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BASELINE MONITORING OF AQUATIC ECOSYSTEM HEALTH IN THE ORANGE-SENQU RIVER BASIN:

FINAL REPORT: PART 1 – SUMMARY REPORT

Report No. ORASECOM
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EXECUTIVE SUMMARY

BACKGROUND

Article 5.2.5 of the Orange-Senqu River Commission (ORASECOM) Agreement indicates that the Commission can advise its Contracting Parties (Botswana, Lesotho, Namibia and South Africa on 'standardised forms of collecting, processing and disseminating data or information with regard to all aspects of the River System". Article 7.12 requires the Parties to individually and jointly take all measures that are necessary to protect and preserve the River System from its sources and headwaters to its common terminus. To do this the Parties would need to be advised on the state of aquatic ecosystems throughout the basin. This gives ORASECOM the mandate and responsibility to develop an aquatic ecosystem health monitoring programme. Such a monitoring programme will also serve to satisfy some of the requirements of the Revised SADC Protocol on Shared Watercourses, to which all Parties are signatory (ORASECOM, 2009).

ORASECOM intends to monitor the Aquatic Ecosystem Health of the Orange-Senqu River through this programme. This monitoring programme provides for annual assessments of aquatic ecosystem health using the SASS5 system, as well as for 5 yearly more through assessments including a wider range of bio-monitoring protocols. The EU support to ORASECOM provided for the piloting of the first of these 5 yearly assessments. It was decided that this should form part of a Joint Basin Survey being undertaken by ORASECOM. This first assessment was intended to provide a snapshot of the health or condition of the entire basin – and would serve as a baseline against which ORASECOM could assess progress with measures to improve aquatic ecosystem health across the basin.

ORASECOM has proposed and agreed an Aquatic Ecosystem Health (AEH) monitoring programme (available at: http://www.orasecom.org/publications/eu+project+support.aspx?fileid=24). This programme suggested that annual monitoring of macroinvertebrates using the SASS5 system was supplemented by a 5 yearly intensive and detailed monitoring of aquatic ecosystem health using a wider range of biomonitoring protocols. This study was to be the first of these 5 yearly intensive monitoring programmes. It was, however, recognised in the original monitoring programme that this first survey would not only set a baseline condition for the system against which ORASECOM could monitor the impacts of any basin wide measures taken, but would also better define the most appropriate sampling sites based on local knowledge and site visits.

PURPOSE OF THIS ASSIGNMENT

The specific purpose of this assignment, which forms part of the greater EU project, is to undertake the first baseline monitoring of aquatic ecosystem health in the Orange-Senqu River System and to support the broader joint baseline survey. The focus of this specific assignment is to investigate the Aquatic Ecosystem Health of the Orange-Senqu River System and includes a detailed assessment of aquatic ecosystem health indicators, including the impacts affecting these systems.

PURPOSE OF THIS REPORT

This report serves to summarise the results of the Orange-Senqu Aquatic Ecosystem Health (OSAEH) monitoring undertaken during October to March 2011 at 16 selected sites and includes the summarised results of previous Reserve (environmental flow) studies conducted at 26 sites during 2007 - 2010. Background information is provided on the Lesotho Highlands Development Authority Monitoring programme as well as a literature review of studies undertaken in the Fish River to determine potential biomonitoring sites. As such information, at different levels of intensity, is available from 42 sites across the entire basin. Summarised information provided at most of the sites includes:

- Site description.
- Present Ecological State (PES) of each biological component.
- Main impacts on the site.
- EcoStatus for the site.
- Site suitability.

This report therefore serves as the primary reporting of the baseline AEH of the whole of the Orange-Senqu River System, but also the AEH component of the JBS-1. A separate summary report on the JBS entitled "The State of the Water Resources of the Orange-Senqu River System – Setting the baseline quality in 2010" is being prepared using information from all the components of the JBS-1.

SITE SELECTION

The Terms of Reference (ToR) initially provided fifty six (56) possible monitoring sites that could be included in a basin wide ecological monitoring programme. However, sampling of all the sites provided in the ToR could not be accommodated, due to budgetary constraints. For the purposes of this study, the study area was divided into four sub-areas which consisted of:

- Area 1: The Vaal River catchment – From the origins of the Vaal River to downstream of Douglas Weir in the Northern Cape Province. This includes the Upper, Middle and Lower Water management Areas (WMAs).
- Area 2: The Upper Orange catchment – The Upper Orange River and tributaries from the Lesotho border downstream to the confluence with the Vaal River below Douglas in the Northern Cape Province.
- Area 3: Lower Orange catchment – From the Vaal River confluence to the Orange River mouth.
- Area 4: Senqu River – From the origins of the Senqu to the South African border.

The proposed sites outlined in the ToR did not, however, take into account recent Reserve studies undertaken in the Orange River basin during 2007 – 2010. These studies included:

- Work package 5 of the GIZ DFID support: Assessment of Environmental Flow Requirements as part of Support to Phase 2 of the ORASECOM Basin-wide Integrated Water Resources Management Plan. The focus of this study was on eight Ecological Flow Requirement (EFR) sites occurring in the Caledon River, Orange River downstream of Gariep Dam, the Kraai River and the Molopo River from its source to the Ramabatlama confluence (2010).
- Comprehensive Reserve Determination study for the Integrated Vaal River System: Upper, Middle and Lower Water Management Area -WP8829/1-8. Nineteen Ecological Water Requirement (EWR) sites were selected which covered the Vaal main stem and associated tributaries – commissioned by the Department of Water Affairs and Forestry.

Abundant data are available for the above-mentioned studies, although all the Reserve sites do not correspond with the monitoring sites provided in the ToR. However, the information generated by the current Reserve studies is adequate to be included in this assignment and the results of these studies have been included in the first part of the main report. These sites could also replace some of the current proposed OSAEH sites in future monitoring programmes. These options are discussed under Conclusions and Recommendations.

SITES SURVEYED

Based on the above information, the original 56 sites were re-examined and firstly either:

- Shifted as they were close to EFR sites.
- Shifted as they were close to Reserve sites.

After this elimination process sites were selected for surveying. This meant that the study could take advantage of data from previous studies.

Sixteen OSAEH sites were selected within these sub-areas, which represented the range of EcoRegions occurring in the study area; incorporated reference sites, potential monitoring sites as well as Ecological Reserve sites and allowed for the full suite of ecological components to be assessed i.e. fish, macroinvertebrates, diatoms, riparian vegetation, *in situ* water quality measurements and the determination of Instream Habitat Integrity. These sites also incorporated various impacts from the study area.

ASSESSMENT METHODS

The suite of assessment methods applied during the baseline survey were those incorporated within the South African River Health Programme (RHP), known as the EcoStatus methods and considered suitable for the Orange-Senqu River – and as outlined in ORASECOM Report no. 009/2009.

These response indices applied during this assignment and during the Reserve studies were:

- Macroinvertebrates – MIRAI (Macroinvertebrate Response Assessment Index);
- Fish – FRAI (Fish Response Assessment Index);
- Riparian vegetation – VEGRAI (Riparian Vegetation Response Assessment Index, Level 3 or 4);
- Habitat Integrity – IHI (Index of Habitat Integrity) and
- Diatoms as outlined in Taylor *et al*. (2007).

RESERVE ASSESSMENT RESULTS

A review of the proposed OSAEH monitoring sites indicated that sixteen of the sites listed were in close proximity to EWR/EFR sites or represented EWR/EFR sites. As these sites were assessed as part of the Reserve studies listed in Section 2.1, most of the sites were not assessed during the baseline survey, but the results are summarised and included in this report. The detailed results will however not be included in Part 2 of the final report as the results are well documented and available.

There are good data available on these sites as Ecological Specifications (EcoSpecs) and Thresholds of Potential Concern (TPCs) have been developed for these sites specifically with the aim of future monitoring.

RECOMMENDATIONS

As it is the mandate and responsibility of ORASECOM to develop an aquatic ecosystem health monitoring programme, key sites within the Basin have been identified for further monitoring. These sites are high priority sites which would detect impact and impairment in the basin.

As the information summarised in this document are from various studies each with its own site numbering, it is recommended that a unique site numbering system is used for ORASECOM. Therefore the new site numbers are provided in the following table, cross referenced with other site names used in this document.

AREA 1: Vaal River Catchment

Proposed monitoring sites in the Vaal River Catchment

SITE	REACH	EC	Motivation	New site number
UPPER VAAL RIVER MAIN STEM				
EWR 1	MRU Vaal B	C	Indications that there are water quality problems as the fish show signs of serious bacterial infection and quality sensitive macroinvertebrates are absent.	JBS1
EWR 3	MRU Vaal C	C	EWR 3 is upstream of the Waterval River confluence and therefore the deteriorated water quality entering the Vaal River from the Waterval catchment will not be detected. OSAEH 11.2 is downstream of this confluence but may be influenced by inundation from the Vaal Dam which would make sampling difficult. Based on the data availability and level of analysis undertaken at EWR 3, this site is a preferred biomonitoring site.	JBS2
OSAEH 11.13 (NEW SITE)	MRU Vaal E	C	The new site at Parys, situated on the RB just upstream of the R53 road bridge, may be better suited as a monitoring site as it is located at Parys and would detect upstream impacts. This reach is very important as the Vredefort Dome World Heritage site is located in this reach and is therefore a very high priority monitoring site.	JBS3
EWR 5	MRU Vaal E	C/D	EWR 5 is situated at the end of the WMA 10 km upstream of the Mooi River confluence and the farthest EWR site in the Vaal River. It is impacted by major upstream anthropogenic activities upstream. This site is situated downstream of the Vredefort Dome World Heritage area and is therefore a very high priority monitoring site.	JBS4
KLIP RIVER				
EWR 6	MRU Klip C	B	Considering the importance of this tributary as well as data availability and the level of analysis undertaken at EWR 6, this site is a preferred biomonitoring site.	JBS5
WILGE RIVER				
EWR 7	MRU Wilge A	B	The Braamhoek pump storage scheme upstream of this site is under development will impact the Wilge River and therefore this site is a good location for detecting these impacts. The new dams (Eskom pumped storage scheme) coming online and will cause reductions in baseflows, as well as likely changes to moderate floods which will impact geomorphology while water quality may deteriorate due to increased turbidity and nutrient loading and the	JBS6

SITE	REACH	EC	Motivation	New site number
			drivers therefore have a negative trajectory of change. The site is not the most ideal site in terms of habitat availability and exotic alien fish are impacting the site neegatively.	
EWR 8	MRU Wilge B	C	The site is impacted by WWTWs (Harrismith, Industriqwa, Warden and Tshiane) and receives diffuse runoff from agricultural, urban (Harrismith) and industrial activities (Industriqwa). Weirs occur in the system for the purposes of abstraction for purification purposes, fish dams and abstraction by tankers. This site could be valuable for detecting upstream anthropogenic activities. Sterkfontein releases impact on turbidity levels, habitat loss, decreased temperature and oxygen levels.	JBS7
WATERVAL RIVER				
OSAEH 11.11	MRU Waterval B	D	MRU delineated as Boesmanspruit to the Vaal River confluence. The reach has a PES EcoStatus of a D and is heavily impacted by industrial activity (DWAF, 2008b).	JBS8
SUIKERBOSRAND RIVER				
OSAEH 11.15	MRU Suiker A	B/C	OSAEH 11.15 is at the same locality as EWR 9 and considering that the lower reaches of the Suikerbosrand is impacted by mining and other industrial activities this site should be included in a monitoring programme.	JBS9
EWR 10	MRU Suiker B	C/D	Close proximity to OSAEH 11.14 which is downstream of EWR 10. This site should be included to detect upstream impacts and to determine if the site condition improves when the planned water quality management plan for the Blesbokspruit is initiated which would include purification of mine water decant.	JBS10
BLESBOKSPRUIT RIVER				
OSAEH 11.8	MRU Bles A	D/E	Same locality as EWR 11. The site is severely impacted, especially biota, and therefore this site should be included to detect these impacts and to determine if the site improves when the planned water quality management plan for the Blesbokspruit when initiated which would include purification of mine water decant.	JBS11
KLIP RIVER (GAUTENG)				
OSAEH 11.12		N/S[1]	The river is highly polluted, habitat has been altered due to elevated flows. This site may not be the ideal monitoring site but should be included in future monitoring programmes due to the significant impacts on this river and the deteriorated water quality that enters the Vaal River.	JBS12
MIDDLE VAAL RIVER MAIN STEM				
EWR 12	MRU Vaal F	C	EWR 12 is situated in quaternary catchment C24A, upstream of the confluence with the Koekemoerspruit at Vermaasdrift on the main stem of the Vaal River but downstream of the Rhenoster and Mooi river. The site is adequate for biotic monitoring and an important future monitoring site as it is important to understand the influence of the Upper Vaal WMA.	JBS13
OSAEH 11.1	MRU Vaal G	C	OSAEH 11.1 is situated approximately 5 km downstream of EWR 13 in quaternary catchment C24J. Both sites are adequate as future monitoring sites. However OSAEH 11.1 may be more suitable as there are more unique habitats present and the site is located further downstream in quaternary catchment C24J. As both sites occur within the same EcoRegion and MRU and as the PES results were similar, the data collected at both these sites are valid. However within MRU Vaal G the presence of a Nature Reserve would warrant a further delineation of the MRU into Reserve Assessment Units as the habitat at OSAEH 11.1 is more unique and more responsive to flow changes than EWR 13, although the EWR site is more representative of the reach.	JBS14
RHENOSTER RIVER				
OSAEH 11.6	MRU Rhenoster C	B/C	OSAEH 11.6 is situated in the lower reaches of the Rhenoster River, and has good habitat available for the full suite of biological components to be monitored. This site is a valuable monitoring site for future monitoring programmes as it is located in a tributary and has many upstream impacts. As the Vaal River main stem has deteriorated water quality, tributaries play an important role in diluting these impacts and providing refugia for biota.	JBS15
SCHOONSPRUIT				
OSAEH 11.4	MRU Schoon-spruit D	C	During 2003 – 2005 an Intermediate Reserve Determination Study was commissioned by the Free State Regional Office, as part of a Catchment Management Strategy Development for the Schoon- and Koekemoerspruit catchments. As the Schoonspruit has a major influence on the Vaal River main stem, OSAEH 11.4 is an important site in terms of a future monitoring programme. The lower reaches of the Schoonspruit are heavily impacted by anthropogenic activity and water quality is deteriorated. Substantial data is available on this river and the site is suitable for monitoring the full suite of biotic components.	JBS16
VALS RIVER				
OSAEH 11.5	MRU Vals B	D	EWR 14 is at the same location as OSAEH 11.5 and is the only site that has been identified in the Vals River. The data collated during the Reserve study is important and adequate.	JBS17
VET RIVER				
OSAEH 29.3	MRU Vet C	D	EWR 15 is at the same location as OSAEH 29.3 and is situated in the Vet River downstream of the confluence with the Sand River. As this is the only site that has been identified in the Vet River, the data collated during the Reserve study is important and adequate.	JBS18
LOWER VAAL RIVER MAINSTEM				
OSAEH	MRU Vaal	C	The site was not sampled during this study. From Google Earth imagery habitat availability	JBS19

SITE	REACH	EC	Motivation	New site number
29.2	M		seems adequate for the full suite of biological components to be monitored. This site may be more valuable in a monitoring programme than EWR 16 as it is situated further downstream in the Vaal River and therefore more suitable to detect upstream impacts.	
OSAEH 29.4	MRU Vaal O	C	OSAEH 29.4 is at the same location as EWR 18. Although this site was identified as a priority reach for maintaining the integrity of the Lower Vaal, sampling at this site is difficult as the river is non-wadeable due to the steep gradient of the river. Limited biotopes occur for biotic sampling, and the riparian zone is very dense. This site could be included in a monitoring programme although due to the non-wadeable nature of the Vaal River in this reach, assessment of biotic components would be limited.	JBS20
HARTS RIVER				
OSAEH 29.1	MRU Harts C	C	OSAEH 29.1 is at the same location as EWR 17 and is situated downstream of Spitskop Dam in the Harts River. The MRU includes Wentzel Dam. It is suggested that this site is included as a future monitoring site as Present Day flows are higher than natural and the deteriorated water quality impact heavily on the site and is the only site proposed for this system.	JBS21
RIET RIVER				
OSAEH 26.10	MRU Riet A	D	The site has adequate habitats for the full suite of biological components to be monitored. This site is also an EWR site (IFR 03) and was assessed during the Reserve study in 2003. Although the reach represents a relatively unimpacted part of the Riet River, the EWR assessment resulted in a PES of a D. The current assessment also indicates impacts relating to anthropogenic activities. As the water quality of the Riet River is deteriorated this site should be included as a future monitoring site to detect ongoing impacts especially relating to impaired water quality.	JBS22
OSAEH 29.5	MRU Riet D	C	OSAEH 29.5 is the most downstream site within the Riet River, and is located just downstream of Ritchie at the same location as EWR 19. This reach was identified as a priority reach for maintaining the integrity of the Lower Vaal. Therefore it is an ideal site for detecting impacts from upstream anthropogenic activities originating from the Modder and Riet Rivers. The site occurs in the Mokala National Park on the LB of the river.	JBS23
MODDER RIVER				
OSAEH 11.18	MRU Riet C1	D	OSAEH 11.18 is located downstream of Botshabelo and Thabu Nchu but upstream from Bloemfontein. It is the only OSAEH site situated in the upper reaches of the river and should be included as a biomonitoring site. The habitat at this site is good and the full suite of biological components can be monitored. This site will be a good monitoring site to detect and monitor on-going impacts which include impacts from sewage works, interbasin transfer, and Rustfontein Dam upstream.	JBS24

N/S = not sampled for this baseline survey, but recommended for future surveys.

AREA 2: UPPER ORANGE RIVER CATCHMENT

Proposed monitoring sites in the Upper Orange River Catchment

SITE	REACH	EC	Motivation	New site number
UPPER ORANGE RIVER MAIN STEM				
OSAEH 11.22		N/S	OSAEH 11.22 is located in the upper reaches of the Upper Orange River approximately 65 km downstream of the Lesotho border. This site could be viable as a future monitoring site to detect impacts from Lesotho. From Google Earth imagery this site may be limited in terms of habitat availability to monitor the full suite of biotic components and access may be problematic.	JBS25
OSAEH 26.14		N/S	Google Earth imagery indicates that habitat availability seems more than adequate to monitor the full suite of biotic components. The water quality in the Upper Orange is stable and does not deteriorate significantly downstream, but the Stormbergspruit discharges poor quality water from Burgersdorp sewage works into the Orange River.	JBS26
OSAEH 26.2	MRU Orange B	C	OSAEH 26.2 is at the same location as EFR O1. A monitoring site will be very important in the lower reaches of the Upper Orange as the hydro-electric releases from Vanderkloof Dam impact the lower reaches considerably along with other impacts that include barrier effects of the dams, water quality problems and the destruction of and removal of vegetation on floodplains for agriculture. Based on the data availability and level of analysis undertaken at EFR O1, this site is a preferred biomonitoring site.	JBS27
CALEDON RIVER				
EFR C5	MRU Caledon A/B	C	OSAEH 15.1 is located approximately 50 km downstream of EFR C5. Based on the data availability and level of analysis undertaken at EFR C5, this site is a preferred biomonitoring site.	JBS28
OSAEH 11.6	MRU Caledon B	N/S	Situated downstream of Maseru and is an important site in terms of detecting impacts from upstream Ficksburg and Maseru. However, from Google Earth imagery the Caledon River within this reach has very little riffle and rapid habitat that would allow for the full suite of biological components to be monitored.	JBS29
OSAEH 26.8	MRU Caledon	C	EFR C6 is at the same location as OSAEH 26.8. Habitat at the site is moderate to good for biotic monitoring, although it may be influenced by backup from Gariep Dam. The main	JBS30

SITE	REACH	EC	Motivation	New site number
	D		landuse around the Caledon River is characterised by extensive agriculture. This site may be a good monitoring site to detect agricultural impacts in the river reach between the Welbedacht and Gariep Dams.	
KRAAI RIVER				
EWR 7	MRU Kraai C	C	The landuse in this reach is dominated by irrigation and dry land agriculture and aquaculture.	JBS31

AREA 3: LOWER ORANGE RIVER CATCHMENT

Proposed monitoring sites in the Lower Orange River Catchment

SITE	REACH	EC	Motivation	New site number
LOWER ORANGE MAIN STEM				
EFR O2	MRU Orange D	C	EFR 2 is less disturbed than the rest of the reach and no farming occurs in the riparian zone. The site is downstream of Boegoeberg Dam and is suitable for detecting impacts relating to an altered hydrological regime which seems to be the biggest problem in this reach. Elevated flows may be problematic and therefore gauge records should be checked when planning routine monitoring.	JBS32
OSAEH 26.17	MRU Orange D	C	Located further downstream of EFR O2 just upstream of Upington. This is a multi-channel section of the Orange River. The river reach below EFR O2 is characterised by irrigation, levees in the riparian zone and weirs. This site is suitable for sampling the full suite of biotic components.	JBS33
OSAEH 28.2	MRU Orange E	C	EFR O3 is at the same location as OSAEH 28.2 and is less disturbed than the rest of the MRU. The site is suitable for detecting impacts relating to an altered hydrological regime and agricultural activities, which seems to be the biggest problem in this reach.	JBS34
OSAEH 28.4	MRU Orange F	C	EFR O4 and OSAEH 28.4 are at the same location and in a better condition than the rest of the reach. Agricultural return flows and mining activities are impacting on water.	JBS35
OSAEH 28.5		B/C	Situated at Sendlingsdrift and suitable site to monitor agricultural impacts.	JBS36

AREA 4: SENQU RIVER – FROM THE ORIGINS OF THE SENQU TO THE SOUTH AFRICAN BORDER

Proposed monitoring sites in the Senqu River

Site	Description	New site number
IFR Site 1	On the Matsoku River near the village of Seshote, representing the Matsoku River from the site of the proposed Matsoku Weir to the confluence with the Malibamats'o River (IFR Reach 1). Same location as OSAEH 15.1	JBS37
IFR Site 2	On the Malibamats'o River downstream of the Katse Bridge representing, the Malibamats'o River from Katse Bridge to the confluence with the Matsoku River (IFR Reach 2).	JBS38
IFR Site 3	On the Malibamats'o River at Paray, representing the Malibamats'o River from the confluence with the Matsoku River to the confluence with the Senqu River (IFR Reach 3).	JBS39
IFR Site 4	On the Senqu River at Sehonghong, representing the Senqu River from the confluence with the Malibamats'o River to the confluence with the Tsoelike River (IFR Reach 4).	JBS40
IFR Site 5	On the Senqu River at Whitehills, representing the Senqu River from the confluence with the Tsoelike River to the confluence with the Senqunyane River (IFR Reach 5). Same location as OSAEH 15.3.	JBS41
IFR Site 6	On the Senqu River at Seaka Bridge, representing the Senqu River from the confluence with the Senqunyane River to the Lesotho/South Africa border (IFR Reach 6).	JBS42
IFR Site 7	On the Senqunyane River at Marakabei, representing the Senqunyane River from the site of the proposed Mohale Dam to the confluence with the Lesobeng River (IFR Reach 7).	JBS43
IFR Site 9	Matsoku River upstream of the headwaters of Matsoku Weir – reference for IFR Site 1.	JBS44

FISH RIVER, NAMIBIA

Proposed monitoring sites in the Fish River, Namibia

Site	Description	New site number
B2	Impact site, 26 km downstream of dam site at Seeheim	JBS45

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ACRONYMS

ASPT	Average Score Per Taxon
CMA	Catchment Management Agency
DO	Dissolved Oxygen
EFR	Environmental Flow Requirement
FD	Fast Deep fish habitat
FRAI	Fish Response Assessment Index
FS	Fast Shallow fish habitat
Geom	Geomorphology
GSM	Gravel, sand, mud habitat
GWS	Government Water Scheme
IHI	Index of Habitat Integrity
IIHI	Instream Index of Habitat Integrity
Inverts	Macroinvertebrates
LB	Left Bank
LHWP	Lesotho Highlands Water Project
MIRAI	Macro Invertebrate Response Assessment Index
MRU	Management Resource Unit
MV	Marginal Vegetation
NF	Non Flow related
NWRS	National Water Resources Strategy
ORASECOM	Orange-Senqu River Commision
OSAEH	Orange-Senqu Aquatic Ecosystem Health
PES	Present Ecological State
RAU	Resource Assessment Unit
RB	Right Bank
RHP	River Health Programme
RIHI	Riparian Index of Habitat Integrity
Rip Veg	Riparian vegetation
RU	Resource Unit
SASS5	South African Scoring System version 5
SD	Slow Deep fish habitat
SIC	Stones-in-current habitat
SOOC	Stones-out-of-current habitat
SPI	Specific Pollution Index
SS	Slow Shallow fish habitat
TDS	Total Dissolved Salts
ToR	Terms of Reference
TPC	Threshold of Potential Concern
VEGRAI	Vegetation Response Assessment Index
WMA	Water Management Area
WWTW	Waste Water Treatment Works

1 INTRODUCTION

1.1 BACKGROUND

Article 5.2.5 of the Orange-Senqu River Commission (ORASECOM) Agreement indicates that the Commission can advise its Contracting Parties (Botswana, Lesotho, Namibia and South Africa on 'standardised forms of collecting, processing and disseminating data or information with regard to all aspects of the River System". Article 7.12 requires the Parties to individually and jointly take all measures that are necessary to protect and preserve the River System from its sources and headwaters to its common terminus. To do this the Parties would need to be advised on the state of aquatic ecosystems throughout the basin. This gives ORASECOM the mandate and responsibility to develop an aquatic ecosystem health monitoring programme. Such a monitoring programme will also serve to satisfy some of the requirements of the Revised SADC Protocol on Shared Watercourses, to which all Parties are signatory (ORASECOM, 2009).

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In the interim, the GIZ/DFID Phase 2 support to ORASECOM initiated a study to propose environmental flows for the system. This study included monitoring of AEH at selected sites throughout the basin – specifically were determinations of e-flows was considered to be important. Moreover, the Department of Water Affairs in South Africa had commissioned several studies as part of determining the ecological Reserve over the preceding few years, while the Lesotho Highlands Development Authority (LHDA) had done some sampling in the highlands of Lesotho. It made little sense to repeat sampling at these sites. Sampling specifically for this current survey was therefore done at fewer sites, but drew on these other recent surveys to provide an overall assessment of the AEH of the whole of the Orange-Senqu River system. Key recommendations from this report are however to propose the sites and revised Sampling Site numbering system that should serve as the basis for the next 5 yearly survey in 2015, as well as the interim SASS5 sites.

Lastly, during the planning for this survey it became clear that other surveys, notably a survey of Persistent Organic Pollutants (POPs) and an inter -laboratory survey, were going to be undertaken. It was therefore decided to undertake a single "Joint Basin Survey" (JBS-1) to set the baseline for

the system in 2010. ORASECOM also recognised the value of using this survey as a public outreach opportunity, and therefore proposed 5 Public Events where inter alia school children were shown how to use the miniSASS method to assess AEH. A booklet on this broader JBS is available from
http://www.orasecom.org/publications/joint+water+resources+quality+baseline+survey.aspx?fileid=43.

1.2 PURPOSE OF THIS ASSIGNMENT

The specific purpose of this assignment, which forms part of the greater EU project, is to undertake the first baseline monitoring of aquatic ecosystem health in the Orange-Senqu River System and to support the broader joint baseline survey. The focus of this specific assignment is to investigate the Aquatic Ecosystem Health of the Orange-Senqu River System and includes a detailed assessment of aquatic ecosystem health indicators, including the impacts affecting these systems.

1.2.1 Outcomes of this assignment

According to the Terms of Reference (ToR) the results of this assignment include:

1 **Report 1: Detailed sampling programme.** This report was finalised during October 2009 and outlines the sites selected for the purpose of this assignment, and provides detailed information on the sampling protocols that would be applied at each site. A detailed sampling programme was also provided.

2 **Presentation of sampling programme.** The sampling programme was presented at the briefing session held at St. Georges Hotel, Irene on 22 September 2010.

3 **Undertaking of monitoring according to monitoring programme.** Field trips were undertaken during 25 – 29 October 2010 and 1 – 6 November 2010, and March 2011.

4 **Final report:** The final report is provided in two parts.

- The first part of the report (this report) also referred to as the summary report provides a summary of the results of the aquatic ecological baseline survey undertaken at the monitoring sites outlined in Section 2.2. This report also includes the summarised results of the Ecological Water Requirement (EWR sites) of the Reserve studies undertaken during 2007 – 2010 by other agencies – including the environmental flows work undertake as part of the GIZ/DFID support to ORASECOM.
- The second part of the report, also referred to the main report includes the detailed results of the ecosystem health baseline monitoring and includes an analysis of the raw data, as well as some indication of the overall status of the site when compared to a reference condition. A qualitative assessment of the macroinvertebrate data made available by the Lesotho Highlands Development Authority for the Senqu River as well as macroinvertebrate data from a Fish River study undertaken during 2009-2010 by Nepid Consultants is provided.
- The suite of EcoStatus models and component assessment models applied to this study will be provided in electronic format.

1.3 PURPOSE OF THIS REPORT

This report serves to summarise the results of the Orange-Senqu Aquatic Ecosystem Health (OSAEH) monitoring undertaken during October to March 2011 at 16 selected sites and includes the summarised results of previous Reserve (environmental flow) studies conducted at 26 sites during 2007 - 2010. Background information is provided on the Lesotho Highlands Development Authority Monitoring programme as well as a literature review of studies undertaken in the Fish River to determine potential biomonitoring sites. As such information, at different levels of

intensity, is available from 42 sites across the entire basin. Summarised information provided at most of the sites includes:

- Site description.
- Present Ecological State (PES) of each biological component.
- Main impacts on the site.
- EcoStatus for the site.
- Site suitability.

This report therefore serves as the primary reporting of the baseline AEH of the whole of the Orange-Senqu River System, but also the AEH component of the JBS-1. A separate summary report on the JBS entitled "The State of the Water Resources of the Orange-Senqu River System – Setting the baseline quality in 2010" is being prepared using information from all the components of the JBS-1.

1.4 REPORT OUTLINE

The outline of the report is provided below.

1.4.1 Chapter 1: Introduction

This chapter.

1.4.2 Chapter 3 - 36: Results of Area 1: Upper Vaal Catchment

A summary of the EcoClassification results are provided of the Comprehensive Reserve studies undertaken in the catchment during 2007 – 2010 at various EWR sites occurring in catchment as well as the results of the surveys undertaken at the OSAEH sites during October 2010 to March 2011. The results of Area 1[1] are sub-divided into:
Chapter 3 – 17: Summarised results of the Upper Vaal WMA (WMA 8)
Chapter 8 – 26: Summarised results of the Middle Vaal WMA (WMA 9)
Chapter 27 – 36: Summarised results of the Lower Vaal WMA (WMA 10 and part of 13)

1.4.3 Chapter 37 – 42: Results of Area 2: The Upper Orange catchment

A summary of the EcoClassification results are provided of the EFR assessment undertaken with support from GIZ and DFID (by Water for Africa), during 2010 at various environmental flow (EFR) sites situated within the catchment.

1.4.4 Chapter 43 – 49: Results of Area 3: Lower Orange catchment

A summary of the EcoClassification results are provided of the EFR assessment undertaken by Water for Africa, during 2010 at various EFR sites situated within the catchment as well as the results of the surveys undertaken at the OSAEH sites during November 2010.

1.4.5 Chapter 50: Area 4: Senqu River – From the origins of the Senqu to the South African border

Background information is provided on the Lesotho Highlands Development Authority Monitoring programme.

1.4.6 Chapter 51: Fish River, Namibia

A summary is provided of the specialist study undertaken by Nepid Consultants during 2009-2010 which formed part of an Environmental and Social Impact Assessment (ESIA) for the proposed Neckartal Dam development.

[1] The following section provides a description of each Area.

1.4.7 Chapter 52: Recommendations

Recommendations are made for the selection of biomonitoring sites within the Orange-Senqu River Basin.

1.4.8 Chapter 53: References

2 APPROACH

2.1 SITE SELECTION

The Terms of Reference (ToR) initially provided fifty six (56) possible monitoring sites that could be included in a basin wide ecological monitoring programme. However, sampling of all the sites provided in the ToR could not be accommodated, due to budgetary constraints. For the purposes of this study, the study area was divided into four sub-areas which consisted of:

- Area 1: The Vaal River catchment – From the origins of the Vaal River to downstream of Douglas Weir in the Northern Cape Province. This includes the Upper, Middle and Lower Water management Areas (WMAs).
- Area 2: The Upper Orange catchment – The Upper Orange River and tributaries from the Lesotho border downstream to the confluence with the Vaal River below Douglas in the Northern Cape Province.
- Area 3: Lower Orange catchment – From the Vaal River confluence to the Orange River mouth.
- Area 4: Senqu River – From the origins of the Senqu to the South African border.

The proposed sites outlined in the ToR did not, however, take into account recent Reserve studies undertaken in the Orange River basin during 2007 – 2010. These studies included:

- Work package 5 of the GIZ DFID support: Assessment of Environmental Flow Requirements as part of Support to Phase 2 of the ORASECOM Basin-wide Integrated Water Resources Management Plan. The focus of this study was on eight Ecological Flow Requirement (EFR) sites occurring in the Caledon River, Orange River downstream of Gariep Dam, the Kraai River and the Molopo River from its source to the Ramabatlama confluence (2010).
- Comprehensive Reserve Determination study for the Integrated Vaal River System: Upper, Middle and Lower Water Management Area -WP8829/1-8. Nineteen Ecological Water Requirement (EWR) sites were selected which covered the Vaal main stem and associated tributaries – commissioned by the Department of Water Affairs and Forestry.

Abundant data are available for the above-mentioned studies, although all the Reserve sites do not correspond with the monitoring sites provided in the ToR. However, the information generated by the current Reserve studies is adequate to be included in this assignment and the results of these studies have been included in the first part of the main report. These sites could also replace some of the current proposed OSAEH sites in future monitoring programmes. These options are discussed under Conclusions and Recommendations.

2.2 SITES SURVEYED

Based on the above information, the original 56 sites were re-examined and firstly either:

- Shifted as they were close to EFR sites.
- Shifted as they were close to Reserve sites.

After this elimination process sites were selected for surveying. This meant that the study could take advantage of data from previous studies.

Sixteen OSAEH sites were selected within these sub-areas, which represented the range of EcoRegions occurring in the study area; incorporated reference sites, potential monitoring sites as well as Ecological Reserve sites and allowed for the full suite of ecological components to be

assessed i.e. fish, macroinvertebrates, diatoms, riparian vegetation, *in situ* water quality measurements and the determination of Instream Habitat Integrity. These sites also incorporated various impacts from the study area.

Table 2.1 provides a summary of the OSAEH sites sampled as part of this study as well as EWR sites relevant to this study, in close proximity to or representing OSAEH sites and other EWR sites occurring in the study area that are not in close proximity to any of the OSAEH sites. The colouring refers to the three sub-areas within which the sites occur:

Area 1: The Vaal River catchment
Area 2: The Upper Orange catchment
Area 3: Lower Orange catchment
Area 4: Senqu River

Table 2.1 Proposed aquatic monitoring sites in the Orange-Senqu River Basin

Site	Monitoring type	Eco-Region	Major River	Latitude	Longitude	Site code	
OSAEH sites surveyed							
OSAEH 11.1[1]	Monitoring Site P	11: Highveld	Vaal	-27.51729	26.21604	C2VAALBLOEM	
OSAEH 11.3	Monitoring Site C	11: Highveld	Vaal/Mooi	-26.68283	27.09856	C2MOOIMEULS	
OSAEH 11.4	Monitoring Site C	11: Highveld	Vaal/Skoonspruit	-26.93333	26.66527	C2SKOOURANI	
OSAEH 11.6	Monitoring Site P	11: Highveld	Vaal/Renoster	-27.05286	27.00991	C7RENOR501B	
OSAEH 11.8	Ecological Reserve Site	11: Highveld	Vaal/Blesbokspruit	-26.475	28.43194	C2BLESMARAI	
OSAEH 11.13[2]	Reference Site	11: Highveld	Vaal/Kromellenboog	-26.8003	27.58428	C2KROMAVAAL	
OSAEH 11.14	Monitoring Site C	11: Highveld	Vaal/Suikerbosrand	-26.68122	28.05011	C2SUIKBADFO	
OSAEH 11.18	Monitoring Site P	11: Highveld	Riet/Modder	-29.16111	26.57194	C5MODDSANNA	
OSAEH 11.21	Reference Site	11: Highveld	Modder/Karonnasprt	-29.08107	26.62615	C5KORAMOCKE	
OSAEH 26.1	Ecological Reserve Site	26: Nama Karoo	Vaal	-29.00083	23.80646	C9VAALDOUGL	
OSAEH 26.10	Ecological Reserve Site	26: Nama Karoo	Riet	-29.57528	25.70805	C5RIETIFR03	
OSAEH 26.17	Monitoring Site P	26: Nama Karoo	Orange	-28.43861	21.40583	D7ORANGIFKL	
OSAEH 28.5	Ecological Reserve Site	28: Orange River Gorge	Orange	-28.04051	17.06967	D8ORANBOOMR	
OSAEH 29.2[3]	Monitoring Site P	29: Southern Kalahari	Vaal	-28.11097	24.80193	C9VAALWARRE	
OSAEH 29.4	Monitoring Site C	29: Southern Kalahari	Vaal	-28.72533	24.07293	C9VAALSCHMI	
OSAEH 29.5	Ecological Reserve Site	29: Southern Kalahari	Riet	-29.02805	24.5125	C5RIETIFR01	
EWR sites in close proximity to or representing OSAEH sites							
VAAL RIVER SYSTEM							
OSAEH 11.2/EWR 3	Monitoring Site P	11: Highveld	Vaal	-27.0382	28.57393	C1VAAL-VILLI	EWR 3
OSAEH 11.9/EWR 6	Reference Site	11: Highveld	Vaal/Klip	-27.47008	29.60048	C1KLIP-UNSPE	EWR 6
OSAEH 11.15/EWR 9	Reference Site	11: Highveld	Vaal/Suikerbosrand	-26.64672	28.38197	C2SUIK-DEHOE	EWR 9
OSAEH 11.14/EWR 10	Monitoring Site C	11: Highveld	Vaal/Suikerbosrand	-26.68122	28.05011	C2SUIK-BADFO	EWR 1
OSAEH 11.8/EWR 11	Ecological Reserve Site	11: Highveld	Vaal/Blesbokspruit	-26.475	28.43194	C2BLES-MARAI	EWR 11
OSAEH 11.5/EWR 14	Monitoring Site C	11: Highveld	Vaal/Vals	-27.48683	26.81305	C6VALS-PROKL	EWR 14
OSAEH 29.3/EWR 15	Monitoring Site C	29: Southern Kalahari	Vaal/Vet	27.93412	26.12094	C4VET-HOOPS	EWR 15
OSAEH 29.1/EWR 17	Monitoring Site P	29: Southern Kalahari	Vaal/Harts	-28.35124	24.31354	C3HART-DELPO	EWR 17
OSAEH 29.4/EWR 18	Monitoring Site C	29: Southern Kalahari	Vaal	-28.72533	24.07293	C9VAAL-SCHMI	EWR 18
OSAEH 29.5/EWR 19	Ecological Reserve Site	29: Southern Kalahari	Riet	-29.02805	24.5125	C5RIET-IFR05	EWR 19
LOWER ORANGE RIVER SYSTEM							
OSAEH 26.2/EFR OR1	Reference Site	26: Nama Karoo	Orange	-29.6007	24.0916	D3ORANHOPET	EFR OR 1
OSAEH 28.2/EFR OR3	Monitoring Site P	28: Orange River Gorge	Orange	-28.51115	20.17482	D8ORAN-BLOUP	EFR OR 3

Site	Monitoring type	Eco-Region	Major River	Latitude	Longitude	Site code	
OSAEH 28.4/EFROR3	Ecological Reserve Site	28: Orange River Gorge	Orange	-28.73645	17.61856	D8ORAN-VIOOL	EFR OR 4
UPPER ORANGE RIVER SYSTEM							
OSAEH 15.1/EFR C5	Ecological Reserve Site	15: Eastern Escarpment Mountains	Caledon	-28.72231	28.15083	D2CALE-EWR03	EFR C5
OSAEH 26.8/EFR C6	Monitoring Site P	26: Nama Karoo	Caledon	-30.45233	26.27088	D2CALE-TUSSE	EFR C6
OSAEH 26.11/EFR K7	Monitoring Site P	26: Nama Karoo	Caledon/Kraai	-30.70364	26.77132	D1KRAA-CORAN	EFR K7
Ecological Reserve sites that could replace proposed OSAEH sites or could be added							
UPPER VAAL RIVER SYSTEM							
EWR 1	Ecological Reserve Site	11: Highveld	Vaal mainstem	-26.8728	29.61384	C1Geel_Unspe	
EWR 2	Ecological Reserve Site	11: Highveld	Vaal mainstem	-26.9211	29.27929	C1Vaal Braks	
EWR 4	Ecological Reserve Site	11: Highveld	Vaal mainstem	-26.84262	28.1123	C2Vaal-Deny	
EWR 6	Ecological Reserve Site	11: Highveld	Klip River	-27.36166	29.48503	C1Klip-Unspe2	
EWR 5	Ecological Reserve Site	11: Highveld	Vaal mainstem	-26.93243	27.01367		
EWR 8	Ecological Reserve Site	11: Highveld	Wilge River	-27.80017	28.76778	C8Wilg-Belwh	
MIDDLE VAAL RIVER SYSTEM							
EWR12	Ecological Reserve Site	11: Highveld	Vaal mainstem	-26.93615	26.85025	C2-Vaal Orkne	
EWR13	Ecological Reserve Site	11: Highveld	Vaal mainstem	-27.10413	26.52185	C2-Vaal Orkne	
LOWER VAAL RIVER SYSTEM							
EWR 16	Ecological Reserve Site	11 AND 29	Vaal mainstem	-27.65541	25.59564		
Senqu River: Proposed OSAEH sites							
OSAEH_15_2	Reference Site	15	Malibamatso/Matsuko	-29.25583	28.56417	LHDAIFR1	
OSAEH_15_3	Monitoring Site P	15	Senqu	-30.06556	28.4077	LHDAIFR5	
OSAEH_15_4	Reference Site	15	Malibamatso	To be decided		LHDA site	
OSAEH_15_5	Monitoring Site P	15	Malibamatso	-30.0363	28.2225	LHDAIFR8	
Senqu River: IFR sites							
IFR Site 1	On the Matsoku River near the village of Seshote, representing the Matsoku River from the site of the proposed Matsoku Weir to the confluence with the Malibamats'o River (IFR Reach 1). Same location as OSAEH 15.1			29°15'21"	28°33'51"		
IFR Site 2	On the Malibamats'o River downstream of the Katse Bridge representing, the Malibamats'o River from Katse Bridge to the confluence with the Matsoku River (IFR Reach 2).			29°21'08"	28°31'32"		
IFR Site 3	On the Malibamats'o River at Paray, representing the Malibamats'o River from the confluence with the Matsoku River to the confluence with the Senqu River (IFR Reach 3).			29°29'52"	28°39'04"		
IFR Site 4	On the Senqu River at Sehonghong, representing the Senqu River from the confluence with the Malibamats'o River to the confluence with the Tsoelike River (IFR Reach 4).			29°44'20"	28°45'19"		
IFR Site 5	On the Senqu River at Whitehills, representing the Senqu River from the confluence with the Tsoelike River to the confluence with the Senqunyane River (IFR Reach 5). Same location as OSAEH 15.3.			30°03'56"	28°24'28"		
IFR Site 6	On the Senqu River at Seaka Bridge, representing the Senqu River from the confluence with the Senqunyane River to the Lesotho/South Africa border (IFR Reach 6).			30°21'48"	28°11'30"		
IFR Site 7	On the Senqunyane River at Marakabei, representing the Senqunyane River from the site of the proposed Mohale Dam to the confluence with the Lesobeng River (IFR Reach 7).			29°32'09"	28°09'15"		
IFR Site 8	On the Senqunyane River upstream of the confluence with the Senqu River, representing the Senqunyane River from the confluence with the Lesobeng River to the confluence with the Senqu River (IFR Reach 8).			30°02'11"	28°13'21"		
IFR Site 9	Matsoku River upstream of the headwaters of Matsoku Weir – reference for IFR Site 1.						
IFR Site 10	Senqu River downstream of Mokhotlong – reference for IFR Sites 2, 3 and 7.						

1 OSAEH 11.1 was relocated to Wolwespruit Nature Reserve, as Google Imagery indicated very little instream habitat. Based on information provided by the Reserve manager, Mr Mmole Teme, riffle areas were present in the Reserve and provided adequate instream habitat for the full suite of biotic component sampling. Based on land use this site could provide different/unique habitat types, and direct landuse impacts would be less than outside the reserve which is agriculturally dominated.
2 A new site was selected to accommodate the PR event. The site is located in the Vaal River at Parys.

3 OSAEH 29.2 was substituted by EWR 16 which was assessed as part of the Middle Vaal Reserve Study during 2007-2008. EWR 16 is situated below Bloemhof Dam and is the border between two EcoRegions and 120 km upstream of OSAEH 29.2. This site was selected as there was adequate instream habitat and access.

The Senqu River was not assessed as part of this study. A summary of the OSAEH sites is provided based on data provided in ORASECOM Report no. 009/2009.

2.3 ASSESSMENT METHODS

The suite of assessment methods applied during the baseline survey were those incorporated within the South African River Health Programme (RHP), known as the EcoStatus methods and considered suitable for the Orange-Senqu River – and as outlined in ORASECOM Report no. 009/2009.

These response indices applied during this assignment and during the Reserve studies were:

- Macroinvertebrates – MIRAI (Macroinvertebrate Response Assessment Index);
- Fish – FRAI (Fish Response Assessment Index);
- Riparian vegetation – VEGRAI (Riparian Vegetation Response Assessment Index, Level 3 or 4);
- Habitat Integrity – IHI (Index of Habitat Integrity) and
- Diatoms as outlined in Taylor *et al*. (2007).

The models indicated above are called EcoStatus models and are used in the EcoClassification process. Each model characterises the biological component being assessed into an Ecological Category. This is expressed as a category in a continuum from A to F, where A represents conditions close to natural and F being critically modified condition (Table 2.3).

This project followed the EcoClassification process, mostly as far as the biological responses are concerned. The drivers were very broadly characterized as they form a cause and effect relationship with the biological responses. The EcoClassification process determines causes and sources of biophysical attribute deviation from the reference condition.

Table 2.2 Generic ecological categories for EcoStatus components (Kleynhans and Louw (2007)

Ecological Category	Description	Score (% of Total)
A	Unmodified, natural.	90-100
B	Largely natural with few modifications. A small change in natural habitats and biota may have taken place but the ecosystem functions are essentially unchanged.	80-89
C	Moderately modified. Loss and change of natural habitat and biota have occurred but the basic ecosystem functions are still predominantly unchanged.	60-79
D	Largely modified. A large loss of natural habitat, biota and basic ecosystem functions has occurred.	40-59
E	Seriously modified. The loss of natural habitat, biota and basic ecosystem functions is extensive.	20-39
F	Critically/extremely modified. Modifications have reached a critical level and the system has been modified completely with an almost complete loss of natural habitat and biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible.	0-19

2.4 RESERVE ASSESSMENT RESULTS

A review of the proposed OSAEH monitoring sites indicated that sixteen of the sites listed were in close proximity to EWR/EFR sites or represented EWR/EFR sites. As these sites were assessed as part of the Reserve studies listed in Section 2.1, most of the sites were not assessed during the

baseline survey, but the results are summarised and included in this report. The detailed results will however not be included in Part 2 of the final report as the results are well documented and available.

There are good data available on these sites as Ecological Specifications (EcoSpecs) and Thresholds of Potential Concern (TPCs) have been developed for these sites specifically with the aim of future monitoring.

3 UPPER VAAL CATCHMENT (WMA 8) – FROM HEADWATERS TO MOOI RIVER CONFLUECE

3.1 BACKGROUND

WMA 8 is part of a larger water supply system, which includes adjacent WMAs, as well as Lesotho. The Upper Vaal WMA is one of three WMAs in the Vaal River catchment, which is the drainage area of the Vaal River from its headwaters to the confluence of the Vaal and Orange Rivers (DWAF, 2004).

The Upper Vaal WMA includes the Vaal, Klip, Wilge, Liebenbergsvlei, Waterval, Suikerbosrand and Mooi Rivers and extends to the confluence of the Mooi and Vaal Rivers. It covers a catchment area of 55 565 km^2. This WMA includes the very important Vaal, Grootdraai and Sterkfontein Dams. The southern half of the WMA extends over the Free State, the north-east mainly occurs within Mpumalanga and the northern and western parts in Gauteng and North West provinces respectively (DWAF, 2004).

The Upper Vaal is the uppermost WMA in the Vaal River catchment and one of five WMAs in the Orange River Basin. It is surrounded by the Crocodile (West) and Marico, Olifants, Inkomati, Usutu to Mhlathuze, Thukela, Upper Orange and Middle Vaal WMAs and adjoins Lesotho in the southern extreme. The National Water Resource Strategy (NWRS) describes and discusses the Upper Vaal WMA in three sub-areas *viz* the Vaal upstream of Vaal Dam, Wilge and the Vaal downstream of the Vaal Dam (DWAF, 2004).

Due to the extensive development in the Vaal River System and in the Upper Vaal and Crocodile (West) WMA, which are supplied from the Upper Vaal WMA, the local surface water resources in all three of the Vaal WMAs had been fully exploited for more than 30 years. It was therefore necessary to augment the supply by developing various transfer schemes importing water from the Thukela and Usutu to Mhlathuze WMAs, as well as from the Kingdom of Lesotho through the Lesotho Highlands Water Project (LHWP) (DWAF, 2004).

The surface water availability in the Vaal River System is estimated through a set of water resource models, each fulfilling a particular function in the management of the water resources. Combined, these models serve as a decision support tool that contains a large and comprehensive database of hydrological and physical system characteristics, required to simulate the water resource systems as realistically as possible. Due to the interdependencies, the management and planning of flows and water availability in the Vaal River System is undertaken at the national level and not by the Upper Vaal Catchment Management Agency (CMA) when it is established, until then the DWAF Regional Office) (DWAF, 2004).

The Upper Vaal water managers are, however, responsible for the assessment of the availability of the local groundwater and surface water resources used to supply local authorities and district councils without access to the Vaal River System water supply infrastructure (DWAF, 2004).

For this project, fourteen sites were identified as possible monitoring sites while eleven EWR sites occur within the Upper Vaal WMA that was assessed as part of the Vaal Comprehensive Reserve study undertaken by Water for Africa and Koekemoer Aquatic Services during 2007 – 2010. Four OSAEH sites were assessed during October 2010. Section 5 to 16 summarises the results of the October 2010 assessment as well as the EWR results of the EWR results.

Figure 3.1 provides the locality of the EWR sites as well as the OSAEH sites that occur in the Vaal River where the green pins represent the OSAEH monitoring sites not assessed, the red pins represent the EWR sites assessed during 2010 and the yellow pins represent the OSAEH sites assessed during October 2010. Site information is provided in Table 3.1.

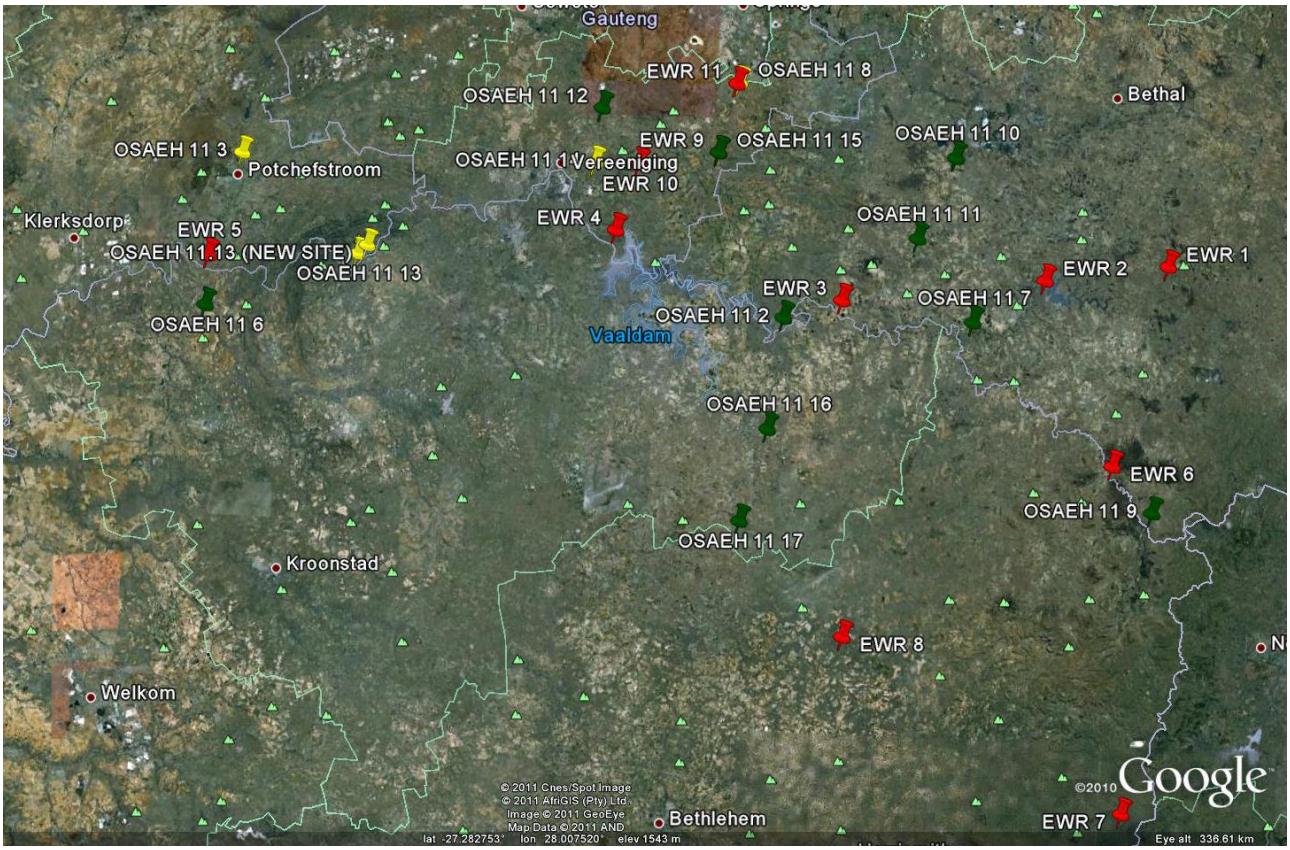

Figure 3.1 OSAEH monitoring and EWR sites occurring within the Upper Vaal River catchment (Google Earth image, 2010)

Table 3.1 OSAEH monitoring and EWR site detail

Site	Monitoring type	Eco-Region	Major River	Latitude	Longitude	Site code
OSAEH_11_2	Monitoring Site P	11	Vaal	-27.0382	28.57393	C1VAALVILLI
OSAEH_11_3	Monitoring Site C	11	Vaal/Mooi	-26.68283	27.09856	C2MOOIMEULS
OSAEH_11_6	Monitoring Site P	11	Vaal/Renoster	-27.05286	27.00991	C7RENOR501B
OSAEH_11_7	Monitoring Site P	11	Vaal	-27.0304	29.08733	C1VAALBRAKS
OSAEH_11_8	Ecological Reserve Site	11	Vaal/Blesbokspruit	-26.475	28.43194	C2BLESMARAI
OSAEH_11_9	Reference Site	11	Vaal/Klip	-27.47008	29.60048	C1KLIPUNSPE
OSAEH_11_10	Ecological Reserve Site	11	Vaal/Waterval	-26.63518	29.02262	C1WATEEWR01
OSAEH_11_11	Ecological Reserve Site	11	Vaal/Waterval	-26.83428	28.92836	C1WATEEWR02
OSAEH_11_12	Monitoring Site C	11	Vaal/Klip	-26.54934	28.06435	C2KLIPSLANG
OSAEH_11_13[1]	Reference Site	11	Vaal/Kromellenboogsp	-26.8003	27.58428	C2KROMAVAAL
OSAEH_11_14	Monitoring Site C	11	Vaal/Suikerbosrand	-26.68122	28.05011	C2SUIKBADFO
OSAEH_11_15	Reference Site	11	Vaal/Suikerbosrand	-26.64672	28.38197	C2SUIKDEHOE
OSAEH_11_16	Monitoring Site P	11	Vaal/Wilge	-27.307	28.54195	C8WILGUNSPE
OSAEH_11_17	Monitoring Site P	11	Wilge/Liebenber	-27.53083	28.47556	C8LIEBTWEEL
EWR 1	Ecological Reserve Site	11.05	Vaal	-26.8728	29.61384	C1GEEL_UNSPE
EWR 2	Ecological Reserve Site	11.03	Vaal	-26.9211	29.27929	C1VAAL BRAKS
EWR 3	Ecological Reserve Site	11.03	Vaal	-26.99087	28.72971	C1VAAL-VILLI
EWR 4	Ecological Reserve Site	11.03	Vaal	-26.84262	28.1123	C2VAAL-DENY

Site	Monitoring type	Eco-Region	Major River	Latitude	Longitude	Site code
EWR 5	Ecological Reserve Site	11.08	Vaal	-26.93243	27.01367	
EWR 6	Ecological Reserve Site	11.06	Klip	-27.36166	29.48503	C1KLIP-UNSPE2
EWR 7	Ecological Reserve Site	11.03	Wilge	-28.20185	29.55827	
EWR 8	Ecological Reserve Site	11.03	Wilge	-27.80017	28.76778	C8WILG-BELWH
EWR 9	Ecological Reserve Site	11.01	Suikerbosrand	-26.6467	28.38197	C2SUIK-DEHOE
EWR 10	Ecological Reserve Site	11.01	Suikerbosrand	-26.68137	28.16798	CLOSE TO C2SUIK-BADFO
EWR 11	Ecological Reserve Site	11.03	Blesbokspruit	-26.47892	28.42488	C2BLES-MARAI (locality incorrect)

1 Location of this site was moved to accommodate PR event. See section 8 for new details.

4 EWR 1: UITKOMS (VAAL RIVER)

The information is summarised from DWA (2008a,b; 2009a; 2010a).

4.1 SITE DESCRIPTION

For the purposes of the EWR study, the Vaal River from the origins of the Vaal to the confluence of the Mooi River was delineated into five Management Resource Units (MRU Vaal A – E). EWR 1 falls within MRU Vaal B which is the delineated reach from the Klein Vaal confluence to the Grootdraai Dam. A transfer from Heyshope Dam takes place through the Perdewater, Skulpspruit and Rietspruit.

EWR1 is situated in the Vaal River downstream of the transfer which is characterised by extensive rapids and backwaters which form unique and the most critical habitat within this section. The site is a boulder riffle section which is highly atypical of the reach. Alluvial sections upstream show indications of increased flows (cut banks, likely due to interbasin transfers) – but the site is not very flow sensitive. Floodplain wetlands are present. Fish habitat is well represented at site as well as flow-depth categories and cover. Macroinvertebrate habitat availability is moderate.

Location	EWR 1	**Altitude**	1570 m
Longitude	29.61384	**Latitude**	-26.8728
EcoRegion	Highveld/Southern Central Kalahari 11.05	**Quaternary catchment**	C11J
Water Management Area	Upper Vaal	**Geomorphological zone**	Lowland

EWR 1, Uitkoms, September 2007

4.2 PRESENT ECOLOGICAL STATE (PES)

Geom	The Resource Assessment Unit (RAU) consists of an anastamosing rapid section with off-channel pools and backwaters, making this a very critical habitat within this very homogenous MRU of the Vaal River. Wetlands (pools) are located in the bed of a seasonal channel at this site. The permanent nature of these pools appears to be unique in the reach. Very high base flows are present due to interbasin transfers and this may account for the cut banks on both banks upstream of the site. Google Earth images indicate an absence of bars and islands in the reach which may also be a result of the elevated base flows. No change in moderate or large floods is evident from the available hydrological data, although there are several farm dams in the upper catchment area.
WQ	Physico-chemical variables indicate that the water quality is fairly good, although some impacts are detected. Increased Total Dissolved Salts (TDS) could be diffuse impacts originating from coal mines. Witpuntspruit tributary is impacted (low pH, high sulphates) by Acid Mine Drainage (AMD) and there are temperature

	changes due to the interbasin transfer from the Usutu River to the Perdewaterspruit which also raise the base flow from April to October. Occasional fish kills occur in the MRU that could be related to water quality problems. Cattle grazing also occurs in the riparian zone.
Fish	All the expected fish species are still present within this Resource Unit (RU) although the Frequency of Occurrence (FROC) of some species has been reduced from reference conditions. The FROC of *L. kimberleyensis* has been altered potentially as a result of water quality deterioration as well as habitat deterioration (increased siltation and benthic algae). The FROC of *B. anoplus*, *B. paludinosus* and *Pseudocrenilabrus philander* have also been reduced and relates to loss of cover (vegetation loss as result of bank erosion and sedimentation of substrates) and especially due to the presence of the aggressive alien predator *Micropterus salmoides.*
Inverts	Sep 07: SASS5 score: 104 No of Taxa: 18 ASPT: 5.8 Apr 08: SASS5 score: 89 No of Taxa: 17 ASPT: 5.2 Key taxa expected but not observed were generally those that are sensitive to water quality changes, such as Perlidae, Leptophlebiidae, Heptageniidae, Gerridae, *Centroptiloides bifasciata,* Hydracarina, *Caridina nilotica* and *Hydropsyche longifurca.* Tricorythidae were more abundant than expected, while Hydropsychidae were less abundant than expected.
Rip veg	This site occurs within the Soweto Highveld Grassland vegetation type, which has an endangered conservation status with 52.7% of the type remaining and only 0.2% protected.
Diatoms	Three diatom samples were taken at the site (September and December 2007, and April 2008) and 2003 diatom data was also available (Taylor, 2004). The overall biological[2] water quality EC is a C, but there are indications that the water quality deteriorates markedly during the months of March and September – November. The Specific Pollution Index (SPI[3]) during these months indicates an increase in nutrient load, ionic concentrations and organic pollution. Due to the transfer schemes (Heysope and Zaaihoek) that cause elevated base flows there seems to be a dilution effect on the water quality.

4.3 MAIN IMPACTS AT THE SITE

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
WQ	C	Increased TDS.	Diffuse impacts originating from coal mines. Cattle grazing.	NF
		Some indication of phosphate contamination.	Agriculture.	
		Temperature changes.	Interbasin transfer and Perdewaterspruit.	F
Geom	B/C	Elevated base flows are causing river bank cutting and likely decreased beds and bars.	Interbasin transfers.	F
		Reduced sediment supply.	Small dams.	
Rip veg	A/B	Vegetation removal.	Some trampling/grazing pressure, but minimal impact.	NF
		Exotic invasion.	<10%, *Salix babylonica* and non-woody weeds mainly.	
		Water quantity.	Reduced sedge cover in marginal zone due to increased dry season base flows, but the same cause has increased sedge cover and vigour in the lower zone.	F
Fish	C	Loss of habitat (decreased SS and SD) diversity as a result of flow modification (especially during natural low flow periods).	Interbasin transfer.	F
		Decreased overhanging vegetation as cover for fish.	Increased bank erosion related to agricultural and livestock farming activities.	NF
		Increased sedimentation results in deterioration of substrate as habitat (clogging interstitial spaces, loss of important spawning habitats, etc.).	Bank erosion and dryland crops.	
		Decreased substrate quality related to increased benthic growth.	Effluents from mines and agricultural areas.	
		Decreased water quality affect species with requirement for high water quality.		
		Decreased species diversity and abundance (especially small species) as result of presence of aggressive alien predator (*Micropterus salmoides*).	Presence of aggressive alien predatory species (*M. salmoides*) naturally spreading and introduced for recreation / angling.	

[2] Diatoms are primary producers and form the base of the aquatic foodweb. Within the EcoClassification process diatoms are used as an additional response variable to physico-chemical information and therefore reference is made to biological water quality.
[3] A diatom based water quality index. The index evaluates organic and inorganic pollution based on the sensitivity of each taxon, while taking into account the response of the whole diatom community (Almeida, 2001). The index is used to indicate general water quality.

	PES	Causes[1]	Sources[2]	F[3]/NF[4]
		Increased turbidity and disturbed bottom substrates.	Erosion and presence of bottom feeding alien *Cyprinus carpio*.	
		Presence of migration barriers reduces migration success (breeding, feeding and dispersal) of some species.	Grootdraai Dam and other major downstream dams as well as weirs. Also farm dams in tributaries reduce refuge areas.	
Inverts	C	Increased flows during dry season.	Interbasin transfer.	F
		Water temperature shocks.		
		Water quality and associated benthic growth.	Agriculture and mining.	NF

1 **CAUSE:** A stressor that occurs at an intensity, duration and frequency of exposure that results in a change in the ecological conditions.
2 **SOURCE:** A source is the origin of a stressor. It is an entity or action that releases or imposes a stressor into the waterbody (EPA, 2000).
3 Flow related 4 Non Flow related

4.4 RESULTS: PRESENT ECOLOGICAL STATE

Driver Components	PES	Trend
GEOMORPHOLOGY	B/C	Negative
WATER QUALITY	C	Stable
DIATOMS	C	
Response Components	**PES**	**Trend**
FISH	C	Negative
MACRO INVERTEBRATES	C	Stable
INSTREAM	C	
RIPARIAN VEGETATION	A/B	Stable
ECOSTATUS	B/C	

The PES of a C is due to a combination of flow and non-flow related impacts. Flow related impacts are mainly due to interbasin transfers (Heysope and Zaaihoek). Mining and agricultural activities in area has caused water quality deterioration and erosion.

4.5 SUITABILITY AS FUTURE BIOMONITORING SITE

The site is adequate for biotic monitoring and below the Heysope transfer. It seems that the water quality at this site is problematic as the fish show signs of serious bacterial infection and quality sensitive macroinvertebrates are absent. This is the first site within the Upper Vaal WMA and could therefore be included in monitoring programmes.

5 EWR 2: GROOTDRAAI (VAAL RIVER)

The information is summarised from DWA (2008a,b; 2009a; 2010a).

5.1 SITE DESCRIPTION

EWR 2 is located in MRU Vaal C which is delineated from Grootdraai to Vaal Dam in a riffle section immediately below Grootdraai Dam. All upstream sediment sources (with possibility of fines, maybe maintained through bottom releases) are being cut off bedrock banks. The channel is incised with paired low benches but terraces are absent. Exotic vegetation is present (20% cover). Fish habitat, flow-depth categories and cover is well represented at site. Due to flow modification unnatural habitat fluctuation is expected as well as unnaturally high abundances of species during migrations.

Location	EWR 2	**Altitude**	1537 m
Longitude	29.27929	**Latitude**	-26.9211
EcoRegion	Highveld/Southern Central Kalahari 11.03	**Quaternary catchment**	C11L
Water Management Area	Upper Vaal	**Geomorphological zone**	Lowland

EWR 2, Grootdraai, September 2007

5.1 PRESENT ECOLOGICAL STATE (PES)

Geom	The site is located immediately below Grootdraai Dam with bedrock banks and the channel is incised. There are large paired bars composed of fines which are well vegetated which is unusual. This is due to the bottom releases (large suspended/fines load) from Grootdraai Dam and the reduction of scouring moderate floods. No terraces are present. The site was a bedload system, but now upstream sediment supply is cut off due to Grootdraai Dam.
WQ	Data records (1979 - 2007 (n = 516)) from water quality station C1H019Q01 were used for the physico chemical PES assessment. The impacts of the higher TDS and sulphate values in the Blesbokspruit are attributed to the coal mining in the Ermelo area. There are also high phosphate concentrations (average 303 ug/l) as well as fairly high nitrogen concentrations from sewage and agricultural runoff. The impacts of the Blesbokspruit and Leeuspruit are attenuated in the Grootdraai Dam due to mixing with good water quality runoff and water transferred from Zaaihoek Dam, although phosphate levels are sufficient to drive algal blooms in the dam. The Grootdraai Dam is of strategic importance as it supplies water to power stations as well as Sasol (Secunda). The outflows of the dams are for downstream farmers and for domestic water in Standerton.
Fish	All the expected fish species is still present within this MRU. The FROC of *Labeobarbus kimberleyensis* and *Labeo capensis* have been altered potentially as a result of flow modification/fluctuations and deteriorated substrate quality related to benthic algal growth at times. Water quality deterioration can also not be excluded as potential contribution as *L. kimberleyensis* is moderately intolerant to water quality changes. The Frequency of Occurrence (FROC) of *Barbus anoplus*, *Pseudocrenilabrus philander* and *Tilapia sparrmanii*

	have also been reduced, potentially related to the presence of the aggressive alien predator *M. salmoides*, although alterations in slow habitats due to flow modification from Grootdraai Dam, as well as potential loss of cover (vegetation as result of bank erosion and sedimentation of substrates) may also have contributed to the present condition.
Inverts	Sep 07: SASS5 score: 141 No of Taxa: 25 ASPT: 5.6 Apr 08: SASS5 score: 110 No of Taxa: 25 ASPT: 5.0 Macroinvertebrate taxa were typical of impoundment outlets, with plenty of zooplankton discharged from Grootdraai Dam, and dominated by filter feeders (e.g. Tricorythidae, *Plumatella*, *Simulium damnosum, S. adersi*). Taxa that were expected but missing or scarce were mainly taxa that prefer slow-flowing water in the vegetation (e.g. Naucoridae, Hydroptilidae, Gyrinidae and Ceratopogonidae), and the gravel-sand-mud (GSM) habitat (e.g. Gomphidae, Tipulidae, Sphaeriidae and Corbiculiidae). This suggests that the main driver of macroinvertebrate composition is the release of water from Grootdraai Dam. Absence of blackflies in September 2007 is significant, and presumably linked to the release of bottom water. Impoundment-induced changes in temperature are likely to have highly significant impact on seasonality, as reflected by a massive emergence of Tricorythidae in April 2008 that was not seen at other sites along the river at that time. Four species of Hydropsychidae and the presence of Heptageniidae mayflies indicate that water quality is not a major problem.
Rip veg	The site occurs within the Soweto Highveld Grassland vegetation type, which has an endangered conservation status with 52.7% of the type remaining and only 0.2% protected. The channel morphology appears modified or landscaped. **Marginal zone:** Dominated by non-woody component (sedges) due to altered flow regime and increased fine alluvia. Vegetation removal and mowing occurs in the upper and lower zone and has led to a decrease in non-woody cover.
Diatoms	Two diatom samples were taken at this site (September and December 2007) and 2003 diatom data was also available (Taylor, 2004). The overall biological water quality EC is a C. The Leeuspruit and Blesbokspruit enter the Grootdraai Dam. The Leeuspruit has poor water quality with high levels of N and P (average 161 ug/l), which poses a threat to the long term trophic status of Grootdraai Dam. The nutrients are as a result of sewage plants in Bethal, Tukukani and New Denmark Colliery. The 2002 - 2003 monthly diatom monitoring data (Taylor, 2004) indicated that there was no drastic decline in water quality over the 12 month period and this was the only part of the Vaal that was classified as mesotrophic by Taylor (2004). It is assumed that the constant releases from Grootdraai Dam and the cleaner water from the Zaaihoek transfer were diluting water quality related impacts. The 2007 samples however indicate an increase in the presence of pollution tolerant diatoms and the water is classified as eutrophic. It is therefore evident that the biological water quality has deteriorated markedly from 2004 to present and that the buffer capacity of the Grootdraai Dam is impaired.

5.2 MAIN IMPACTS AT THE SITE

	PES	Causes	Sources	F/NF
WQ	B/C	Temperature fluctuations.	Grootdraai Dam.	F
		High levels of N and P.	Sewage plants in Bethal, Tukukani, New Denmark Colliery and agriculture.	NF
		Elevated TDS and sulphates.	Coal mining.	
Geom	D	Reduced sediment transport capacity due to decreased flood frequency and near constant baseflow.	Grootdraai Dam.	F
		Reduced sediment supply.	Coarse sediment is trapped in Grootdraai Dam which is immediately upstream. Some replenishment of fines through bottom releases from the dam.	NF
Rip veg	B/C	Increased non-woody (sedge) cover in marginal zone.	Grootdraai Dam.	F
		Reduced non-woody cover in lower and upper zones.	Vegetation removal, mowing.	NF
Fish	C	Altered habitat diversity (fluctuation from natural composition) as a result of flow modification.	Flow modification by Grootdraai Dam, other sources of abstraction upstream of dam and water transfer schemes.	F
		Decreased overhanging vegetation as cover for fish.	Increased bank erosion related to agricultural and livestock farming activities.	NF
		Increased sedimentation resulting in deterioration of substrate as habitat (clogging interstitial spaces, loss of important spawning habitats, etc.).	Bank erosion and dryland crops.	
		Decreased substrate quality related to increased benthic growth.	Increased nutrients from point and diffuse sources.	

	PES	Causes	Sources	F/NF
		Decreased water quality affect species with requirement for high water quality.	Bottom release from Grootdraai dam.	
		Decreased species diversity and abundance (especially small species) as result of presence of aggressive alien predator (*M. salmoides*).	Presence of aggressive alien predatory species (*M. salmoides*) naturally spreading and for recreation/angling.	
		Presence of migration barriers reduces migration success (breeding, feeding and dispersal) of some species.	Grootdraai Dam and other major downstream dams as well as various weirs. Also farm dams in tributaries reduce refuge areas.	
Inverts	C	Changed flow regime.	Grootdraai Dam.	F
		Temperature changes.		
		Release of bottom water.		

5.3 RESULTS: PRESENT ECOLOGICAL STATE

Driver Components	PES	Trend
GEOMORPHOLOGY	D	Stable
WATER QUALITY	B/C	Negative
DIATOMS	C	
Response Components	**PES**	**Trend**
FISH	C	Stable
MACRO INVERTEBRATES	C	Stable
INSTREAM	C	
RIPARIAN VEGETATION	B/C	Stable
ECOSTATUS	C	

The PES of a C is due to a combination of flow and non-flow related impacts. Impacts are mostly related to changes in flow regime due to Grootdraai Dam while agriculture and sewage impact the site as well.

5.4 SUITABILITY AS FUTURE BIOMONITORING SITE

The site is located just below Grootdraai Dam. Due to flow modification originating from Grootdraai Dam, habitat may be altered and the site is too high in the catchment to detect impacts lower downstream and not considered as a high priority site. However, as there are indications that water quality is deteriorating, this site should be included as a water quality monitoring site.

6 EWR 3: GLADDEDRIFT (VAAL RIVER)

The information is summarised from DWA (2008a,b; 2009a; 2010a).

6.1 SITE DESCRIPTION

EWR 3 is situated in Management Resource Unit (MRU) Vaal C immediately below a bridge near Villiers. The site is a riffle over a dyke across the river. The morphology is not representative of the reach, but although the bedrock riffle with no terraces is well represented. The banks are cut, and erosion is present in the right bank (RB) upper zone. Some paths on the lower and upper zone have resulted in bank erosion and there is up to 20% cover by exotics. Fish habitat, flow-depth categories and cover is well represented at site, but macroinvertebrate habitat is poor.

Location	EWR 3	**Altitude**	1487 m
Longitude	28.72971	**Latitude**	-26.99087
EcoRegion	Highveld/Southern Central Kalahari 11.03	**Quaternary catchment**	C12H
Water Management Area	Upper Vaal	**Geomorphological zone**	Lowland

EWR 3, Gladdedrift, April 2008

6.2 PRESENT ECOLOGICAL STATE (PES)

Geom	The site consists of bedrock and riffles. The bed is predominantly (>70%) bedrock, but cobbles/boulders are present in the main riffle and fines/mobile sediment are found in the lee and hollows of the bedrock bed. The cobbles in the main riffle have a median around 40 cm, but this is not representative of the reach which generally has a finer sediment load. There are no morphological cues and the banks are cut and steep. The upper level of the main channel bank is composed of quaternary sedimentary deposits which is highly dispersive. There is decreased transport capacity due to the altered flow regime, although the impact is less here than at EWR 2 due to the tributaries influence that ameliorate this impact. Sediment input is limited to a few tributaries, many of which are eroding and increasing the fines load causing an increase in islands at this site.
WQ	Data records (1984 - 2008 (n = 979)) from water quality station C1H017Q01 were used for the physico-chemical PES assessment. The water quality data that has been used for EWR 3 is downstream of EWR 3 and the Waterval confluence. It is important to note that EWR 3 is upstream of the impacts of the Waterval River. The Waterval catchment is impacted by effluents from Sasol 2 and 3, Evander Goldmine, Evander and Secunda. Phosphate values are relatively low although the total phosphate (TP) values are high. Nitrogen concentrations are low and electrical conductivity and sulphates do not seem problematic.
Fish	All the expected fish species are still present within this RU although the FROC of some species has been reduced from reference conditions. Increased siltation and flow modification have resulted in altered habitat conditions which include deteriorated substrate condition and the loss of fast shallow (FS) and slow deep (SD) habitats causing a reduced occurrence of *Austroglanis sclateri*, *L. kimberleyensis* and *L. umbratus*. Bank erosion and sedimentation of substrates has caused a loss in cover for T. sparrmanii as well as the presence of the alien predator *M. salmoides*.
Inverts	Sep 07: SASS5 score: 103 No of Taxa: 20 ASPT: 5.2 Apr 08: SASS5 score: 120 No of Taxa: 20 ASPT: 6.0 The macroinvertebrates present during low flow conditions in September 2007 were dominated by low-scoring

	taxa, such as Turbellaria and Chironomidae. The highest scoring taxon was Leptophlebiidae, and the ASPT was low (5.2). In April 2008 the flows were higher, and the ASPT increased to 6.0. The fauna was dominated by baetid mayflies (mainly *Baetis glaucus*) and the pest blackfly, *Simulium damnosum.* Taxa that were notably absent included those with a presence for SIC (Heptageniidae, Elmidae) and marginal vegetation (MV) (Atyidae, Hydracarina, Gerridae, Notonectidae and Dytiscidae).
Rip veg	The riparian zone occurs within Frankfort Highveld Grassland which has a conservation status of "Vulnerable" (although 65.8% of vegetation type remains). The riparian vegetation composition is close to reference, with some exotic vegetation and bank slumping occurring from the upstream bridge and cattle trampling. Vegetation is impacted by extensive livestock trampling, erosion due to the bridge and debris control. There is extensive harvesting of sedges for crafts.
Diatoms	Three diatom samples were taken at this site (September, December 2007 and April 2008) and 2003 diatom data was also available (Taylor, 2004), although only the September 2007 sample was viable as the flows during the other sampling effort was very high, and diatom counts were too low to provide results. The overall biological water quality EC is a C. The SPI score of the September 2007 sample was 14.4 indicating good water quality although the diatom community indicates the onset of severe water quality impacts with the presence of dominant species (*Nitzschia frustulum, Navicula reichardtiana* and *N. palea*) which tolerate very high to critical levels of pollution (Taylor *et al.*, 2007b). The 2002 - 2003 monthly monitoring data (Taylor, 2004) indicated that there were sharp declines in biological water quality during the months February, March, May and August (deterioration to a C/D and D EC) and the SPI scores indicate an increase in nutrient load, ionic concentrations and organic pollution. This is most likely due to increased agricultural activities and increased abstraction during this period as well as mines upstream of the site as well as Waste Water Treatment Works (WWTW) in Standerton. Salinity, nutrients and organic pollution are increasing and are variables of concern.

6.3 MAIN IMPACTS AT THE SITE

	PES	Causes	Sources	F/NF
WQ	C	Increased TP, some salinity and nutrients.	Agricultural runoff and as a result increased nutrients from point and diffuse sources (e.g. agriculture, Standerton WWTW, industrial and residential runoff).	NF
Geom	C	Decreased transport capacity as there is almost no floods.	Grootdraai Dam.	F
		Decreased sediment supply.		
		Morphological change: increased islands.	Due to increased fines load and decreased floods.	NF
Rip veg	C	Removal of vegetation.	Extensive trampling by livestock and erosion; small scale from cattle and large scale from bridge and debris control. Also extensive harvesting of sedges for crafts.	NF
Fish	C	Altered habitat diversity (fluctuation from natural composition) as a result of flow modification.	Grootdraai Dam, water transfer scheme upstream of Grootraai Dam, other sources of abstraction.	F
		Decreased overhanging vegetation as cover for fish due to bank erosion.	Agricultural and livestock farming activities.	NF
		Increased sedimentation result in deterioration of substrate as habitat (clogging interstitial spaces, loss of important spawning habitats, etc.)	Bank erosion and vegetation removal and dryland crops and grazing.	
		Decreased substrate quality related to increased benthic growth.	Increased nutrients from point and diffuse sources (e.g. agriculture, Standerton WWTW, industrial and residential runoff).	
		Decreased water quality affect species with requirement for high water quality.		
		Decreased species diversity and abundance (especially small species) as result of presence of aggressive alien predator (*M. salmoides*) and *Gambusia affinis*..	Presence of aggressive alien predatory species (*M. salmoides*) naturally spreading for recreation/angling.	
		Increased turbidity.	Erosion and presence of bottom feeding alien *C. carpio*.	
		Loss of aquatic vegetation (AV) and MV as cover for fish.	Potential presence of herbivorous alien *Ctenopharyngodon idella* (grass carp).	
		Presence of migration barriers reduces migration success (breeding, feeding and dispersal) of some species.	Grootdraai Dam upstream and Vaal Dam downstream, as well as other major dams and various weirs. Farm dams in tributaries reduce refuge areas.	

	PES	Causes	Sources	F/NF
Inverts	C	Reduced baseflows.	Grootdraai Dam.	F
		Water quality (nutrients).	Agricultural runoff.	NF

6.4 RESULTS: PRESENT ECOLOGICAL STATE

Driver Components	PES	Trend
GEOMORPHOLOGY	C	Stable
WATER QUALITY	C	Stable
DIATOMS	C	
Response Components	**PES**	**Trend**
FISH	C	Stable
MACRO INVERTEBRATES	C	Stable
INSTREAM	C	
RIPARIAN VEGETATION	C	Stable
ECOSTATUS	C	

The PES is a C mainly due to impacts relating to changes in flow regime due to Grootdraai Dam, illegal irrigation, livestock farming and vegetation removal.

6.5 SUITABILITY AS FUTURE BIOMONITORING SITE

OSAEH 11.2 and EWR 3 are close together and is in the lower reach of the MRU and therefore will be a valuable site to detect upstream impacts. However the site is upstream of the Waterval River confluence and therefore the deteriorated water quality entering the Vaal River from the Waterval catchment will not be detected.

7 EWR 4: DENEYS (VAAL RIVER)

The information is summarised from DWA (2008a,b; 2009a; 2010a).

7.1 SITE DESCRIPTION

EWR 4 occurs in MRU Vaal D which is delineated from the Vaal Dam to the Vaal barrage. The site is immediately below Vaal Dam and consists of a bedrock riffle rapid across the river. Morphology is not representative of the reach and site conditions are better than the reach which is mostly affected by the dam/barrage backwaters). Small scale erosion is present due to trampling, and large scale erosion is due to the bridge which has caused minor channel manipulation. Fish habitat is fairly well represented at site and habitat requirements are also met at site. Slow (especially slow-deep (SD)) habitats had to be supplemented by sampling another site. Macroinvertebrate habitat is moderate.

Location	EWR 4	**Altitude**	1445 m
Longitude	28.1123	**Latitude**	-26.84262
EcoRegion	Highveld/Southern Central Kalahari 11.03	**Quaternary catchment**	C22F
Water Management Area	Upper Vaal	**Geomorphological zone**	Lower Foothills

EWR 4, De Neys, August 2007

7.2 PRESENT ECOLOGICAL STATE (PES)

Geom	The multi-thread straight channel is within a bedrock anastomosing section below the Vaal Dam. The channel is dominated by bedrock with cobbles and consists of morphological units that include rapids, riffles, bedrock runs, shallow pools, vegetated islands and secondary channels. Sediment supply is reduced as well as coarsening of the bed material, which is essentially absent due to critically reduced moderate and large floods. Moderate and large floods have been critically reduced. The banks are disturbed by farming and housing.
WQ	Data records from water quality station C2H122Q01 and Rand Water data from CV2: Engelbrecht's Drift (2003 – 2005; n = 225) were used for the physico-chemical PES assessment. The data indicates that there is phosphate contamination due to agricultural runoff into the Vaal Dam. Nitrogen concentrations, salts and faecal coliforms are low at this site. The water temperature is increased due to the dam releases while oxygen levels are high. Turbidity is highly variable due to runoff and natural soils but generally low due to settling in the dam. Chl-a is seasonally high due to algal blooms in the Vaal Dam.
Fish	All the expected fish species is still present within this RU although the FROC of some species has been reduced from reference conditions. The FROC of *A. sclateri* have been reduced from reference conditions, probably related to deteriorated substrates condition (increased siltation) as well as decreased flows (loss of FS habitats) and fluctuations. The FROC of *L. kimberleyensis*, *Labeobarbus aeneus* and *Labeo capensis* has been altered potentially as a result of flow modification (decreased flow and therefore fast habitat) deteriorated substrate quality related to benthic algal growth and siltation as well as potential water quality deterioration.

	FROC of *L. umbratus* has also been reduced, potentially related to loss of SD habitats (siltation and decreased flows). The FROC of *B. anoplus* and *T. sparrmanii* have also been reduced potentially related to the presence of the aggressive alien predator *M. salmoides*, although alterations in slow habitats as a result of flow modification as well as potential loss of cover (vegetation as result of bank erosion and sedimentation of substrates) may also have contributed to the scenario.
Inverts	Aug 07: SASS5 score: 131 No of Taxa: 20 ASPT: 6.6 Apr 08: SASS5 score: 120 No of Taxa: 18 ASPT: 6.7 Taxa expected but not present are mainly taxa that prefer standing water (Gerridae; Notonectidae; Veliidae; Dytiscidae; Oligochaeta). These are mainly low-scoring SASS taxa, which explain why the present ASPT is significantly higher than expected. The scarcity of taxa that prefer standing water is related to high base flows. The SASS scores are high in relation to the quality of habitats, and this supports the Macroinvertebrate Response Assessment Index (MIRAI) results. The reduced seasonal variation in water temperature is likely to have changed significantly from reference conditions because of the buffering effect on temperature by Vaal Dam.
Rip veg	The current and historic vegetation type is Andesite Mountain Bushveld of which 85% of this vegetation type is remaining and it has a conservation status of "Least threatened". **Marginal Zone:** Is dominated by non-woody vegetation with small woody (S. mucronata and *G. virgatum*) component. Cover is reduced due to increased base flows. **Lower Zone:** Is as the marginal zone and merged (both zones inundated more frequently than expected). There is an increased occurrence of exotic woody species due to reduced moderate flows. **Upper Zone:** Is dominated by grassland with rocky tree/shrub mix. It is largely modified due to anthropogenic activities. Reduced cover and abundance of species due to exotic species and recreational housing in the area.
Diatoms	Three diatom samples were taken at this site (August 2007, January and April 2008) and 2003 diatom data was also available (Taylor, 2004). The overall biological water quality EC is a C. The SPI score of the August 2007 sample was 6.5 indicating poor water quality. Of the 16 species present, 11 species (e.g. *Mayamaea atomus var. permitis*, *Navicula veneta, Nitzschia palea and Amphora pendiculus*) are tolerant to critical levels of pollution and their presence indicate very high pollution which may be due to a source point pollution at the site or mixed releases from the Vaal Dam. The 2002 - 2003 monthly monitoring data (Taylor, 2004) indicated moderate water quality (C category). No drastic decline in water quality was observed during the 12-month monitoring period which is most probably due to the required releases from the Vaal Dam to maintain a target TDS concentration of 600 mg/l downstream of Vaal Barrage. Both 2008 samples are similar to the 2002 – 2003 data although slightly deteriorated. Salinity and organic pollution has increased from 2002 and is problematic at this site along with nutrient input. It is evident that pollution levels in the Vaal Dam are increasing and may be more polluted than is generally thought.

7.3 MAIN IMPACTS AT THE SITE

	PES	Causes	Sources	F/NF
WQ	C	Fluctuations in temperature.	Vaal Dam.	F
		Phosphate contamination.	Agricultural runoff entering Vaal Dam.	NF
Geom	D	Transport capacity impacted by decreased frequency of moderate floods.	Vaal Dam.	F
		Sediment supply – sediment is trapped in the dam although small tributaries are replenishing some of the bed sediment.		
		Connectivity – loss of floods has almost severed connectivity between active channel and upper islands/riparian zones.		
Rip veg	C	Reduced vegetation cover in marginal zone.	Vaal Dam.	F
		Increased occurrence of exotic woody species in lower zone.		
		Reduce cover, abundance and species composition throughout all zones.	Exotic species and recreational houses.	NF
Fish	C	Altered habitat diversity (fluctuation from natural composition).	Flow modification due to Vaal Dam, the barrage and other sources of abstraction.	F
		Decreased overhanging vegetation as cover for fish.	Increased bank erosion related to agricultural and livestock farming and recreational activities.	NF
		Increased sedimentation result in deterioration of substrate as habitat (clogging interstitial spaces, loss of important spawning habitats, etc.).	Bank erosion and vegetation removal (grazing) contribute to increased sedimentation.	
		Decreased substrate quality related to increased benthic growth.	Increased nutrients from point and diffuse sources (agriculture).	

	PES	Causes	Sources	F/NF
		Decreased water quality affect species with requirement for high water quality.	Bottom released from Vaal Dam, agricultural activities.	
		Decreased species diversity and abundance (especially small species) as result of presence of aggressive alien predator (*M. salmoides*) and *G. affinis*.	Presence of aggressive alien predatory species (*M. salmoides*) naturally spreading and introduced for recreation / angling.	
		Increased turbidity.	Erosion and presence of bottom feeding alien *C. carpio.*	
		Decreased bottom substrate quality.	Impact of bottom feeding alien *C. carpio.* and siltation.	
		Loss of AV and MV as cover for fish.	Potential presence of herbivorous alien *C. idella* (grass carp).	
		Presence of migration barriers reduces migration success (breeding, feeding and dispersal) of some species.	Vaal Dam upstream and Lethabo weir and Vaal Barrage downstream, as well as other major dams and various weirs. Farm dams in tributaries reduce refuge areas.	
Inverts	C/D	Elevated and constant baseflow releases from Vaal Dam.	Vaal Dam.	F
		Water temperature fluctuations are buffered, and seasonality probably changed significantly		F

7.4 RESULTS: PRESENT ECOLOGICAL STATE

Driver Components	PES	Trend
GEOMORPHOLOGY	D	Stable
WATER QUALITY	C	Stable
DIATOMS	C	
Response Components	**PES**	**Trend**
FISH	C	Stable
MACRO INVERTEBRATES	C/D	Stable
INSTREAM	C	
RIPARIAN VEGETATION	C	Negative
ECOSTATUS	C	

The PES EcoStatus is a C mostly due to flow related problems, especially the presence of Vaal Dam and lack of flow variability. Increased base flows (dry season) occur as well as reduced frequencies of moderate floods due to releases from the Vaal Dam to maintain a target TDS concentration of 600 mg/l downstream of Vaal Barrage. Present Day flows are higher than natural and seasonal reversal has occurred at this site.

7.5 SUITABILITY AS FUTURE BIOMONITORING SITE

This site is situated just below the Vaal Dam and represents critical habitat in the reach as the rest of the reach is inundated by the Vaal Barrage. This site is however too close to the Vaal Dam to detect any major impacts and access to the site is difficult as Rand Water controls access.

8 OSAEH 11.13 (VAAL RIVER)

Originally it was planned to sample OSAEH 11.13 which is situated upstream of Parys in the Kromelmboogspruit which is a tributary of the Vaal River. However the site visit had to coincide with a planned PR event and an alternative site had to be selected in order to accommodate this event. A new site was selected at Parys in the Vaal River main stem.

8.1 SITE DESCRIPTION

The sampling site is situated in Parys on the RB just after the R53 road bridge. The site is bedrock dominated with multiple channels. The substratum at the sampling site is slightly embedded with sediments and algae were present on the cobbles. The marginal vegetation is very well developed as a result of the available nutrients. The abundance of watercress (*Rorippa nasturtium-aquaticum*) is often an indication of excessive nutrients entering the system. The site has a diversity of instream habitats available.

Location:	Parys	**Altitude:**	1376 m
Longitude:	27.444185	**Latitude:**	-26.898356
EcoRegion	Highveld 11.01	**Quaternary catchment**	C23C
Water Management Area	Upper Vaal	**Geomorphological zone:**	Lower foothills

OSAEH 11.13 Good marginal vegetation in the multi channel section of the river.

8.2 SAMPLING CONDITIONS

The site is situated upstream of a road bridge at the town of Parys. The macro channel is >100m wide at the site. The site has a diversity of instream habitats available for macroinvertebrate colonization. Filamentous algae are present on the cobbles, restricting colonization by macroinvertebrates. There is abundant, diverse marginal vegetation. The abundance of watercress (*Rorippa nasturtium-aquaticum*) is often an indication of excessive nutrients entering the system. At the time of sampling, moderate flow was present.

8.3 PRESENT ECOLOGICAL STATE

IIHI	The Instream Index of Habitat Integrity (IIHI) was rated a C/D (57.5%). This is mostly due to changes in water quality as a result of extensive upstream urban and mining runoff as well as some cultivation. The hydrology has also changed significantly due to upstream inundation and flow modification.
RIHI	The Riparian Index of Habitat Integrity (RIHI) is a C (63.3%) with the main impacts being bank modification in the marginal and non-marginal zones due to altered hydrological regimes, an increase in exotic vegetation, riparian irrigation, trampling, erosion and vegetation removal.
Fish	Six of the ten expected fish species were collected within this Resource Unit (RU) during the present survey suggesting that the FROC of some species has been reduced from reference conditions. Based on their absence or low abundance of smaller species such as *B. trimaculatus*, *B. paludinosus, P philander* and *T sparrmanii* the FROC at this site was rated to be reduced from reference. Although *L umbratus and L. kimberleyensis* was not collected at this site during the present survey, the sampling site did not provide suitable habitat for these species. The FRAI model rates the Present Ecological State for fish as a Class C

	(62.3%).
Inverts	Oct 2010: SASS5 score: 126 No of Taxa: 22 ASPT: 5.7 Key taxa expected but not observed included Aeshnidae and Libellulidae. Hirudinea, Dytiscidae, Tricorythidae and Elmidae were more abundant than expected, while Heptageniidae were less abundant than expected. The MIRAI model generates a Present Ecological State for macroinvertebrates as a Category C (77.3%).
Rip veg	This site occurs within the Vredefort Dome Granite Grassland vegetation type, which has an endangered conservation status with 0% protected. Almost half of this vegetation type is already transformed by cultivation (maize fields), by urban development or by road building. Riparian vegetation (C EC, 71.5%).
Diatoms	The October 2010 sample indicated moderately polluted waters with low organic levels and elevated nutrient levels. A release was made a few days before sampling and this could have had a dilution effect of pollutants. This reach is known for deteriorated water quality at times as sewage is discharged just upstream of the site by Parys municipality. The overall EC of a C/D is based on data used for the Reserve study (See EWR 5), and it should be noted that salinity levels along with nutrient and organic levels do increase to critical levels in this reach at times.

8.4 MAIN IMPACTS AT THE SITE

	PES	Causes	Sources	F/NF
Rip veg	C	Footpaths and firewood collection.	Picnic and recreation facilities in and adjacent to study site.	NF
		Exotic invasion.	*Salix babylonica, Gleditsia triacanthos,* and *Eucalyptus* sp., and the site has non-woody weeds.	
		Water quality.	Chicken farms, non-point pollution, sewage plants, recreation facilities, etc. Housing developments on the banks of the Vaal River.	F
Fish	C	Loss of habitat diversity as a result of flow modification.	Inundation upstream and flow modification.	F
		Decreased water quality affect species with requirement for high water quality.	Increased nutrients, sediments and toxins from urban areas diamond & gold mines and agricultural areas.	NF
		Increased turbidity and disturbed bottom substrates.	Erosion and presence of bottom feeding alien (*C carpio*).	
		Presence of migration barriers reduces migration success (breeding, feeding and dispersal) of some species.	Major upstream and downstream dams as well as weirs.	
Inverts	C	Sedimentation.	Urbanization and agriculture.	NF
		Water quality and associated benthic growth.	Agriculture and urbanization.	

8.5 BASELINE SURVEY RESULTS: PRESENT ECOLOGICAL STATE

Driver Components	PES	Trend
IHI: INSTREAM	C/D	
IHI: RIPARIAN	C	
DIATOMS (WQ)	C	
Response Components	**PES**	**Trend**
FISH	C	Stable
MACRO INVERTEBRATES	C	Stable
INSTREAM	C	
RIPARIAN VEGETATION	C	Stable
ECOSTATUS	C	

The main reasons for the Present Ecological State (PES) EcoStatus of a C are increased nutrients, sediments and toxins from urban areas, mining and agriculture. Flow modification due to inundation from upstream dams and weirs also impacts the site negatively. Dams and weirs also create migration barriers for the movement of biota, impacting negatively on their breeding, feeding and dispersal success.

8.6 SITE SUITABILITY AS FUTURE BIOMONITORING SITE

This site has diverse instream habitat available for SASS sampling. Good quantity of cobbles, marginal vegetation in and out of current, stones out of current and GSM biotopes are available. Algal growth is present on the cobble biotope. The site is easily accessible with wadeable areas. The fast deep habitat provides suitable habitat for larger fish species. The diversity of substratum provides good cover for all fish species. The site provides an abundance of undercut banks, marginal and overhanging vegetation as suitable habitat for small fish species. The marginal riparian zone has relatively good vegetation cover. No erosion is present in the marginal zone, although localised impacts are present along with exotic vegetation.

Although OSAEH 11.13 in the Kromelmboogspruit was proposed this site may be better suited as a monitoring site as it is located at Parys and would detect upstream impacts. This reach is very important as the Vredefort Dome World Heritage site is located just downstream of this point. The reach is especially impacted by deteriorated water quality entering the Vaal from the Klip and Suikerbosrand Rivers.

9 EWR 5: SCANDINAVIA (VAAL RIVER)

The information is summarised from DWA (2008a,b; 2009a; 2010a).

9.1 SITE DESCRIPTION

MRU Vaal E is delineated from the Vaal Barrage to the end of the Water Management Area (WMA). The site is 10 km upstream of the Mooi River confluence and the lowest EWR site situated in the Vaal River. The cross-section runs across a bedrock/boulder riffle area, but the reach characterised by generally long pools. Well developed alluvial terraces are present with minor landscaping and boulder piling. There is a high incidence of exotic species in some places with some landscaping occurring on the RB. Fish habitat, flow-depth categories and cover is well represented at site although fast habitats were limited and was supplemented by sampling another site. Macroinvertebrate habitat is moderate.

Location	EWR 5	**Altitude**	1309 m
Longitude	27.01367	**Latitude**	-26.93243
EcoRegion	Highveld/Southern Central Kalahari 11.08	**Quaternary catchment**	C23L
Water Management Area	Upper Vaal	**Geomorphological zone**	Lowland

EWR 5, Scandinavia, August 2007

9.2 PRESENT ECOLOGICAL STATE (PES)

Geom	The site is a bedrock/boulder riffle area, but the reach is characterised by generally long pools. There are limited impacts at the site. Although flow regulation effects from Vaal Dam and the Vaal Barrage are still prominent, these are ameliorated by tributaries. Islands are still common in the reach, suggesting that sediment supply is not critically reduced. The site has pronounced alluvial terraces on the north bank.
WQ	Data records from water quality station C2H018Q01 (1979 – 2008; n = 1227) and Rand Water data from V17: Barrage outlet (2003 – 2008; n = 226) were used for the physico-chemical PES assessment. Turbidity is variable due to releases from the Vaal Barrage but the Barrage also allows for settlement. There are seasonal water quality changes due to high flushes from the Vaal Dam which negate the return flows from the WWTWs. It is suspected that the town of Parys is also a major point source polluter in this reach due to the uncompliant WWTW.
Fish	All the expected fish species is still present within this RU. The FROC of both *A. sclateri* and *L. kimberleyensis* have been reduced from reference conditions, probably related to deteriorated substrate condition (increased siltation and algal growth) as well as decreased flows (loss of fast habitats) and fluctuations and deteriorated water quality. The FROC of *L. umbratus* has been reduced, potentially related to loss of SD habitats (siltation and decreased flows). The FROC of *B. anoplus*, *B. trimaculatus* and *B. paludinosus* have also been reduced, potentially related to the presence of the aggressive alien predator *M. salmoides* and other alien fish species contributes to the deterioration in habitat quality (*C. carpio* and *C. idella*). Alterations in slow habitats as a result of flow modification as well as loss of cover (vegetation as result of bank erosion and sedimentation of substrates) may also have contributed to their decline as well as the presence of hyacinth. Predation on

	indigenous fish larvae by *G. affinis* may also have an impact on the occurrence of smaller fish species.
Inverts	Aug 07: SASS5 score: 103 No of Taxa: 19 ASPT: 5.4 Apr 08: SASS5 score: 102 No of Taxa: 17 ASPT: 6 The most notable taxa that were absent from this site were those that are sensitive to water quality changes. These included Perlidae, Ancylidae, Heptageniidae and Prosopistomatidae. The SASS scores are extremely low in relation to the quality of biotopes available. Overall the data indicate that the macroinvertebrate composition is driven mainly by deterioration in water quality, and elevated winter base flows. The abundance of water hyacinth is likely to have a major influence on oxygen levels, and this could partly explain why sensitive macroinvertebrates are absent from or scarce at this site. Physidae were recorded at the site in August 2007. The species was not recorded but it was presumably *Physa acuta*, which is an exotic species that could impact on local snail species. Elevated base flows during winter allow pest blackfly populations to overwinter, and this leads to major problems with outbreaks of blackflies, particularly in spring.
Rip veg	The current vegetation type is Rand Highveld Grassland, which is endangered with only 0.9% of the vegetation type protected and 58.5% remaining. There is reduced cover, abundance and species composition throughout all zones due to the presence of exotic species. Increased low flows facilitate more exotic woody species in lower zone and increased terrestrialization (*Acacia karoo*).
Diatoms	Three diatom samples were taken at this site (August 2007, January and April 2008) and 2003 diatom data was also available (Taylor, 2004). The data indicates high salinity levels due to mine water decants from Witwatersrand and high nutrient levels due to waste water treatment works discharges and informal settlement runoff. This has led to seasonal algal growth (rooted macrophytes, filamentous, exotic and floating). Diffuse runoff from un-sewered areas leads to seasonally high microbiological contamination. Chlorophyll-a values are seasonally high. High ammonia values are evident as well as occasional high metal values due to mining and industrial discharges into and directly downstream of the Vaal River Barrage. Water temperature is elevated due to warming due to weirs while there are diurnal fluctuations in DO due to algal growth and releases from the Vaal Barrage. SPI scores ranged between 6.9 – 9.9 for samples taken during 2007 – 2008 (moderate – bad water quality) and the overall biological water quality EC is a C/D. All samples indicated deteriorated water quality due to highly urbanised industrialised and intensely mined areas of Southern Gauteng. The 2003 data shows that water quality conditions deteriorate alarmingly to unacceptable levels for survival of biota, and general recreational activities (E/F EC) at Goosebay canyon and Schoemansdrift. Metal contamination is evident and the diatom communities of all three samples have a dominance of species that are tolerant of high to critical levels of pollution indicate industrially impacted waters.

9.3 MAIN IMPACTS AT THE SITE

	PES	Causes	Sources	F/NF
Water Quality	E	High salinity. High nutrients which has led to seasonal algal growth – rooted macrophytes, filamentous, exotic and floating. Chlorophyll-a values seasonally high.	Mine water decants from Witwatersrand. WWTW treatment works discharges and informal settlement runoff. Mining and industrial discharges into and directly downstream of the Vaal River Barrage.	NF
		High microbiological contamination.	Diffuse runoff from unsewered areas leads to seasonally dense algal blooms and diurnal oxygen fluctuations.	
			Input from Klip River and Rietspruit that are a combination of microbial input from uncompliant WWTW such as Sebokeng works and Parys and Vereeniging works as well as diffuse runoff from unserviced areas.	
		High ammonia values.	Seasonal water quality changes due to high flushes from Vaal dam which negate the return flows from the waste water treatment works.	F
		Occasional high metal values.		
Geomorphology	C	Deceased transport capacity. Moderate floods are very reduced and prolonged elevated base flows.	Upstream dams (Vaal Dam and farm dams).	F
		Connectivity – loss of floods has reduced connectivity between active channel and upper islands/riparian zones.	Vaal Dam.	
		Sediment supply is altered due to dams and catchment erosion.	Erosion from the agricultural areas has increased sediment supply, and this might offset the effects of the Vaal Barrage and Vaal Dam.	NF
Rip veg	D	Reduced vegetation cover in marginal zone.	Increased low flows – Vaal Dam and Barrage.	F
		Facilitates more exotic woody species in lower zone and increased terrestrialization (*Acacia karoo*).		
		Reduced cover, abundance and species composition throughout all zones.	Exotic species.	NF

	PES	Causes	Sources	F/NF
Fish	C	Altered habitat diversity (fluctuation from natural composition) as a result of flow modification.	Flow modification by Vaal Barrage, other sources of abstraction.	F
		Decreased overhanging vegetation as cover for fish.	Increased bank erosion related to agricultural and livestock farming and recreational activities.	NF
		Increased sedimentation result in deterioration of substrate as habitat (clogging interstitial spaces, loss of important spawning habitats, etc.).	Bank erosion and vegetation removal (grazing) contribute to increased sedimentation.	
		Decreased substrate quality related to increased benthic growth.	Increased nutrients from point and diffuse sources.	
		Decreased water quality affect species with requirement for high water quality.	Diffuse effluent from industrial activities and agriculture. Excessive exotic macrophytes contribute to oxygen fluctuation.	
		Decreased species diversity and abundance (especially small species) as result of presence of aggressive alien predator (*M. salmoides*) and G. affinis.	Presence of aggressive alien predatory species (*M. salmoides*) naturally spreading and introduced for recreation/angling.	
		Increased turbidity reduces predatory success (*L. kimberleyensis*, *Clarias gariepinus*).	Erosion and presence of bottom feeding alien *C. carpio*.	
		Decreased bottom substrate quality.	Impact of bottom feeding alien *C. carpio* and siltation.	
		Loss of AV and MV as cover for fish.	Presence of herbivorous alien *C. idella* (grass carp).	
		Presence of migration barriers reduces migration success (breeding, feeding and dispersal) of some species.	Vaal Barrage upstream and Goosebay weir, as well as other major dams and various weirs. Also farm dams in tributaries reduce refuge areas.	
Inverts	C	Water quality.	Agriculture, and urban sewage and industrial waste (high metals).	NF
		Low oxygen.	Water hyacinth.	
		Elevated base flows in winter.	Releases from the Barrage, comprising mainly return flows from sewer works and mines.	F

9.4 RESULTS: PRESENT ECOLOGICAL STATE

Driver Components	PES	Trend
GEOMORPHOLOGY	C	Negative
WATER QUALITY	E	Negative
DIATOMS	C/D	
Response Components	**PES**	**Trend**
FISH	C	Stable
MACRO INVERTEBRATES	C	Stable
INSTREAM	C	
RIPARIAN VEGETATION	D	Negative
ECOSTATUS	C/D	

The PES EcoStatus is a C mostly due to a combination of flow and non-flow related impacts. Flow related impacts include increased base flows and reduced frequency of moderate floods due to

Vaal Dam and Barrage and releases to regulate TDS levels. Non-flow related impacts include agriculture, and urban sewage and industrial waste and the occurrence of gauges, weirs and dams in the system.

9.5 SUITABILITY AS FUTURE BIOMONITORING SITE

This site is situated at the end of the WMA and is impacted by major anthropogenic activities upstream. This site is situated within the Vredefort Dome World Heritage area and is therefore a very high priority monitoring site.

10 EWR 6: KLIP (KLIP RIVER)

The information is summarised from DWA (2008a,b; 2009a; 2010a).

10.1 SITE DESCRIPTION

EWR 6 is in MRU Klip C which extends from the Lower Foothill geomorphic zone to Lowland zone. The cross-section runs across a bedrock/boulder riffle area, and there are numerous such areas in the reach. The bed is alluvial (cobble- dominated). The left bank (LB) is bedrock, so no paired terraces occur. There is less than 20% undercutting, and stabilized by vegetation. An unnatural canal on upper zone is present and there is up to 40% cover by exotics. Fish habitat, flow-depth categories and cover is well represented at site but the presence of small weir at the site may alter natural habitat and species composition slightly. Macroinvertebrate habitat is moderate.

Location	EWR 6	**Altitude**	1593 m
Longitude	29.48503	**Latitude**	-27.36166
EcoRegion	Highveld/Southern Central Kalahari 11.06	**Quaternary catchment**	C13D
Water Management Area	Upper Vaal	**Geomorphological zone**	Lower Foothills

EWR 6, Klip, September 2007

10.2 PRESENT ECOLOGICAL STATE (PES)

Geom	The site is representative of the reach and consists of a bedrock/boulder riffle area, cobble beds with some fines; in a long reach consisting of dolerites. The right bank (RB) is bedrock, so no paired terraces occur. Upstream there is a large meandering floodplain located in the sandstone areas. There seems to be little impact on the site, and the bedrock nature of the river also makes the site relatively insensitive to flow changes. The site is a bedload system, and although there are dams far upstream, the fines component at the site suggests that the impact of the upstream dam is lessened due to subsequent tributary inputs of sediment.
WQ	Data records from water quality station C1H002Q01; Klip River at Sterkfontein/Delangesdrift (1974 – 2004; n = 1239) and Rand Water data from C-KD Klip River at Delangesdrif (2003 – 2008; n = 56) were used for the physico-chemical PES assessment. Increased organic pollution levels at the site are of concern and may be due to the presence of dead cows in the vicinity, observed during December 2007 and April 2008. There is evidence that the upstream wetland plays an important role in the filtration of water and improvement of water quality. This is evident from the presence of wetland diatom species e.g. *Pinnularia gibba*, *Diadesmis contenta* and *Tryblionella debilis* (September 2007 sample).
Fish	It is perceived that all the expected fish species are still present within this RU although the FROC of some species have been reduced from reference conditions. Although *Labeobarbus aeneus* and *B. pallidus* were not sampled during the current study, they have been sampled at site C1Klip-Unspe1 during 2001 (Kotze and Niehaus, 2001). It is estimated that the decreased FROC of *Labeobarbus aeneus* may be attributed to the decreased flow (which resulted in less habitat for breeding, feeding and refuge) and presence of migration barriers (weirs and farm dams). The FROC of *B. pallidus* (if it naturally occurred in this reach) may have been reduced by decreased water quality (the only moderately intolerant species expected), together with a loss of habitat.

Inverts	Sep 07: SASS5 score: 173 No of Taxa: 28 ASPT: 6.2 Apr 08: SASS5 score: 169 No of Taxa: 30 ASPT: 5.6 The site is in an excellent ecological state, despite the very low flows and limited biotopes present during the September 2007 site visit. Key indicators recorded at this site were taxa that are highly sensitive to deterioration in water quality, such as Polymitarcyidae, Oligoneuridae, Heptageniidae, Leptophlebiidae, Perlidae and Psephenidae. The only consistently missing taxon was Hydroptilidae.
Rip veg	The site falls within the Amersfoort Highveld Clay Grassland vegetation type, which has a conservation status of "Vulnerable" with 75.5% remaining. **Marginal zone:** Dominated by non-woody vegetation (mainly sedges and grasses). The zone is moderately impacted by the removal of sedge species. Exotic species (non-woody weeds) have a 10% presence and has a small impact on this zone. **Lower zone:** Dominated by non-woody vegetation (mainly sedges and grasses). Cover and species composition of the non-woody component has been reduced due to the high proportion of exotics (presence of 20 – 40% exotic non-woody weeds) and especially the shading impact of *S. babylonica*). There has also been vegetation loss due to soil erosion around *S. babylonica* trees. **Upper zone:** Is essentially a grass/tree/shrub mix and is seriously impacted by the presence of exotics (40 – 60% non-woody weeds mainly) and vegetation removal due to farming, roads and artificial canals. There is higher proportion of *Leucosidea* spp. due to canalisation.
Diatoms	Three diatom samples were taken at this site (September and December 2007, April 2008) and no additional data was available. SPI scores ranged between 12 – 12.8 for samples taken during 2007 – 2008 (moderate water quality) and the overall biological water quality EC is a B/C. The diatom samples and physico-chemical data indicates elevated nutrient and turbidity levels due to agricultural runoff. Due to the high seasonal sediment flows the turbidity is variable. Cattle trampling in the riparian and instream zone is present which may impact slightly on the water quality at the site. Overall the data set indicates low nitrogen and phosphate levels as well as low salt values and metal values are below detection limits.

10.3 MAIN IMPACTS AT THE SITE

	PES	Causes	Sources	F/NF
WQ	B/C	Variable turbidity.	High seasonal sediment flows.	F
		Elevated nutrients and salinity levels.	Agricultural runoff.	NF
		Benthic growth.	Cattle and agriculture.	
Geom	B	Slight reduction in system connectivity.	Small farm dams.	NF
		Increased sediment supply due to erosion in smaller tributaries, buffered somewhat by upstream wetland.	Cattle grazing.	
		Slight reduction in transport capacity due to reduction in base flows and moderate floods.	Presence of dams in the upper catchment.	F
Rip veg	B/C	Reduced non-woody cover.	Exotic species, especially *S. babylonica*.	NF
		Reduced or absent woody recruitment.	Reduced moderate floods.	F
		Reduced or absent woody recruitment.	Disturbance at the site, agricultural activities, roads within the riparian zone and sedge removal.	NF
Fish	B	Loss of habitat (decreased FS and fast deep (FD)) diversity as a result of flow modification (especially during natural low flow periods).	Dams in main stream and tributaries.	F
		Decreased overhanging vegetation as cover for fish.	Increased bank erosion related to agricultural and livestock farming activities.	NF
		Increased sedimentation resulting in deterioration of substrate as habitat (clogging interstitial spaces, loss of important spawning habitats, etc.).		
		Decreased substrate quality related to increased benthic growth.	Increased nutrients from point and diffuse sources.	
		Decreased water quality affect species with requirement for high water quality.	Effluents from mines and agricultural areas (pesticides).	
		Presence of migration barriers reduces migration success (breeding, feeding and dispersal) of some species.	Weirs in Klip River and also farm dams in tributaries reduce refuge areas.	
Inverts	B	Decreased low flows.	Abstraction and various small weirs.	F
		Nutrients and associated benthic growth.	Cattle.	NF
		Sedimentation.	Roads, farming activities.	

10.4 RESULTS: PRESENT ECOLOGICAL STATE

Driver Components	PES	Trend
GEOMORPHOLOGY	B	Stable
WATER QUALITY	B/C	Negative
DIATOMS	B/C	
Response Components	**PES**	**Trend**
FISH	B	Stable
MACRO INVERTEBRATES	B	Stable
INSTREAM	B	
RIPARIAN VEGETATION	B/C	Negative
ECOSTATUS	B/C	

The B/C PES EcoStatus is due to flow related impacts which include reduced base flows and moderate floods due to weirs and farm dams. Non-flow related impacts include agriculture, cattle grazing, and alien vegetation. The sole reason for the PES not being a B EcoStatus is because the current vegetation EC (B/C EC) is due to the high proportion of exotic species

10.5 SUITABILITY AS FUTURE BIOMONITORING SITE

The Klip River is largely natural and is an important tributary of the Vaal River, in terms of providing natural variable flow downstream of Grootdraai Dam (DWAF, 2009a). Considering the good condition of the site and the importance of this tributary it should be included in future monitoring programmes.

11 EWR 7: UPPER WILGE (WILGE RIVER)

The information is summarised from DWA (2008a,b; 2009a; 2010a).

11.1 SITE DESCRIPTION

MRU Wilge A extends from the origin of Wilge River to the confluence with the Nuwejaarspruit and EWR 7 is located in this reach. The site is a meandering floodplain area within an extensive reach, and generally little impacts are present, but Braamhoek pumped storage scheme is under construction in the upper reaches - approx 17 km upstream from the site. The meandering alluvial floodplain system has good morphological cues (ox-bows etc.) Only natural undercutting and slumping was observed on cutting bends of main channel and no channel manipulation was observed at site Fish habitat, flow-depth categories and cover is well represented at site although very limited stable flow-sensitive habitats are available, although the site is representative of this reach. Non-flow related impacts may have a negative impact on fish species (alien predatory bass) which may reduce the ability of site to sustain these species, and therefore reflect adequate flow conditions. While the channel was sufficient for sampling the floodplain was too extensive. Macroinvertebrate habitat is very poor.

Location	EWR 7	**Altitude**	1692 m
Longitude	29.55827	**Latitude**	-28.20185
EcoRegion	Highveld/Southern Central Kalahari 11.03	**Quaternary catchment**	C81A
Water Management Area	Upper Vaal	**Geomorphological zone**	Lowland

EWR 7, Upper Wilge, April 2008

11.2 PRESENT ECOLOGICAL STATE (PES)

Geom	This is a meandering floodplain area – representative of the whole reach. The system is a suspended load (fine silts and clays) dominated system and the site is near reference condition.
WQ	Data records from water quality station WMW (Wilge on Bethlehem Warden road) 2000 – 2002 were used for the physico-chemical PES assessment. There are elevated turbidity levels due to highly erodable soils and nutrient levels may be slightly elevated due to agriculture in the area.
Fish	It is perceived that all the expected fish species is still present within this RU. *L. aeneus* was the only indigenous species sampled at the site, but in very low abundance. The other two expected species (*B. anoplus* and *B. pallidus*) were absent, but have been sampled in the area previously. It is thought that their absence from the site and general low abundance in this reach is not habitat related (as habitat was optimal) but rather as a result of the presence of the predatory alien *M. salmoides*. The PES is D considering the impact of alien species. The habitat is however still optimal, and if alien species are not considered, a PES of

	B is calculated for this reach.
Inverts	Apr 08: SASS5 score: 108 No of Taxa: 19 ASPT: 5.7 The available instream aquatic biotopes were poor and limited to a small riffle upstream of a road bridge. As such, the site was not suitable for the application of SASS5. The riffle was made up mainly by wood debris that had accumulated upstream of the bridge, plus small stones and gravels in current that provided reasonable habitat for flow-dependent species. The site provides the best available sampling instream biotopes, although it is unrepresentative of the type of stream, which is a meandering lowland system that is naturally devoid of fast-flowing water. Oxbow lakes were abundant in the area, and although the diversity of invertebrates in each of these lakes was low, each lake supported a different biota, so the invertebrate diversity of the combined lakes was high. The diversity of aquatic invertebrates was good, although the standard method of assessment (SASS5) could not be used because of the limited riffle habitats available, so the confidence in the assessment is low. The presence of the mayfly *Adenophlebia auriculata* indicates excellent quality water. Taxa expected but not found were Turbellaria, Hydracarina, Hydraenidae and Hydrophilidae.
Rip veg	The site falls within the Eastern Free State Sandy Grassland vegetation type which has a conservation status of "Endangered", with 55.3% remaining and only 1.8% protected. Reduced cover and changed species composition is present due to minor exotic species component.
Diatoms	Three diatom samples were taken during the site visit. One sample was taken upstream of the cross section at a roadbridge the other at the cross section one in an oxbow lake adjacent to EWR 7. The diatom samples indicate that there is minimal impact on this site, with the water being generally circumneutral, and oxygen rich.

11.3 MAIN IMPACTS AT THE SITE

	PES	Causes	Sources	F/NF
WQ	B	Elevated turbidity.	Erodable soils.	NF
		Slightly elevated nutrient levels.	Agriculture.	
Geom	A	System connectivity.	A few small farm dams are very slightly reducing connectivity.	NF
		Sediment supply.	Small change in sediment supply from the catchment due to a few small farm dams as well as fire and grazing in the upper catchment areas.	
Rip veg	A/B	Some reduced cover and changed species composition.	Minor exotic species component. Presence of roads in the wetland. Mowing of wetland grasses.	NF
Fish	B (D)	Decreased species diversity and abundance (especially small species) as result of presence of aggressive alien predator (*M. salmoides*).	Presence of aggressive alien predatory species (*M. salmoides*) naturally spreading and introduced for recreation/angling.	NF
Inverts	B	Predation by exotic fish.	*M. salmoides*.	NF
		Periodic elevated levels of ammonia.	Cattle Farming.	

11.4 RESULTS: PRESENT ECOLOGICAL STATE

Driver Components	PES	Trend
GEOMORPHOLOGY	A	Negative (B/C)
WATER QUALITY	B	Negative (B/C)
DIATOMS	B	
Response Components	**PES**	**Trend**
FISH	B (D)	Negative (D/E)
MACRO INVERTEBRATES	B	Stable
INSTREAM	B	
RIPARIAN VEGETATION	A/B	Stable
ECOSTATUS	A/B	

The PES EcoStatus of an A/B is mainly due to non-flow related impacts that include small dams for agriculture and exotic fish species (*M. salmoides*). It must however be noted that in lieu of the Braamhoek pump storage scheme development the trend is negative for Driver components. New dams (Eskom pumped storage scheme) coming online and will cause reductions in baseflows, as well as likely changes to moderate floods which will impact geomorphology while water quality may deteriorate due to increased turbidity and nutrient loading. It is estimated that the predatory alien *M. salmoides* may over the long term eradicate the indigenous barbs from the system, which would lead to a further decrease in ecological integrity.

11.5 SUITABILITY AS FUTURE BIOMONITORING SITE

EWR 7 is situated in the upper reaches of the Wilge River. As the Braamhoek pump storage scheme is under development this will impact the Wilge River and this site has a good location for detecting these impacts although suitable habitat for sampling is limited. It was noted during a field visit in 2009 to the Braamhoek pump storage scheme that biomonitoring is being conducted by Eskom as part of the Environmental Management Programme (EMP) requirements.

12 EWR 8: BAVARIA (WILGE RIVER)

The information is summarised from DWA (2008a,b; 2009a; 2010a).

12.1 SITE DESCRIPTION

EWR 8 in the Wilge occurs in MRU Wilge B which extends from Nuwejaarspruit to the Holspruit. The site is at the beginning of a bedrock gorge and not representative of most of the reach. The bedrock nature of the channel makes the banks insensitive to flow changes, and therefore not a good area for obtaining information on the condition of the river. There are no morphological cues in this predominantly fixed boulder dominated area. There are less than 10% exotic species at the site, and poplars are aggressive invaders locally. No channel manipulation was observed at site. Fish habitat, flow-depth categories and cover is well represented at site, but macroinvertebrate habitat is poor.

Location	EWR 8	**Altitude**	1573 m
Longitude	28.76778	**Latitude**	-27.80017
EcoRegion	Highveld/Southern Central Kalahari 11.03	**Quaternary catchment**	C82C
Water Management Area	Upper Vaal	**Geomorphological zone**	Lowland

EWR 8, Bavaria, December 2007

12.2 PRESENT ECOLOGICAL STATE (PES)

Geom	The moderate floods have been reduced and high (although infrequent) flush releases are made from Sterkfontein Dam. The banks are cut extensively on both sides upstream of the site (but at the site, which is near a gorge, the banks are largely bedrock and not sensitive to flow changes). This condition is probably in response to the infrequent releases from Sterkfontein Dam. Large volumes of exotic woody debris at the site suggest that bank erosion is accelerating and eroding the trees from the bank.
WQ	Data records from water quality station C8H014Q01 (1984 – 1992; n = 93) and Rand Water data from C-WH: Harrismith (2003 – 2008; n = 56) were used for the physico-chemical PES assessment. The site is impacted by WWTWs (Harrismith, Industriqwa, Warden and Tshiane) and receives diffuse runoff from agricultural, urban (Harrismith) and industrial activities (Industriqwa). Weirs occur in the system for the purposes of abstraction for purification purposes, fish dams and tankers. Sterkfontein Dam releases potentially have an impact on turbidity levels, habitat loss, decreased temperature and oxygen levels. Physico-chemical data indicates that nitrogen and phosphate concentrations are relatively low. There are indications that EC and sulphate levels reach seasonal winter highs and metal contamination is below detection limits.
Fish	All of the expected fish species are still present within this Resource Unit although the FROC of some species have been reduced from reference conditions. The most prominent reduction in FROC is evident in the small barb species (*B. anoplus*, *Barbus pallidus* and *B. paludinosus*), most probably related to the impact of the predatory alien *M. salmoides*. Some deterioration in habitats due to decreased flows and sedimentation has also impacted the overall ecological integrity slightly.
Inverts	Sep 07: SASS5 score: 118 No of Taxa: 22 ASPT: 5.4 Apr 08: SASS5 score: 115 No of Taxa: 23 ASPT: 5.0

	Biotopes were highly suitable for assessing the PES, particularly the stones-in-current (SIC) and stones-out-of-current (SOOC). However, flows were very low in September 2007, and there was limited habitat available. Biotopes that were notably scarce were sand and aquatic vegetation. The diversity of macroinvertebrates was relatively high, but most taxa were low scoring, so the ASPT was lower than expected. Taxa that were notably absent were high-scoring taxa that are sensitive to changes in water quality (Perlidae, Heptageniidae, Leptophlebiidae and Baetidae >2spp). Three species of Hydropsychidae were present.
Rip veg	The site occurs in the Eastern Free State Clay Grassland vegetation type which has a conservation status of Endangered (44.5% remaining and only 0.1% under protection). **Marginal zone:** Is dominated by non-woody vegetation (*C. marginatus* mainly), but exotic woody debris is abundant and reduces zone habitat. **Upper zone:** Is a mix of terrestrial grasses (soils) and grass/shrub mix where it is rocky and steeper. Extensive grazing occurs in this zone leading to vegetation loss.
Diatoms	Two diatom samples were taken at this site (August 2007 and April 2008) and 2003 diatom data was also available (Taylor, 2004). Both diatom samples indicate alkaline waters with low oxygen saturation and sodium based salinity (presence of *A. coffaeformis*) problems. The 2003 diatom data shows that water quality fluctuated between a C and D EC during the year. The biological water quality is overall of poor quality and the current biological water quality is a C/D.

12.3 MAIN IMPACTS AT THE SITE

	PES	Causes	Sources	F/NF
WQ	C	Elevated turbidity, habitat loss, cold water and low oxygen levels.	Sterkfontein Dam releases.	F
		Elevated N and P at times. Seasonal increase in salts.	WWTW, diffuse runoff from urban and industrial activities (Harrismith and Warden).	NF
			Abstraction for water purification, tankers, fish dams and agriculture.	
Geom	C	Decreased transport capacity.	Moderate floods are smaller, but there are occasional high releases from Stekfontein Dam.	F
		Increased sediment supply.	Erosion of upstream tributaries and channel banks has increased the sediment load.	F/NF
		Slight reduction in connectivity and change in sediment structure.	High releases (specifically occasional high releases from Stekfontein Dam) have caused cut banks and probably coarsened/armoured channel beds, thus reducing connectivity.	
Rip veg	C	Vegetation removal.	Extensive grazing on upper zone.	NF
		Exotic species invasion.	< 10% low impact, but exotic woody debris is unnatural.	
		Water quantity changes.	Non-woody cover increased by reduced low flows and increased fine sediments.	F
Fish	C	Slightly altered habitat diversity (fluctuation from natural composition) as a result of flow modification.	Abstraction.	F
		Decreased overhanging vegetation as cover for fish.	Increased bank erosion related to agricultural and livestock farming and recreational activities.	NF
		Increased sedimentation result in deterioration of substrate as habitat (clogging interstitial spaces, loss of important spawning habitats, etc.).	Bank erosion and vegetation removal (grazing) contribute to increased sedimentation.	
		Decreased species diversity and abundance (especially small species) as result of presence of aggressive alien predator (*M. salmoides*).	Presence of aggressive alien predatory species (*M. salmoides*) naturally spreading and introduced for recreation / angling.	
		Decreased bottom substrate quality.	Impact of bottom feeding alien CCAR and siltation.	
		Presence of migration barriers reduces migration success (breeding, feeding and dispersal) of some species.	Dams and various weirs. Also farm dams in tributaries reduce refuge areas.	
Inverts	C/D	Water quality.	WWTW, diffuse runoff from urban and industrial activities (Harrismith and Warden).	NF
		Decreased low flows.	Abstraction for irrigation.	F

12.4 RESULTS: PRESENT ECOLOGICAL STATE

Driver Components	PES	Trend
GEOMORPHOLOGY	C	Positive
WATER QUALITY	C	Stable
DIATOMS	C/D	
Response Components	**PES**	**Trend**
FISH	C	Stable)
MACRO INVERTEBRATES	C/D	Stable
INSTREAM	C	
RIPARIAN VEGETATION	C	Stable
ECOSTATUS	C	

The C PES EcoStatus is due to flow related impacts include alteration of hydrological regime due to interbasin transfers from Sterkfontein Dam, the LHWP, abstraction and agriculture. Non-flow related impacts include water quality problems, erosion and exotic species invasion. The improved management of Sterkfontein Dam releases has resulted in the cut banks on site becoming increasingly vegetated and therefore geomorphology has a positive trend.

12.5 SUITABILITY AS FUTURE BIOMONITORING SITE

The lower reaches of the Wilge is largely unregulated with only small dams for water supply to local users. Water users within this catchment comprise of both urban and irrigation user groups. EWR 8 is situated upstream of the Liebenbergsvlei confluence downstream of Warden. This site could be valuable for detecting upstream anthropogenic activities. As Sterkfontein releases and the LHWP impact on turbidity levels, habitat loss, temperature and oxygen levels this site should be monitored.

13 EWR 9: SUIKERBOS US (SUIKERBOSRAND RIVER)

The information is summarised from DWA (2008a,b; 2009a; 2010a).

13.1 SITE DESCRIPTION

EWR 9 is situated in the upper reaches of the Suikerbosrand River, and falls within MRU Suiker A delineated as from the origin of river to the confluence with Blesbokspruit River. The site is in a bedrock rapid, and although the reach is generally characterised by long pools, there are a number of such rapids in the reach. Some morphological cues present in the upstream pool area - upper terrace is paired on opposite the bank and the lower bench is annually flooded. Some channel manipulation from the construction of bridge downstream was observed and there is 40% exotic species coverage. Fish habitat, flow-depth categories and cover is well represented at site and macroinvertebrate habitat is moderate.

Location	EWR 9	**Altitude**	1509 m
Longitude	28.38197	**Latitude**	-26.6467
EcoRegion	Highveld/Southern Central Kalahari 11.01	**Quaternary catchment**	C21C
Water Management Area	Upper Vaal	**Geomorphological zone**	Lower Foothills

EWR 9, Suikerbos US, August 2008

13.2 PRESENT ECOLOGICAL STATE (PES)

Geom	There are large areas of relatively pristine sections of this river, and the Suikerbosrand River is often considered as a "reference state" system for the Highveld rivers (which are otherwise generally very highly impacted rivers). The site is a bedrock rapid, and although the reach is generally characterised by long pools, there are a number of such rapids in the reach. The upper terrace is paired on the opposite bank and the lower bench is annually flooded. Erosion in the catchment has increased the fines load of the river, so possibly the pools are infilling and channels are reducing in width due to sedimentation.
WQ	Data from C2H131Q01 (Colliery point on Suikerbosrand River) and Rand Water Data from C-S1 (2003 – 2008; n = 92) were used for the physico-chemical PES assessment. Agricultural runoff (nutrients and sediments) are impacting this site. Instream dams (Harhoff and Belfast) for agricultural water supply and farm dams in tributaries are causing higher water temperatures. There are some sand mining activities in the area and may be causing elevated salt concentrations and turbidity levels. Faecal coliforms have seasonal highs while the physico-chemical data indicates that sulphates are low.
Fish	Most of the expected fish species are still present at this site. It is expected that *A. sclateri* have been lost as a result of the flow modification (Balfour Dam and abstraction), and the FROC of *L. kimberleyensis*, *Labeobarbus aeneus*, and *Labeo capensis* have been reduced. Another prominent reduction in FROC is evident in the small species (*B. anoplus*, *B. pallidus* and *P. philander*), most probably related to the impact of the predatory alien *M. salmoides*.
Inverts	Aug 07: SASS5 score: 69 No of Taxa: 12 ASPT: 5.8

	Apr 08: SASS5 score: 119 No of Taxa: 20 ASPT: 6.0 Composition of macroinvertebrates is variable, depending on releases from Balfour Dam. In August 2007 the flow comprised a trickle only, and various taxa needing higher flows disappeared (Heptageniidae; 3 spp Hydropsychidae; and Hydraenidae). The total SASS score was significantly lower (69) than expected (182), but the ASPT was not significantly different to natural. This suggests that flow changes were more important in determining the PES than any deterioration in water quality. In April 2008, when flows were moderate, the composition of invertebrates recovered significantly (C EC). Overall, the taxa missing or scarce were mainly those that prefer slow or standing water in gravel, sand and mud substrates (Corixidae, Caenidae, Sphaeriidae, Leptophlebiidae, and Ceratopogonidae). The reason for this is not clear.
Rip veg	This site occurs within the Soweto Highveld Grassland vegetation type, which has an endangered conservation status with 52.7% of the type remaining and only 0.2% protected. Moderate to high rates of alien infestation is present in the lower zone.
Diatoms	Four diatom samples were taken at this site (August and December 2007 and January and April 2008). The August 2007 diatom sample indicated that the biological water quality was good with moderate pollution levels, and that there slightly elevated levels of organically bound nitrogen in the water. The rest of the samples showed a gradual deterioration in biological water quality and the biological water quality is a C EC.

13.3 MAIN IMPACTS AT THE SITE

	PES	Causes	Sources	F/NF
WQ	C/D	Faecal coliforms seasonal highs.	WWTW upstream.	NF
		Increased sediment and turbidity.	Agricultural runoff, upstream dams (Balfour and Harhoff).	
		Increased N and P.	Agricultural runoff and cattle.	
		Elevated temperatures.	Sand mining activities, upstream dams (Balfour and Harhoff).	
Geom	B/C	Reduced transport capacity.	Upstream farm dams and Balfour and Harhoff Dams.	F
		Increased sediment supply.	Erosion of the upstream tributaries in the farming areas.	NF
		Slight reduction in connectivity.	Upstream farm dams and two moderately large dams.	F/NF
		Slight reduction in channel width.	Sedimentation and reduced floods.	
Rip veg	B/C	Higher than expected woody and non-woody cover.	Reduced or loss of dry season base flows.	F
		Reduced indigenous riparian species cover and proportions in lower and upper zones.	Moderate to high alien infestation in lower and upper zones respectively.	NF
Fish	D	Altered habitat diversity (fluctuation from natural composition) as a result of flow modification (especially low flow).	Balfour Dam and abstraction.	F
		Decreased overhanging vegetation as cover for fish.	Increased bank erosion related to agricultural and livestock farming.	NF
		Increased sedimentation result in deterioration of substrate as habitat (clogging interstitial spaces, loss of important spawning habitats, etc.).	Bank erosion and vegetation removal (grazing) contribute to increased sedimentation.	
		Decreased species diversity and abundance (especially small species) as result of presence of aggressive alien predator (*M. salmoides*).	Presence of aggressive alien predatory species (*M. salmoides*) naturally spreading and introduced for recreation/angling.	
		Decreased bottom substrate quality.	Impact of bottom feeding alien *C. carpio* and siltation.	
		Decreased fish species abundance.	Poaching.	
		Presence of migration barriers reduces migration success (breeding, feeding and dispersal) of some species.	Dams and various weirs. Also farm dams in tributaries reduce refuge areas.	
Inverts	D	Increased periods of very low flow.	Upstream dam and abstractions.	F

13.4 RESULTS: PRESENT ECOLOGICAL STATE

Driver Components	PES	Trend
GEOMORPHOLOGY	B/C	Negative
WATER QUALITY	C/D	Negative
DIATOMS	C	
Response Components	**PES**	**Trend**
FISH	D	Stable
MACRO INVERTEBRATES	D	Stable
INSTREAM	D	
RIPARIAN VEGETATION	B/C	Negative
ECOSTATUS	C	

The C EcoStatus PES can be contributed to flow related impacts which include altered flow regime due to Balfour and Harhoff Dams and non-flow related impacts include deteriorated water quality due to WWTW and agriculture, erosion and alien species (fish and vegetation).

13.5 SUITABILITY AS FUTURE BIOMONITORING SITE

This portion of the Suikerbosrand River catchment is largely natural, there are no significant abstractions or discharges influencing the river flow. OSAEH 11.15 is at the same locality as EWR 9 and considering that the lower reaches of the Suikerbosrand are impacted by mining and other industrial activities this site should be included in a monitoring programme.

14 EWR 10: SUIKERBOS DS (SUIKERBOSRAND RIVER)

The information is summarised from DWA (2008a,b; 2009a; 2010a).

EWR 10 occurs downstream of the Blesbokspruit River which is heavily impacted an in close proximity to OSAEH 11.14 which is downstream of EWR 10. During the Reserve assessment there was very low confidence in the hydrology and after personal communication with Ms Delana Louw it was decided to include EWR 10 in the current study and instead of assessing OSAEH 11.14, EWR 10 was assessed in March 2011. The EWR study allowed for good data availability and understanding of the site however the major issue at this site is that the PES baseline could have changed due to the uncertainties regarding the hydrology. Therefore the results provided below are mainly the results from the EWR study, and any significant changes in the condition of the biota observed during the 2011 assessment is included.

14.1 SITE DESCRIPTION

MRU Suiker B is delineated as the Suikerbosrand River reach from the Blesbokspruit confluence to the Vaal River confluence. EWR 10 is below the Blesbokspruit confluence and the morphology is generally representative of the reach, but impacts concentrated around the road/bridge access results in the banks being in a poorer condition than generally seen along the reach. Upper and lower terraces are paired on opposite bank. Some channel manipulation from roads is present although this has a minor influence on the site. There is up to 60% exotics in places. Fish habitat, flow-depth categories and cover is well represented at site while excellent macroinvertebrate habitat is present.

Location	EWR 10	**Altitude**	1453 m
Longitude	28.16798	**Latitude**	-26.68137
EcoRegion	Highveld/Southern Central Kalahari 11.01	**Quaternary catchment**	C21G
Water Management Area	Upper Vaal	**Geomorphological zone**	Lowland

EWR 10, Suikerbos DS, August 2008

14.2 PRESENT ECOLOGICAL STATE (PES)

Geom	The site is representative of the reach. Although the floods are relatively natural, the upstream confluence with the Blesbokspruit River has resulted in increased base flows due to mine dewatering. The banks are largely natural, although some erosion is present in places and has increased in the catchment due to increased fines load of the river. Water quality is impacting the marginal vegetation, which is in turn is destabilizing the banks as the vegetation dies off.
WQ	The current water quality status of the lower Suikerbosrand River is driven by the water quality of the

	Blesbokspruit River discussed under Section 15. Low and moderated flows in the Suikerbosrand River are being changed by increased Blesbokspruit River base flows.
Fish	Most of the expected fish species are still present within this reach. It is expected that *B. pallidus* has been lost from this reach as a result of the deteriorated water quality and increased flows (loss of slow habitats). This loss of slow habitats also influenced other species with a preference for this habitat such as *B. anoplus*, *L. umbratus* and possibly also *C. gariepinus*. *A. sclateri* and *L. kimberleyensis* assemblages have been altered due to substrate deterioration (sediment and algae) as well as water quality. Another prominent reduction in FROC is evident in the small species (*B. anoplus*, *B. pallidus* and *P. philander*) as a result of the presence of the predatory alien *M. salmoides*. Other alien species *G. affinis* and *C. carpio* are also expected to have an impact on the indigenous species, especially regarding breeding (egg and larvae disturbance and predation). Migration barriers in the form of weirs also affect the fish assemblages of this reach to some extent.
Inverts	Sep 07: SASS5 score: 64 No of Taxa: 13 ASPT: 4.9 Apr 08: SASS5 score: 85 No of Taxa: 15 ASPT: 5.7 The SASS Scores (64 and 86) were significantly lower than expected (182), and results were very low in relation to the quality of biotopes available. Likewise, the ASPT results (4.9 and 5.7) were significantly lower than expected (6.1). The results suggest that habitat availability is having a significant impact on the composition. Three species of caddisflies and three species of blackflies indicate significant improvement compared to EWR 9, further upstream. However, all species present were tolerant of water quality deterioration. Taxa that were missing or scarce were those that prefer moderately fast-flowing water (e.g. Elmidae; Hydraenidae; Turbellaria), and taxa that are sensitive to water quality deterioration and found in cobble biotopes (e.g. Baetidae; Hydropsychidae; Elmidae). Heptageniidae were present on one occasion, and shrimps were present on both occasions.
Rip veg	This site occurs within the Soweto Highveld Grassland vegetation type, which has an endangered conservation status with 52.7% of the type remaining and only 0.2% protected. Increased dry season base flows have resulted in the loss of marginal vegetation. There are high levels of exotic species present in the lower and upper zones.
Diatoms	Four diatom samples were taken at this site (August and December 2007 and January and April 2008). All four samples indicate that pollution levels are extreme and that the poor water quality of the Blesbokspruit River impacts heavily on this site. Nutrient loading, organic pollution and salinity are a major concern and mine water decant and industrial effluent impact at critical levels. Toxics, oxygen and temperature are also variables of concern at this site. Due to the continual elevated flows the impacts are diluted constantly. The biological water quality was assessed as a C/D EC due to the dilution effect. It must however be noted that this is not a true reflection of prevailing conditions and that a slight reduction in flows will cause the biological water quality to deteriorate rapidly to a D or E category. This site is the most severely impacted site of all the EWR sites assessed, and urgent management action is needed to prevent major biological water quality impacts on biota in the near future.

14.3 MAIN IMPACTS AT THE SITE

	PES	Causes	Sources	F/NF
WQ	D/E	High salts (electrical conductivity and sulphates).	Mine water decants (point sources) of saline water – some of which are being pretreated and released above Merrievale (Blesbok RAMSAR) wetland.	F
			Diffuse runoff from mining activities and urban runoff.	NF
		Faecal contamination (potential water borne disease) and high nutrients (mainly phosphates).	Point source discharges from WWTW, runoff from formal and informal settlements.	
		Increased nutrient loading and algal growth.	WWTW, agriculture.	
Geom	C	Increased transport capacity.	Moderate floods are larger due to baseflow increase from mine dewatering as well as development from the upper catchment.	F
		Increased sediment supply.	Erosion of the headwaters of upstream tributaries in farming areas has increased the sediment load.	NF
		Slight reduction in connectivity.	Upstream small farm dams and two moderately large dams.	NF
		Change in sediment structure.	Sedimentation, reduced floods and increased base flow together may offset each other slightly.	F/NF
Rip veg	C	Loss of marginal zone vegetation.	Increased dry season base flows.	F
		Reduction in lower and upper zone species cover and composition.	High levels of aliens.	NF
Fish	C/D	Altered habitat composition (slow habitats transformed to fast habitats).	Increased flows / altered hydrological regime.	F

	PES	Causes	Sources	F/NF
		Decreased overhanging vegetation as cover for fish.	Grazing, agriculture and water level fluctuations.	NF
		Increased sedimentation result in deterioration of substrate as habitat (clogging interstitial spaces, loss of important spawning habitats, etc.).	Bank erosion and vegetation removal (grazing) contribute to increased sedimentation.	
		Decreased species diversity and abundance (especially small species).	Presence of aggressive alien predatory species (*M. salmoides*) and *G. affinis* naturally spreading and introduced for recreation / angling.	
		Decreased bottom substrate quality.	Impact of bottom feeding alien *C. carpio* and siltation.	
		Presence of migration barriers reduces migration success (breeding, feeding and dispersal) of some species.	Dams and various weirs. Also farm dams in tributaries reduce refuge areas.	
Inverts	C/D	Water quality problems, particularly elevated salinity and bacteria.	Industries (Mines, Sappi) and urban storm water.	NF
		Benthic algae.	Elevated nutrients and clear water.	
		High base flows.	Decanting mines, sewage treatment works and seepage from urban development.	F

14.4 RESULTS: PRESENT ECOLOGICAL STATE

Driver Components	PES	Trend
GEOMORPHOLOGY	C	Negative (C)
WATER QUALITY	D/E	Negative
DIATOMS	C/D	
Response Components	**PES**	**Trend**
FISH	C/D	Stable
MACRO INVERTEBRATES	C/D	Stable
INSTREAM	C/D	
RIPARIAN VEGETATION	C	Negative
ECOSTATUS	C/D	

The C/D EcoStatus can be attributed to flow related impacts which include elevated base flows and increased floods due to mining, SAPPI, urban runoff and Blesbokspruit input. Non-flow related impacts include deteriorated water quality due to industries, agriculture and urban activities; erosion, and exotic alien invasion (fish and vegetation).

14.5 SUITABILITY AS FUTURE BIOMONITORING SITE

EWR 10 occurs downstream of the Blesbokspruit River which is heavily impacted. This site should be included to detect these impacts and to determine if the site improves when the planned water quality management plan for the Blesbokspruit is initiated which would include desalination of mine water decant.

15 EWR 11: BLESBOK (BLESBOKSPRUIT RIVER)

The information is summarised from DWA (2008a,b; 2009a; 2010a).

EWR 11 and OSAEH 11.8 have the same locality. During the Reserve assessment there was very low confidence in the hydrology and after personal communication with Ms Delana Louw it was decided to reassess this site which was undertaken during March 2011. The Reserve study allowed for good data availability and understanding of the site however the major issue at this site is that the PES baseline could have changed due to the uncertainties regarding the hydrology. Therefore the results provided below are mainly the results from the EWR study, and any significant changes in the condition of the biota observed during the 2011 assessment is included.

15.1 SITE DESCRIPTION

The whole Blesbokspruit River has been delineated as one MRU, MRU Bles A. The site morphology is generally representative of the reach, but impacts concentrated around the road/bridge access results in the banks being in a poorer condition than generally seen along the reach. There are approximately paired terraces on both banks and instream features are scoured out (probably due to increased flows and recent floods). Some channel manipulation from low and high-level bridges upstream was observed and there is up to 20% exotics in places. Fish habitat, flow-depth categories and cover is well represented at site. Non-flow related impacts may have negative impact on semi-rheophilic species (reduced water quality, extensive algal growth on substrate) which may reduce the ability of site to sustain these species. Macroinvertebrate habitat is poor.

Location	EWR 11	**Altitude**	1528 m
Longitude	28.42488	**Latitude**	-26.47892
EcoRegion	Highveld/Southern Central Kalahari 11.03	**Quaternary catchment**	C21F
Water Management Area	Upper Vaal	**Geomorphological zone**	Lower Foothills

EWR 11, Blesbokspruit, August 2008

15.2 PRESENT ECOLOGICAL STATE (PES)

Geom	Due to the large increases in base flows the active channel banks are cutting, and the competence[4] of the river has increased. Water quality is impacting the marginal vegetation, which is in turn would destabilize the banks as the vegetation dies off. Paired terraces occur on each bank and instream features have been scoured out due to increased flows and recent floods.
WQ	Data from C2H133Q01 and Rand Water C-B10 at Heidelberg on Blesbokspruit (2003 - 2008) with n = 227 was used for the physico-chemical PES assessment. The current water quality status of the Blesbokspruit is driven by the following: • Mine water decants (point sources) of saline water – some of which are being pre-treated and released above the wetland. This results in high salts as seen in electrical conductivity and sulphates measurements. • Diffuse runoff from mining activities on the Witwatersrand that are over 100 years old such as waste dumps and slimes dams. When it rains in the summer the salts are washed off the mine waste dumps and enter the surface and groundwater. In the winter months there are highly mobile particles that are blown around which have an effect on human health (respiratory). • Urban runoff originating from large numbers of formal and informal settlements which results in faecal contamination (potential water borne diseases) and high nutrients (mainly phosphates) from areas with poor or failing waste infrastructure. • Point source discharges from waste water treatment works. These treatment works are currently under capacitated and the final effluent discharged rarely meets the discharge requirements. • Point and source discharges from industries such as SAPPI. • Higher base flows due to higher surface area of impervious surfaces, return effluents from WWTW, mine water decants.
Fish	Most of the expected fish species have been altered within this Resource Unit. It is expected that *A. sclateri* has been lost from this reach as a result of the deteriorated water quality and substrate habitats. LCAP and *L. umbratus* have also most probably been lost as a result of water quality deterioration and especially loss of substrate quality. The loss of slow habitats influenced species such as *B. anoplus*, *B. pallidus*, *B. paludinosus* and *L. umbratus* and possibly also *C. gariepinus* with a preference for slow habitats. The presence of alien species *G. affinis* and *C. carpio* are also expected to have an impact on the indigenous species, especially regarding breeding (egg and larvae disturbance and predation). Migration barriers in the form of weirs also affect the fish assemblages of this reach to some extent.
Inverts	Aug 07: SASS5 score: 57 No of Taxa: 14 ASPT: 4.1 Apr 08: SASS5 score: 61 No of Taxa: 16 ASPT: 3.8 The composition of macroinvertebrates is highly modified from expected natural conditions, and extremely low in relation to the availability of biotopes. The only species of baetid mayfly recorded was *Baetis harrisoni,* which is well-known to be highly tolerant to water quality deterioration. Likewise, the only species of hydropsychid caddisfly was *Cheumatopsyche thomasetti,* while the only species of blackfly was *Simulium adersi*. Both these species are highly tolerant to water quality deterioration. The SASS Scores (57 and 61) were significantly lower than expected (164). Likewise, the ASPT (4.1 and 3.8) was significantly lower than expected (5.9). Notable taxa that were absent included those that are sensitive to water quality (e.g. Heptageniidae), as well as taxa that prefer slow-flowing water (e.g. Sphaeriidae, Leptophlebiidae and Caenidae). The absence of the latter taxa reflects the elevated base flows that occur at this site.
Rip veg	The site occurs within the Tsakane Clay Grassland vegetation unit, which has a conservation status of "Endangered", mainly because only 24% of this vegetation type remains, with only 1.5% under protection. **Marginal zone:** Has no sedges; these appear to be "drowned out", and only non-woody vegetation is present that is associated with sediment i.e. *Phragmites* and *Typha.* Woody vegetation is absent. **Lower zone:** Similarly is dominated by reeds and *Typha*, with *Schoenoplectus* spp. Indigenous woody species are also absent. Loss of indigenous species due to overgrazing. **Upper zone:** Characterised by grassland species, but indicative of overgrazing (*Stoebe* spp.) and woody species are minimal. Loss of indigenous species due to overgrazing.
Diatoms	Four diatom samples were taken at this site (August and December 2007 and January and April 2008). All four diatom samples indicate that pollution levels are extreme and that the Blesbokspruit River is of poor water quality. Organic pollution, metal contamination and salinity are a major concern and mine water decant and industrial effluent impact at critical levels. Oxygen and temperature are also variables of concern at this site. Due to the continual elevated flows the impacts are diluted constantly. The biological water quality was assessed as a C/D EC due to the dilution effect. It must however be noted that this is not a true reflection of prevailing conditions and that a slight reduction in flows will cause the biological water quality to deteriorate rapidly to a D or E category..

[4] The maximum size or weight of material a river can transport. In times of flood, a river's competence will increase – it will be able to carry bigger particles (http://www.slideshare.net/jacksonthree/river-transportation-hjulstrom-curve).

15.3 MAIN IMPACTS AT THE SITE

	PES	Causes	Sources	F/NF
WQ	D/E	High salinity levels.	Mine water decants and waste dump diffuse pollution. Some of which are being pretreated and released above Merriespruit wetland.	F
		Traces of metals such as arsenic and cyanide.	From mines, mine ground water discharges, and industrial discharges. Large surface area of wetlands, urban runoff as well as constant groundwater temperature releases.	
		Diurnal temperature changes.	High algal growth – rooted macrophytes, filamentous, exotic floating macrophytes (Water hyacinth) and single cell blooms. Can result in diurnal oxygen fluctuations that can cause fish kills.	
		Microbial contamination (potential water borne disease) and high nutrients.	Urban runoff from large number of formal and informal settlements as well as point source discharges from waste water treatment works.	NF
		Elevated water temperatures.	Large surface area of wetlands, urban runoff as well as constant groundwater temperature releases. .	
Geom	C	Increased transport capacity due to increased base flows.	Primarily dewatering from the mines; but also sewage return flows and runoff from urban areas.	F
		Morphological change: Cutting of the active channel banks; increased channel competency.	Increased base flows.	
		Increased sediment supply.	Erosion of the upstream tributaries and locally from eroding banks.	NF
		Slight reduction in connectivity.	Upstream small dams and weirs.	
Rip veg	D	Loss of marginal zone vegetation.	Increased flows.	F
		Loss of riparian habitat.	Erosion from bridge, localized effect.	
		Change in species composition.	Exotic species, but small influence.	NF
		Loss of indigenous species.	Overgrazing in lower and upper zones.	
Fish	D	Altered habitat composition (slow habitats transformed to fast habitats).	Increased flows / altered hydrological regime.	F
		Altered bottom substrate habitats result in loss of fish species diversity.	Increased filamentous algal growth related to increased nutrients.	NF
		Decreased overhanging vegetation as cover for fish.	Grazing, agriculture and water level fluctuations.	
		Increased sedimentation result in deterioration of substrate as habitat (clogging interstitial spaces, loss of important spawning habitats, etc.).	Bank erosion, residential areas and vegetation removal (grazing) contribute to increased sedimentation.	
		Decreased species diversity and abundance (especially small species) as result of presence of GAFF that preys on larvae.	Presence of aggressive alien predatory species (MSAL) and GAFF naturally spreading and introduced for recreation / angling.	
		Decreased bottom substrate quality.	Impact of bottom feeding alien CCAR and siltation.	
		Presence of migration barriers reduces migration success (breeding, feeding and dispersal) of some species.	Dams and various weirs. Also farm dams in tributaries reduce refuge areas..	
Macroinvertebrates	D/E	High baseflows.	Decanting mines, sewage treatment works and seepage from urban development.	F
		Water quality problems, particularly elevated salinity and bacteria.	Industries (Mines, Sappi) and urban stormwater.	NF
		Benthic algae.	Elevated nutrients and clear water.	
		Sediment (sand).	Large amount of sand from general erosion in catchment and sand mining.	

15.4 RESULTS: PRESENT ECOLOGICAL STATE

Driver Components	PES	Trend
GEOMORPHOLOGY	C	Negative
WATER QUALITY	D/E	Negative
DIATOMS	C/D	
Response Components	**PES**	**Trend**
FISH	D	Stable
MACRO INVERTEBRATES	D/E	Stable
INSTREAM	D/E	
RIPARIAN VEGETATION	D	Negative
ECOSTATUS	D	

The site is in a D EcoStatus PES. Non-flow related impacts include increased base flows and floods due to mine water decants, urban runoff, agriculture and return flows from WWTW. Water quality is also heavily impacted due to these activities and erosion has increased. Alien fish species are present.

15.5 SUITABILITY AS FUTURE BIOMONITORING SITE

The site is severely impacted, especially biota, and therefore this site should be included to detect these impacts and to determine if the site improves when the planned water quality management plan for the Blesbokspruit is initiated which would include treatment of mine water decant.

16 OSAEH 11.3 (MOOI RIVER)

16.1 SITE DESCRIPTION

The site falls with MRU Mooi C which is the delineated reach from Boskop Dam to the Vaal River confluence. This site is situated in a park, in a residential area surrounded by plots approximately 1.6 km downstream of Potchefstroom Dam. The site constitutes a small, perennial stream with a dominant clay substrate, with riffles, runs and pools characterising the system. The stream is approximately 2 m in width and approximately 15 m in width at the pool areas. No local erosion exists. Bank undercutting is abundant, with exotic trees dominating the riparian vegetation. The river is incised and no channel modification is present at the site. Bed modification exists due to extensive siltation of the stream bed. No free floating algae and benthic algae are present. The marginal riparian zone is narrow, incised and mostly open due to extensive shading from alien woody species, especially taller trees such as *Salix babylonica* and *Populus sp*.

Location	OSAEH 11.3	**Altitude**	1393 m
Longitude	27.09856	**Latitude**	-26.68283
EcoRegion	Highveld 11.01 & 11.08	**Quaternary catchment**	C23H
Water Management Area	Upper Vaal	**Geomorphological zone**	Foothill

OSAEH 11.3. Site and riffle habitat

16.2 SAMPLING CONDITIONS

Low flow was present at the time of sampling. The water was well within the active channel and the level did not reach the riparian vegetation. The water was relatively clear with no odours. Solid waste disposal was present, including bottles, drums and bricks.

16.3 PRESENT ECOLOGICAL STATE

IIHI	The Instream Index of Habitat Integrity (IIHI) is a C (65.7%). This is mostly due to poor bed and bank conditions, especially since the riparian component is highly altered. Altered flow regimes and deteriorating water quality from large dams upstream of the site also impact negatively on the site.
RIHI	The Riparian Index of Habitat Integrity (RIHI) is a D/E (39.0%) with the main impacts being poor bank conditions due to a high degree of manipulation of geomorphic features and extreme density and cover of perennial and annual alien vegetation, some of which have been planted.
Fish	Most of the fish species expected under reference conditions are still expected to be present under the present conditions at this site, although the FROC of some species have been reduced from reference conditions. These are mainly moderately tolerant to tolerant species. The main impacts on these fish are decreased flows, loss of water column in fast deep (FD) and fast shallow (FS) as cover, siltation and loss of substrate as cover, and the absence of aquatic macrophytes. The presence of *G. affinis*, which preys on fish eggs and larvae, will also negatively impact on the fish species present in the system. Two species *L. kimberleyensis* and *A. sclateri* are, however, no longer expected to occur due to a loss of their preferred habitat. The main impacts on these fish are decreased flows, loss of water column in FD and

	FS as cover, siltation and loss of substrate (cobbles and rock) as cover. Damming of the stream due to fallen woody debris and dead trees (exotics) also reduce fast flowing habitats, and alter habitat and water quality. This seems to be the major impact at the site. The PES was a D as determined by the FRAI (56%).
Inverts	Oct 2010: SASS5 score: 97 No of Taxa: 20 ASPT: 4.9 Key taxa expected but not observed were generally those that are sensitive to water quality changes, such as those of genus Hydropsychidae (>2spp), Heptageniidae, Perlidae, Philopotamidae, Psephenidae, Chlorocyphidae, Athericidae, Tricorythidae and Leptophlebidae. However, Baetidae (>2spp) was expected and found on site as expected under reference conditions. Most of taxa observed during the time of sampling were generally those with low to moderate requirement in water quality. The MIRAI model generates a Present Ecological State for macroinvertebrates as a Category D (48.1%).
Rip veg	The site has a VEGRAI score of 27.7% (E EC) with a confidence of 3.8. Marginal Zone: Narrow, incised, mostly open due to extensive shading from alien woody species, especially taller trees such as *Salix babylonica* and *Populus sp*. Mostly open fine alluvium or dominated by exposed roots. Lower Zone: same as marginal zone, with large cover by *Pyracantha angustifolia*. Upper Zone and MCB (Macro Channel Bank): Right Bank (RB): dominated by mowed parkland with planted alien trees which cause intense shading, dominant non-woody species is *Bromus catharticus** and several weed species. Left Bank (LB) and mid-channel bar: extensively dominated by dense woody vegetation and deep shade, mostly alien species, especially *Ligustrum** species, but also with *Celtis africana, Searsia pyroides, S. lancea* and some open grassed areas on the terrace with a healthy population of *Crinum bulbispermum* (Declining).
Diatoms	The assessment is based on the site visit as well as data collected as part of a MSc study (Koekemoer, 2010). The diatom community is typical of urban waters with nutrient and organic pollution levels becoming critically elevated at times. Due to industrial activity salinity is also elevated. The EC is a D.

16.4 MAIN IMPACTS AT THE SITE

	PES	Causes	Sources	F[1]/NF[2]
Rip veg	E	Significantly reduced cover of indigenous riparian obligate species, especially in the marginal and lower zones.	Severe shading from tall and dense alien woody species overhanging.	NF
		Altered species composition.	High cover (up to 70%) and density of perennial alien species , and mowing of upper zone terraces.	
Fish	D	Loss of habitat (decreased FD and FS) diversity as a result of flow modification (especially during natural low flow periods).	Dam, water abstraction for plots/irrigation, urbanization.	F
		Decreased substrate quality due to embedding.	Lower than natural flushes and floods.	
		Loss of FD and FS habitat.	Damming of stream due to fallen exotic trees and woody debris.	NF
		Decreased aquatic vegetation as cover for fish.	Increased exotic riparian vegetation and shading. Less light penetration – very shaded.	
		Lower oxygen and temperature levels.	Exotic trees causing excessive shading.	
		Increased sedimentation resulting in deterioration of substrate as habitat (clogging and loss of important spawning habitats, and cover etc.).	Upstream bank erosion due to urbanization, and developments.	
		Decreased species diversity and abundance due to presence of *G. affinis*.	Presence of alien predatory species (*G. affinis*) introduced for aquariums and mosquito control.	
		Enrichment of water and anaerobic decomposition.	Fallen woody debris and trees (exotics).	
		Possible pollution and enrichment of water.	Urbanization.	
		Presence of dams and weirs as migration barriers (breeding, feeding and dispersal), also causing loss of habitat of some species (inundation).	Potchefstroom Dam and other smaller weirs in area.	
Inverts	D	Lack of key habitat.	Urbanization and agriculture.	F
		Poor water quality and associated benthic growth.	Agriculture and urbanization.	NF

16.5 BASELINE SURVEY RESULTS: PRESENT ECOLOGICAL STATE

Driver Components	PES	Trend
IHI: INSTREAM	C	
IHI: RIPARIAN	D/E	
DIATOMS (WQ)	D	
Response Components	**PES**	**Trend**
FISH	D	Stable
MACRO INVERTEBRATES	D	Stable
INSTREAM	D	
RIPARIAN VEGETATION	E	Negative
ECOSTATUS	E	

The EcoStatus for this site is an E category. Reasons for this include loss of instream habitat and instream substrate quality due to damming, water abstraction and urbanization. Enrichment of water and anaerobic decomposition due to fallen woody debris also impact negatively on the site. Presence of dams and weirs as migration barriers for instream biota which impacts on their feeding, breeding and dispersal also has a negative impact at this site. Furthermore, significantly reduced cover of indigenous riparian obligate species, especially in the marginal and lower riparian zones, due to severe shading from alien woody species, has a negative impact at this site.

16.6 SUITABILITY AS FUTURE MONITORING SITE

Low instream habitat diversity is available for SASS sampling. Biotopes present include good quality but moderate quantity of cobble biotope present. Moderate Gravel, Sand & Mud (GSM) biotope is present, with moderate overhanging marginal vegetation available. Limited Stones Out Of Current (SOOC) is present as well as low diversity of velocities present.

The Mooi River is a perennial stream and is highly impacted by urban disturbances, pollution, and siltation (substrate embedded) and therefore habitat diversity is reduced. Bank undercutting, root wads and overhanging vegetation are abundant for fish cover, however there is an absence of substrate (rocks and cobbles), and siltation may be a limiting factor at the site (mainly muddy/clay bottom). Pools are abundant and provide water column cover and refugia for fish species. Limited cobble biotope is present and no Fast Deep (FD) flow depth class is present.

An abundance of exotic riparian vegetation exists, with increased instream siltation and solid waste disposal present. Alluvial habitat is available in the riparian zone and a good geophyte population is present. Extremely high coverage by alien perennial vegetation exists in the riparian zone. A limited availability of indigenous riparian species are present in the riparian zone.

The site is not adequate for monitoring. The RHP site below Mooi River Mall has been flooded due to development and therefore no site exists downstream of the Mall and no other suitable site could be found. It must however be noted that the Mooi River impacts are driven by water quality problems, and before a catchment management plan is not initiated in this system the biotic condition in the Mooi will not be improved. The Mooi has also been significantly altered. This site is not considered a high priority site for future monitoring.

17 CONCLUSIONS

Fourteen sites were identified as possible monitoring sites while eleven EWR sites occur within the Upper Vaal WMA that was assessed as part of the Vaal Comprehensive Reserve study undertaken by Water for Africa and Koekemoer Aquatic Services during 2007 – 2010. Four OSAEH sites were assessed during October 2010. The eleven EWR sites that have been assessed in the Lower Vaal WMA, have provided additional information that can contribute to future monitoring programmes in the Orange River Basin. The main impacts in the different Upper Vaal MRUs and system operation is summarised from DWAF (2009a) in the following sections.

17.1 UPPER VAAL RIVER

For the purposes of the EWR study, the Vaal River from the origins of the Vaal to the confluence of the Mooi River was delineated into five Management Resource Units (MRU Vaal A – E). Five EWR sites and three OSAEH sites are situated in the Vaal River main stem.

17.1.1 MRU VAAL B: Klein Vaal confluence to Grootdraai Dam

A transfer from Heyshope Dam takes place through the Perdewater, Skulpspruit and Rietspruit and EWR 1 is located in the Vaal River downstream of the transfer. Water is transferred from Heyshope Dam into the Little Vaal River (i.e. into the lower part of quaternary C11C). Skulpspruit River (C11E): The transfer from Zaaihoek Dam discharges water into the Perdewaterspruit, which is a tributary of the Skulpspruit (C11E). The water is released in the river system upstream of Amersfoort Dam, which is a small storage dam providing water to the town. Msukaligwa Local Municipality (former Ermelo Transitional Local Council (TLC)) is situated within the Rietspruit River catchment (C11F). There are two dams, Willem Brummer and Douglas dams, in this river system supplying water to Msukaligwa. There are also coal mining activities in the catchment upstream of these dams.

EWR 1 is the first site within the Upper Vaal WMA and adequate for biotic monitoring. The PES EcoStatus of this reach is a C and there are indications that there are water quality problems as the fish show signs of serious bacterial infection and quality sensitive macroinvertebrates are absent. This site could therefore be included in monitoring programmes.

17.1.2 MRU Vaal C: Between Grootdraai and Vaal Dam

The Vaal River reach downstream of Grootdraai Dam receives compensation water from Grootdraai Dam. This is a variable flow (dependent on the inflow) and this water is used by Lekwa Local Municipality (LM) (former Standerton TLC) as well as downstream irrigators.

Immediately downstream of the Vaal Dam wall and gauging weir is an extensive riffle/rapid system, and due to the scarcity of such habitat between the two dams, EWR 2 was selected in this reach upstream of Standerton. Due to flow modification originating from Grootdraai Dam, habitat may be altered and the site is too high in the catchment to detect impacts lower downstream and not considered as a high priority site.

OSAEH 11.7 is situated at the Vaal and Brakspruit confluence downstream of EWR 2 and upstream of the Klein Vaal confluence. Flow modification impacts this site negatively due to releases made from Grootdraai Dam and sampling may be difficult at times. This site is not considered as a high priority site.

EWR 3 is located 31 km upstream of Villiers and has the same location as RHP site C1Vaal-Villie. OSAEH 11.2 is also indicated as having the same location as C1Vaal-Villie, however the co-ordinates provided for OSAEH 11.2 indicates that the site is downstream of EWR 3 and Villiers. There is therefore uncertainty of the exact location of C1Vaal-Villie. Both sites are in the lower reach of the MRU and therefore this will be a valuable site to detect upstream impacts. However EWR 3 is upstream of the Waterval River confluence and therefore the deteriorated water quality entering the Vaal River from the Waterval catchment will not be detected. OSAEH 11.2 is downstream of this confluence but may be influenced by inundation from the Vaal Dam which would make sampling difficult. Based on data availability and level of analysis undertaken at EWR 3 this site is a preferred biomonitoring site.

The reach is impacted in C11M below Standerton. After the confluence with the Klip River the reach improves to a C (DWA, 2008b).

17.1.3 MRU VAAL D: Vaal Dam wall to Vaal Barrage.

The water body created by the Vaal Barrage dominates this river reach. Management of the flow into this reach is from the Vaal Dam and is influenced by the water users in and downstream of the Vaal Barrage, the urban return flows and mine dewatering discharges as well as the releases from the Vaal Dam to maintain the Total Dissolved Salts (TDS) concentration at 600 mg/ℓ. The three main tributaries (Suikerbosrand, Klip and Rietspruit rivers) discharging into the Vaal Barrage, each convey significant volumes of treated wastewater and mine discharge water.

The area not inundated is characterised by extensive rapids which forms a critical area and as most of the rest of the MRU is inundated from the Barrage, EWR 4 was selected in this reach approximately 1 km downstream of the Vaal Dam. This site, is however, too close to the Vaal Dam to detect any major impacts and access to the site is difficult as Rand Water controls access. This site is therefore not considered a high priority biomonitoring site.

The reach has a PES of a D (DWAF, 2008b) mainly due to deteriorated water quality from tributaries entering this reach.

17.1.4 MRU VAAL E: Barrage to the end of the WMA 8

The main flow regulating capability for this reach is from the Vaal Barrage with support from the Vaal Dam. There are obviously contributing flows from the Schoonspruit, Mooi, Vals and Rhenoster tributary rivers. The flow in this river reach is influenced by various factors as listed below:

- Return flows from mine dewatering and treated urban wastewater into this reach and upstream of the Vaal Barrage contribute to the flow in this river reach.
- In the past. a flow dilution operating rule has been applied where water is released from Vaal Dam to maintain the TDS concentration in the Vaal Barrage not to exceed 600 mg/ℓ. The increased releases from Vaal Barrage can be as much as 200 million m^3/annum.
- There are significant evaporative losses in this river reach.

OSAEH 11.13 is located in the Kromelmboogspruit a tributary of the Vaal River upstream of Parys. Originally it was planned to sample OSAEH 11.13 however the site visit had to coincide with a planned PR event and an alternative site had to be selected in order to accommodate this event. A new site was selected at Parys in the Vaal River main stem. The new site at Parys, situated on the RB just upstream of the R53 road bridge may be better suited as a monitoring site as it is located at Parys and would detect upstream impacts. This reach is very important as the Vredefort

Dome World Heritage site is located in this reach and is therefore a very high priority monitoring site.

EWR 5 is situated at the end of the WMA 10 km upstream of the Mooi River confluence and the EWR site situated the farthest downstream in the Vaal River. It is impacted by major upstream anthropogenic activities. This site is situated below the Vredefort Dome World Heritage area and is therefore a very high priority monitoring site.

The reach from the Vaal Dam to the Mooi River deteriorates from a C to a C/D EcoStatus PES, based on the results provided. However this reach can deteriorate to a D EcoStatus at times. Species occurring in this reach are resilient and the releases made from the Vaal Barrage to maintain the TDS concentrations in this reach are vitally important. The Vredefort Dome World Heritage Site is in this reach and therefore this reach is of critical importance.

17.2 KLIP RIVER

The Klip River is largely natural and there is no large regulating storage in the catchment. The yield balance of the river system is positive. This catchment contributes a large portion of the incremental runoff to the Vaal Dam and is an important tributary of the Vaal River, in terms of providing natural, variable flow downstream of Grootdraai Dam.

17.2.1 MRU KLIP C: Lower Foothill geomorphic zone to Lowland zone

This reach is distinctly different due to changes in the geomorphic zone from the upper and lower geomorphic zones and is not wetland dominated. As this geomorphic zone is classified as lower foothills, it is more likely that rapids will occur here than in the lower Lowland section which would represent critical habitat.

EWR 6 is located downstream of OSAEH 11.9. The condition of the river is good at EWR 6 and considering the importance of this tributary as well as data availability and the level of analysis undertaken at EWR 6, this site is a preferred biomonitoring site.

The EcoStatus of this reach is overall in a B EC (DWAF, 2008b).

17.3 WILGE RIVER

This river system has Sterkfontein Dam (located in C81D) as the only regulating storage facility. Sterkfontein Dam receives water from the Thukela-Vaal Transfer Scheme and contains the “reserve” water for the Integrated Vaal River System. The operating rule of Sterkfontein Dam is such that water is only released from the dam when Vaal Dam is at low levels. In the upper portion of quaternary C81F water is abstracted from Fika Patso and Metsi Matso dams to supply the Phuthaditjaba area. Water users within this catchment comprise both urban and irrigation user groups.

The upper reaches of the Wilge River are in good condition ranging from a B to B/C EcoStatus above Harrismith. The river deteriorates to a D EcoStatus below Harrismith and recovers to a C EcoStatus from C81K to the Vaal River confluence (DWAF, 2008b).

17.3.1 MRU WILGE A: Origins of the Wilge River to confluence with the Nuwejaarspruit

The operation of the river changes at the confluence of the Wilge River with the Nuwejaarspruit (releases from Sterkfontein Dam). This reach is important due to the different operation and wetland character.

EWR 7 is situated in the upper reaches of the Wilge River. The Braamhoek pump storage scheme upstream of this site is under development and will impact the Wilge River and therefore this site is a good location for detecting these impacts. The new dams (Eskom pumped storage scheme) coming online will cause reductions in baseflows, as well as likely changes to moderate floods which will impact the geomorphology while water quality may deteriorate due to increased turbidity and nutrient loading. The system drivers therefore have a negative trajectory of change. The site is not the most ideal site in terms of habitat availability and exotic alien fish have a negative impact on the site. Although it was noted during a field visit in 2009 to the Braamhoek pump storage scheme that biomonitoring was being conducted by Eskom as part of the Environmental Management Programme (EMP) requirements, this site should be considered as a monitoring site.

17.3.2 MRU WILGE B: Nuwejaarspruit confluence to the Holspruit confluence.

Land cover in this reach is different to other reaches which is dominated by temporary dryland crops. The lower reaches of the Wilge are largely unregulated with only small dams for water supply to local users. Water users within this catchment comprise of both urban and irrigation user groups.

EWR 8 is situated upstream of the Liebenbergsvlei confluence, downstream of Warden. The site is impacted by WWTWs (Harrismith, Industriqwa, Warden and Tshiane) and receives diffuse runoff from agricultural, urban (Harrismith) and industrial activities (Industriqwa). Weirs occur in the system for the purposes of abstraction for purification purposes, fish dams and abstraction by tankers. This site could be valuable for detecting upstream anthropogenic activities. Sterkfontein releases impact negatively upon turbidity levels, habitat loss, decreased temperature and oxygen levels. The water from the Lesotho Highlands Water Project is released into the Ash/Liebensbergvlei River, a tributary of the Wilge. This will increase flows in this river, which may affect ecological functioning. This site should be monitored.

OSAEH 11.16 is located in the Wilge River downstream of EWR 8. According to the co-ordinates provided the site is located just upstream of the Liebenbergsvlei confluence. From Google Earth imagery the habitat seems limited and although there is no other monitoring sites identified in the Wilge River downstream of EWR 8, considering the data availability and level of assessment done at EWR 8 preference is given to EWR 8 over OSAEH 11.16 as a future monitoring site.

17.4 LIEBENBERGSVLEI

The flow in the Liebenbergsvlei River is dominated by the transfer from the Lesotho Highlands Water Project (LHWP). The LHWP water is discharged into the river system upstream of Saulspoort Dam (located in quaternary catchment C83A). Saulspoort Dam supplies water to the town of Bethlehem as well as to irrigation farmers. There are significant irrigation abstractions along the Liebenbergsvlei River, of which a significant portion is considered to be unlawful.

OSAEH 11.17 is located in this river reach. Although monitoring the impacts of the LHWP transfer in this river system is important, the site is not recommended as a biomonitoring site as there are continuous elevated flows and very limited habitat for sampling. Impacts from LHWP transfer could rather be monitored in the Wilge River.

This system is highly impacted with the upper reaches above Saulspoort ranging in a D – to E/F EcoStatus and lower reach is in a D EcoStatus (DWAF, 2008b).

17.5 WATERVAL

The Waterval River receives discharges from the Sasol Secunda Complex as well as treated urban wastewater. From the salinity balance undertaken as part of the Vaal River System Analysis Update (VRSAU) study, there is also evidence of mine water seepage and runoff from the paved urbanised areas contributing to the flow in the river. There are irrigators situated downstream of the above-mentioned discharges.

This tributary impacts the Vaal River negatively and a monitoring site should be considered in this reach. Two OSAEH sites, OSAEH 11.10 (US) and OSAEH 11.11 (DS) are situated in this tributary, and coincide with the two EWR sites (WA1 and WA2) selected and assessed during a previous Intermediate Ecological Reserve study conducted during 2005 by BKS.

The reach has a PES EcoStatus of a D and is heavily impacted by industrial activity (DWAF, 2008b). It is recommended that OSAEH 11.11 (WA2) be included in future monitoring programmes.

17.6 SUIKERBOSRAND RIVER

17.6.1 MRU SUIKER A: Origin of the Suikerbosrand River to the confluence of the Blesbokspruit

The Blesbokspruit with its significant problems regarding water quality makes this the logical boundary for the MRU. The Suikerbosrand River in quaternary catchments C21A - C is largely natural, there are no significant abstractions or discharges influencing the river flow.

OSAEH 11.15 is at the same locality as EWR 9 and considering that the lower reaches of the Suikerbosrand are impacted by mining and other industrial activities this site should be included in a monitoring programme.

The upper reaches are in a B/C EcoStatus deteriorating slightly to a C (DWAF, 2008b).

17.6.2 MRU SUIKER B: Between the Blesbokspruit and Vaal River confluences

The change in water quality due to the Blesbokspruit as well as the change in natural hydrology defines this MRU.

EWR 10 occurs downstream of the Blesbokspruit River which is heavily impacted and in close proximity to OSAEH 11.14 which is downstream of EWR 10. It was decided to include EWR 10 in the current study and instead of assessing OSAEH 11.14, EWR 10 was assessed in March 2011. The Reserve study allowed for good data availability and understanding of the site however the major issue at this site is that the PES baseline could have changed due to the uncertainties regarding the hydrology. This site should be included to detect upstream impacts and to determine if the site condition improves when the planned water quality management plan for the Blesbokspruit is initiated which would include treatment of mine water decant.

Due to the impact of the Blesbokspruit the lower reaches are in a C/D EcoStatus (DWAF, 2008b).

17.6.3 MRU BLES A: Origin of the Blesbokspruit to confluence of the Suikerbosrand River

However, the Blesbokspruit Ramsar site is situated in the middle stretch of river. The river should be managed as a whole.

EWR 11 and OSAEH 11.8 have the same locality. The Reserve study allowed for good data availability and understanding of the site, however the major issue at this site is that the PES baseline could have changed due to the uncertainties regarding the hydrology. EWR 11 was assessed during March 2011. The site is severely impacted, especially biotically, and therefore this site should be included to detect these impacts and to determine if the site improves when the planned water quality management plan for the Blesbokspruit is initiated which would include treatment of mine water decant.

The reach is currently in a D/E EcoStatus (DWAF, 2008b).

17.7 KLIP RIVER (GAUTENG)

This river reach receives about 200 million m^3/annum of treated urban wastewater which significantly changed the flow pattern from natural conditions. There is also significant runoff from the paved urbanised areas contributing to the flow in the Klip River and discharges from the mines are estimated at approximately 10 million m^3/annum.

OSAEH 11.12 is situated in this reach at Meyerton. The river is highly polluted, habitat has been altered due to elevated flows. This site may not be the ideal monitoring site but should be included in future monitoring programmes due to the significant impacts on this river and the deteriorated water quality that enters the Vaal River.

17.8 MOOI RIVER

Boskop Dam is located upstream of this river reach and the catchment upstream of Boskop Dam is partly underlain by dolomite. The Wonderfonteinspruit is the most significant tributary of the Mooi River. Water from the Gerhard Minnebron eye is used for irrigation purposes. Urban return flows from the Flip Human Wastewater Treatment Works are also discharged into the Mooi River upstream of Boskop Dam. Potchefstroom Town is supplied from a small storage dam, Lakeside Dam, which is supported from Boskop Dam. Boskop Dam also supplies water to the Mooi River Irrigation Scheme. Klerkskraal Dam is located upstream of Boskop Dam in quaternary catchment C23F. There are irrigation water users supplied directly from Klerkskraal Dam. Under certain conditions, water is released from Klerkskraal Dam to support Boskop Dam. In order to minimise river losses these releases are, however, made via the concrete lined Klerkskraal canal system. Portions of the natural spills from Klerkskraal Dam are also routed through the right bank canal that spills into Boskop Dam. It should be noted that there is a significant canal and pipe infrastructure conveying the urban return flows, mine discharges and irrigation water supply in this area.

17.8.1 MRU MOOI C: Boskop Dam wall to confluence with the Vaal River

OSAEH 11.3 is situated in a park, in a residential area surrounded by plots approximately 1.6 km downstream of Potchefstroom Dam and was assessed during October 2010. The site is not adequate for monitoring, although data are available. This site was assessed because the RHP site downstream of Mooi River Mall has been flooded due to development and therefore no site exists downstream of the Mall and no other suitable site could be found. It must however be noted that the Mooi River impacts are driven by water quality problems, and before a catchment management plan is initiated in this system to address these problems, the biotic condition in the Mooi will not be improved. The Mooi has also been significantly altered and the reach is in a D/E EcoStatus (DWAF, 2008b). This site is not considered a high priority site for future monitoring as the overriding problem in this system is water quality and not an altered flow regime. The biota in this reach will not improve unless water quality problems are addressed and therefore it is recommended that this site be included in a water quality monitoring programme.

18 MIDDLE VAAL CATCHMENT (WMA 9) – FROM VERMAASDRIFT TO BLOEMHOF DAM

18.1 BACKGROUND

The Middle Vaal WMA forms part of the integrated Vaal River System, and falls within the C drainage region of South Africa. The Middle Vaal WMA is one of the three cascading WMAs in the Vaal River System catchment, which includes the drainage area of the Vaal River from its headwaters to the confluence of the Vaal and Orange Rivers (DWA, 2009b).

The Middle Vaal WMA covers a catchment area of 52 563 km^2, and includes parts of the Free State and North-West Provinces. It is situated in the north-western part of the country and forms part of the Orange River watercourse. The Vaal River flows in a westerly direction to the Lower Vaal WMA. It is the middle WMA within the Vaal River System, with water being transferred *via* the Vaal River through this WMA to Bloemhof Dam, from the Upper Vaal WMA to the Lower Vaal WMA. The WMA consists of the C24, C25, C41, C42, C43, C60 and C70 tertiary catchments (DWA, 2009b).

The Middle Vaal WMA is dependant on the Upper Vaal WMA for meeting the bulk water requirements of its mining, industrial and urban sectors in the Klerksdorp-Orkney and Welkom-Virginia areas. The surface flow of the Vaal River, most of which originates in the Upper Vaal WMA, represents the bulk of the surface water in the Middle Vaal WMA. The Vaal River is fed by a number of tributaries of which the most significant are the Rhenoster, Schoonspruit, Vals and Vet Rivers. Vlei areas occur along the lower Vet River and in the upper Schoonspruit catchment. The surface water flows that originate within the WMA are highly seasonal and intermittent (DWA, 2009b).

Most of the major tributaries of the Middle Vaal WMA support irrigation schemes. The Sand-Vet Irrigation Scheme within the Sand-Vet Government Water Scheme (GWS) is the most important in the Middle Vaal WMA. Other significant irrigation schemes in this WMA are the Schoonspruit and Rhenoster GWS.

Five OSAEH sites were identified as possible monitoring sites while four EWR sites occur within the Middle Vaal WMA that was assessed as part of the Vaal Comprehensive Reserve study undertaken by Golder and Associates during 2007 – 2010. All the OSAEH sites were assessed during October 2010 except OSAEH 11.5 and OSAEH 29.3 which is the same locality as EWR 14 and 15 respectively and therefore it was deemed that adequate data exists for this monitoring site. Section 19 to 25 summarises the results of the October 2010 assessment as well as a summary of the EWR results.

Figure 18.1 provides the locality of the EWR sites as well as the OSAEH sites that occur in the Vaal River where the green pins represent the OSAEH monitoring sites, and the red pins represent the EWR sites assessed during 2010. Site information is provided in Table 18.1.

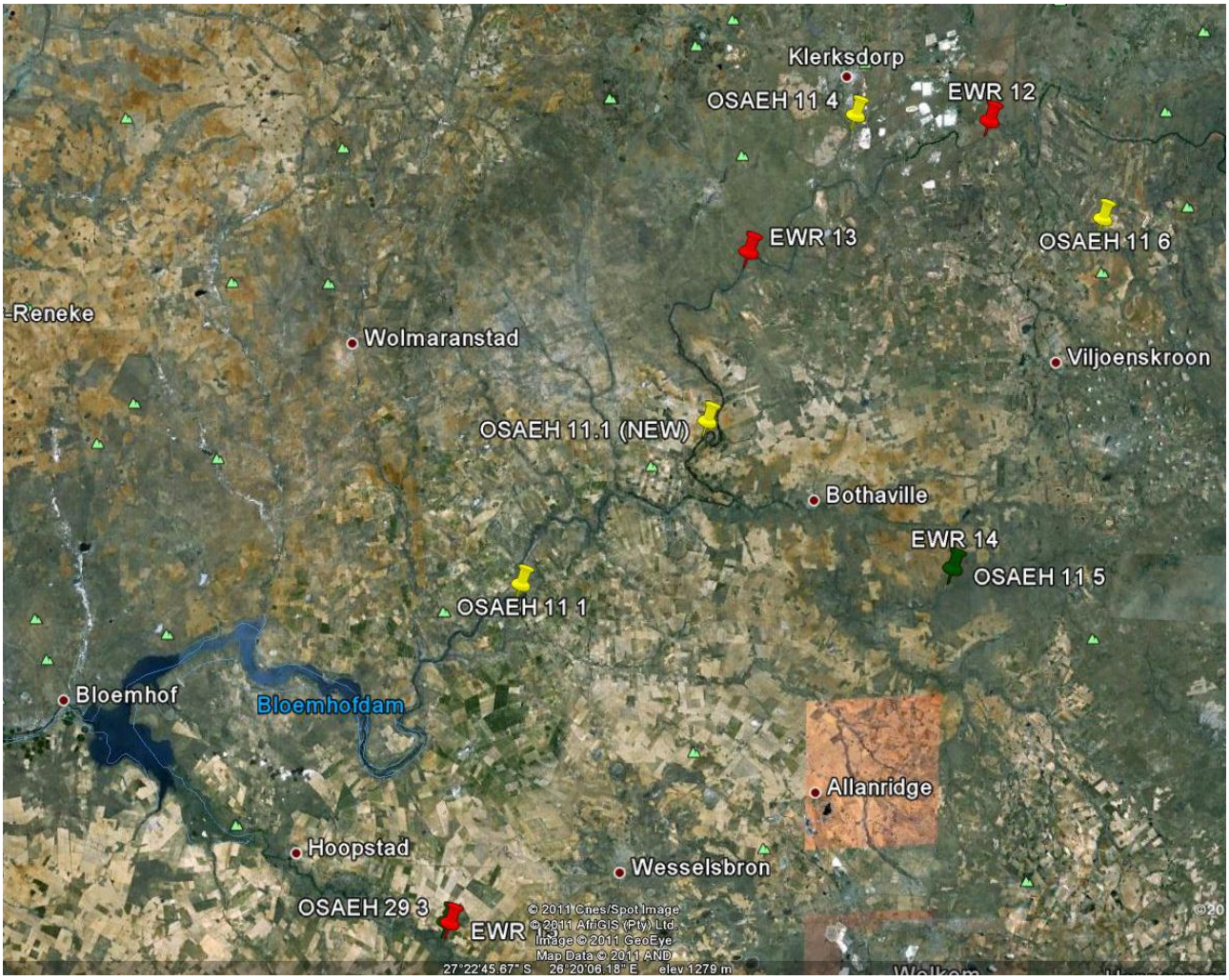

Figure 18.1 OSAEH monitoring and EWR sites occurring within the Middle Vaal WMA (WMA 9) (Google Earth image, 2010)

Table 18.1 OSAEH monitoring and EWR site detail

Site	Monitoring type	Eco-Region	Major River	Latitude	Longitude	Site code
OSAEH_11_1[1]	Monitoring Site P	11	Vaal	-27.51729	26.21604	C2VAALBLOEM
OSAEH_11_4	Monitoring Site C	11	Vaal/Skoonspruit	-26.93333	26.66527	C2SKOOURANI
OSAEH_11_5	Monitoring Site C	11	Vaal/Vals	-27.48683	26.81305	C6VALSPROKL
OSAEH_11_6	Monitoring Site P	11	Vaal/Renoster	-27.05286	27.00991	C7RENOR501B
OSAEH_29_3	Monitoring Site C	29	Vaal/Vet	-27.93412	26.12094	C4VETHOOPS
EWR 12	Ecological Reserve Site	11	Vaal	26.93615	26.85025	Vermaasdrift
EWR 13	Ecological Reserve Site	11	Vaal	27.10413	26.52185	Regina Bridge
EWR 14	Ecological Reserve Site	11	Vals	27.48685	26.81320	Proklameersdrift
EWR 15	Ecological Reserve Site	11	Vet	27.93482	26.12569	Fisantkraal

1 Location of this site was moved. See section 23 for new details.

19 OSAEH 11.6: RHENOSTERSPRUIT

19.1 SITE DESCRIPTION

The site is situated approximately 18 km upstream of its confluence with the Vaal River in MRU Rhenoster C according to DWA (2009b). The water was slightly turbid and the river channel was notably stable with well developed marginal vegetation. The abundance of watercress (*Rorippa nasturtium-aquaticum*) is often an indication of excessive nutrients entering the system. The substratum at the sampling site was slightly embedded and benthic algae were also present. There is abundant, diverse marginal vegetation, with good cobble habitat available if suitable flow is present. GSM (Gravel, Sand and Mud) and SOOC (Stones Out Of Current) biotopes were also present in suitable quantity and quality.

Location	Renosterspruit	**Altitude**	1308m
Longitude	27.0099	**Latitude**	-27.0529
EcoRegion	Highveld 11.08	**Quaternary catchment**	C70K
Water Management Area	Middle Vaal	**Geomorphological zone**	Lowland River

Site OSAEH 11.6 indicating excellent marginal vegetation but poor stream flow

19.2 SAMPLING CONDITIONS

At the time of sampling, little to no flow was present at the site. The site consists of pool sections, as well as cobble and sand sections with very little flow. Marginal vegetation was of excellent quality and quantity. The substratum was mostly cobbles, sand and mud, with good SOOC biotope present. Algae were also present on the cobbles.

19.3 PRESENT ECOLOGICAL STATE

IIHI	The Instream Index of Habitat Integrity (IIHI) was rated a D (60.1%). This is mostly due to changes in water quality as a result of extensive cultivation and farming. The hydrology has probably changed due to reduced roughness in the catchment.
RIHI	The Riparian Index of Habitat Integrity (RIHI) is a C/D (73.4%) with the main impacts being riparian encroachment due to increased nutrients and increased flow peaks from extensive hardened as well as the presence of exotic vegetation.
Fish	Three of the ten expected fish species were collected within this Resource Unit (RU) during the present survey suggesting that the FROC of some species have been reduced from reference conditions and that the site did not provide suitable habitat for the larger fish species. Based on their abundance, the FROC of smaller species such as *B. paludinosus* and *P. philander* at this site was rated to be close to reference and can be contributed to plentiful marginal vegetation and slightly turbid waters, providing suitable cover. Although *T sparrmanii, L. capensis L. umbratus, L. aeneus* and *L. kimberleyensis* was not collected at this site during the present survey, it is probable that these species are still present in the system where suitable habitat is available.
Inverts	Oct 2010: SASS5 score: 127 No of Taxa: 27 ASPT: 4.7 Key taxa expected but not observed were generally those that are sensitive to water quality changes, such as Perlidae and Heptageniidae. Notonectidae, Pleidae and Belostomatidae were more abundant than expected, while Elmidae, Caenidae, Coenagrionidae and Libellulidae were less abundant than expected. Those taxa which have a preference for very fast flowing water (>0.6 m/s) were notably absent, namely Perlidae, Psephenidae, Hydropsychidae >2spp. Tricorythidae and Philopotamidae. Some taxa with a preference for moderately fast flowing water (0.3 – 0.6 m/s) were also absent, including Heptageniidae, Leptoceridae and Naucoridae.
Rip veg	The main impacts are substrate exposure due to trampling and the presence of exotic vegetation.
Diatoms	The diatom community indicated that the biological water quality at the site was moderate (C EC) with a SPI score of 9.6. Elevated concentrations of organically bound nitrogen were present, with moderate saturated oxygen levels. Although organic pollution is moderate this site is strongly polluted.

19.4 MAIN IMPACTS AT THE SITE

	PES	Causes	Sources	F[1]/NF[2]
Rip veg	C	Terrestrialisation.	Burning regime out of control. Annual burns enhance the encroachment of terrestrial species into the riparian zone.	NF
		Exotic invasion.	*Salix babylonica, Gleditsia triacanthos,* and *Eucalyptus* sp., and non-woody weeds.	
		Water quality.	Chicken farms, non-point source pollution (cultivation).	F
Fish	C	Loss of habitat diversity as a result of changes in hydrology.	Decreased flow in dry season and increased flood peaks.	F
		Decreased water quality affect species with requirement for high water quality.	Increased nutrients, sediments and toxins from agricultural areas.	NF
		Increased turbidity and disturbed bottom substrates.	Erosion and presence of bottom feeding alien (*C. carpio*).	
Inverts	C	Low flow conditions.	Abstraction - agriculture.	F
		Water quality and associated benthic growth.	Agriculture	NF

19.5 BASELINE SURVEY RESULTS: PRESENT ECOLOGICAL STATE

Driver Components	PES	Trend
IHI: INSTREAM	D	
IHI: RIPARIAN	C/D	
DIATOMS (WQ)	C	
Response Components	**PES**	**Trend**
FISH	C	Stable
MACRO INVERTEBRATES	C	Stable
INSTREAM	C	
RIPARIAN VEGETATION	C	Stable
ECOSTATUS	C	

The PES is a category C. Reasons for this include changes in the hydrology of the system due to agriculture in the catchment. Increased nutrients, sediments and toxins from agricultural practices in the area impact negatively on the site with a resultant decrease in instream habitat integrity. Presence of exotic vegetation impacts negatively on the site, thus decreasing the overall ecological integrity of the site.

19.6 SUITABILITY AS FUTURE BIOMONITORING SITE

Good habitat diversity is available at the site for SASS sampling, if suitable flow is present. Excellent quality and quantity of marginal vegetation is present, with good quantity of cobble biotope and sand and mud biotopes present. Few localized impacts are present. Dense benthic algal growth is present due to nutrient enrichment. The site is easily accessible with wadeable areas. There is an abundance of undercut banks and marginal and/or overhanging vegetation present, which provide suitable habitat for small fish species. The marginal riparian zones present relatively good vegetation cover. Clear hydro-geomorphogical zones are present. Very little erosion is present. Exotic species are present in the riparian zone as well as localised impacts.

Access to the site may be problematic as permission from landowners will be needed.

This site is a valuable monitoring site, although the landowner will have to be approached by a senior official as he is very negative and hostile; if the site is to be included in future monitoring programmes.

20 EWR 12: VERMAASDRIFT (VAAL RIVER)

The information is summarised from DWA (2009a, b; 2010b).

20.1 SITE DESCRIPTION

For the purposes of the EWR study, the Vaal River from the start of WMA 9 at Vermaasdrift on Vaal River to Bloemhof Dam was delineated into four Management Resource Units (MRU Vaal F – J) (DWA, 2009b). EWR 12 falls within MRU Vaal F which is the delineated reach from the start of WMA 9 at Vermaasdrift on Vaal River to just upstream of the Schoonspruit River. This reach is important to understand the influence of the Upper Vaal WMA as it is just downstream of the Upper Vaal WMA (downstream of the Mooi River confluence).

EWR 12 is situated downstream of Parys and upstream of the confluence with the Koekemoerspruit at Vermaasdrift on the main stem of the Vaal River. The site is a single thread straight channel with a flat bed which is alluvial controlled. A fixed boulder floor with sand dominates the reach. Fish habitat is well represented at site as well as flow-depth categories and cover. Macroinvertebrate survey habitat availability is moderate at EWR 12 and is not a limiting factor of macroinvertebrate diversity. The site is not ideal for vegetation assessment as 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.

Location	EWR 12 Vermaasdrift	**Altitude**	1348 m
Longitude	26.85025	**Latitude**	-26.93615
EcoRegion	Highveld 11.01	**Quaternary catchment**	C24A
Water Management Area	Middle Vaal River	**Geomorphological zone**	Lower Foothills

EWR 12, Vermaasdrift

20.2 PRESENT ECOLOGICAL STATE (PES)

Geom	Wet season baseflows and small and moderate floods have been reduced from natural within this reach, whilst dry season baseflows are elevated. This has degraded the in-channel condition of the river through reduced scour and bed activation events. Large dams far upstream have also likely reduced some of the sediment supply, but large tributaries do reinstate some of this. Elevated salinity also helps reduce sediment loads by encouraging flocculation.
WQ	The present state is based on data collected from C2H018. The data indicated that the nutrients are stable

	with slightly higher salts (EC) and sulphates. The system is driven by DO (oxygen fluctuations due to releases) all year round. This increases turbidity, pH, temperature and toxicants. Large algal diversity on the rocks, traps suspended solids (sedimentation) and decreases turbidity.
Fish	The EC of D at site EWR 12 can be ascribed to the absence of 4 expected species namely *A. sclateri*, *B. anoplus*, *L. umbratus* and *T. sparrmanii* from the observed fish assemblage. The introduced species, G. affinis occurred at this site.
Inverts	Sep 07: SASS5 score: 106 No of Taxa: 21 ASPT: 5 Apr 08: SASS5 score: 76 No of Taxa: 19 ASPT: 4 The assemblage is characterised by tolerant taxa.
Rip veg	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. 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.
Diatoms	Diatom results are based on a sample taken during 2007 and a 12 month data set taken during 2002-2003. The Ecological Category (EC) was a D, mainly to high nutrient and organic loading. The 2002-2003 data indicated continual pollution and during the survey the diatoms remained in a D EC for 10 of the 12 months.

20.3 MAIN IMPACTS AT THE SITE

	PES	Causes	Sources	F/NF
WQ	D/E	High salts.	Mining impacts.	F
		High nutrients.	Waste Water Treatment Works (WWTW) discharge.	
Geom	C/D	Decreased intra-annual floods and high flow events.	Operation of the system.	F
Rip veg	C	Terrestrial exotic invasive species.	Anthropogenic.	NF
		Aquatic exotic invasive species.	Anthropogenic.	F
Fish	D	Non availability of specific habitat cover units due to the explosive growth of invasive aquatic macrophytes.	Primarily due to WWTW.	NF
		Lack of access to upstream river reaches for fish species with this migratory requirement	Gauging weirs without fish ladders.	
		Lack of suitable refugia in tributaries. Available tributaries all highly impacted – Mooi River and Koekemoerspruit.	Mining, WWTW.	
Inverts	C/D	Poor water quality.	Mine effluent, agriculture run off and waste water treatment works.	NF
		Poor habitat availability.	Due to algal blooming due to eutrophication.	F

20.4

20.5 RESULTS: PRESENT ECOLOGICAL STATE

Driver Components	PES	Trend
GEOMORPHOLOGY	C/D	Stable
WATER QUALITY	D/E	Stable
DIATOMS	D	
Response Components	**PES**	**Trend**
FISH	D	Stable
MACRO INVERTEBRATES	C/D	Stable
INSTREAM	C/D	
RIPARIAN VEGETATION	C	Negative
ECOSTATUS	D	

The main reasons for the PES are altered flow regime and deteriorated water quality. Due to the Vaal Dam and Vaal Barrage upstream of the site the altered flow regime has resulted in increased winter base flows in the Middle Vaal River and reduced flood peaks in summer. Poor water quality impacts biota and habitat availability. Exotic riparian vegetation species also have an impact.

20.6 SUITABILITY AS FUTURE BIOMONITORING SITE

The site is adequate for biotic monitoring and important to understand the influence of the Upper Vaal WMA. The Vaal River up to Schoonspruit is highly regulated due to releases made from Vaal Dam and Vaal Barrage and this along with impaired water quality from WWTW and abstraction for mining and irrigation the PES is a D at this site. Tributaries occurring within this reach are also impacted by anthropogenic activities and therefore play a diminished role as refugia. Due to elevated flows habitat availability may not always be conducive to aquatic monitoring and therefore future monitoring should occur at lower flows when all habitats are available.

21 OSAEH 11.4: SCHOONSPRUIT

21.1 SITE DESCRIPTION

The sampling site is situated in the Schoonspruit approximately 10 km upstream of its confluence with the Vaal River and falls within MRU Schoonspruit D according to DWA (2009b). The only significant change that occurs along these lower reaches below the Klerkskraal Dam is an increase in urban/built up areas and therefore an increase in return flows from these areas into the Schoonspruit. The substratum at the site was covered with benthic algae indicating the presence of excessive nutrients entering the system. The marginal vegetation is very well developed as a result of the available nutrients. Watercress (*Rorippa nasturtium-aquaticum*) was abundant, indicating excessive nutrients entering the system. Due to the dense algal mats present on the cobbles, macroinvertebrate colonization of this substrate is restricted. There was abundant, diverse marginal vegetation present. GSM and SOOC biotopes were also present.

Location	Schoonspruit	**Altitude**	1291 m
Longitude	26.6653	**Latitude**	-26.9333
EcoRegion	Highveld 11.01	**Quaternary catchment**	C24H
Water Management Area	Middle Vaal	**Geomorphological zone**	Lowland River

Site OSAEH 11.4 indicating a riffle section as well as dense algal growth on the substratum.

21.2 SAMPLING CONDITIONS

At the time of sampling, moderate flow was present at the site. The site consisted of pool sections, interspersed with riffle sections. Marginal vegetation was of excellent quality and quantity. The substratum was mostly cobbles, with gravel, sand and mud also present. Some bedrock was also present. Dense algal growth was present on the substratum. Adequate SOOC biotope was also present for sampling purposes.

21.3 PRESENT ECOLOGICAL STATE

IIHI	The Instream Index of Habitat Integrity (IHI) was rated a D (59.5%). This is mostly due to changes in water quality as a result of extensive urban and mining runoff as well as cultivation. The hydrology has probably changed significantly due urban runoff and hardened surfaces.
RIHI	The Riparian Index of Habitat Integrity (RIHI) is a C/D (61.3%) with the main impacts being increased flow peaks from extensive hardened, the presence of exotic vegetation and riparian encroachment due to increased nutrients.
Fish	Four of the ten expected fish species were collected within this Resource Unit (RU) during the present survey suggesting that the FROC of some species have been reduced from reference conditions. Based on their abundance, the FROC of smaller species such as *Barbus trimaculatus*, *B. paludinosus* and *P. philander* at this site was rated to be close to reference and can be contributed to plentiful marginal vegetation and slightly turbid waters, providing suitable cover. Although *T sparrmanii, L umbratus and L. kimberleyensis* was not collected at this site during the present survey, it is probable that these species are still present at the site. The FRAI model rates the Present Ecological State for fish as a Class C (64.5%).
Inverts	Oct 2010: SASS5 score: 47 No of Taxa: 13 ASPT: 3.6

	Key taxa expected but not observed were generally those that are sensitive to water quality changes, such as Perlidae, Hydropsychidae >2spp. and Heptageniidae. Hirudinea, Dytiscidae, Planorbinae, and Oligochaeta were more abundant than expected, while Nepidae and Coenagrionidae were less abundant than expected. The MIRAI model generates a Present Ecological State for macroinvertebrates as a Category C (67.8%).
Rip veg	The RIHI is a C (68.3%) with the main impacts being burning regime, trampling and the presence of exotic vegetation.
Diatoms	The biological water quality at this site was poor with a SPI score of 4.9. This relates to a EC of a D/E. Oxygen saturation was low, and organically bound nitrogen levels were continuously elevated indicating that nutrient loading is problematic at this site. Organic pollution levels were elevated indicating that organics may be problematic at times.

21.4 MAIN IMPACTS AT THE SITE

	PES	Causes	Sources	F/NF
Rip veg	C	Terrestrialisation.	Burning regime out of control. Annual burns enhance the encroachment of terrestrial species into the riparian zone.	NF
		Exotic invasion.	*Salix babylonica, Gleditsia triacanthos,* and *Eucalyptus* sp., and non-woody weeds.	
		Water quality.	Mining, chicken farms, non-point pollution, etc.	F
Fish	C	Loss of habitat diversity as a result of flow modification.	Inundation upstream and flow modification.	F
		Decreased water quality affect species with requirement for high water quality.	Increased nutrients, sediments and toxins from urban areas diamond and gold mines and agricultural areas.	NF
		Increased turbidity and disturbed bottom substrates.	Erosion and presence of bottom feeding alien (*C. carpio*).	
		Presence of migration barriers reduces migration success (breeding, feeding and dispersal) of some species.	Major upstream and downstream dams as well as weirs.	
Inverts	C	Flow modification.	Agriculture.	F
		Water quality and associated benthic growth.	Agriculture, settlements and urbanization.	NF

21.5 BASELINE SURVEY RESULTS: PRESENT ECOLOGICAL STATE

Driver Components	PES	Trend
IHI: INSTREAM	D	
IHI: RIPARIAN	C/D	
DIATOMS (WQ)	D/E	
Response Components	**PES**	**Trend**
FISH	C	Stable
MACRO INVERTEBRATES	C	Stable
INSTREAM	C	
RIPARIAN VEGETATION	C	Stable
ECOSTATUS	C	

The PES is a category C. Reasons for this include flow modification with a resultant decrease in the instream habitat integrity. Increased nutrients, sediments and toxins from diamond and gold mining in the catchment, urban and agricultural areas, impact negatively on the site with a resultant decrease in instream habitat integrity. Erosion, presence of exotic vegetation and instream migration barriers such as dams and weirs also decrease the ecological integrity of the site.

21.6 SITE SUITABILITY

Habitat diversity is fair with a good quantity of cobbles present. However due to the dense benthic algal growth, macroinvertebrate colonization is restricted. Good quantity and quality of marginal vegetation is available for sampling. The site is easily accessible with wadeable areas. An abundance of undercut banks and marginal and/or overhanging vegetation provides suitable habitat for small fish species. The substratum is slightly embedded with sediments. A low diversity of flow velocities is present and is dominated by a slow shallow habitat for fish species. The marginal riparian zone has relatively good vegetation cover, with good species diversity. No erosion is present at the site. Exotic riparian vegetation species are present within the narrow riparian zone.

Access to the site is not problematic.

22 EWR 13: REGINA BRIDGE (VAAL RIVER)

The information is summarised from DWA (2009a, b; 2010b).

22.1 SITE DESCRIPTION

The site is situated upstream of the confluence with the Vet River on the main stem of the Vaal River and falls within MRU Vaal G which is delineated from downstream the Schoonspruit confluence to Regina Bridge (a weir). Landuse is mostly natural grassland (dominant) with some thicket/ bushveld. Limited cultivated land (commercial/dryland crops) occurs in this reach.

Fish habitat is well represented although unnatural habitat fluctuations may occur due to upstream weir and an unnatural high abundance of species during migrations may occur. Macroinvertebrate survey habitat availability is good at EWR 13 and not a limiting factor of macroinvertebrate diversity. The site is ideal for vegetation assessment as 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.

Location	EWR 13 Regina bridge	**Altitude**	1285 m
Longitude	26.85025	**Latitude**	-27.10413
EcoRegion	Highveld 11.08	**Quaternary catchment**	C24J
Water Management Area	Middle Vaal River	**Geomorphological zone**	Lower Foothills
			
EWR 13			

22.2 PRESENT ECOLOGICAL STATE (PES)

Geom	Due to the low slopes at this site, very large discharges are required to scour the coarse sediment on the bed. The site and reach are moderately bedrock influenced with many of the upstream islands and riffle areas created by bedrock outcrops. Since 1944, the islands have become increasingly vegetated with trees – probably stabilized due to reduced floods as well as increased exotic vegetation. The PES is in a C Ecological Category due to sediment supply and transport potential reductions. Sediment distribution on the bars here is better than at EWR 12, suggesting that tributaries have somewhat ameliorated the effects of upstream dams.
WQ	The PES is based on data collected from C2H007 and shows high salinity and nutrients.
Fish	The EC of D at site EWR 13 can be ascribed to the absence of *B. anoplus*), *L. kimberleyensis*, and *L. umbratus* from the observed assemblage, combined with the lower than reference FROC of *L. aeneus*, *B.*

	paludinosus and *T. sparrmanii*.
Inverts	Sep 07: SASS5 score: 101 No of Taxa: 19 ASPT: 5.3 Apr 08: SASS5 score: 82 No of Taxa: 18 ASPT: 4.6 The assemblage is characterised by tolerant taxa and the PES is due to a combination of flow and non-flow related impacts. Impacts mostly relate to changes in flow regime due to Vaal Dam and Vaal River Barrage.
Rip veg	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 at EWR 12. Furthermore, the lack of extreme events, such as fire and flooding, are causing homogenization of the riparian vegetation 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.
Diatoms	Diatom results are based on a sample taken during 2007 and a 12 month data set taken during 2002-2003. The Ecological Category (EC) was a D, mainly to high nutrient and organic loading. The 2002-2003 data indicated continual pollution and during the survey the diatoms remained in a D EC for the whole year, with deterioration to an E EC at times.

22.3 MAIN IMPACTS AT THE SITE

	PES	Causes	Sources	F/NF
WQ	D	High steady salts.	Mining impacts.	NF
		High nutrients with worsening trend.	Algal degradation, and WWTW diffuse agricultural impacts.	
Geom	C	Reduced moderate flows and small floods have reduced scour and thus caused fining of the channel bed.	Operation of the Vaal system.	F
Rip veg	B/C	Terrestrial exotic invasive species.	Anthropogenic.	NF
		Aquatic exotic invasive species.	Anthropogenic.	F
Fish	D	Non availability of specific habitat cover units due to the growth of invasive aquatic macrophytes.	Primarily due to WWTW.	NF
		Lack of access to upstream river reaches for fish species with this migratory requirement.	DWA gauging weir without fish ladders.	
Inverts	C	Poor water quality that has a negative effect on taxa that have a high preference for unmodified water quality.	Tributaries upstream of the site in the Vaal, including agricultural runoff and waste water works effluent.	NF
		Loss of vegetation due to blooming of algae that covers riffles.	Nutrient enrichment of the water due to effluent.	F

22.4 RESULTS: PRESENT ECOLOGICAL STATE

Driver Components	PES	Trend
GEOMORPHOLOGY	C	Stable
WATER QUALITY	D	Stable
DIATOMS	D	
Response Components	**PES**	**Trend**
FISH	D	Stable
MACRO INVERTEBRATES	C	Stable
INSTREAM	C/D	
RIPARIAN VEGETATION	B/C	Negative
ECOSTATUS	C	

The main reasons for the PES are altered flow regime and deteriorated water quality. Due to the Vaal Dam and Vaal Barrage upstream of the site the altered flow regime has resulted in increased winter base flows in the Middle Vaal River and reduced smaller floods in summer.

22.5 SUITABILITY AS FUTURE BIOMONITORING SITE

This reach is important as it is downstream of the Schoonspruit catchment which is a major influence in the system. The weir captures major water quality impacts from the upper and middle Vaal catchments. It is important to note that developments in the form of small dams and irrigation schemes along the tributaries contributing to this reach do reduce the runoff to the Vaal River.

23 OSAEH 11.1: WOLWESPRUIT (VAAL RIVER) – OSAEH 11.5

23.1 SITE DESCRIPTION

This site is situated in the Wolwespruit Nature Reserve, on the Vaal River main stem. The river is approximately 100 m wide with small, vegetated islands which provide diverse marginal vegetation. The site has extensive cobble beds for sampling purposes; however dense benthic algal growth is present on the cobbles. There is a good diversity of instream habitats present. The sampling site is situated approximately 128 km upstream of Bloemhof Dam. The river channel is scoured locally as a result of upstream impoundments.

From Google imagery it was determined that the originally proposed site had limited instream habitat available for sampling purposes, hence the Wolwespruit site was selected as an appropriate monitoring site for this project. This new site in the Wolwespruit Nature Reserve provides unique/different habitat types when compared to the originally proposed site. Furthermore, the land use impact within the Nature Reserve is less than outside the Reserve which is that of agricultural use.

Location	Wolwespruit Nature Reserve	**Altitude**	1242 m
Longitude	26°19'48.1"	**Latitude**	27°24'06.2"
EcoRegion	Highveld 11.08	**Quaternary catchment**	C24J
Water Management Area	Middle Vaal	**Geomorphological zone**	Lowland River

Site OSAEH 11.1 indicating extensive runs over mainly cobble substrate.

23.2 SAMPLING CONDITIONS

The site, at the time of sampling, was dominated by extensive instream runs, with dense algal growth occurring on the substratum. Marginal vegetation was of excellent quality and quantity, with limited stones out of current biotope present. The substratum was mostly cobbles, gravel and sand, with some boulders present.

23.3 PRESENT ECOLOGICAL STATE

IIHI	The Instream Index of Habitat Integrity (IHI) was rated a C/D (59.5%). This is mostly due to changes in water quality as a result of extensive cultivation as well as urban and mining runoff in upstream tributaries. The hydrology has also changed significantly due to upstream inundation and flow modification.
RIHI	The Riparian Index of Habitat Integrity (RIHI) is a C (68.5%) with the main impacts being substrate exposure due to extensive cultivation and diamond mining as well as the presence of exotic vegetation.
Fish	Seven of the ten expected fish species were collected at this site during the recent survey within this Resource Unit (RU) suggesting that the FROC of some species have been reduced from reference conditions. Alien and invasive species such as C*tenopharyngodon idella* and *C. carpio* and were notably abundant at the site. *L. aeneus* were notably less abundant than *C. carpio* at this site probably as a result of habitat deterioration (bethic algae and sedimentation). Based on their abundance, the FROC of smaller species such as *B. trimaculatus*, *B. paludinosus* and *P. philander* at this site was rated to be close to reference and can be contributed to plentiful marginal vegetation and slightly turbid waters, providing suitable

	cover. Although *T sparrmanii, L umbratus and L. kimberleyensis* was not collected at this site during the present survey, it is probable that these species are still present at the site. The FRAI model rates the Present Ecological State for fish as a Class C (64.5%).
Inverts	Oct 2010: SASS5 score: 110 No of Taxa: 19 ASPT: 5.8 Key taxa expected but not observed were generally those that are sensitive to water quality changes, such as Perlidae and Heptageniidae. The dense algal growth has a negative impact on the instream habitat available for macroinvertebrate colonization and can be seen in the high rating for the cobble habitat (3.5). Taxa expected but not observed in this biotope include Aeshnidae, Ecnomidae, Libellulidae and Psephenidae. Tricorythidae were more abundant than expected, while Atyidae, Coenagrionidae and Hydrophilidae were less abundant than expected. The MIRAI model generates a Present Ecological State for macroinvertebrates as a Category C (65.9%).
Rip veg	The main impacts are substrate exposure due to overgrazing, trampling and the presence of exotic vegetation. An easy distinction can be made between marginal and non-marginal riparian vegetation. The marginal zone exhibits relatively good vegetation cover. The site is dominated by exotic pioneer species mainly in the marginal zone. Bank slumping and undercutting is prevalent, whilst the slope of the non-marginal zone is steep. Agricultural activities present adjacent to the left bank.
Diatoms	The SPI score at this site was 11.7, a C EC. The community indicated fairly high oxygen saturation with elevated levels of organically bound nitrogen. Organic pollution levels are low and overall the site is moderately polluted.

23.4 MAIN IMPACTS AT THE SITE

	PES	Causes	Sources	F/NF
Rip veg	C	Vegetation removal.	Trampling/grazing by game/cattle and some fishermen activity.	NF
		Exotic invasion.	*S. babylonica, G. triacanthos,* and *Eucalyptus* sp., and dominant non-woody weeds.	
		Bank undercutting and scouring	Substrate of site consists out of sand and alluvial material. Due to dynamics of aggradation and degradation habitat change is constant. Bank instability and the impact of trampling and exotic vegetation among others, contribute towards bank erosion.	F
Fish	C	Loss of habitat diversity as a result of flow modification.	Inundation upstream and flow modification.	F
		Decreased water quality affect species with requirement for high water quality.	Increased nutrients, sediments and toxins from urban areas diamond and gold mines and agricultural areas.	NF
		Increased turbidity and disturbed bottom substrates.	Erosion and presence of bottom feeding alien (*C. carpio*).	
		Presence of migration barriers reduces migration success (breeding, feeding and dispersal) of some species.	Major upstream and downstream dams as well as weirs.	
Inverts	C	Loss of habitat diversity.	Inundation upstream and flow modification.	F
		Water quality and associated benthic growth of algae.	Agriculture, mining and urbanization.	NF

23.5 BASELINE SURVEY RESULTS: PRESENT ECOLOGICAL STATE

Driver Components	PES	Trend
IHI: INSTREAM	C/D	
IHI: RIPARIAN	C	
DIATOMS (WQ)	C	
Response Components	**PES**	**Trend**
FISH	C	Stable
MACRO INVERTEBRATES	C	Stable
INSTREAM	C	
RIPARIAN VEGETATION	C	Stable
ECOSTATUS	C	

The PES EcoStatus for this site is a category C. Reasons for this include flow modification due to major dams and weirs upstream and downstream of the site which impact negatively on the available instream habitat. Increased nutrients, sediments and toxins from mining, urban and agricultural areas with a resultant decrease in instream habitat integrity is also a main reason for the overall condition of the site. Erosion, presence of exotic vegetation, vegetation removal, bank undercutting, scouring and instream migration barriers such as dams and weirs, impact negatively on the site, thus decreasing the ecological integrity of the site.

23.6 SUITABILITY AS FUTURE BIOMONITORING SITE

Good habitat diversity is available at the site for SASS sampling, including excellent quantity of cobble biotope, excellent quantity and quality of marginal vegetation, limited SOOC biotope available and good GSM biotope present. A fair diversity of velocities was present. The site has few localised impacts due to the fact that it is situated in the Wolwespruit Nature Reserve.

The site is easily accessible with wadeable areas. For fish sampling there is abundant fast, deep habitat available, providing good cover for larger species, as well as diverse substratum providing good cover for all fish species. An abundance of undercut banks and overhanging vegetation provides suitable habitat for small fish species. The substratum is slightly embedded with sediments.

Access to the site is gained via entry into the Wolwespruit Nature Reserve. The site is easily accessible once in the Reserve.

24 EWR 14: PROKLAMEERSDRIFT (VALS RIVER)

The information is summarised from DWA (2009a, b; 2010b).

24.1 SITE DESCRIPTION

The site is situated in the Vals River downstream of the town of Kroonstad within MRU Vals B which includes the Vals River downstream of the Kroonvaal weir to the confluence with the Vaal River. Water quality is impacted by Kroonstad and Bothaville, and from agricultural runoff. The overall modification to bed, channel and flow in the Vals River is moderate to large due to the presence of several weirs, roads through the river and road bridges over the river, as well as Serfontein Dam. Some sand mining occurs in the river and these lead to bank erosion and siltation of the river.

The site consists of a relatively narrow area of flow with moderately sloping banks. Fish habitat is well represented at site as well as flow-depth categories and cover. Macroinvertebrate survey habitat availability is adequate and is not a limiting factor of macroinvertebrate diversity. Riparian vegetation at the site is representative of the area.

Location	EWR 14 Proklameersdrift	**Altitude**	1285 m
Longitude	26.81320	**Latitude**	-27.48685
EcoRegion	Highveld 11.07	**Quaternary catchment**	C60J/C60G
Water Management Area	Middle Vaal River	**Geomorphological zone**	Lower Foothills

EWR 14, narrow main channel with cobble dominated riffle.

24.2 PRESENT ECOLOGICAL STATE (PES)

Geom	Reduced baseflows and decline in small floods have reduced sediment transport; so flushing of fines and scour is reduced. There are no large dams to remove sediment or trap large floods. Thus, the continued provision of small and moderate floods will maintain the PES at this site.
WQ	Data from monitoring site C6H001 was used for the PES. This data showed moderate salts with low sulphates and high nutrients. The higher nutrients could be due to the discharge from the WWTW at Kroonstad.
Fish	The EC of D can be ascribed to the absence of *A. sclateri* and *L. umbratus* from the observed fish assemblage combined with the lower than reference FROC of *T. sparrmanii*.
Inverts	Sep 07 SASS5 score: 87 No of Taxa: 18 ASPT: 4.8 Apr 08 SASS5 score: 57 No of Taxa: 16 ASPT: 3.6 The EC of C/D can be ascribed to season water flows (less winter flows) as well as variable water quality (turbidity smothering habitats and high nutrient levels).
Rip veg	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.

Diatoms	Diatom results are based on a sample taken during 2007. The Ecological Category (EC) was a D and the community indicated very high levels of organic pollution.

24.3 MAIN IMPACTS AT THE SITE

	PES	Causes	Sources	F/NF
WQ	C/D	Discharges from WWTWs and irrigation return flows	Increased nutrients	F
Geom	B/C	Reduced baseflows and decline in small floods have reduced sediment transport; so flushing of fines and scour is reduced.	Abstraction	NF
Rip veg	D	Terrestrial exotic invasive species.	Anthropogenic.	NF
		Aquatic exotic invasive species.	Anthropogenic.	
Fish	D	Water quality impairment, nutrient enrichment especially high ammonia concentrations.	Agricultural activities in the catchment. WWTW and abattoirs near Kroonstad.	NF
Inverts	C/D	Absence of taxa with a preference for very fast flowing water. Loss of taxa that prefers loose cobbles.	Moderate flows absent.	F
		Loss of taxa with a high requirement for water quality.	Effluent coming from Kroonstad and surrounding areas.	NF

24.4 RESULTS: PRESENT ECOLOGICAL STATE

Driver Components	PES	Trend
GEOMORPHOLOGY	B/C	Stable
WATER QUALITY	C/D	Stable
DIATOMS	D	
Response Components	**PES**	**Trend**
FISH	D	Negative
MACRO INVERTEBRATES	C/D	Stable
INSTREAM	C/D	
RIPARIAN VEGETATION	D	Negative
ECOSTATUS	C/D	

The main reasons for the PES are reduced flows due to abstraction and deteriorated water quality. Riparian vegetation is impacted by exotic species while biota are in a deteriorated condition mainly due to impaired water quality.

24.5 SUITABILITY AS FUTURE BIOMONITORING SITE

EWR 14 is at the same location as OSAEH 11.5 and therefore this site was not assessed during this study. As this is the only site that has been identified in the Vals River, the data collated during the Reserve study is important and adequate and this site should be included in future monitoring programmes.

25 EWR 15: FISANTSKRAAL (VET RIVER) – OSAEH 29.3

25.1 SITE DESCRIPTION

EWR 15 is situated in the Vet River downstream of the confluence with the Sand River, within MRU Vet C which is delineated from Erfenis Dam to the Sand River confluence (downstream of Erfenis Dam) (DWAF, 2009). No significant change in land use occurs in this MRU which is mainly bushland thicket and natural grassland. However it does include two Eco-regions.

Fish habitat fairly is well represented at site as well as flow-depth categories and cover for species favoring fast habitats. Slow (especially SD) habitats had to be supplemented by sampling of another site. Macroinvertebrate survey habitat availability is adequate and is not a limiting factor of macroinvertebrate diversity. Vegetation is not ideal as there is disturbance due to farming activities and a large degree of colonisation by exotic species. Land use in the area is predominantly agricultural and pastoral farming.

Location	EWR 15 Fisantkraal	**Altitude**	1247 m
Longitude	26.12569	**Latitude**	-27.93482
EcoRegion	Highveld 11.08	**Quaternary catchment**	C43A
Water Management Area	Middle Vaal River	**Geomorphological zone**	Lower Foothills

EWR 15, shallow cobble dominated rapid area

25.2 PRESENT ECOLOGICAL STATE (PES)

Geom	Reduced baseflows and a decline in floods have reduced sediment transport; so flushing of fines and scour is reduced. The continued provision of small and moderate floods (from catchment below the dams) will maintain the PES at this site.
WQ	The present state is based on water quality data from monitoring site C4H004. Moderate changes to the salts (EC- moderate to high) and SO_4. Increased nutrients (high ammonia) are due to mainly return flows from irrigation. Presence of high electrolyte content and highly polluted water tolerant diatom species.
Fish	The EC of D can be ascribed to the absence of *A. sclateri*, *B. anoplus* and *T. sparrmanii* from the observed fish assemblage.
Inverts	Sep 07: SASS5 score: 73 No of Taxa: 16 ASPT: 4.6 Apr 08: SASS5 score: 62 No of Taxa: 14 ASPT: 4.4 The EC of C/D is due to the seasonal flows being reduced in winter and the water quality changes seasonally driven by high turbidities and nutrients. Both of these variables smother riffle habitats.

Rip veg	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 extreme events, such as fire and flooding, are causing homogenization of the riparian vegetation.
Diatoms	Diatom results are based on a sample taken during 2007. The Ecological Category (EC) was a D and the community indicated high levels of organic pollution with pollution tolerant species dominating the community.

25.3 MAIN IMPACTS AT THE SITE

	PES	Causes	Sources	F/NF
WQ	C	Moderate in-stream toxicity.	Possibly toxins from agricultural practices (fertilizers/pesticides).	NF
		High ammonia (moderate to low nutrients).	Agricultural activity.	
Geom	C	Reduced baseflows and decline in number and size of floods.	Allemanskraal and Erfenis dams upstream of the EWR site.	F
Rip veg	E	Terrestrial exotic invasive species.	Anthropogenic.	NF
		Aquatic exotic invasive species.	Anthropogenic.	F
Fish	D	Changes in seasonality especially the reduction in spring freshets and moderate flows.	Extensive abstractions for irrigation.	F
		Reduction in water quality due to runoff from agriculture.	Water abstraction for irrigation. Return flows from agriculture in the catchment leads to decreased water quality and eutrophication.	NF
Inverts	C/D	Loss of almost all taxa that prefers very fast flowing water.	Water abstraction upstream in the Vet River for irrigation purposes.	F
		Loss of taxa that have a high and moderate requirement for good water quality.	Agricultural runoff from irrigation practices.	NF

25.4 RESULTS: PRESENT ECOLOGICAL STATE

Driver Components	PES	Trend
GEOMORPHOLOGY	C	Stable
WATER QUALITY	C	Stable
DIATOMS	D	
Response Components	**PES**	**Trend**
FISH	D	Stable
MACRO INVERTEBRATES	C/D	Stable
INSTREAM	D	
RIPARIAN VEGETATION	E	Negative
ECOSTATUS	D/E	

The main reasons for the PES are intense agriculture, loss of riparian vegetation and encroachment of alien vegetation and to a lesser extent abstraction.

25.5 SUITABILITY AS FUTURE BIOMONITORING SITE

The Vet River catchment includes the secondary drainage (C4) of the Vaal River catchment and the Sand River is a major tributary of the Vet River. The river system includes two major dams, Erfenis Dam on the Vet River, and Allemanskraal Dam on the Sand River and has flow release regulating capabilities. EWR 15 is at the same location as OSAEH 29.3 and therefore this site was not assessed during this study. As this is the only site that has been identified in the Vet River, the data collated during the Reserve study is important and adequate and this site should be included in future monitoring programmes.

26 CONCLUSIONS

The four EWR sites that have been assessed in the Middle Vaal River have provided additional information that can contribute to future monitoring programmes in the Orange River Basin. Four of the five OSAEH sites were monitored during October 2010 and the suitability of all the sites as future monitoring points are discussed. The main impacts in the different Middle Vaal MRUs and system operation are summarised from DWAF (2009) in the following sections.

26.1 VAAL RIVER FROM VERMAASDRIFT TO BLOEMHOF DAM

Two EWR sites (EWR 12 and 13) and one OSAEH site (OSAEH 11.1) occur in the Middle Vaal main stem.

The main urban centres are Klerksdorp, Orkney and Stilfontein in the NW Goldfields and Odendaalsrus in the Free State. The requirements of Stilfontein, Buffelsfontein, Vaal Reefs and Hartebeesfontein Gold Mines make up the bulk requirements in the area. Effluent from these towns and mines increase the water resources of the area significantly. This area is also typified by large abstractions of water from the Vaal River to a number of adjacent key areas, the most significant being Sedibeng Water export of water at Balkfontein to the Free State Goldfields in the Vet key area.

The local water resources within the WMA are used by smaller towns (Bothaville and Wolmaranstad) and for irrigation. Some small transfers also occur from Vaal Dam to Heilbron in the Middle Vaal WMA and out of Erfenis Dam to the Upper Orange WMA. Water is also transferred via the Vaal River through this WMA to Bloemhof Dam, from the Upper Vaal WMA to the Lower Vaal WMA. Management of water quality and quantity in the Middle Vaal WMA is therefore integrally linked to both the Upper and Lower Vaal WMAs. Notable abstractions in the river reach between Vaal Barrage and Bloemhof Dam include Midvaal Water, Sedibeng Water and abstractions for irrigation. These abstractions are supported with releases from Vaal Barrage (backed by Vaal Dam). The releases from Vaal Barrage are driven by either these downstream water requirements or through excess water in the Vaal Barrage (spills).

Most of the major tributaries of the Middle Vaal WMA support irrigation schemes. The Sand-Vet Irrigation Scheme within the Sand-Vet Government Water Scheme (GWS) is the most important in the Middle Vaal WMA. Other significant irrigation schemes in this WMA are the Schoonspruit and Rhenoster GWS.

The entire Vaal River reach in WMA 9 has a PES EcoStatus of a C (DWAF, 2009a).

26.1.1 MRU VAAL F: Start of Middle Vaal WMA to upstream of Schoonspruit confluence

The water entering Middle Vaal WMA from the Upper Vaal WMA brings with it a large contribution of urban, industrial and mining return flows from the highly industrialised and urbanised areas within the Upper Vaal WMA. These carry with it high salinity levels and high nutrient concentrations which are “transferred” into the Middle WMA. As a consequence these high salinity levels need to be managed through dilution with fresh water from Vaal Dam to ensure that water of an acceptable quality reaches the Middle Vaal WMA. Flow is highly regulated in the Vaal and three conditions/events influence the flow in the Vaal River from the Vaal Barrage to downstream of the confluence with the Schoonspruit, namely:

- Releases from Vaal Barrage (source Vaal Dam): Supplies urban and industrial demands as well as riparian irrigation.

- Releases from Vaal Dam for users downstream of Bloemhof Dam during prolonged droughts.
- Additional releases from the Vaal Barrage: To achieve specific water quality blending objective (the additional release of Vaal Dam water to maintain the TDS concentration in Vaal Barrage at 600 mg/ℓ).

Goldfields Water and MidVaal Water Company withdraw significant amounts of water from the Vaal River within this reach. The Pilgrims Estate weir (C2H007) also influences flow in the Middle Vaal River and is located just outside Orkney. The weir captures the inflows from the Koekemoerspruit and Vierfontein Spruit, and supports irrigation upstream of the Schoonspruit and Koekemoerspruit catchments. The MidVaal Water Company abstraction is at the Pilgrims Estate weir.

EWR 12 is situated in quaternary catchment C24A, upstream of the confluence with the Koekemoerspruit at Vermaasdrift on the main stem of the Vaal River but downstream of the Rhenoster and Mooi river. The site is adequate for biotic monitoring and an important future monitoring site as it is important to understand the influence of the Upper Vaal WMA.

26.1.2 MRU VAAL G: Downstream of Schoonspruit confluence to Regina Bridge

This reach is important as it is downstream of the Schoonspruit catchment which is a major influence in the system. Regina weir captures major water quality impacts from the upper and middle Vaal catchments. It is important to note that developments in the form of small dams and irrigation schemes along the tributaries contributing to this reach do reduce the runoff to the Vaal River.

EWR 13 is located in the upper reaches of quaternary catchment C24J downstream of the Schoonspruit confluence while OSAEH 11.1 is situated in the lower reaches of C24J just upstream of the Vals River. Both sites occur within MRU Vaal G.

OSAEH 11.1 was originally situated approximately 29 km upstream of the Bloemhof Dam inundation effect backup and provided habitat similar to EWR 13. From Google Earth a new site in the Wolwespruit Nature Reserve seemed to provide unique/different habitat types when compared to the originally proposed site and was confirmed during the site visit. The site has extensive cobble beds and good diversity of instream habitats for sampling purposes; however dense benthic algal growth is present on the cobbles. Furthermore, the land use impact within the Nature Reserve is less than outside the Reserve which is that of agricultural use. The sampling site is situated approximately 128 km upstream of Bloemhof Dam and 45 km downstream of EWR 13 in quaternary catchment C24J.

Both sites are adequate as future monitoring sites. However OSAEH 11.1 may be more suitable as there are more unique habitats present and the site is located further downstream in quaternary catchment C24J. As both sites occur within the same EcoRegion and MRU and as the PES results were similar, the data collected at both these sites are valid. However within MRU Vaal G the presence of a Nature Reserve would warrant a further delineation of the MRU into Reserve Assessment Units as the habitat at OSAEH 11.1 is more unique and more responsive to flow changes than EWR 13, although the EWR site is more representative of the reach.

26.2 RHENOSTER RIVER

No EWR site was selected in this River. The Rhenoster catchment is rural in nature and has significant controlled irrigation and rural requirements (87% of total requirements). Heilbron and Viljoenskroon are the most significant urban centers in the area. The presence of a large number of weirs (61), road bridges and roads has resulted in a large to serious impact on the Rhenoster River. Koppies Dam also adds to this impact. Large areas of the river are inundated and this has a serious impact on the flow, bed and channel characteristics of the river. The riparian zone is also impacted upon by these obstructions in the river as the wetted and dry riparian zones of the river are altered. The presence of many abstraction pumps also indicate that there is a large volume of water abstracted from the river although not many irrigated lands were visible (DWAF, 2009a).

OSAEH 11.6 is situated in the lower reaches of the Rhenoster River, and has good habitat available for the full suite of biological components to be monitored. This site is a valuable monitoring site for future monitoring programmes as it is located in a tributary and there are many upstream impacts. As the Vaal River main stem has deteriorated water quality, tributaries play an important role in diluting these impacts and providing refugia for biota.

The upper reaches of the Rhenoster River is in a C PES but improves downstream from C70J to a B/C EC (DWAF, 2009a).

26.3 SCHOONSPRUIT

The Schoonspruit catchment is characterised by intensive development and is heavily utilised. Various dams and canals are present which supply water to various towns and irrigation schemes. Informal or diffuse irrigation also takes place within the tributary sub-catchments of the Schoonspruit. Water is abstracted directly from the streams or from farm dams located in the tributary sub-catchment. Urban/Industrial return flows from Klerksdorp, Hartbeesfontein and Orkney enter the lower Schoonspruit catchment downstream of Johan Neser Dam. Return flows from Ventersdorp are relatively small and enter the Schoonspruit downstream of Kalk Dam. The whole river reach has a PES EcoStatus of a C (DWAF, 2009a).

OSAEH 11.4 is situated in the Schoonspruit approximately 10 km upstream of its confluence with the Vaal River and occurs within MRU Schoonspruit D according to DWAF (2009a). The only significant change that occurs along these lower reaches downstream of the Klerkskraal Dam is an increase in urban/built up areas and therefore an increase in return flows from these areas into the Schoonspruit.

During 2003 – 2005 an Intermediate Reserve Determination Study was commissioned by the Free State Regional Office, as part of a Catchment Management Strategy Development for the Schoon- and Koekemoerspruit catchments. As the Schoonspruit has a major influence on the Vaal River main stem, OSAEH 11.4 is an important site in terms of a future monitoring programmes. The lower reaches of the Schoonspruit are heavily impacted by anthropogenic activity and water quality is deteriorated. Substantial data is available on this river and the site is suitable for monitoring the full suite of biotic components.

26.4 VALS RIVER

While the Vals River catchment is rural in nature, it has significant urban requirements (73% of total water requirements). The urban requirements are dominated by the requirement of Kroonstad Municipality. Water is imported from the Vaal River by Sedibeng Water to supply the needs of the

Bothaville local municipality. Treated sewage and storm water returns from Kroonstad in particular, contribute significantly (33% of total resource) to the water resources of the Vals key area (DWA, 2009).

Water quality deterioration as a result of Kroonstad, Lindley and Bothaville Sewage Works runoff as well as runoff from irrigated and drylands has a serious to critical impact on the Vals River. Prolific growth of algae in the lower reach of the river has been observed.

EWR 14 is at the same location as OSAEH 11.5 and therefore this site was not assessed during this study. As this is the only site that has been identified in the Vals River, the data collated during the Reserve study is important and adequate and this site should be included in future monitoring programmes.

The river reach is highly impacted and ranges mostly in a D and E PES EcoStatus.

26.5 VET RIVER

The water resources of this catchment area are augmented by transfers from Vaal River by Sedibeng Water for urban and bulk use in the Free State Goldfields and by the upstream yields of Erfenis and Allemanskraal catchment areas. The mining and urban water requirements of the Free State Goldfields dominate the water requirements of this catchment. The main urban centres are Welkom and Virginia and the main mines are Harmony, President Steyn, African Rainbow Minerals and Bambanani Gold Mines.

The Allemanskraal Dam and Erfenis Dam catchments are rural in nature. In the Allemanskraal catchment area consumptive requirements by urban and rural users make up the rest of the requirements, with irrigation water requirements not being significant. Senekal is the most important urban centre in the area. The upper reaches of this catchment do contribute to the downstream yield of the Sand River.

Irrigation water requirements for controlled irrigation are significant in the Vet River catchment and are the most important in the Middle WMA as a whole. Approximately 122 km^2 is scheduled for irrigation in three areas, namely Sand-Vet GWS (Sand), Sand-Vet GWS (Vet) and Vet River GWS. Actual irrigation requirements are significant therefore Vet River catchment does not contribute to the yield of the Lower Vaal WMA.

EWR 15 is at the same location as OSAEH 29.3 and therefore this site was not assessed during this study. EWR 15 is situated in the Vet River downstream of the confluence with the Sand River, within MRU Vet C which is delineated from Erfenis Dam to the Sand River confluence (downstream of Erfenis Dam). As this is the only site that has been identified in the Vet River, the data collated during the Reserve study is important and adequate and this site should be included in future monitoring programmes.

The PES EcoStatus of the Vet River ranges from a C EC and deteriorates downstream to a D EC.

27 LOWER VAAL CATCHMENT (WMA 10 AND 13) – FROM DOWNSTREAM OF BLOEMHOF DAM TO ORANGE RIVER CONFLUENCE

27.1 BACKGROUND

The Lower Vaal River includes the Vaal catchment within the Lower Vaal and Upper Orange WMAs (part of WMA 10 and 13) and forms part of the integrated Vaal River System, and occurs 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 catchment, which includes the drainage area of the Vaal River from its headwaters to the confluence of the Vaal and Orange Rivers (DWA, 2010c).

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 occurs 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, these rivers are insignificant. The WMA consists of D41 (excluding D41A), parts of D42C and D42D, parts of D73A and D73C, C31, C32, C33, C91, and C92 tertiary catchments (DWA, 2010c).

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 (DWA, 2010c).

The Lower Vaal WMA is dependent on the Upper Vaal and Middle Vaal WMAs for supply of utilisable surface water resources, with over 90% of the water required being sourced through releases from the Upper Vaal WMA and from Bloemhof Dam. More than 50% of the yield from natural water resources in the tributary catchments within the WMA is supplied from groundwater. Water use in the water management area is dominated by irrigation, which represent 80% of the local requirements for water. About 12% of the requirements is for urban and industrial use, 7% for rural domestic supplies and stock watering, and the remainder for mining purposes. Over 85% of the requirements for irrigation are in the Harts sub-area, mainly at the Vaalharts irrigation scheme, with the balance being along the Vaal River. Water is also transferred into the WMA from the Upper Orange WMA into Douglas Weir. Large quantities of water are transferred from the Vaalharts weir on the Vaal River to supply the Vaalharts irrigation scheme in the Harts River catchment. The Vaalharts Irrigation scheme generates irrigation return flows which enter the Harts River upstream of Spitskop Dam. The return flows contribute salinity and nutrients to the Harts River (DWAF, 2009b).

Twelve OSAEH sites were identified as possible monitoring sites while four EWR sites occur within the Lower Vaal WMA that was assessed as part of the Vaal Comprehensive Reserve study undertaken by Golder and Associates during 2007 – 2010. Six OSAEH sites were assessed

during October 2010. Section 28 to 35 summarises the results of the October 2010 assessment as well as a summary of the EWR results.

Figure 27.1 provides the locality of the EWR sites as well as the OSAEH sites that occur in the Vaal River where the green pins represent the OSAEH monitoring sites, and the red pins represent the EWR sites assessed during 2010. Site information is provided in Table 27.2.

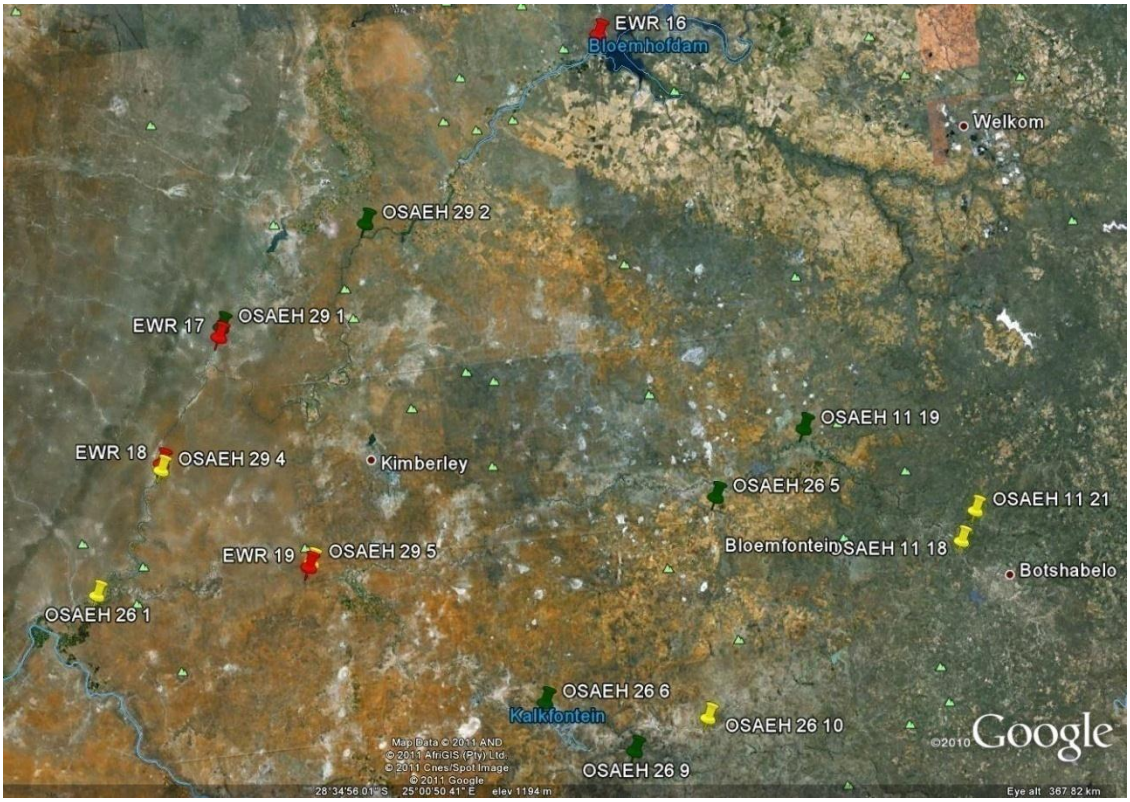

Figure 27.1 OSAEH monitoring and EWR sites occurring within the Lower Vaal WMA (WMA 10 and 13) (Google Earth image, 2010)

Table 27.1 OSAEH monitoring and EWR site detail

Site	Monitoring type	Eco-Region	Major River	Latitude	Longitude	Site code
OSAEH_11_18	Monitoring Site P	11	Riet/Modder	-29.16111	26.57194	C5MODDSANNA
OSAEH_11_19	Monitoring Site P	11	Riet/Modder	-28.80722	26.10694	C5MODDSOETD
OSAEH_11_21	Reference Site	11	Modder/Karonnaspruit	-29.08107	26.62615	C5KORAMOCKE
OSAEH_26_1	Ecological Reserve Site	26	Vaal	-29.00083	23.80646	C9VAALDOUGL
OSAEH_26_5	Reference Site	26	Modder/Kaalspruit	-28.97005	25.80632	C5KAALKRUGE
OSAEH_26_6	Ecological Reserve Site	26	Riet	-29.48389	25.19861	C5RIETIFR04
OSAEH_26_9	Reference Site	26	Riet/Kromelenboogspt	-29.6447	25.46472	C5KROMCRIET
OSAEH_26_10	Ecological Reserve Site	26	Riet	-29.57528	25.70805	C5RIETIFR03
OSAEH_29_1	Monitoring Site P	29	Vaal/Harts	-28.35124	24.31354	C3HARTDELPO
OSAEH_29_2	Monitoring Site P	29	Vaal	-28.11097	24.80193	C9VAALWARRE
OSAEH_29_4	Monitoring Site C	29	Vaal	-28.72533	24.07293	C9VAALSCHMI
OSAEH_29_5	Ecological Reserve Site	29	Riet	-29.02805	24.5125	C5RIETIFR01
EWR 16	Ecological Reserve Site	11, 29	Vaal	-27.65541	25.59564	DS of Bloemhof
EWR 17	Ecological Reserve Site	29, 30	Harts	-28.37694	24.30305	Lloyds weir
EWR 18	Ecological Reserve Site	29, 30	Vaal	-28.70758	24.07578	Schmidtsdrift
EWR 19	Ecological Reserve Site	29	Riet	-29.02723	24.51294	Lilydale lodge

28 EWR 16: DOWNSTREAM OF BLOEMHOF DAM (VAAL RIVER)

This site was assessed as part of the Lower Vaal Reserve study, during 2007-2008 and was assessed during October 2010 as part of this study. The information provided below is summarised from DWA (2009c,d; 2010c). The results of the October 2010 assessment are provided in Technical Report 2. A comparison between the Reserve results and current results is provided in Section 28.7.

28.1 SITE DESCRIPTION

For the purposes of the EWR study, the Vaal River from the start of WMA 10 at the outlet of Bloemhof Dam to the confluence of the Orange River below Douglas was delineated into six Management Resource Units (MRU Vaal K – P). EWR 16 falls within MRU Vaal K which is the delineated reach from the outlet of Bloemhof Dam to the Vaalharts weir. This reach is important to understand the influence of the Upper and Middle Vaal Vaal WMA.

EWR16 is situated downstream of Bloemhof Dam in the town of Bloemhof on the main stem of the Vaal River. The site is a boulder riffle section which is highly atypical of the reach. Alluvial sections upstream show indications of increased flows (cut banks likely due to interbasin transfers) although the EWR site is not very sensitive to flow changes. Fish habitat is well represented at site as well as flow-depth categories and cover. Macroinvertebrate habitat availability is moderate with ample marginal vegetation in and out of current as well as Stones in Current (SIC). Aquatic vegetation is absent and the occurrence of sand habitat is very low. Riparian vegetation is locally very impacted at this site and not suitable for assessment.

Location	EWR 16 DS of Bloemhof	**Altitude**	1211 m
Longitude	25.59564	**Latitude**	-27.65541
EcoRegion	Highveld/Southern Central Kalahari 11.08, 29.02	**Quaternary catchment**	C91A
Water Management Area	Lower Vaal	**Geomorphological zone**	Lower Foothills

EWR 16, single thread channel with cut banks.

28.2 PRESENT ECOLOGICAL STATE (PES)

Geom	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.
WQ	Data are 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	The Ecological Category of E can be attributed primarily to the absence of 5 of the 11 expected species and the lower than expected FROC 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 *C. carpio*, *G. affinis*, *C. idella* and *O. mossambicus* were sampled.
Inverts	Sep 07: SASS5 score: 64 No of Taxa: 15 ASPT: 4.3 Apr 08: SASS5 score: 56 No of Taxa: 14 ASPT: 4 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 Key families not sampled were: Baetidae >2spp, Ecnomidae, Elmidae, Heptageniidae, Hydropsychidae >2spp, Oligoneuridae, Perlidae, Philopotamidae and Tricorythidae.
Rip veg	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. 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).
Diatoms	Diatom results are based on a sample taken during 2007 and a 12 month data set taken during 2002-2003. The 2002-2003 data indicated continual pollution and during the survey the diatoms remained in a D EC for 7 of the 12 months. During the 12 month period there was some recovery to a C EC for 4 months but during the summer the biological water quality deteriorated to an E EC. The current sample indicated moderately polluted conditions with elevated nutrients and low organic pollution and the overall EC was set at a D.

28.3 MAIN IMPACTS AT THE SITE

	PES	Causes	Sources	F/NF
WQ	C	Slightly increased salts.	Mining upstream.	F
		Eutrophication.	High nutrients (although not indicated by the data) from agriculture and WWTW discharge.	
Geom	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
Rip veg	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

28.4 RESULTS: PRESENT ECOLOGICAL STATE

2007-2008			2010		
Driver Components	**PES**	**Trend**	**Driver Components**	**PES**	**Trend**
GEOMORPHOLOGY	D/E	Stable	IHI: INSTREAM	C	
WATER QUALITY	C	Negative (C)	IHI: RIPARIAN	B	
DIATOMS	C		DIATOMS (WQ)	D	
Response Components	**PES**	**Trend**	**Response Components**	**PES**	**Trend**
FISH	E	Negative	FISH	C	Stable
MACRO INVERTEBRATES	C/D	Stable	MACRO INVERTEBRATES	D	Stable
INSTREAM	D		INSTREAM	C/D	
RIPARIAN VEGETATION	F	Negative	RIPARIAN VEGETATION	D	Stable
ECOSTATUS	E		ECOSTATUS	D	

The main reasons for the 2007-2008 PES are altered flow regime and anthropogenic activities. Due to the Bloemhof Dam upstream of the site the altered flow regime has resulted in reduced base flows and moderate floods impacting severely on geomorphology and fish as limited habitats are available. Riparian vegetation is completely altered at this site due to anthropogenic activities and exotic vegetation. It should be noted that the EcoStatus mainly due to the F category for riparian vegetation as a result of non-flow related impacts and therefore the instream PES of a D should be used as a measure of the condition of the site. The 2010 results indicate a slightly improved overall PES of a D due to the fish and riparian vegetation components which were assessed to be in better condition than the 2007-2008 results. It should however be noted that this assessment is based on one site visit and therefore the EWR study results take precedent.

28.5 SUITABILITY AS FUTURE BIOMONITORING SITE

Although the site is suitable for fish and macroinvertebrate sampling, the riparian vegetation is highly altered. The site occurs just downstream of Bloemhof Dam and the altered flow regime may be problematic for sampling. In terms of future biomonitoring this site may be too close to Bloemhof Dam in the upper reach of C91A and would not detect impacts occurring downstream in the Vaal River.

29 EWR 17: LLOYDS WEIR (HARTS RIVER) – OSAEH 29.1

The information is summarised from DWA (2009c,d; 2010c).

The Harts River system is in the C3 drainage region of South Africa and its source is near the town of Lichtenburg in the North West Province, although the larger part of the catchment is situated in the Northern Cape Province. The Harts River flows in a south-westerly direction *via* Barberspan, the Taung and Spitskop dams, after which it flows into the Vaal River near Delportshoop.

29.1 SITE DESCRIPTION

EWR 17 falls within MRU Harts C which includes Wentzel Dam which is delineated as a unit. The dam supports the domestic water use in Wentzel and the yield of the dam is fully utilised. The EWR site is in close proximity to OSAEH 29.1. This site was not assessed during the October 2010 field trip and the results of the EWR assessment are summarised below.

EWR 17 is situated downstream of Spitskop Dam in the Harts River. The banks are composed of bedrock, and the channel is incised. Paired low benches occur but terraces are absent. Some paths in the upper and lower riparian zones has caused erosion. Fish habitat is well represented at site but flow modification by Spitskop Dam a short distance upstream of site is expected to result in unnatural habitat fluctuation. The weir directly upstream of site may result in unnaturally high abundance of species during migrations. Macroinvertebrate habitat is good with limited aquatic vegetation and mud habitats.

Location	EWR 17 Lloyds weir	**Altitude**	1114 m
Longitude	24.30305	**Latitude**	-28.37694
EcoRegion	Southern/Central Kalahari/Ghaap plateau 29.02; 30.01	**Quaternary catchment**	C33C
Water Management Area	Lower Vaal	**Geomorphological zone**	Lower Foothills

EWR 17, Lloyds weir. Trampling and grazing pressure are evident along both banks.

29.2 PRESENT ECOLOGICAL STATE (PES)

Geom	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.
WQ	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	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 FROC 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 *C. carpio*, *G. affinis*, *C. idella* and *O. mossambicus*.
Inverts	Sep 07 SASS5 score: 91 No of Taxa: 21 ASPT: 4.3 Apr 08 SASS5 score: 61 No of Taxa: 16 ASPT: 3.8 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.
Rip veg	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. 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.
Diatoms	Diatom results are based on a sample taken during 2007. The Ecological Category (EC) was a C.

29.3 MAIN IMPACTS AT THE SITE

	PES	Causes	Sources	F/NF
WQ	D	High salts.	Mining impacts, agricultural return flows (salts and nutrient) and sedimentation.	F/NF
		High nutrients and other agro-chemicals.		
Geom	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
Rip veg	D	Homogenisation of riparian zone.	Encroachment of terrestrial exotic invasive species (Anthropogenic).	NF
		Aquatic exotic invasive species.	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
		Lack of access to upstream river reaches for fish species with this migratory requirement.	Upstream Spitskop Dam is a significant upstream migration barrier breaking the link between the Vaal and Harts River catchments.	
Inverts	C/D	Water quality has a detrimental effect on taxa that have a high and moderate preference for good water quality.	Agricultural return flows from upstream agriculture.	NF

29.4 RESULTS: PRESENT ECOLOGICAL STATE

Driver Components	PES	Trend
GEOMORPHOLOGY	D	Stable
WATER QUALITY	D	Negative (D)
DIATOMS	C	
Response Components	**PES**	**Trend**
FISH	D	Negative (D)
MACRO INVERTEBRATES	C/D	Stable
INSTREAM	D	
RIPARIAN VEGETATION	D	Negative
ECOSTATUS	D	

The main reasons for the PES are a mixture of flow and non-flow related impacts. Return flows from Vaalharts Irrigation scheme and Spitskop Dam upstream of the site have impacted present day low flows which are higher than natural low flows and this may have a major impact on the system. Anthropogenic activities in the reach are impacting heavily on water quality which in turn impacts on available habitat and biota.

29.5 SUITABILITY AS FUTURE BIOMONITORING SITE

According to DWAF (2009), based on the River Health Programme results of 2003, the overall water quality status of the lower Harts River is in a fair to poor condition while the upper region remains in a good to fair condition. In the river reach between Taung and Spitskop Dam the water quality and flows are impacted by return flows from the Vaalharts Irrigation Scheme. As a result of saline leachate from the irrigation fields, the water is of exceptional high salinity (± 1 100 mg/ℓ TDS) and the salinity and nutrient loads associated with these return flows have resulted in increased concentrations in the lower reaches of the Harts River and in Spitskop Dam. Management of water quality (salinity) at the Vaalharts irrigation scheme and downstream of Spitskop Dam thus remains of primary importance.

Based on the results provided in RHP (2003) and the assessment results from October 2010 this site is an important monitoring point within the Harts River

30 EWR 18: SCHMIDTSDRIFT (VAAL RIVER) – OSAEH 29.4

This site was assessed as part of the Lower Vaal Reserve study, during 2007-2008 and was assessed during October 2010 as part of this study. The information provided below is summarised from DWA (2009c,d; 2010c). The results of the October 2010 assessment are provided in Technical Report 2. A comparison between the Reserve results and current results is provided in Section 30.7.

30.1 SITE DESCRIPTION

OSAEH 29.4 falls within MRU Vaal O which is the delineated reach from Schmidtsdrift weir to Douglas Barrage. The site consists of a deep, wide (approximately 60 m), open water channel. Reeds, riparian vegetation and water grass (*Potamogeton* and *Ceratophyllum)* are dense, and the substrate is very muddy with heavy siltation. The sampling site has a steep gradient and becomes deep very quickly. Together with the mud and silt substrate, it makes this site non-wadeable. Low habitat diversity was available for fish sampling as well as for macroinvertebrate sampling. The Slow Deep (SD) habitat is available for fish, with abundant marginal vegetation (reeds) present and riparian trees and grass. Some Slow Shallow (SS) biotope is also available. Macroinvertebrate habitat available includes marginal vegetation, sand and mud. The surrounding land use consists of natural fields and pastures due to agriculture in the area. Diamond mining also occurs in the area.

Location	EWR 18 Schmidtsdrift/OSAEH 29.4	**Altitude**	1239 m
Longitude	24.07578	**Latitude**	-28.70758
EcoRegion	Southern/Central Kalahari/Ghaap plateau 29.02; 30.01	**Quaternary catchment**	C92B
Water Management Area	Lower Vaal	**Geomorphological zone**	Lower Foothills

EWR 18, Schmidtsdrift. Left: 2010 - Uniform, deep, wide channel (SD dominant). Right: 2007 - *Myriophyllum spicatum* has colonised and taken over the aquatic habitat.

30.2 PRESENT ECOLOGICAL STATE (PES)

Geom	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, 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 chocked by the excessive algal growth. Thus although the impacts of the upstream dams on sediment reduction are lessened due to the ameliorating effects of larger tributaries, the flows in the river in this reach have dropped so much that the PES is now in a C/D.
WQ	The water quality data from monitoring site C9H024 was used for the PES. The data shows high salts and low nutrients. However high growth of aquatic macrophytes does occur, hence the ammonia higher than the nutrients.
Fish	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.* The EC for this site is a C as determined by the FRAI.
Inverts	Sep 07: SASS5 score: 33 No of Taxa: 9 ASPT: 3.7 Apr 08: SASS5 score: 74 No of Taxa: 17 ASPT: 4.4 The EC 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 07) and 74 (April 08). The key families that were not sampled were: Baetidae >2spp, Ecnomidae, Elmidae, Heptageniidae, Hydropsychidae >2spp, Oligoneuridae, Perlidae and Philopotamidae.
Rip veg	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 the site. 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.
Diatoms	The assessment is based on a single sample taken during the Reserve assessment. The overall EC of this site is a C.

30.3 MAIN IMPACTS AT THE SITE

	PES	Causes	Sources	F/NF
WQ	C	High salinity.	Mining impacts.	F
		Nutrients (high ammonia).	Degrading algal matter visible at site.	
Geom	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
Rip veg	C/D	Encroachment of terrestrial exotic invasive species.	Mining activities, bridges and other infrastructure.	NF
		Colonisation of aquatic exotic invasive weeds.	Nutrient enrichment.	
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.	
		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.	
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

30.4 BASELINE SURVEY RESULTS: PRESENT ECOLOGICAL STATE

2007-2008			2010		
Driver Components	**PES**	**Trend**	**Driver Components**	**PES**	**Trend**
GEOMORPHOLOGY	C/D	Stable	IHI: INSTREAM	C	
WATER QUALITY	C	Negative (C)	IHI: RIPARIAN	C	
DIATOMS	B/C		DIATOMS (WQ)	C	
Response Components	**PES**	**Trend**	**Response Components**	**PES**	**Trend**
FISH	C	Negative	FISH	D	Stable
MACRO INVERTEBRATES	C/D	Stable	MACRO INVERTEBRATES	C/D	Stable
INSTREAM	C/D		INSTREAM	C	
RIPARIAN VEGETATION	C/D	Negative	RIPARIAN VEGETATION	D	Stable
ECOSTATUS	C/D		ECOSTATUS	C	

It is evident that from the 2007-2008 Reserve assessment and the current study that the main reasons for the PES is flow modification due to weirs and abstraction, reduced base flows due to upstream abstraction and deteriorated water quality. Anthropogenic activities have also led to an increase in exotic vegetation. Heavy sedimentation is present due to diamond mining and agriculture in the area.

30.5 SUITABILITY AS FUTURE BIOMONITORING SITE

Good quantity and quality of marginal vegetation is present for macroinvertebrate sampling. No SOOC and SIC biotope was present for sampling. Sampling at this site is difficult as the river is non-wadeable due to the steep gradient of the river. Limited biotopes occur for biotic sampling, and the riparian zone is very dense. Fish habitat diversity is low and siltation is problematic. Habitat requirements (flow-depth categories and cover) of most expected species not well represented at site and there is habitat loss due to flow modification, although limnophilic habitat requirements are still met. A limiting factor is serious siltation which limits sampling success, and reduces habitat suitability for some species. Easy access to site but the site is basically non-wade-able.

Although this site was identified as a priority reach for maintaining the integrity of the Lower Vaal sampling at this site is difficult as the river is non-wadeable due to the steep gradient of the river. Limited biotopes occur for biotic sampling, and the riparian zone is very dense.

31 OSAEH 26.1: VAAL RIVER

31.1 SITE DESCRIPTION

OSAEH 26.1 falls within MRU Vaal P which comprises the Douglas Barrage, and is inundated with water. This is the most downstream section of the Vaal River before the confluence with the Orange River. The Riet River flows into the Douglas Barrage from the Upper Orange WMA and water is also transferred into the WMA at Douglas from the Upper Orange WMA for water quality management purposes. The Barrage supports the Douglas Irrigation System.

This site is situated approximately 1.6 km downstream of Douglas Weir. The substratum consists of cobbles, rock, gravel and sand. The site has good habitat diversity with all fish flow depth classes and cover well represented. Undercut banks and root wads are, however, absent. The surrounding land use consists of natural fields, pastures and agriculture. The main channel is about 500 m wide at the site with numerous side or secondary channels. Habitat types present include rapids (5%), riffles (10%), runs (15%), glides (20%), and pools (50%). Riparian vegetation includes trees, shrubs, grasses, sedges and reeds.

Location	OSEAH 26.1	**Altitude**	997 m
Longitude	23.80646	**Latitude**	-29.00083
EcoRegion	Ghaap Plateau 30.01	**Quaternary catchment**	C92C
Water Management Area	Lower Orange	**Geomorphological zone**	Foothill

OSAEH 26.1. Left: Small rapid and riffle in Vaal River below Douglas Weir – very good site and habitat diversity for fish assessments (note benthic growth on rocks). Right: Riffle, run and glide habitats with cobbles, rocks and sand substrate.

31.2 SAMPLING CONDITIONS

At the time of sampling, marginal vegetation was abundant and consisted of reeds and sedges. Abundant filamentous algae and benthic growth or rocks was observed. No local erosion was observed, however upstream erosion does occur. Slight sedimentation occurred and no odours were detected. The water was slightly opaque. No bed- or channel modification was present at the site. Some exotic vegetation removal was observed, with some exotic vegetation encroachment present.

31.3 PRESENT ECOLOGICAL STATE

IIHI	The Instream Index of Habitat Integrity (IIHI) is a C (76.3%). This is mostly due to poor bed conditions, with elevated levels of nutrients and associated benthic growth, and to a less extent loss of longitudinal connectivity due to weirs.
RIHI	The Riparian Index of Habitat Integrity (RIHI) is a B/C (79.6%) with the main impacts being poorer bank conditions due to alien invasive species, especially *Eucalyptus camuldensis*. Reduced base flows and small floods also facilitate an increase in marginal and lower zone vegetation and flow regulation promoted reed

	expansion and density.
Fish	All of the eleven species expected under reference conditions are still expected to be present under the present conditions at this site and in the river. **Note:** *L. capensis* (juveniles) and *L. aeneus* (mature large) were sampled, indicating that habitat conditions are suitable for species (with different length classes life stages) with a preference for a variety of flow depth classes, and species which are moderately intolerant to no flow conditions (*L. aeneus*, *L. kimberleyensis*, and *L. capensis*). The FROC of some species is expected to have been reduced due to deterioration of certain habitat conditions. All flow depth classes are represented. But due to flow modification and reduced base flows there is a loss of FD and FS habitats resulting in a loss of water column and substrate as cover, reducing the FROC of *A. sclateri*, *L. capensis* and BKIM. Due to reduced flows there is also a loss in vegetation overhang as cover resulting in a loss of preferred habitat and a reduced FROC for *B. anoplus* and *B. trimaculatus*. Increased benthic growth also reduced the habitat suitability (substrate – cobbles and rocks) for *A. sclateri*, *L. kimberleyensis*, *L. capensis*, and *L. umbratus*, further aiding in their reduced FROCs. Large pools were present and all the species will be able to utilise the pools as cover and refugia. Good habitat is present for spawning during high floods, and pools are present as refugia and nursery area, after floods. The presence of carp, which can prey on fish eggs and causes bio-turbation, may also negatively impact on the fish species present in the system. The FROC of *C. gariepinus* (quiet water benthic species), *P. philander* and *T. sparrmanii* is unchanged from reference as these species are moderately tolerant to tolerant to no-flow conditions. Habitat diversity is also high in terms of their different habitat preferences (SD, SS, and Cover – water column, rocks and cobbles, instream veg., and marginal aquatic veg. etc.). The EC for this site is a C as determined by the FRAI (68.7%).
Inverts	Oct 2010: SASS5 score: 128 No of Taxa: 28 ASPT: 4.6 Key taxa expected but not observed were generally those that are sensitive to water quality changes, such as Hydropsychidae (>2spp), Aeshnidae, Atyidae, Chlorocyphidae, Dixidae, Ecnomidae, Gerridae, Hydrometridae, Philopotamidae, Tricorythidae and Vellidae/ Mesovellidae. The MIRAI model generates a PES for macroinvertebrates as a Category C/D (61.4%).
Rip veg	The site has a VEGRAI score of 82.4% (B EC). **Marginal Zone:** Close to reference, with a high degree of algae, slightly reduced woody component and elevated sedge cover due to a combination of grazing of grasses and flow regulation. **Lower Zone:** As marginal: with decreasing impacts from LB to RB; extreme *S. mucronata* density on RB, high levels of recruitment of *G. virgatum* and *Eucalyptus camuldensis.* **Upper Zone:** Two components: 1) cobble beds dominated by *Schoenoplectus* and *Cyperus* species; 2) alluvial bars dominated by woody species such as *A. karoo, Z. mucronata, D. lyceoides* and the alien *E. camuldensis.* **MCB:** Woody dominated community; LB with high degree of alien perennials and clearing for the canal, rail road and physical earth dumping: RB woody, high density with small impacts.
Diatoms	The assessment is based on a single sample taken during the current assessment. The overall EC of this site is a B/C. Pollution levels were low along with organically bound nitrogen levels. Nutrient levels may be problematic at this site but due to elevated flows this impact is ameliorated.

31.4 MAIN IMPACTS AT THE SITE

	PES	Causes	Sources	F/NF
Rip veg	B	Reduced cover of indigenous riparian obligate species, mainly on upper zone and LB.	Physical clearing, removal, dumping and high grazing pressure.	NF
		Altered species composition.	Up to 20% cover by perennial alien species, especially *Eucalyptus camuldensis.*	
		Increased sedge and reed cover.	Flow regulation and reduced flooding disturbance facilitates an increase in reed and sedge cover and density in the marginal and lower zone, especially when accompanied by grazing and clearing.	F
Fish	C	Loss mainly FD and FS habitat as a result of flow modification (especially during naturally low flow periods).	Weirs and water abstraction for farming and irrigation upstream.	F
		Lower breeding success and recruitment for fish = lower FROC.	Lower, less and/or no natural flushes and smaller floods. Flow modification due to weirs and water abstraction for farming and irrigation upstream.	
		Loss of species diversity or numbers due to loss of habitat diversity due to lower flows.	Flow modification due to weirs and water abstraction for farming and irrigation upstream.	
		Loss of habitat with substrate (cobbles and rock), and water column in FD and FS due to lower than natural flows.	Flow modification due to weirs and water abstraction for farming and irrigation upstream.	
		Loss of vegetation overhang and habitat for cover.	Reduced flows – flow modification.	
		Decreased species diversity and abundance due to presence of carp.	Presence of alien species (carp) introduced for aquaculture and angling.	NF

	PES	Causes	Sources	F/NF
		Enrichment, increased benthic growth and loss of substrate and habitat.	Agriculture upstream.	
		Presence of weirs as migration barriers (breeding, feeding and dispersal), also causing loss of habitat of some species (inundation).	Weirs in area.	
Inverts	C/D	Loss of instream habitat.	Flow modification due to weirs and abstraction for agriculture.	F
		Poor water quality and associated benthic growth.	Agriculture	NF

31.5 BASELINE SURVEY RESULTS: PRESENT ECOLOGICAL STATE

Driver Components	PES	Trend
IHI: INSTREAM	C	
IHI: RIPARIAN	B/C	
DIATOMS (WQ)	B/C	
Response Components	**PES**	**Trend**
FISH	C	Stable
MACRO INVERTEBRATES	C/D	Stable
INSTREAM	C	
RIPARIAN VEGETATION	B	Negative
ECOSTATUS	C	

The main reasons for the Present Ecological State Category of a C are due to flow modification and resultant loss of habitat diversity due to weirs and water abstraction for farming and agriculture. Poor water quality and associated benthic growth on the substratum is extensive at this site. Instream weirs result in migration barriers to movement of fish, thus impacting on their breeding, feeding and dispersal abilities. Reduced cover of indigenous riparian obligate species has occurred mainly in the upper zone and on the LB.

31.6 SUITABILITY AS FUTURE BIOMONITORING SITE

A good quantity of cobble biotope is present for SASS sampling. A diversity of velocities is present, however extensive filamentous algae and benthic growth decreases the quality of the cobble biotope. Limited overhanging vegetation out of current is present for use by macroinvertebrates. A very good habitat diversity and cover is present for all expected fish species. Marginal and instream aquatic vegetation, overhanging vegetation, water column and substrate are all abundant for fish cover. Pools are abundant and function as water column cover and refugia for fish. Perennial flow is present in this reach of the river. Riparian alluvial and bedrock habitats are available. Riparian vegetation obligate species are present and dominant at the site. A disadvantage for this site is its close proximity to an upstream weir and transfer scheme.

This site is located in the most downstream section of the Vaal River with the Riet River entering the Vaal River upstream of the Barrage. Although this is a very good site in terms of habitat availability, water is also transferred into the WMA at Douglas from the Upper Orange WMA for water quality management purposes and therefore monitoring the accumulative impacts of the Vaal and Riet Rivers may be obscured due to the water transfer from the Orange River. Nevertheless, as the most downstream point on the Vaal River system – just before the river forms a confluence with the Orange River, this site has considerable transboundary significance value and is therefore recommended as part of future surveys.

32 OSAEH 11.18: MODDER RIVER

The Modder River is the main tributary of the Riet River and joins the Riet River just upstream of Ritchie. The Modder River has its source in the hills at the watershed near Dewetsdorp (1600m above mean sea level). The Krugersdrift Dam is located on the Modder River. Most of the natural runoff into the Modder River is from above the confluence of the Modder and Klein Modder Rivers. The rest of the Modder River catchment is very flat and very little runoff occurs. Current land use in the catchment is related agricultural activities (primarily irrigated crops), urbanisation and mining and industrial activities. Livestock watering also occurs, but to a lesser extent. The major urban centres in the catchment are Bloemfontein, Botshabelo and Thabu Nchu and the Modder River is a major source of water to these urban areas (DWA, 2009).

32.1 SITE DESCRIPTION

OSAEH 11.18 falls within MRU Riet C1 which is delineated from origin of Modder River to Krugerdrif Dam. Water in this reach is used to supply irrigation needs, urban centres and industrial activities. This site is bedrock-dominated with good marginal vegetation comprising sedges and overhanging vegetation. The river width varies from 2 m to 15 m in places. Some sedimentation is present with filamentous algae on the rocks at the river's edge. The instream habitat consists of pools, riffles and runs, with some boulders, cobbles, gravel and sand present. The site is approximately 13 km downstream of Rustfontein Dam. Instream weirs are prevalent in the river, impacting negatively on the movement of instream biota. Bank undercutting and root wads also occur at the site. The surrounding land use consists of natural fields for grazing and agriculture.

Location	OSAEH 11.18	**Altitude**	1346 m
Longitude	26.57194	**Latitude**	-29.16111
EcoRegion	Highveld 11.03	**Quaternary catchment**	C52B
Water Management Area	Upper Orange	**Geomorphological zone**	Foothill

OSAEH 11.18, Modder River – Riffle and run over bedrock.

32.2 SAMPLING CONDITIONS

The site, at the time of sampling, was dominated by extensive instream runs, with dense algal growth occurring on the substratum. Marginal vegetation was of excellent quality and quantity, with limited stones out of current biotope present. Very little sedimentation was present, with the

water colour a light brown and slightly turbid. Some solid waste was observed. Cattle trampling was also observed. No exotic macrophytes were observed, as well as no exotic vegetation encroachment.

32.3 PRESENT ECOLOGICAL STATE

IIHI	The Instream Index of Habitat Integrity (IIHI) is a C (68.1%). This is mostly due to poor bed conditions, with elevated levels of sediment and benthic growth (also associated with elevated nutrients at the site due to close upstream proximity of weir and high density cattle), and altered flow regimes with reduced base flows and flooding. Longitudinal connectivity also scored poorly due to impoundments.
RIHI	The Riparian Index of Habitat Integrity (RIHI) is a C (66.7%) with the main impacts being poor bank conditions due to a high degree of erosion and substrate exposure, with trampling pressure exacerbating the situation. Reduced base flows and small floods facilitate an increase in marginal and lower zone vegetation.
Fish	All of the fish species (6 out of 6) expected under reference conditions are still expected to be present under the present conditions at this site. **Note:** Some species (*L. aeneus* and *L. capensis* P) were sampled at an increased/improved FROC from reference conditions as they were sampled in high densities at the site, indicating that habitat conditions are suitable for species with a preference for a variety of flow depth classes, and species which are moderately intolerant to no flow conditions. The FROC of *L. kimberleyensis* was reduced due to flow modification and lower base flows resulting in a loss of FD habitat. Good spawning habitat is present for spawning during high floods, and pools are present as refugia and nursery area, after floods. Reduced base flows and loss of longitudinal connectivity, due to the impacts as discussed in this document, are causes of concern for the fish population and their successful migration, spawning and recruitment. The presence of carp, which can prey on fish eggs and causes bio-turbation, may also negatively impact on the fish species present in the system. The FROC of *C. gariepinus* and *L. umbratus* (quiet water benthic species) is expected to be low due to the stream being dominantly bedrock with fast flow. EC: FRAI = C, FRAI% = 67.2%.
Inverts	Oct 2010: SASS5 score: 95 No of Taxa: 21 ASPT: 4.5 Key taxa expected but not observed were generally those that are sensitive to water quality changes, such as Hydropsychidae >2spp, Pyralidae, Tricorythidae, Leptophlebiidae, Philopotamidae and Chlorocyphidae. The MIRAI model generates a Present Ecological State for macroinvertebrates as a Category D (57.3%).
Rip veg	The site has a VEGRAI score of 82.3% (B EC) with a confidence of 2.9. **Marginal Zone:** Bedrock controlled with riffle/runs and pools; some cobble but mostly sheet rock. Some alluvial deposits (fine alluvium) and well vegetated. *Gomphostigma virgatum, C. marginatus* and *Cyclosorus interruptus* dominate the open and bedrock areas. *Salix mucronata* common with overgang, rooted where aluvia are consolidated. **Lower Zone:** As marginal zone, but with extensive high density and cover areas of *S. mucronata* along lateral consolidated alluvial bars. **Upper Zone:** Characterised by open sheet rock, highly exposed and eroded due to high grazing and trampling pressure and scour of sediments due to lack of vegetated cover. Alluvial terraces dominated by grasses with woody patches, mainly *Searsia pyroides, Acacia karoo* and *Lycium hirsutum*. **MCB:** Dominated by woody vegetation (as Upper zone) with terrestrial grasses in between.
Diatoms	The assessment is based on a single sample taken during the current assessment. The overall EC of this site is a C. This site was critically polluted with organic pollution levels being high and organically bound nitrogen levels being periodically elevated. From the diatom community it is evident that agricultural runoff and fertilizer use is impacting the site.

32.4 MAIN IMPACTS AT THE SITE

	PES	Causes	Sources	F/NF
Rip veg	B	Reduced cover of indigenous riparian obligate species.	Moderate to high trampling and grazing pressure with bank destabilization and erosion, also minimal wood cutting.	NF
		Altered species composition.	Small impact of alien vegetation (5% annuals, 5% perennial mainly *Eucalyptus camuldensis*).	
		Altered species composition.	Reduced maintenance flows and small floods promote and increase in woody vegetation and sedges in the marginal and lower zone, especially when coupled with high grazing pressure.	F
Fish	C	Decreased species diversity and abundance due to presence of carp.	Presence of alien species (carp) introduced for aquaculture and angling.	NF
		Enrichment.	Cattle farming, trampling – erosion and excrement upstream.	
		Presence of dams and weirs as migration barriers (breeding, feeding and dispersal), also causing loss of habitat of some species (inundation).	Dam and other smaller weirs in area.	

	PES	Causes	Sources	F/NF
		Loss of mainly FD habitat and other flow depth classes to lesser extent as a result of flow modification (especially during naturally low flow periods).	Large dam, smaller weirs and water abstraction for farming and irrigation and urbanization upstream.	F
		Lower breeding success and recruitment for fish = lower FROC.	Lower, less and/or no natural flushes and smaller floods. Flow modification due to dam etc.	
		Loss of species diversity or numbers due to loss of habitat diversity due to lower flows.	Flow modification due to dam etc.	
		Loss of habitat with substrate (cobbles and rock) due to lower than natural flows.	Flow modification due to dam etc.	
Inverts	D	Increased sedimentation.	Agriculture.	F
		Poor water quality and associated benthic growth.		NF

32.5 BASELINE SURVEY RESULTS: PRESENT ECOLOGICAL STATE

Driver Components	PES	Trend
IHI: INSTREAM	C	
IHI: RIPARIAN	C	
DIATOMS (WQ)	C	
Response Components	**PES**	**Trend**
FISH	C	Stable
MACRO INVERTEBRATES	D	Stable
INSTREAM	C	
RIPARIAN VEGETATION	B	Stable
ECOSTATUS	C	

The PES EcoStatus for this site is a category C. Reasons for this include flow modification and resultant loss of instream habitat due to instream dams and weirs. Poor water quality and associated benthic growth also impact the site. Exotic fish species and altered riparian species composition and reduced cover of indigenous riparian obligate species are another reason for this EC.

32.6 SUITABILITY AS FUTURE MONITORING SITE

A diversity of flow velocities is present for SASS sampling. Biotopes present include SIC, marginal vegetation in- and out of current as well as GSM. The site is bedrock dominated which reduces the amount of instream habitat for macroinvertebrates. Sedimentation occurs as well as turbid waters. The river is perennial with good fish habitat diversity and cover. Bank undercutting, instream and marginal aquatic and overhanging riparian vegetation are abundant for fish cover. Pools occur frequently which serve as water column cover and refugia for fish. The FD fish habitat is rare or sparse at low base flows and will be more abundant during high base flows. Instream substrate, for example cobbles, is sparse. The site is situated downstream of a bridge and a weir.

Trampling, overgrazing, urbanization, erosion and abstraction are some examples of local and catchment scale impacts. Riparian vegetation obligate species are present (rheophytes, heliophytes and bank species) and are also dominant at the site.

OSAEH 11.18 is located downstream of Botshabela and Thabu Nchu but upstream from Bloemfontein, and as this is the only OSAEH site situated in the upper reaches of the river, this site will be a good monitoring site to detect and monitor on-going impacts which include impacts from sewage works, interbasin transfer, and Rustfontein Dam upstream.

33 OSAEH 11.21: KORANNASPRUIT

33.1 SITE DESCRIPTION

The Korannaspruit is a seasonal tributary of the Modder River and is situated in C52C and the confluence falls within MRU Riet C1 (DWAF, 2009). This site is situated downstream of a large dam, upstream of the confluence of the Modder River. The width of the stream varies from 2 – 15 cm. The substrate is dominantly sand and mud, with silt covering the substratum in the pool section. Abundant marginal vegetation occurs, including reeds, sedges and overhanging trees. Aquatic vegetation is also present. The surrounding land use is natural fields for grazing. The river is unchannelled and is partly shaded by the riparian trees. Bank undercutting and root wads occur at the site. GSM is biotope available for sampling. .

Location	OSAEH 11.21	**Altitude**	1350 m
Longitude	-29.08107	**Latitude**	26.62615
EcoRegion	Highveld 11.03	**Quaternary catchment**	C52C
Water Management Area	Upper Orange	**Geomorphological zone**	Foothill

OSAEH 11.22, Korannaspruit – large pool with riparian vegetation overhang.

33.2 SAMPLING CONDITIONS

At the time of sampling, no flow was present and the site consisted of pool sections only. No stones, cobbles or bedrock substrate were observed. The site was heavily eroded, with thick sedimentation occurring in the pools. The water colour was brown and very turbid. No odours were detected. No exotic macrophytes, solid waste disposal and vegetation removal were observed. No exotic vegetation encroachment was present. The water level in the pools did not reach the roots or stems of the marginal vegetation.

33.3 PRESENT ECOLOGICAL STATE

IIHI	The Instream Index of Habitat Integrity (IIHI) is a D (42.8%). This is mostly due to poor bed conditions, with elevated levels of fine alluvia, and altered flow regimes with reduced base flows and flooding and increased occurrence of zero flows.
RIHI	The Riparian Index of Habitat Integrity (RIHI) is a D (53.4%) with the main impacts being poor bank conditions due to a high degree of erosion at and upstream of the site, with trampling pressure exacerbating the situation.
Fish	Most of the fish species (5 out of 6) expected under reference conditions are still expected to be present under the present conditions at this site and in the river, although the FROC of some species have been

	drastically reduced from reference conditions, with the loss of one species (*L. kimberleyensis*). This is mainly due to no flow conditions experienced during the time of the survey (low flow – base flow dry season). It is expected that the fish species will make use of the Korannaspruit as spawning area during high floods, and that they will use the pools in the Korannaspruit as refugia and nursery area, after floods. But the reduced base flows and loss of longitudinal connectivity, as well as heavy siltation due to the impacts as discussed in this document, are causes of concern for the fish utilising this system, and the suitability of the site for monitoring. Three of the expected fish species are moderately intolerant and two are moderately tolerant to no flow conditions, explaining the lower derived FROC for this site. The main impacts on these fish are decreased flows, loss of water column in FD and FS as cover, siltation and loss of substrate as cover, and the absence of instream aquatic macrophytes. The presence of carp, which can prey on fish eggs and causes bio-turbation, will also negatively impact on the fish species present in the system. *L. kimberleyensis* is, however, not expected to occur anymore due to a major loss of its preferred habitat conditions (flow and substrate). The EC for this site is a E as determined by the FRAI (35.4%).
Inverts	Oct 2010: SASS5 score: 55 No of Taxa: 15 ASPT: 3.7 Key taxa expected but not observed were generally those that are sensitive to water quality changes, such as Baetidae (>2spp), Hydropsychidae (>2spp), Aeshnidae, Atyidae, Elmidae, Hydracarina, Leptophlebiidae, Tricorythidae, and Vellidae/Mesovellidae. The low SASS5 scores observed during the time of sampling were due to a lack of key habitat for macroinvertebrates as there was no flow. The conditions would have been different had the river been flowing and for a while. The reason for no flow at the site could be due to impediments or/and farm dams upstream. The MIRAI model generates a Present Ecological State for macroinvertebrates as a Category D/E (41.4%).
Rip veg	The site has a VEGRAI score of 76.9% (C EC). **Marginal Zone:** Dominated by alluvium, deep mud in pools, all cobles embedded. Marginal zone vegetation a mix of sedges and grasses and *S. mucronata* overhang. **Lower Zone:** As marginal zone but with steeper banks and a high degree of erosion which has been exacerbated by high grazing and trampling pressure. **Upper Zone and MCB**: Mixed grass and woody thickets (see species lists).
Diatoms	The assessment is based on single sample taken during the current assessment. Due to the zero flow and the presence of cattle, organic pollution levels are very high and the EC was a D with critical pollution levels.

33.4 MAIN IMPACTS AT THE SITE

	PES	Causes	Sources	F/NF
Rip veg	C	Reduced cover of indigenous riparian obligate species, especially in the marginal and lower zones.	High trampling pressure around pools, with associated grazing.	NF
		Altered species composition.	Low cover and presence of alien species (only annuals noted), but trampling and grazing pressure also reduces grass cover which caters for an increase in sedge density and cover.	
		Reduced vigour and vegetation cover, especially in marginal and lower zone.	zero flow at the time, base flows seem to be reduced with no spring flush or vigour at the site in October.	F
Fish	E	Loss of habitat (loss of all flow depth classes) diversity as a result of flow modification (especially during naturally low flow periods).	Large dam, smaller weirs and water abstraction for farming and irrigation and small villages upstream.	F
		Lower breeding success and recruitment for fish = lower FROC.	Lower, less and/or no natural flushes and floods. Flow modification due to dam etc.	
		Fluctuating daily oxygen and temperature levels.	No Flow. Flow modification due to dam etc.	
		Decreased substrate quality due to embedding.	Lower, less and/or no natural flushes and floods. Flow modification due to dam etc.	
		Decreased aquatic vegetation as cover for fish.	Increased exotic riparian vegetation and shading. Less light penetration.	NF
		Excessive erosion and increased sedimentation resulting in deterioration of substrate as habitat (clogging and loss of important spawning habitats, and cover etc.).	Local and catchment scale bank erosion due to cattle farming – trampling, and bad farming practices.	
		Decreased species diversity and abundance due to presence of carp.	Presence of alien species (carp) introduced for aquaculture and angling.	
		Siltation, enrichment of water and anaerobic decomposition.	Cattle farming, trampling – erosion and excrement.	
		Possible pollution and enrichment of water.	Fertilizers.	
		Presence of dams and weirs as migration barriers (breeding, feeding and dispersal), also causing loss of habitat of some species (inundation).	Dam and other smaller weirs in area.	

	PES	Causes	Sources	F/NF
Inverts	D/E	No flow. Limited habitat for macroinvertebrates.	Agriculture	F
		Water quality and associated benthic growth.		NF

33.5 BASELINE SURVEY RESULTS: PRESENT ECOLOGICAL STATE

Driver Components	PES	Trend
IHI: INSTREAM	D	
IHI: RIPARIAN	D	
DIATOMS (WQ)	D	
Response Components	**PES**	**Trend**
FISH	E	Stable
MACRO INVERTEBRATES	D/E	Stable
INSTREAM	D/E	
RIPARIAN VEGETATION	C	Stable
ECOSTATUS	C/D	

The PES EcoStatus for this site is a C/D and the main impacts include flow modification with a resultant loss of instream habitat due to a large dam upstream, several small instream weirs and water abstraction for farming and irrigation. Several small villages also exist upstream which may also result in water abstraction and therefore flow modification. Local and catchment scale erosion occurs, with resultant increased instream sedimentation and deterioration of instream habitat quality. Presence of alien fish species (carp) introduced for aquaculture and angling, results in decreased fish species diversity and abundance. Possible nutrient enrichment occurs, due to agriculture in the catchment. Increased trampling pressure due to cattle grazing around the pools decreases the cover of indigenous riparian obligate species, especially in the marginal and lower zones. Altered riparian vegetation species composition results in low cover and presence of alien species.

33.6 SUITABILITY AS A FUTURE BIOMONITORING SITE

Some marginal vegetation is present in the pools for SASS sampling, with some GSM biotope present. No biotope is available in current due to no flows present. Limited overhanging vegetation is available for use by macroinvertebrates. Undercut banks, root wads, marginal aquatic and overhanging riparian vegetation is abundant for fish cover. Pools provide abundant water column cover and refugia for fish. Low habitat diversity is present and no flow depth classes are present. Extensive erosion and siltation is present and no aquatic vegetation is present. Riparian vegetation obligate species are present and dominant although the banks are fairly unmodified with respect to the riparian vegetation.

The Korannaspruit is a seasonal narrow river and any type of flow modification impact will have a severe impact on the site. It is evident that anthropogenic activities are impacting this site, however habitat is very limited at this site and sampling will be difficult as the river is dry at times. This site was initially identified as a reference site, but due to the high degree of impact at the site and the absence of habitat for biota, as well as the deteriorated Instream Habitat Integrity this site is not recommended as a future monitoring site.

34 OSAEH 26.10: RIET RIVER

The Riet River generally flows in a north-westerly, to the confluence with the Vaal River. The Tierpoort Dam which is used for irrigation purposes is situated on the tributary of the Riet River, and the Kalkfontein Dam which supplies water to the Riet River Government Water Scheme, is located just downstream of the confluence of the Kromellenboogspruit and Riet Rivers (DWAF, 2009).

34.1 SITE DESCRIPTION

The site is situated in the upper reaches of the Riet River and falls within MRU C1 which is delineated from the origin of the Riet River to the Kalkfontein Dam. Region is rural in nature and includes irrigated agriculture as major land use. The site mainly constitutes bedrock and boulder substrate and no flow was present at the time of sampling. Large pools were present with abundant marginal vegetation consisting of sedges and reeds. GSM biotope occurs at the site. Riparian vegetation consists of trees, shrubs, grasses, sedges and reeds. No large dams occur upstream but small weirs are present upstream. Surrounding land use is natural fields for grazing and agriculture.

Location	OSAEH 26.10	**Altitude**	1273
Longitude	25.70805	**Latitude**	-29.57528
EcoRegion	Nama Karoo 26.03	**Quaternary catchment**	C51F
Water Management Area	Upper Orange	**Geomorphological zone**	Foothill

OSAEH 26.10, Riet River. Large deep pool below bridge with bedrock and rocks, as well as marginal vegetation for cover.

34.2 SAMPLING CONDITIONS

At the time of sampling no flow was present at the site. Large pools with bedrock and boulder substrate were present for sampling. Moderate sedimentation occurred and no odours were detected. No exotic macrophytes or vegetation encroachment observed. Benthic algal growth and filamentous algae were present.

34.3 PRESENT ECOLOGICAL STATE

IIHI	The Instream Index of Habitat Integrity (IIHI) is a C (72.7%). This is mostly due to poor bed conditions, with elevated levels of sediment and benthic growth (also associated with elevated nutrients at the site), and to a

	less extent altered flow regimes with reduced base flows and flooding, and increased occurrence of zero flows.
RIHI	The Riparian Index of Habitat Integrity (RIHI) is a B/C (77.9%) with the main impacts being poorer bank conditions due to a higher substrate exposure, with trampling pressure exacerbating the situation. Reduced base flows and small floods facilitate an increase in marginal and lower zone vegetation and flow regulation promoted reed expansion and density.
Fish	All of the fish species (8 out of 8) expected under reference conditions are still expected to be present under the present conditions at this site and in the river. **Note:** *L. capensis* was sampled at an increased/improved FROC from reference conditions as it was sampled in high densities at the site, indicating that habitat conditions are suitable for species with a preference for a variety of flow depth classes, and species which are moderately intolerant to no flow conditions (*L. aeneus*, *L. kimberleyensis*, and *L. capensis*). The FROC of *L. kimberleyensis* was reduced due to flow modification and lower base flows resulting in a loss of FD habitat. No flow at time of sampling. Very large pools were present and all the species will be able to survive in these pools over extended periods of time. The pools serve as cover and refugia. Good spawning habitat is present for spawning during high floods, and pools are present as refugia and nursery area, after floods. Reduced base flows and loss of longitudinal connectivity, due to the impacts as discussed in this document, may be causes of concern for the fish population and their successful migration, spawning and recruitment. The presence of carp, which can prey on fish eggs and causes bio-turbation, may also negatively impact on the fish species present in the system. The FROC of *C. gariepinus*, *L. umbratus* (quiet water benthic species), *B. anoplus*, *P. philander* and *T. sparrmanii* is unchanged from reference as these species are moderately tolerant to tolerant to no-flow conditions. Habitat diversity is also high in terms of their different habitat preferences (Cover – water column, bedrock, rocks and cobbles, bank undercut, marginal aquatic veg. and tree overhang etc.). The EC was a C as determined by the FRAI (72.9%).
Inverts	Oct 2010: SASS5 score: 74 No of Taxa: 16 ASPT: 4.6 Key taxa expected but not observed were generally those that are sensitive to water quality changes, such as Hydropsychidae (>2 spp), Baetidae (>2 spp), Aeshnidae, Chlorocyphidae, Elmidae, Gerridae, Leptophlebidae, Tricorythidae, and Vellidae/ Mesovellidae. Most of cobble dwelling expected taxa were missing during the time of sampling despite moderate abundance of stones habitat. The MIRAI model generated a PES for macroinvertebrates as a Category C (65.4%).
Rip veg	The site has a VEGRAI score of 83.5% (B EC). **Marginal Zone:** Various vegetation components exist: 1) Narrow high density *Phragmites australis* along deep pools, 2) Open sheet rock or damp mud where the river has stopped flowing, with some grazed *Cynodon dactylon*, 3) Alluvial deposits with dense and tall stands of *S. mucronata*, 4) *Schoenoplectus* species or *Gomphostigma virgatum* associated with sunny areas with some bedrock. **Lower Zone:** Marginal zone components 1 and 3 similar, with dominant and extensive component 4 above; also *Agrostis lachnantha* (a hydrophilic grass). **Upper Zone:** Dry: RB - is an alluvial terrace with *Searsia pyroides* and *Lycium* sp. as dominants mixed with terrestrial grasses; LB - open sheet rock with some fine sediments, not well vegetated. **MCB:** Alluvial; woody and grass mix, with *Diospyros lyceoides* and terrestrial grasses dominant.
Diatoms	The assessment is based on a single sample taken during the current assessment. The overall EC of this site is a C. Nutrient levels are elevated at times while organic loading is moderate. The site is generally moderately polluted.

34.4 MAIN IMPACTS AT THE SITE

	PES	Causes	Sources	F/NF
Rip veg	B	Reduced cover of indigenous riparian obligate species, mainly grasses and some woody species.	Moderate to high trampling and grazing pressure (sheep mainly) with bank destabilization in places.	NF
		Altered species composition.	Small impact of alien vegetation (5% annuals, 5% perennial mainly *Populus alba*).	
		Increased vegetation cover of sedges and reeds.	Flow regulation and reduced flooding disturbance facilitates an increase in reed and sedge cover and density in the marginal and lower zone.	F
Fish	C	Loss of all flow classes and mainly FD habitat as a result of flow modification (especially during naturally low flow periods).	Smaller weirs and water abstraction for farming and irrigation upstream.	F
		Lower breeding success and recruitment for fish = lower FROC.	Lower, less and/or no natural flushes and smaller floods. Flow modification due to smaller weirs and water abstraction for farming and irrigation upstream.	
		Loss of species diversity or numbers due to loss of habitat diversity due to lower flows.	Flow modification due to smaller weirs and water abstraction for farming and irrigation upstream.	
		Loss of habitat with substrate (cobbles and rock), and water column in FD due to lower than natural flows.		

	PES	Causes	Sources	F/NF
		Loss of longitudinal connectivity for migration.		
		Decreased species diversity and abundance due to presence of carp.	Presence of alien species (carp) introduced for aquaculture and angling.	NF
		Enrichment.	Agriculture upstream.	
		Presence of dams and weirs as migration barriers (breeding, feeding and dispersal), also causing loss of habitat of some species (inundation).	Dam downstream and other smaller weirs in area.	
Inverts	C	No flow. Sedimentation and bank erosion.	Agriculture	F
		Poor water quality and associated benthic growth.		NF

34.5 BASELINE SURVEY RESULTS: PRESENT ECOLOGICAL STATE

Driver Components	PES	Trend
IHI: INSTREAM	C	
IHI: RIPARIAN	B/C	
DIATOMS (WQ)	C	
Response Components	**PES**	**Trend**
FISH	C	Stable
MACRO INVERTEBRATES	C	Stable
INSTREAM	C	
RIPARIAN VEGETATION	B	Stable
ECOSTATUS	C	

The main reasons for the Present Ecological State Category of a C are flow modification and resultant loss of habitat diversity due to smaller weirs and water abstraction for farming and irrigation. Lower breeding success and recruitment of fish, as well as loss of species diversity or fish numbers occur due to flow modification. Loss of connectivity for movement of aquatic biota due to small weirs. Nutrient enrichment due to agriculture, instream sedimentation and bank erosion reduce the quality of the available biotopes. Altered riparian vegetation species composition and increased vegetation cover of sedges and reeds due to flow regulation and reduced flooding disturbance.

34.6 SUITABILITY AS FUTURE BIOMONITORING SITE

A moderate quality and quantity of SOOC biotope is available for SASS sampling. Marginal vegetation out of current is also available. No instream biotopes are available for SASS sampling. Good habitat diversity and cover for all expected fish species is available. Undercut banks, aquatic marginal and overhanging vegetation, water column and substrate provide abundant cover for fish. Pools are abundant for water column cover for fish. Erosion and abstraction upstream, instream weirs modify flows and thus instream habitat. Site is situated downstream of a bridge. Benthic growth due to nutrient enrichment impacts negatively on the available habitat. Riparian vegetation obligate species are present and dominant at the site.

As the site is located in the upper reaches of the Riet River in a reach is minimally impacted compared to the lower reaches this site is a valuable biomonitoring point. This site is also a EWR site and therefore there is good data availability and a good understanding of the catchment. However the Reserve results indicate that the PES was in a D and therefore it could be concluded that monitoring of this site is needed to identify specific impacts.

35 EWR 19: LILYDALE LODGE (RIET RIVER) – OSAEH 29.5

This site was assessed as part of the Lower Vaal Reserve study, during 2007-2008 and was assessed during October 2010 as part of this study. The information provided below is summarised from DWA (2009c,d; 2010c). The results of the October 2010 assessment are provided in Technical Report 2. A comparison between the Reserve results and current results is provided in Section 35.7.

35.1 SITE DESCRIPTION

OSAEH 29.5 is situated in the lower reaches of the Riet River, below Ritchie in MRU Riet D which is delineated from Riet River confluence with Modder River to the inflow into Douglas Barrage and lies within Mokala National Park. The catchment area is dominated by irrigated agriculture. The dominant substrate at the site is bedrock and boulder. Cobble, boulder and rocky substrate is very abundant for cover for aquatic biota. Adequate flow was present at the time of sampling. Large pools for fish refugia were present with abundant marginal vegetation consisting of sedges and reeds and GSM biotope occurs at the site. Good habitat diversity for bio-monitoring purposes is present. Riparian vegetation consists of trees, shrubs, grasses, sedges and reeds. No large dams occur upstream but small weirs are present. The surrounding land use is natural veld for the game reserve.

Location	OSAEH 29.5	**Altitude**	1107 m
Longitude	24.075780	**Latitude**	-28.707580
EcoRegion	Southern/Central Kalahari 29.02	**Quaternary catchment**	C51L
Water Management Area	Upper Orange	**Geomorphological zone**	Lower Foothills

OSAEH 29.5, Riet River, 2007

35.2 PRESENT ECOLOGICAL STATE

Geom	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.
WQ	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	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.
Inverts	Sep 07: SASS5 score: 124 No of Taxa: 23 ASPT: 5.3 Apr 08: SASS5 score: 187 No of Taxa: 19 ASPT: 4.6 The PES 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.
Rip veg	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. 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.
Diatoms	The assessment is based on the single sample taken at the site during 2007. The EC was a D and generally the water quality was poor with critical pollution levels. Organic pollution levels were very high. This assessment is of low confidence as it is uncertain if elevated flows in the system might have a dilution effect at this site or if there is really an improvement in water quality.

35.3 MAIN IMPACTS AT THE SITE

	PES	Causes	Sources	F/NF
WQ	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.	
		High ammonia.	Ammonia from the degrading algal matter.	
Geom	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
Rip veg	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

35.4 BASELINE SURVEY RESULTS: PRESENT ECOLOGICAL STATE

2007-2008			2010		
Driver Components	**PES**	**Trend**	**Driver Components**	**PES**	**Trend**
GEOMORPHOLOGY	C	Stable	IHI: INSTREAM	B/C	
WATER QUALITY	D	Negative	IHI: RIPARIAN	A/B	
DIATOMS	D		DIATOMS (WQ)	B/C	
Response Components	**PES**	**Trend**	**Response Components**	**PES**	**Trend**
FISH	D	Stable	FISH	C	Stable
MACRO INVERTEBRATES	C	Stable	MACRO INVERTEBRATES	C	Stable
INSTREAM	D		INSTREAM	C	
RIPARIAN VEGETATION	C/D	Negative	RIPARIAN VEGETATION	B	Negative
ECOSTATUS	D		ECOSTATUS	C	

The main reasons for the PES of a C are mainly due to flow modification and resultant loss of habitat diversity due to smaller weirs and water abstraction for farming and agriculture. Poor water quality and associated benthic growth is due to nutrient enrichment from agriculture. There are decreased wet season base flows and the loss of flow and especially FD and FS habitat, most probably due to water abstraction upstream, and increased dry season base flows due to Orange River water being transferred to improve water quality. Smaller weirs and water abstraction upstream for agriculture are the main reasons for flow modification. The water quality is also negatively affected due to the agricultural activities.

The results from the Reserve study however indicate that the PES was a D. According to DWA (2010c) the major impacts on this site were flow modification due to dams upstream in the system and return flows from irrigation and possibly the transfer of water from the Orange River which has resulted in increased dry season baseflows and reduction in moderate events. Water quality was also impacted by upstream agriculture. These two main impacts have lead to deterioration in availably biotic habitat and impacted the biota.

It is evident that there is a discernable difference in the results of the Riparian vegetation assessment. The site is now part of the Mokala National Park and together with Working for Water a lot of exotic species have been removed. This is ongoing and the vegetation has improved drastically (*Pers. comm*. H Bezuidenhout).

The EWR 8 assessment showed drastic denudation and impacts of past mining, agriculture and a high proportion of alien vegetation, none of which was prevalent at the 2010 site. In the 2010 assessment there were signs of alien perennial species (notably *Eucalyptus* sp.) but these had all been removed. Some recruitment of Bluegum was evident (very young seedlings) and noted as

such, but the impact of alien vegetation on the score was negligible. (Perennial aliens absent from marginal zone, 1% in lower zone and 4% in upper zone). The main impact in the 2010 assessment was flow related i.e. an increase in reed cover due to flow regulation, but the species composition was close to expected for reference condition. Clearly this was not the case at the EWR 8 site where up to 20% cover of alien species was recorded.

35.5 SUITABILITY AS FUTURE MONITORING SITE

Good quality and quantity of cobble biotope is present for macroinvertebrate sampling. A diversity of instream habitats is present. Very good habitat diversity and cover occurs for expected fish species. Pools are abundant for water column cover and refugia for fish. This site could serve as a good fish spawning area during high floods with ample marginal vegetation and substrate present (cobbles and rocky areas). All fish flow depth classes are present and well represented. Upstream water abstraction and weirs result in flow modification which impacts negatively on the available habitat. Benthic algae are present due to nutrient enrichment. Riparian obligate species are present and dominant at the site. The site is situated within a protected area. The river is not wadeable and a boat would be needed to cross the river.

OSAEH 29.5 is the lowest site within the Riet River and was identified as a priority reach for maintaining the integrity of the Lower Vaal. Therefore it is an ideal site for detecting impacts from upstream anthropogenic activities originating from the Modder and Riet Rivers. The site occurs in the Mokala National Park.

36 CONCLUSIONS

Twelve OSAEH sites were identified as possible monitoring sites while four EWR sites occur within the Lower Vaal WMA that was assessed as part of the Vaal Comprehensive Reserve study undertaken by Golder and Associates during 2007 – 2010. Six OSAEH sites were assessed during October 2010. The four EWR sites assessed in the Lower Vaal WMA, have provided additional information that can contribute to future monitoring programmes in the Orange River Basin. The main impacts in the different Lower Vaal MRUs and system operation is summarised from DWAF (2009c) in the following sections.

36.1 LOWER VAAL RIVER

For the purposes of the EWR study, the Vaal River from the start of WMA 10 at the outlet of Bloemhof Dam to the confluence of the Orange River below Douglas was delineated into six Management Resource Units (MRU Vaal K – P). Two EWR sites and three OSAEH sites are situated in the Vaal River main stem.

36.1.1 MRU VAAL K: Vaal River from Bloemhof Dam outflow to Vaalharts Weir (C91A -B)

Water stored in Bloemhof Dam is used to supply the downstream irrigation and urban users and only if Bloemhof Dam is empty, will water be released from Vaal Dam to support those demands. Only sufficient releases are made from Vaal Barrage and Vaal Dam for users along the Middle Vaal Reach (between Vaal Barrage and Bloemhof Dam) to satisfy their requirements and to maintain the 600mg/ℓ TDS concentration. These releases are mostly captured in Bloemhof Dam for subsequent supply to the downstream users.

The flow in this river reach is dominated by the releases made from Bloemhof Dam for the Vaalharts irrigation Scheme. Vaalharts Weir serves as the structure from where the irrigation water is diverted into the canal that feeds the Vaalharts Irrigation Scheme. Bloemhof Dam has substantial flow regulation capability. Due to the relative long river reach downstream of Bloemhof Dam and Vaalharts Weir, significant quantities of consumptive evaporative losses and non-consumptive operating losses are associated with releases in the river system. To meet spiralling water demands within the basin, various importation schemes have been implemented.

The Vaal River has improved water in this reach with a PES EcoStatus of a B (DWAF, 2009c) due to releases made from Bloemhof Dam.

EWR 16 is the only site that occurs in MRU Vaal K. The reach is important in order to understand the influence of the Upper and Middle Vaal WMA. Although the site is suitable for fish and macroinvertebrate sampling, the riparian vegetation is highly altered. The site occurs just downstream of Bloemhof Dam and the altered flow regime may be problematic for sampling. In terms of future biomonitoring this site may be too close to Bloemhof Dam in the upper reach of C91A and would not detect impacts occurring downstream in the Vaal River.

36.1.2 MRU VAAL M: Vaal River from Vaalharts Barrage to Harts River confluence (C91D - E)

The predominant water use in this region of the catchment is for irrigation agriculture with minor urban and industrial demands of which the water supply to Kimberley is the most significant. The Vaal River also provides water to other riparian towns and for the Vaal Gamagara pipeline serving the Kalahari (Hotazel-Postmasburg) mineral complex.

OSAEH 29.2 is located in this MRU and was not assessed during this study. From Google Earth imagery habitat availability seems adequate for the full suite of biological components to be monitored. This site may be more valuable in a monitoring programme than EWR 16 as it is situated further downstream in the Vaal River and therefore more suitable to detect upstream impacts.

The PES EcoStatus of this reach is a C (DWAF, 2009c).

36.1.3 MRU VAAL O: Vaal River from Schmidtsdrift weir to Douglas Barrage (C92A-C)

In this part of the catchment the quality of surface water in the Harts and Vaal Rivers is highly impacted upon by irrigation return flows of the Vaalharts Irrigation Scheme as well as by water use in the Upper and Middle Vaal WMAs, which limits the usability of water in the lower reaches of these rivers. Water quality in the lower reaches of the Vaal River is also impacted upon by irrigation return flows from the Riet/Modder River necessitating further blending with low salinity water from the Orange River at the Douglas weir. The PES EcoStatus in C92A is a C but deteriorates in C92B to a D EC (DWAF, 2009c).

OSAEH 29.4 occurs within MRU Vaal O and was assessed during 2010 as this site was identified as a priority reach for maintaining the integrity of the Lower Vaal. This site was also assessed as part of the Comprehensive Reserve study, EWR 18. Although this site was identified as a priority reach for maintaining the integrity of the Lower Vaal, sampling at this site is difficult as the river is non-wadeable due to the steep gradient of the river. Limited biotopes occur for biotic sampling, and the riparian zone is very dense. This site could be included in a monitoring programme although due to the non-wadeable nature of the Vaal River in this reach, assessment of biotic components would be limited and therefore the site is not recommended as a future monitoring site.

36.1.4 MRU VAAL P: Douglas Barrage

Douglas Barrage occurs just outside the Lower Vaal WMA, immediately upstream of the Vaal River confluence with the Orange River. This is the most downstream section of the Vaal River before the confluence with the Orange River. Douglas Weir is the upstream storage structure, which has limited flow-regulating capability. Currently this river reach has no flow for most of the time and is operated to minimise spills from the Vaal River system into the Orange River. The Douglas Irrigation Scheme is supplied from the Douglas Weir and, in addition to the runoff entering Douglas Weir from the upstream incremental catchments, water is transferred (pumped) from the Orange River into Douglas Weir. No releases are made from storage structures in the Vaal, Harts or Riet/Modder river systems to support the water requirements in Douglas Weir. Since the inception of the Douglas irrigation scheme, water quality in the Lower Vaal River has deteriorated dramatically. The layout of the scheme as well as the position where the water transferred from the Orange River is discharged upstream of the weir, are poorly suited for water quality management purposes and the continued feasibility of the scheme is unclear. Without excess releases from Bloemhof Dam the scheme would not be sustainable. Douglas weir is operated such that no water apart from spills flows into the Orange River.

OSAEH 26.1 occurs within MRU Vaal P and is situated approximately 1.6 km downstream of Douglas Weir and was sampled during October 2010. Although this is a very good site in terms of habitat availability, monitoring the accumulative impacts of the Vaal and Riet Rivers may be obscured due to the water transfer from the Orange River. This site is nevertheless of significant value as a transboundary site and should be included in future surveys.

36.2 HARTS RIVER

The major water uses in the Harts River catchment are domestic and agriculture. Agriculture consists of irrigation and stock watering. Irrigation is the biggest water user with the majority of the irrigation located in the Vaalharts Irrigation Scheme. There is also irrigation located along the reach of the Harts River downstream Spitskop Dam.

Significant flows occur in the Harts River reach upstream of Spitskop Dam from the return flows of the Vaalharts Irrigation Scheme. The return flows have changed the flow and quality regimes substantially compared to natural conditions. The water available in Spitskop Dam is more than the water requirements supplied from the dam. This is due to the large volume of return flows generated by the Vaalharts Irrigation Scheme located upstream of the dam. Water is released from Spitskop Dam from where it is abstracted for irrigation along the river reach. Spitskop Dam has the capability to regulate flow releases in this river reach. Investigations are in progress to identify potential further use of the excess water available in the dam. An appropriate balance exists for the Harts River catchment as only enough water is transferred from the Vaal River into the area to meet the water requirements, while return flows from the catchment are available for use along the lower Vaal River.

The upper reaches of the Harts is in a D EcoStatus and improves in C33E and F to a C. Due to releases made from Spitskop Dam, the EcoStatus of the Harts River improves to a B and as impacts increase downstream the EcoStatus deteriorates to a D at the confluence with the Vaal River (DWAF, 2009c).

Only OSAEH 29.1 was identified for the Harts River and is at the same location as EWR 17. The site was therefore not assessed during October 2010. EWR 17 is situated downstream of Spitskop Dam in the Harts River and occurs within MRU Harts C, and includes Wentzel Dam which is delineated as a unit. The dam supports the domestic water use in Wentzel and the yield of the dam is fully utilised. It is suggested that this site is included as a future monitoring site as present day flows are higher than natural and the deteriorated water quality impact heavily on the site.

36.3 MODDER AND RIET RIVERS

The Modder Riet catchment is situated in the Free State and Northern Cape Provinces. It is part of the Upper Orange WMA, but forms part of the C drainage region (Vaal River System). It covers a catchment area of 35 000 km^2. The Modder and Riet Rivers are the only major rivers in the catchment, which drain into the Vaal River which subsequently flows into the Orange River. The catchment includes Kalkfontein, Rustfontein, Tierpoort, Groothoek and Krugersdrift Dams.

Current land use in the catchment is related agricultural activities, urbanisation and mining and industrial activities. In the Modder and Riet River catchments agricultural use comprises primarily the irrigation of crops. Agricultural activities are concentrated around the dams in the catchment. Livestock watering also occurs, but to a lesser extent. The major urban centres in the catchment are Bloemfontein, Botshabelo and Thabu Nchu. The Modder River is a major source of water to these urban areas. Most industries in the Modder and Riet catchments are centred around Bloemfontein and use treated water from the municipal supply system. Only one industry that uses water directly out of the river is known.

The majority of the Riet and Modder River reaches are a C EcoStatus with C52C and J in a slightly better condition (B/C EcoStatus).

One EWR site and nine OSAEH sites are located in the Modder Riet river system.

36.3.1 MRU RIET A: ORIGINS OF RIET RIVER TO KALKFONTEIN DAM

OSAEH 26.10 occurs in this MRU and was assessed during 2010. The site has adequate habitats for the full suite of biological components to be monitored. This site is also an EWR site (IFR 03) and was assessed during the Reserve study in 2003. Although the reach represents a relatively unimpacted part of the Riet River, the EWR assessment resulted in a PES of a D. The current assessment also indicates impacts relating to anthropogenic activities. As the water quality of the Riet River is deteriorated this site should be included as a future monitoring site to detect ongoing impacts especially relating to impaired water quality.

OSAEH 26.9 is situated in the Kromelenboogspruit tributary which enters the Riet downstream of OSAEH 26.10. This site was not assessed during this study. The site is not considered as a priority site in future monitoring programmes as the stream is non-perennial which very seldom flows. The site is dominated by pools and is difficult to sample due to irregularity of flow (Watson, *pers. comm*. 2010).

36.3.2 MRU RIET B: Kalkfontein Dam

Kalkfontein Dam supports mainly irrigation water use and forms part of the Riet River Government Water Scheme (GWS). OSAEH 26.6 occurs just below the dam and was not assessed during 2010. This site is also an EWR site (IFR 04) and was assessed during the Reserve study in 2003. The site is not an ideal monitoring site due to its locality downstream of Kalkfontein Dam. There is very little habitat available and consists of mostly pools (Watson, *pers. comm*. 2010).

36.3.3 MRU RIET D: Modder River confluence to inflow to Douglas Barrage

OSAEH 29.5 is the site situated farthest downstream in the Riet River, and is located just downstream of Ritchie. This reach was identified as a priority reach for maintaining the integrity of the Lower Vaal. Therefore it is an ideal site for detecting impacts from upstream anthropogenic activities originating from the Modder and Riet Rivers. The site occurs in the Mokala National Park on the LB of the river.

This site was assessed during 2010 and was also assessed as part of the Comprehensive Reserve study (EWR 19).

Based on personal communication with Ms M Watson[5] a diamond mine was present on the RB during the 2003 EWR study which had an impact on the site and therefore the results, however the Modder Riet strategy makes no mention of the mine. The salts at the site are also normally very high but rainfall was high before the October 2010 assessment and this could have led to some dilution and therefore resulted in improved conditions. The Orange-Riet transfer scheme releases water into the Riet river upstream of the site and at a meeting recently attended by Ms Watson, the Riet River Water Users Association representative indicated that more water from the Orange River is being released into the Riet to dilute the high salt load which could also have influenced the results of the October survey.

36.3.4 MRU RIET C1: Origin of Modder River to Krugersdrift Dam

OSAEH 11.18 was assessed during October 2010 and is located downstream of Botshabela and Thabu Nchu but upstream from Bloemfontein. It is the only OSAEH site situated in the upper reaches of the river and should be included as a biomonitoring site. The habitat at this site is good and the full suite of biological components can be monitored. This site will be a good monitoring

[5] Centre for environmental Management, UFS.

site to detect and monitor on-going impacts which include impacts from sewage works, interbasin transfer, and Rustfontein Dam upstream.

OSAEH 11.21 is located in the Korannaspruit, is a seasonal tributary of the Modder River and is situated in C52C. The confluence occurs within MRU Riet C1 (DWAF, 2009b). This site is situated downstream of a large dam, upstream of the confluence with the Modder River. The Korannaspruit is a seasonal, narrow river and any type of flow modification will have a severe impact on the site. During the October 2010 assessment it was evident that anthropogenic activities were negatively impacting this site. Habitat is very limited at this site and sampling will be difficult as the river is dry at times. This site was initially identified as a reference site, but due to the high degree of impact at the site and the absence of habitat for biota, as well as the deteriorated Instream Habitat Integrity this site is not recommended as a future monitoring site.

OSAEH 11.19 is located just upstream of the Krugersdrift Dam and was not assessed. Although habitat types are present sampling is difficult and irregular due to runoff from Bloemfontein metro area causing high elevated flows. Many times the Krugersdrift Dam has pushed back into site or flows are very low (Watson, *pers. comm*. 2010). Therefore this site is not recommended as a future biomonitoring site.

36.3.5 MRU Riet C3: Downstream Krugerdrif Dam to Riet River confluence.

The area is impacted by return flows from the urban centres, bulk water users and irrigation. This reach has importance as it is a migratory corridor from Modder to Riet River confluence. OSAEH 26.5 occurs in this reach and is situated in the Kraalspruit which is a tributary of the Modder River. The site was initially identified as a reference site but the site receives return flow from Bainsvlei Sewage works. The site is not recommended as a future monitoring site as the site is mostly dry and only flows when releases are made from the sewage works or high rainfall occurs (Watson, *pers. comm*. 2010).

37 UPPER ORANGE CATCHMENT – FROM THE LESOTHO BORDER TO THE VAAL RIVER CONFLUENCE

37.1 BACKGROUND

The Upper Orange River can be defined as that part of the system from the Lesotho border to upstream of the Orange-Vaal River confluence. The two major river systems that drain the Upper Orange Water Management Area (WMA) are the Modder-Riet and the Orange Rivers. The main urban and industrial development areas in the Upper Orange WMA are Bloemfontein and Thaba 'Nchu, with two large hydropower stations at Gariep and Vanderkloof Dams. Mining activities have significantly declined and currently mainly relate to salt works and small diamond mining operations. The largest land use in the catchment is agriculture, with 80% of the water requirements in the Upper Orange WMA being for agriculture (ORASECOM, 2007).

No OSAEH sites were assessed as part of this study. This area was assessed as part of the EFR study undertaken during 2010 by Water for Africa (WFA, 2010 a, b). The EFR sites are located in the Orange River, Caledon and Kraai River. Therefore Section 38 to 41 summarises the results of this study.

Figure 37.1 provides the locality of the EFR sites as well as the OSAEH sites that occur in the Orange River downstream of the Lesotho border up to the Vaal River confluence where the green pins represent the OSAEH monitoring sites, and the red pins represent the EFR sites assessed during 2010.

Eleven OSAEH monitoring sites were identified in this area while four EFR sites were assessed during 2010 as part of the Environmental Flow Assessment (WFA, 2010a). Site information is provided in Table 37.1.

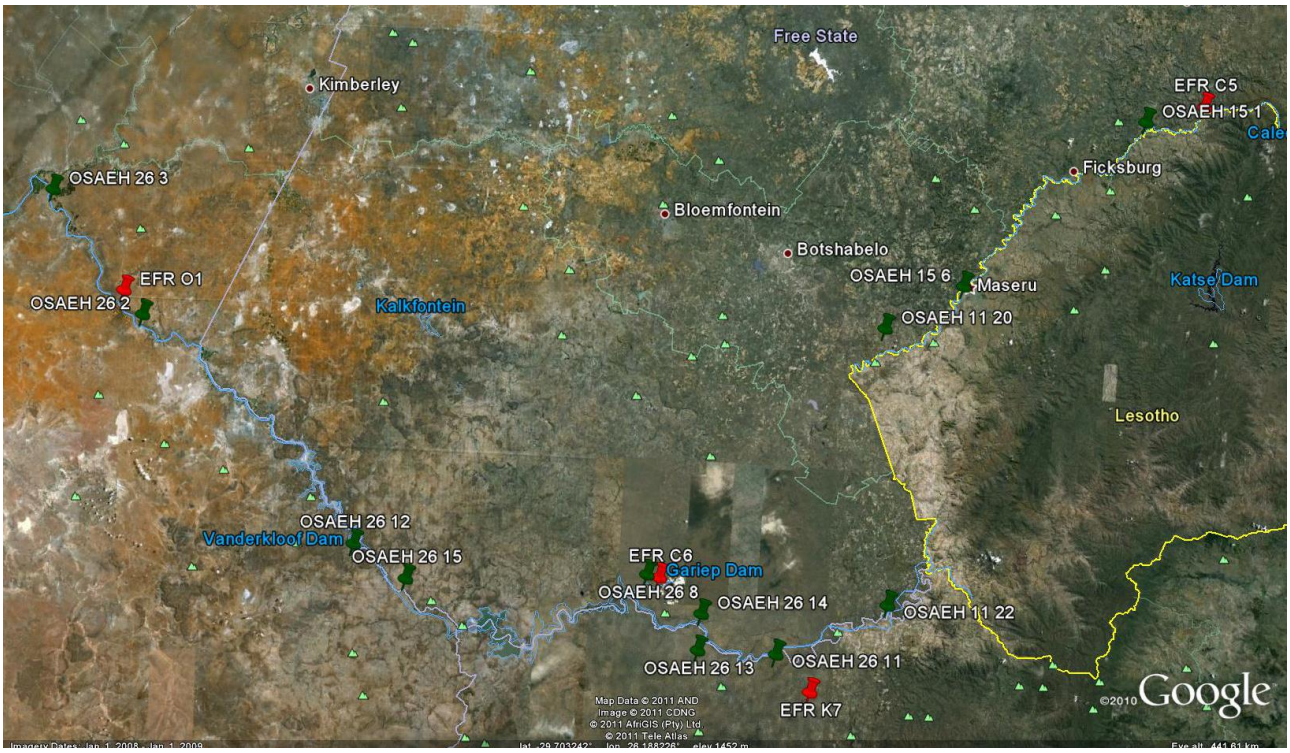

Figure 37.1 OSAEH monitoring and EFR sites located in the Upper Orange River below Lesotho up to the Vaal River confluence (Google Earth image, 2010)

Table 37.1 OSAEH monitoring and EFR site detail

Site	Monitoring type	Eco-Region	Major River	Latitude	Longitude	Site code
OSAEH_11_20	Ecological Reserve Site	11	Caledon/Leeuspruit	-29.52197	27.13561	D2LEEUEWR06
OSAEH_11_22	Monitoring Site P	11	Orange	-30.50472	27.21889	D1ORANHERSC
OSAEH_15_1	Ecological Reserve Site	15	Caledon	-28.72231	28.15083	D2CALEEWR03
OSAEH_15_6	Monitoring Site P	15	Caledon	-29.35434	27.44597	D2CALELADYB
OSAEH_26_2	Reference Site	26	Orange	-29.6007	24.0916	D3ORANHOPET
OSAEH_26_3	Monitoring Site P	26	Orange	-29.16207	23.69651	D3ORANMARKS
OSAEH_26_8	Monitoring Site P	26	Caledon	-30.45233	26.27088	D2CALETUSSE
OSAEH_26_11	Monitoring Site P	26	Orange/Kraai	-30.70364	26.77132	D1KRAACORAN
OSAEH_26_12	Monitoring Site P	26	Orange/Seekoei	-30.38766	25.00357	D3SEEKVANDE
OSAEH_26_13	Monitoring Site P	26	Orange/Stormbergsprt	-30.70364	26.44681	D1STORCORAN
OSAEH_26_14	Monitoring Site P	26	Orange	-30.57305	26.45305	D1ORANGOEDE
OSAEH_26_15	Monitoring Site P	26	Orange	-30.50305	25.22555	D3ORANBULTF
EFR O1	Ecological Reserve Site	26	Orange	-29.516	24.00927	Hopetown
EFR C5	Ecological Reserve Site	15	Caledon	-28.6508	28.3875	Upper Caledon
EFR C6	Ecological Reserve Site	26	Caledon	-30.4523	26.27088	Lower Caledon
EFR K7	Ecological Reserve Site	26	Kraai	-30.8306	26.92056	Lower Kraai

38 EFR C5: UPPER CALEDON

The information is summarised from WFA (2010a;b).

38.1 SITE DESCRIPTION

For the purposes of the EFR study, the Caledon River was delineated into four MRUs. EFR C5 is situated in the upper reaches of the Caledon River on the border of MRU A and B which is just upstream of the Klein Caledon River confluence. The site is approximately 10 m wide, and alluvial, although some bedrock is exposed on the lower bank with rapids being boulder/cobble/bedrock dominated. Grazing and trampling pressure is high on both banks and high levels of erosion were present. Flow sensitive habitats for fish (FS and FD) are very well represented at the site and although habitat diversity is good there is potentially some loss of deep areas due to sedimentation. Macroinvertebrate habitat is moderate with limited stones-out-of-current, marginal vegetation in current and aquatic vegetation habitats.

The sediment production in the catchment is very high as much of the catchment has been cleared for cultivation, and grazing pressures are high. The steep slopes, poor vegetation cover and intense rainfall events promote erosion. Dongas across the catchment are widespread. Exotic vegetation is, in places, play some role in stabilising sections of eroding banks and dongas. This high sediment load is reflected in the instream condition of the river. The original bed of the river was probably gravels and cobbles with some sands. These larger bed elements have been smothered by the high sands and fine loads from the eroding lands in the catchment. Some cut banks near the EFR site indicate up to 2 metres of fine sediment having been deposited over the original cobble beds over only a few flow events.

Location	EFR C5 Upper Caledon	**Altitude**	1640 m
Longitude	28.3875	**Latitude**	-28.65078
EcoRegion	Eastern Escarpment Mountains 15	**Quaternary catchment**	D21A
Water Management Area	Upper Orange	**Geomorphological zone**	Lowland Foothills

EFR C5, Caledon River. The site under different flow conditions.

38.2 PRESENT ECOLOGICAL STATE (PES)

Geom	This is primarily attributed to the high sediment loads (sands and fines) being introduced from the eroding upstream hill slopes and associated drainage lines, and destabilisation of the banks along the channel. These impacts have caused large changes to the condition of the instream habitats through reduction in cobble and gravel in-channel habitats, and loss of marginal vegetation.
WQ	Salinity levels are naturally elevated. Suspected toxics and suspended solids from upstream farming activities dominate the water quality assessment.
Fish	Two of the expected fish species (*A. sclateri* and *L. capensis*) have disappeared from this river reach, primarily as a result of habitat deterioration. Both these species have a preference for fast habitats over rocky substrates, which have been extensively altered by sedimentation in this reach. The FROC of the two fish species presently occurring within this reach have been reduced. *Labeobarbus aeneus* is also thought to have been primarily impacted by the deterioration of bottom substrates by siltation, while the impact on overhanging vegetation as cover (trampling, overgrazing, bank erosion) probably have the biggest impact on the FROC of *Barbus anoplus*. The presence of predatory alien fish species (*Oncorhynchus mykiss* and *Salmo trutta*) is thought to be another primary impact on the fish assemblage of this reach.
Inverts	2010 SASS5 score: 97 No of Taxa: 17 ASPT: 5.7 Key taxa expected but not observed included Perlidae, Heptageniidae, Dytiscidae, Caenidae, Hydracarina, Dixidae, Ecnomidae, and Lymnaeidae. Only two species of Baetidae were recorded, and only one species of hydropsychid caddisflies was recorded. The fauna was dominated by baetid mayflies (mainly *Baetis harrisoni),* and blackflies (mainly *Simulium nigritarse and S. medusaeforme)*. These species are highly tolerant of water quality deterioration.
Rip veg	**Marginal Zone:** Patchy, open boulder/cobble with *G. virgatum* and *S. mucronata* as woody indigenous riparian obligates. Alluvial deposits with cobble areas dominated by sedges, especially *C. marginatus*. Composition is close to reference, but cover has been reduced by high grazing and trampling pressure. Reduced base flows would favour sedge establishment, but this is marginally evident due to the overriding effect of domestic stock (grazing and trampling). Because grasses are more palatable than sedges, the latter has increased at the expense of the former under the current grazing regime. Increased sediment loads do not appear to have resulted in changes to riparian vegetation as an impact on its own, but together with grazing, has favoured the establishment of *C. marginatus*. **Lower Zone:** Portions of the lower zone are dominated by low density sedges (*C. marginatus*) and mixed with hydrophilic grasses. Grassed terraces have a high degree of trampling which has caused bank slumping and accelerated erosion. Exotic woody species occur in the zone (20% cover). Increased sediment loads do not appear to have resulted in changes to the riparian vegetation. **Upper Zone:** Grassland dominated, with grasses that indicate overutilization common. High cover (% aerial) by *Artemisia affra* also supports the overgrazed landuse. Woody exotic cover is high (20% aerial cover), especially where banks have been destabilized by overgrazing and trampling.
Diatoms	Diatom results are based on samples taken during 2010 at various sites situated in MRU A/B. There are indications of elevated nutrient levels as well as elevated turbidity and calcium-based salinity although water quality data indicated that salinity and nutrient levels are naturally elevated. Pollution levels are elevated at this site and organic pollution may be problematic. The biological water quality however seemed in a good condition as the reach upstream of the site is situated in the Golden Gate Nature Reserve. The Ecological Category (EC) for this reach is a B.

38.3 MAIN IMPACTS AT THE SITE

	PES	Causes	Sources	F/NF
WQ	B/C	Although this system is naturally turbid, elevated sediment levels are present due to land-use activities, particularly from the Lesotho Lowlands area. These activities also result in elevated nutrients and potential toxicant loads due to fertilizer and pesticide use.	Agriculture - Some toxicant and nutrient loading expected.	NF
Geom	C	Increased sediment yields from catchment.	Clearing of catchment for cultivation; high grazing pressure.	NF
		Bank destabilization.	Grazing/trampling, tree removal, high fine loads deposited over more stable original cobble beds due to increased sediment yields.	
Rip vegn	C	Reduced vegetation cover and abundance.	Grazing and trampling.	NF
		Species compositional changes.	Perennial (15% average) and annual (5% average) exotic species.	
Fish	D	Decreased overhanging vegetation as cover for fish.	Agriculture – bank erosion.	NF

	PES	Causes	Sources	F/NF
		Deterioration of substrate as habitat (clogging interstitial spaces, loss of important spawning habitats, etc.).	Bank erosion and extensive overgrazing.	
		Decreased substrate quality related to increased benthic growth.	Agriculture: increased nutrients and organics.	
		Impact on species with requirement for high water quality.	Over grazing, human settlements and agriculture.	
		Decreased species diversity and abundance (especially small species).	Presence of aggressive alien predatory species.	
		Increased turbidity and disturbed bottom substrates.	Erosion (agriculture).	
		Presence of migration barriers reduces migration success (breeding, feeding and dispersal) of some species.	Small barriers in tributaries and larger weirs downstream of site in Caledon River.	
Inverts	C	Increased sedimentation.	Farming activities (crops).	NF
		Increased nutrient loads.	Livestock.	

38.4 RESULTS: PRESENT ECOLOGICAL STATE

Driver Components	PES	Trend
GEOMORPHOLOGY	B/C	Negative
WATER QUALITY	C	Stable
DIATOMS	B	
Response Components	**PES**	**Trend**
FISH	D	Stable
MACRO INVERTEBRATES	C	Stable
INSTREAM	D	
RIPARIAN VEGETATION	C	Stable
ECOSTATUS	C	

The main reasons for the PES are grazing and trampling, bank erosion, sedimentation, exotic vegetation and fish species. Geomorphology has a negative trend and this is due to erosion that will still increase with resulting increased sedimentation. Riparian vegetation is largely stable because grazing prevents exotic vegetation from increasing.

38.5 SUITABILITY AS FUTURE BIOMONITORING SITE

The site is adequate for biotic monitoring. The site is situated in the upper Caledon River bordering the Golden Gate National Park. Most of the river reach has Lesotho on the left bank (LB) with associated sedimentation problems due to land-use activities. Considerable irrigation development opportunity has been planned for small farmers in the Lesotho Lowlands area, which might exacerbate existing erosion problems depending on land management practices.

39 EFR C6: LOWER CALEDON

The information is summarised from WFA (2010a;b).

39.1 SITE DESCRIPTION

EFR C6 is situated in the lower reaches of the Caledon River in MRU D which is delineated from Tussen-Die-Riviere Game Reserve to backup of Gariep Dam. The site is 100 m wide at places and channel substrate includes boulder, bedrock, cobble and sand. The morphology of the site is generally representative of the reach, although such large bedrock riffles are not common. Although this is a bedrock rapid section, fines dominate the bed. Recent floods have deposited several metres of sediment along the banks. In the faster flowing sections of the bedrock rapid section of the channel there are some gravels and cobbles on the bed, but these are all embedded by fines. The condition of the site is probably slightly better than the reach due to location within nature reserve. Flow sensitive habitats for fish (FS and FD) are very well represented at the site and although habitat diversity is moderate. Turbidity is high with extensive sedimentation/siltation. Macroinvertebrate habitat is moderate with limited stones-in-current, marginal vegetation in and out of current and aquatic vegetation habitats.

Location	EFR C6 Lower Caledon	**Altitude**	1270 m
Longitude	26.2708	**Latitude**	-30.4523
EcoRegion	Nama Karoo 26.03	**Quaternary catchment**	D24J
Water Management Area	Upper Orange	**Geomorphological zone**	Lowland River

EFR C6, Upper Caledon River. Channel substrate includes boulder, bedrock, cobble and sand.

39.2 PRESENT ECOLOGICAL STATE (PES)

Geom	High sediment loads (sands and fines) being introduced from the eroding upstream hill slopes and drainage lines, bottom release flushes (from Welbedacht Dam) during low flows. Sedimentation of the lower riparian zone and smothering of the instream habitats through reduction in deep areas and gravels.
WQ	Salinity levels in the system seem to be naturally elevated. Turbidities are particularly high in this stretch of the river, with the impact of the dam shown in changing temperature and oxygen levels. Bloem Water intake data also indicates high toxics. The most likely source of aluminium in the surface water is due to alum or aluminium sulphate used in most water treatment processes as a flocculating agent for suspended solids.
Fish	Loss of some FS and FD habitat as a result of flow modification, loss of SD due to sedimentation of pools, loss of rocky bottom substrates as a result of sedimentation, water quality deterioration (especially increased turbidity levels). Loss of marginal zone overhanging vegetation furthermore reduces cover for *especially B. anoplus* and *B. paludinosus*. The presence of the bottom feeding alien *C. carpio* can especially be detrimental in this reach due to the already altered bottom substrates (sedimentation) and high turbidity. This species can lead to further deterioration in bottom substrates and increased turbidity. Potential presence of predatory alien species (*O. mykiss*) may further impact on indigenous fish species. The presence of some complete migratory obstructions (Gariep Dam and Welbedacht Dam) as well as various smaller dams/weirs reduces migration success of species with requirement for movement between reaches.
Inverts	2010 SASS5 score: 52 No of Taxa: 10 ASPT: 5.2 Key taxa expected but not observed included Heptageniidae, Elmidae, Coenagrionidae, Caenidae and

	Leptophlebiidae. Gomphidae were notably scarce, despite the abundance of suitable sediments. Only one species of hydropsychid caddisflies recorded. Abundance of all taxa very low, with no taxon exceeding 100 specimens per sample (i.e. >B abundance).
Rip veg	**Marginal zone:** Mostly open cobble/boulder and alluvial deposits. Scour damage from recent floods is high. Sedges and *G. virgatum* are sparse and a mix of *P. australis* and *S. mucronata* dominates steeper alluvial banks. **Lower zone:** Extensive new alluvial deposits in the lower zone (clear evidence of smothered existing vegetation), with some open bedrock. Recolonisation by grasses especially prevalent, but sedges also occur). **Upper zone:** Alluvial terraces are similar to the lower zone. Channel banks are dominated by woody vegetation, mainly *D. lycioides, Olea europea africana* and *R. pyroides.*
Diatoms	Diatom results are based on samples taken during 2005, 2008 – 2010 at various sites situated in the MRU D. The diatom assemblage at EFR C6 in MRU D indicated elevated flows and although the SPI score indicated the site was in an A EC, this might not be a true reflection of current conditions. The dominant species is an indicator of anthropogenic disturbance and at an abundance of 88% this site is exposed to high levels of disturbance. Other species present indicated that nutrients, organics and salinity are variables that could impact these sites, but due to releases from Welbedacht Dam these impacts are ameliorated. It is estimated that the biological water quality condition of MRU D is in a C EC, although this is a low confidence determination.

39.3 MAIN IMPACTS AT THE SITE

	PES	Causes	Sources	F/NF
WQ	C	Turbidity levels are highly elevated.	Poor land management.	NF
		Elevated nutrients and potential toxicant loads.	Agriculture. Upstream towns, with industrial/urban activities and poorly functioning STW. The most likely source of aluminium in is due to aluminium sulphate used in most water treatment processes as a flocculating agent for suspended solids.	
		Impact on temperature and oxygen levels.	Bottom releases (Welbedacht Dam).	F
Geom	C/D	Increased sediment yields from catchment.	Agriculture.	NF
		Back up effects of Welbedacht Dam.	Backup of dam.	
		Bottom releases from Welbedacht Dam.	Sediment slugs released during low flow periods.	F
Rip Veg	B	Reduced vegetation cover and abundance.	Sediment deposition (dam flushing & catchment).	NF
		Changes to species composition.	Reduced flows and increased sedimentation.	
		Reduced woody species cover in marginal zone.	Reduced base flows.	F
Fish	D	Decrease in FROC and abundance of fish species with preference for fast habitats.	Decreased base flows.	F
		Decrease in FROC and abundance of fish species with preference for SD habitats.	Loss of SD habitats through sedimentation of pools.	
		Deterioration of spawning habitat.	Bank erosion and extensive overgrazing.	F & NF
		Decreased substrate quality increased benthic growth.	Increased nutrients and organics.	NF
		Decreased overhanging vegetation (cover).	Increased bank erosion.	
		Decreased water quality affect species with requirement for high water quality.	High turbidity and possibly toxins (aluminum).	
		Decreased species diversity and abundance (especially small species)	Aggressive alien predatory species (O. mykiss and *S. trutta*.	
		Increased turbidity and disturbed bottom.	Presence of alien *C. carpio*.	
		Reduced migration success (breeding, feeding and dispersal) of some species.	Large dam wall and small dams/weirs.	
Inverts	D	Sediments (high turbidity).	Agriculture (crops).	NF
		Flow cessation.	Regulation.	F
		A-seasonal releases.	Regulation.	

39.4 RESULTS: PRESENT ECOLOGICAL STATE

Driver Components	PES	Trend
GEOMORPHOLOGY	C/D	Stable
WATER QUALITY	C	Stable
DIATOMS	C	
Response Components	**PES**	**Trend**
FISH	D	Stable
MACRO INVERTEBRATES	D	Stable
INSTREAM	D	
RIPARIAN VEGETATION	B	Stable
ECOSTATUS	C	

The main reasons for the PES are sedimentation (bank erosion), significantly reduced base flows and alien fish species.

39.5 SUITABILITY AS FUTURE BIOMONITORING SITE

Habitat at the site is moderate to good for biotic monitoring, although it may be influenced by backup from Gariep Dam. The sediment load from this catchment is naturally high, but is elevated due to clearing for cultivation on soils that are naturally easily erodible. As the main landuse around the Caledon River is characterised by extensive agriculture this site may be a good monitoring site to detect agricultural impacts in the river reach between the Welbedacht and Gariep dams.

40 EFR K7: LOWER KRAAI

The information is summarised from WFA (2010a;b).

40.1 SITE DESCRIPTION

The Kraai River is a tributary of the Orange River which flows near Barkley East in the Eastern Cape. The river originates to the south of Lesotho and flows westward, where it joins the Orange near Aliwal North. Agricultural intensity in the area has declined since the 1980's, with many of the slopes previously cultivated now being abandoned to pasture or grassland. For the purposes of the EFR study, the Kraai River was delineated into three MRUs. EFR K7 is situated in the lower reaches of the Kraai River in MRU C approximately 42 km from the Orange River confluence. The landuse in this reach is dominated by irrigation and dry land agriculture and aquaculture. The site is approximately 30 m wide, and riffles are cobble/gravel bed dominated. Grazing and trampling pressure is high on the LB. Flow sensitive habitats for fish (FS and FD) are very well represented at the site and overall habitat diversity at site very good with all flow-depth categories well represented although overhanging vegetation and undercut banks are absent in FS and FD habitats. Macroinvertebrate habitat is very good although aquatic vegetation and mud habitats are limited.

Location	EFR K7 Lower Kraai	**Altitude**	1327 m
Longitude	26.92055	**Latitude**	-30.83055
EcoRegion	Nama Karoo 26	**Quaternary catchment**	D31M
Water Management Area	Upper Orange	**Geomorphological zone**	Lowland Foothills

EFR K7, Lower Kraai River. Cobble/gravel bed dominated riffle.

40.2 PRESENT ECOLOGICAL STATE (PES)

Geom	The PES is close to reference condition and is only slightly modified from natural. Although base flows are slightly reduced the small farm dams and weirs upstream, and extensive agriculture in the catchment, have not had a measurable impact on the geomorphology at the site. High flows and floods are relatively unimpacted by the changes in the catchment, and the geomorphology at this site – dominated by larger cobble/gravel bed elements – is not sensitive to the small changes in base flows.
WQ	Salt levels as slightly elevated naturally. Some impacts from toxicants are expected due to farming-related pesticides and fertilizer use. Aluminium levels are high. The source of the aluminium shown in the Kraai data is unclear and the likely source of aluminium in the surface water is due to alum or aluminium sulphate used in most water treatment processes as a flocculating agent for suspended solids.
Fish	All the expected fish species are still present in this river reach albeit in a slightly reduced FROC. The primary changes responsible for deterioration in the fish assemblage include the loss of some FS and FD habitat as a result of flow modification, possibly slight deterioration in bottom substrate habitats related to some

	sedimentation and benthic algal growth, water quality deterioration (especially toxins and possibly nutrients). Some loss of marginal zone overhanging vegetation furthermore reducing cover for especially *B. anoplus*. The presence of the bottom feeding alien *C. carpio* contributes to bottom substrate disturbance while the potential presence of predatory alien species may further impact on indigenous fish. Presence of small migration barriers has a further contribution to the PES.
Inverts	2010 SASS5 score: 81 No of Taxa: 13 ASPT: 6.2 Key taxa expected but not observed included Heptageniidae, Dytiscidae, Hydracarina, Corixidae, Coenagrionidae, Oligochaeta and Ancylidae. Only two species of Baetidae were recorded, and only one species of hydropsychid caddisflies was recorded. The fauna was dominated by Chironomidae, which were very abundant (D abundance). Baetid mayflies were dominated by the highly tolerant *Baetis harrisoni,* and blackflies were dominated by the pest blackfly *Simulium damnosume)*. Sensitive taxa recorded included stoneflies (Perlidae) and Leptophlebiidae. The high abundance of Chironomidae indicates organic enrichment.
Rip veg	**Marginal zone:** Mostly open cobble/boulder and some alluvial deposits. *G. virgatum, S. mucronata* and *C. marginatus* are dominant species. **Lower zone:** Also mostly an open cobble bed, with low vegetation cover. Dominant species are the same as the marginal zone, together with *C. dactylon* and *Sporobolis spp.* **Upper zone:** Alluvial terraces and banks are dominated by woody vegetation, mainly *Salix (*both indigenous and exotic*), Lycium hirsutum (*endemic) and *P. australis.* Alien vegetation is present in all the zones – especially the upper zone.
Diatoms	Diatom results are based on samples taken during 2008 - 2010 at various sites situated in MRU C. From the range of samples assessed it is evident that organic pollution and elevated nutrient levels are problematic in this reach. Calcium-based salinity is present and it seems that the river is very turbid at times. The overall EC of this reach in terms of biological water quality is a C.

40.3 MAIN IMPACTS AT THE SITE

	PES	Causes	Sources	F/NF
WQ	B/C	Elevated nutrients and potential toxicant loads. Elevations in turbidity levels.	Agricultural activities.	NF
Geom	A/B	Slight increased sediment yields from catchment.	Cultivation has cleared some slopes. Change in flow.	F/NF
Rip Veg	C	Reduced indigenous cover on marginal and lower zone.	Reduced base flows.	F
		Reduced indigenous cover, abundance& species composition.	Exotic species.	NF
		Reduced recruitment.	Grazing and trampling pressure (right bank) and competition with exotic species.	
Fish	C	Decrease in FROC and abundance fish species with preference for fast habitats.	Slight decreased base flows.	F
		Deterioration of substrate habitat .	Bank erosion and some catchment erosion (sedimentation).	F/NF
		Decreased substrate quality related to increased benthic growth.	Increased nutrients and organics.	NF
		Decreased water quality.	High nutrients, organics and possibly toxins (aluminum) – agriculture.	
		Decreased species diversity and abundance (especially small species).	Presence of aggressive alien predatory species.	
		Increased turbidity and disturbed bottom substrates.	Presence of alien *C. carpio*.	
		Decreased overhanging vegetation as cover.	Increased bank erosion and alien vegetation.	
		reduced migration success (breeding, feeding and dispersal) of some species.	Barriers: Some small dams/weirs.	
Inverts	C	Zero flows.	Abstraction.	F
		Organic enrichment.	Irrigated agriculture.	NF

40.4 RESULTS: PRESENT ECOLOGICAL STATE

Driver Components	PES	Trend
GEOMORPHOLOGY	A/B	Stable
WATER QUALITY	B/C	Stable
DIATOMS	C	
Response Components	**PES**	**Trend**
FISH	C	Stable
MACRO INVERTEBRATES	C	Stable
INSTREAM	C	
RIPARIAN VEGETATION	C	Negative
ECOSTATUS	C	

Agricultural practices in the catchment seem to be the main impact in this reach leading to small driver changes which include decreased flows, zero flows, and increased nutrient levels. Alien fish and riparian vegetation species also impact on the site. Riparian vegetation has a negative trend due to increased growth of alien vegetation.

40.5 SUITABILITY AS FUTURE BIOMONITORING SITE

Habitat at the site is good for biotic monitoring. The presence of rare and unique riparian vegetation as well as the sensitivity of the habitat associated with a small and steep (gradient) river in the upper reaches, increases the ecological importance of this system. The river is also widely used for recreational activities such as river rafting and fly-fishing in the Rhodes area.

41 EFR O1: HOPETOWN (ORANGE RIVER)

The information is summarised from WFA (2010a;b).

41.1 SITE DESCRIPTION

EFR O1 is situated in the MRU B approximately 77 km upstream of the Vaal River confluence. The landuse in this reach is dominated by irrigation and influence by the hydro-electric operation from Vanderkloof Dam. The gross morphology is bedrock controlled, but the bed is primarily composed of mobile cobbles, gravels and sands. The site is within a relatively narrow gorge/valley. The morphology of the site is generally consistent with the reach; but the condition (especially of the banks and riparian vegetation) is in far better condition. The LB has more rocky habitats than the RB which is more alluvial. The site is atypical of the reach especially due to presence of rapids (FS and FD) over bedrock and secondary channels (therefore most probably higher habitat variability than most of reach). The reach most probably dominated by FD habitats. The site did however provide the best diversity of habitats (i.e. rapids, riffles, side channels, and pools in side channels) and therefore the highest possibility of sampling fish species present in this reach. Macroinvertebrate habitat is good at the site.

Location	EFR O1 Hopetown	**Altitude**	1060 m
Longitude	24.009270°	**Latitude**	-29.516°
EcoRegion	Nama Karoo 26	**Quaternary catchment**	D33G
Water Management Area	Upper Orange	**Geomorphological zone**	Lowland Foothills

EFR O1, Orange River. The banks and mid-channel bars are well-vegetated.

41.2 PRESENT ECOLOGICAL STATE (PES)

Geom	Present Day flows in this section are about half of the Mean Annual Runoff (MAR). A peaking hydro-power dam operates about 100km upstream of the site with twice-daily floods. Despite these daily floods, large flood sizes and frequencies are highly reduced; accounting for the increased area of bars and islands in the reach (observed over the historical record), and especially the progressive stabilisation of the sedimentary features by vegetation. Scouring events across these bars are too infrequent and small to keep sedimentary and vegetation encroachment in check. Although there are increased sediment loads from the upper catchment, much of this is trapped in the upstream dams, but tributaries and flushing of fines and suspended load through the dams compensates for some of the reduced sediment supply downstream. Additionally, large floods are reduced, so the reduced sediment is somewhat offset by a reduced frequency of large scour events. Moderate floods now occur as twice-daily flows due to peaking hydropower generation, and this has likely armoured sections of the channel, but may be responsible for the increased vegetation in the lower riparian zones due to more frequent wetting.
WQ	Salt concentrations are similar to reference condition, except for sulphate, sodium and chloride which show increases. Impacts from toxicants are expected due to farming-related pesticides and fertilizer use. Although biotic indicators suggest that a category C situation exists, instream dams have large impacts on water quality in terms of changing conditions from the reference state, particularly for temperature. Seasonal fluctuations have been severely impacted on, so that although that the overall present state for water quality seems

	acceptable, changes from the natural state have been severe. Elevated nutrients from farming impact on the water quality assessment. Aluminium levels are high, although this assessment is based on very limited data. The most likely source of aluminium in the surface water is due to alum or aluminium sulphate used in most water treatment processes as a flocculating agent for suspended solids, or aluminium loads carried in suspended solids. However, sediment loads are low due to the upstream dams. Temperature impacts due to the presence of instream dams are significant.
Fish	All the expected fish species should still be present in this river reach albeit in a moderately to highly reduced FROC. Species that are thought to have been impacted the most include L. umbratus, B. anoplus, *L. kimberleyensis* and Clarias gariepinus. The primary changes responsible for deterioration in the fish assemblage are primarily associated with altered hydrology/flow modifications related to fluctuating water releases for hydro-electric power generation. This results in loss of marginal vegetation as cover, flushing of substrates (critical impact during spawning of substrate breeders) and laying dry of marginal zone (especially significant during breeding season for vegetation spawners). The impacts of migration barriers on the natural movement of fish are furthermore expected to impact the fish assemblage negatively in this river reach. Other impacts are related to water quality deterioration (especially impacts from dams on temperature and oxygen, as well as presence of toxics). The presence of alien fish species (both predacious and habitat modifying) furthermore impact on the natural fish populations of this reach.
Inverts	2010 SASS5 score: 128 No of Taxa: 21 ASPT: 6.1 Key taxa expected but not observed were mainly taxa that prefer slow-flowing water, such as shrimps (Atyidae), Coroxidae, Notonectidae, Ceratopogonidae, and Lymnaeidae. The fauna was dominated by baetid mayflies. No other taxa were abundant. Leptophlebiid mayflies and gomphid dragonflies were less abundant than expected. A number of sensitive taxa were recorded, including Leptoceridae (Leptoceridae (Parasetodes and Oecetis sp), flat-headed mayflies (Heptageniidae) Tricoryhtidae and Leptophliidae.
Rip veg	**Marginal Zone:** Dominated by dense stands of *P. australis* with a distinct lack of woody marginal zone species such as *G. virgatum* and *S. mucronata*, although these species occur with very low abundance. The frequency of inundation disturbance is likely to prohibit recruitment of these species while reeds are able to withstand and even benefit. **Lower Zone:** The zone is frequently flooded, which is clearly shown by scour and also species composition. Marginal zone woody species are common in this zone, as well as many sedge and wetland species. Woody species have attained high densities and stature and have likely benefited from frequent wetting that is not extreme enough to be an impact as it is in the marginal zone. Upper zone and even terrestrial woody species (such as *A. karoo* and *Z. mucronata*) are also commonly recruiting in this zone, but seem to fail to reach full maturity (due to flooding disturbance). **Upper Zone:** Terrace or bar vegetation component is absent and represents the expected for the lower zone. **Macro Channel Bank**: Dominated by woody riparian and terrestrial savanna species with a mix of open areas that are either sandy or colonised by grasses.
Diatoms	Diatom results are based on samples taken during 2008 - 2010 at various sites situated in MRU B. The water entering Vanderkloof Dam was mainly impacted by agriculture as the diatoms indicated that the water was eutrophic and salinity levels were elevated. However, due to top releases, the biological water quality entering the Orange River from this dam was a B and these releases have a dilution effect on pollution impacts. Further downstream up to the confluence with the Vaal River impacts are attenuated by increased flows. The biological water quality is in a B condition with calcium based salinity and elevated nutrients being problematic at times in this reach. The results may be overestimated due to the size of the Orange River and the large flow volumes, which may have a dilution effect of pollution.

41.3 MAIN IMPACTS AT THE SITE

	PES	Causes	Sources	F/NF
WQ	D	Elevated nutrients and potential toxicant loads due to fertilizer and pesticide use.	Land-use is agricultural, resulting in some toxicant and nutrient loading expected, although data only reflects a small increase in salts and nutrients.	NF
		Temperature fluctuations result in a change in water quality category from a C to D category.	The location of the upstream dam and twice daily peaks in flow impact on temperature and levels.	F
Geom	C/D	Reduced frequency and size of large floods.	Large dams upstream trap big floods and reduce the magnitude and frequency downstream.	F
		Reduced sediment load.	Upstream dams trap sediment and reduce supply to downstream reaches. These impacts have been ameliorated somewhat by reduced flows, and flushing of suspended loads through the dams.	NF
		Peaking power generation – daily stage fluctuations	Daily stage fluctuations are reworking sediments in the marginal and lower riparian zones, and probably armouring the bed.	F
p ve	B/C	Increased reed cover in the marginal zone.	Reduced and regulated flows.	F

	PES	Causes	Sources	F/NF
		Increased woody cover and density especially on lower zone and mid-channel bars.	Bi-daily fluctuations and reduced moderate floods.	
		Altered species composition.	Small percentage of exotic annuals.	NF
Fish	C/D	Decreased overhanging vegetation as cover for fish resulted in decreased FROC of species with preference for these habitats. Loss of habitat (cover) also resulted in increased exposure to predators.	Continuous fluctuation in water levels due to hydro power releases. Increased bank erosion, flow modification and inundation. Farming: removal or change in riverine vegetation.	F
		Decrease in FROC and abundance of fish species with preference for fast habitats.	Loss in abundance and diversity of especially fast habitats as result of decreased base flows.	
		Reduced spawning success resulting in decreased FROC of many species.	Flushing away of eggs or laying dry of marginal zone breeding areas (rocky/cobbles and vegetated). Flow modification: Absence or lag effect on spring flushes, reduced habitat suitability and stimuli, modified flow pattern disrupt normal breeding cycle of fish species.	
		Decreased water quality affect species with requirement for good water quality.	Presence of toxins, altered temperature and oxygen due to dams and other human activities. Farming: water abstraction, reduced flows, pollutants. Farming - mineralization and eutrophication (fertilizers) due to irrigation run-off. Potential presence of pesticides and herbicide. Dams trapping silt altering water clarity, altered temperature and O_2 regimes.	NF
		Decreased species diversity and abundance as result of presence of predacious alien species (*M. salmiodes*) feeding on indigenous fish.	Presence of alien predatory species. Dams create further suitable habitat for undesirable species.	
		Bio-turbation from *C. carpio*. Increased turbidity and disturbed bottom substrates reduce bottom substrate quality and water quality for indigenous fish (especially impact on *L. umbratus* breeding habitats)	Presence of alien *C. carpio*. Dams create habitat for undesirable species.	
		Decreased abundance, and therefore FROC related to over utilization of fish resource for human consumption.	Poaching and over-fishing of fish using nets (gill and seine nets, often home-made).	
		Presence of migration barriers reduces migration success (breeding, feeding and dispersal) of some species.	Large dams and some weirs.	
Macroinvertebrates	C	Flow fluctuations (bi-daily).	Generation of peak demand hydro-powe.r	F
		Elevated low flows.	Discharges to meet demands for winter power generation and irrigation demands.	
		Increased photic depth.	Upstream impoundments trapping silt.	NF
		Altered water temperature (warmer winters, colder summers).	Thermal inertia of upstream impoundment.	
		Increased Phytoplankton.	Upstream impoundments.	
		Toxic algal blooms, such as *Microcystis.*	Annual overturn.	

41.4 RESULTS: PRESENT ECOLOGICAL STATE

Driver Components	PES	Trend
GEOMORPHOLOGY	C/D	Negative
WATER QUALITY	D	Stable
DIATOMS	B	
Response Components	**PES**	**Trend**
FISH	C/D	Stable
MACRO INVERTEBRATES	C	Stable
INSTREAM	C	
RIPARIAN VEGETATION	B/C	Stable
ECOSTATUS	C	

The major issues that have caused the change from reference conditions are the releases for hydropower, barrier effects of the dams, water quality problems and the destruction of and removal of vegetation on floodplains for agriculture. The dominant factor seems to be the hydro-electric releases. Geomorphology indicated a long term negative trend and this was due to sediment which is still moving through the system.

41.5 SUITABILITY AS FUTURE BIOMONITORING SITE

Habitat at the site is good for biotic monitoring. This site is situated well below Vanderkloof Dam and may be a suitable site for biomonitoring the impacts of irrigation and the influence of the hydro-electric operation in this reach. However it must be noted that this site is in a better condition than the rest of the reach.

42 CONCLUSIONS

The four EFR sites that have been assessed in the Lower Orange River (WFA, 2010), have provided additional information that can contribute to future monitoring programmes in the Orange River Basin. However these sites were selected on the basis of suitable habitat to determine flow requirements specifically. Therefore, these sites alone will not be adequate if included in a future monitoring programme to detect catchment based impacts.

42.1 CALEDON RIVER

42.1.1 MRU CALEDON A AND B: Source to Welbedacht Dam

Most of the area has Lesotho on the left bank (LB) with associated sedimentation problems due to erosion. On the right bank (RB), formal irrigation and dry land irrigation takes place. Many farm dams occur in the tributaries. Ficksburg and Maseru also impact negatively on the river, specifically MRU B.

EFR C5 is located in the upper reaches of the river bordering MRU A and B. The river upstream of EFR 5 (MRU A) is mostly inaccessible with the RB being the border of the Golden Gate Nature Reserve and the LB comprising inaccessible areas and typical subsistence farming and erosion associated with Lesotho. EFR 5 could be a valuable biomonitoring point as impacts are minimal in this area.

Three OSAEH sites are located in MRU B. OSAEH 15.1 is located approximately 50 km downstream of EFR C5 while OSAEH 11.20 is situated in the Leeuspruit, a tributary of the Caledon River. As OSAEH 15.1 and EFR C5 are relatively close to each other EFR C5 could be used in future monitoring programmes although the site is above the Klein Caledon confluence.

OSAEH 11.6 is situated below Maseru and is an important site in terms of detecting impacts from upstream Ficksburg and Maseru and should be included in future monitoring programmes. The Caledon River consists mainly of sand substratum and minimal marginal vegetation for assessment purposes.

42.1.2 MRU CALEDON C AND D: Welbedacht Dam to Orange River (Gariep Dam)

This river reach includes MRU C and D. The only water flowing down the river spills from the Welbedacht Dam, inflows from tributaries and compensation water releases. EFR C6 which is at the same location as OSAEH 26.8, is located in MRU D and is suitable because habitat at the site is moderate to good for biotic monitoring, although it may be influenced by inundation from Gariep Dam. The sediment load from this catchment is naturally high, but is elevated due to clearing for cultivation of soils that are naturally easily erodible. As the main land use around the Caledon River is characterised by extensive agriculture this site may be a good monitoring site to detect agricultural impacts in the river reach between the Welbedacht and Gariep Dams.

42.2 KRAAI RIVER

The upper reaches of the Kraai River (MRU Kraai A and B) is mostly inaccessible with the main land use being irrigation agriculture. The lower reach (MRU C) is impacted by extensive agriculture and irrigation. EFR K7 is located in this reach and is approximately 35 km upstream of OSAEH 26.11. Based on the data availability and level of analysis undertaken at EFR K7, this site is a preferred biomonitoring site.

42.3 ORANGE RIVER FROM LESOTHO BORDER TO VAAL RIVER CONFLUENCE

As there was only one site assessed in this reach of the Orange River as part of the EFR study, which is approximately 77 km from the Vaal River confluence, more biomonitoring sites would be needed in the Orange River main stem for future biological monitoring programmes.

OSAEH 11.22 is located in the upper reaches of the Upper Orange River approximately 65 km downstream of the Lesotho border. This site could be viable as a future monitoring site to detect impacts from Lesotho. From Google Earth imagery this site may be limited in terms of habitat availability to monitor the full suite of biotic components and access may be problematic.

OSAEH 26.13 and 26.14 are located downstream of Aliwal North. OSAEH 26.13 is located in the Stormbergspruit, a tributary of the Orange River, while OSAEH 26.14 is situated in the Orange River main stem approximately 40 km downstream of Aliwal North. According to DWAF (2009e), a new water quality site, OS3 – Saamwerk was proposed in the Orange River, as the Stormbergspruit spruit discharges poor quality water from Burgersdorp sewage works into the Orange River. The site is just downstream of a long, shallow weir and accessibility to the site is good. This proposed site is at the same location as OSAEH 26.14 and from Google Earth imagery habitat availability seems more than adequate to monitor the full suite of biotic components. Although the introduction of this site as a water quality biomonitoring site was not considered to be a high priority because the water quality in the Upper Orange is fairly stable and did not change significantly downstream in terms of monitoring biological impact (DWA, 2009e), this site could be important. A future monitoring programme could therefore exclude OSAEH 26.13 if OSAEH 26.14 is considered.

OSAEH 26.15 is located between Gariep and Vanderkloof Dams and OSAEH 26.12 in the Seekoei River which is a tributary of the Orange River just upstream of Vanderkloof Dam. These dams are migration barriers for fish and therefore impact this component, however these two sites are deemed less important as biological monitoring sites although water quality monitoring may be important. There is limited irrigation in this reach of the Orange River and flow regulation may hamper biological assessment.

EFR O1 is situated in the MRU Orange B approximately 77 km upstream of the Vaal River confluence and in the same location as OSAEH 26.2. The landuse in this reach is dominated by irrigation and EFR O1 could replace OSAEH 26.3 as a future biomonitoring site due to the comprehensive data collection and analysis at this site. A monitoring site will be very important in the lower reaches of the Upper Orange River as the hydro-electric releases from Vanderkloof Dam impact the lower reaches considerably along with other impacts that include barrier effects of the dams, water quality problems and the destruction of and removal of vegetation on floodplains for agriculture.

OSAEH 26.3 is situated in MRU Orange B, 20 km upstream of the Vaal River confluence and downstream of EFR O1. As OSAEH 26.2 is located in the same MRU as EFR O1 preference is given to the EFR site.

43 AREA 3: LOWER ORANGE CATCHMENT – FROM THE VAAL RIVER CONFLUENCE TO THE ORANGE RIVER MOUTH

43.1 BACKGROUND

The Lower Orange River can be defined as that stretch of the Orange River between the Orange-Vaal confluence and Alexander Bay or Oranjemund where the river meets the ocean (Figure 1.1). The area is hot and dry with rainfall varying from 400 mm in the east to 50 mm on the west coast and large parts of the catchment considered desert with annual precipitation dropping to below 25 mm in some areas. The major river systems that may contribute to flows in the Orange River include the Ongers and Sak rivers from the northern Karoo; the Kuruman and Molopo rivers from the Northern Cape Province, north of the Orange and the southern part of Botswana; and the Fish River from Namibia (ORASECOM, 2007).

Land-use is primarily irrigation and mining, with the area highly dependent on water from the Orange River. Sheep and goat farming is practised over most of the area, with large parts falling within conservation areas. Cultivation is restricted to isolated patches where somewhat higher rainfall occurs, and extensive irrigation is practised in the fertile alluvial soils along the Orange River valley. This irrigation is supplied with releases from the Vanderkloof Dam. Large mining operations occur in various parts areas. The water quality in the Lower Orange WMA is affected by upstream activities in the Vaal and Orange River catchments. Given the arid nature of the Lower Orange River and the high potential evaporation, the evaporative losses and irrigation return flows result in an increase in salt concentrations along the length of the lower Orange River (ORASECOM, 2007).

Figure 43.1 provides the locality of the EFR sites as well as the OSAEH sites that occur in the Orange River below the Vaal River confluence where the green pins represent the OSAEH monitoring sites, the red pins represent the EFR sites and yellow pins indicate the OSAEH sites sampled during November 2010. Section 44 to 48 summarises the results of the October 2010 assessment as well as a summary of the EWR results.

Eight OSAEH monitoring sites were identified in this area while three EFR sites were assessed during 2010 as part of the Environmental Flow Assessment (WFA, 2010a). During November 2010 two OSAEH sites were surveyed which coincided with planned PR events at Upington (OSAEH 26.17) and Sendlingsdrift (OSAEH 28.5). Site information is provided in Table 43.1.

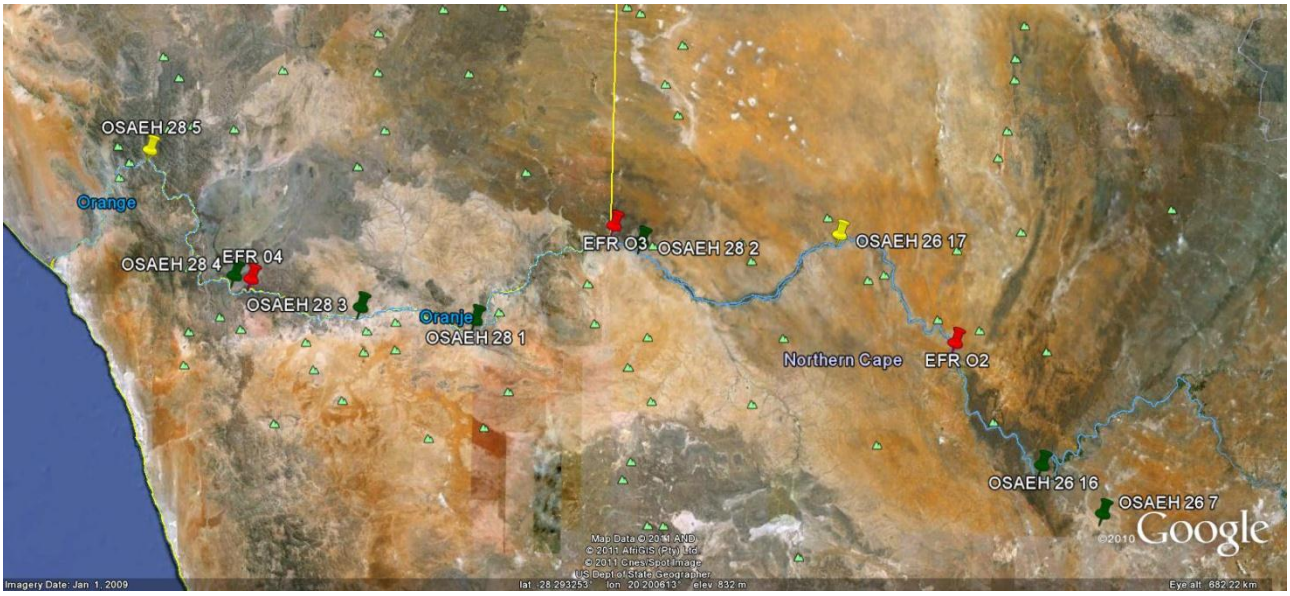

Figure 43.1 OSAEH monitoring and EFR sites located in the Orange River below the Vaal confluence (Google image, 2010)

Table 43.1 OSAEH monitoring and EFR site detail

Site	Monitoring type	Eco-Region	Major River	Latitude	Longitude	Site code
OSAEH_26_4	Monitoring Site P	26	Orange/Hartbees	-28.84095	20.6119	D5HARTCORAN
OSAEH_26_7	Monitoring Site P	26	Orange/Brak	-29.915	23.17031	D6BRAKCONFL
OSAEH_26_16	Monitoring Site P	26	Orange	-29.66075	22.75574	D7ORANPRIES
OSAEH_26_17	Monitoring Site P	26	Orange	-28.43861	21.40583	D7ORANGIFKL
OSAEH_28_1	Monitoring Site P	28	Orange	-28.96411	19.14531	D8ORANPELLA
OSAEH_28_2	Monitoring Site P	28	Orange	-28.51115	20.17482	D8ORANBLOUP
OSAEH_28_3	Ecological Reserve Site	28	Orange	-28.90205	18.42036	D8ORANABBAS
OSAEH_28_4	Ecological Reserve Site	28	Orange	-28.73645	17.61856	D8ORANVIOOL
OSAEH_28_5	Ecological Reserve Site	28	Orange	-28.04051	17.06967	D8ORANBOOMR
EFR O2	Ecological Reserve Site	28	Orange	-29.0055	22.16225	Boegoeberg
EFR O3	Ecological Reserve Site	28	Orange	-28.4287	19.9983	Augrabies
EFR O4	Ecological Reserve Site	28	Orange	-28.7553	17.71696	Vioolsdrif

44 EFR O2: BOEGOEBERG (ORANGE RIVER)

The information is summarised from WFA (2010a;b).

44.1 SITE DESCRIPTION

The site is situated below the Boegoeberg Dam and falls within MRU Orange D, RAU D1 which is delineated as the river reach below Boegoeberg Dam up to Augrabies Waterfall. The site falls within a reach that is less disturbed with no cultivation in the riparian zone and a canal is present on the left bank. This is a bedrock anastomosing reach, with well-vegetated bedrock core bars and islands between the distributary channels, and large bedrock riffle areas in the active channels. The macro-channel is approximately 400 – 500m wide with an average depth of 3 m. Flow sensitive habitats for fish (fast shallow (FS) and fast deep (FD)) are very well represented at site. High habitat diversity is present with various secondary canals.

Location	EFR O2 Boegoeberg	**Altitude**	871 m
Longitude	22.16225	**Latitude**	-29.0055
EcoRegion	Nama Karoo 26.05	**Quaternary catchment**	D73C
Water Management Area	Lower Orange River	**Geomorphological zone**	Lowland River

EFR O2, Lower Orange River. There is a high degree of physical habitat diversity associated with the numerous distributary channels at this site.

44.2 PRESENT ECOLOGICAL STATE (PES)

Geom	Although the flows are critically reduced at the site, this has been in some ways compensated for by the reduced sediment loads (since much is trapped in upstream dams). The site is generally not very sensitive to the impacts of base flow and small flood changes, nor to small changes in sediment load. The key issue for this site is the loss of large floods that scour and maintain the distributary channels and beds. The very large dams now in place in the upstream catchment will probably prevent any sufficiently large scour events to occur in future, and thus stabilisation and increasing vegetation on the lower banks and bars will occur in the future. There are some indications in the historical aerial photographs of slight encroachment of vegetation in to the channels.
WQ	Salt ions are not problematic although sulphate, sodium and chloride show increases from the reference condition (RC), particularly sulphate and chloride. Site is downstream from Boegoeberg dam and significant changes in temperature and oxygen is expected. Some toxicant levels are problematic.
Fish	All the expected fish species are still present in this river reach albeit in a slightly to moderately reduced FROC (*Labeo umbratus*, *Barbus anoplus* and *L. kimberleyensis*). Some loss of marginal zone overhanging vegetation due to altered hydrological regime also impact fish assemblage negatively. The negative impacts associated with the alien species – *Ctenopharyngodon idella*, *Gambusia affinis*, *Cyprinus carpio* – include: loss of vegetation and habitat, bio-turbation and habitat loss, water quality alteration, and predation on native fish eggs and larvae.
Inverts	2010 SASS5 score: 116 No of Taxa: 20 ASPT: 5.8 The most obvious change from natural has been outbreaks of pest blackflies (mainly *Simulium chutteri*) following impoundment. The bivalve *Corbicula fluminalis* was noticeably absent during the site-visit. This bivalve is particularly sensitive to elevated sediments, and its absence is probably associated with the periodic emptying of Boegoeberg Dam, which releases high concentrations of sediment. Other taxa that were expected but not observed included Heptageniidae, Ecnomidae, Hirudinea, Sisyridae, Corixidae and Ceratopogonidae. The most sensitive taxa recorded at the site were Atyidae, Tricorythidae and Leptophlebiidae. Elevated nutrients lead to excessive growth of epilithic algae, particularly during low-flow periods, and this reduces the suitability of substrates for colonisation of benthic invertebrates. The chironomid *Cardiocladius africana* thrive under these conditions. Monthly data on aquatic invertebrates were collected at Gifkloof, near Upington, between 1991 and 1996. These data provide a reliable indication of the key ecological drivers that affect the diversity and abundance of benthic macroinvertebrates in the middle and lower Orange River.
Rip veg	**Marginal Zone:** Cobble and bedrock areas have a vibrant population of *Gomphostigma virgatum*. Other dominants however are *Salix mucronata, Phragmites australis, Cyperus marginatus, Persecaria decipiens, P. lapathifolia* and *Cynodon dactylon.* **Lower Zone:** Well wooded in places with *G. virgatum*, and *S. mucronata* mainly, but also with *Acacia karoo* recruits. Areas which are open (mainly cobble/boulder) or dominated by non-woody vegetation (*P. australis, Crinum bulbispermum, C. marginatus, Persecaria* and *C. dactylon* mainly) make up the mosaic. **Upper Zone:** The right bank (RB) has extensive open areas (cobble or boulder) with *Tamarix usneoides* mainly. Otherwise the zone is predominantly woody with common species on both banks but the left bank (LB) mainly being *T. usneoides, Accacia karoo, Rhus pendulina, Ziziphus mucronata. Diospyros lycioides, Lycium hirsutum A. erioloba, Prosopis glandulosa*, and *Prosopis velutina*). A single specimen of *Combretum erythrophyllum* was found. Macro Channel Bank: similar to upper zone, but without the cobble/boulder beds Floodplain: Similar to Macro Channel Bank, with terrestrial species and dominated by woody thickets.
Diatoms	Diatom results are based on samples taken during 2005, 2008 – 2010 at various sites situated in the reach from Boegoeberg Dam to Augrabies. The biological water quality fluctuated between a B and C EC during 2005, 2008 – 2009, and 2010. It is evident that there is a gradual deterioration within the reach from Boegoeberg Dam to Augrabies. Nutrient levels are elevated throughout the reach and agriculture seems to be the major impact in this reach. Chloride concentrations were problematic during July 2005 in this reach. Although elevated at times organic pollution does not seem to be a major problem in this reach. Nutrients were elevated for all sampling years indicating continuous impact, while salinity may be problematic at times. The Ecological Category (EC) for this reach which is delineated as Management Resource Unit D is a B/C.

44.3 MAIN IMPACTS AT THE SITE

	PES	Causes	Sources	F[1]/NF[2]
WQ	C	Elevated nutrients and potential toxicant loads due to fertilizer and pesticide use.	Agriculture, resulting in some toxicant and nutrient loading expected.	NF
Geom	C	Reduced frequency and size of large floods.	Large dams.	F
		Reduced sediment load.	Although upstream dams have reduced the sediment load, annual flushing of the upstream dam reintroduces some sediments.	
Rip veg	B	Increased vegetation cover.	Reduced base flows especially in summer and reduced moderate and large floods.	F
		Altered species composition.	Small percentage of perennial exotic species.	NF

	PES	Causes	Sources	F[1]/NF[2]
Fish	C	Decreased overhanging vegetation as cover for fish result in decreased Frequency of Occurrence (FROC) of species with preference for these habitats. Loss of habitat (cover) also results in increased exposure to predators.	Increased bank erosion, flow modification and inundation. Farming: removal or change in riverine vegetation.	F NF
		Decrease in FROC and abundance of fish species with preference for fast habitats.	Decreased base flows.	F
		Decreased water quality.	Presence of toxics, agriculture, dams trapping silt altering water clarity, stratification in dams.	NF
		Decreased species diversity and abundance.	Presence of alien predatory species (GAFF) feeding on indigenous fish eggs and larvae.	
		Increased turbidity and disturbed bottom substrates reduce bottom substrate quality and water quality for indigenous fish (especially impact on LUMB breeding habitats).	Presence of alien CCAR which cause bio-turbation. Dams create habitat for undesirable species.	
		Decreased native species diversity and abundance as result of presence of alien species.	Alien species will have negative impact on native species – Clarias gariepinus (CCAR) – bio-turbation; GAFF - predation on eggs and fry; CIDE - loss of aquatic vegetation and habitat.	NF
		Decreased abundance, and therefore FROC related to over utilization for human consumption.	Poaching and over-fishing of fish using nets (gill and seine nets, often home-made).	
		Reduced spawning success resulting in decreased FROC of many species.	Flow modification: Absence of spring flushes, reduced habitat suitability and stimuli, flow pattern disrupts normal breeding cycle.	F
		Presence of migration barriers reduces migration success (breeding, feeding and dispersal) of some species.	Some dams/weirs (incl. Boegoeberg Dam).	NF
Macroinvertebrates	C	Elevated low flows.	Discharges to meet demands for winter power generation and irrigation demands.	F
		Water quality deterioration	Agricultural return flows.	
		Aseasonal releases.	Operation of Vanderkloof Dam.	
		Pesticides.	Blackfly Control Programme.	NF/F
		Elevated sediment.	Periodic emptying of Boegoeberg Dam for maintenance, usually during winter (i.e. low flow).	NF
		Toxic algal blooms, such as *Microcystis.*	Annual overturn of vanderkloof Dam, plus inputs from Harts River (Spitzkop Dam).	

1 Flow related 2 Non Flow related

44.4 RESULTS: PRESENT ECOLOGICAL STATE

Driver Components	PES	Trend
GEOMORPHOLOGY	C	Stable
WATER QUALITY	C	Stable
DIATOMS	B/C	
Response Components	**PES**	**Trend**
FISH	C	Stable
MACRO INVERTEBRATES	C	Stable
INSTREAM	C	
RIPARIAN VEGETATION	B	Stable
ECOSTATUS	C	

The main reasons for the PES is a loss of frequency of large floods, agricultural return flows, higher low flows than natural in the dry season, drought and dry periods, decreased low flows at other times, release of sediment, presence of alien fish species and the barrier effects of dams.

44.5 SUITABILITY AS FUTURE BIOMONITORING SITE

Habitat at the site is very good for biotic monitoring. The site represents the delineated reach and is in a better state than the majority of the reach especially as agricultural clearing is high in the reach. The site is downstream of Boegoeberg Dam and is suitable for detecting impacts relating to an altered hydrological regime which seems to be the biggest problem in this reach. Elevated flows may be problematic and therefore gauge records should be checked when planning routine monitoring.

45 OSAEH 26.17: GIFKLOOF (ORANGE RIVER)

45.1.1 Site description

The site is situated approximately 0.4 km downstream of Gifkloof Weir and falls within MRU D as delineated in WFA (2010a). The river has a wide river valley, with low-energy fluvial environment. Sediment banks are present, mainly colonized by *Phragmites*. Although the surrounding environment consists of undulating, rocky hills, the river bank is situated on a steep slope with patches where terraces have formed. The riparian vegetation formed a thicket, with the exotic, *Prosopis glandulosa* var. *glandulosa* as the most prominent species present. Various habitat types were available at the site namely stones in current (rapids and riffles), marginal vegetation and a limited area of gravel and sand. The macro-channel width was >50 - 100 m and the active channel and surface water width was 20 – 50 m. The substratum in the river was mostly bedrock, boulders, cobbles and pebbles with limited sand and gravel.

Location	Gifkloof	**Altitude**	804 m
Longitude	21° 24.046	**Latitude**	28° 26.240
EcoRegion	Nama Karoo 26.05	**Quaternary catchment**	D73E
Water Management Area	Lower Orange River	**Geomorphological zone**	Lowland River

Rapids and Riffles at OSAEH 26.17, Lower Orange River

Marginal vegetation at OSAEH 26.17, Lower Orange River

45.2 SAMPLING CONDITIONS

A DWA technician at the Gifkloof weir said that the water level was lower than normal for this time of the year. The river bank (just above the waterline) was covered with cobbles, boulders and pebbles and as a result of this very little gravel/sand/mud was found along the banks. Flow at the site varied from low (0.06 m/s) to very high (1.14 m/s) in the rapid riffle section and low (0.03 m/s) to moderate (0.35 m/s) in the marginal vegetation.

45.3 PRESENT ECOLOGICAL STATE

IIHI	Changes in hydrology due to large dams (Gariep and Vanderkloof) in Upper Orange River as well as various weirs upstream, modification of the riverbank and deteriorating water quality due to irrigation return flow to the river.
RIHI	Heavy infestation of alien vegetation (Mesquite or Suidwesdoring – *Prosopis*) and a change in hydrology leading to associated changes in riparian vegetation.
Fish	The reference conditions set for the FROC-site, D7ORAN-GIFKL (Kleynhans *et al*., 2007), was used as a starting point for setting reference conditions for the present site. Seven of the eleven expected fish species were sampled. The majority of the expected fish species are still present although the FROC of some species have been reduced from reference conditions. A decrease in the FROC of three species strongly associated with overhanging vegetation, namely *Barbus paludinosus*, *Pseudocrenilabrus philander* and *Tilapia sparrmanii*, was also observed. It is not clear why this is, but the strong flow and the low abundance of overhanging and instream vegetation cover could partly explain this. Of the two IUCN Red Data listed endemic species expected to occur in the middle Orange River, *L. kimberleyensis* ("near threathened") and *A. sclateri* ("least concern"), only the latter species has been recorded. The other two, *L. umbratus* and *B. anoplus*, were not recorded in the middle Orange River. Although *C. carpio* is known to be present in this part of the river, albeit in low numbers (Benade, 1993), *C. idella* and *G. affinis* have been recorded for the first time.
Inverts	Nov 2010: SASS5 score: 134 No of Taxa: 22 ASPT: 6.1 Key taxa expected but not observed were generally those that prefer no to low flow and vegetation namely Gerridae, Hydrometridae, Nepidae and Protoneuridae. Flow at the site even in the vegetation was mostly moderate to high. Very few areas of low to no flow were present at the site. Prosopistomatidae that prefer very high flow and cobbles were also not sampled. This family is difficult to sample and also relatively scarce so their absence in the sample could be due to sampling error. The abundance of most macroinvertebrates at the site was as expected.
Rip veg	**Marginal Zone:** This zone can be described as a narrow band on the bank of the river, with *Cynodon dactylon,* and *Phragmites australis* patches. The most dominant tree was *Salix mucronata.* **Lower Zone:** This zone was characterized by shrubs, *Diospyros lyciodes,* and *Prosopis grandulosa*, an aggressive invasive tree, as well as a clump of *Equisetum ramosissimum* (Perdestert) and *Psilocaulon coriarium*, the only succulent in this zone. The most dominant grass was *Stipagrostis uniplumis.* **Upper Zone:** The most dominant trees in the upper zone were: *Prosopis grandulosa, Ziziphus mucronata, Acacia karoo, A. mellifera, Searcia pendulina* and *Tamarix usneoides.* It is important to note that most dominant species was *Prosopis grandulosa*, the rest of the trees were individuals occurring on the site. Grasses that occurred were: *Stipagrostis uniplunis, Aristida ciliata* and *Brachiaria eruciformis*, with *Stipagrostis* being the most dominant. No annuals were noted. The rainy season has not started by the time the site visit was conducted. Crops are planted on the edge of the riparian zone, increasing the erosion potential and the amount of pesticides that will enter the river.
Diatoms	As this site falls within MRU D the EC for the reach is a B/C. See discussion under EFR O2.

45.4 MAIN IMPACTS AT THE SITE

	PES	Causes	Sources	F[1]/NF[2]
Rip veg	D	Altered species composition.	Exotic vegetation, especially in the upper and lower zones.	NF
		Bank erosion.	Cultivation farming.	
Fish	B/C	Change in seasonality of the flow regime could influence spawning reproduction (of e.g. *L. kimberleyensis*).	River regulation has leveled out seasonal differences in the total annual flow and changed character of seasonal floods. Increased flow in the dry season and practically eliminated periods of flow intermittence.	F
		Changes in the natural structure of fish community due to increased flow during dry season.		
		Temperature regime altered downstream of dam and weirs.	Presence of Boegoeberg Dam and a number of other weirs.	
		Presence of migration barriers reduces migration success (breeding, feeding and dispersal) of some species.		
Inverts	B	Decreased flows during wet season and increased dry season flow as well as a change in the seasonality (winter and summer flows are not as distinct as before dams were built upstream).	Dams and weirs upstream.	F
		Loss of habitat due to decrease in flow.		
		Water quality and associated benthic growth.	Agriculture. Increase in nutrients as result of irrigation.	NF

45.5 BASELINE SURVEY RESULTS: PRESENT ECOLOGICAL STATE

Driver Components	PES	Trend
IHI: INSTREAM	C	
IHI: RIPARIAN	C/D	
DIATOMS (WQ)	B/C	
Response Components	**PES**	**Trend**
FISH	B/C	Stable
MACRO INVERTEBRATES	B	Stable
INSTREAM	B/C	
RIPARIAN VEGETATION	D	Negative
ECOSTATUS	C	

45.6 SITE SUITABILITY

Habitat at the site is moderate to good for SASS sampling although the biotope availability according to the SASS5 template (attached as appendix) indicates a poor (D) category. Habitat was restricted at the time of sampling as a result of lower flow than normal for November (DWA official (*pers. comm.).* Depending on flow at time of sampling most biotopes and flow types would be present. Marginal habitat is restricted mostly to reeds and very little grass. No aquatic vegetation was present at time of sampling. Gravel/sand and mud are available during normal flow. A number of fish were missed during electro-shocking in the fast flowing deeper habitats (FD) due to the strong flow present at the time of sampling and this could be a constraint that should be considered for future monitoring programmes. A very clear distinction can be made between the riparian zone and the terrestrial zone although there is a high occurrence of exotic species.

Access to site is good – permission has to be obtained from Stanley at 054 334 0067 and a DWA official has to accompany you to site.

46 EFR O3: AUGRABIES (ORANGE RIVER)

The information is summarised from WFA (2010a;b).

46.1 SITE DESCRIPTION

The site is situated at Blouputs and falls within MRU E which is delineated as the river reach from Augrabies Waterfall up to Vioolsdrift weir. This reach is less disturbed with no cultivation in the riparian zone and a canal is present on the left bank. This is a bedrock anastomosing reach, with well-vegetated bedrock core bars and islands between the distributary channels, and large bedrock riffle areas in the active channels. Flow sensitive habitats for fish (FS and FD) are very well represented at site. Moderate habitat diversity is present with various secondary canals. The loss of the floodplains to agriculture removed a very important component of the riparian habitat. Alluvial floodplain channels and associated vegetation) is presented in the upper and lower riparian zone.

Location	EFR O3 Augrabies	**Altitude**	425
Longitude	19.9983	**Latitude**	-28.4287
EcoRegion	Orange River Gorge 28.01	**Quaternary catchment**	D81B
Water Management Area	Lower Orange River	**Geomorphological zone**	Lowland River

EFR O3, Lower Orange River. Large cobble bars and small fines deposits are present.

46.2 PRESENT ECOLOGICAL STATE

Geom	Critically reduced flows at the site constrain channel maintenance. However, despite the lower flows, the PES is ameliorated by concomitant declines in sediment loads (since much is trapped in upstream dams), although some sediment replenishment occurs from tributary inputs. The site has some bedrock control and therefore is not very sensitive to the impacts of base flow and small flood changes. Cobbles, boulders and gravels in the channel and along the margins are generally not embedded, although they are slightly armoured. This suggests that scouring of the bed is occurring frequently enough that the bed is remaining mobile.
WQ	Salt concentrations are similar for the PES, except for sulphate, sodium and chloride which show increases from the RC, particularly sulphate and chloride. Little impact is expected on temperature and oxygen, although temperature less variable than natural. Impacts from toxicants are expected due to intensive farming-related pesticides and fertilizer use. There is some indication of elevated nutrient levels throughout the reach; probably due to intensive agricultural activities in the area. The presence of toxic algae has been reported in the Lower Orange River passing Upington. Toxics from herbicide and pesticide use are also expected. Data collected from WMS and that collected by the diatom component do not support the reported intermittent high concentrations of some metals, i.e. Al, Cd, Cu and Pb, in the Upington and Neusberg weir area. Temperature levels are probably less variable than under natural conditions, as the system was naturally more variable than at present (despite the system now being more manipulated).
Fish	All the expected fish species are still present in this river reach albeit in a slight to moderately reduced FROC.

	The species that are thought to have been impacted the most are *Barbus hospes*, *L. umbratus*, *Labeobarbus aeneus*, *L. kimberleyensis*, *Labeo capensis*, *B. paludinosus*, *P. philander* and *T. Sparrmanii.* The primary changes responsible for deterioration in the fish assemblage are primarily associated with altered hydrology/flow modifications (due to large dams and flow regulation), causing habitat deterioration and loss; and water quality alterations. Other impacts are related to water quality deterioration, some loss of marginal zone overhanging vegetation which may also be associated with the fluctuating flows and altered hydrological regime. The presence of alien and introduced indigenous fish species (trans-located *Oreochromis mossambicus*) furthermore have a potential negative impact on the fish assemblage of this river reach (in terms of competition for habitat, feeding, and predation pressure).
Inverts	2010 SASS5 score: 135 No of Taxa: 20 ASPT: 6.8 Taxa that were abundant during the site-visit included the mayflies *Tricorythus discolor* and *Baetis glaucus*, and the blackfly *S. chutteri*. The most obvious change from natural has been outbreaks of pest blackflies (mainly *S. chutteri)* following impoundment. The site experienced a flood of 700 m^3/s six weeks before the site visit. The threatened blackfly *S. gariepense* was recorded during the site visit, reflecting the post-flood conditions suitable for this species. The invertebrate fauna at this site is similar to that expected at EFR O2, so the description presented under Section 44. is applicable to this site.
Rip veg	**Marginal Zone:** Sparse cover, with recent flood scour observed. LB mostly open *C. dactylon* and *C. marginatus*. Cobble areas have a vibrant population of *G. virgatum*. Other dominants are *S. mucronata* and *P. australis* and features well on RB, but have almost completely been removed on LB by high grazing pressure. *C. dactylon* also shows evidence of grazing and form lawns where it occurs. **Lower Zone:** LB dominated by open cobble with *T. usneoides*. RB is mainly reed dominated (*P. australis*) alluvium with *S. mucronata*. **Upper Zone:** LB has extensive open areas (cobble or alluvium) as a result of grazing and physical removal, with vegetation mainly comprised of riparian thickets (common species are *T. usneoides*, *A. karoo, R. pendulina, Z. mucronata. D. lycioides, Euclea pseudobenus, Lycium bosciifolium, A. erioloba, M. linearis, Prsopis glandulosa, P. velutina*). RB mainly reeds as lower, but also with open bedrock areas and a cobble/alluvium mixed ephemeral channel. Annual and bi-annual exotic species are abundant. Macro channel bank: Same as upper zone, with *Schotia affra* on the RB. Floodplain: Only occurs on LB and has been removed and transformed into agricultural land for grapes and vegetables.
Diatoms	Diatom results are based on samples taken during 2005, 2008 – 2010 at various sites situated in the reach delineated as MRU E. During July 2005 chloride concentrations were problematic. Although elevated at times organic pollution does not seem to be a major problem in this reach, although during 2009 organic pollution increased drastically at Pella. Nutrients were elevated for all sampling years (except at OR 21 during 2005) indicating continuous impact, while salinity may be problematic at times. The EC for this reach is a C.

46.3 MAIN IMPACTS AT THE SITE

	PES	Causes	Sources	F[1]/NF[2]
WQ	C	Elevated nutrients and potential toxicant loads due to fertilizer and pesticide use from agricultural activities.	Agricultural activities.	NF
		Less variability in temperatures than under the natural state.	Operation for irrigation and other users.	F
Geom	C	Reduced sediment loads.	Large dams upstream trap sediment loads, but this is in some ways ameliorated by tributary inputs downstream of the dams. The impact of reduced sediment is also ameliorated by the concomitant reduction of floods.	NF
Rip Veg	B/C	Altered species composition and loss of indigenous riparian cover.	Invasions of alien vegetation.	NF
		Increased reed density.	Frequent fires (unnatural).	
		Altered non-woody vegetation structure (forming of lawns) and increased cover.	High grazing pressure, especially LB.	
		Increased reed and other non-woody cover in marginal and lower zones.	Reduced base flows, especially in the wet season. Reduced small and moderate floods.	F
Fish	C	Decreased overhanging vegetation as cover.	Erosion, change in flow, agriculture.	F/NF
		Decrease in FROC and abundance of fish species with preference for fast habitats.	Decreased base flows.	F
		Decreased water quality affect species with requirement for high water quality.	Presence of toxics, farming, changes hydrology, dams trapping silt.	NF
		Decreased FROC of species with preference for substrate as preferred cover and habitat for spawning, feeding etc.	Increased algal growth on substrates (increased nutrients from farming).	F/NF

	PES	Causes	Sources	F[1]/NF[2]
		Decreased species diversity and abundance.	Presence of alien predatory species.	
		Increased turbidity and disturbed bottom substrates (impact on *L. umbratus* breeding habitats)	Presence of alien C. carpio.	NF
		Decreased abundance and FROC of detritus feeders (esp. *L. umbratus*)	Competition by introduced indigenous (*O. mossambicus*).	
		Decreased abundance, and therefore FROC.	Poaching and over-fishing using nets (gill and seine nets, often home-made).	
		Reduced spawning success resulting in decreased FROC of many species.	Flow modification: Absence or lag effect of spring flushes.	F
		Reduced migration success (breeding, feeding and dispersal) of some species.	Some small dams/weirs.	NF
Macroinvertebrates	C	Elevated low flows.	Discharges to meet demands for winter power generation and irrigation demands.	F
		Water quality deterioration.	Agricultural return flows.	
		Aseasonal releases.	Operation of Vanderkloof Dam.	
		Toxic algal blooms, such as *Microcystis.*	Annual overturn of Vanderkloof Dam plus inputs from Harts River (Spitzkop Dam) as well as Upington, WWTW and agro-chemicals.	NF
		Pesticides.	Blackfly Control Programme.	NF/F

46.4 RESULTS: PRESENT ECOLOGICAL STATE

Driver Components	PES	Trend
GEOMORPHOLOGY	C	Stable
WATER QUALITY	C	Stable
DIATOMS	C	
Response Components	**PES**	**Trend**
FISH	C	Stable
MACRO INVERTEBRATES	C	Stable
INSTREAM	C	
RIPARIAN VEGETATION	B/C	Negative
ECOSTATUS	C	

The main reasons for the PES are decreased frequency of large floods as well as agricultural return flows, agricultural activities and associated water quality impacts. Higher low flows than natural in the dry season, drought and dry periods occurs while decreased low flows occur at other times. The presence of alien fish species, alien vegetation and barrier effects of dams as well as decreased sedimentation impact this site. The site has a high degree of physical disturbance (vegetation removal, grazing, trampling and lighting fires) which has already and will continue to promote pioneer species, especially exotic riparian species such as *Prosopis gladulosa*. *P. glandulosa* recruitment was extensive at the site, and cover of perennial exotics will increase over

time. If the structure of the riparian zone is altered, this will change the habitat from a patch mosaic to dense woodland, uncommon for these areas.

46.5 SUITABILITY AS FUTURE BIOMONITORING SITE

Habitat at the site is good for biotic monitoring. The site represents the delineated reach (MRU E) and is less disturbed than the rest of the MRU, with no cultivation in the riparian zone and a canal is present on the left bank. The site is downstream of Augrabies Waterfall and is suitable for detecting impacts relating to an altered hydrological regime and agricultural activities, which seems to be the biggest problem in this reach. It is also an important transboundary site, situated just upstream of the border with Namibia.

47 EFR O4: VIOOLSDRIF (ORANGE RIVER)

The information is summarised from WFA (2010a;b).

47.1 SITE DESCRIPTION

The site is situated below Vioolsdrift weir and falls within MRU F which is delineated as the river reach from Vioolsdrift weir to the Fish River confluence. The site is bedrock dominated with rapid and riffle sections. There is some bedrock exposed at the site, but angular boulders, cobbles and sands are present. The LB is completely artificial to facilitate a canal and road. Flow sensitive habitats for fish (FS and FD) well represented at the site. There is low diversity of habitats for macroinvertebrates especially stones-out-of-current and mud while marginal vegetation habitats were moderate and instream aquatic vegetation was present.

Location	EFR O4 Vioolsdrif	**Altitude**	167 m
Longitude	17.71696	**Latitude**	-28.7553
EcoRegion	Orange River Gorge 28.01	**Quaternary catchment**	D82F
Water Management Area	Lower Orange River	**Geomorphological zone**	Lowland River

EFR O4, Lower Orange River. There is a mix of cobbles, gravels and fine sediment deposits within the bedrock-controlled reach.

47.2 PRESENT ECOLOGICAL STATE (PES)

Geom	The reduced sediment loads (since much is trapped in upstream dams) is being increasingly replenished by tributary inputs. The critically reduced flows at the site and lack of moderate and large floods continue to constrain channel and habitat maintenance. The key issue for this site is the loss of floods that scour and maintain the channel bed and bars.
WQ	PES data show significant elevations for all ions as compared to the natural state. Impacts on temperature and oxygen is expected due to the extreme reductions of flow for large parts of the year, although now more similar to natural. Impacts from toxicants are expected due to farming activities and large abstractions. References suggest mining impacts There is an increase in electrical conductivity from Prieska to Vioolsdrift along the reaches of the lower Orange River. This is due to a cumulative effect of irrigation return flows (although limited agriculture in the immediate area) and evaporative losses along the river. The last significant volume of water is abstracted and return flows form the bulk of the flow in the river during dry periods. Elevations in nutrient levels are also evidence of this trend. The concentration of some metals was reported to be intermittently high at Pella and Vioolsdrift – some evidence of these elevations was seen, although data is very limited. A health incident (blisters and skin rashes after rafting in the Orange River) and fish kills were reported in the Richtersveld (De Hoop camp and Grasdrif respectively) upstream of EFR O4 during April 2008, with an

	additional fish kill incident in May 2008. Causes are unknown although fish kills might be related to seasonal temperature changes and human skin conditions due to toxic blue-green algae or *Schistosome cercarial*. The latter is also known as swimmer's itch, duck itch or cercarial dermatitis. It is a short-term, immune reaction occurring in the skin of humans that have been infected by water-borne schistosomatidae.
Fish	All the expected fish species are still present in this river reach albeit in a moderately reduced FROC. The species that are thought to have been impacted the most (due to the catchment changes) are *B. hospes*, *L. umbratus*, *A. sclateri*, *L. aeneus*, and *L. kimberleyensis*.
Inverts	2010 SASS5 score: 147 No of Taxa: 24 ASPT: 6.1 The only taxon that was abundant during the site visit was the blackfly *S. chutteri*. Empty shells of freshwater limpets (*Burnupia* sp) and bivalves (Unionidae) were found. Instream conditions at these sites are much the same as found further upstream at EFR O2 and EFR O3, except that water temperatures are significantly warmer, so life-cycles of invertebrates are faster. Outbreaks of pest blackflies (mainly *S. chutteri)*. The most obvious change from natural has been outbreaks of pest blackflies (mainly *S. chutteri)* following flow regulation. The site experienced a flood of 700 m^3/s six weeks before the site visit. The threatened blackfly *S. gariepense* was recorded as an empty pupal case during the site-visit, reflecting the post-flood conditions suitable for this species.
Rip veg	**Marginal Zone:** Mostly open bedrock with some alluvium. *P. australis*, *S. mucronata* and *G. virgatum* are dominants. **Lower Zone:** Predominantly reeds (*P. australis*) or open unconsolidated alluvium with some woody vegetation. Both *A. karoo* and *Prosopis glandulosa* are recruiting. **Upper Zone:** Open alluvia or dominated by woody vegetation. Extensive mortality of *P. glandulosa* due to recent flooding. **Macro channel bank:** Dominated by woody vegetation. RB is artificial with boulder rubble, road and canal. LB vegetation with distinct browse line except for *P. glandulosa*. Extensive *P. glandulosa* recruitment. The site has a high degree of physical disturbance (vegetation removal, grazing and trampling) which has already and will continue to promote pioneer species, especially exotic riparian species such as *Prosopis glandulosa* and other perennial and annual species. The site has a high abundance of invasive weeds on the LB and extreme overutilization on the RB. The change in riparian structure due to the exotic riparian influx will impact adversely on the riverine fauna assemblage.
Diatoms	Diatom results are based on samples taken during 2005, 2008 – 2010 at various sites situated in MRU F which is delineated as the river reach from Vioolsdrift weir to the Fish River confluence. The biological water quality of this reach is a C EC. Elevated nutrient levels are of concern as well as salinity. Although still to be verified the presence of *Coscinodiscus devius* indicates that salinity levels have increased drastically since 2009 and is of major concern.

47.3 MAIN IMPACTS AT THE SITE

	PES	Causes	Sources	F/NF
WQ	C/D	Toxicant levels elevated, possibly from upstream pesticide use (agriculture) and mining activities.	Results in increased toxicant levels.	NF
		Lower flows cause elevated temperatures and drops in oxygen levels.	Abstractions are fewer in this area but evaporation concentrates salts.	F
Geom	C	Reduced sediment loads due to loss of floods.	Upstream dams.	NF
Riparian vegetation	C	Altered species composition and loss of indigenous vegetation cover.	Exotic vegetation invasion.	NF
		Reduced non-woody cover and absence of woody recruitment.	Intense grazing and trampling pressure, especially on RB.	
		Reduced riparian woody cover and abundance.	Physical disturbance and removal, especially due to road and canal construction and maintenance (LB).	
		Increased reed and non-woody riparian vegetation cover in the marginal and lower zones.	Reduced base flows and floods.	F
Fish	C	Decreased overhanging vegetation as cover.	Erosion, change in flow, agriculture.	F/NF
		Decreased FROC of species with preference for substrate as preferred cover and habitat for spawning, feeding etc.	Increased algal growth on substrates (increased nutrients from farming)	
		Decrease in FROC and abundance of fish species with preference for fast habitats.	Decreased base flows.	F
		Reduced spawning success resulting in decreased FROC of many species.	Flow modification: Absence or lag effect of spring flushes.	

	PES	Causes	Sources	F/NF
		Decreased water quality affect species with requirement for high water quality.	Presence of toxics, farming, changes hydrology, dams trapping sit.	
		Decreased species diversity and abundance.	Presence of alien predatory species.	
		Increased turbidity and disturbed bottom substrates (impact on *L. umbratus* breeding habitats).	Presence of alien *C. carpio*.	NF
		Decreased abundance and FROC of detritus feeders (esp. *L. umbratus*).	Competition by introduced indigenous *O. mossambicus*).	
		Decreased abundance, and therefore FROC.	.Poaching and over-fishing using nets (gill and seine nets, often home-made).	
		Reduced migration success (breeding, feeding and dispersal) of some species.	Some small dams/weirs.	NF
Macroinvertebrates	C	Elevated low flows.	Discharges to meet demands for winter power generation and irrigation demands.	F
		Water quality deterioration.	Agricultural return flows.	
		Aseasonal releases.	Operation of Vanderkloof Dam.	
		Toxic algal blooms, such as *Microcystis.*	Annual overturn of Vanderkloof Dam plus inputs from Harts River (Spitzkop Dam).	NF
		Deteriorate marginal habitat for waders.	Loss of floods (dams) and lack of zero flows.	F

47.4 RESULTS: PRESENT ECOLOGICAL STATE

Driver Components	PES	Trend
GEOMORPHOLOGY	C	Stable
WATER QUALITY	C/D	Stable
DIATOMS	C	
Response Components	**PES**	**Trend**
FISH	C	Stable
MACRO INVERTEBRATES	C	Stable
INSTREAM	C	
RIPARIAN VEGETATION	C	Negative
ECOSTATUS	C	

The main reasons for the PES are decreased frequency of large floods. Agricultural return flows and mining activities are impacting on water. Higher low flows than natural in the dry season, drought and dry periods occurs while decreased low flows occur at other times. The presence of alien fish species and barrier effects of dams impact on fish. There is decreased sedimentation due to a lack of large floods and upstream dams.

47.5 SUITABILITY AS A FUTURE BIOMONITORING SITE

Habitat at the site is moderate for macroinvertebrates while fish habitats are well represented. There is a high occurrence of alien vegetation species and the river banks are modified. However, there is good data availability for this site and is adequate as a biomonitoring site.

48 OSAEH 28.5: SENDELINGSDRIFT (ORANGE RIVER)

48.1 SITE DESCRIPTION

The site is situated approximately 130 km downstream of Vioolsdrif Weir in the lower section of the Orange River (downstream of Augrabies Falls to the estuary) where the river flows through the Orange River Gorge EcoRegion. The site is located on the river's mainstem, at the exact point where it is joined by the south flowing Boom River. The Boom River was however dry at the time of sampling, and no pools or other surface water were evident. The river flows in a wide valley, with low-energy fluvial environment, and big boulders and rocks in the main channel. Sediment banks are present, mainly colonized by *Phragmites*. These islands are habitat to many bird species.

Location	Sendlingsdrif	**Altitude**	54 m
Longitude	17° 4.400	**Latitude**	28° 2.062
EcoRegion	Orange River Gorge 28.01	**Quaternary catchment**	D82K
Water Management Area	Lower Orange River	**Geomorphological zone**	Lowland River


Rapids and Riffles at OSAEH 28.5, Lower Orange River


Marginal vegetation at OSAEH 28.5, Lower Orange River

48.2 SAMPLING CONDITIONS

The site, at the time of sampling, was dominated by riffles and rapids with slower-flowing habitat occurring upstream and downstream of these. The macro-channel width was >100 m and the active channel and surface water width was 50 – 100 m. Various habitat types were available for macroinvertebrates at the site namely stones in current (rapids and riffles, marginal vegetation and gravel, sand and mud. The substratum was mostly bedrock, boulders, cobbles and pebbles and gravel, limited sand and mud. Some stones (especially those in areas of lower flow) were covered with a thickish layer of diatoms and sediment. Flow at the site varied from low (0.03 m/s) to very high (0.85 m/s) in the rapid riffle section and low (0.1 m/s) to high (0.63 m/s) in the marginal

vegetation. A small area of aquatic vegetation was present with a flow of 0.1 m/s (low). Flow in gravel/sand/mud biotope varied from 0.1 m/s (low) to 0.24 m/s (moderate).

48.3 PRESENT ECOLOGICAL STATE

IIHI	Changes in bank and bed due to influence of irrigation upstream as well as change in hydrology and sediment load as a result of large dams (Gariep and Vanderkloof) in Upper Orange River and various weirs upstream.
RIHI	The main impact being added nutrients from irrigation upstream leading to increased growth of reeds etc. as well as change in hydrology affecting plant growth on banks. Some trampling (probably wildlife) was also seen at site.
Fish	The reference conditions set for the FROC-site, D8ORAN-SENDE (Kleynhans *et al*., 2007), was used as a starting point for setting reference conditions for the present site. All eleven expected fish species were sampled of which three species are red data species. The majority of the expected fish species are still present although the FROC of some species have been reduced from reference conditions. The reference FROC of species preferring fast flow and substrate cover remained the same while A slight decrease in the reference FROC was however recorded for the majority of species associated with slower flowing habitats and overhanging vegetation cover. Habitats hosting overhanging and instream vegetation cover aree however rare at the site and could to an extent explain the reduction in FROC for not only *M. brevianalis*, but also for *B. paludinosus* and *P. philander*. One exotic, *Cyprinus carpio*, and two introduced species, *Oreochromis mossambicus* and *T. rendalli* are known to occur between Vioolsdrif and the mouth and of these, *C. carpio* and *O. mossambicus* have been recorded during the recent surveys. Although very few *C. carpio* individuals were recorded, *O. mossambicus* were found to be widely distributed and more abundant. Concern has been expressed that this species is becoming increasingly more widespread and abundant in the lower Orange River.
Inverts	Nov 2010: SASS5 score: 150 No of Taxa: 26 ASPT: 6.3 Key taxa expected but not observed were generally those that prefer no to low flow and vegetation or water column namely Belostomatidae, Corixidae, Culicidae, Gerridae, Hydrophilidae, Hydroptilidae and Planorbinae. Flow at the site even in the vegetation was mostly moderate to high. Very few areas of low to no flow were present at the site. Aeshnidae that prefer any flow and cobbles or vegetation was also not sampled. This could be due to sampling error. The abundance of most macroinvertebrates at the site was as expected.
Rip veg	**Marginal zone:** Was dominated by *Cynodon dactylon* and *Salix mucronata.* **Lower zone:** Characterized by an increase in the abundance and cover of trees. The most dominant trees on this zone were: *Salix mucronata, Tamarix usneoides, Acacia karoo and Ziziphus mucronata.* The most abundant grass was *Cynodon dactylon*, with a few individual plants of *Gomphocarpus fruticosus.* **Upper zone:** Most of the annuals were dead, but some were blooming. However, it was eminent from the dead plants, that the non-woody cover was good. The rainy season had not started by the time the site visit was conducted. On the edge between the upper and terrestrial zone, *Lycium horridum, Sisyndite spartea* and *Euclea sedibens* occurred. There was also a difference in the structure of *Tamarix usneoides*, as the distance increased from the river. The trees became smaller and their leaf colour also became more dull green. This could be explained by a possible decrease in soil moisture content, as the distance from the river increases.
Diatoms	Diatom results are based on samples taken during 2005, 2008 – 2010 at various sites situated in the reach below MRU F. The EC for this reach is a C. Nutrient levels are elevated at times with slight levels of pollution.

48.4 MAIN IMPACTS AT THE SITE

	PES	Causes	Sources	F/NF
Rip veg	B	Decrease in cover.	Animal grazing and trampling..	NF
		Increased sedge and reed cover.	Flow regulation and reduced flooding disturbance facilitates an increase in reed and sedge cover and density in the marginal and lower zone.	F
Fish	B/C	Loss of habitat (decreased SD and SS) diversity as a result of flow modification (especially during natural low flow periods).	River regulation has leveled out seasonal differences in the total annual flow and removed periods of intermittence in the lower Orange. Natural cessations of flow removed by regulation.	F
		Change in seasonality of the flow regime could influence spawning reproduction as well as natural community structures.		
		Decreased substrate quality related to increased benthic growth.	Return flows from irrigated agricultural areas.	
		Increased turbidity and disturbed bottom substrates.	Presence of bottom feeding alien CCAR.	
		Presence of migration barriers reduces migration success (breeding, feeding and dispersal) of some species.	The weir at Vioolsdrif, as well as the new gauging weir under construction nearby Sendelingsdrif. According to an official from Namibia, a fish ladder is to be built to allow fish migration.	

	PES	Causes	Sources	F/NF
		Decrease in the condition of species moderately intolerant to modified water quality (e.g. BKIM).	Return flows from irrigated lands downstream of Vioolsdrif to the river. The introduced OMOS is becoming increasingly more widespread and more abundant in the lower Orange.	
		Decrease in species diversity and abundance as a result of competition between TSPA, PPHI and OMOS.		
Inverts	B/C	Decreased flows during wet season and increased dry season flow as well as a change in the seasonality (winter and summer flows are not as distinct as before dams were built upstream).	Dams and weirs upstream.	F
		Loss of habitat due to decrease in flow.		
		Water quality and associated benthic growth.	Agriculture. Increase in nutrients as result of irrigation.	NF

48.5 BASELINE SURVEY RESULTS: PRESENT ECOLOGICAL STATE

Driver Components	PES	Trend
IHI: INSTREAM	**C**	
IHI: RIPARIAN	**C**	
DIATOMS (WQ)	**C**	
Response Components	**PES**	**Trend**
FISH	**B/C**	**Negative (B/C)**
MACRO INVERTEBRATES	**B/C**	**Negative (B/C)**
INSTREAM	**B/C**	
RIPARIAN VEGETATION	**B**	**Stable**
ECOSTATUS	**B/C**	

48.6 SUITABILITY AS A FUTURE BIOMONITORING SITE

Habitat at the site is good for SASS sampling and the biotope availability according to the SASS5 template indicates a good (B) category. All habitat and flow types were present at site. Marginal vegetation was however restricted (only small area available) as most of the bank was either mud or cobbles and pebbles. The riparian zones could be distinguished easily and all fish depth classes were available and could be sampled.

Access to site is easy – site is accessed from the Namibian side in the Ai Ais Richtersveld Transfrontier Park. Turn off from road at the Boom tributary and drive in dry river bed to site. If the Boom River is flowing access is still possible from the gravel road travelling from Noordoewer to Rosh Pinah.

49 CONCLUSIONS

Nine OSAEH sites were identified as possible monitoring sites while three EFR sites occur within the Lower Orange WMA that was assessed as part of the EFR Reserve study, undertaken by Water for Africa during 2010. Two OSAEH sites were assessed during October 2010. The thee EFR sites that were assessed, have provided additional information that can contribute to future monitoring programmes in the Orange River Basin. The main impacts in the different Lower Orange MRUs and system operation is summarised from WFA (2010a, b) in the following sections.

49.1 ORANGE RIVER

49.1.1 MRU Orange B: Downstream of Vanderkloof Dam to Prieska

This reach is dominated by releases for hydropower, abstractions and return flows.

OSAEH 26.16 is located at Prieska. The water level fluctuation is less significant at Prieska and irrigation decreases downstream of the town. Sampling is very difficult due to the elevated flows and this site is not recommended as a monitoring site.

OSAEH 26.7 is located in the Brak River which enters the Orange River approximately 10 km upstream of Prieska. As the region is arid, most tributaries are dry for long periods and this site would therefore not be viable as a monitoring site.

49.1.2 MRU ORANGE D: Downstream of Boegoeberg Dam up to Augrabies Waterfall

From Boegoeberg Dam to Upington a canal system exists, and there is extensive irrigation for crops such as grapes.

EFR O2 falls within this reach in Resource Assessment Unit D.1. EFR 2 is less disturbed than the rest of the reach and no farming occurs in the riparian zone. The site is downstream of Boegoeberg Dam and is suitable for detecting impacts relating to an altered hydrological regime which seems to be the biggest problem in this reach. Elevated flows may be problematic and therefore gauge records should be checked when planning routine monitoring.

OSAEH 26.17 occurs further downstream of EFR O2 just upstream of Upington. This is a multi-channel section of the Orange River. The river reach below EFR O2 is characterised by irrigation, levees in the riparian zone and weirs. This site is suitable for sampling the full suite of biotic components.

Based on the data availability and level of analysis undertaken at EFR O2, this site is a preferred biomonitoring site.

49.1.3 MRU ORANGE E: Downstream of Augrabies Falls to Vioolsdrift

Irrigation is limited in the upper section of the MRU and constrained by accessibility. Irrigation occurs again at Onseepkans. EFR O3 is at the same location as OSAEH 28.2 and is less disturbed than the rest of the MRU, with no cultivation in the riparian zone and a canal is present on the left bank. EFR O2 is situated at Blouputs, downstream of Augrabies Waterfall and is suitable for detecting impacts relating to an altered hydrological regime and agricultural activities, which seems to be the biggest problem in this reach.

OSAEH 28.1 and 28.3 is located in a section of MRU E where there is very little to no irrigation. Therefore these sites are not priority biomonitoring sites.

49.1.4 MRU ORANGE F: Vioolsdrift weir to Fish River Confluence

There are extensive canals and irrigation in the floodplain zones on the left bank in this reach. The reach also falls within a section of National Parks (both banks and wilderness areas). EFR O4 and OSAEH 28.4 is at the same location and occurs in a section of MRU F that falls within National Parks boundaries and wilderness areas. There is no access from the left bank after Piece of Paradise, and therefore the site is in a better condition than the rest of the reach. This site is suitable for biomonitoring.

49.1.5 Orange River below MRU F

OSAEH 28.5 is situated approximately 130 km downstream of Vioolsdrift Weir at Sendelingsdrift, in the lower section of the Orange River and is the furthest downstream site on the river. The site is located on the river's mainstem, at the exact point where it is joined by the south flowing Boom River and is suitable for biomonitoring.

The three EFR sites that have been assessed in the Lower Orange River (WFA, 2010), has provided additional information that can contribute to future monitoring programmes in the Orange River Basin.

The proposed monitoring sites that were sampled during November 2010 as part of this study have the potential to be included as future monitoring sites as OSAEH 26.17 is located at Upington between EFR O2 and O3 while OSAEH 28.5 is located at Sendlingsdrift which would be the furthest monitoring point.

The five monitoring points should be adequate to monitor aquatic ecosystem health in the Lower Orange River. However OSAEH 26.16 at Prieska should be investigated further as a potential monitoring site as this is the only site identified in the upper reaches of the Lower Orange River.

50 AREA 4: SENQU RIVER – FROM THE ORIGINS OF THE SENQU TO THE SOUTH AFRICAN BORDER

50.1 BACKGROUND

The Lesotho Highlands Development Authority's (LHDA) Instream Flow Requirements (IFR) Policy was approved by the Lesotho Highlands Water Commission (LHWC) on 13 December, 2002. The purpose of the IFR Policy is to provide for the management of flow releases for the maintenance of predetermined conditions for riverine ecosystems downstream of Phase 1 impoundments and for the mitigation of, and compensation for, flow related impacts on resources and communities in downstream areas. The implementation of the IFR Policy is guided by the IFR Procedures which were approved on 30 July 2003 (LHDA, 2008).

An IFR monitoring programme was developed as part of the IFR Policy to determine the effects of particular management strategies or policies, and the response of systems to changes in the wider environment especially the rivers downstream of the LHWP dams which are subject to modified flow regimes.

According to LHWP (2010)[6], the goals of IFR monitoring are:

- To assess the efficacy of the recommended instream flow requirements (IFR) allocated for the lower Senqunyane, lower Malibamats'o, lower Matsoku and Senqu rivers.
- To verify that compensation to affected communities is being effective.
- The objectives of monitoring are:
- To establish whether or not the agreed IFR flows are being released;
- To determine whether the objectives linked to different components of the flow regime are being achieved, e.g., if small floods are maintaining wetbank vegetation;
- To verify that the overall environmental objective, that is, targeted river condition, is being achieved;
- To augment river condition data with incidental information that would assist with recognising potential problems in the study rivers;
- To assess the standard of living of the population at risk such that changes in livelihoods and welfare due to the project can be detected;
- To use this information to guide management interventions as necessary

50.2 MONITORING SITES

Initially 10 IFR sites were selected for IFR monitoring (LHDA, 2002) and are described in Table 50.1 while their location is provided in Figure 50.1.

Table 50.1 IFR monitoring sites in Lesotho

Site	Description	Coordinates	
		Latitude	Longitude
IFR Site 1	On the Matsoku River near the village of Seshote, representing the Matsoku River from the site of the proposed Matsoku Weir to the confluence with the Malibamats'o River (IFR Reach 1). Same location as OSAEH 15.1	29˚15'21"	28˚33'51"
IFR Site 2	On the Malibamats'o River downstream of the Katse Bridge representing, the Malibamats'o River from Katse Bridge to the confluence with the Matsoku River (IFR Reach 2).	29˚21'08"	28˚31'32"
IFR Site 3	On the Malibamats'o River at Paray, representing the Malibamats'o River from the confluence with the Matsoku River to the confluence with the Senqu River (IFR Reach 3).	29˚29'52"	28˚39'04"

[6] IFR Procedures - 3 Biophysical [http://www.lhwp.org.ls/downloads/default.htm]

IFR Site 4	On the Senqu River at Sehonghong, representing the Senqu River from the confluence with the Malibamats'o River to the confluence with the Tsoelike River (IFR Reach 4).	29˚44'20"	28˚45'19"
IFR Site 5	On the Senqu River at Whitehills, representing the Senqu River from the confluence with the Tsoelike River to the confluence with the Senqunyane River (IFR Reach 5). Same location as OSAEH 15.3.	30˚03'56"	28˚24'28"
IFR Site 6	On the Senqu River at Seaka Bridge, representing the Senqu River from the confluence with the Senqunyane River to the Lesotho/South Africa border (IFR Reach 6).	30˚21'48"	28˚11'30"
IFR Site 7	On the Senqunyane River at Marakabei, representing the Senqunyane River from the site of the proposed Mohale Dam to the confluence with the Lesobeng River (IFR Reach 7).	29˚32'09"	28˚09'15"
IFR Site 8	On the Senqunyane River upstream of the confluence with the Senqu River, representing the Senqunyane River from the confluence with the Lesobeng River to the confluence with the Senqu River (IFR Reach 8).	30˚02'11"	28˚13'21"
IFR Site 9	Matsoku River upstream of the headwaters of Matsoku Weir – reference for IFR Site 1.		
IFR Site 10	Senqu River downstream of Mokhotlong – reference for IFR Sites 2, 3 and 7.		

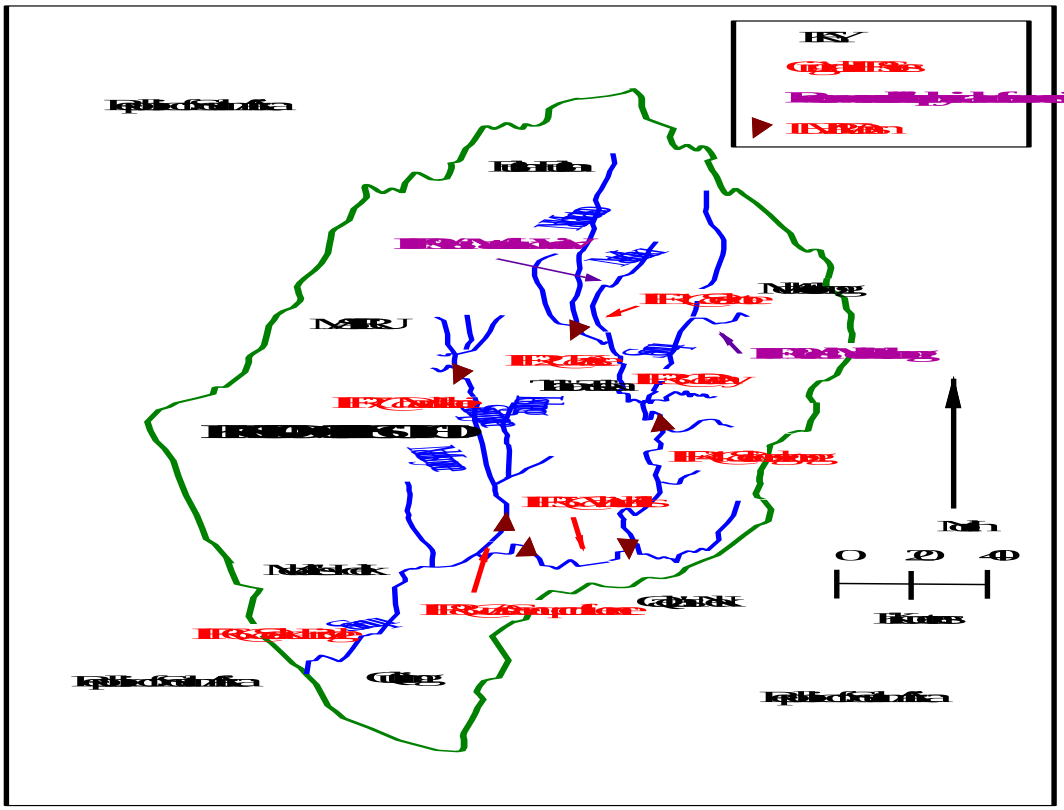

Figure 50.1 Localities of IFR sites within Lesotho (LHDA, 2002)

Long term monitoring (over the Project lifetime) is guided by the approved IFR policy, and the performance of LHDA in implementing the IFR has been undertaken on an annual basis since 2002 (LHDA, 2010).

During 2005 the LHDA commissioned contract 1237 and the main objectives were to focus on training and building capacity within LHDA, while also ensuring that the data collection and analytical tasks incorporated in the monitoring programme were meeting the goals and objectives set out in the IFR Policy and Procedures (LHDA, 2006).

The sites sampled on the preliminary data collection trip, during 2005, consisted of eight of the ten IFR sites recommended in LHDA 648. They included IFR Sites 1, 2, 3, 4, 5, 6, 7 and 9. IFR 8 was dropped from the monitoring programme due to difficulties with obtaining accurate hydrological data and difficulties in access. IFR 10, which was originally designated as a possible control site,

was not included in the IFR Monitoring Programme because of the long travel time to the site, and the fact that IFR 9 was ultimately a better control site for IFR Sites 1, 2 and 7 (LHDA, 2006).

50.3 FUTURE MONITORING

The current monitoring programme applied in Lesotho does not follow the same approach as routine monitoring undertaken during this study. Within the LHDA monitoring programme, the river condition classification is based on a set of key indicators or qualitative descriptors of the state of the riverine ecosystem and ranges from pristine, natural conditions through to a point where the system is transformed to be 'non-functional'. The attainment of these target river condition classes has been used as a Key Performance Indicator (KPI) in the assessment of the implementation of the IFR Policy and Procedures. A number of other KPIs have also been used which reflect the requirements of the biophysical monitoring for each of the biophysical parameters (fish, geomorphology, vegetation, water quality and macro-invertebrates) as set out in Policy and Procedures (LHDA, 2008).

Although sampling methods may be similar as those used within the EcoClassification approach, the set of response assessment indices used in the EcoClassification process is not applied in the LHDA monitoring programme, but rather KPI, and target river condition classes. As an example, current SASS monitoring in Lesotho does not conform to the SASS protocol (LHDA, 2008). This makes it very difficult to use the data for other projects, in this case OSAEH monitoring. It is therefore recommended that OSAEH monitoring as conducted during the current study not be applied in Lesotho, as there is a current monitoring programme that has been designed specifically for the river systems occurring within Lesotho. However the results of the LHDA monitoring programme could be incorporated in future OSAEH monitoring designs.

A qualitative analysis of the macroinvertebrate monitoring data collected so far has been included in Technical Report 2 by Dr Eliot Taylor[7]. It must however be noted that the analysis is of low confidence.

[7] Principal Consultant and Team Leader, Water Resources Investment Strategy. WS ATKINS International Ltd.

51 FISH RIVER, NAMIBIA

The potential of a monitoring site in the Fish River was investigated as part of this study. The current proposed monitoring site, OSAEH 26.18 is located approximately 2.5 km upstream of Seeheim in Namibia. The assessment of this site was not included in the current study, but a literature review was conducted of previous work done in the area to ascertain whether this site or any other site would be suitable for future monitoring.

51.1 BACKGROUND

Knight Piésold (Pty) Ltd was appointed by the Namibian Ministry of Agriculture, Water and Forestry (MAWF) to conduct an Environmental and Social Impact Assessment (ESIA) for the proposed Neckartal Dam development. This forms part of the MAWF feasibility study of the proposed Neckartal Dam and associated irrigation development, in the middle reaches of the Fish River, west of Keetmanshoop, in southern Namibia. Nepid Consultants undertook a specialist study of the aquatic ecosystem as part of the ESIA to determine the potential impacts of the proposed development on aquatic ecosystems. The report was based on a review of available data and initial scoping, field surveys undertaken in August 2009 and April 2010, and liaison with key people. The report provides baseline information, assesses potential impacts, and recommends mitigation measures, where appropriate. The selected sites are in close proximity to the OSAEH site and based on the possible future developments, these sites could potentially be good sites to be included in future monitoring programmes. Therefore the following sections provided a summary of the results of the aquatic assessment undertaken by Nepid Consultants (Nepid Consultants, 2010).

51.2 STUDY SITES

Three sites were identified during the study of which two sites (B1 and B2) were located in the Fish River downstream of the proposed development, and one in the Löwen River (B3), immediately downstream of Naute Dam. The details of the sites are provided in Table 51.1 and the position of the sites within the study area relative to OSAEH 26.18 is shown in Figure 51.1. OSAEH 26.18 is located approximately 2.2 km upstream of Site B2. The selection of sampling sites was based on the diversity of instream habitats, accessibility, and position relative to potential impacts.

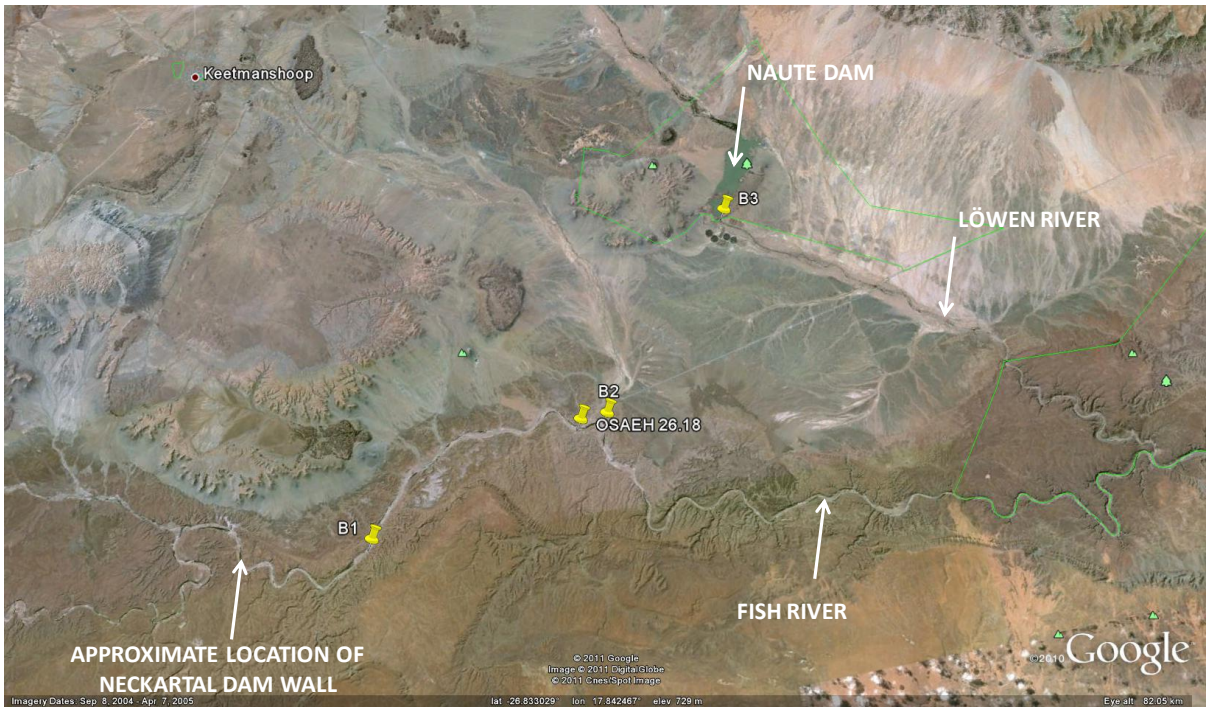

Figure 51.1 Site location relative to OSAEH 26.18

Table 51.1 Site detail

Site	Description	River	Coordinates	
			Latitude	Longitude
B1	Impact site, 0.4 km downstream of Neckartal Dam	Fish	S26.64631	E17.72846
B2	Impact site, 26 km downstream of dam site at Seeheim	Fish	S26.82215	E17.79040
B3	Löwen River, 0.4 km downstream of Naute Dam	Löwen	S26.93255	E17.93481

Fish River at Site B1, 0.4 km downstream of the proposed Neckartal Dam site in August 2009.

Fish River at Site B1, 0.4 km downstream of the proposed Neckartal Dam site in February 2010

Fish River at Seeheim (Site B2) in August 2009.	Fish River at Seeheim (Site B2) in February 2010.
	
Löwen River, immediately downstream of Naute Dam (Site B3), in February 2010.	**Löwen River, 14.5 km downstream of Naute Dam, in February 2010.**

51.3 BASELINE ASSESSMENTS UNDERTAKEN DURING 2009 AND 2010

During the 2009 and 2010 baseline assessment undertaken by Nepid Consultants, data was collected on *in situ* water quality, phytoplankton, fish, macroinvertebrates and diatoms. Sampling methods and results of the biotic components, fish, macroinvertebrates and diatoms are summarised below according to Nepid Consultants (2010).

51.4 METHODS

51.4.1 Fish

Fish were sampled at B1-B3 during August 2009 and February 2010, using a portable, battery operated electro-fisher (Samus 725M). This equipment allowed unrestricted access to shallow areas, and was effective in collecting small to medium sized fish. The comparative abundance of each species caught at each site was expressed as the total number that would have been caught had sampling been conducted for one hour (i.e. Catch per Unit Effort). Specimens that were not needed for verification of identity were returned. The results were expressed as a percentage of the total number of fish caught. Selected specimens were sent to the South African Institute for Aquatic Biodiversity for DNA analysis.

51.4.2 Macroinvertebrates

Benthic aquatic macroinvertebrates were collected according to the Namibian Scoring System Version 2 (NASS2), where sufficient instream habitats were available (Palmer and Taylor, 2004). The NASS2 is based on the South African Scoring System version 5 (SASS5), which was developed as a rapid method of assessing the ecological health of perennial rivers and streams (Dickens and Graham, 2002). The method can be applied to seasonal systems, but with caution only. In August 2009 the flows in the Fish River were such that the method could be applied at Site B1 only. During February 2010 the flows were slightly higher, and the method could be applied at Sites B1 and B2.

Where instream habitats were unsuitable for the application of NASS2, macroinvertebrates were collected and identified, and results interpreted qualitatively only.

The macroinvertebrates found at a site often reflect the diversity and quality of habitats available, so the interpretation of biomonitoring data is enhanced by recording the quality of habitats sampled. In this study the quality of each habitat sampled was assessed in terms of the suitability for aquatic invertebrates using a simple, five-point scale (1=very poor, and 5=highly suitable). Each habitat category was assigned weighted importance value that varied according to the geomorphological stream type. The weighted values were multiplied by the suitability rating (0 - 5),

and the results were expressed as a percentage, where 100% = all habitats highly suitable. The percentage values were converted to a category (A to F), to allow easy comparison among sites or sampling events.

51.4.3 Diatoms

Benthic diatoms were sampled at B1-B3 during August 2009 and February 2010. Sampling methods and data analysis protocols were the same as used during the current study.

51.5 RESULTS

51.5.1 Fish

Fifteen species of fish have been recorded in the Fish River Catchment, of which seven species are indigenous, one exotic and several hybrids are known to occur near the proposed dam (Table 51.2). Five species, excluding hybrids, were recorded during baseline surveys (Table 51.2). The most common species recorded was the Orange River labeo (*Labeo capensis)*, followed by the Straightfin barb (*Barbus paludinosus)* and Mozambique tilapia (*Oreochromis mossambicus)* (Table 51.2). Species that occur in the area but not recorded during this study were larger species that need deeper waters. The main flow-depth category present at the sampling sites during this study was Slow-Shallow, so the absence of larger species is not considered significant.

Table 51.2 List of fish species expected and recorded near the proposed Neckartal Dam, and the percentage of total catch recorded at three sites in August 2009 and February 2010

Scientific name	Common name	B1		B2		B3	
		Aug 09	Feb 10	Aug 09	Feb 10	Aug 09	Feb 10
*Labeo capensis**	Orange River labeo	30	12	93	31	53	27
Labeo capensis X *L. umbratus*	Labeo hybrid	-	-	-	-	*	33
Barbus paludinosus	Straightfin barb	3	15	6	31	27	38
Oreochromis mossambicus	Mozambique tilapia	59	48	1	33	15	2
Clarias gariepinus	Sharptooth catfish	9	25	-	3	5	-
Labeobarbus aeneus	Smallmouth yellowfish	-	-	-	2	-	-
Labeobarbus kimberleyensis	Largemouth yellowfish	-	-	-	-	-	-
Labeo umbratus	Moggel	-	-	-	-	-	-
Total number		**80**	**101**	**166**	**100**	**60**	**100**
Sampling effort (Min)		**26**	**25**	**10**	**20**	**26**	**15**
Catch per Unit Effort		**185**	**242**	**996**	**300**	**138**	**400**
Number of species		**4**	**4**	**3**	**5**	**4**	**4**

Labeo capensis plus *Labeo capensis* X *L. Umbratus*, and/or undescribed species

A notable feature of the fish fauna in the area is the naturally low number of species. The low diversity is attributed to the seasonal nature of the Fish River. All species recorded in the study area are capable of surviving in remaining pools during periods of no flow.

Hybridisation

Hybridisation among the *Labeo* and *Labeobarbus* species from the Fish River has been documented, and this makes correct identification of some specimens problematic. Specimens collected during this study indicate two distinct *Labeos* in the Löwen River, but both key out to *L. capensis*. The differences do not appear to be associated with hybridisation, so there is a potentially undescribed species of fish in the system. The specimens from fast river currents are deeper bodied than fish caught in impoundments, and differences in pigmentation may also be related to environment. Samples have been sent to the South African Institute for Aquatic Biodiversity for DNA analysis, but the results were not available at the time of writing this report.

Conservation Status

The following species of fish from the Fish River are of conservation interest:

- **Largemouth yellowfish (*Labeobarbus cf kimberleyensis)*.** This is the only species of fish in the area that is listed in the IUCN Red data book, and is listed as *Near Threatened*. This species is uncommon in the area, as the habitats are not suited to this species.
- **Namaqua barb (*Barbus hospes)*.** This species is endemic to the lower Orange and Fish Rivers, and is listed as *Least Concern* in the IUCN red data list. This species does not occur within the project area, but is found further downstream, within the Fish River Canyon.
- **Moggel (*Labeo umbratus)*.** This species is endemic to Orange-Vaal system, although distributed elsewhere.
- **Orange River Labeo (*Labeo cf capensis*).** The presence of two distinct forms of this species in the Löwen River is of conservation interest, and warrants further investigation.

Supersaturation

The field survey in August 2009 noted a major kill of *Labeo cf capensis* in the Löwen River downstream of Naute Dam. The fish kill is probably attributed to oxygen supersaturation in the plunge-pool immediately downstream of Naute Dam during a spillage earlier in the season. Oxygen supersaturation creates symptoms similar to "the bends", and can be lethal to fish. The phenomenon is typically associated with impoundment outlets, and can cause major kills, especially during spawning migrations.

Fish Harvesting

A subsidised fish harvesting programme in the Hardap and Naute Dam Reservoirs is managed by the Freshwater Fish Institute, Mariental, and it is certain that the proposed dam would also create opportunities to extend the harvesting programme.

51.5.2 Macroinvertebrates

Despite large variations in river conditions, biomonitoring data collected during this study were remarkably consistent, with total NASS2 scores ranging between 80 and 95 (Table 51.3). The extent to which these results have changed from natural conditions is unknown, but it is probable that the biota in the area have not changed significantly from reference conditions.

Table 51.3 Summary of aquatic invertebrate biomonitoring results recorded near the proposed Neckartal Dam

Site	B1 (Neckartal)		B2 (Seeheim)	
Variable	**Aug-09**	**Feb-10**	**Aug-09**	**Feb-10**
Flow	trickle	low	zero	low
Biotope Suitability (%)	29	51	n/a	38
NASS2 Score	84	80	n/a	95
NASS2 Taxa	14	16	n/a	20
ASPT	6.0	5.0	n/a	4.8

The riverine aquatic invertebrate fauna was characterised by a low diversity of tolerant taxa, typical of a seasonal system. The most common trophic group were filter-feeders, including freshwater sponges (Porifera), moss animalcules (Bryozoa), and blackfly larvae (Simuliidae). In August 2009 the Fish River was dominated by high numbers of scavengers and predators, including water mites and gomphid dragonflies. Filter-feeders were present, but in low numbers. In February 2010 the river was dominated by filter-feeding blackflies (*Simulium chutteri*) (larvae and pupae) and deposit feeding cainflies (Caenidae). The composition and abundance of invertebrates on both visits

reflected a recent drop in flow levels, in which conditions had become unfavourable for filter-feeding taxa, but favourable to predators and scavengers. The data collected indicate that the aquatic invertebrate fauna in the Fish River tolerates extreme variations in flow and associated natural variations in water quality.

The list of aquatic invertebrates presented for the Fish River Catchment is noticeably short, but includes the following noteworthy taxa:

- a seedshrimp *Candonopsis nama*, endemic to Namibia;
- the snail *Bulinus forskalii*, an intermediate host for various bilharzia and trematode species than infect man and livestock;
- the snail *Bulinus tropicus,* an intermediate host for the trematode parasite *Calicophoron microbothrium*, a parasite of livestock;

Noteworthy taxa recorded in the Fish River during this study included the following:

- the blackfly *Simulium ruficorne*, typically associated with slow flowing water (<0.1 m/s) and high salinity, and widely distributed throughout Africa and the Arabian Peninsula;
- the pest blackfly *Simulium chutteri*, typically associated with fast-flowing water (>0.6 m/s), and endemic to the Orange River System.
- the hydropsychid caddisflies *Cheumatopsyche thomasseti* and *Amphipsyche scottae,* both predators and filter-feeders, and typically associated with impoundment outlets;
- the ecnomic caddisfly *Ecnomus thomasseti,* associated with unpolluted waters.

Exotic Aquatic Invertebrates

The snail *Physa acuta* is an alien invasive species and was first recorded in the Orange River System at Boegoeberg Dam in 1971. This species has subsequently spread dramatically; in 1993 specimens were recorded near Upington and Augrabies Falls, and in 1994 specimens were recorded near the river mouth. This species is suspected of outcompeting indigenous snail species.

Pest Aquatic Invertebrates

The most noticeable pest invertebrate recorded in the area of the proposed dam was the blackfly *Simulium chutteri*. This species is a serious pest of livestock in the middle and lower Orange River. Its numbers could reach pest proportions in the Fish River during periods of high-flow, but such periods are not expected to occur frequently or for extended duration. Besides, the problem could be easily controlled through flow manipulation from the proposed dam.

Large-scale irrigation developments often lead to the proliferation of pest species and the promotion of diseases, such as malaria and bilharzia. Carriers of these diseases (i.e. infected people) are almost certain to enter the area in search of work, but the probability of serious problems of this nature occurring in the proposed development area is considered very low on account of the limited aquatic habitats that are likely to be created. The occurrence of temporary and/or permanent ponding is likely to be very low on account of the highly permeable soils.

51.5.3 Diatoms

The Specific Pollution Index scores for the diatom samples are given in Table 51.4 and the diatom based ecological classification for water quality is given in Table 51.5.

Table 51.4 Specific Pollution sensitivity Index (SPI) score classification

Site	No species	Specific Pollution sensitivity Index (SPI)	Category	Class
August 2009				
B1	25	16.1	Strongly polluted	B
B2	22	14.9	Strongly polluted	B
B3	40	9.2	Very heavily polluted	C/D
February 2010				
B1	40	5.8	Moderately polluted	D
B2	41	6.4	Strongly polluted	D
B3	36	10.1	Moderately polluted	C

Table 51.5 Generic diatom based ecological classification

Diatom based ecological classification						
Site	**pH**	**Salinity**	**Organic nitrogen**	**Oxygen levels**	**Pollution levels**	**Trophic status**
August 2009						
B1	Circumneutral	Fresh brackish (Cond <139 mS/m)	Continuously elevated concentrations of organically bound nitrogen	Very low (~10% saturation)	Strongly polluted	Hyper-eutrophic
B2	Circumneutral	Fresh brackish (Cond <139 mS/m)	Continuously elevated concentrations of organically bound nitrogen	Very low (~10% saturation)	Strongly polluted	Hyper-eutrophic
B3	Alkaline	Fresh brackish (Cond <139 mS/m)	Periodically elevated concentrations of organically bound nitrogen	Low (>30% saturation)	Very heavily polluted	Eutrophic
February 2010						
B1	Alkaline	Fresh brackish (Cond <139 mS/m)	Elevated concentrations of organically bound nitrogen	Moderate (>50% saturation)	Moderately polluted	Eutrophic
B2	Alkaline	Fresh brackish (Cond <139 mS/m)	Elevated concentrations of organically bound nitrogen	Moderate (>50% saturation)	Strongly polluted	Oligo - Eutrophic
B3	Alkaline	Fresh brackish (Cond <139 mS/m)	Periodically elevated concentrations of organically bound nitrogen	Low (>30% saturation)	Moderately polluted	Eutrophic

Site B1:

From the results it is evident that during summer organic pollution and elevated nutrient levels impact heavily at the site which may be likely due to cattle. The site seems to recover during the winter months when temperatures are lower. The overall biological water quality PES is estimated at a C.

Site B2:

As with site B1 recovery during the winter months seem good, although organic pollution is problematic. Nutrient levels are continuously high stimulating high algal production and the overall water quality PES is estimated at a C.

Site 3B:

The overall biological water quality at this site is a C/D. Nutrient and organic pollution due to livestock seems to be the major impacts at this site and recovery during winter is not as good as the other sites. This may be due to the close proximity of the Naute Dam, which does not allow for flushing of instream habitat.

51.6 ECOSYSTEM PROCESSES

51.6.1 Keystone Species

The aquatic fauna in the Fish River is characterised by highly opportunistic and hardy species whose abundances fluctuate mainly in response to changes in physical conditions, so the presence of important keystone aquatic species is unlikely. One species that may be classified as

a possible keystone species is the Sharptooth catfish (*Clarias gariepinus*). This is a common and widespread species that is often associated with disturbance.

51.6.2 Ecosystem Drivers

The most important factors driving aquatic ecosystems in the Fish River are likely to be the following:

- ***Floods.*** The Fish River is a flood-driven system in which the riverine biota are adapted to short periods of high flow, followed by long periods with no surface flows, or no surface water. Floods are needed to recharge riparian aquifers and mobilise sediments. Mobilised sediments provide areas for recruitment of riparian vegetation which, in turn, protect stream banks from erosion. Floods are also important for flushing sediments and maintaining pool depths, and also triggering spawning migration of fish. Any activities that disrupt the frequency, timing and/or size of floods are likely to affect the health of the river ecosystem.
- ***Groundwater.*** The Fish River has isolated permanent pools that are critically important for the ecological maintenance of the river, particularly with respect to the recovery of fish populations when flows resume. The permanent pools appear to be maintained by groundwater inflows.
- ***Sediments.*** Tributaries introduce large volumes of sediment into the Fish River, and much of this is deposited at tributary junctions. These tributary deposits tend to constrict the river to the opposite bank, and this creates short-sections of faster flowing water, with pools upstream. This process increases instream habitat diversity, and is therefore likely to increase instream biodiversity. Riparian zones are also maintained by the periodic deposition of sediments during flood events. Primary production during periods of high flow is likely to be light-limited, but the river becomes increasingly clear during periods of low or no flow, and water clarity is likely to increase further as salinity levels rise. Clear and warm temperatures are ideal for growth of benthic algae, which were particularly abundant during the field survey in August 2009. These ever-changing conditions are key to maintaining a healthy river system, and any activities that disrupt the transport of sediments are likely to affect the health of the river ecosystem.

51.6.3 Resilience

The Fish River is characterised by extreme fluctuations in environmental conditions. The instream and riparian flora and fauna expected in such an environment are hardy taxa, with life histories geared to withstand extreme and unpredictable events. The aquatic ecosystem is therefore, in general, likely to be highly resilient to change.

51.6.4 Connectivity

Instream connectivity in the Fish River is low because of a series of waterfalls that restrict the movement of instream biota, particularly fish. There are two waterfalls upstream of the proposed development, near Tses, each about 10 m high, and a smaller fall about 5 m high downstream of the Neckartal dam site, near the farm Witputs. The latter limits the distribution of three species that are restricted to the lower reaches (*Barbus hospes, B. trimaculatus* and *Mesobola brevianalis)*.

The riparian zone, on the other hand, is a linear oasis in an arid environment, and is therefore an important corridor for many terrestrial and riparian species. The importance of the river as a migration corridor is reflected in the distribution of many species, such as kingfisher and cormorants, which are restricted to the river corridor.

51.7 SUITABILITY AS FUTURE BIOMONITORING SITES

The final recommendation made by Nepid consultants regarding long term monitoring is provided below.

The highly variable nature of the Fish River makes it difficult to select appropriate and reliable indicators that can be used to monitor ecological conditions and detect significant trends. The only instream indicator that is recommended for long-term monitoring is fish species composition and fish habitats. Fish and fish habitats should be monitored annually at three sites during construction and operation during the dry period (Aug/Sep). Particular attention should focus on naturally perennial pools, as these are ecologically important areas that are sensitive to sedimentation and predicted long-term downstream impacts of the dam.

Benthic diatoms are typically used to detect trends in trophic conditions, particularly with respect to changes in nutrient and salinity levels. The baseline data collected on benthic diatoms during this study indicate that the results are too variable for diatoms to be appropriate indicators.

Similarly, flows in the Fish River are too variable for aquatic invertebrates to provide appropriate or reliable indicators of ecological conditions.

If a monitoring site is to be selected exclusively as part of aquatic ecosystem health monitoring for ORASECOM, it is recommended that Site B2 is selected, as it is situated downstream of the new dam development, is close to OSAEH 26.18 and data are available. Site B1 should be excluded as it is situated too close downstream of the proposed dam wall. Surveys should be undertaken during late February – March as it seems that this is when the Fish River has the greatest potential for flow.

A qualitative analysis of the macroinvertebrate data has been included in Technical Report 2 which was provided by Dr Eliot Taylor. It must however be noted that the analysis is of low confidence as the results are based on Dallas (2007) and the Fish River is essentially an ephemeral system.

52 RECOMMENDATIONS

To determine the state of the aquatic ecosystems throughout the basin fifty six OSAEH sites were proposed as possible monitoring sites that could be included in a basin wide ecological monitoring programme. Sampling of all the sites provided in the ToR could not be accommodated, due to budgetary constraints. Based on available information, data generated from different ecological Reserve studies undertaken in the Orange River Basin as well as the results from this study, the state of aquatic ecosystems throughout the basin have been determined.

As it is the mandate and responsibility of ORASECOM to develop an aquatic ecosystem health monitoring programme, key sites within the Basin have been identified for further monitoring. These sites are high priority sites which would detect impact and impairment in the basin.

52.1 SITE NOMENCLATURE

As the information summarised in this document are from various studies each with its own site numbering, it is recommended that a unique site numbering system is used for ORASECOM. Therefore the new site numbers are provided in the following table, cross referenced with other site names used in this document.

52.2 RECOMMENDED MONITORING SITES

52.2.1 AREA 1: Vaal River Catchment

A total of thirty one proposed OSAEH sites and nineteen EWR sites are located in this catchment and thirteen of these sites were assessed during this study. The sites that are recommended as future monitoring sites are listed in Table 52.1 and reasoning is provided.

Table 52.1 Proposed monitoring sites in the Vaal River Catchment

SITE	REACH	EC	Motivation	New site number
UPPER VAAL RIVER MAIN STEM				
EWR 1	MRU Vaal B	C	Indications that there are water quality problems as the fish show signs of serious bacterial infection and quality sensitive macroinvertebrates are absent.	JBS1
EWR 3	MRU Vaal C	C	EWR 3 is upstream of the Waterval River confluence and therefore the deteriorated water quality entering the Vaal River from the Waterval catchment will not be detected. OSAEH 11.2 is downstream of this confluence but may be influenced by inundation from the Vaal Dam which would make sampling difficult. Based on the data availability and level of analysis undertaken at EWR 3, this site is a preferred biomonitoring site.	JBS2
OSAEH 11.13 (NEW SITE)	MRU Vaal E	C	The new site at Parys, situated on the RB just upstream of the R53 road bridge, may be better suited as a monitoring site as it is located at Parys and would detect upstream impacts. This reach is very important as the Vredefort Dome World Heritage site is located in this reach and is therefore a very high priority monitoring site.	JBS3
EWR 5	MRU Vaal E	C/D	EWR 5 is situated at the end of the WMA 10 km upstream of the Mooi River confluence and the farthest EWR site in the Vaal River. It is impacted by major upstream anthropogenic activities upstream. This site is situated downstream of the Vredefort Dome World Heritage area and is therefore a very high priority monitoring site.	JBS4
KLIP RIVER				
EWR 6	MRU Klip C	B	Considering the importance of this tributary as well as data availability and the level of analysis undertaken at EWR 6, this site is a preferred biomonitoring site.	JBS5
WILGE RIVER				
EWR 7	MRU Wilge A	B	The Braamhoek pump storage scheme upstream of this site is under development will impact the Wilge River and therefore this site is a good location for detecting these impacts. The new dams (Eskom pumped storage scheme) coming online and will cause reductions in baseflows, as well as likely changes to moderate	JBS6

SITE	REACH	EC	Motivation	New site number
			floods which will impact geomorphology while water quality may deteriorate due to increased turbidity and nutrient loading and the drivers therefore have a negative trajectory of change. The site is not the most ideal site in terms of habitat availability and exotic alien fish are impacting the site neegatively.	
EWR 8	MRU Wilge B	C	The site is impacted by WWTWs (Harrismith, Industriqwa, Warden and Tshiane) and receives diffuse runoff from agricultural, urban (Harrismith) and industrial activities (Industriqwa). Weirs occur in the system for the purposes of abstraction for purification purposes, fish dams and abstraction by tankers. This site could be valuable for detecting upstream anthropogenic activities. Sterkfontein releases impact on turbidity levels, habitat loss, decreased temperature and oxygen levels.	JBS7
WATERVAL RIVER				
OSAEH 11.11	MRU Waterval B	D	MRU delineated as Boesmanspruit to the Vaal River confluence. The reach has a PES EcoStatus of a D and is heavily impacted by industrial activity (DWAF, 2008b).	JBS8
SUIKERBOSRAND RIVER				
OSAEH 11.15	MRU Suiker A	B/C	OSAEH 11.15 is at the same locality as EWR 9 and considering that the lower reaches of the Suikerbosrand is impacted by mining and other industrial activities this site should be included in a monitoring programme.	JBS9
EWR 10	MRU Suiker B	C/D	Close proximity to OSAEH 11.14 which is downstream of EWR 10. This site should be included to detect upstream impacts and to determine if the site condition improves when the planned water quality management plan for the Blesbokspruit is initiated which would include purification of mine water decant.	JBS10
BLESBOKSPRUIT RIVER				
OSAEH 11.8	MRU Bles A	D/E	Same locality as EWR 11. The site is severely impacted, especially biota, and therefore this site should be included to detect these impacts and to determine if the site improves when the planned water quality management plan for the Blesbokspruit when initiated which would include purification of mine water decant.	JBS11
KLIP RIVER (GAUTENG)				
OSAEH 11.12		N/S[1]	The river is highly polluted, habitat has been altered due to elevated flows. This site may not be the ideal monitoring site but should be included in future monitoring programmes due to the significant impacts on this river and the deteriorated water quality that enters the Vaal River.	JBS12
MIDDLE VAAL RIVER MAIN STEM				
EWR 12	MRU Vaal F	C	EWR 12 is situated in quaternary catchment C24A, upstream of the confluence with the Koekemoerspruit at Vermaasdrift on the main stem of the Vaal River but downstream of the Rhenoster and Mooi river. The site is adequate for biotic monitoring and an important future monitoring site as it is important to understand the influence of the Upper Vaal WMA.	JBS13
OSAEH 11.1	MRU Vaal G	C	OSAEH 11.1 is situated approximately 5 km downstream of EWR 13 in quaternary catchment C24J. Both sites are adequate as future monitoring sites. However OSAEH 11.1 may be more suitable as there are more unique habitats present and the site is located further downstream in quaternary catchment C24J. As both sites occur within the same EcoRegion and MRU and as the PES results were similar, the data collected at both these sites are valid. However within MRU Vaal G the presence of a Nature Reserve would warrant a further delineation of the MRU into Reserve Assessment Units as the habitat at OSAEH 11.1 is more unique and more responsive to flow changes than EWR 13, although the EWR site is more representative of the reach.	JBS14
RHENOSTER RIVER				
OSAEH 11.6	MRU Rhenoster C	B/C	OSAEH 11.6 is situated in the lower reaches of the Rhenoster River, and has good habitat available for the full suite of biological components to be monitored. This site is a valuable monitoring site for future monitoring programmes as it is located in a tributary and has many upstream impacts. As the Vaal River main stem has deteriorated water quality, tributaries play an important role in diluting these impacts and providing refugia for biota.	JBS15
SCHOONSPRUIT				
OSAEH 11.4	MRU Schoon-spruit D	C	During 2003 – 2005 an Intermediate Reserve Determination Study was commissioned by the Free State Regional Office, as part of a Catchment Management Strategy Development for the Schoon- and Koekemoerspruit catchments. As the Schoonspruit has a major influence on the Vaal River main stem, OSAEH 11.4 is an important site in terms of a future monitoring programme.	JBS16

SITE	REACH	EC	Motivation	New site number
			The lower reaches of the Schoonspruit are heavily impacted by anthropogenic activity and water quality is deteriorated. Substantial data is available on this river and the site is suitable for monitoring the full suite of biotic components.	
VALS RIVER				
OSAEH 11.5	MRU Vals B	D	EWR 14 is at the same location as OSAEH 11.5 and is the only site that has been identified in the Vals River. The data collated during the Reserve study is important and adequate.	JBS17
VET RIVER				
OSAEH 29.3	MRU Vet C	D	EWR 15 is at the same location as OSAEH 29.3 and is situated in the Vet River downstream of the confluence with the Sand River. As this is the only site that has been identified in the Vet River, the data collated during the Reserve study is important and adequate.	JBS18
LOWER VAAL RIVER MAINSTEM				
OSAEH 29.2	MRU Vaal M	C	The site was not sampled during this study. From Google Earth imagery habitat availability seems adequate for the full suite of biological components to be monitored. This site may be more valuable in a monitoring programme than EWR 16 as it is situated further downstream in the Vaal River and therefore more suitable to detect upstream impacts.	JBS19
OSAEH 29.4	MRU Vaal O	C	OSAEH 29.4 is at the same location as EWR 18. Although this site was identified as a priority reach for maintaining the integrity of the Lower Vaal, sampling at this site is difficult as the river is non-wadeable due to the steep gradient of the river. Limited biotopes occur for biotic sampling, and the riparian zone is very dense. This site could be included in a monitoring programme although due to the non-wadeable nature of the Vaal River in this reach, assessment of biotic components would be limited.	JBS20
HARTS RIVER				
OSAEH 29.1	MRU Harts C	C	OSAEH 29.1 is at the same location as EWR 17 and is situated downstream of Spitskop Dam in the Harts River. The MRU includes Wentzel Dam. It is suggested that this site is included as a future monitoring site as Present Day flows are higher than natural and the deteriorated water quality impact heavily on the site and is the only site proposed for this system.	JBS21
RIET RIVER				
OSAEH 26.10	MRU Riet A	D	The site has adequate habitats for the full suite of biological components to be monitored. This site is also an EWR site (IFR 03) and was assessed during the Reserve study in 2003. Although the reach represents a relatively unimpacted part of the Riet River, the EWR assessment resulted in a PES of a D. The current assessment also indicates impacts relating to anthropogenic activities. As the water quality of the Riet River is deteriorated this site should be included as a future monitoring site to detect ongoing impacts especially relating to impaired water quality.	JBS22
OSAEH 29.5	MRU Riet D	C	OSAEH 29.5 is the most downstream site within the Riet River, and is located just downstream of Ritchie at the same location as EWR 19. This reach was identified as a priority reach for maintaining the integrity of the Lower Vaal. Therefore it is an ideal site for detecting impacts from upstream anthropogenic activities originating from the Modder and Riet Rivers. The site occurs in the Mokala National Park on the LB of the river.	JBS23
MODDER RIVER				
OSAEH 11.18	MRU Riet C1	D	OSAEH 11.18 is located downstream of Botshabelo and Thabu Nchu but upstream from Bloemfontein. It is the only OSAEH site situated in the upper reaches of the river and should be included as a biomonitoring site. The habitat at this site is good and the full suite of biological components can be monitored. This site will be a good monitoring site to detect and monitor on-going impacts which include impacts from sewage works, interbasin transfer, and Rustfontein Dam upstream.	JBS24

N/S = not sampled for this baseline survey, but recommended for future surveys.

52.3 AREA 2: UPPER ORANGE RIVER CATCHMENT

A total of twelve proposed OSAEH sites and four EWR sites are located in WMA 13. No OSAEH sites were visited as part of this study. This area was assessed as part of the EFR study

undertaken during 2010 by Water for Africa (WFA, 2010 a, b). The sites that are recommended as future monitoring sites are listed in Table 52.2 and reasoning is provided.

Table 52.2 Proposed monitoring sites in the Upper Orange River Catchment

SITE	REACH	EC	Motivation	New site number
UPPER ORANGE RIVER MAIN STEM				
OSAEH 11.22		N/S	OSAEH 11.22 is located in the upper reaches of the Upper Orange River approximately 65 km downstream of the Lesotho border. This site could be viable as a future monitoring site to detect impacts from Lesotho. From Google Earth imagery this site may be limited in terms of habitat availability to monitor the full suite of biotic components and access may be problematic.	JBS25
OSAEH 26.14		N/S	Google Earth imagery indicates that habitat availability seems more than adequate to monitor the full suite of biotic components. The water quality in the Upper Orange is stable and does not deteriorate significantly downstream, but the Stormbergspruit discharges poor quality water from Burgersdorp sewage works into the Orange River.	JBS26
OSAEH 26.2	MRU Orange B	C	OSAEH 26.2 is at the same location as EFR O1. A monitoring site will be very important in the lower reaches of the Upper Orange as the hydro-electric releases from Vanderkloof Dam impact the lower reaches considerably along with other impacts that include barrier effects of the dams, water quality problems and the destruction of and removal of vegetation on floodplains for agriculture. Based on the data availability and level of analysis undertaken at EFR O1, this site is a preferred biomonitoring site.	JBS27
CALEDON RIVER				
EFR C5	MRU Caledon A/B	C	OSAEH 15.1 is located approximately 50 km downstream of EFR C5. Based on the data availability and level of analysis undertaken at EFR C5, this site is a preferred biomonitoring site.	JBS28
OSAEH 11.6	MRU Caledon B	N/S	Situated downstream of Maseru and is an important site in terms of detecting impacts from upstream Ficksburg and Maseru. However, from Google Earth imagery the Caledon River within this reach has very little riffle and rapid habitat that would allow for the full suite of biological components to be monitored.	JBS29
OSAEH 26.8	MRU Caledon D	C	EFR C6 is at the same location as OSAEH 26.8. Habitat at the site is moderate to good for biotic monitoring, although it may be influenced by backup from Gariep Dam. The main landuse around the Caledon River is characterised by extensive agriculture. This site may be a good monitoring site to detect agricultural impacts in the river reach between the Welbedacht and Gariep Dams.	JBS30
KRAAI RIVER				
EWR 7	MRU Kraai C	C	The landuse in this reach is dominated by irrigation and dry land agriculture and aquaculture.	JBS31

52.4 AREA 3: LOWER ORANGE RIVER CATCHMENT

A total of nine proposed OSAEH sites and three EWR sites are located in WMA 14. Two OSAEH sites were assessed as part of this study. This area was also assessed as part of the EFR study undertaken during 2010 by Water for Africa (WFA, 2010 a, b). The sites that are recommended as future monitoring sites are listed in Table 52.3 and reasoning is provided.

Table 52.3 Proposed monitoring sites in the Lower Orange River Catchment

SITE	REACH	EC	Motivation	New site number
LOWER ORANGE MAIN STEM				
EFR O2	MRU Orange D	C	EFR 2 is less disturbed than the rest of the reach and no farming occurs in the riparian zone. The site is downstream of Boegoeberg Dam and is suitable for detecting impacts relating to an altered hydrological regime which seems to be the biggest problem in this reach. Elevated flows may be problematic and therefore gauge records should be checked when planning routine monitoring.	JBS32
OSAEH 26.17	MRU Orange D	C	Located further downstream of EFR O2 just upstream of Upington. This is a multi-channel section of the Orange River. The river reach below EFR O2 is characterised by irrigation, levees in the riparian zone and weirs. This site is suitable for sampling the full suite of biotic components.	JBS33

SITE	REACH	EC	Motivation	New site number
OSAEH 28.2	MRU Orange E	C	EFR O3 is at the same location as OSAEH 28.2 and is less disturbed than the rest of the MRU. The site is suitable for detecting impacts relating to an altered hydrological regime and agricultural activities, which seems to be the biggest problem in this reach.	JBS34
OSAEH 28.4	MRU Orange F	C	EFR O4 and OSAEH 28.4 are at the same location and in a better condition than the rest of the reach. Agricultural return flows and mining activities are impacting on water.	JBS35
OSAEH 28.5		B/C	Situated at Sendlingsdrift and suitable site to monitor agricultural impacts.	JBS36

52.5 AREA 4: SENQU RIVER – FROM THE ORIGINS OF THE SENQU TO THE SOUTH AFRICAN BORDER

As a current IFR monitoring programme is being applied in the Senqu River the current monitoring sites should be included in future monitoring programmes and are listed in Table 52.4.

Table 52.4 Proposed monitoring sites in the Senqu River

Site	Description	New site number
IFR Site 1	On the Matsoku River near the village of Seshote, representing the Matsoku River from the site of the proposed Matsoku Weir to the confluence with the Malibamats'o River (IFR Reach 1). Same location as OSAEH 15.1	JBS37
IFR Site 2	On the Malibamats'o River downstream of the Katse Bridge representing, the Malibamats'o River from Katse Bridge to the confluence with the Matsoku River (IFR Reach 2).	JBS38
IFR Site 3	On the Malibamats'o River at Paray, representing the Malibamats'o River from the confluence with the Matsoku River to the confluence with the Senqu River (IFR Reach 3).	JBS39
IFR Site 4	On the Senqu River at Sehonghong, representing the Senqu River from the confluence with the Malibamats'o River to the confluence with the Tsoelike River (IFR Reach 4).	JBS40
IFR Site 5	On the Senqu River at Whitehills, representing the Senqu River from the confluence with the Tsoelike River to the confluence with the Senqunyane River (IFR Reach 5). Same location as OSAEH 15.3.	JBS41
IFR Site 6	On the Senqu River at Seaka Bridge, representing the Senqu River from the confluence with the Senqunyane River to the Lesotho/South Africa border (IFR Reach 6).	JBS42
IFR Site 7	On the Senqunyane River at Marakabei, representing the Senqunyane River from the site of the proposed Mohale Dam to the confluence with the Lesobeng River (IFR Reach 7).	JBS43
IFR Site 9	Matsoku River upstream of the headwaters of Matsoku Weir – reference for IFR Site 1.	JBS44

52.6 FISH RIVER, NAMIBIA

If a monitoring site is to be selected exclusively as part of aquatic ecosystem health monitoring for ORASECOM, it is recommended that Site B2 is selected, as it is situated downstream of the new dam development, is close to OSAEH 26.18 and data are available (Table 52.5).

Table 52.5 Proposed monitoring sites in the Fish River, Namibia

Site	Description	New site number
B2	Impact site, 26 km downstream of dam site at Seeheim	JBS45

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