/s)
0.50	0.26	0.183	22.1	22.10	0.03
0.55	0.28	0.237	24.7	24.70	0.03
0.60	0.30	0.299	27.0	27.10	0.04
0.65	0.32	0.369	29.7	29.70	0.04
0.70	0.34	0.450	32.4	32.40	0.04
0.75	0.37	0.549	34.4	34.40	0.04
0.80	0.40	0.658	36.6	36.70	0.05
0.85	0.41	0.759	40.7	40.70	0.05
0.90	0.36	0.813	52.0	52.10	0.04
0.95	0.38	0.965	56.9	57.00	0.04
1.00	0.37	1.091	66.4	66.50	0.04
1.05	0.37	1.265	75.4	75.50	0.04
1.10	0.41	1.527	79.1	79.20	0.05
1.15	0.44	1.829	82.0	82.10	0.05
1.20	0.48	2.177	83.6	83.70	0.05
1.25	0.52	2.548	85.6	85.70	0.06
1.30	0.56	2.943	87.8	87.90	0.06
1.35	0.53	3.144	101.3	101.30	0.06
1.40	0.57	3.637	103.2	103.30	0.06
1.45	0.61	4.181	104.6	104.70	0.07
1.50	0.65	4.773	105.6	105.70	0.07
1.55	0.70	5.403	106.5	106.60	0.07
1.60	0.74	6.078	107.3	107.40	0.08
1.65	0.79	6.791	108.1	108.20	0.08
1.70	0.83	7.538	109.0	109.10	0.08
1.75	0.87	8.325	109.8	110.00	0.09
1.80	0.92	9.152	110.7	110.90	0.09
1.85	0.96	10.020	111.6	111.80	0.09
1.90	1.00	10.936	112.4	112.60	0.10
1.95	1.05	11.907	113.0	113.20	0.10
2.00	1.09	12.920	113.6	113.70	0.10
2.05	1.14	13.978	114.2	114.30	0.11
2.10	1.18	15.080	114.8	114.90	0.11
2.15	1.22	16.227	115.3	115.50	0.11
2.20	1.27	17.420	115.9	116.10	0.12
2.25	1.31	18.661	116.5	116.70	0.12
2.30	1.36	19.965	117.0	117.20	0.13
2.35	1.40	21.326	117.3	117.60	0.13
2.40	1.45	22.734	117.7	118.00	0.13
2.45	1.49	24.193	118.1	118.40	0.14
2.50	1.54	25.704	118.5	118.80	0.14

Max depth	Average depth	Discharge	Width	Perimeter	Average Velocity
(m)	(m)	(m3/s)	(m)	(m)	(m/s)
2.55	1.58	27.268	118.9	119.20	0.14
2.60	1.63	28.886	119.3	119.60	0.15
2.65	1.67	30.581	119.5	119.90	0.15
2.70	1.72	32.338	119.8	120.20	0.16
2.75	1.77	34.154	120.0	120.40	0.16
2.80	1.81	36.024	120.3	120.70	0.17
2.85	1.86	37.954	120.5	121.00	0.17
2.90	1.90	39.946	120.8	121.20	0.17
2.95	1.95	46.022	121.0	121.50	0.19
3.00	2.00	50.000	121.3	121.80	0.21
3.05	2.04	54.471	121.6	122.20	0.22
3.10	2.08	59.260	122.1	122.60	0.23
3.15	2.13	64.382	122.5	123.10	0.25
3.20	2.17	69.855	123.0	123.50	0.26
3.25	2.21	75.699	123.5	124.10	0.28
3.30	2.25	81.930	124.1	124.70	0.29
3.35	2.29	88.569	124.6	125.20	0.31
3.40	2.33	95.636	125.1	125.70	0.33
3.45	2.37	103.150	125.7	126.30	0.35
3.50	2.41	111.134	126.2	126.80	0.37
3.55	2.45	119.610	126.7	127.30	0.39
3.60	2.49	128.599	127.2	127.80	0.41
3.65	2.53	138.127	127.7	128.30	0.43
3.70	2.57	148.215	128.2	128.80	0.45
3.75	2.61	158.890	128.7	129.40	0.47
3.80	2.65	170.178	129.3	129.90	0.50
3.85	2.69	182.103	129.8	130.50	0.52
3.90	2.72	194.694	130.4	131.10	0.55
3.95	2.76	207.979	131.0	131.70	0.57
4.00	2.80	221.985	131.6	132.30	0.60
4.05	2.84	236.743	132.1	132.80	0.63
4.10	2.88	252.283	132.7	133.40	0.66
4.15	2.91	268.636	133.3	134.00	0.69
4.20	2.95	285.834	133.8	134.60	0.72
4.25	2.99	303.909	134.4	135.20	0.76
4.30	3.03	322.896	135.0	135.70	0.79
4.35	3.06	342.829	135.6	136.30	0.83
4.40	3.10	363.743	136.1	136.90	0.86
4.45	3.14	385.675	136.7	137.50	0.90
4.50	3.17	408.662	137.3	138.10	0.94
4.55	3.21	432.742	137.8	138.60	0.98
4.60	3.25	457.954	138.4	139.20	1.02

Max depth	Average depth	Discharge	Width	Perimeter	Average Velocity
(m)	(m)	(m3/s)	(m)	(m)	(m/s)
4.65	3.28	484.339	139.0	139.80	1.06
4.70	3.32	511.937	139.5	140.40	1.11
4.75	3.36	540.790	140.0	140.90	1.15
4.80	3.40	570.941	140.5	141.40	1.20
4.85	3.44	602.435	141.0	141.90	1.24
4.90	3.47	635.316	141.5	142.30	1.29
4.95	3.51	669.630	141.9	142.80	1.34
5.00	3.55	705.425	142.4	143.30	1.40
5.05	3.59	742.748	142.9	143.80	1.45
5.10	3.63	781.648	143.4	144.30	1.50
5.15	3.66	822.176	143.9	144.80	1.56
5.20	3.70	864.384	144.4	145.30	1.62
5.25	3.74	908.323	144.8	145.80	1.68
5.30	3.78	954.047	145.3	146.30	1.74
5.35	3.81	1001.610	145.8	146.80	1.80
5.40	3.85	1051.069	146.4	147.40	1.87
5.45	3.88	1102.481	147.0	148.00	1.93
5.50	3.92	1155.903	147.5	148.60	2.00
5.55	3.95	1211.394	148.1	149.10	2.07
5.60	3.99	1269.016	148.7	149.70	2.14
5.65	4.02	1328.830	149.3	150.30	2.21
5.70	4.05	1390.898	149.9	150.90	2.29
5.75	4.09	1455.286	150.4	151.40	2.37
5.80	4.13	1522.057	150.7	151.80	2.44
5.85	4.17	1591.279	151.0	152.10	2.52
5.90	4.21	1663.020	151.4	152.50	2.61
5.95	4.25	1737.349	151.7	152.80	2.69
6.00	4.30	1814.335	152.0	153.20	2.78
6.05	4.34	1894.052	152.4	153.50	2.87
6.10	4.38	1976.571	152.7	153.90	2.96
6.15	4.42	2061.967	153.0	154.20	3.05
6.20	4.46	2150.317	153.4	154.60	3.15
6.25	4.50	2241.696	153.7	154.90	3.24
6.30	4.54	2336.184	154.0	155.30	3.34
6.35	4.58	2433.859	154.4	155.60	3.44
6.40	4.62	2534.805	154.7	156.00	3.55
6.45	4.66	2639.102	155.1	156.40	3.65

Table A-2: EWR17 Modelled hydraulics parameters in 0.02 m depth interval

Max depth	Average dept	Discharge	Width	Perimeter	Average Velocity
(m)	(m)	(m3/s)	(m)	(m)	(m/s)
0.10	0.05	0.000	7.7	7.7	0.00
0.12	0.06	0.000	8.2	8.2	0.00
0.14	0.08	0.000	8.7	8.7	0.00
0.16	0.09	0.001	9.7	9.7	0.00
0.18	0.10	0.001	10.6	10.7	0.00
0.20	0.12	0.002	10.9	11.0	0.00
0.22	0.14	0.002	11.2	11.3	0.00
0.24	0.15	0.003	11.5	11.6	0.00
0.26	0.17	0.005	11.8	11.9	0.00
0.28	0.18	0.006	12.1	12.2	0.00
0.30	0.20	0.008	12.4	12.5	0.00
0.32	0.21	0.011	12.7	12.8	0.00
0.34	0.23	0.014	13.0	13.1	0.00
0.36	0.24	0.017	13.3	13.4	0.01
0.38	0.26	0.021	13.6	13.7	0.01
0.40	0.27	0.026	13.9	13.9	0.01
0.42	0.29	0.031	14.2	14.2	0.01
0.44	0.30	0.037	14.5	14.5	0.01
0.46	0.31	0.044	14.7	14.8	0.01
0.48	0.33	0.051	15.0	15.1	0.01
0.50	0.34	0.061	15.2	15.3	0.01
0.52	0.36	0.072	15.4	15.5	0.01
0.54	0.37	0.083	15.7	15.7	0.01
0.56	0.39	0.096	15.9	16.0	0.02
0.58	0.40	0.110	16.1	16.2	0.02
0.60	0.42	0.125	16.2	16.4	0.02
0.62	0.44	0.142	16.4	16.5	0.02
0.64	0.45	0.161	16.6	16.7	0.02
0.66	0.47	0.182	16.7	16.9	0.02
0.68	0.48	0.204	16.9	17.0	0.03
0.70	0.50	0.229	17.0	17.2	0.03
0.72	0.51	0.256	17.2	17.4	0.03
0.74	0.53	0.284	17.4	17.5	0.03
0.76	0.54	0.316	17.5	17.7	0.03
0.78	0.56	0.349	17.7	17.9	0.04
0.80	0.57	0.386	17.8	18.0	0.04
0.82	0.59	0.425	18.0	18.2	0.04
0.84	0.60	0.467	18.2	18.4	0.04
0.86	0.62	0.512	18.3	18.5	0.05
0.88	0.63	0.560	18.5	18.7	0.05
0.90	0.65	0.611	18.7	18.9	0.05
0.92	0.66	0.666	18.9	19.1	0.05
0.94	0.67	0.724	19.1	19.3	0.06
0.96	0.68	0.786	19.3	19.5	0.06
0.98	0.70	0.852	19.5	19.7	0.06
1.00	0.71	0.922	19.7	20.0	0.07
1.02	0.70	0.996	20.6	20.9	0.07
1.04	0.69	1.075	21.5	21.8	0.07
1.06	0.69	1.158	22.1	22.4	0.08

Max depth	Average dept	Discharge	Width	Perimeter	Average Velocity
(m)	(m)	(m3/s)	(m)	(m)	(m/s)
1.08	0.70	1.245	22.3	22.7	0.08
1.10	0.71	1.338	22.6	23.0	0.08
1.12	0.73	1.435	22.8	23.2	0.09
1.14	0.74	1.538	23.1	23.5	0.09
1.16	0.75	1.646	23.3	23.7	0.09
1.18	0.76	1.760	23.6	24.0	0.10
1.20	0.78	1.880	23.8	24.2	0.10
1.22	0.79	2.005	24.0	24.5	0.11
1.24	0.80	2.136	24.3	24.7	0.11
1.26	0.81	2.274	24.5	25.0	0.11
1.28	0.82	2.418	24.8	25.2	0.12
1.30	0.84	2.569	25.0	25.5	0.12
1.32	0.85	2.727	25.2	25.8	0.13
1.34	0.77	2.892	28.6	29.2	0.13
1.36	0.70	3.065	32.0	32.6	0.14
1.38	0.72	3.244	32.4	32.9	0.14
1.40	0.73	3.432	32.7	33.2	0.14
1.42	0.74	3.628	33.0	33.6	0.15
1.44	0.75	3.831	33.3	33.9	0.15
1.46	0.77	4.043	33.7	34.3	0.16
1.48	0.78	4.264	34.0	34.6	0.16
1.50	0.79	4.494	34.3	34.9	0.17
1.52	0.80	4.732	34.6	35.3	0.17
1.54	0.82	4.980	35.0	35.6	0.17
1.56	0.83	5.238	35.3	36.0	0.18
1.58	0.84	5.505	35.8	36.5	0.18
1.60	0.85	5.782	36.3	37.0	0.19
1.62	0.85	6.070	36.8	37.5	0.19
1.64	0.86	6.368	37.3	38.0	0.20
1.66	0.87	6.676	37.8	38.5	0.20
1.68	0.88	6.996	38.3	39.0	0.21
1.70	0.90	7.327	38.4	39.2	0.21
1.72	0.91	7.670	38.6	39.4	0.22
1.74	0.93	8.024	38.8	39.6	0.22
1.76	0.94	8.390	39.0	39.8	0.23
1.78	0.96	8.769	39.2	40.0	0.23
1.80	0.97	9.160	39.4	40.2	0.24
1.82	0.99	9.564	39.6	40.5	0.24
1.84	1.00	9.981	39.8	40.7	0.25
1.86	1.02	10.412	40.1	40.9	0.26
1.88	1.03	10.856	40.3	41.1	0.26
1.90	1.05	11.314	40.5	41.3	0.27
1.92	1.06	11.787	40.7	41.5	0.27
1.94	1.07	12.273	40.9	41.7	0.28
1.96	1.09	12.775	41.1	42.0	0.29
1.98	1.10	13.292	41.3	42.2	0.29
2.00	1.12	13.824	41.5	42.4	0.30
2.02	1.13	14.372	41.8	42.7	0.30
2.04	1.14	14.936	42.1	42.9	0.31
2.06	1.16	15.516	42.3	43.2	0.32

Max depth	Average dept	Discharge	Width	Perimeter	Average Velocity
(m)	(m)	(m3/s)	(m)	(m)	(m/s)
2.08	1.17	16.113	42.6	43.5	0.32
2.10	1.18	16.727	42.9	43.8	0.33
2.12	1.19	17.358	43.1	44.0	0.34
2.14	1.20	18.006	43.6	44.5	0.34
2.16	1.20	18.672	44.2	45.1	0.35
2.18	1.21	19.357	44.8	45.7	0.36
2.20	1.21	20.060	45.3	46.2	0.36
2.22	1.22	20.782	45.9	46.8	0.37
2.24	1.19	21.523	47.7	48.6	0.38
2.26	1.17	22.283	49.5	50.4	0.39
2.28	1.17	23.063	50.5	51.4	0.39
2.30	1.18	23.864	50.7	51.6	0.40
2.32	1.20	24.685	50.9	51.8	0.41
2.34	1.21	25.527	51.0	52.0	0.41
2.36	1.23	26.389	51.2	52.2	0.42
2.38	1.24	27.274	51.4	52.4	0.43
2.40	1.26	28.180	51.6	52.6	0.43
2.42	1.27	29.109	51.8	52.8	0.44
2.44	1.29	30.060	52.1	53.0	0.45
2.46	1.30	31.034	52.3	53.3	0.46
2.48	1.32	32.031	52.5	53.5	0.46
2.50	1.33	33.052	52.8	53.8	0.47
2.52	1.34	34.097	53.0	54.0	0.48
2.54	1.36	35.166	53.3	54.4	0.49
2.56	1.37	36.260	53.7	54.7	0.49
2.58	1.38	37.379	54.0	55.0	0.50
2.60	1.39	38.524	54.3	55.3	0.51
2.62	1.41	39.695	54.6	55.6	0.52
2.64	1.42	40.891	54.8	55.8	0.53
2.66	1.43	42.115	55.1	56.1	0.53
2.68	1.44	43.365	55.4	56.4	0.54
2.70	1.45	44.643	55.7	56.7	0.55
2.72	1.46	45.949	56.2	57.2	0.56
2.74	1.47	47.283	56.6	57.7	0.57
2.76	1.46	48.646	57.9	58.9	0.58
2.78	1.43	50.037	60.0	61.0	0.58
2.80	1.44	51.458	60.5	61.5	0.59
2.82	1.45	52.909	60.8	61.9	0.60
2.84	1.46	54.390	61.2	62.2	0.61
2.86	1.47	55.901	61.5	62.6	0.62
2.88	1.48	57.444	61.8	62.9	0.63
2.90	1.50	59.018	62.1	63.2	0.63
2.92	1.51	60.624	62.4	63.5	0.64
2.94	1.52	62.262	62.7	63.8	0.65
2.96	1.54	63.933	63.0	64.1	0.66
2.98	1.55	65.637	63.3	64.4	0.67
3.00	1.55	67.375	64.0	65.1	0.68
3.02	1.56	69.146	64.6	65.7	0.69
3.04	1.57	70.952	64.9	66.0	0.70
3.06	1.58	72.793	65.3	66.4	0.71

Max depth	Average dept	Discharge	Width	Perimeter	Average Velocity
(m)	(m)	(m3/s)	(m)	(m)	(m/s)
3.08	1.59	74.669	65.6	66.7	0.71
3.10	1.60	76.581	65.9	67.1	0.72
3.12	1.62	78.530	66.3	67.4	0.73
3.14	1.63	80.514	66.6	67.8	0.74
3.16	1.64	82.536	67.0	68.1	0.75
3.18	1.65	84.596	67.3	68.4	0.76
3.20	1.66	86.693	67.6	68.8	0.77
3.22	1.67	88.829	68.0	69.1	0.78
3.24	1.69	91.004	68.3	69.5	0.79
3.26	1.70	93.218	68.7	69.8	0.80
3.28	1.71	95.472	69.0	70.1	0.81
3.30	1.72	97.766	69.3	70.5	0.82
3.32	1.68	100.101	72.0	73.1	0.83
3.34	1.68	102.477	72.8	74.0	0.84
3.36	1.68	104.895	73.6	74.8	0.85
3.38	1.68	107.355	74.5	75.6	0.86
3.40	1.68	109.858	75.3	76.5	0.87
3.42	1.68	112.404	76.1	77.3	0.88
3.44	1.69	114.993	76.9	78.0	0.89
3.46	1.69	117.627	77.4	78.6	0.90
3.48	1.70	120.306	78.0	79.1	0.91
3.50	1.71	123.029	78.5	79.7	0.92

Table A-3: EWR18 Modelled hydraulics parameters in 0.05 m depth interval

Max depth	Average depth	Discharge	Width	Perimeter	Average Velocity
(m)	(m)	(m3/s)	(m)	(m)	(m/s)
0.50	0.32	0.000	22.4	22.4	0.00
0.55	0.35	0.000	23.5	23.5	0.00
0.60	0.39	0.000	24.5	24.6	0.00
0.65	0.42	0.000	25.6	25.7	0.00
0.70	0.45	0.000	26.7	26.8	0.00
0.75	0.48	0.000	27.9	28.0	0.00
0.80	0.51	0.000	29.3	29.4	0.00
0.85	0.53	0.000	30.7	30.8	0.00
0.90	0.49	0.000	37.1	37.2	0.00
0.95	0.53	0.000	38.0	38.1	0.00
1.00	0.56	0.000	39.1	39.2	0.00
1.05	0.59	0.001	40.4	40.5	0.00
1.10	0.62	0.001	41.7	41.8	0.00
1.15	0.65	0.001	42.9	43.1	0.00
1.20	0.67	0.002	44.8	44.9	0.00
1.25	0.67	0.003	48.4	48.6	0.00
1.30	0.68	0.004	51.8	52.0	0.00
1.35	0.67	0.006	56.4	56.7	0.00
1.40	0.67	0.008	61.2	61.4	0.00
1.45	0.62	0.010	70.6	70.8	0.00
1.50	0.65	0.014	73.6	73.9	0.00
1.55	0.67	0.018	76.4	76.7	0.00
1.60	0.69	0.024	79.4	79.6	0.00

Max depth	Average depth	Discharge	Width	Perimeter	Average Velocity
(m)	(m)	(m3/s)	(m)	(m)	(m/s)
1.65	0.72	0.031	82.5	82.7	0.00
1.70	0.69	0.039	91.9	92.2	0.00
1.75	0.69	0.049	98.5	98.7	0.00
1.80	0.67	0.062	110.1	110.4	0.00
1.85	0.67	0.077	117.2	120.9	0.00
1.90	0.72	0.094	118.1	121.8	0.00
1.95	0.76	0.115	119.0	122.7	0.00
2.00	0.81	0.140	119.8	123.5	0.00
2.05	0.85	0.169	120.7	124.4	0.00
2.10	0.90	0.203	121.6	125.3	0.00
2.15	0.94	0.243	122.3	126.0	0.00
2.20	0.99	0.289	122.9	126.7	0.00
2.25	1.03	0.341	123.6	127.3	0.00
2.30	1.07	0.402	124.3	128.0	0.00
2.35	1.12	0.470	124.9	128.7	0.00
2.40	1.16	0.549	125.6	129.3	0.00
2.45	1.21	0.638	126.2	130.0	0.00
2.50	1.25	0.739	126.8	130.6	0.00
2.55	1.30	0.853	127.3	131.1	0.01
2.60	1.34	0.981	127.7	131.6	0.01
2.65	1.39	1.124	128.2	132.0	0.01
2.70	1.43	1.285	128.6	132.5	0.01
2.75	1.48	1.465	129.1	133.0	0.01
2.80	1.52	1.652	129.4	133.3	0.01
2.85	1.57	1.759	129.5	133.5	0.01
2.90	1.62	1.869	129.6	133.6	0.01
2.95	1.67	1.984	129.7	133.7	0.01
3.00	1.72	2.103	129.8	133.9	0.01
3.05	1.77	3.036	129.8	134.0	0.01
3.10	1.82	3.400	129.9	134.1	0.01
3.15	1.86	3.799	130.0	134.3	0.02
3.20	1.91	4.237	130.1	134.4	0.02
3.25	1.96	4.717	130.2	134.5	0.02
3.30	2.01	5.240	130.3	134.7	0.02
3.35	2.06	5.811	130.4	134.8	0.02
3.40	2.11	6.433	130.5	134.9	0.02
3.45	2.16	7.109	130.5	135.1	0.03
3.50	2.21	7.843	130.6	135.2	0.03
3.55	2.25	8.639	130.8	135.4	0.03
3.60	2.30	9.502	130.9	135.6	0.03
3.65	2.35	10.434	131.1	135.8	0.03
3.70	2.39	11.442	131.2	136.0	0.04
3.75	2.44	12.530	131.4	136.2	0.04
3.80	2.49	13.702	131.5	136.4	0.04
3.85	2.54	14.964	131.7	136.5	0.04
3.90	2.58	16.321	131.8	136.7	0.05
3.95	2.63	17.779	132.0	136.9	0.05
4.00	2.68	19.344	132.2	137.1	0.05
4.05	2.72	21.022	132.5	137.5	0.06
4.10	2.76	22.820	132.8	137.8	0.06

Max depth	Average depth	Discharge	Width	Perimeter	Average Velocity
(m)	(m)	(m3/s)	(m)	(m)	(m/s)
4.15	2.81	24.743	133.1	138.2	0.07
4.20	2.85	26.799	133.4	138.5	0.07
4.25	2.90	28.996	133.7	138.7	0.07
4.30	2.94	31.340	133.9	139.0	0.08
4.35	2.98	33.840	134.2	139.3	0.08
4.40	3.03	36.504	134.4	139.6	0.09
4.45	3.07	39.340	134.7	139.8	0.10
4.50	3.12	42.357	134.9	140.1	0.10
4.55	3.16	45.564	135.3	140.4	0.11
4.60	3.20	48.970	135.6	140.8	0.11
4.65	3.24	52.586	135.9	141.1	0.12
4.70	3.29	56.421	136.3	141.5	0.13
4.75	3.33	60.486	136.6	141.9	0.13
4.80	3.37	64.791	137.0	142.2	0.14
4.85	3.41	69.349	137.3	142.6	0.15
4.90	3.45	74.171	137.6	142.9	0.16
4.95	3.49	79.268	138.0	143.3	0.16
5.00	3.53	84.653	138.3	143.6	0.17
5.05	3.58	90.339	138.7	144.0	0.18
5.10	3.62	96.340	139.0	144.3	0.19
5.15	3.66	102.668	139.3	144.7	0.20
5.20	3.70	109.339	139.7	145.0	0.21
5.25	3.74	116.366	140.0	145.4	0.22
5.30	3.78	123.765	140.3	145.7	0.23
5.35	3.82	131.552	140.6	146.0	0.24
5.40	3.87	139.742	140.9	146.4	0.26
5.45	3.91	148.351	141.3	146.7	0.27
5.50	3.95	157.398	141.6	147.0	0.28
5.55	3.99	166.899	141.9	147.4	0.29
5.60	4.03	176.872	142.2	147.7	0.31
5.65	4.07	187.336	142.5	148.0	0.32
5.70	4.11	198.310	142.8	148.4	0.34
5.75	4.15	209.814	143.2	148.8	0.35
5.80	4.17	221.868	144.2	149.7	0.37
5.85	4.19	234.492	145.2	150.7	0.39
5.90	4.22	247.709	146.2	151.7	0.40
5.95	4.24	261.539	147.1	152.7	0.42
6.00	4.26	276.006	148.1	153.7	0.44
6.05	4.29	291.133	148.9	154.5	0.46
6.10	4.33	306.943	149.3	154.9	0.48
6.15	4.36	323.461	149.7	155.3	0.50
6.20	4.40	340.712	150.2	155.8	0.52
6.25	4.44	358.721	150.6	156.2	0.54
6.30	4.47	377.516	151.0	156.7	0.56
6.35	4.51	397.123	151.5	157.1	0.58
6.40	4.55	417.570	151.9	157.6	0.60
6.45	4.59	438.886	152.3	158.0	0.63
6.50	4.62	461.099	152.8	158.5	0.65
6.55	4.66	484.239	153.2	158.9	0.68
6.60	4.70	508.338	153.6	159.4	0.70

Max depth	Average depth	Discharge	Width	Perimeter	Average Velocity
(m)	(m)	(m3/s)	(m)	(m)	(m/s)
6.65	4.73	533.426	154.1	159.8	0.73
6.70	4.77	559.537	154.5	160.2	0.76
6.75	4.81	586.701	154.9	160.7	0.79
6.80	4.84	614.955	155.3	161.1	0.82
6.85	4.87	644.331	156.0	161.8	0.85
6.90	4.90	674.865	156.7	162.5	0.88
6.95	4.94	706.594	157.1	162.9	0.91
7.00	4.98	739.554	157.5	163.3	0.94
7.05	5.02	773.784	157.8	163.7	0.98
7.10	5.05	809.322	158.2	164.0	1.01
7.15	5.09	846.207	158.6	164.4	1.05
7.20	5.13	884.480	158.9	164.8	1.08
7.25	5.17	924.183	159.3	165.1	1.12
7.30	5.21	965.357	159.6	165.5	1.16
7.35	5.25	1008.047	160.0	165.9	1.20
7.40	5.29	1052.295	160.3	166.2	1.24
7.45	5.32	1098.148	160.7	166.6	1.28
7.50	5.36	1145.651	161.0	167.0	1.33
7.55	5.40	1194.851	161.4	167.4	1.37
7.60	5.44	1245.797	161.7	167.7	1.42
7.65	5.48	1298.537	162.0	168.0	1.46
7.70	5.52	1353.122	162.4	168.4	1.51
7.75	5.55	1409.602	162.8	168.8	1.56
7.80	5.58	1468.031	163.5	169.6	1.61
7.85	5.60	1528.460	164.3	170.3	1.66
7.90	5.64	1590.945	164.7	170.8	1.71
7.95	5.67	1655.541	165.2	171.3	1.77
8.00	5.71	1722.304	165.6	171.7	1.82

Table A-4: EWR19 Modelled hydraulics parameters in 0.05 m depth interval

Max depth	Average depth	Discharge	Width	Perimeter	Average Velocity
(m)	(m)	(m3/s)	(m)	(m)	(m/s)
0.10	0.06	0.003	3.8	3.9	0.01
0.15	0.09	0.013	5.2	5.2	0.03
0.20	0.11	0.036	6.5	6.6	0.05
0.25	0.12	0.068	9.3	9.3	0.06
0.30	0.12	0.103	15.3	15.3	0.06
0.35	0.09	0.150	31.9	32.0	0.05
0.40	0.13	0.304	36.8	37.0	0.07
0.45	0.15	0.498	44.9	45.2	0.08
0.50	0.18	0.794	49.9	50.4	0.09
0.55	0.21	1.173	55.3	56.1	0.10
0.60	0.24	1.649	59.7	60.7	0.11
0.65	0.28	2.179	63.1	64.3	0.12
0.70	0.30	2.820	69.2	70.6	0.14
0.75	0.34	3.584	71.4	73.0	0.15
0.80	0.39	4.486	72.2	73.9	0.16

Max depth	Average depth	Discharge	Width	Perimeter	Average Velocity
(m)	(m)	(m3/s)	(m)	(m)	(m/s)
0.85	0.43	5.540	73.8	75.7	0.18
0.90	0.46	6.758	77.2	79.2	0.19
0.95	0.49	8.156	80.6	82.8	0.21
1.00	0.51	9.749	85.3	87.7	0.22
1.05	0.54	11.553	88.6	91.2	0.24
1.10	0.57	13.582	91.8	94.5	0.26
1.15	0.60	15.853	94.5	97.4	0.28
1.20	0.64	18.382	96.5	99.5	0.30
1.25	0.67	21.186	99.9	103.1	0.32
1.30	0.71	24.283	101.5	104.7	0.34
1.35	0.75	27.689	102.8	106.0	0.36
1.40	0.79	31.423	103.7	106.9	0.38
1.45	0.83	35.502	105.7	109.0	0.41
1.50	0.87	39.946	106.2	109.5	0.43
1.55	0.92	44.771	106.7	110.0	0.46
1.60	0.96	49.999	107.2	110.5	0.48
1.65	1.01	55.647	107.7	111.0	0.51
1.70	1.06	61.736	108.0	111.3	0.54
1.75	1.08	68.285	111.1	114.5	0.57
1.80	1.11	75.315	112.3	115.7	0.60
1.85	1.16	82.846	113.0	116.4	0.63
1.90	1.20	90.898	113.7	117.2	0.67
1.95	1.25	99.493	113.9	117.4	0.70
2.00	1.29	108.652	114.1	117.7	0.74
2.05	1.34	118.396	114.4	118.0	0.77
2.10	1.39	128.748	114.6	118.2	0.81
2.15	1.44	139.728	114.8	118.5	0.85
2.20	1.48	151.360	115.1	118.8	0.89
2.25	1.53	163.666	115.3	119.0	0.93
2.30	1.58	176.669	115.5	119.3	0.97
2.35	1.62	190.391	115.7	119.6	1.01
2.40	1.67	204.857	116.0	119.8	1.06
2.45	1.72	220.089	116.2	120.1	1.10
2.50	1.76	236.111	116.8	120.7	1.15
2.55	1.76	252.947	119.8	123.8	1.20
2.60	1.77	270.621	122.9	127.1	1.24
2.65	1.79	289.158	124.8	129.0	1.29
2.70	1.82	308.583	126.3	130.6	1.34
2.75	1.86	328.920	127.2	131.6	1.39
2.80	1.90	350.194	127.8	132.4	1.44
2.85	1.94	372.431	128.4	133.0	1.50
2.90	1.98	395.655	129.0	133.6	1.55
2.95	2.00	419.894	130.6	135.4	1.60
3.00	2.04	445.173	131.5	136.3	1.66
3.05	2.08	471.517	132.4	137.3	1.71
3.10	2.11	498.954	133.4	138.3	1.77
3.15	2.15	527.509	134.2	139.2	1.83
3.20	2.19	557.211	135.0	140.0	1.89
3.25	2.23	588.085	135.4	140.4	1.95
3.30	2.28	620.159	135.6	140.6	2.01

Max depth	Average depth	Discharge	Width	Perimeter	Average Velocity
(m)	(m)	(m3/s)	(m)	(m)	(m/s)
3.35	2.32	653.460	135.8	140.9	2.07
3.40	2.37	688.016	136.0	141.2	2.14
3.45	2.41	723.854	136.3	141.4	2.20
3.50	2.46	761.004	136.5	141.7	2.27
3.55	2.51	799.492	136.7	142.0	2.33
3.60	2.55	839.347	136.9	142.2	2.40
3.65	2.60	880.597	137.2	142.5	2.47
3.70	2.64	923.273	137.4	142.7	2.54
3.75	2.69	967.401	137.6	143.0	2.61
3.80	2.73	1013.012	137.8	143.3	2.69
3.85	2.78	1060.135	138.1	143.5	2.76
3.90	2.83	1108.799	138.3	143.8	2.84
3.95	2.87	1159.035	138.6	144.1	2.91
4.00	2.91	1210.871	138.9	144.4	2.99
4.05	2.96	1264.338	139.2	144.8	3.07
4.10	3.00	1319.466	139.5	145.1	3.15
4.15	3.04	1376.286	139.9	145.5	3.23
4.20	3.09	1434.828	140.2	145.8	3.32
4.25	3.13	1495.123	140.6	146.2	3.40
4.30	3.17	1557.202	140.8	146.5	3.49
4.35	3.21	1621.096	141.4	147.1	3.57
4.40	3.23	1686.836	142.6	148.3	3.66
4.45	3.26	1754.454	143.5	149.2	3.75
4.50	3.31	1823.981	143.7	149.5	3.84

APPENDIX B

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GOLDER ASSOCIATES AFRICA (PTY) LTD

APPENDIX C
FISH ASSESSMENT

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REPORT ON

LOWER VAAL COMPREHENSIVE RESERVE DETERMINATION FISH SURVEY RESULTS

Report No : 8856

Submitted to:

Department of Water Affairs and Forestry
Client Address

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May 2009 8856

EXECUTIVE SUMMARY

Golder Associates Africa (Pty) Ltd. was commissioned by the Department of Water Affairs and Forestry (DWAF) to conduct the Comprehensive Reserve Determination Study for the Integrated Vaal River System: Lower Vaal Water Management Area.

This document presents the results of the high flow and low flow fish sampling surveys conducted at the Lower Vaal Comprehensive Reserve Determination sites in September 2007 and April 2008.

Based on the results of this assessment the following conclusions were reached:

- The fish assemblage in the Lower Vaal is composed primarily of species that are moderately tolerant or tolerant of physico-chemical changes in water quality with a high preference for specific cover elements.
- Of the eleven expected indigenous fish species 91% show a strong preference for either slow deep or slow fast habitats.
- Thirty six percent of the expected fish species are moderately intolerant of no flow conditions, while a further 36% are moderately tolerant of lack of flow.
- Forty five percent of the expected fish species have a requirement for migration between reaches.
- Based on the September 2007 and April 2008 fish survey results the Ecological Category at site EWR16 was in a Class E. This can be attributed to the absence of 5 of the 11 expected species from the observed assemblage and the lower than expected frequency of occurrence of certain species. Expected species that were absent from site EWR16 included *Austroglanis sclateri, Barbus anoplus, Barbus paludinosus* and *Barbus trimaculatus*.
- Site EWR16 is situated just downstream of Bloemhof Dam which acts as a significant migration barrier. Water from the dam is released in order to supplement the Vaal Harts Irrigation Scheme further downstream in the catchment. The natural flow regime has been completely modified which together with the migration barrier may have contributed to the poor ecological integrity of the site.
- Based on the September 2007 and April 2008 fish survey results the Ecological Category at site EWR17 was in a Class D. This can be attributed primarily to the absence of three expected species and the lower than reference frequency of occurrence of several species including *B.paludinosus, B.trimaculatus, L.umbratus* and *T.sparrmanii*.
- Site EWR17 is situated in the lower reach of the Harts River, approximately 5km before the confluence with the Vaal River. Dams such as Spitskop and Taung Dam together with the Vaal-Harts Irrigation Scheme have resulted in modified flow levels and disruption of migration routes. These factors may have contributed to the modified ecological integrity at the site.
- Based on the September 2007 and April 2008 fish survey results the Ecological Category at site EWR18 was in a Class C. This can be attributed primarily to the absence of *Austroglanis sclateri*

and *Barbus anoplus* from the observed fish assemblage and the lower than expected abundance of *Barbus paludinosus*, *Barbus trimaculatus*, and *Labeobarbus kimberleyensis.*

- Site EWR18 is situated in the Vaal River at Schmidtsdrif and is the most downstream site that was sampled in the Vaal River. Impacts that may have contributed to the poor state of ecological integrity at the site include dredging of the river for diamond mining, extensive diamond mining in the catchment and disruption of migration routes due to weirs.
- Based on the September 2007 and April 2008 fish survey results the Ecological Category at site EWR19 was in a Class D. This can be attributed to the absence of *Austroglanis sclateri*, *Labeobarbus kimberleyensis* and *Labeo umbratus* from the observed fish assemblage.
- Site EWR19 is situated in the Riet River approximately 15km downstream of the confluence with the Modder River. Impacts which may have contributed to the impaired state of ecological integrity at the site include water quality impairment due to return water from irrigation. Abstraction of water for irrigation purposes resulting in changes in the seasonal flow patterns.

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1 INTRODUCTION

Golder Associates Africa (Pty) Ltd. was commissioned by the Department of Water Affairs and Forestry (DWAF) to conduct the Comprehensive Reserve Determination Study for the Integrated Vaal River System: Lower Vaal Water Management Area.

This document presents the results of the high flow and low flow fish sampling surveys conducted at the Lower Vaal Comprehensive Reserve Determination sites in September 2007 and April 2008.

2 OBJECTIVES

The objectives of the fish sampling surveys included the following:

- To characterise the fish assemblages at the selected Reserve sites by means of standardized and recognised sampling techniques;
- To compile expected fish species lists for all the Reserve sites by means on a desktop survey of available literature;
- To describe the Ecological Categories (EC) of fish assemblages at the Reserve sites based on the Fish Response Assessment Index (FRAI).

3 APPROACH

- Determine reference conditions for fish assemblages based on an assessment of least-impacted sites, historical data or expert knowledge.
- Determine the Present Ecological State (PES) of the fish assemblage based on the species collected during the field survey.
- Determine the trends in fish assemblage. A trend can be either absent (close to natural or changed but stable), negative (away from reference) or positive (moving back to reference). The purpose is to determine whether biota have adapted to the current habitat template or are still in a state of flux.
- Determine reasons for PES and whether these are flow or non-flow related.
- Determine the Ecological Importance and Sensitivity (EIS) of the fish assemblage and habitat
- Based on the PES and EIS, suggest a realistic Recommended Ecological Category (REC) for the fish assemblage as well as for the EcoStatus.
- Determine alternative Ecological Categories (ECs) for the fish assemblage as well as for the EcoStatus.

4 STUDY AREA

The study area is situated in the Lower Vaal Water Management Area (Water Management Area 10). The Lower Vaal Water Management Area includes the catchment of the Vaal River from below Bloemhof Dam to the confluence with the Orange River at Douglas.

Potential sampling sites were identified on a desktop level. This was followed by a site selection survey which was conducted prior to the September 2007 survey. Major tributaries of the Vaal River that were included in the assessment were the Harts River (site EWR17) and the Modder-Riet River (EWR19).

The locations and descriptions of the Lower Vaal Reserve Determination sites are provided in Table 1. Photographs of sampling sites are provided in Appendix B.

Table 1: Location and description of Lower Vaal Reserve Determination sites

SITE	DESCRIPTION	CO-ORDINATES		WEIRS CLOSE TO SITE
		Latitude	Longitude	
EWR16	Vaal River approximately 3km downstream of Bloemhof Dam.	27.65541	25.59564	C9H021 (Bloemhof Dam – downstream weir)
EWR17	Harts River at Lloyds weir, approximately 5km before the confluence with the Vaal River.	28.38028	24.30110	C3H016 (at Delportshoop Lloyds weir on Harts River)
EWR18	Vaal River at Schmidtsdrif. Most downstream site on the Vaal River	28.70480	24.07603	C9H024 (Schmidtsdrift weir)
EWR19	Riet River approximately 15km downstream of confluence with Modder River.	29.02723	24.51294	C5H048 (Weir is downstream of site)

5 METHODOLOGY

5.1 *In situ* water quality

During the field survey the following variables were determined on site with lightweight, compact field instruments:

- Electrical Conductivity (ECScan)
- pH (pHScan)
- Dissolved Oxygen (Oxyguard Handy Alpha)
- Temperature (Alcohol thermometer)

These parameters have a direct influence on aquatic life forms and although these measurements only provide a "snapshot" of the current *in situ* environment during the time of the survey, they provide valuable insight into the *in situ* characteristics of a specific sample site.

5.2 Ichthyofauna

Fish samples were collected by means of a portable battery driven electrofishing device (DC 12V pulsating). Electrofishing is the use of electricity to temporarily stun and catch fish. The electricity is generated by a system whereby a high voltage potential is applied between two electrodes that are placed in the water (USGS, 2004). Electrofishing is regarded as the most effective single method for sampling fish communities in wadeable streams and rivers (Plafkin *et al.*, 1989). In order to standardise the sampling effort 2 sampling runs of 30min each were conducted at each of the sites.

Additional gill netting, seine netting and cast netting was conducted at sites where the habitat was suitable.

5.2.1 Fish Response Assessment Index (FRAI)

The Fish Response Assessment Index (FRAI) is an assessment index based on the environmental intolerances and preferences of the reference fish assemblage and the response of the constituent species of the assemblage to particular groups of environmental determinants or drivers (Kleynhans, 2007).

The 8 main steps and procedures in the calculation of the FRAI are presented in Table 2.

Table 2: Main steps and procedures in the calculation of the FRAI (Kleynhans, 2007)

Step	Procedure
River section earmarked for assessment	As for study requirements and design
Determine reference fish assemblage: species and frequency of occurrence	• Use historical data & expert knowledge • Model: use ecoregional and other environmental information • Use expert fish reference frequency of occurrence database if available
Determine present state for drivers	• Hydrology • Physico-chemical • Geomorphology or • Index of habitat integrity
Select representative sampling sites	Field survey in combination with other survey activities
Determine fish habitat condition at site	• Assess fish habitat potential • Assess fish habitat condition
Representative fish sampling at site or in river section	• Sample all velocity depth classes per site if feasible • Sample at least three stream sections per site
Collate and analyse fish sampling data per site	Transform fish sampling data to frequency of occurrence ratings
Execute FRAI model	• Rate the FRAI metrics in each metric group • Enter species reference frequency of occurrence data • Enter species observed frequency of occurrence data • Determine weights for the metric groups • Obtain FRAI value and category • Present both modelled FRAI & adjusted FRAI.

6 RESULTS

6.1 *In situ* water quality

Water quality was measured in the field with lightweight compact field instruments and the results are presented in Table 3. These results are important to assist in the interpretation of biological results because of the direct influence water quality has on aquatic life forms.

It should however be noted that these values represent single moments in time, and cannot be interpreted as representative of overall water quality conditions of the sites.

Table 3: *In situ* water quality measured during the Sep 07 and Apr 08 Comprehensive Reserve Determination surveys

Site	pH		DO* (mg/ℓ)		TDS** (mg/ℓ)		Temp (°C)	
	Sep '07	Apr '08	Sep '07	Apr '08	Sep '07	Apr '08	Sep '07	Apr '08
EWR16	7.9	7.5	5.4	5.2	429	371	20	17
EWR17	7.9	7.5	6.5	4.5	1235	1118	19	20
EWR18	7.9	7.3	3.4	5.2	657	627	20	18
EWR19	8.1	8.0	5.4	4.9	345	273	19	19

** Dissolved Oxygen; **Total Dissolved Solids*

6.1.1 pH

The pH of natural waters is determined by both geological and atmospheric influences, as well as by biological activities. Most fresh waters are usually relatively well buffered and more or less neutral, with a pH range from 6 to 8, and most are slightly alkaline due to the presence of bicarbonates of the alkali and alkaline earth metals (DWAF, 1996). The pH target for fish health is presented as ranging between 6.5 and 9.0, as most species will tolerate and reproduce successfully within this range (Alabaster & Lloyd, 1982). Background pH values, in addition to daily and seasonal variability, need to be established if deviation from natural pH values for a particular water body at a particular time is to be assessed (DWAF, 1996).

Changes in pH affect the ionic balance of aquatic organisms, although the lethal affects of decreased pH are usually the result of the mobilisation of metallic complexes (Davies & Day, 1998). Small changes in pH may lead to large changes in the concentration of available metallic complexes and can lead to significant increases in the availability and toxicity of most metals (DWAF, 1996).

During the September 2007 survey pH values were relatively constant and ranged from 7.9 at sites EWR16, EWR17 and EWR18 to 8.1 at site EWR19 (Table 3). In April 2008 *in situ* pH values ranged from 7.3 at site EWR18 to 8.0 at site EWR19 (Table 3). During both surveys the pH values between sites EWR16, EWR17 and EWR18 were similar in range and during both surveys the highest pH values were measured at site EWR19 (Table 3).

6.1.2 Dissolved Oxygen

The maintenance of adequate dissolved oxygen (DO) concentrations is critical for the survival and functioning of the aquatic biota because it is required for the respiration of all aerobic organisms (DWAF, 1996). Therefore, DO concentration provides a useful measure of the health of an ecosystem (DWAF, 1996). The median guideline for DO for the protection of aquatic biota is >5 mg/l (Kempster *et al.*, 1980).

During the September 2007 survey *in situ* DO concentrations were adequate (> 5 mg/l) at all the sites except site EWR18 (3.4 mg/l) (Table 3). During the April 2008 survey *in situ* DO concentrations were adequate (> 5 mg/l) at sites EWR16 and EWR18 and marginally low (< 5 mg/l) at sites EWR17 and EWR19 (Table 3). If DO concentrations < 5 mg/l persist for extended periods of time aquatic ecosystem function may be impeded.

6.1.3 Electrical Conductivity (EC)/ Total Dissolved Solids (TDS)

Electrical conductivity (EC) is a measure of the ability of water to conduct an electrical current (DWAF, 1996). This ability is a result of the presence in water of ions such as carbonate, bicarbonate, chloride, sulphate, nitrate, sodium, potassium, calcium and magnesium, all of which carry an electrical charge (DWAF, 1996). Many organic compounds dissolved in water do not dissociate into ions (ionise), and consequently they do not affect the EC (DWAF, 1996). Electrical conductivity (EC) is a rapid and useful surrogate measure of the Total Dissolved Solids (TDS) concentration of waters with a low organic content (DWAF, 1996). For the purpose of interpretation of the biological results collected during the July 2007 survey the TDS concentrations were calculated by means of the EC using the following **generic** constant (DWAF, 1996):

$$\text{TDS (mg/l)} = \text{EC (mS/m at 25 °C)} \times 6.5$$

If more accurate estimates of the TDS concentration from EC measurements are required then the conversion factor should be experimentally determined for each specific site and for specific runoff events (DWAF, 1996). According to Davies & Day (1998), freshwater organisms usually only naturally occur at TDS values less than 3000 mg/l. According to the South African Water Quality Guidelines for Aquatic Ecosystems (DWAF, 1996) the rate of change of the TDS concentration, and the duration of the change is more important than absolute changes in the TDS concentration.

During the September 2007 survey TDS concentrations in the Lower Vaal catchment ranged from 345 mg/l at site EWR19 to 1235mg/l at site EWR17 (Table 3). In April 2008 TDS concentrations ranged from 273 mg/l at site EWR19 to 1118 mg/l at site EWR17 (Table 3). During both surveys the highest TDS concentrations were measured at site EWR17 in the lower reaches of the Harts River (Table 3).

6.1.4 Temperature

Water temperature plays an important role in aquatic ecosystems by affecting the rates of chemical reactions and therefore also the metabolic rates of organisms (DWAF, 1996). Temperature affects the

rate of development, reproductive periods and emergence time of organisms (DWAF, 2005). Temperature varies with season and the life cycles of many aquatic macroinvertebrates are cued to temperature (DWAF, 2005).

During the September 2007 survey *in situ* water temperatures varied between 19 and 20 °C at all the sites (Table 3). In April 2008 water temperatures ranged from 17 to 20 °C (Table 3).

6.2 Ichthyofauna

6.2.1 Expected fish species list

Based on a desktop review of available literature an expected species list was compiled for the Lower Vaal Comprehensive Reserve Determination sites utilising the following sources: Skelton (2001), Kleynhans *et al.*, (2007) and personal communications with Pierre de Villiers (previously with Free State Department of Nature Conservation).

Based on this assessment a total of 11 indigenous fish species are expected at the Lower Vaal Comprehensive Reserve Determination sites (8 to 11 indigenous species per site) (Table 5). Eight indigenous fish species are expected to occur at site EWR19 and 11 at the remainder of the sites (Table 5). In addition the introduced species *Cyprinus carpio* (Carp) is expected to occur at all of the sites (Table 5). This species was first introduced into South Africa in the 1700s and has since spread throughout southern Africa (Skelton, 2001).

The expected frequency of occurrence is rated from 1 to 5. If a species under natural reference conditions occurs at 3 out of 5 sites, its frequency of occurrence would be 60%, this would relate to a frequency of occurrence rating of 4 (present at most sites; > 50-75% of sites) (Kleynhans *et al.*, 2007). A breakdown of frequency of occurrence ratings is provided in Table 4.

Table 4: Frequency of occurrence ratings (Kleynhans, 2007)

Frequency of Occurrence Rating	Description
0	Absent
1	Present at very few sites (< 10% of sites)
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%)

Table 5: Expected fish species and reference frequency of occurrence ratings for the Lower Vaal Comprehensive Reserve Determination sites

Species	Common name	EWR16	EWR17	EWR18	EWR19
Family Austroglanididae					
Austroglanis sclateri	Rock catfish	3	3	3	3
Family Cyprinidae					
Barbus anoplus	Chubbyhead barb	3	3	3	1
Barbus paludinosus	Straightfin barb	3	3	3	
Barbus trimaculatus	Threespot barb	3	3	3	
Labeobarbus aeneus	Smallmouth yellowfish	3	3	3	
Labeobarbus kimberleyensis	Largemouth yellowfish	3	3	3	1
Labeo capensis	Orange river mudfish	3	3	3	1
Labeo umbratus	Moggel	3	3	3	3
*Cyprinus carpio**	Carp	3	3	3	3
Family Clariidae					
Clarias gariepinus	Sharptooth catfish	3	3	3	1
Family Cichlidae					
Pseudocrenilabrus philander	Southern mouthbrooder	3	3	3	1
Tilapia sparrmanii	Banded tilapia	3	3	3	1
Total number of expected species		**12**	**12**	**12**	**9**

** Introduced species*

6.2.2 Red Data Fish Species

In order to assess the Red Data Book status of the expected fish species in the sample area, the IUCN Red List of Threatened Species was consulted (IUCN, 2008). The result of the IUCN Red List assessment is presented in Table 6.

Table 6: Red Data Status of fish species expected to occur in the Lower Vaal Water Management Area (IUCN, 2008)

Species	Red Data Status
Family Austroglanididae	
Austroglanis sclateri	Least Concern
Family Cyprinidae	
Labeobarbus aeneus	Least Concern
Labeobarbus kimberleyensis	Near Threatened
Barbus anoplus	Least Concern
Barbus paludinosus	Least Concern
Barbus trimaculatus	Unlisted
Labeo capensis	Least Concern
Labeo umbratus	Least Concern
*Cyprinus carpio**	Vulnerable
Family Clariidae	

Clarias gariepinus	Unlisted
Family Cichlidae	
Pseudocrenilabrus philander	Unlisted
Tilapia sparrmanii	Unlisted

Of the 12 fish species expected to occur in the sampling area:

- Four are currently unlisted on the IUCN Red List;
- Six are currently listed as Least Concern on the IUCN Red List. Species in this category are considered to be widespread and abundant (IUCN, 2008);
- *Labeobarbus kimberleyensis* is currently listed as Near Threatened. Species in this category are likely to qualify for a threatened category in the near future (IUCN, 2008);
- *Cyprinus carpio* is currently listed as Vulnerable. A taxon is classified as Vulnerable when it is considered to be facing a high risk of extinction in the wild (IUCN, 2008).

Labeobarbus kimberleyensis (Largemouth yellowfish) is endemic to the Orange River system and is widespread in both the Orange and Vaal Rivers (IUCN, 2008). The major threat to this species is poor water quality in the Vaal River below the Vaal Dam and from tributaries which receive treated effluent water (IUCN, 2008). Instream dams and weirs are not a problem if suitable spawning habitat is available (IUCN, 2008). River regulation and destruction of different habitat types may be causing hybridisation between this species and *Labeobarbus aeneus* (IUCN, 2008).

The original range of *Cyprinus carpio* (Carp) included the Black, Caspian and Aral Sea basins. It has however been introduced throughout the world including South Africa. The native populations are currently threatened by hybridisation with introduced domesticated stocks and river regulation and are listed as Vulnerable. In South Africa this species is considered to be a pest by conservation authorities due to its destructive feeding habitats. The population of *Cyprinus carpio* in South Africa is derived from introduced domesticated stocks and the Vulnerable status is therefore unlikely to apply to this population.

6.2.3 Observed fish species list

Ten of the 11 expected indigenous fish species were recorded at the Lower Vaal sites during the September 2007 and April 2008 surveys (5 to 9 indigenous fish species per site) (Table 7). The highest combined fish abundance (n = 369) was recorded at site EWR17, the lowest abundance (n = 85) at site EWR19 (Table 7). The highest indigenous fish species diversity (n = 9) was recorded at site EWR18 (Table 7). The lowest indigenous fish species diversity (n = 5) was recorded at sites EWR16 and EWR19 (Table 7).

Austroglanis sclateri (Rock catfish) was expected to occur at all of the sampling sites but was not recorded at any of the sites (Table 7).

In addition to the ten indigenous fish species four introduced fish species were recorded in the sampling area during the September 2007 and April 2008 surveys namely *Cyprinus carpio* (Carp), *Gambusia affinis* (Mosquitofish), *Ctenopharyngodon idella* (Grass carp) and *Oreochromis mossambicus* (Mozambique tilapia) (Table 7).

C.carpio was recorded at sites EWR16 and EWR18 during both surveys and at sites EWR17 and EWR19 during the September 2007 survey (Table 7). The origin and impact of this species is discussed in more detail in section 6.2.2. *G.affinis* was 1st introduced into South African rivers before 1936 by aquarists but was later widely distributed and introduced in efforts to control mosquitoes and malaria (Skelton, 2001). It has proved to be an aggressive invader species capable of restricting indigenous fish populations by preying on fish larvae (Skelton, 2001). This species was recorded at sites EWR17 and EWR18 during both surveys (Table 7). *C.idella* was 1st introduced into South Africa in 1967 from Malaysia (Skelton, 2001). The species is native to China (Skelton, 2001). This species is widely utilised as means of controlling aquatic macrophyte growth in dams. One specimen was collected at site EWR16 during the April 2008 survey (Table 7). *O.mossambicus* was recorded at site EWR18 during the April 2008 survey (Table 7). This species is indigenous to southern Africa but was originally restricted to East Coast Rivers from the lower Zambezi system south to the Bushman's River system in the Eastern Cape (Skelton, 2001). The spread of this species in the Vaal and Orange Rivers will most likely be limited by the cold winter temperatures. This species is currently listed as Near Threatened on the IUCN Red List of Threatened Species due to the threat of hybridization with the introduced species *Oreochromis niloticus* (Nile tilapia) (IUCN, 2008).

Table 7: Observed fish species list for the September 2007 and April 2008 surveys. Introduced species are highlighted in red

Species	EWR16		EWR17		EWR18		EWR19	
	Sep 07	Apr 08	Sep 07	Apr 08	Sep 07	Apr 08	Sep 07	Apr 08
Family Cichlidae								
Pseudocrenilabrus philander	149		95	35	9	5	23	14
Tilapia sparrmanii	8	1	2	3		4	4	
Oreochromis mossambicus*						**12**		
Family Cyprinidae								
Barbus paludinosus			130	1	5			
Barbus anoplus								
Barbus trimaculatus			1			1		
Labeo capensis	15	4	19	5	31	84	18	
Labeobarbus aeneus	8	5		1	5	22	12	6
Labeobarbus kimberleyensis					2	3		
Labeo umbratus			20		7	4		
Cyprinus carpio*	**4**	**1**	**1**		**1**	**1**	**1**	
Ctenopharyngodon idella*		**1**						
Family Clariidae								
Clarias gariepinus	2		2		4	2	7	

Family Poeciliidae								
Gambusia affinis*			**31**	**23**	**40**	**15**		
Total number of fish per survey	**186**	**12**	**301**	**68**	**104**	**153**	**65**	**20**
Total number of indigenous species per site	**5**		**8**		**9**		**5**	
Total number of introduced species per site	**2**		**2**		**3**		**1**	

** Introduced species*

6.2.4 Fish Response Assessment Index (FRAI)

The FRAI results for the Lower Vaal Comprehensive Reserve Determination sites will be discussed individually for each site.

Site EWR16

Table 8 indicates the weights of the different metric groups for site EWR16. According to Table 8 the migration metric carried the most weight at this site followed by the cover, flow modification and impact of introduced species metrics. This site is situated downstream of Bloemhof Dam which represents a major migration barrier. Water from the dam is released in order to supplement the Vaal-Harts Irrigation Scheme further downstream. Two introduced fish species were recorded at the site contributing to the weighting of the impact of introduced species metric.

Table 8: Site EWR16 Metric Group Weights

METRIC GROUP	WEIGHT (%)
VELOCITY-DEPTH	74.60
COVER	90.48
FLOW MODIFICATION	85.71
PHYSICO-CHEMICAL	49.21
MIGRATION	100.00
IMPACT OF INTRODUCED	82.54

Table 9 provides the FRAI results and associated Ecological Categories (EC) for site EWR16. Based on this assessment the fish assemblage at site EWR16 at the time of the surveys was classified in an EC of E (Table 9).

Table 9: Site EWR16 FRAI results (%) and associated Ecological Categories (EC)

AUTOMATED	
FRAI (%)	32.0

Ecological Category (EC)	**E**
ADJUSTED	
FRAI (%)	32.0
Ecological Category (EC)	**E**

Table 10 provides the Reference and Observed Frequency of Occurrence for site EWR16. Six of the 11 expected indigenous fish species were recorded at site EWR16 during the September 2007 and April 2008 surveys (Table 10). The Ecological Category of E can be attributed primarily to the absence of 5 of the 11 expected species and the lower than expected frequency of occurrence of certain species (Table 10).

Table 10: Reference and Observed Frequency of Occurrence for site EWR16

Scientific Names	Reference Frequency of Occurrence	Observed Frequency of Occurrence
Austroglanis sclateri	3	0
Barbus anoplus	3	0
Barbus paludinosus	3	0
Barbus trimaculatus	3	0
Labeobarbus aeneus	3	3
Labeobarbus kimberleyensis	3	0
Clarias gariepinus	3	2
Labeo capensis	3	2
Labeo umbratus	3	2
Pseudocrenilabrus philander	3	1
Tilapia sparrmanii	3	3

Site EWR17

Table 11 provides the metric group weights for site EWR17. Based on Table 11 the cover and flow modification metrics carried the most weight followed by migration and velocity depth. The physico-chemical metric received the lowest weight (Table 11). Based on the FRAI database all the expected fish species have a very high level (> 3) of preference for specific cover elements such as overhanging vegetation, undercut banks and substrate whereas all of the species, with the exception of *Labeobarbus kimberleyensis*, are moderately tolerant or tolerant of modified physico-chemical parameters.

Table 11: Site EWR17 Metric Group Weights

METRIC GROUP	WEIGHT (%)
VELOCITY-DEPTH	80.60
COVER	100.00
FLOW MODIFICATION	94.03

PHYSICO-CHEMICAL	41.79
MIGRATION	83.58
IMPACT OF INTRODUCED	59.70

Table 12 provides the FRAI results and associated Ecological Categories (EC) for site EWR17. Based on this assessment the fish assemblage at site EWR17 at the time of the surveys was classified in an EC of D (Table 12).

Table 12: Site EWR17 FRAI results (%) and associated Ecological Categories (EC)

AUTOMATED	
FRAI (%)	52.1
EC: FRAI	**D**
ADJUSTED	
FRAI (%)	52.1
EC: FRAI	**D**

Table 13 provides the Reference and Observed Frequency of Occurrence for site EWR17. Eight of the 11 expected indigenous fish species were recorded at site EWR17 during the September 2007 and April 2008 surveys (Table 13). Three of the expected fish species were absent from the site (Table 13). The Ecological Category of D recorded at this site can be attributed primarily to the absence of three expected species and the lower than reference frequency of occurrence of several observed species including *B.paludinosus*, *B.trimaculatus*, *L.umbratus* and *T.sparrmanii* (Table 13).

Table 13: Reference and Observed Frequency of Occurrence for site EWR17

Scientific Names	Reference Frequency of Occurrence	Observed Frequency of Occurrence
Austroglanis sclateri	3	0
Barbus anoplus	3	0
Barbus paludinosus	3	1
Barbus trimaculatus	3	1
Labeobarbus aeneus	3	3
Labeobarbus kimberleyensis	3	0
Clarias gariepinus	3	3
Labeo capensis	3	3
Labeo umbratus	3	1
Pseudocrenilabrus philander	3	2
Tilapia sparrmanii	3	1

Site EWR18

Table 14 provides the metric group weights for site EWR18. The cover metric received the highest weighting at site EWR18 followed by flow modification, velocity-depth and migration metrics (Table 14). The physico-chemical metric received the lowest weight (41.79). Based on the FRAI database all the expected fish species have a very high level (> 3) of preference for specific cover elements such as overhanging vegetation, undercut banks and substrate whereas all of the species, with the exception of *Labeobarbus kimberleyensis*, are moderately tolerant or tolerant of modified physico-chemical parameters. The impact of introduced fish species metric received a weight of 62.69% due to the presence of the predaceous invasive fish species *Gambusia affinis* (Mosquitofish) and the habitat modifying fish species *Cyprinus carpio* (Carp) at the site.

Table 14: Site EWR18 Metric Group Weights

METRIC GROUP	WEIGHT (%)
VELOCITY-DEPTH	80.60
COVER	100.00
FLOW MODIFICATION	94.03
PHYSICO-CHEMICAL	41.79
MIGRATION	80.60
IMPACT OF INTRODUCED	62.69

Table 15 provides the FRAI results and associated Ecological Categories (EC) for site EWR18. Based on this assessment the fish assemblage at site EWR18 was classified in an EC of C (Table 15).

Table 15: Site EWR18 FRAI results (%) and associated Ecological Categories (EC)

AUTOMATED	
FRAI (%)	63.7
EC: FRAI	**C**
ADJUSTED	
FRAI (%)	63.7
EC: FRAI	**C**

Table 16 provides the Reference and Observed Frequency of Occurrence for site EWR18. The Ecological Category of C that was recorded at site EWR18 can be attributed primarily to the absence of *Austroglanis sclateri* and *Barbus anoplus* from the observed fish assemblage and the lower than expected abundance of *Barbus paludinosus*, *Barbus trimaculatus*, and *Labeobarbus kimberleyensis* (Table 16).

Table 16: Reference and Observed Frequency of Occurrence for site EWR18

Scientific Names	Reference Frequency of Occurrence	Observed Frequency of Occurrence
Austroglanis sclateri	3	0
Barbus anoplus	3	0
Barbus paludinosus	3	1
Barbus trimaculatus	3	1
Labeobarbus aeneus	3	3
Labeobarbus kimberleyensis	3	2
Clarias gariepinus	3	3
Labeo capensis	3	3
Labeo umbratus	3	3
Pseudocrenilabrus philander	3	2
Tilapia sparrmanii	3	1

Site EWR19

Table 17 provides the metric group weights for site EWR19. The cover metric received the highest weighting followed by the flow modification and velocity depth metrics (Table 17). The physico-chemical metric received the lowest weighting (Table 17). Based on the FRAI database all the expected fish species have a very high level (> 3) of preference for specific cover elements such as overhanging vegetation, undercut banks and substrate whereas all of the species, with the exception of ***Labeobarbus kimberleyensis***, are moderately tolerant or tolerant of modified physico-chemical parameters.

Table 17: Site EWR19 Metric Group Weights

METRIC GROUP	WEIGHT (%)
VELOCITY-DEPTH	80.88
COVER	100.00
FLOW MODIFICATION	92.65
PHYSICO-CHEMICAL	44.12
MIGRATION	63.24
IMPACT OF INTRODUCED	66.18

Table 18 provides the FRAI results and associated Ecological Categories (EC) for site EWR19. Based on this assessment the fish assemblage at site EWR19 was classified in an Ecological Category of D (Table 18).

Table 18: Site EWR19 FRAI results (%) and associated Ecological Categories (EC)

AUTOMATED	
FRAI (%)	43.0

EC: FRAI	**D**
ADJUSTED	
FRAI (%)	43.0
EC: FRAI	**D**

Table 19 provides the Reference and Observed Frequency of Occurrence for site EWR19. The Ecological Category of D that was determined for site EWR19 can be attributed to the absence of ***Austroglanis sclateri***, ***Labeobarbus kimberleyensis*** and ***Labeo umbratus*** from the observed fish assemblage (Table 19).

Table 19: Reference and Observed Frequency of Occurrence for site EWR19

Scientific Names	Reference Frequency of Occurrence	Observed Frequency of Occurrence
Austroglanis sclateri	3	0
Labeobarbus aeneus	1	2
Labeobarbus kimberleyensis	1	0
Clarias gariepinus	1	2
Labeo capensis	1	2
Labeo umbratus	3	0
Pseudocrenilabrus philander	1	2
Tilapia sparrmanii	1	1

7 CONCLUSIONS

Based on the results of this assessment the following conclusions were reached:

- The fish assemblage in the Lower Vaal is composed primarily of species that are moderately tolerant or tolerant of physico-chemical changes in water quality with a high preference for specific cover elements.
- Of the eleven expected indigenous fish species 91% show a strong preference for either slow deep or slow fast habitats.
- Thirty six percent of the expected fish species are moderately intolerant of no flow conditions, while a further 36% are moderately tolerant of lack of flow.
- Forty five percent of the expected fish species have a requirement for migration between reaches.
- Based on the September 2007 and April 2008 fish survey results the Ecological Category at site EWR16 was in a Class E. This can be attributed to the absence of 5 of the 11 expected species from the observed assemblage and the lower than expected frequency of occurrence of certain species. Expected species that were absent from site EWR16 included *Austroglanis sclateri*, *Barbus anoplus*, *Barbus paludinosus* and *Barbus trimaculatus*.
- Site EWR16 is situated just downstream of Bloemhof Dam which acts as a significant migration barrier. Water from the dam is released in order to supplement the Vaal Harts Irrigation Scheme further downstream in the catchment. The natural flow regime has been completely modified which together with the migration barrier may have contributed to the poor ecological integrity of the site.
- Based on the September 2007 and April 2008 fish survey results the Ecological Category at site EWR17 was in a Class D. This can be attributed primarily to the absence of three expected species and the lower than reference frequency of occurrence of several species including *B.paludinosus*, *B.trimaculatus*, *L.umbratus* and *T.sparrmanii*.
- Site EWR17 is situated in the lower reach of the Harts River, approximately 5km before the confluence with the Vaal River. Dams such as Spitskop and Taung Dam together with the Vaal-Harts Irrigation Scheme have resulted in modified flow levels and disruption of migration routes. These factors may have contributed to the modified ecological integrity at the site.
- Based on the September 2007 and April 2008 fish survey results the Ecological Category at site EWR18 was in a Class C. This can be attributed primarily to the absence of *Austroglanis sclateri* and *Barbus anoplus* from the observed fish assemblage and the lower than expected abundance of *Barbus paludinosus*, *Barbus trimaculatus*, and *Labeobarbus kimberleyensis.*
- Site EWR18 is situated in the Vaal River at Schmidtsdrif and is the most downstream site that was sampled in the Vaal River. Impacts that may have contributed to the poor state of ecological integrity at the site include dredging of the river for diamond mining, extensive diamond mining in the catchment and disruption of migration routes due to weirs.

- Based on the September 2007 and April 2008 fish survey results the Ecological Category at site EWR19 was in a Class D. This can be attributed to the absence of ***Austroglanis sclateri***, ***Labeobarbus kimberleyensis*** and ***Labeo umbratus*** from the observed fish assemblage.
- Site EWR19 is situated in the Riet River approximately 15km downstream of the confluence with the Modder River. Impacts which may have contributed to the impaired state of ecological integrity at the site include water quality impairment due to return water from irrigation. Abstraction of water for irrigation purposes resulting in changes in the seasonal flow patterns.

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\\JOH1-S-FS1\GAADATA\PROJECTS\8856 - LOWER VAAL WMA\REPORTS\FINAL REPORTS DWA 2011\ECOCLASSIFICATION\APPENDIX C_LOWER VAAL WMA FISH REPORT.DOCX

APPENDIX A

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APPENDIX B

Site EWR16: Vaal River approximately 3km downstream of Bloemhof Dam

Site EWR17: Harts River approximately 5km before the confluence with the Vaal River.

Site EWR18: Vaal River at Schmidtdrif

Site EWR19: Riet River approximately 15km downstream of the confluence with the Modder River

APPENDIX D
MACROINVERTEBRATE ASSESSMENT

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REPORT ON

RESERVE DETERMINATION STUDY OF THE LOWER VAAL RIVER AQUATIC MACROINVERTEBRATE REPORT

Report No : 8856-8638-4

Submitted to:

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May 2009 8856

EXECUTIVE SUMMARY

Golder Associates Africa (Pty) Ltd. was commissioned by Zitholele to conduct a biological monitoring program for the reserve determination of the lower Vaal River. The biological monitoring deals with sections and tributaries associated with the lower Vaal River.

This document presents the results obtained during the September 2007 and the April 2008 surveys. Both surveys included assessments of in situ water quality, general habitat parameters, invertebrate habitat availability and aquatic macroinvertebrate diversity.

The objectives of surveys were to classify the ecological integrity of each of the sites in terms of selected indicators.

During the September 2007 survey pH values were neutral and should not have a limiting effect on aquatic biota. During the April 2008 survey pH values were neutral to slightly alkaline and should not have a limiting effect on aquatic biota.

During the September 2007 survey, DO concentrations were adequate at all sites except EWR18. During the April 2008 survey DO concentrations were adequate at EWR16 and EWR18. The DO concentrations at EWR17 and EWR19 were < 5mg/l and might have a negative effect on biota.

During the September 2007 survey TDS concentrations ranged from 345 mg/l at EWR19 to 1235 mg/l at EWR17. During the April 2008 survey TDS concentrations ranged from 273 mg/l at EWR19 to 1118 mg/l at EWR17. TDS concentrations might have a limiting effect on aquatic biota.

Temperature recorded throughout the sampling area should not have a limiting effect on aquatic biota.

During the September 2007 survey habitat availability was good at all the sites except site for site EWR18 were habitat availability was poor. During the April 2008 survey habitat availability was good at all the sites except EWR18 that showed poor habitat availability.

Based on the September 2007 and the April 2008 assessment of the aquatic macroinvertabrate assemblage at site EWR16 at the time of the surveys was classified in an EC of D.

Based on the September 2007 and the April 2008 assessment of the aquatic macroinvertabrate assemblage at site EWR17 at the time of the surveys was classified in an EC of D.

Based on the September 2007 and the April 2008 assessment of the assessment the aquatic macroinvertabrate assemblage at site EWR18 at the time of the surveys was classified in an EC of D.

Based on the September 2007 and the April 2008 assessment of this assessment the aquatic macroinvertabrate assemblage at site EWR19 at the time of the surveys was classified in an EC of C.

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Appendix A Document Limitations

1 INTRODUCTION

1.1 Background

Golder Associates Africa (Pty) Ltd. was commissioned by Zitholele to conduct a biological monitoring program for the reserve determination of the lower Vaal River. The biological monitoring deals with sections and tributaries associated with the lower Vaal River.

This document presents the results obtained during the September 2007 and the April 2008 surveys. Both surveys included assessments of in situ water quality, general habitat parameters, invertebrate habitat availability and aquatic macroinvertebrate diversity.

1.2 Objectives

The objectives of surveys were:

- To classify the ecological integrity of each of the sites in terms of selected indicators.

2 APPROACH

In order to enable a characterization of the general integrity of the aquatic environment, certain ecological indicators were selected to represent each of the responding, habitat and stressor components involved in the aquatic environment. These included:

2.1.1 Stressor Indicators

- *In situ* water quality

2.1.2 Habitat Indicators

- General habitat assessment
- Invertebrate Habitat Assessment System (IHAS, Version 2)

2.1.3 Response Indicators

- Aquatic Macroinvertebrates (SASS5)

3 STUDY AREA

The study area is situated in the Lower Vaal Water Management Area. Four sites were selected in this area of the river. Two sites are situated on the main stem of the Vaal River, site EWR16 is situated downstream of Bloemhof Dam in the town of Bloemhof. Site EWR17 is situated in the Vaal River downstream of the confluence with the Harts River but upstream of the confluence with the Riet River. Site EWR17 is situated on the Harts River downstream of Spitskop Dam. Site EWR19 is situated on the Riet River downstream of the confluence with the Modder River.

The GPS coordinates of each of the sites were recorded using a Garmin GPS60 (Table 1). Maps of the study area are provided in Figure 1.

Table 1: GPS coordinates and site descriptions

Site	Co-ordinates*		Description
	Latitude	Longitude	
EWR16	-27.6551	25.5953	Situated downstream of Bloemhof Dam on the main stem of the Vaal River.
EWR17	-28.3773	24.3032	Situated in the Harts River downstream of Spitskop Dam.
EWR18	-28.7040	24.0758	Situated in the Vaal River downstream of the confluence with the Harts River but upstream with the confluence with the Riet River.
EWR19	-29.0416	24.5366	Situated in the Riet River downstream of the confluence with the Modder River.

** Datum: WGS_84, Coordinate system: hddd.ddddd°*

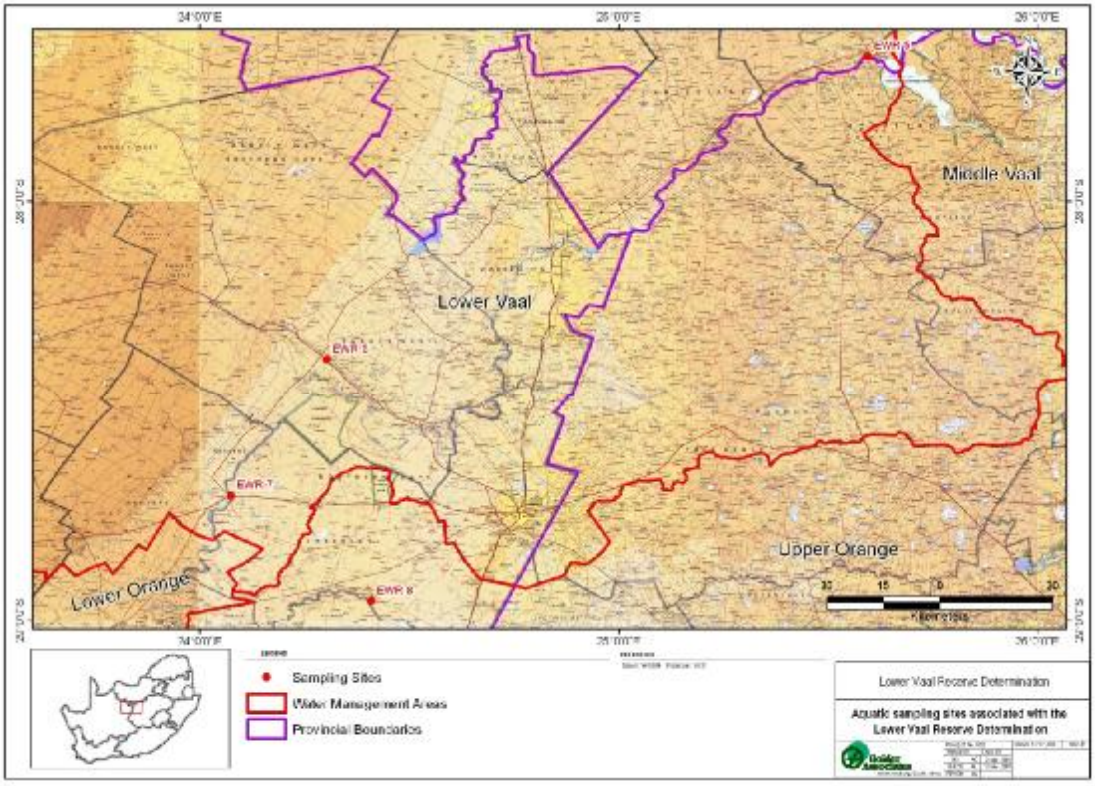

Figure 1: Sample sites in the Lower Vaal River (sites EWR 5 – 8 refer to sites EWR 16 – 19)

4 METHODOLOGY

4.1 *In situ* water quality

During the field surveys the following variables were measured on site with lightweight, compact field instruments:

- Dissolved Oxygen *(Eutech DO110)*
- TDS *(Eutech TDSTestr)*
- pH *(Eutech pHTester2)*
- Temperature *(Eutech DO110)*

Water quality has a direct influence on aquatic life forms. Although these measurements only provide a "snapshot", they can provide valuable insight into the characteristics of a specific sample site.

4.2 Habitat Assessment

Habitat assessment can be defined as the evaluation of the structure of the surrounding physical habitat that influences the quality of the water resource and the condition of the resident aquatic community (Barbour *et al.*, 1996). Habitat quality and availability plays a critical role in the occurrence of aquatic biota. For this reason habitat evaluation is conducted simultaneously with biological evaluations in order to facilitate the interpretation of results.

4.2.1 Invertebrate Habitat Assessment System (IHAS, Version 2)

The Invertebrate Habitat Assessment System (IHAS, *version 2*) was applied at each of the sampling sites in order to assess the availability of habitat biotopes for macroinvertebrates. The IHAS was developed specifically for use with SASS5 and rapid biological assessment protocols in South Africa (McMillan, 1998). It is presently thought that a total score of over 65% represents good habitat conditions, a score over 55% indicates adequate/fair habitat conditions (McMillan, 2002) (Table 2).

Table 2: Invertebrate Habitat Assessment System (*version 2*)

IHAS Score	Description
> 65%	**Good**
55-65%	**Adequate/Fair**
< 55%	**Poor**

4.3 Aquatic Macroinvertebrates

The monitoring of benthic macroinvertebrates forms an integral part of the monitoring of the health of an aquatic ecosystem as they are relatively sedentary and enable the detection of localized disturbances. Their relatively long life histories (±1 year) allow for the integration of pollution effects over time. Field sampling is easy and since the communities are heterogeneous and several phyla are usually represented, response to environmental impacts is normally detectable in terms of the community as a whole (Hellawell, 1977).

Aquatic macroinvertebrates were sampled using the qualitative kick sampling method called SASS5 (South African Scoring System, Version 5) (Dickens and Graham, 2001). The SASS5 protocol is a biotic index of the condition of a river or stream, based on the resident macroinvertebrate community, whereby each taxon is allocated a score according to its level of tolerance to river health degradation (Dallas, 1997). This method relies on churning up the substrate with your feet and sweeping a finely meshed SASS net (pore size of 1000 micron), over the churned up area. In the Stones-In-Current (SIC) biotope the net is rested on the substrate and the area immediately upstream of the net disturbed by kicking the stones over and against each other to dislodge benthic invertebrates. The net is also swept under the edge of marginal and aquatic vegetation. Kick samples are collected from areas with gravel, sand and mud (GSM) substrates. Identification of the organisms is made to family level (Thirion *et al.*, 1995; Davies & Day, 1998; Dickens & Graham, 2001; Gerber & Gabriel, 2002).

The endpoint of any biological or ecosystem assessment is a value expressed either in the form of measurements (data collected) or in a more meaningful format by summarising these measurements into one or several index values (Cyrus *et al.*, 2000). The indices used for this study were, SASS5 Total Score and Average Score per Taxon (ASPT). All sites were scored, according to these indices.

4.4 MACROINVERTABRATE RESPONSE ASSESSMENT INDEX (MIRAI)

The following approach is used to relate rivers and the resultant habitat to the aquatic invertebrate condition:

- Information about the habitat preferences and requirements of each of the taxa present must be obtained.
- The habitat features are evaluated in terms of their suitability as well as the requirements of the aquatic invertebrates inhabiting the region.
- Habitat integrity form part of the index to assess the response of the invertebrates.

The determination of the aquatic macroinvertebrate Ecological Category is based on the following:

- The interpretation of the environmental requirements, preferences and intolerances of taxa.
- The response to changes.

4.4.1 Rating Approach

The first step in determining the Present Ecological State (PES) of the invertebrates the abundance and frequency of occurrence of the different invertebrate taxa under natural conditions as well as the abundance and frequency of the taxa present must be recorded. The six point rating works as follows:

- 0 = No change from reference.
- 1 = Small change from reference.
- 2 = Moderate change from reference.
- 3 = Large change from reference
- 4 = Serious change from reference.
- 5 = Extreme change from reference.

In addition to the rating of the different metrics, each metric is also ranked and weighted according to its importance in determining the Ecological Category of the invertebrate assemblage. Basically each metric is ranked in terms of which metric best would indicate good integrity in terms of the metric group.

The metric ranked 1 (most important) is weighted 100%. The other metrics are then ranked as a percentage relative to the most important metric.

4.4.2 Flow Modification

In order to facilitate the evaluation of the impact of different flows on the invertebrate community four different velocity categories have been defined:

- Very fast flowing water (>0.6 m/s)
- Moderately fast flowing water (0.3 – 0.6 m/s)
- Slow flowing water (0.1 – 0.3 m/s
- Very slow flowing/standing water (<0.1 m/s)

Each invertebrate taxon has been assigned a velocity preference score (0 – 5), based on previous surveys and personal experience. The velocity preference scores were allocated according to the following system:

- 0 = No preference
- 1 = Very small preference
- 2 = Small preference
- 3 = Moderate preference
- 4 = High preference
- 5 = Very high preference

In the flow modification metric group the presence/absence, as well as the abundance and/or frequency of occurance of taxa in all velocity categories, are evaluated.

4.4.3 Habitat Modification

In order to facilitate the evaluation of the impact of habitat changes on the invertebrate community, five different habitat types have been defined:

- Bedrock – All hard surfaces larger than 256mm and includes bedrock/boulders in current as well as out-of-current.
- Cobbles – Hard surfaces within the 16 – 256mm size range, in current as well as out-of-current.
- Vegetation – All vegetation that can provide habitat for invertebrates, in current as well as out-of-current.
- Gravel, sand and mud – Combination of smaller grain types (<16mm), in current as well as out of current.
- Water column – The water surface and the water column.

Habitat preference scores were allocated in the same way as the velocity preference scores.

4.4.4 Water Quality Modification

To facilitate the evaluation of changes in water quality on the invertebrate community' four different groups were identified. These groups are based on SASS5 weights and are as follows:

- High requirement for unmodified physico – chemical conditions: SASS5 weights 12 – 15.
- Moderate requirement for unmodified physico – chemical conditions: SASS5 weights 7 – 11.
- Low requirement for unmodified physico – chemical conditions: SASS5 weights 4 – 6.
- Very low requirement for unmodified physico – chemical conditions: SASS5 weights 1- 3.

In addition to the normal set of metrics regarding the presence/absence and the abundance and/or frequency of occurrence of taxa, two additional metrics, the SASS5 score and the ASPT value, are included.

4.4.5 Ecological Category

The four metric groups discussed are combined to derive the invertebrate ecological category. The model automatically calculates the ecological category based on the percentage of reference.

5 RESULTS AND DISCUSSION

5.1 *In situ* water quality

In situ water quality was measured in the field and the results presented in Table 3. This information is used in the interpretation of biological results because of the direct influence water quality has on aquatic life forms.

Table 3: *In situ* water quality recorded during the September 2007 and April 2008 surveys.

Site	pH		DO* (mg/ℓ)		TDS** (mg/ℓ)		Temp (°C)	
	Sep '07	Apr '08	Sep '07	Apr '08	Sep '07	Apr '08	Sep '07	Apr '08
EWR16	7.9	7.5	5.4	5.2	429	371	20	17
EWR17	7.9	7.5	6.5	4.5	1235	1118	19	20
EWR18	7.9	7.3	3.4	5.2	657	627	20	18
EWR19	8.1	8.0	5.4	4.9	345	273	19	19

** Dissolved Oxygen; ** Total Dissolved Solids; - No sampling conducted*

5.1.1 pH

The pH of natural waters is determined by both geological and atmospheric influences, as well as by biological activities. Most fresh waters are usually relatively well buffered and more or less neutral, with a pH range from 6 to 8, and most are slightly alkaline due to the presence of bicarbonates of the alkali and alkaline earth metals (DWAF, 1996). The pH target for fish health is presented as ranging between 6.5 and 9.0, as most species will tolerate and reproduce successfully within this range (Alabaster and Lloyd, 1982).

During the September 2007 survey pH values were slightly alkaline and had a value of 7.9 at all the sites except EWR19 where a value of 8.1 was recorded (Table 3). Within this range pH values should not have a limiting effect on aquatic biota.

During the April 2008 survey pH values were neutral to slightly alkaline and ranged from 7.3 (EWR18) to 8.0 (EWR19) (Table 3). Within this range pH values should not have a limiting effect on aquatic biota.

5.1.2 Dissolved Oxygen

The maintenance of adequate dissolved oxygen (DO) is critical for the functioning of aquatic ecosystems since it is required for the respiration of all aerobic organisms (DWAF, 1996). Therefore, DO concentration provides a useful measure of the health of an ecosystem (DWAF, 1996). The median guideline for DO for the protection of aquatic biota is > 5 mg/ℓ (Kempster *et al.*, 1980).

During the September 2007 survey, DO concentrations were adequate (> 5 mg/l) at all sites except EWR18. The DO concentrations at EWR18 might have a limiting effect on aquatic biota.

During the April 2008 survey DO concentrations were adequate (> 5 mg/l) at EWR16 and EWR18. The DO concentrations at EWR17 and EWR19 were < 5mg/l and might have a negative effect on biota (Table 3).

5.1.3 Total Dissolved Solids

During the September 2007 survey TDS concentrations ranged from 345 mg/l at EWR19 to 1235 mg/l at EWR17 (Table 3).

During the April 2008 survey TDS concentrations ranged from 273 mg/l at EWR19 to 1118 mg/l at EWR17 (Table 3).

The high TDS concentrations at EWR17 can be attributed to the agricultural runoff in the Harts River due to centre pivot irrigation.

According to the South African Water Quality Guidelines for Aquatic Ecosystems the rate of change of TDS concentration and the duration of change is more important than the absolute change (DWAF, 1996 and Dallas and Day, 1993). Many organisms are able to adjust to gradual changes in TDS concentration by a process of physiological acclimation; it is a sudden increase (shock) that is more detrimental.

5.1.4 Temperature

Water temperature plays an important role in aquatic ecosystems by affecting the rates of chemical reactions and therefore also the metabolic rates of organisms (DWAF, 1996). Temperature affects the rate of development, reproductive periods and emergence time of organisms (DWAF, 2005). Temperature varies with season and the life cycles of many aquatic macroinvertebrates are cued to temperature (DWAF, 2005).

During the September 2007 survey water temperatures varied between 19°C and 20°C (Table 3).

During the April 2008 survey water temperatures ranged from 17°C at EWR16 to 20°C at EWR17 (Table 3).

Within these ranges water temperatures should not have a limiting effect on aquatic biota.

5.2 Habitat Assessment

The quantity and quality of the instream and riparian habitat has a direct influence on the aquatic community. Evaluating the structure and functioning of an aquatic ecosystem must therefore take into account the physical habitat to assess the ecological integrity.

5.2.1 Invertebrate Habitat Assessment System (IHAS, Version 2)

The Invertebrate Habitat Assessment System (IHAS) was developed by McMillan (1998) for use in conjunction with the SASS5 protocol. The results of the IHAS assessment are provided in Table 4.

Table 4: Invertebrate Habitat Assessment System Scores (IHAS, *version 2*).

Site	IHAS	
	Sept '07	Apr '08
EWR16	75	78
EWR17	67	66
EWR18	51	44
EWR19	77	75

During the September 2007 survey habitat availability were good at all the sites except site for site EWR18 were habitat availability was poor (Table 4). During the April 2008 survey habitat availability was good at all the sites except EWR18 that showed poor habitat availability.

Based on an assessment of IHAS data collected over the period September 2007 to April 2008 it can be concluded that habitat availability in the lower Vaal River does not have a limiting factor of aquatic macroinvertebrate diversity except for site EWR18 in the Vaal River.

5.3 Aquatic Macroinvertebrates (SASS5)

A total of 32 aquatic macroinvertebrate taxa were collected in the sample area during the September 2007 survey. During the September 2007survey SASS5 scores ranged from 33 at EWR18 to 124 at EWR19. The Average Score per Taxa (ASPT) scores ranged from 3.7 at EWR18 to 5.3 at EWR19 showing that the aquatic macroinvertebrate assemblage in this river is characterised by tolerant taxa (Intolerance Rating < 5) except for site EWR19 (Table 5).

A total of 30 aquatic macroinvertebrate taxa were collected in the sample area during the April 2008 survey. During the April 2008 survey SASS5 scores ranged from 56 at EWR16 to 87 at EWR19. The ASPT scores ranged from 3.8 to 4.6 confirming that the assemblage is characterised by tolerant taxa (Intolerance Rating < 5) (Table 5).

Table 5: SASS results recorded in the project area during the September 2007 and April 2008 surveys.

Site	Number of taxa		ASPT*		SASS5 Score	
	Sep '07	Apr '08	Sep '07	Apr '08	Sep '07	Apr '08
EWR16	15	14	4.3	4.0	64	56
EWR17	21	16	4.3	3.8	91	61
EWR18	9	17	3.7	4.4	33	74
EWR19	23	19	5.3	4.6	124	87

** Average Score per Taxon;*

5.4 MACROINVERTABRATE RESPONSE ASSESSMENT INDEX (MIRAI)

The MIRAI results for the Lower Vaal Comprehensive Reserve Determination sites will be discussed individually for each site.

Site EWR16

Table 6 indicates the weights of the different metric groups for site EWR16. According to Table 6 the flow modification metric carried the most weight at this site followed by the water quality, habitat and connectivity and seasonality. This site is situated downstream from Bloemhof Dam in the town of Bloemhof on the main stem of the Vaal River.

Table 6: Site EWR16 Metric Group Weights

METRIC GROUP	WEIGHT (%)
FLOW MODIFICATION	100
HABITAT	90
WATER QUALITY	95
CONNECTIVITY AND SEASONALITY	20

Table 7 provides the MIRAI results and associated Ecological Categories (EC) for site EWR16. Based on this assessment the aquatic macroinvertabrate assemblage at site EWR16 at the time of the surveys was classified in an EC of D (Table 7).

Table 7: Site EWR4 MIRA5 results (%) and associated Ecological Categories (EC)

AUTOMATED	
MIRAI (%)	58.97
Ecological Category (EC)	**D**

Site EWR17

Table 8 indicates the weights of the different metric groups for site EWR17. According to Table 8 the flow modification metric carried the most weight at this site followed by the, water quality, habitat and connectivity and seasonality. This site is situated upstream of the confluence of the Vet River, on the main stem of the Vaal River.

Table 8: Site EWR17 Metric Group Weights

METRIC GROUP	WEIGHT (%)
FLOW MODIFICATION	100
HABITAT	90
WATER QUALITY	95
CONNECTIVITY AND SEASONALITY	20

Table 9provides the MIRAI results and associated Ecological Categories (EC) for site EWR17. Based on this assessment the aquatic macroinvertabrate assemblage at site EWR17 at the time of the surveys was classified in an EC of D (Table 9).

Table 9: Site EWR17 MIRAI results (%) and associated Ecological Categories (EC)

AUTOMATED	
MIRAI (%)	58.75
Ecological Category (EC)	**D**

Site EWR18

Table 10 indicates the weights of the different metric groups for site EWR18. According to Table 10 the flow modification metric carried the most weight at this site followed by the habitat, water quality and connectivity and seasonality. This site is situated on the main stem of the Vaal River downstream of the confluence of the Harts River, but upstream of the confluence with the Riet River.

Table 10: Site EWR18 Metric Group Weights

METRIC GROUP	WEIGHT (%)
FLOW MODIFICATION	100
HABITAT	90
WATER QUALITY	95
CONNECTIVITY AND SEASONALITY	20

Table 11 provides the MIRAI results and associated Ecological Categories (EC) for site EWR18. Based on this assessment the aquatic macroinvertabrate assemblage at site EWR18 at the time of the surveys was classified in an EC of D (Table 11).

Table 11: Site EWR18 MIRAI results (%) and associated Ecological Categories (EC)

AUTOMATED	
MIRAI (%)	58.40
Ecological Category (EC)	**D**

Site EWR19

Table 12 indicates the weights of the different metric groups for site EWR19. According to Table 12 the flow modification metric carried the most weight at this site followed by the habitat, water quality and connectivity and seasonality. This site is situated in the Riet River downstream with the confluence of the Modder River.

Table 12: Site EWR19 Metric Group Weights

METRIC GROUP	WEIGHT (%)
FLOW MODIFICATION	100
HABITAT	90
WATER QUALITY	95
CONNECTIVITY AND SEASONALITY	20

Table 13 provides the MIRAI results and associated Ecological Categories (EC) for site EWR19. Based on this assessment the aquatic macroinvertabrate assemblage at site EWR19 at the time of the surveys was classified in an EC of C (Table 13).

Table 13: Site EWR19 MIRAI results (%) and associated Ecological Categories (EC)

AUTOMATED	
MIRAI (%)	70.06
Ecological Category (EC)	**C**

6 CONCLUSIONS

- Based on an assessment of IHAS data collected over the period September 2007 to April 2008 it can be concluded that habitat availability in the lower Vaal River does not have a limiting effect on aquatic macroinvertebrate diversity except for site EWR18.
- Based on the September 2007 and the April 2008 assessment of the aquatic macroinvertabrate assemblage at site EWR16 at the time of the surveys was classified in an EC of D.
- Based on the September 2007 and the April 2008 assessment of the aquatic macroinvertabrate assemblage at site EWR17 at the time of the surveys was classified in an EC of D.
- Based on the September 2007 and the April 2008 assessment of the assessment the aquatic macroinvertabrate assemblage at site EWR18 at the time of the surveys was classified in an EC of D.
- Based on the September 2007 and the April 2008 assessment of this assessment the aquatic macroinvertabrate assemblage at site EWR19 at the time of the surveys was classified in an EC of C.

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\\JOH1-S-FS1\GAADATA\PROJECTS\8856 - LOWER VAAL WMA\REPORTS\FINAL REPORTS DWA 2011\ECOCLASSIFICATION\APPENDIX D_LOWER VAAL WMA INVERTS REPORT.DOCX

APPENDIX A

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APPENDIX E
RIPARIAN VEGETATION ASSESSMENT

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REPORT ON

VEGRAI COMPONENT OF LOWER VAAL WMA

Report No : 8856-8279-1

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EXECUTIVE SUMMARY

Most of the EWR sites surveyed during the study showed considerable amounts of degradation due to human activities, including mining and agricultural activities as well as the construction of infrastructure and settlement activities. The degradation in these area are however not directly related to the flow regime and any alteration in flow regime is unlikely to have much, if any, effect on the PES of the already altered vegetation at any of the sites. Most of the sites require extensive rehabilitation in order to return them to a semi-natural state. Some EWR sites were extensively degraded and total transformation of the natural vegetation had taken place, such as Site EWR16. These sites will take many years and a considerable financial undertaking to rehabilitate and were poorly selected for a study of this kind. The VEGRAI system, although a good broad scale method of analysing the ecological status of riparian vegetation does appear to have a number of shortfalls when utilised for this type of study. Firstly, the VEGRAI system appears to have been developed for an area where the woody component is far better represented than in many of the sites studied for this project. The marginal and aquatic vegetation is much more likely to be affected by flow regime; however, because of the weight of the woody vegetation (which is usually not in the marginal zone at sites in the Vaal River system) the results are skewed towards the vegetation types least likely to be affected by a change in flow regime.

Recommendation proposed:

- Improved site selection for the determination of vegetation ecological status.
- Refinement of the VEGRAI system for river systems with less woody vegetation.
- Refinement of the VEGRAI system in order to account for the increased importance of the marginal and aquatic zones of the water

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1 INTRODUCTION

Golder Associates Africa (Pty) Ltd was contracted, by the Department of Water Affairs and Forestry via Zitholele Consulting to conduct the VEGRAI study component of the WMA for the Lower Vaal reach.

The main aim of this survey was to determine the status of the riparian vegetation along the Lower reaches of the Vaal River and its tributaries and also determine whether this status would be altered due to an increase or decrease in the flow rate of the Vaal River and its tributaries.

2 OBJECTIVES

The objective of this survey was to determine the status of the riparian vegetation community at the EWR sites selected along the lower reaches of the Vaal River using the VEGRAI methodology as set out in the WRC report by Kleynhans, McKenzie and Louw (2007).

As no further instructions for this study were given, the study was restricted to conducting the VEGRAI survey at each of the EWR sites along the lower reach of the Vaal River.

3 METHODOLOGIES

The methodologies set out in Kleynhans, McKenzie and Louw (2007) were followed in order to complete this study. Slight variations in the methodology were required in order to complete the survey and where such variations were required they are stated as such. No additional surveys were conducted during the fieldwork stage, but ecologically important observations were noted during the site inspections. Although VEGRAIN is a suitable methodology for determining and classifying riparian vegetation status it has a number of limitations with regards to this particular study and these limitations are identified and discussed later in this report.

3.1 Fieldwork methodology

Fieldwork was conducted in accordance with section 4 of Kleynhans, McKenzie and Louw (2007). This involved determination of site extent, zone definition, drawing of a plan view and cross section sketch, creation of a key species list (limited to 10-15 key / indicator / dominant / easily identifyable species per zone as per VEGRAI methodology), assessment of land-use and impacts, assessment of exotic vegetation and invasion, reconstruction of the reference condition and rating response metrics.

3.2 Data capture and processing

Once the field survey stage was completed, all the field form data was transferred to the VEGRAI Excel spreadsheet. In addition to the field form data, the following were entered into the VEGRAI 4 Excel spreadsheet:

- Present and reference state descriptions;
- Additional information on identified species;

- On/off switches in the response metrics workbook.
- Rank and weight of each zone according to their importance in the creation and maintenance of instream habitat.

4 FINDINGS

4.1 EWR12, Vermaasdrif, Vaal River

4.1.1 General description

The site at Vermaasdrif on the Vaal River consists of a relatively broad area of flow with moderately sloping banks, on which vegetation would easily colonise and recruit. The site selection at this site is, however, not ideal as the vegetation in the area has been disturbed by the construction of the bridge at Vermaasdrif and is not representative of the vegetation along this reach of the Vaal River. For this reason the vegetation surveyed for the purposes of this study was the vegetation at the transect site itself as well as vegetation further upstream of the site. Land use in the area is predominantly agricultural and pastoral farming.

4.1.2 Plan and cross section view.

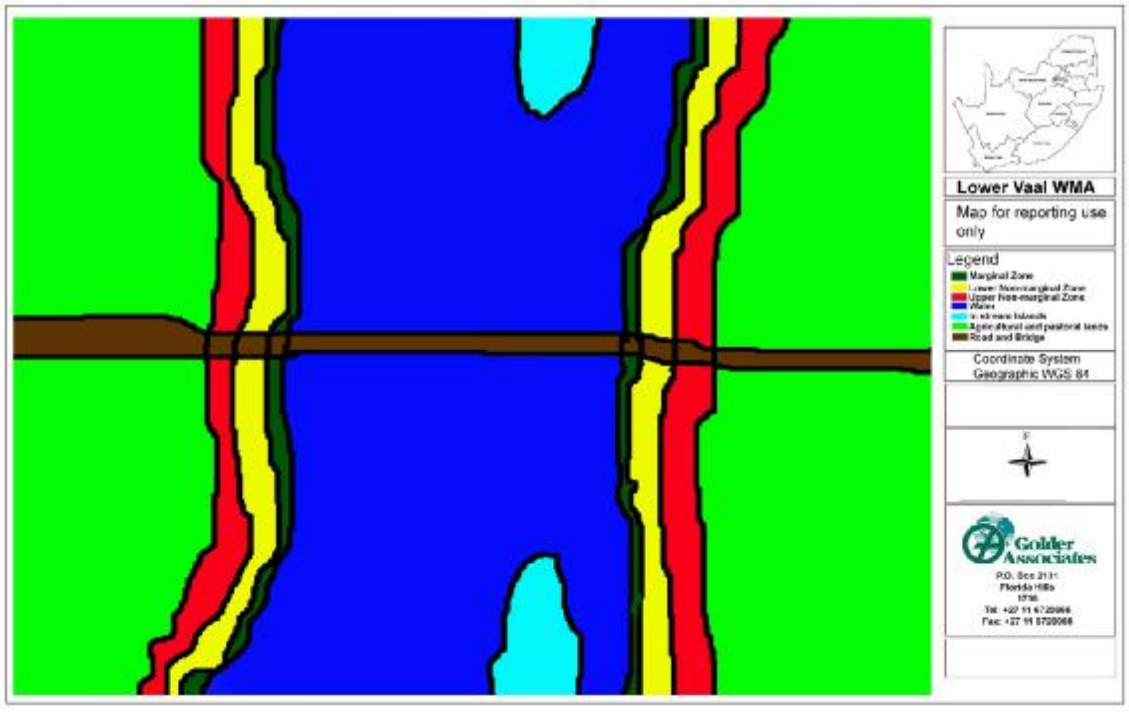

Figure 1: Plan view of Site EWR12

Figure 2: Cross-section view of site EWR12

4.1.3 Species composition

The marginal zone at Site EWR12 is dominated by graminoid and cyperoid species including *Brachiaria marlothii, Cyperus denudatus, Cyperus longus, Echinochloa holubii, Panicum coloratum, Pycreus mundii, Sporobulus africanus, Sporobulus fimbriatus, Azolla filiculoides, Eichhornia crassipes* and *Myriophyllum spicatum* while the lower non-marginal zone is dominated by mainly by graminoids and herbaceous species such as *Agrostis lachnantha, Andropogon eucomus, Chloris virgata, Cynodon dactylon, Phragmites australis, Eragrostis plana, Hemarthria altissima, Imperata cylindrical , Ischaemum fasciculatum, Miscanthus junceus, Paspalum distichum, Andropogon appendiculatus, Brachiaria marlothii, Cyperus denudatus, Cyperus longus, Echinochloa holubii, Eragrostis obtuse, Eragrostis porosa, Fimbristylis ferruginea, Panicum coloratum, Pycreus mundii, Sporobulus africanus, Sporobulus fimbriatus, Urochloa panicoides, Persicaria lapathifolia, Alternanthera sessilis, Barleria macrostegia, Corchorus asplenifolius, Equisetum ramosissimum, Galium capense, Hibiscus pusillus, Lobelia angolensis, Nidorella resedifolia, Persicaria amphibian*and the upper non-marginal zone is dominated by tree and shrub species including *Acacia karroo, Salix mucronata, Ziziphus mucronata, Rhus lancea, Gymnosporia buxifolia, Rhus pyroides, Diospyros lycoides, Ehretia rigida, Grewia flava, Asparagus laricinus* and *Asparagus sauveolens.*

4.1.4 VEGRAI discussion

REFERENCE CONDITIONS

As the Vaal river system (particularly the system falling within the Highveld Alluvial vegetation type) is highly degraded, due to the introduction of exotic species and other anthropogenic impacts, a hypothetical reference position was determined using existing historical data, as well as the data collected from all the sites within the study area. Reductions in exotic species diversity and abundance, as well as exotic species cover, were utilised in order to obtain a hypothetical reference site. Many of the decisions made in order to determine the hypothetical reference site were subjective decisions based on existing literature and field experience.

RESULTS

Table 1 indicates the results of the VEGRAI assessment for EWR12.

Current status: The area is currently considerably degraded due to the introduction of a number of exotic species. The exotic species in the area, in fact, contribute to a total of almost 50% of the total number of species identified during the surveys. Furthermore, the lack of stochastic events, such as fire and flooding, are causing homogenization of the riparian vegetation at site EWR12.

Trajectory of change: Due to the factors mentioned above under the section “Current Status” and the fact that these factors are not being remedied or arrested it must be assumed, in order to comply with cautionary principles, that the trajectory of change is negative.

LEVEL 4 VEGRAI EC : **C**

Table 1: EWR12 VEGRAI

LEVEL 4 ASSESSMENT						
RIPARIAN VEGETATION EC METRIC GROUP	**CALCULATED RATING**	**WEIGHTED RATING**	**CONFIDENCE**	**RANK**	**WEIGHT**	**NOTES: (give reasons for each assessment)**
MARGINAL	71.9	24.8	3.0	1.0	100.0	marginal zone most important for year-round refuge habitat, overhanging vegetation important for habitat creation / variability
LOWER ZONE	49.6	17.1	2.0	2.0	100.0	lower zone has high seasonal importance for breeding habitat, also shading of aquatic habitats
UPPER ZONE	73.4	22.8	2.0	3.0	90.0	not directly important for instream habitat, but bank stabilty indirectly important, possibly some shading and litter input
	3.0				290.0	

LEVEL 4 VEGRAI (%)	64.7
VEGRAI EC	C
AVERAGE CONFIDENCE	2.3

	Zone		
	Marginal	Lower	Upper
VEGRAI % (Zone)	71.9	49.6	73.4
EC (Zone)	C	D	C
Confidence (Zone)	3.0	2.0	2.0

REASONS FOR PES

The Vaal river system (particularly the section falling within the Highveld Alluvial vegetation type) is highly degraded, due to the introduction of exotic species and other anthropogenic impacts, a hypothetical reference position was determined using existing historical data, as well as the data collected from all the sites within the study area. Reductions in exotic species diversity and abundance, as well as exotic species cover, were utilised in order to obtain a hypothetical reference site. Many of the decisions made in order to determine the hypothetical reference site were subjective decisions based on existing literature and field experience.

The area is currently considerably degraded due to the introduction of a number of exotic species. The exotic species in the area, in fact, contribute to a total of almost 50% of the total number of species identified during the surveys. Furthermore, the lack of stochastic events, such as fire and flooding, are causing homogenization of the riparian vegetation at site EWR12.

Due to the factors mentioned above under the section "Current Status" and the fact that these factors are not being remedied or arrested it must be assumed, in order to comply with cautionary principles, that the trajectory of change is negative.

Causes and sources

PES	CAUSES	SOURCES	F[1]/NF[2]	Conf[3]
C	Terrestrial exotic invasive species	Anthropogenic	N	4
	Aquatic exotic invasive species	Anthropogenic	F	

1: Flow related 2: Non Flow related 3: Confidence

Trend

PES	TREND	TREND PES	TIME	REASONS	Conf
	Negative	C Negative	10 years	According to the data collected as well as the literature (covering approximately the last ten years) consulted a negative trend in the PES has been identified.	4

RECOMMENDED ECOLOGICAL CATEGORY (REC)

PES	REC	COMMENTS
C	C	Due to the fact that no previous surveys of this nature have been conducted in this area, the REC can only be given as C. There is a possibility that further surveys in the area may provide enough information to recommend an REC in future.

ALTERNATIVE ECs TO SERVE AS THE RANGE OF ECOLOGICAL RESERVE SCENARIOS

AEC C (Increased flows)

PES	REC	AEC	COMMENTS	CONF
C	C	C	Although increasing the flow would not cause an increase in the PES, it would increase the ecological state of the area by reducing the percentage cover of exotic species and possibly flushing a number of the invasive aquatic species occurring in the area.	3

AEC (Decreased flows)

PES	REC	AEC	COMMENTS	CONF
n/a	n/a	n/a	Due to the low current PES it would be unwise to manage the flow in order to reduce the PES from its current level.	

4.2 EWR13, Regina Bridge, Vaal River

4.2.1 General description

The site at Regina Bridge on the Vaal River consists of a relatively broad area of flow with moderately sloping banks on the both banks on which vegetation would easily colonise and recruit. The site selection at this site is ideal as the vegetation in the area of the site is representative of the vegetation of the reach. Land use in the area is predominantly agricultural and pastoral farming and this has impacted on the site with regard to exotic species and possibly increases in nutrient levels in the river itself.

4.2.2 Plan and cross section view.

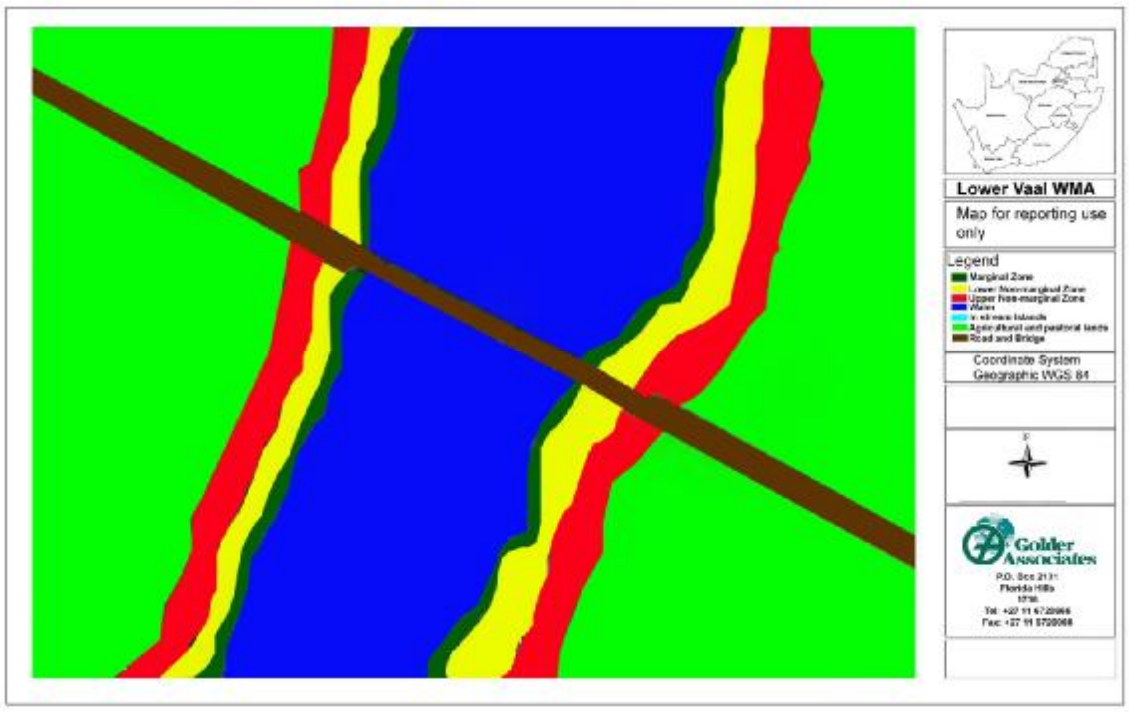

Figure 3: Plan view of Site EWR13

Figure 4: Cross-section view of site EWR13

4.2.3 Species composition

The marginal zone at Site EWR13 is dominated by graminoid and cyperoid species including *Cyperus denudatus, Cyperus longus, Echinochloa holubii*, *Panicum coloratum, Sporobulus africanus, Azolla filiculoides* and *Myriophyllum spicatum* while the lower non-marginal zone is dominated by mainly by tree species such as *Salix mucronata, Ziziphus mucronata* and the upper non-marginal zone is dominated by tree and shrub species including *Acacia karroo, Salix mucronata, Ziziphus mucronata, Rhus lancea, Gymnosporia buxifolia, Rhus pyroides, Diospyros lycoides, Ehretia rigida, Grewia flava, Asparagus laricinus* and *Asparagus sauveolens.*.

4.2.4 VEGRAI discussion

REFERENCE CONDITIONS

As the Vaal river system (particularly the system falling within the Highveld Alluvial vegetation type) is highly degraded, due to the introduction of exotic species and other anthropogenic impacts, a hypothetical reference position was determined using existing historical data, as well as the data collected from all the sites within the study area. Reductions in exotic species diversity and abundance, as well as exotic species cover, were utilised in order to obtain a hypothetical reference site. Many of the decisions made in order to determine the hypothetical reference site were subjective decisions based on existing literature and field experience.

RESULTS

Table 2 indicates the results of the VEGRAI assessment for EWR13.

Current status: The area is currently degraded due to the introduction of a number of exotic species. The exotic species in the area contribute to a total of almost 30% of the total number of species identified during the surveys, but the exotic species do not make up as significant a percentage of the cover as they do in Site 1. Furthermore, the lack of stochastic events, such as fire and flooding, are causing homogenization of the riparian vegetation at site EWR13 as well as the colonisation of the islands with more vegetation as well as more exotic species than would usually occur there. It must be noted that the disturbances and the degradation in this area are mostly due to anthropogenic changes that are not directly related to- or due to the flow regime. Therefore, although there may be a certain reduction in the abundance of less firmly rooted exotic species, due to large flood events, a change in flow regime is unlikely to change the ecological status of the reach significantly.

Trajectory of change: Due to the factors mentioned above under the section “Current Status” and the fact that these factors are not being remedied or arrested it must be assumed, in order to comply with cautionary principles, that the trajectory of change is negative.

LEVEL 4 VEGRAI EC : **B/C**

Table 2: EWR13 VEGRAI

LEVEL 4 ASSESSMENT						
RIPARIAN VEGETATION EC METRIC GROUP	**CALCULATED RATING**	**WEIGHTED RATING**	**CONFIDENCE**	**RANK**	**WEIGHT**	**NOTES: (give reasons for each assessment)**
MARGINAL	79.3	26.4	3.3	1.0	100.0	marginal zone most important for year-round refuge habitat, overhanging vegetation important for habitat creation / variability
LOWER ZONE	80.8	26.9	4.2	2.0	100.0	lower zone has high seasonal importance for breeding habitat, also shading of aquatic habitats
UPPER ZONE	79.7	26.6	4.2	3.0	100.0	not directly important for instream habitat, but bank stabilty indirectly important, possibly some shading and litter input
	3.0				300.0	
LEVEL 4 VEGRAI (%)				79.9		
VEGRAI EC				B/C		
AVERAGE CONFIDENCE				3.9		

	Zone		
	Marginal	Lower	Upper
VEGRAI % (Zone)	79.3	80.8	79.7
EC (Zone)	B/C	B/C	B/C
Confidence (Zone)	3.3	4.2	4.2

REASONS FOR PES

As the Vaal river system (particularly the system falling within the Highveld Alluvial vegetation type) is highly degraded, due to the introduction of exotic species and other anthropogenic impacts, a hypothetical reference position was determined using existing historical data, as well as the data collected from all the sites within the study area. Reductions in exotic species diversity and abundance, as well as exotic species cover, were utilised in order to obtain a hypothetical reference site. Many of the decisions made in order to determine the hypothetical reference site were subjective decisions based on existing literature and field experience.

The area is currently degraded due to the introduction of a number of exotic species. The exotic species in the area contribute to a total of almost 30% of the total number of species identified during the surveys, but the exotic species do not make up as significant a percentage of the cover as they do in Site 1. Furthermore, the lack of stochastic events, such as fire and flooding, are causing homogenization of the riparian vegetation at site EWR13 as well as the colonisation of the islands with more vegetation as well as more exotic species than would usually occur there. It must be noted that the disturbances and the degradation in this area are mostly due to anthropogenic changes that are not directly related to- or due to the flow regime. Therefore, although there may be a certain reduction in the abundance of less firmly rooted exotic species, due to large flood events, a change in flow regime is unlikely to change the ecological status of the reach significantly.

Due to the factors mentioned above under the section "Current Status" and the fact that these factors are not being remedied or arrested it must be assumed, in order to comply with cautionary principles, that the trajectory of change is negative.

Causes and sources

PES	CAUSES	SOURCES	F[1]/NF[2]	Conf[3]
B/C	Terrestrial exotic invasive species	Anthropogenic	N	4
	Aquatic exotic invasive species	Anthropogenic	F	

1: Flow related 2: Non Flow related 3: Confidence

Trend

PES	TREND	TREND PES	TIME	REASONS	Conf
B/C	Negative	B/C Negative	5 years	According to the data collected as well as the literature (covering approximately the last five years) consulted a negative trend in the PES has been identified.	4

RECOMMENDED ECOLOGICAL CATEGORY (REC)

PES	REC	COMMENTS
B/C	B/C	Due to the fact that no previous surveys of this nature have been conducted in this area, the REC can only be given as B/C. There is a possibility that further surveys in the area may provide enough information to recommend an REC in future.

ALTERNATIVE ECs TO SERVE AS THE RANGE OF ECOLOGICAL RESERVE SCENARIOS

AEC C (Increased flows)

PES	REC	AEC	COMMENTS	CONF
B/C	B/C	B/C	Although a change in the flow regime would not cause an increase in the PES, it would increase the ecological state of the area by reducing the percentage cover of exotic species and possibly flushing a number of the invasive aquatic species occurring in the area.	3

AEC C (Decreased flows)

PES	REC	AEC	COMMENTS	CONF
n/a	n/a	n/a	It would be unwise to manage the flow in order to reduce the PES from its current level.	

4.3 EWR14, Proklameerdrif, Vals River

4.3.1 General description

The site at Proklameersdrif on the Vals River consists of a relatively narrow area of flow with moderately sloping banks, on which vegetation would easily colonise and recruit. This being said, there is a large amount of grass cover on the slopes and, due to the competitiveness of graminoids, recruitment by woody species will be hampered by the high abundance of graminoids. The site selection at this site is very good as this site well represents the riparian vegetation in the area. The fact that few woody species occur in this area, due to the fact that it falls within the grassland biome, does call into question the usefulness of VEGRAI in this specific vegetation type. The only woody species occurring in this area are exotics with few indigenous species and VEGRAI appears to have been developed for areas with significant woody vegetation present in the riparian vegetation. The vegetation at Proklameersdrif, although representative of the vegetation along this reach of the Vals River, has been affected by land use in the surrounding areas. Land use in the area is predominantly agricultural and pastoral farming.

4.3.2 Plan and cross section view.

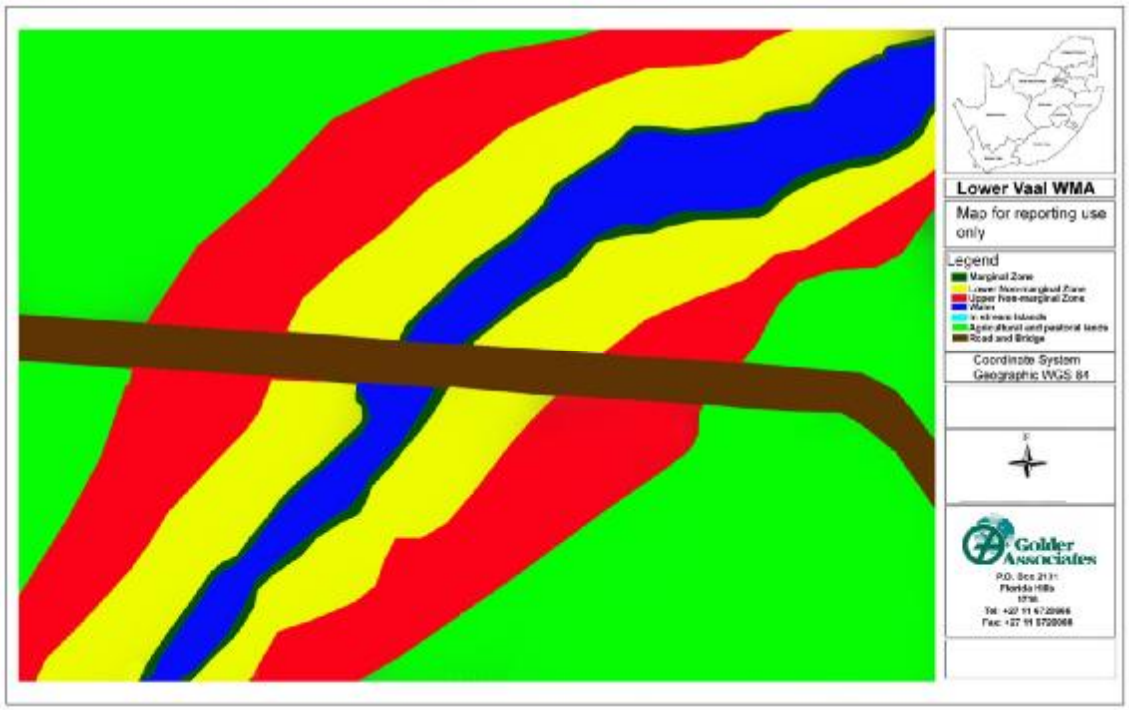

Figure 5: Plan view of Site EWR14

Figure 6: Cross-section view of site EWR14

4.3.3 Species composition

The marginal zone at Site EWR14 is dominated by graminoid and cyperoid species including *Cyperus denudatus, Cyperus longus, Echinochloa holubii, Cyperus denudatus, Cyperus longus, Pycreus mundii* and *Sporobulus fimbriatus* while the lower non-marginal zone is dominated by mainly by graminoids and herbaceous species such as *Agrostis lachnantha, Andropogon eucomus, Chloris virgata, Cynodon dactylon, Phragmites australis, Eragrostis plana, Hemarthria altissima, Ischaemum fasciculatum, Echinochloa holubii, Eragrostis obtuse, Eragrostis porosa, Fimbristylis ferruginea, Panicum coloratum, Pycreus mundii, Sporobulus africanus, Sporobulus fimbriatus, Urochloa panicoides, Persicaria lapathifolia, Alternanthera sessilis, Barleria macrostegia, Corchorus asplenifolius, Equisetum ramosissimum, Galium capense, Hibiscus pusillus, Lobelia angolensis, Nidorella resedifolia, Persicaria amphibian*and the upper non-marginal zone is dominated by graminoid species but sparse woody species include *Acacia karroo, Salix mucronata, Ziziphus mucronata, Rhus lancea, Gymnosporia buxifolia, Grewia flava,* and *Asparagus sauveolens.*.

4.3.4 VEGRAI discussion

REFERENCE CONDITIONS

Little literature is available concerning the vegetation of the Vals River. The vegetation is not highly degraded due to the introduction of exotic species and other anthropogenic impacts, but some impacts are visible throughout the reach. As historical data for this site was not found a hypothetical reference position was determined using the data collected from the sites itself and reductions in exotic species diversity and abundance, as well as exotic species cover, were utilised in order to obtain a hypothetical reference site. Many of the decisions made in order to determine the hypothetical reference site were subjective decisions based on existing literature and field experience.

RESULTS

Table 3 indicates the results of the VEGRAI assessment for EWR14.

Current status: The area is currently degraded due to the introduction of a number of exotic species. Although not as degraded as the sites along the Vaal River, the Vals River has been impacted upon by surrounding agricultural practices and burning regimes. For this reason, combined with the lack of significant historical data, it was difficult not only to determine the correct reference site conditions, but also the actual current status of this site

Trajectory of change: Due to the factors mentioned above under the section “Current Status” and the fact that these factors are not being remedied or arrested it must be assumed, in order to comply with cautionary principles, that the trajectory of change is negative.

LEVEL 4 VEGRAI EC : **D**

Table 3: EWR14 VEGRAI

LEVEL 4 ASSESSMENT						
RIPARIAN VEGETATION EC METRIC GROUP	**CALCULATED RATING**	**WEIGHTED RATING**	**CONFIDENCE**	**RANK**	**WEIGHT**	**NOTES: (give reasons for each assessment)**
MARGINAL	63.1	36.1	3.3	1.0	100.0	marginal zone most important for year-round refuge habitat, overhanging vegetation important for habitat creation / variability
LOWER ZONE	45.7	6.5	4.2	3.0	25.0	lower zone has high seasonal importance for breeding habitat, also shading of aquatic habitats
UPPER ZONE	49.5	14.2	4.2	2.0	50.0	not directly important for instream habitat, but bank stabilty indirectly important, possibly some shading and litter input
	3.0				175.0	
LEVEL 4 VEGRAI (%)				56.8		
VEGRAI EC				D		
AVERAGE CONFIDENCE				3.9		

	Zone		
	Marginal	Lower	Upper
VEGRAI % (Zone)	63.1	45.7	49.5
EC (Zone)	C	D	D
Confidence (Zone)	3.3	4.2	4.2

REASONS FOR PES

Little literature is available concerning the vegetation of the Vals River. The vegetation is not highly degraded due to the introduction of exotic species and other anthropogenic impacts, but some impacts are visible throughout the reach. As historical data for this site was not found a hypothetical reference position was determined using the data collected from the sites itself and reductions in exotic species diversity and abundance, as well as exotic species cover, were utilised in order to obtain a hypothetical reference site. Many of the decisions made in order to determine the hypothetical reference site were subjective decisions based on existing literature and field experience. The area is currently degraded due to the introduction of a number of exotic species. Although not as degraded as the sites along the Vaal River, the Vals River has been impacted upon by surrounding agricultural practices and burning regimes. For this reason, combined with the lack of significant historical data, it was difficult not only to determine the correct reference site conditions, but also the actual current status of this site**.** Due to the factors mentioned above under the section "Current Status" and the fact that these factors are not being remedied or arrested it must be assumed, in order to comply with cautionary principles, that the trajectory of change is negative.

Causes and sources

PES	CAUSES	SOURCES	F[1]/NF[2]	Conf[3]
D	Terrestrial exotic invasive species	Anthropogenic	N	4
	Aquatic exotic invasive species	Anthropogenic	F	

1: Flow related 2: Non Flow related 3: Confidence

Trend

PES	TREND	TREND PES	TIME	REASONS	Conf
D	Negative	C Negative	0 years	According to the data collected, the application of the cautionary principle as well as the fact that no historical vegetation data was found for this site, a negative trend in the PES has been identified.	4

RECOMMENDED ECOLOGICAL CATEGORY (REC)

PES	REC	COMMENTS
D	D	Due to the fact that no previous surveys of this nature have been conducted in this area, the REC can only be given as D. There is a possibility that further surveys in the area may provide enough information to recommend an REC in future.

ALTERNATIVE ECs TO SERVE AS THE RANGE OF ECOLOGICAL RESERVE SCENARIOS

AEC C (Increased flows)

PES	REC	AEC	COMMENTS	CONF
D	D	D	It is unlikely that an increase in flow regime would have any significant influence of the ecological status at the site in question.	3

AEC C (Decreased flows)

PES	REC	AEC	COMMENTS	CONF
n/a	n/a	n/a	Due to the low current PES it would be unwise to manage the flow in order to reduce the PES from its current level.	

4.4 EWR15, Fisantkraal, Vet River

4.4.1 General description

The site at Fisantkraal on the Vet River consists of a relatively narrow area of flow with moderately sloping banks, on which vegetation would easily colonise and recruit. The vegetation at this site is varied, from a large number of woody species encroachments in areas of lesser disturbance to areas of denudation with a large proportion of herbaceous exotic species in areas more affected by disturbance. The site selection at this site is, however, not ideal as the vegetation in the area has been disturbed by farming practices in the area and a large degree of colonisation by exotic species. Land use in the area is predominantly agricultural and pastoral farming.

4.4.2 Plan and cross section view.

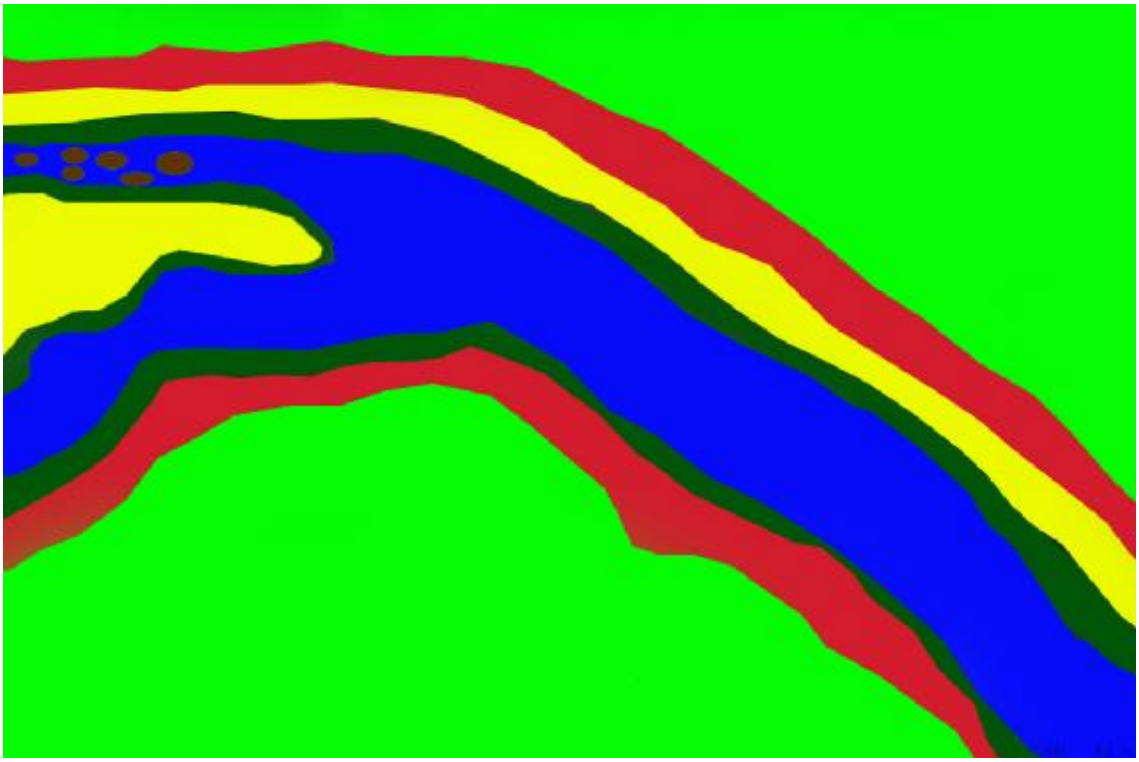

Figure 7: Plan view of Site EWR15

Figure 8: Cross-section view of site EWR15

4.4.3 Species composition

The marginal zone at Site EWR15 is dominated by graminoid and cyperoid species including *Cyperus denudatus, Cyperus longus, Panicum coloratum* and especially *Cynodon dactylon, Cirsium vulgare, Datura ferox, Datura stramonium* and *Xanthium strumarium* while the lower non-marginal zone is dominated by mainly by graminoids and herbaceous species such as *Cynodon dactylon, Cirsium vulgare, Datura ferox, Datura stramonium* and *Xanthium strumarium* and woody species such as *Acacia karroo* and *Salix mucronata*. The upper non-marginal zone is dominated by tree and shrub species including *Acacia karroo, Salix mucronata, Ziziphus mucronata*, *Rhus lancea*, and *Grewia flava*.

4.4.4 VEGRAI discussion

REFERENCE CONDITIONS

As the Vaal river system (particularly the system falling within the Highveld Alluvial vegetation type) is highly degraded, due to the introduction of exotic species and other anthropogenic impacts, a hypothetical reference position was determined using existing historical data, as well as the data collected from all the sites within the study area. Due to the lack of historical vegetation data for the Vet River and the highly degraded nature of this area the construction of a reference site for this site was particularly difficult. Reductions in exotic species diversity and abundance, as well as exotic species cover, were utilised in order to obtain a hypothetical reference site. Many of the decisions made in order to determine the hypothetical reference site were subjective decisions based on existing literature and field experience.

RESULTS

Table 4 indicates the results of the VEGRAI assessment for EWR15.

Current status: The area is currently considerably degraded mainly due to the introduction of a number of exotic species. The exotic species in the area, in fact, contribute to a total of over 50% of the total number of species identified during the surveys. Furthermore, the lack of stochastic events, such as fire and flooding, are causing homogenization of the riparian vegetation at site EWR15.

Trajectory of change: Due to the factors mentioned above under the section “Current Status” and the fact that these factors are not being remedied or arrested it must be assumed, in order to comply with cautionary principles, that the trajectory of change is negative.

LEVEL 4 VEGRAI EC : **E**

Table 4: EWR15 VEGRAI

LEVEL 4 ASSESSMENT						
RIPARIAN VEGETATION EC METRIC GROUP	**CALCULATED RATING**	**WEIGHTED RATING**	**CONFIDENCE**	**RANK**	**WEIGHT**	**NOTES: (give reasons for each assessment)**
MARGINAL	23.2	7.7	3.9	1.0	100.0	marginal zone most important for year-round refuge habitat, overhanging vegetation important for habitat creation / variability
LOWER ZONE	27.6	9.2	4.2	2.0	100.0	lower zone has high seasonal importance for breeding habitat, also shading of aquatic habitats
UPPER ZONE	37.0	12.3	4.2	3.0	100.0	not directly important for instream habitat, but bank stabilty indirectly important, possibly some shading and litter input
	3.0				300.0	
LEVEL 4 VEGRAI (%)				29.3		
VEGRAI EC				E		
AVERAGE CONFIDENCE				4.1		

	Zone		
	Marginal	Lower	Upper
VEGRAI % (Zone)	23.2	27.6	37.0
EC (Zone)	E	E	E
Confidence (Zone)	3.9	4.2	4.2

REASONS FOR PES

As the Vaal river system (particularly the system falling within the Highveld Alluvial vegetation type) is highly degraded, due to the introduction of exotic species and other anthropogenic impacts, a hypothetical reference position was determined using existing historical data, as well as the data collected from all the sites within the study area. Due to the lack of historical vegetation data for the Vet River and the highly degraded nature of this area the construction of a reference site for this site was particularly difficult. Reductions in exotic species diversity and abundance, as well as exotic species cover, were utilised in order to obtain a hypothetical reference site. Many of the decisions made in order to determine the hypothetical reference site were subjective decisions based on existing literature and field experience. The area is currently considerably degraded mainly due to the introduction of a number of exotic species. The exotic species in the area, in fact, contribute to a total of over 50% of the total number of species identified during the surveys. Furthermore, the lack of stochastic events, such as fire and flooding, are causing homogenization of the riparian vegetation at site EWR15. Due to the factors mentioned above under the section "Current Status" and the fact that these factors are not being remedied or arrested it must be assumed, in order to comply with cautionary principles, that the trajectory of change is negative.

Causes and sources

PES	CAUSES	SOURCES	F[1]/NF[2]	Conf[3]
E	Terrestrial exotic invasive species	Anthropogenic	N	4
	Aquatic exotic invasive species	Anthropogenic	F	

1: Flow related 2: Non Flow related 3: Confidence

Trend

PES	TREND	TREND PES	TIME	REASONS	Conf
E	Negative	C Negative	0 years	According to the data collected, the application of the cautionary principle as well as the fact that no historical vegetation data was found for this site, a negative trend in the PES has been identified.	4

RECOMMENDED ECOLOGICAL CATEGORY (REC)

PES	REC	COMMENTS
E	E	Due to the fact that no previous surveys of this nature have been conducted in this area, the REC can only be given as E. There is a possibility that further surveys in the area may provide enough information to recommend an REC in future.

ALTERNATIVE ECs TO SERVE AS THE RANGE OF ECOLOGICAL RESERVE SCENARIOS

AEC C (Increased flows)

PES	REC	AEC	COMMENTS	CONF
E	E	E	Although increasing the flow would not cause an increase in the PES, it would increase the ecological state of the area by reducing the percentage cover of exotic species and possibly flushing a number of the invasive aquatic species occurring in the area. The only way to cause a significant change in the PES of the area would be to undertake a rehabilitation program in the area.	3

AEC C (Decreased flows)

PES	REC	AEC	COMMENTS	CONF
n/a	n/a	n/a	Due to the low current PES it would be unwise to manage the flow in order to reduce the PES from its current level.	

4.5 EWR16, Downstream of Bloemhof Dam, Vaal River

4.5.1 General description

The site downstream of Bloemhof Dam on the Vaal River consists of a relatively broad area of flow with shallow sloping banks, on which vegetation could easily colonise and recruit. The site selection at this site is, however, not ideal as the vegetation in the area has been disturbed by construction of weirs and bridges as well as the fact that the riparian vegetation has been completely transformed by anthropogenic disturbances and is not representative of the vegetation along this reach of the Vaal River. The riparian vegetation has been transformed in order to create recreational areas and a number of exotic tree species have been planted along the edge of the river, possibly to control erosion. Land use in the area is predominantly urban settlement, agricultural and pastoral farming and recreation.

4.5.2 Plan and cross section view.

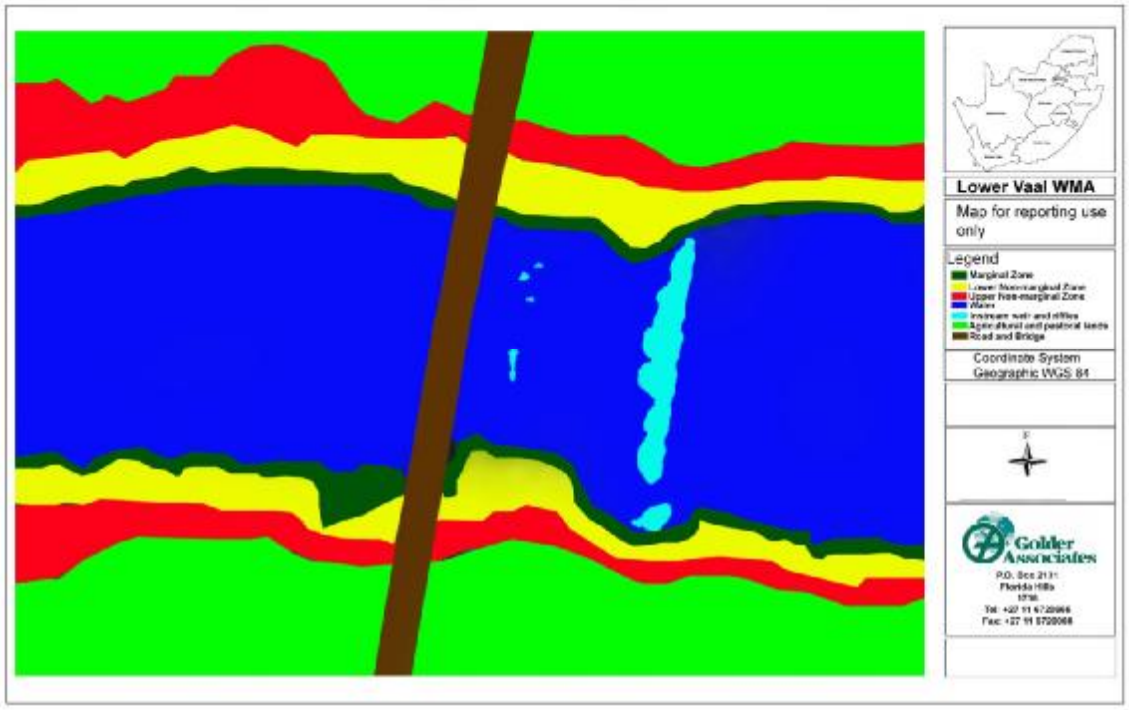

Figure 9: Plan view of Site EWR16

Figure 10: Cross-section view of site EWR16

4.5.3 Species composition

The marginal zone at Site EWR16 is dominated by graminoid and cyperoid species including *Cyperus denudatus, Phragmites australis,Cyperus longus* and *Pennisetum clandestinum.* The lower non-marginal zone is dominated by mainly by exotic graminoids and herbaceous species such as *Pennisetum clandestinum, Cirsium vulgare* with some individuals of the woody species *Acacia karroo.* The upper non-marginal zone is dominated by exotic tree species, mainly *Eucalyptus* spp, with some *Acacia karroo* and *Salix mucronata* present.

4.5.4 VEGRAI discussion

REFERENCE CONDITIONS

As the Vaal river system (particularly the system falling within the Highveld Alluvial vegetation type) is highly degraded, due to the introduction of exotic species and other anthropogenic impacts, a hypothetical reference position was determined using existing historical data, as well as the data collected from all the sites within the study area. Reductions in exotic species diversity and abundance, as well as exotic species cover, were utilised in order to obtain a hypothetical reference site. Many of the decisions made in order to determine the hypothetical reference site were subjective decisions based on existing literature and field experience.

RESULTS

Table 5 indicates the results of the VEGRAI assessment for EWR16.

Current status: The area is currently highly degraded due to the removal of indigenous species and transformation of the riparian vegetation by the introduction of a number of exotic species. The exotic species in the area, in fact, contribute to a total of over 70% of the total number of species identified during the surveys.

Trajectory of change: Due to the factors mentioned above under the section “Current Status” and the fact that these factors are not being remedied or arrested it must be assumed, in order to comply with cautionary principles, that the trajectory of change is negative.

LEVEL 4 VEGRAI EC : **F**

Table 5: EWR16 VEGRAI

LEVEL 4 ASSESSMENT						
RIPARIAN VEGETATION EC METRIC GROUP	**CALCULATED RATING**	**WEIGHTED RATING**	**CONFIDENCE**	**RANK**	**WEIGHT**	**NOTES: (give reasons for each assessment)**
MARGINAL	15.1	5.5	3.3	1.0	100.0	marginal zone most important for year-round refuge habitat, overhanging vegetation important for habitat creation / variability
LOWER ZONE	10.4	3.8	4.2	2.0	100.0	lower zone has high seasonal importance for breeding habitat, also shading of aquatic habitats
UPPER ZONE	22.8	6.2	4.2	3.0	75.0	not directly important for instream habitat, but bank stabilty indirectly important, possibly some shading and litter input
	3.0				275.0	
LEVEL 4 VEGRAI (%)				15.5		
VEGRAI EC				F		
AVERAGE CONFIDENCE				3.9		

	Zone		
	Marginal	Lower	Upper
VEGRAI % (Zone)	15.1	10.4	22.8
EC (Zone)	F	F	E
Confidence (Zone)	3.3	4.2	4.2

REASONS FOR PES

The marginal zone at Site EWR16 is dominated by graminoid and cyperoid species including *Cyperus denudatus, Phragmites australis,Cyperus longus* and *Pennisetum clandestinum.* The lower non-marginal zone is dominated by mainly by exotic graminoids and herbaceous species such as *Pennisetum clandestinum, Cirsium vulgare* with some individuals of the woody species *Acacia karroo.* The upper non-marginal zone is dominated by exotic tree species, mainly *Eucalyptus* spp, with some *Acacia karroo* and *Salix mucronata* present. As the Vaal river system (particularly the system falling within the Highveld Alluvial vegetation type) is highly degraded, due to the introduction of exotic species and other anthropogenic impacts, a hypothetical reference position was determined using existing historical data, as well as the data collected from all the sites within the study area. Reductions in exotic species diversity and abundance, as well as exotic species cover, were utilised in order to obtain a hypothetical reference site. Many of the decisions made in order to determine the hypothetical reference site were subjective decisions based on existing literature and field experience. The area is currently highly degraded due to the removal of indigenous species and transformation of the riparian vegetation by the introduction of a number of exotic species. The exotic species in the area, in fact, contribute to a total of over 70% of the total number of species identified during the surveys. Due to the factors mentioned above under the section "Current Status" and the fact that these factors are not being remedied or arrested it must be assumed, in order to comply with cautionary principles, that the trajectory of change is negative.

Causes and sources

PES	CAUSES	SOURCES	F[1]/NF[2]	Conf[3]
F	Terrestrial exotic invasive species	Anthropogenic	N	4
	Aquatic exotic invasive species	Anthropogenic	F	

1: Flow related 2: Non Flow related 3: Confidence

Trend

PES	TREND	TREND PES	TIME	REASONS	Conf
F	Negative	C Negative	0years	According to the data collected a negative trend in the PES has been identified.	4

RECOMMENDED ECOLOGICAL CATEGORY (REC)

PES	REC	COMMENTS
F	F	Due to the fact that no previous surveys of this nature have been conducted in this area, the REC can only be given as F. There is a possibility that further surveys in the area may provide enough information to recommend an REC in future.

ALTERNATIVE ECs TO SERVE AS THE RANGE OF ECOLOGICAL RESERVE SCENARIOS

AEC C (Increased flows)

PES	REC	AEC	COMMENTS	CONF
F	F	F	Increasing the flow would not cause a significant change in the PES. The only way to increase vegetation condition in this area would be to undertake an extensive rehabilitation program.	4

AEC C (Decreased flows)

PES	REC	AEC	COMMENTS	CONF
n/a	n/a	n/a	Due to the low current PES it would be unwise to manage the flow in order to reduce the PES from its current level.	4

4.6 EWR17, Lloyds Weir, Harts River

4.6.1 General description

The site at Lloyds Weir on the Harts River consists of a relatively broad area of flow with steep sloping banks, on which vegetation would not easily colonise and recruit. Erosion is also visible on the banks and much of the area has be degraded by the construction of infrastructure such as bridges and weirs. Although the site selection at this site is not ideal as the vegetation in the area has been disturbed by the construction of the bridge, it is representative of much of the vegetation along this reach of the Harts River as land use in the area is predominantly agricultural and pastoral farming with some mining activities also occurring in the area.

4.6.2 Plan and cross section view.

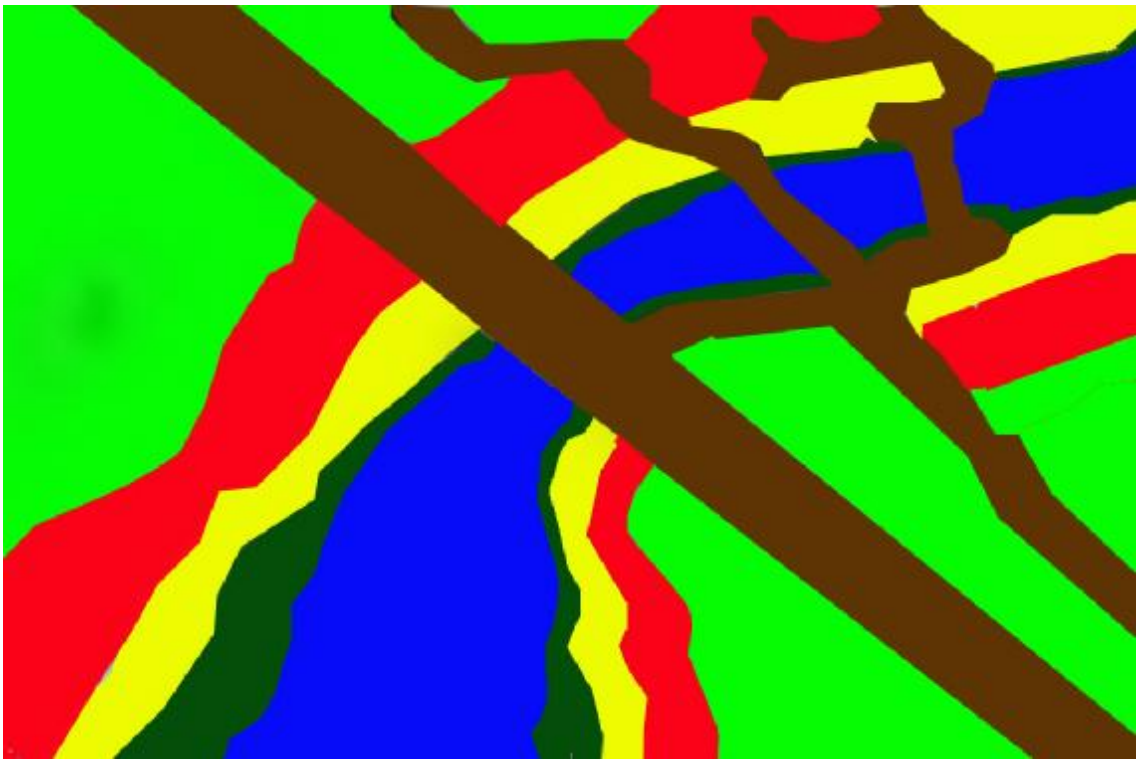

Figure 11: Plan view of Site EWR17

Figure 12: Cross-section view of site EWR17

4.6.3 Species composition

The marginal zone at Site EWR17 is dominated by aquatic, graminoid and cyperoid species including *Phragmites australis, Cynodon dactylon* and *Myriophyllum spicatum* while the lower non-marginal zone is dominated by mainly by graminoids and herbaceous species such as Cynodon dactylon, *Pennisetum clandestinum, Cirsium vulgare* and *Rorripa nasturtium-aquaticum.* The upper non-marginal zone is dominated by tree and shrub species including *Acacia karroo, Salix mucronata, Diospyros lycoides, Melianthus comosus* and *Asparagus sauveolens*..

4.6.4 VEGRAI discussion

REFERENCE CONDITIONS

This site did not fall within the Highveld Alluvial vegetation type and, in fact falls within the Upper Gariep Alluvial vegetation type. This vegetation type appears to be less impacted by the invasion of exotic species than the Highveld Alluvial vegetation type, possibly due to less agriculture in the surrounding areas due to a lower rainfall. Exotic species occur especially in areas where disturbance has taken place as is the case with this site. The area has been impacted by construction of bridges and other infrastructure as well as some mining activities. In these areas along the banks of the river the disturbed riparian vegetation has been invaded by some exotic species and pioneer grasses. Reductions in exotic species diversity and abundance, as well as exotic species cover, were utilised in

order to obtain a hypothetical reference site. Many of the decisions made in order to determine the hypothetical reference site were subjective decisions based on existing literature and field experience.

RESULTS

Table 6 indicates the results of the VEGRAI assessment for EWR17.

Current status: The area is currently considerably degraded due to the construction and mining activities that have disturbed much of the riparian vegetation and the introduction of a number of exotic species. The exotic species in the area contribute to a significant number of the total number of species identified during the surveys as well as a considerable percentage approximately 30% of the abundance recorded during the survey. The most significant reason for the low PES at this site is due to the degradation of the site as well as the invasion of the site by exotic species.

Trajectory of change: Due to the factors mentioned above under the section "Current Status" and the fact that these factors are not being remedied or arrested it must be assumed, in order to comply with cautionary principles, that the trajectory of change is negative.

LEVEL 4 VEGRAI EC : **D**

Table 6: EWR17 VEGRAI

LEVEL 4 ASSESSMENT						
RIPARIAN VEGETATION EC METRIC GROUP	**CALCULATED RATING**	**WEIGHTED RATING**	**CONFIDENCE**	**RANK**	**WEIGHT**	**NOTES: (give reasons for each assessment)**
MARGINAL	45.3	15.1	3.7	1.0	100.0	marginal zone most important for year-round refuge habitat, overhanging vegetation important for habitat creation / variability
LOWER ZONE	47.5	15.8	4.0	2.0	100.0	lower zone has high seasonal importance for breeding habitat, also shading of aquatic habitats
UPPER ZONE	50.1	16.7	4.0	3.0	100.0	not directly important for instream habitat, but bank stabilty indirectly important, possibly some shading and litter input
	3.0				300.0	
LEVEL 4 VEGRAI (%)				47.6		
VEGRAI EC				D		
AVERAGE CONFIDENCE				3.9		

	Zone		
	Marginal	Lower	Upper
VEGRAI % (Zone)	45.3	47.5	50.1
EC (Zone)	D	D	D
Confidence (Zone)	3.7	4.0	4.0

REASONS FOR PES

This was the first site in the study that did not fall within the Highveld Alluvial vegetation type and, in fact falls within the Upper Gariep Alluvial vegetation type. This vegetation type appears to be less impacted by the invasion of exotic species than the Highveld Alluvial vegetation type, possibly due to less agriculture in the surrounding areas due to a lower rainfall. Exotic species occur especially in areas where disturbance has taken place as is the case with this site. The area has been impacted by construction of bridges and other infrastructure as well as some mining activities. In these areas along the banks of the river the disturbed riparian vegetation has been invaded by some exotic species and pioneer grasses. Reductions in exotic species diversity and abundance, as well as exotic species cover, were utilised in order to obtain a hypothetical reference site. Many of the decisions made in order to determine the hypothetical reference site were subjective decisions based on existing literature and field experience. The area is currently considerably degraded due to the construction and mining activities that have disturbed much of the riparian vegetation and the introduction of a number of exotic species. The exotic species in the area contribute to a significant number of the total number of species identified during the surveys as well as a considerable percentage approximately 30% of the abundance recorded during the survey. The most significant reason for the low PES at this site is due to the degradation of the site as well as the invasion of the site by exotic species. Due to the factors mentioned above under the section "Current Status" and the fact that these factors are not being remedied or arrested it must be assumed, in order to comply with cautionary principles, that the trajectory of change is negative.

Causes and sources

PES	CAUSES	SOURCES	F[1]/NF[2]	Conf[3]
D	Terrestrial exotic invasive species	Anthropogenic	N	4
	Aquatic exotic invasive species	Anthropogenic	F	

1: Flow related 2: Non Flow related 3: Confidence

Trend

PES	TREND	TREND PES	TIME	REASONS	Conf
D	Negative	D Negative	0 years	According to the data collected a negative trend in the PES has been identified.	4

RECOMMENDED ECOLOGICAL CATEGORY (REC)

PES	REC	COMMENTS
D	D	Due to the fact that no previous surveys of this nature have been conducted in this area, the REC can only be given as D. There is a possibility that further surveys in the area may provide enough information to recommend an REC in future.

ALTERNATIVE ECs TO SERVE AS THE RANGE OF ECOLOGICAL RESERVE SCENARIOS

AEC C (Increased flows)

PES	REC	AEC	COMMENTS	CONF
D	D	D	Although increasing the flow would not cause an increase in the PES, it could possibly increase the ecological state of the area flushing a number of the invasive aquatic species occurring in the area.	3

AEC C (Decreased flows)

PES	REC	AEC	COMMENTS	CONF
n/a	n/a	n/a	Due to the low current PES it would be unwise to manage the flow in order to reduce the PES from its current level.	

4.7 EWR18, Schmidtsdrif, Vaal River

4.7.1 General description

The site at Schmidtsdrif on the Vaal River consists of a broad area of flow with moderately sloping banks, on which vegetation would easily colonise and recruit. Vegetated sand banks indicate that few flood events take place in this reach of the river and the creation of patches for the colonisation of species due to floods is seldom encountered. Disturbance in the area is mainly due to anthropogenic impacts such as the utilisation of the vegetation in the area for grazing, fuel and possibly medicinal plant species and mining activities that are widespread along the banks of the river. Erosion is also visible on the banks and much of the area has been degraded due to the mining activities on the banks of the river. Although the site selection at this site is not ideal as the vegetation in the area has been disturbed, it is representative of much of the vegetation along this reach of the Vaal River as land use in the area is predominantly mining with some agricultural and pastoral farming also occurring in the area.

4.7.2 Plan and cross section view.

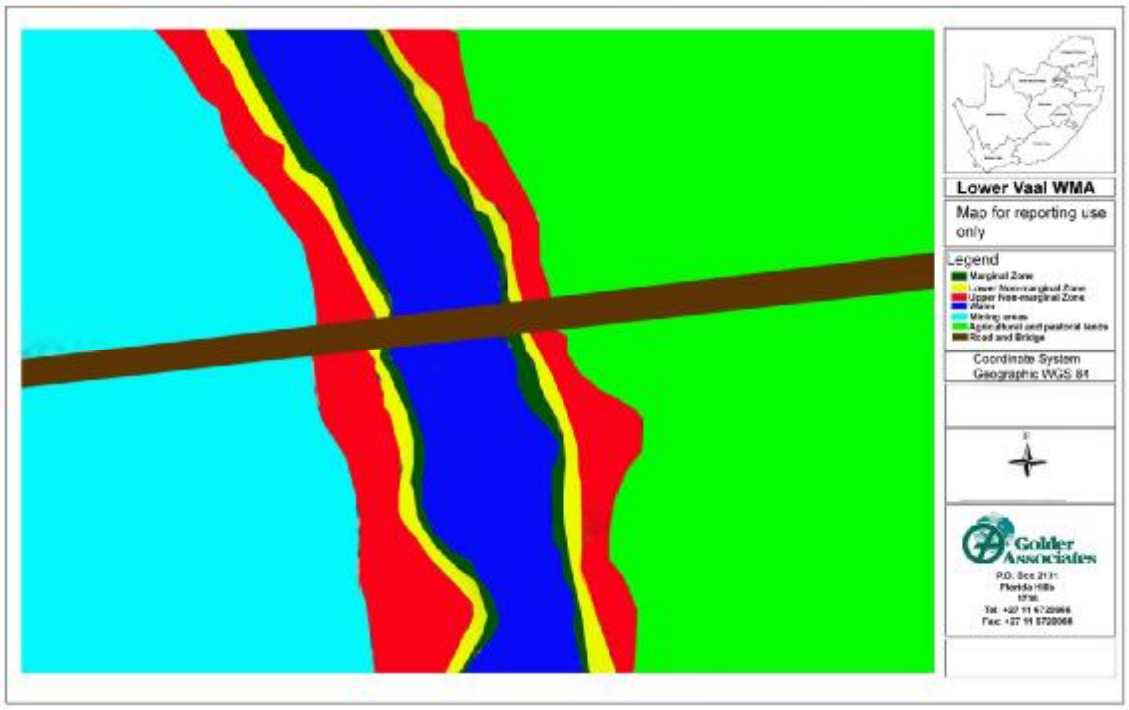

Figure 13: Plan view of Site EWR18

Figure 14: Cross-section view of site EWR18

4.7.3 Species composition

The marginal zone at Site EWR18 is dominated by graminoid and cyperoid species including *Panicum coloratum, Sporobulus africanus, Phragmites australis* and *Myriophyllum spicatum* while the lower non-marginal zone is dominated by mainly by graminoids and herbaceous species such as *Chloris virgata, Cynodon dactylon, Eragrostis* spp., *Paspalum distichum, Sporobulus africanus, Xanthium strumarium, Sporobulus fimbriatus, Clematis brachiata, Lycium arenicola,* and the upper non-marginal zone is dominated by tree and shrub species including *Acacia karroo, Salix mucronata, Diospyros lycoides, Melianthus comosus* and *Rhus pyroides*.

4.7.4 VEGRAI discussion

REFERENCE CONDITIONS

This site did not fall within the Highveld Alluvial vegetation type and, in fact falls within the Upper Gariep Alluvial vegetation type. This vegetation type appears to be less impacted by the invasion of exotic species than the Highveld Alluvial vegetation type, possibly due to less agriculture in the surrounding areas due to a lower rainfall. Exotic species occur especially in areas where disturbance has taken place as is the case with this site. The area has been impacted by construction of bridges and other infrastructure as well as some mining activities. In these areas along the banks of the river the disturbed riparian vegetation has been invaded by some exotic species and pioneer grasses. Reductions in exotic species diversity and abundance, as well as exotic species cover, were utilised in order to obtain a hypothetical reference site. Many of the decisions made in order to determine the hypothetical reference site were subjective decisions based on existing literature and field experience.

RESULTS

Table 1 indicates the results of the VEGRAI assessment for EWR18.

Current status: The area is currently considerably degraded due to the mining activities on the banks of the river resulting in an inflow of silt and the introduction of exotic species in the area. Although the number of exotic species occurring in the area is considerably less than many of the other sites the exotic species only contribute to approximately 20% of the species recorded in the area. The exotic species that appears to be having the greatest impact on the area is the aquatic weed *Myriophyllum spicatum* which has colonised and taken over the aquatic habitat. This species, if it remains unchecked may cause considerable damage in future. Furthermore, the lack of stochastic events, such as flooding may be aiding the colonisation by this species at site EWR12.

Trajectory of change: Due to the factors mentioned above under the section "Current Status" and the fact that these factors are not being remedied or arrested it must be assumed, in order to comply with cautionary principles, that the trajectory of change is negative.

LEVEL 4 VEGRAI EC : **C/D**

Table 7: EWR18 VEGRAI

LEVEL 4 ASSESSMENT						
RIPARIAN VEGETATION EC METRIC GROUP	**CALCULATED RATING**	**WEIGHTED RATING**	**CONFIDENCE**	**RANK**	**WEIGHT**	**NOTES: (give reasons for each assessment)**
MARGINAL	49.0	16.3	3.7	1.0	100.0	marginal zone most important for year-round refuge habitat, overhanging vegetation important for habitat creation / variability
LOWER ZONE	63.4	21.1	4.0	2.0	100.0	lower zone has high seasonal importance for breeding habitat, also shading of aquatic habitats
UPPER ZONE	71.0	23.7	4.0	3.0	100.0	not directly important for instream habitat, but bank stabilty indirectly important, possibly some shading and litter input
	3.0				300.0	
LEVEL 4 VEGRAI (%)				61.2		
VEGRAI EC				C/D		
AVERAGE CONFIDENCE				3.9		

	Zone		
	Marginal	Lower	Upper
VEGRAI % (Zone)	49.0	63.4	71.0
EC (Zone)	D	C	C
Confidence (Zone)	3.7	4.0	4.0

REASONS FOR PES

This site did not fall within the Highveld Alluvial vegetation type and, in fact falls within the Upper Gariep Alluvial vegetation type. This vegetation type appears to be less impacted by the invasion of exotic species than the Highveld Alluvial vegetation type, possibly due to less agriculture in the surrounding areas due to a lower rainfall. Exotic species occur especially in areas where disturbance has taken place as is the case with this site. The area has been impacted by construction of bridges and other infrastructure as well as some mining activities. In these areas along the banks of the river the disturbed riparian vegetation has been invaded by some exotic species and pioneer grasses. Reductions in exotic species diversity and abundance, as well as exotic species cover, were utilised in order to obtain a hypothetical reference site. Many of the decisions made in order to determine the hypothetical reference site were subjective decisions based on existing literature and field experience. The area is currently considerably degraded due to the mining activities on the banks of the river resulting in an inflow of silt and the introduction of exotic species in the area. Although the number of exotic species occurring in the area is considerably less than many of the other sites the exotic species only contribute to approximately 20% of the species recorded in the area. The exotic species that appears to be having the greatest impact on the area is the aquatic weed *Myriophyllum spicatum* which has colonised and taken over the aquatic habitat. This species, if it remains unchecked may cause considerable damage in future. Furthermore, the lack of stochastic events, such as flooding may be aiding the colonisation by this species at site EWR12. Due to the factors mentioned above under the section "Current Status" and the fact that these factors are not being remedied or arrested it must be assumed, in order to comply with cautionary principles, that the trajectory of change is negative.

Causes and sources

PES	CAUSES	SOURCES	F[1]/NF[2]	Conf[3]
C/D	Terrestrial exotic invasive species	Anthropogenic	N	4
	Aquatic exotic invasive species	Anthropogenic	F	

1: Flow related 2: Non Flow related 3: Confidence

Trend

PES	TREND	TREND PES	TIME	REASONS	Conf
C/D	Negative	C Negative	10 years	According to the data collected a negative trend in the PES has been identified.	4

RECOMMENDED ECOLOGICAL CATEGORY (REC)

PES	REC	COMMENTS
C/D	C/D	Due to the fact that no previous surveys of this nature have been conducted in this area, the REC can only be given as C/D. There is a possibility that further surveys in the area may provide enough information to recommend an REC in future.

ALTERNATIVE ECs TO SERVE AS THE RANGE OF ECOLOGICAL RESERVE SCENARIOS

AEC C (Increased flows)

PES	REC	AEC	COMMENTS	CONF
C/D	C/D	C/D	Although increasing the flow would not cause an increase in the PES, it would increase the ecological state of the area by reducing the percentage cover of exotic species and possibly flushing a number of the invasive aquatic species occurring in the area.	3

AEC C (Decreased flows)

PES	REC	AEC	COMMENTS	CONF
n/a	n/a	n/a	Due to the low current PES it would be unwise to manage the flow in order to reduce the PES from its current level.	

4.8 EWR19, Lillydale Lodge, Riet River

4.8.1 General description

The site at Lillydale Lodge on the Riet River consists of a relatively broad area of flow with moderately sloping banks on the western side which are considerably impacted by previous mining activities and the introduction of exotic species. On the eastern bank there is a very small bank with a shallow slope before rising to a steep cliff which would not allow for easy colonisation and recruitment. The site selection at this site is, however, ideal as the vegetation in the area has been disturbed on much of this reach of the river by mining activities and stock grazing in the past. This area has recently been declared a national park, but much degradation is still evident from previous activities. Land use in the area is nature reserve at the moment but was previously pastoral farming and mining.

4.8.2 Plan and cross section view.

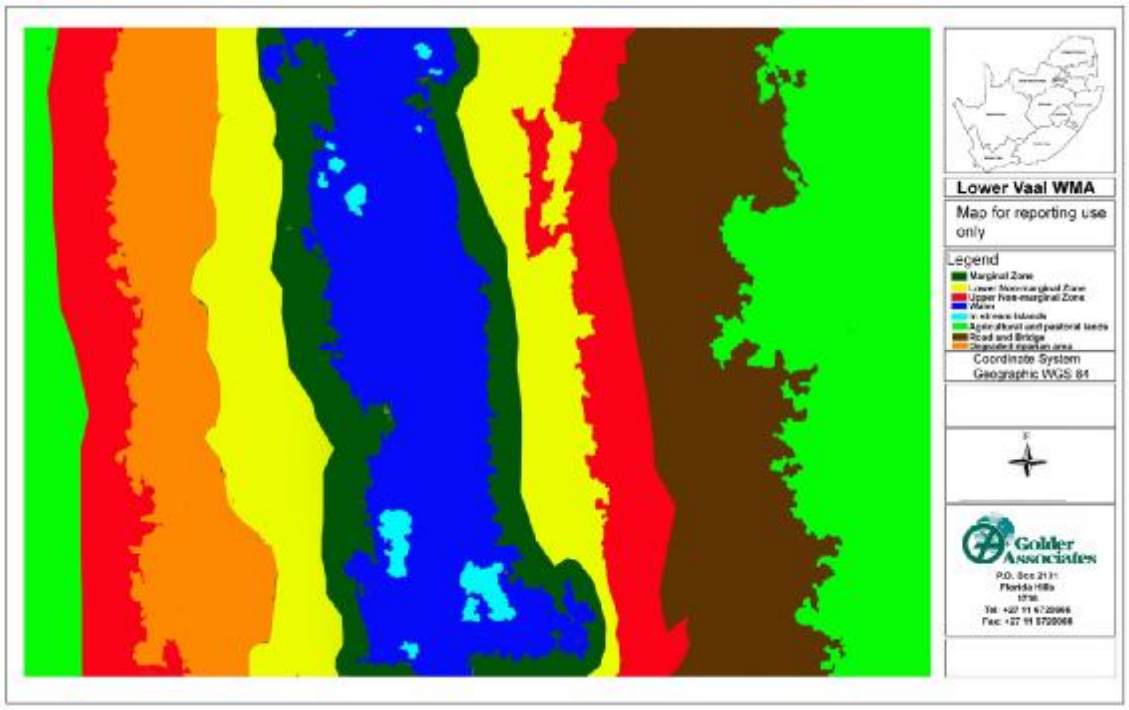

Figure 15: Plan view of Site EWR19

Figure 16: Cross-section view of site EWR19

4.8.3 Species composition

The marginal zone at Site EWR19 is dominated by graminoid and cyperoid species including *Cyperus denudatus, Cyperus longus, Panicum coloratum, Cynodon dactylon, Sporobulus fimbriatus, Phragmites australis* and *Myriophyllum spicatum* while the lower non-marginal zone is dominated by mainly by graminoids and woody species mainly *Cynodon dactylon* and *Eucalyptus* spp. *Eragrostis plana, , Xanthium strumarium* and *Nidorella* spp. and the upper non-marginal zone is dominated by tree and shrub species including *Acacia karroo, Salix mucronata, Diospyros lycoides, Melianthus comosus* and *Rhus pyroides*.

4.8.4 VEGRAI discussion

REFERENCE CONDITIONS

This site also does not fall within the Highveld Alluvial vegetation type and falls within the Upper Gariep Alluvial vegetation type. This vegetation type appears to be less impacted by the invasion of exotic species than the Highveld Alluvial vegetation type, possibly due to less agriculture in the surrounding areas due to a lower rainfall. Exotic species occur especially in areas where disturbance has taken place as is the case with this site. The area has been declared a national park but has been previously impacted by mining activities and farming activities. In these previously mined areas along the banks of the river the disturbed riparian vegetation has been invaded by some exotic species and pioneer grasses. Reductions in exotic species diversity and abundance, as well as exotic species cover, were utilised in order to obtain a hypothetical reference site. Many of the decisions made in order to determine the hypothetical reference site were subjective decisions based on existing literature and field experience..

RESULTS

Table 8 indicates the results of the VEGRAI assessment for EWR19.

Current status: The area is currently degraded due to the introduction of a number of exotic species and the previous mining and farming impacts. The exotic species in the area, in fact, contribute to a total of only 20% of the total number of species identified during the surveys, but do make up a considerable amount of the local biomass.

Trajectory of change: Due to the factors mentioned above under the section “Current Status” and the fact that these factors are not being remedied or arrested it must be assumed, in order to comply with cautionary principles, that the trajectory of change is negative.

LEVEL 4 VEGRAI EC : **D**

Table 8: EWR19 VEGRAI

LEVEL 4 ASSESSMENT						
RIPARIAN VEGETATION EC METRIC GROUP	**CALCULATED RATING**	**WEIGHTED RATING**	**CONFIDENCE**	**RANK**	**WEIGHT**	**NOTES: (give reasons for each assessment)**
MARGINAL	65.3	21.8	3.7	1.0	100.0	marginal zone most important for year-round refuge habitat, overhanging vegetation important for habitat creation / variability
LOWER ZONE	47.5	15.8	4.0	2.0	100.0	lower zone has high seasonal importance for breeding habitat, also shading of aquatic habitats
UPPER ZONE	55.3	18.4	4.0	3.0	100.0	not directly important for instream habitat, but bank stabilty indirectly important, possibly some shading and litter input
	3.0				300.0	
LEVEL 4 VEGRAI (%)				56.0		
VEGRAI EC				D		
AVERAGE CONFIDENCE				3.9		

	Zone		
	Marginal	Lower	Upper
VEGRAI % (Zone)	65.3	47.5	55.3
EC (Zone)	C	D	D
Confidence (Zone)	3.7	4.0	4.0

REASONS FOR PES

This site also does not fall within the Highveld Alluvial vegetation type and falls within the Upper Gariep Alluvial vegetation type. This vegetation type appears to be less impacted by the invasion of exotic species than the Highveld Alluvial vegetation type, possibly due to less agriculture in the surrounding areas due to a lower rainfall. Exotic species occur especially in areas where disturbance has taken place as is the case with this site. The area has been declared a national park but has been previously impacted by mining activities and farming activities. In these previously mined areas along the banks of the river the disturbed riparian vegetation has been invaded by some exotic species and pioneer grasses. Reductions in exotic species diversity and abundance, as well as exotic species cover, were utilised in order to obtain a hypothetical reference site. Many of the decisions made in order to determine the hypothetical reference site were subjective decisions based on existing literature and field experience. The area is currently degraded due to the introduction of a number of exotic species and the previous mining and farming impacts. The exotic species in the area, in fact, contribute to a total of only 20% of the total number of species identified during the surveys, but do make up a considerable amount of the local biomass. Due to the factors mentioned above under the section "Current Status" and the fact that these factors are not being remedied or arrested it must be assumed, in order to comply with cautionary principles, that the trajectory of change is negative.

Causes and sources

PES	CAUSES	SOURCES	F[1]/NF[2]	Conf[3]
D	Terrestrial exotic invasive species	Anthropogenic	N	4
	Aquatic exotic invasive species	Anthropogenic	F	

1: Flow related 2: Non Flow related 3: Confidence

Trend

PES	TREND	TREND PES	TIME	REASONS	Conf
D	Stable	D Stable	10 years	According to the data collected a stable trend in the PES has been identified.	4

RECOMMENDED ECOLOGICAL CATEGORY (REC)

PES	REC	COMMENTS
D	D	Due to the fact that no previous surveys of this nature have been conducted in this area, the REC can only be given as D. There is a possibility that further surveys in the area may provide enough information to recommend an REC in future.

ALTERNATIVE ECs TO SERVE AS THE RANGE OF ECOLOGICAL RESERVE SCENARIOS

AEC C (Increased flows)

PES	REC	AEC	COMMENTS	CONF
D	D	D	Due to the nature of the disturbance in the area and the fact that these disturbances have the most influence on the PES it is unlikely that changing the flow regime would have much impact on the PES.	3

AEC C (Decreased flows)

PES	REC	AEC	COMMENTS	CONF
n/a	n/a	n/a	Due to the low current PES it would be unwise to manage the flow in order to reduce the PES from its current level.	

5 DISCUSSION

Most of the EWR sites surveyed during the study showed considerable amounts of degradation due to human activities, including mining and agricultural activities as well as the construction of infrastructure and settlement activities. The degradation in these area are however not directly related to the flow regime and any alteration in flow regime is unlikely to have much, if any, effect on the PES of the already altered vegetation at any of the sites. Most of the sites require extensive rehabilitation in order to return them to a semi-natural state. Some EWR sites were extensively degraded and total transformation of the natural vegetation had taken place, such as Site EWR16. These sites will take many years and a considerable financial undertaking to rehabilitate and were poorly selected for a study of this kind. The VEGRAI system, although a good broad scale method of analysing the ecological status of riparian vegetation does appear to have a number of shortfalls when utilised for this type of study. Firstly, the VEGRAI system appears to have been developed for an area where the woody component is far better represented than in many of the sites studied for this project. The marginal and aquatic vegetation is much more likely to be affected by flow regime, however, because of the weight of the woody vegetation (which is usually not in the marginal zone at sites in the Vaal River system) the results are skewed towards the vegetation types least likely to be affected by a change in flow regime.

6 RECOMMENDATIONS

Improved site selection for the determination of vegetation ecological status.

Refinement of the VEGRAI system for river systems with less woody vegetation.

Refinement of the VEGRAI system in order to account for the increased importance of the marginal and aquatic zones of the water

7 LIMITATIONS

This Document has been provided by Golder Associates Africa Pty Ltd ("Golder") subject to the following limitations:

(i) VEGRAI was utilised as the data processing tool on request of the client and any restrictions and/or limitations of this methodology will be inherent in this report.

(ii) This study was limited to a single field survey and the restrictions and/or limitations of such a "snapshot" survey will be inherent in the findings of the study and therefore also this report.

(iii) The study was conducted during the dry season (June 2008) and therefore species with limited growing season such as geophytes, orchids and others will be excluded from the findings of this report. Protected and rare species that may occur on the banks of the Vaal River may include certain of these species.

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R. Heath D. Otto

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APPENDIX F
GEOMORPHOLOGY ASSESSMENT

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GEOMORPHOLOGY EWR REPORT:

Additional specialist information for the Ecological Reserve Determination of the Middle and Lower Vaal

M.W. Rountree

June 2010

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1 INTRODUCTION

This report documents the geomorphological data collected and analysis undertaken for the Middle and Lower Vaal River and associated tributaries, conducted as part of a Comprehensive River Determination study conducted in 2008.

The availability of hydrological data enabled potential bed material transport (PBMT) modelling to be undertaken at the EWR (Environmental Water Requirement) sites. This modelling usually greatly improves the confidence of flow requirements for geomorphology in bedload dominated rivers, as the results can be used in conjunction with the more traditional methods of using sedimentary and morphological cues to determine EWR requirements for bed and channel maintenance.

This report is specifically focuses on the methods concerning the determination of the required EWR's. For aspects of the study relating to the determination of the Reference State and Present Ecological State, please refer to the EcoClassification report.

1.1 Site Information

Eight sites (Table 1) were selected for the Comprehensive Ecological Reserve assessment of the Middle and Lower Vaal Water Management Areas (WMAs). These sites were selected to represent reaches of the various resource units which were identified within the WMA. Specialist assessments of the geomorphological Present Ecological State (PES) were undertaken using the Level IV Geomorphological Assessment Index (Rowntree and du Preez, *in prep*).

Table 1: Location and information of the EWR sites in this study.

EWR SITE No.	Site Name	GPS co-ordinates	Weir used for hydrology	Regional Slope	Geomorph PES
12	Vermaasdrift on Vaal River	S26.93615; E26.85025	C2H018	0.00041	**C/D**
13	Regina Bridge on Vaal River	S27.10413; E26.52185	C2H061	0.00028	**C**
14	Proklameerdrift on Vals River	S27.29126; E26.48470	C6H001	0.00066	**B/C**
15	Fisantkraal on Vet River	S27.93482; E26.12569	C4H004	0.00028	**C**
16	Vaal downstream of Bloemhof Dam	S27.65541; E25.59564	C9H021	0.00043	**D/E**
17	Lloyds weir on Harts River	S28.37694; E24.30305	C3H013	0.00036	**D**
18	Schmidtsdrift on Vaal River	S28.70758; E24.07578	C9H024	0.00021	**C/D**
19	Lilydale Lodge – Riet River	S29 02 18.3; E24 30 10.2	C5H016	0.00170	**C**

1.2 River and Site Characteristics

Rapid assessments of sediment size distribution were conducted at each of the EWR sites. The different sediment distributions can have an impact on the size of flows required to maintain bed mobility and sediment transport at each site, since the size of the sediment

dictates the energy of the floods required for the maintenance of the channel bed and bank characteristics (channel maintenance).

The regional slopes of sites 12, 13, 14, 15, 16, 17, and 18 are extremely low, whereas the regional slope of EWR 19 (a tributary) is an order of magnitude steeper (Table 1) and this is reflected in the bedrock nature of this site.

2 METHODS FOR DETERMINING FLOW REQUIREMENTS FOR GEOMORPHOLOGY

Flow requirements for the maintenance of channel form, or geomorphology, can generally be determined using one, or a combination, of two possible approaches. The first relies on specialist knowledge and experience to identify alluvial morphological cues at the site and within the reach which are associated with regular flooding return frequencies (such as active, seasonal and ephemeral paired benches and terraces). The second approach uses the catchment hydrology and site-specific hydraulic characteristics to model the long term potential sediment movement within the river to identify so-called geomorphologically effective discharges. These are ranges of flows which are responsible for a disproportionately large amount of the long term sediment transport (geomorphic work) which is happening at the site.

2.1 Morphological Cues

The rivers in this study area are very low energy systems. Low shear stresses; even at high flood flows; mean that under natural conditions the ability of the river to flush sediments and scour the bed is very limited. The system is however relatively sediment poor (hence the bedrock bases and lack of mobile larger sediment components), and yields of bedload from the catchment are dampened by the low slopes. These low energy characteristics explain why, even with the highly altered flow regime and grossly elevated baseflows, the islands in these lower reaches have remained relatively stable. This is due to the limited capacity of the river to erode.

The limited availability of bedload; reduction in flood flows; trapping of sediment in the numerous dams and weirs along the main stem and tributaries and high degree of physical anthropogenic bank disturbance (particularly at our EWR sites which have been usually selected at or very close to bridge crossings) means that morphological cues (benches and terraces correlated with significant flood return intervals) are consequently poorly developed or absent.

2.2 Sediment Transport Modelling

The form (morphology) of a river channel is dependent on the interaction between the supply of sediment from its catchment, and the ability, or capacity, of that section of the river to transport the sediment it is supplied with. The ability of the river to move sediment is referred to as its sediment transport capacity. Sediment supply and sediment transport capacity interact such that:

- where sediment supply is less than the sediment transport capacity, there is an excess of erosive energy, resulting in net erosion, causing the river channel to erode its bed/banks and incise; but
- where sediment supply is greater than sediment transport capacity, there is an excess of sediment, resulting in net deposition and the development of an aggrading river/floodplain environment.

The interactions described above are generally considered over very long timescales. The Elefantes and Limpopo Rivers in Mozambique are primarily alluvial river systems, meaning that, in the very long term (hundreds to thousands of years), sediment supply is greater than the transport capacity of the river channel.

Over shorter timescales, which are of more interest to river managers (years and decades in southern Africa), studies in southern African rivers have demonstrated that rivers experience periods of metastability or quasi-stability interrupted by periods of rapid change (Rountree *et al*, 2001; Rountree and Rogers, 2004; Parsons *et al*, 2006). During these timescales, it is the discharge of water and sediment supply that determines channel form. Where changes in these driving factors occur, the channel form will adjust in sympathy with the imposed change. This is of significance as the channel form provides the physical habitat for riverine biota.

Where key sediments are required to be moved or flushed, entrainement velocities required to achieve movement of the key sediments can be derived from the hydraulic data.

2.2.1 Geomorphologically Effective Flows

Geomorphologically effective flows are those discharges that, over the longer term, are responsible for transporting disproportionately larger proportions of the sediment load (relative to their duration). These are essentially the flows that do the most “work” in determining the sediment transport capacity of the channel, and therefore influencing its form.

The calculation of these flows is essentially the sediment transport potential of a particular flow event, multiplied by its duration, which yields its potential contribution to the sediment transport of the system in the long term. The theoretical position taken in these methods is that two sets of discharges are significant in maintaining channel form in southern African rivers:

1) a set of gemorphologically effective discharges in the 5-0.1% range on the 1-day daily flow duration curve, which transport a disproportionately large volume of the sediment in the longer term, and
2) larger ‘re-set’ flood events such as the flood events of 2000, which can reshape the channel and remove vegetation from the banks and floodplain.

The theoretical basis for these assumptions is presented in Dollar & Rowntree (2003). These methodologies have been used in various ecological flow determination studies in South Africa (e.g. on the Thukela, Elands, Letaba, Waterval and Inkomati Rivers) and

Mozambique (e.g. the lower Zambezi River). Whilst it is possible to manage flows in the 5 to 0.1% range of the flow duration curve, the large “re-set” events are not manageable events. The focus of flow requirement assessments is therefore focussed on the 5 to 0.1% range of flows.

2.2.2 Methodology

The methods employed to determine geomorphologically effective flows for each of the sites are described below.

The observed daily flows from nearby gauges, together with the regional slope (Table 1), rating curves (provided by the hydraulician) and sediment characteristics for the site or reach were used to model potential bed material transport at each site under the recent (over the observed flow record) flow conditions, using Yang’s (Yang, 1973) total load equations to determine the effectiveness of discharges. This modelling technique assumes:

1) The bed material sampled at the site is representative of the supply of bed material to the channel (hence potential bed material load as opposed to bed load);
2) Bed material sampling can be averaged at each EWR site and used to represent the cross-section;
3) The supply of bed material to each EWR site is based on the existing bed material and its size distribution, and is available for transport at all discharges; and that
4) Average conditions can be used.

A full, detailed description of the technique can be found in Dollar & Rowntree (2003).

Although the Vaal is not strongly bedload system, maintenance of the bed habitats is important for biota. In this study we focussed on the mobile component of the bed material at each site (since many sites are located on atypical bedrock riffle areas, and most of the large boulders and cobbles are likely to be insitu weathered material rather than fluvially transported sediment, as evidenced by the angular nature of these larger rocks). This approach was adopted for sites where reliable hydrological (flow) records existed.

3 RESULTS FROM PBMT MODELLING

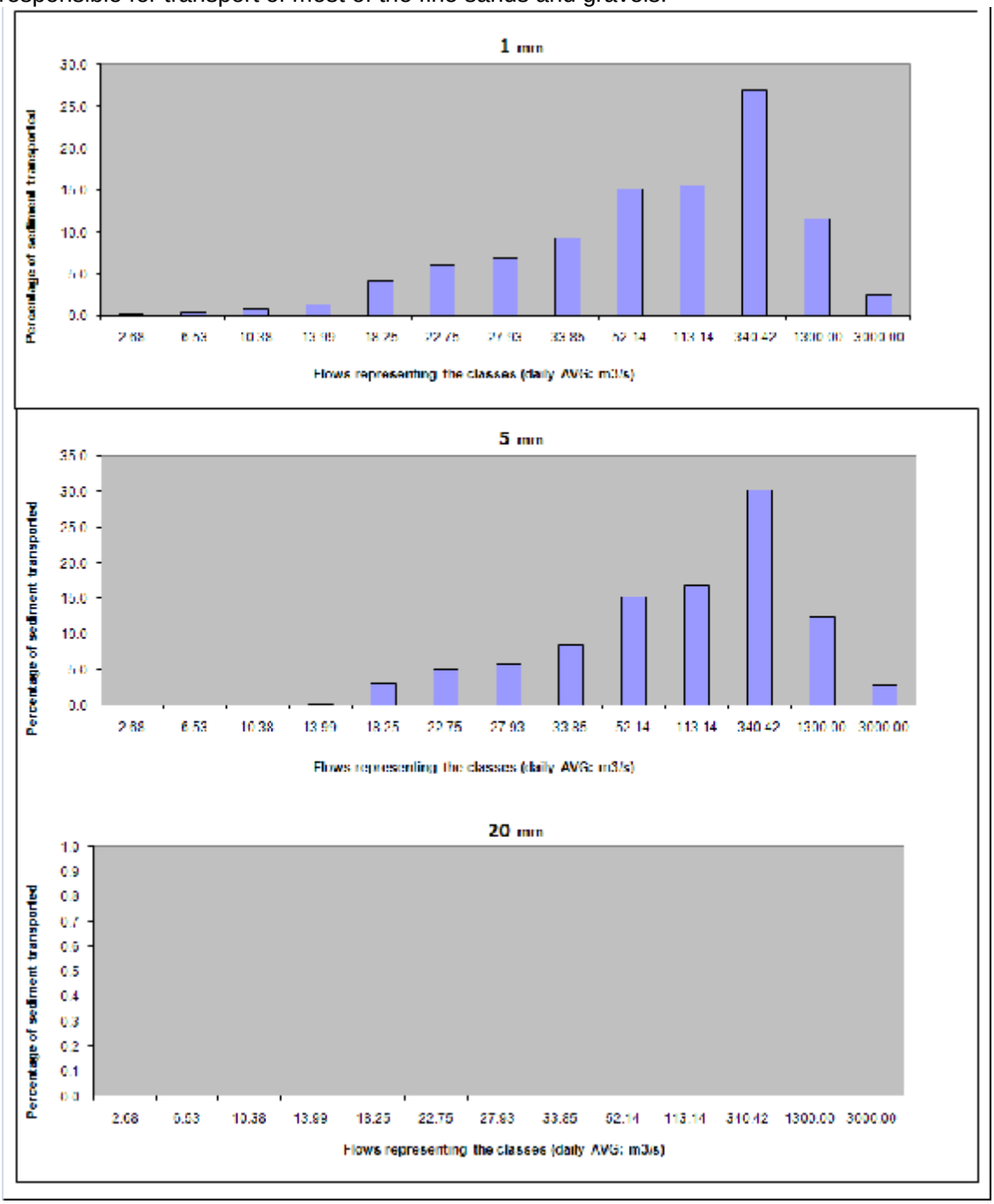
The Potential Bed Material Transport (PBMT) modelling indicated that, for most sites, entrainment and transport of the larger angular cobbles and boulders is very seldom, if ever, achieved. These findings confirmed the initial suspicions from the site visits that the coarser bed material (cobbles and boulders) is more likely to be locally derived than part of the regularly transported bedload component of the sediment of the river.

In most cases even under natural flow conditions there would only be sufficient energy to transport the smaller fractions of the bed material. The boulders and cobbles at the site are derived locally from the underlying dolerite dykes that cross the river, and should not be considered as part of the regularly transported bedload. Additional course material may have been introduced historically for drift crossings.

Focus was thus given to the finer components of the sediment load in the Vaal – the fine sands and gravels which are ecologically important. Additional consideration was also given to the effects of dams on sediment transport and availability when setting the flood requirements for channel maintainence.

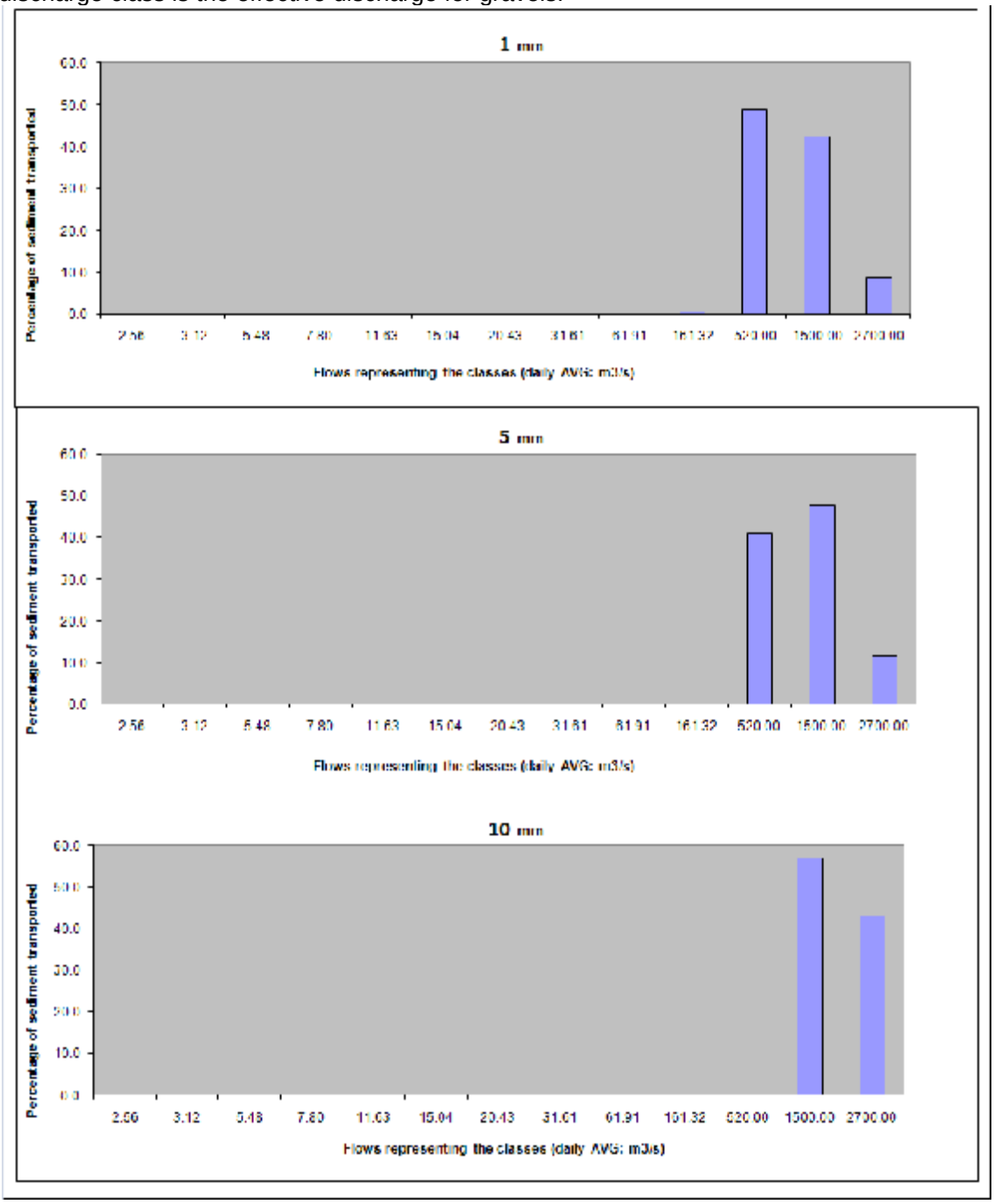
EWR 12

The 340 m3/s discharge class is the effective discharge for fines at this site and is responsible for transport of most of the fine sands and gravels.



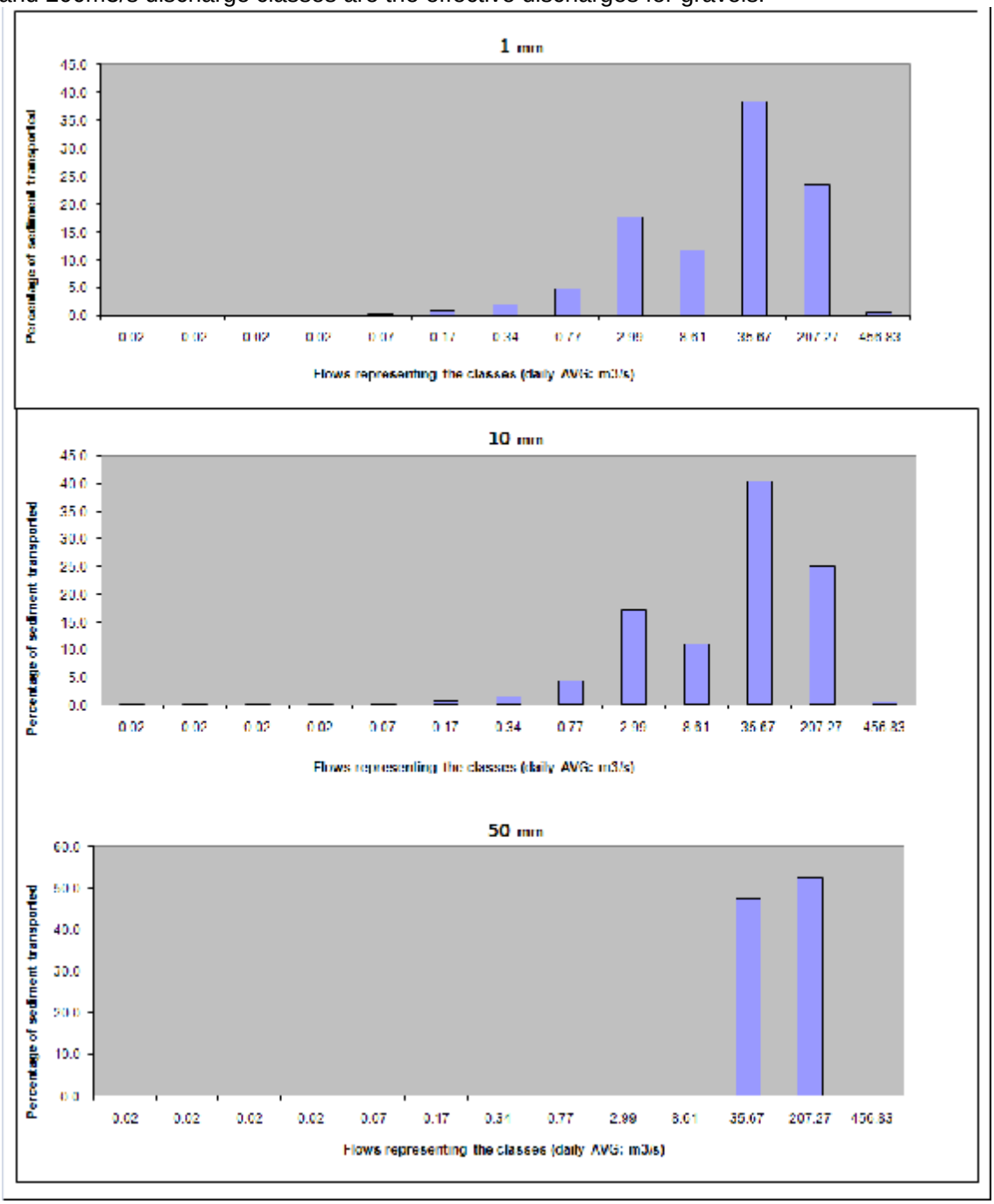
EWR 13

The 520 m3/s discharge class is the effective discharge for fines at this site, and 1500m3/s discharge class is the effective discharge for gravels.



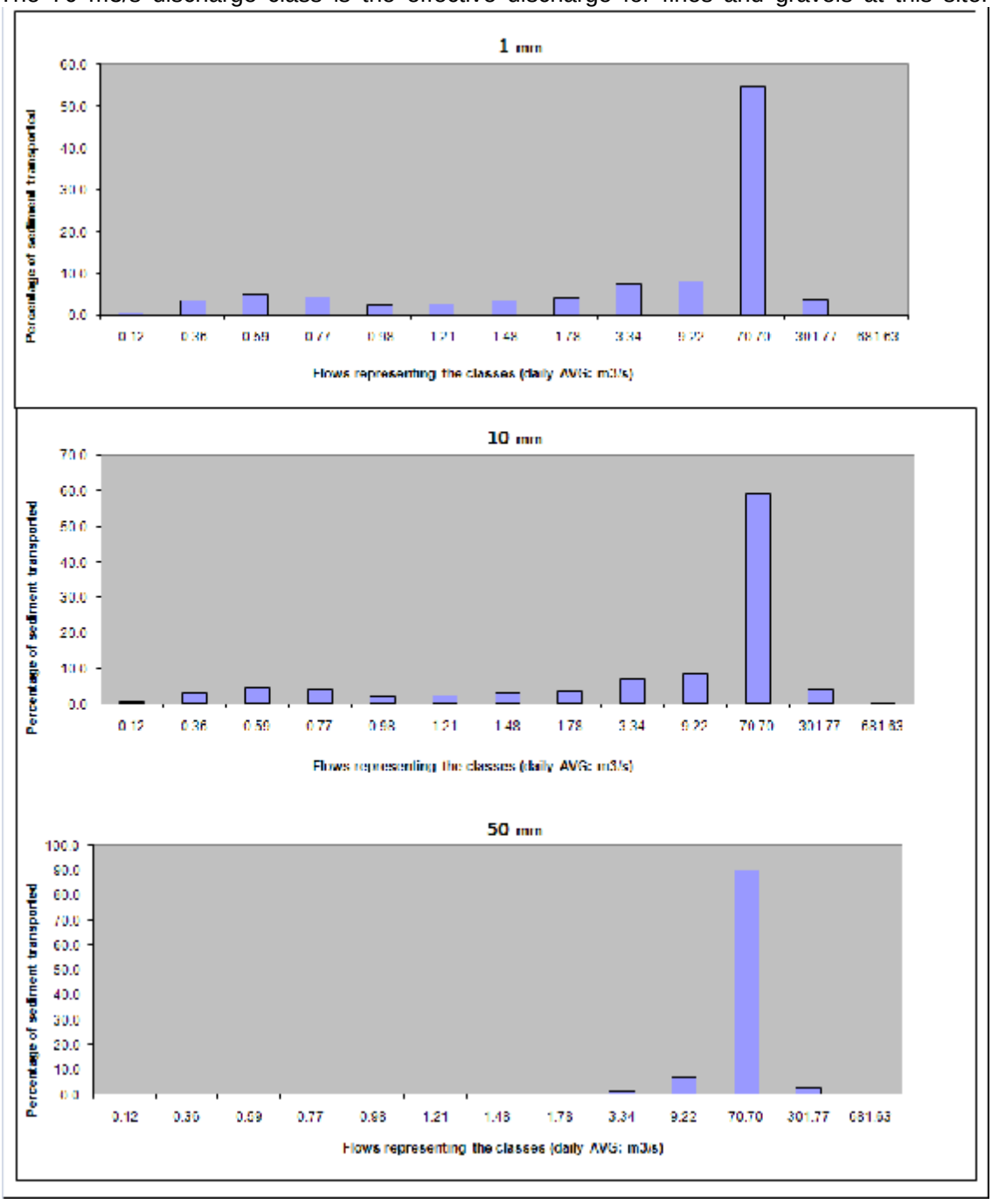
EWR 14

The 35 m3/s discharge class is the effective discharge for fines at this site, and the 35 m3/s and 200m3/s discharge classes are the effective discharges for gravels.



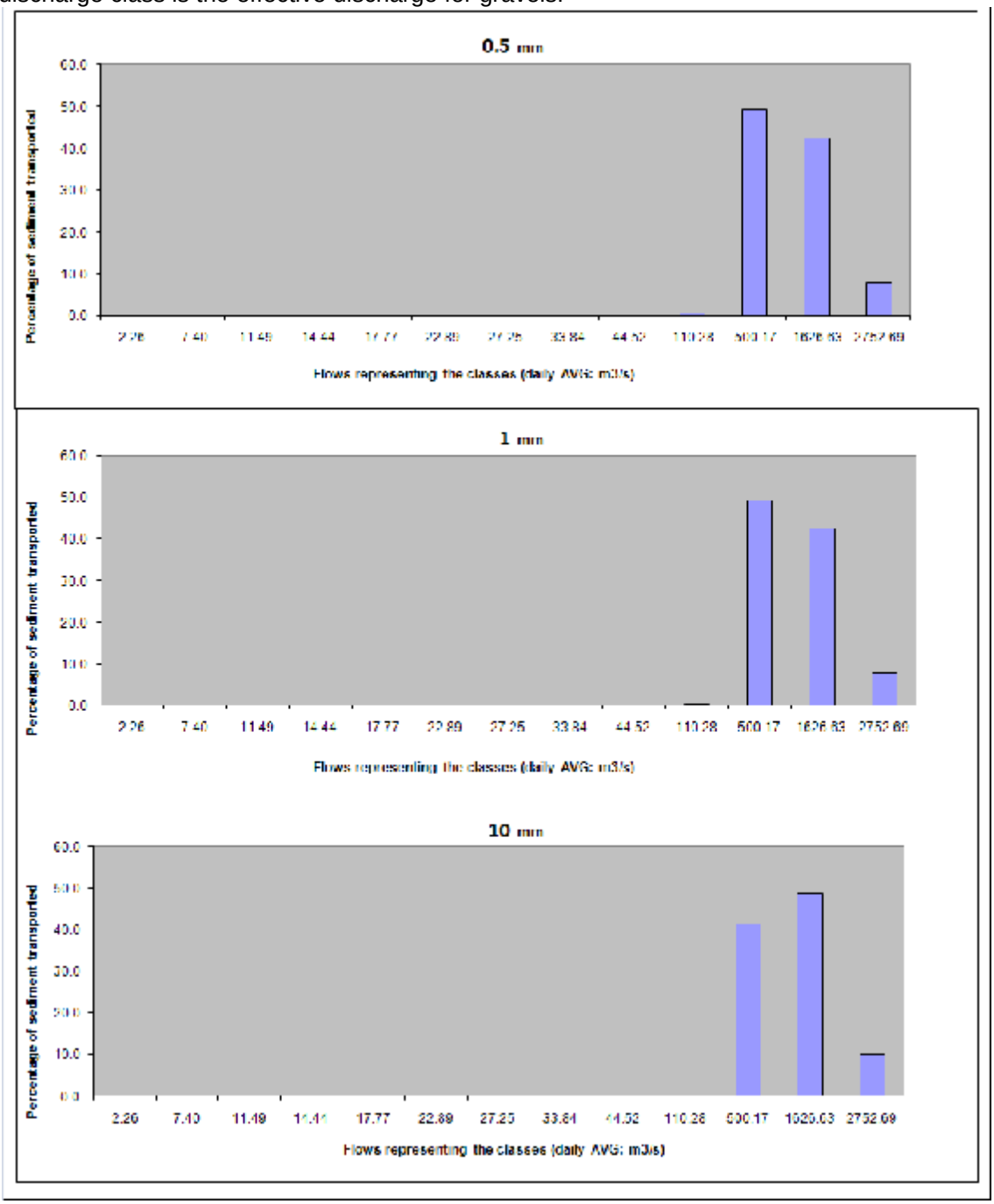
EWR 15

The 70 m3/s discharge class is the effective discharge for fines and gravels at this site.



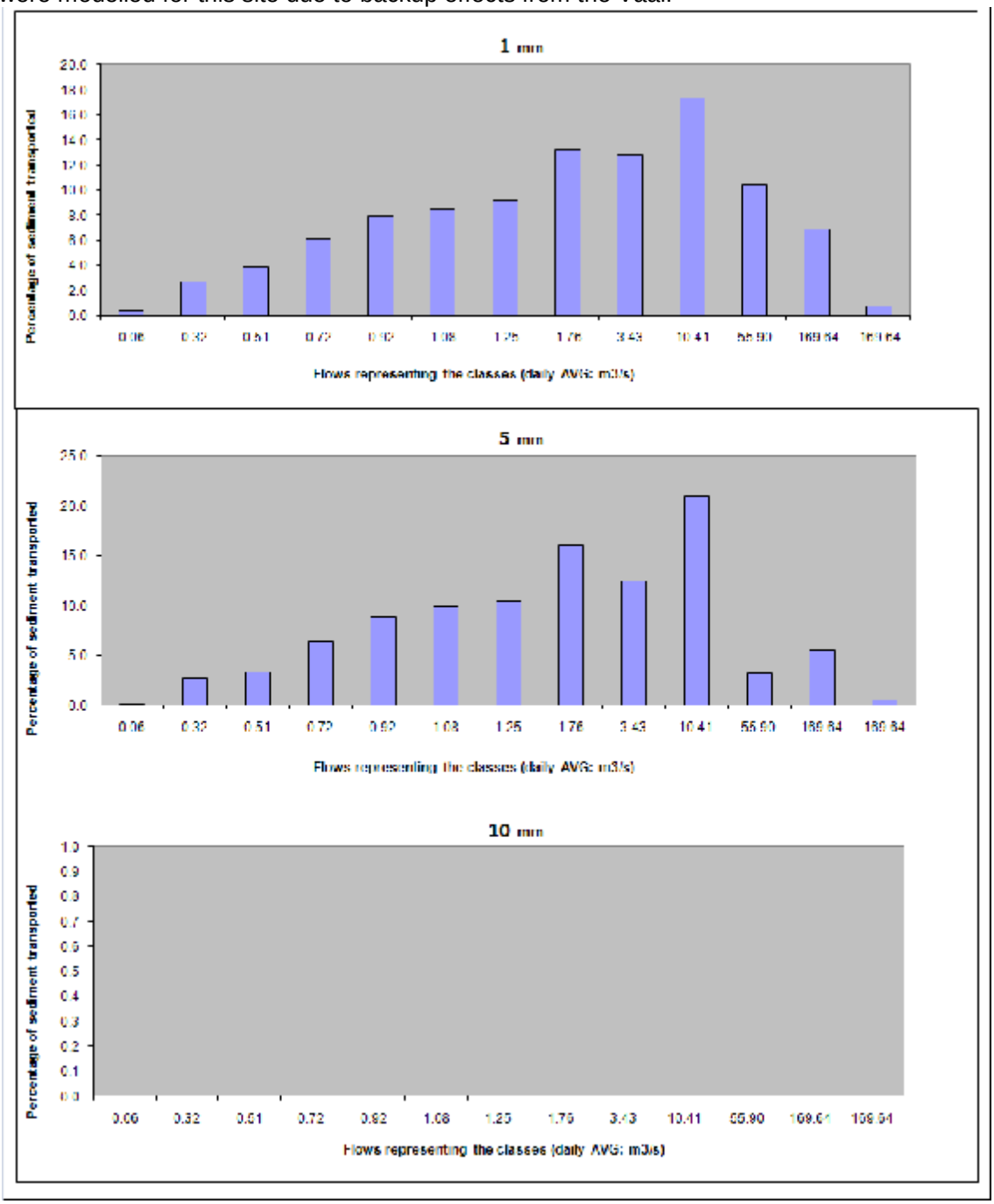
EWR 16

The 500 m3/s discharge class is the effective discharge for fines at this site, and 1600m3/s discharge class is the effective discharge for gravels.



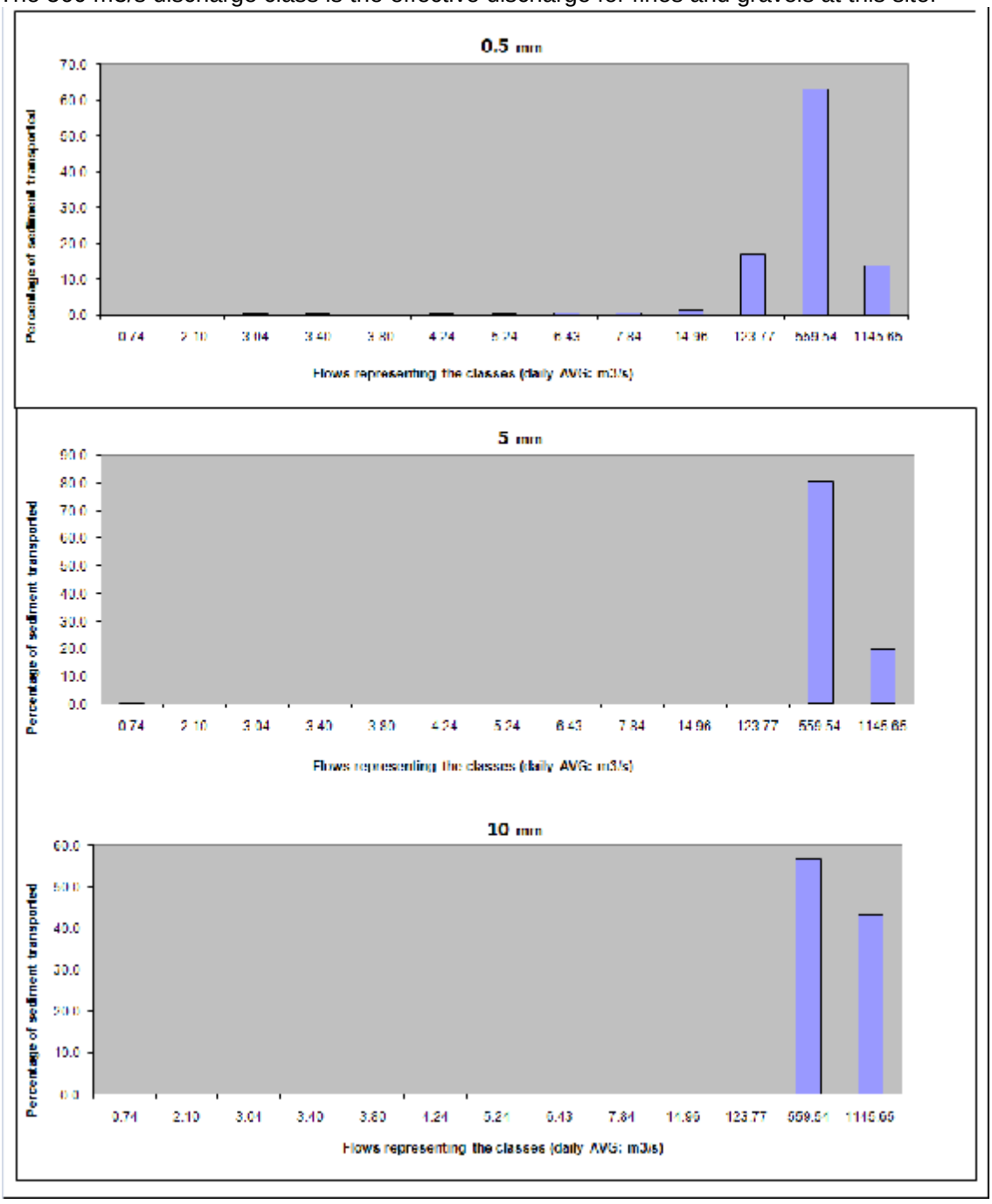
EWR 17

The 10 m3/s discharge class is the effective discharge for fines at this site. No large floods were modelled for this site due to backup effects from the Vaal.



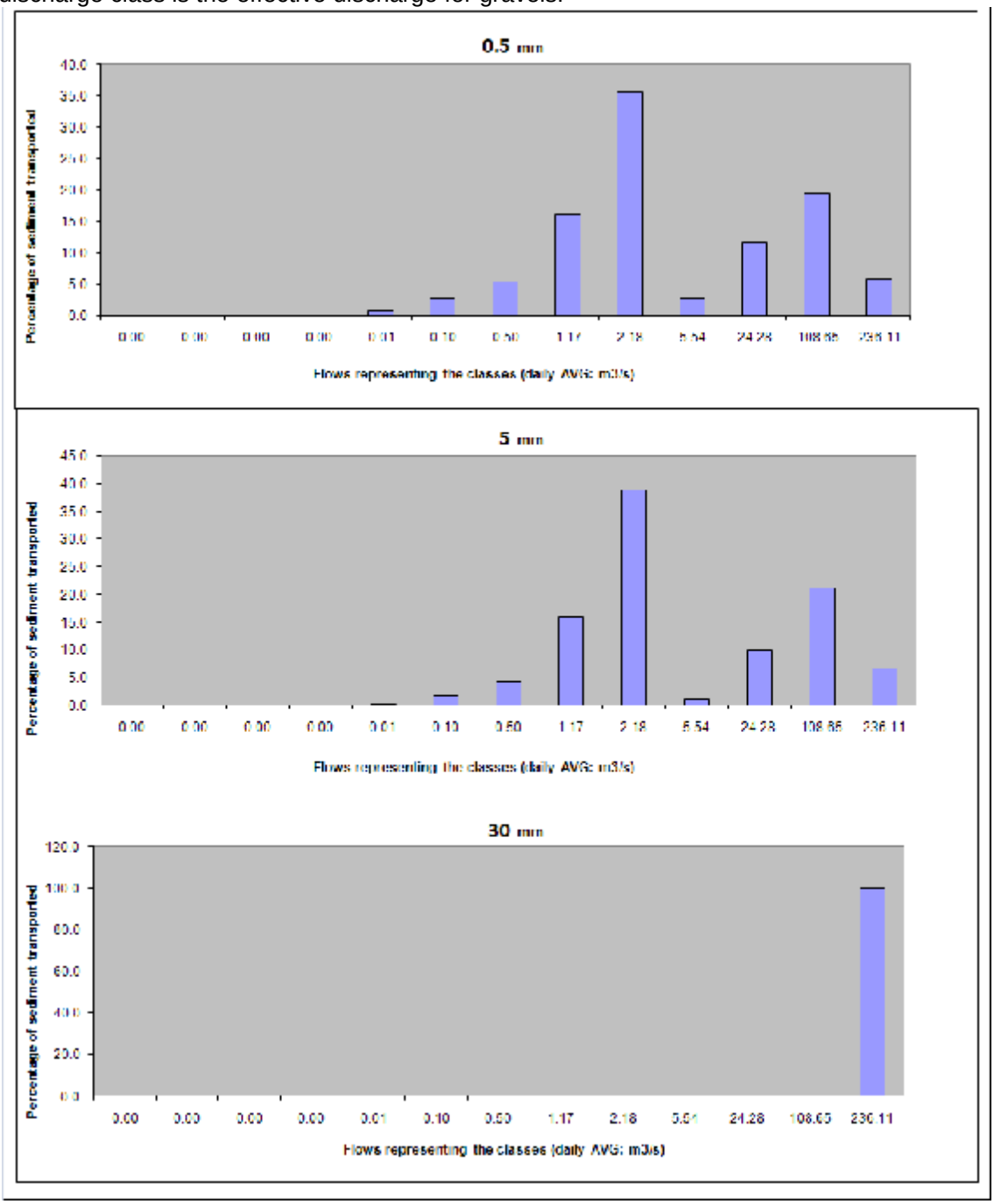
EWR 18

The 560 m3/s discharge class is the effective discharge for fines and gravels at this site.



EWR 19

The 520 m3/s discharge class is the effective discharge for fines at this site, and 1500m3/s discharge class is the effective discharge for gravels.



4 FLOOD REQUIREMENTS FOR THE EWR SITES

*4.1 **Flood motivations for EWR 12***

FLOODS		GEOMORPHOLOGICAL MOTIVATIONS	FREQUENCY		
Class	**Size (daily avg)**		**PES**	**REC**	**AEC**
II	50	This flow class is responsible for transporting about 15% of the fine bed material. These flows will clean the gravels and cobbles at the site and inundate the lower bench.	3	4	
III	100	This flow class is responsible for transporting about 15% of the fine bed material. These flows will scour the gravels and cobbles.	1	2	
IV	340	This flow class represents the effective discharge for the site. It is responsible for the bulk (more than 25%) of the sediment transport. These flows will scour and activate the gravels and cobbles.	1:2	1:1	
Confidence:		**Comments**			
2		Flows for geomorphology are set using the results from Potential Bed Material Transport (PBMT) modelling only. High flow hydraulics are reliable for the site, and a long gauge record of observed flows was used to undertake the modelling. No morphological cues exist at the site to verify the effective flow classes identified through the PBMT modelling			

*4.2 **Flood motivations for EWR 13***

FLOODS		GEOMORPHOLOGICAL MOTIVATIONS	FREQUENCY		
Class	**Size (daily avg)**		**PES**	**REC**	**AEC**
IV	520 (daily avg)	This flow class represents the effective discharge for the site. It is responsible for the bulk (about 50%) of the sediment transport. These flows will scour the bed and clean out gravel and cobble areas.	1:3		
V	1500	This flow class is responsible for about 40% of the PBMT. Although extremely infrequent, these very large flood events are important for scouring the reach.	1:10		
Confidence:		**Comments**			
2		Flows for geomorphology are set using the results from Potential Bed Material Transport (PBMT) modelling only. High flow hydraulics are reliable for the site, and a long gauge record of observed flows was used to undertake the modelling. No morphological cues exist at the site to verify the effective flow classes identified through the PBMT modelling			

*4.3 **Flood motivations for EWR 14***

FLOODS		GEOMORPHOLOGICAL MOTIVATIONS	FREQUENCY		
Class	**Size (daily avg)**		**PES**	**REC**	**AEC**
I	3	This flow class accounts for about 20% of the PBMT of the fines at the site. This flow will frequently activate the bed and flush some fines.	4	5	3
IV	35	This flow class represents the effective discharge for fines and small gravels at the site. It is responsible for the bulk (more than 40%) of the sediment transport. These flows will scour the bed.	1:1	1:1	1:2
V	200	This flow class is responsible for about one quarter of the transport of fines, and is the effective discharge for the coarser gravels.	1:10	1:10	1:10
Confidence:		**Comments**			
2		Flows for geomorphology are set using the results from Potential Bed Material Transport (PBMT) modelling only. High flow hydraulics are reliable for the site, and a long gauge record of observed flows was used to undertake the modelling. No morphological cues exist at the site to verify the effective flow classes identified through the PBMT modelling			

*4.4 **Flood motivations for EWR 15***

FLOODS		GEOMORPHOLOGICAL MOTIVATIONS	FREQUENCY		
Class	**Size (daily avg)**		**PES**	**REC**	**AEC**
IV	70	This flow class is the effective discharge for all sediment sizes (fines, gravels and cobbles). This flood activates the bed.	1:1	1:1	
V	300	Overtopping in sections to activate floodplain, recharge floodplain lakes and pans, maintain floodplain wetlands	1:5	1:5	
Confidence:		**Comments**			
3		Flows for geomorphology are set using the results from Potential Bed Material Transport (PBMT) modelling only. High flow hydraulics are reliable for the site, and a long gauge record of observed flows was used to undertake the modelling. No morphological cues exist at the site to verify the effective flow classes identified through the PBMT modelling The main problem at this site is the increased sediments due to catchment degradation. Flows cannot be used to improve the condition of the site – the floods are still largely natural at the site anyway. Floods for the AEC (up) category do not differ from PES.			

*4.5 **Flood motivations for EWR 16***

Although the site is located immediately below a large dam (and thus no sediments are moving through from the upstream reach), the flows set for this site are to maintain the reach. Thus whilst large floods may cause erosion in the sections *immediately* below the dam; the flows are set to manage the geomorphology of the larger reach.

FLOODS		GEOMORPHOLOGICAL MOTIVATIONS	FREQUENCY		
Class	**Size (daily avg)**		**PES**	**REC**	**AEC**
IV	500	Effective discharge for fines (>50%) and important for gravel activation and movement.	1:3	1:2	
Confidence:		**Comments**			
2		Flows for geomorphology are set using the results from Potential Bed Material Transport (PBMT) modelling only. High flow hydraulics are reliable for the site, and a long gauge record of observed flows was used to undertake the modelling. No morphological cues exist at the site to verify the effective flow classes identified through the PBMT modelling. Additional uncertainty is introduced because the dam immediately upstream cuts off all bed sediment supply from the upstream catchment, and thus for a section downstream, erosion of the bed and banks will continue until the sediment load is increased through tributary and bed/bank erosional inputs.			

*4.6 **Flood motivations for EWR 17***

The site is located on the lower Harts River, but is in the backup zone of the Vaal River. High flow hydraulics are not reliable due to the backup effects of the Vaal; and similarly the sediment characteristics at the site are not representative of the upper reach. Flows for geomorphology have been set using assumed sediment characteristics of reaches upstream of the site, but confidence is extremely low because the hydraulics of these upstream areas are not known.

FLOODS		GEOMORPHOLOGICAL MOTIVATIONS	FREQUENCY		
Class	**Size (daily avg)**		**PES**	**REC**	**AEC**
I	2	One of the important discharge classes for movement of fines through the channel.	3	4	
II	10	An important discharge class for the movement of fines from the bed of the channel.	2	2	
Confidence:		**Comments**			
1		VERY low confidence in the flows estimated to maintain and /or improve the geomorphological condition of the site and reach due to - Poor condition of the site, lack of morphological cues or representivity; - Unreliable high flow hydraulics due to backup impacts; and - The unreliable hydrology from the nearest gauge due to the drowning out of the weir during even small (5m3/s) floods.			

*4.7 **Flood motivations for EWR 18***

The site is located at the downstream end of the Vaal, and the site is characterised by very low energy conditions (very slow velocities).

FLOODS		GEOMORPHOLOGICAL MOTIVATIONS	FREQUENCY		
Class	**Size (daily avg)**		**PES**	**REC**	**AEC**
III	120	This flow class would flush out some of the fines from the channel and clean substrates for instream biota.	1:1	1:1	1:1
IV	560	This flow class is the effective discharge for the fines and small gravels at this site, responsible for more than 60% of PBMT over the long term. These occasional floods would thus activate the bed of the channel.	1:3	1:2	1:3
Confidence:		**Comments**			
2		The reliability of the hydrology used to conduct the PBMT is uncertain. A comparison of the two nearest flow gauges shows large discrepancies in flows and especially in the flood sizes and frequencies.			

*4.8 **Flood motivations for EWR 19***

The site is located in a steep bedrock gorge section of the river. Most of the bed of the active channel is exposed bedrock (i.e. sediment free), and there is thus is little available sediment in the active channel due to the high energy of the site. The intention for the flows for geomorphology are to maintain the potential energy of the site to keep transporting sediment through the reach and thus prevent excessive sedimentation of the active channels and pools. The very large floods may enable some overtopping an inundation/recharge

FLOODS		GEOMORPHOLOGICAL MOTIVATIONS	FREQUENCY		
Class	**Size (daily avg)**		**PES**	**AEC up**	**AEC down**
I	2	These frequent small floods will flush out the fines from the active channel. This is the effective discharge class for fines at this site, responsible for 30 to 40% of the PBMT of fines.	5	6	3
III	20	These small floods will flush fines and small gravels from the bed of the active channel, as well as inundate and activate the lower bench at the site.	1	1	1:2
IV	100	These floods will flush scour the active channel bed, removing accumulated sediment from this bedrock reach. This flow class will also inundate the upper bench and activate the seasonal channel at the site.	1:2	1:2	1:3
V	230	These floods will flush scour the active channel bed and lower banks, removing accumulated sediment fines and gravels from this bedrock reach, as well as activating the cobbles in the reach.	1:5 +	1:5 +	1:5 +
Confidence:		**Comments**			
3.5		Some morphological cues are present at the site, and these correlated in many cases with the important flow classes identified through the PBMT modelling. This corroboration of results from two different approaches increased the confidence of the results.			

5 SUMMARY OF CONFIDENCES IN ASSESSMENT AND RESULTS

A confidence evaluation (on a scale of 0 - no confidence; to 5 - high confidence) for the geomorphological component of the study is provided below. These confidence ratings are provided for various parameters. More detail on each component assessed can be found in the geomorphological sections of the Ecoclassification and EWR report appendices. The following aspects were rated:

- ***Site:*** The confidence in the site for providing reasonable cues to set the EWR requirements.
- ***Available Data:*** The confidence in the available data, both historical and collected, and the ability to interpret the data to recommend flows accurately.
- ***Ecological Classification***: The confidence in all data that contributed to determining EC.
- ***Output Low Flows***: These were not rated as no low flows for geomorphology were requested.
- ***Output High Flows:*** The confidence in the high flows that were recommended to achieve the ecological objectives.

Confidence Ratings for EWR sites (0 = no confidence to 5 = high confidence)

	EWR SITE	*AVAILABLE DATA*	*ECOLOGICAL CLASSIF.*	*OUTPUT LOW FL*	*OUTPUT HIGH FL*
GEOMORPH 12	12	3	3	n/a	2.5
GEOMORPH 13	13	3	3	n/a	2.5
GEOMORPH 14	14	3	3	n/a	2.5
GEOMORPH 15	15	3	3	n/a	3
GEOMORPH 16	16	3	3	n/a	2.5
GEOMORPH 17	17	2	2	n/a	1.5
GEOMORPH 18	18	3	3	n/a	2.5
GEOMORPH 19	19	3	3	n/a	3

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