BI-ANNUAL AQUATIC BIOMONITORING FOR VLAKVARKFONTEIN

June 2016

CLIENT

Geo Soil & Water CC

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Report name	**Bi-annual aquatic biomonitoring of the aquatic resources (rivers & streams) associated with the Vlakvarkfontein Colliery, Mpumalanga.**	
Reference code	**GSW-0174EX**	
Submitted to	**Geo Soil & Water CC**	
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EXECUTIVE SUMMARY

The Biodiversity Company was commissioned to conduct biomonitoring of the aquatic systems associated with the project area as per conditions of the Water Use Licence (WUL, No. 4/B20F/AGJ/1131). The WUL conditions stipulate the following as a minimum requirement for the biomonitoring study:

- An Aquatic Scientist approved by the Regional Head must establish a monitoring programme for the following indices: Invertebrate Habitat Assessment System (IHAS) and the latest SASS (South African Scoring System). Sampling must be done once during the summer season and once during the winter season, annually, to reflect the status of the river upstream and downstream of the mining activities.

The aquatic assessment was based on a desktop assessment of aquatic ecosystems associated with the Vlakvarkfontein Colliery followed by two field surveys conducted on the 30th of August 2015 (low flow), 15th of January 2016 (high flow) and the 22nd of July 2016 (low flow).

Anthropogenic impacts identified within the two sub-quaternary catchments included bed stabilisation, low water crossings, erosion, alien vegetation, inundation, recreational activities, chicken farming, sedimentation, small farm dams, vegetation removal, irrigation, runoff/effluent from irrigation and mining, grazing and trampling, large amounts of abstraction, agricultural land, roads and serious levels of agriculture. These impacts have resulted in the respective moderately and largely modified Present Ecological Status (PES) of each catchment.

Desktop Data for the two Sub-quaternary Catchments

Catchment	**B20E-1290**	**B20F-1150**
NFEPA's	**2 NFEPAs listed**	**8 NFEPAs listed**
Present Ecological Status	**Largely modified (Class D)**	**Moderately Modified (Class C)**
Ecological Importance	**Moderate**	**High**
Ecological Sensitivity	**Moderate**	**Very High**

According to the 2016 low flow biomonitoring assessment, the state of the project area is in a largely modified state, which has led to modified macroinvertebrate community assemblages, reducing the biotic integrity of the associated aquatic systems.

Aquatic Assessment Results for the July 2016 low flow biomonitoring

	Vlak1	**Vlak2**	**Vlak3**	**Vlak4**	**Vlak5**
In Situ Water Quality Parameters	**Poor**	**Poor**	**Poor**	**Poor**	**Adequate**
Integrated Habitat Assessment System	**Poor**	**Adequate**	**Poor**	**Good**	**N/A**
Biotic Integrity Based on SASS5 Results	**E/F**	**E/F**	**E/F**	**E/F**	**N/A**
EcoStatus	**Seriously Modified**				

Survey results indicate that the Leeufontein River, Wilge River and Blesbok River reaches assessed are in a poor condition. The water quality and habitat have shown little to no improvement with a decline in water quality at sites Vlak1 to Vlak5 from previous biomonitoring survey conditions negatively impacting on the aquatic biota. Water quality showed electrical conductivity continuing at elevated levels due to salt in the systems. It is unlikely that water quality issues stem entirely from Vlakvarkfontein Colliery but may be attributed from a combination of impacts within the catchments.

The recent biomonitoring run results have not deviated from trends noted in previous biomonitoring results with the aquatic systems remaining in an impacted condition. Some recent reshaping of the Blesbok River channel was seen during the July 2016 low flow survey. This reshaping will result in the improvement of the biotic integrity in the long run. Some recommendations have been put forth regarding these reshaping activities and stormwater channels according best practice methodologies.

Continued biomonitoring should be carried out to monitor trends in ecological changes. Further biomonitoring programmes should include fish community structures as well as *ex situ* water quality analyses.

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List of Abbreviations

ASPT	Average Score Per Taxon
BA	Basic Assessment
BAR	Basic Assessment Report
DD	Data Deficient
DO	Dissolved Oxygen
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
EAP	Environmental Assessment Practitioner
EC	Electrical conductivity
EI	Ecological Importance
EIS	Ecological Importance and Sensitivity
EPT	Ephemeroptera (Mayflies), Plecoptera (Stoneflies) and Trichoptera (Caddisflies)
ES	Ecological Sensitivity
ESA	Ecological Support Area
FEPA	Freshwater Ecosystem Priority Areas
GSM	Gravel, Sand, and Mud
IHAS	Integrated Habitat Assessment System
IHIA	Intermediate Habitat Integrity Assessment
IT	Invertebrate Tolerance
LC	Least Concern
NEM:BA	National Environment Management Biodiversity Act's
NEMA	National Environmental Management Act
NFEPA	National Freshwater Ecosystem Priority Areas
NWA	National Water Act
PES	Present Ecological Status
SASS	South African Scoring System
SIC	Stones In Current
SOOC	Stones Out Of Current
SQR	sub-quaternary reach
TWQR	Target Water Quality Range
WMA	Water Management Area
WULA	Water Use Licence

DECLARATION

I, **Dale Kindler** declare that:

- I act as the independent specialist in this application;
- I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant;
- I declare that there are no circumstances that may compromise my objectivity in performing such work;
- I have expertise in conducting the specialist report relevant to this application, including knowledge of the Act, regulations and any guidelines that have relevance to the proposed activity;
- I will comply with the Act, regulations and all other applicable legislation;
- I have no, and will not engage in, conflicting interests in the undertaking of the activity;
- I undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing any decision to be taken with respect to the application by the competent authority; and the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority;
- all the particulars furnished by me in this form are true and correct; and
- I realise that a false declaration is an offence in terms of Regulation 71 and is punishable in terms of Section 24F of the Act.

Dale Kindler

The Biodiversity Company

12 September 2016

1 INTRODUCTION

The Biodiversity Company was commissioned by GSW to conduct biomonitoring of the aquatic systems associated with the project area as per conditions of the Water Use Licence (WUL, No. 4/B20F/AGJ/1131). The WUL conditions stipulate the following as a minimum requirement for the biomonitoring study:

- An Aquatic Scientist approved by the Regional Head must establish a monitoring programme for the following indices: Invertebrate Habitat Assessment System (IHAS) and the latest SASS (South African Scoring System). Sampling must be done once during the summer season and once during the winter season, annually, to reflect the status of the river upstream and downstream of the mining activities.

The aquatic assessment was based on a desktop assessment of aquatic ecosystems associated with the Vlakvarkfontein Colliery followed by two field surveys conducted on the 30th of August 2015 (low flow), 15th of January 2016 (high flow) and the 22nd of July 2016 (low flow) as required by the WUL.

1.1 Background

Freshwater biodiversity in Southern Africa is both highly diverse and of great local importance to livelihoods and economies. However, the conservation of these aquatic ecosystems is often poorly represented within the development planning process, and furthermore development is often not compatible with conservation of these resources. The value of the goods and services derived from freshwater ecosystems such as food and drinking water is considerable, however the lack of recognition of this value has led to a rapid decrease in the state of these resources through negative anthropogenic activities (Darwall *et al.,* 2009). Due to the rapid population growth rate in Africa and the increased demand for safe drinking water and sanitation there is a potential large scale impact to freshwater biodiversity. Initiative is required to assess the status of freshwater ecosystems and to integrate that information into the water development planning process. This information is critical to minimise or mitigate significant impacts to freshwater biodiversity and the resulting loss to livelihoods and economies which are dependent on these goods and services (Darwall *et al.,* 2009).

In 1994 the South African Department of Water Affairs and Forestry (DWS) initiated the River Health Programme (RHP). The purpose of this programme was to establish a source of information on the ecological status of aquatic ecosystems in South Africa. Subsequently, in 1998, the South African National Water Act (NWA) came into effect. This act acknowledged the importance of protecting aquatic ecosystems and the maintenance of goods and services provided by these resources. This required the establishment of a national aquatic ecosystem health monitoring system (DWS, 2006).

The RHP monitoring system primarily uses biological indicators such as fish communities, riparian vegetation and aquatic macroinvertebrates to assess the current state or health of river systems in support of the rational management of these natural resources. The use of biological indicators provides a direct, complete and integrated measure of the current ecological state of the river. This is conducted to measure, assess and report on the spatial and temporal trends of the aquatic ecosystem to identify and report emerging problems by providing scientifically and managerially relevant information for national aquatic ecosystem management (DWS, 2006).

1.2 Objectives

The aim of the assessment is to provide information on the current state of the aquatic systems in the area of study through a desktop study, and through the determination of the ecological classification of the current state of biotic and abiotic drivers and responders.

The ecological classification (EcoClassification) of the systems will require the determination and categorisation of the Present Ecological State (PES; health or integrity) of individual biophysical attributes, and then comparing these findings to the natural or close to natural reference conditions, as well as previous biomonitoring projects. These biophysical attributes refer to the drivers and biological responses of an aquatic ecosystem. As per the requirements of the WULs, the biophysical attributes that will be included for the study are the following:

The abiotic driver assessment:

- *In situ* water quality (DWAF standards for aquatic ecology); and
- The Invertebrate Habitat Assessment System (IHAS).

The biotic response indicator assessment:

- South African Scoring System ver 5 (SASS 5); and
- The Average Score Per Taxon (ASPT).

1.3 Limitations

The aquatic baseline assessment was based on the results of two low surveys and a single high flow survey only, and information provided should be interpreted accordingly.

2 KEY LEGISLATIVE REQUIREMENTS

2.1 National Water Act (NWA, 1998)

The DWS is the custodian of South Africa's water resources and therefore assumes public trusteeship of water resources, which includes watercourses, surface water, estuaries, or aquifers. The National Water Act (Act No. 36 of 1998) (NWA) allows for the protection of water resources, which includes:

The maintenance of the quality of the water resource to the extent that the water resources may be used in an ecologically sustainable way.

- The prevention of the degradation of the water resource.
- The rehabilitation of the water resource.

A watercourse means:

- A river or spring.
- A natural channel in which water flows regularly or intermittently.
- A wetland, lake or dam into which, or from which, water flows.
- Any collection of water which the Minister may, by notice in the Gazette, declare to be a watercourse, and a reference to a watercourse includes, where relevant, its bed and banks.

The NWA recognises that the entire ecosystem and not just the water itself, and any given water resource constitutes the resource and as such needs to be conserved.

3 PROJECT AREA

3.1 Study area description

The Vlakvarkfontein coal mining operations are located approximately 40 km South West of the City of Emalahleni, Mpumalanga Province. Biomonitoring is focused on the operational phases of the mine. The project area is located in the Olifants Water Management Area (WMA4), Highveld – upper Ecoregion and within the quaternary catchments B20F and B20E. Details of the sites are presented in Table 1.

The Olifants WMA is mainly occupied by the South African portion of the Olifants River catchment, excluding the Letaba River catchment. The Letaba River catchment is a tributary catchment to the Limpopo Basin shared by South Africa, Botswana, Zimbabwe and Mozambique. The Olifants River originates to the east of Johannesburg, initially flowing northwards before gently curving eastwards towards the Kruger National Park, where it is met at the confluence with the Letaba River before flowing into Mozambique. The climate varies greatly from the cool Highveld in the south to subtropical, east of the escarpment. The region has a mean annual precipitation rate of 500 to 800 mm. Diverse economic activity includes mining, metallurgic industries, irrigation, dryland and subsistence agriculture, and ecotourism. The provision of water to meet ecological requirements in the Olifants River is one of the controlling factors in the management of water resources throughout the WMA. Several large dams control much of the flow in these rivers. The Olifants WMA receives substantial amounts of water from transfers to serves as cooling water for power generation, while smaller transfers are made to neighbouring WMAs (StatsSA, 2010).

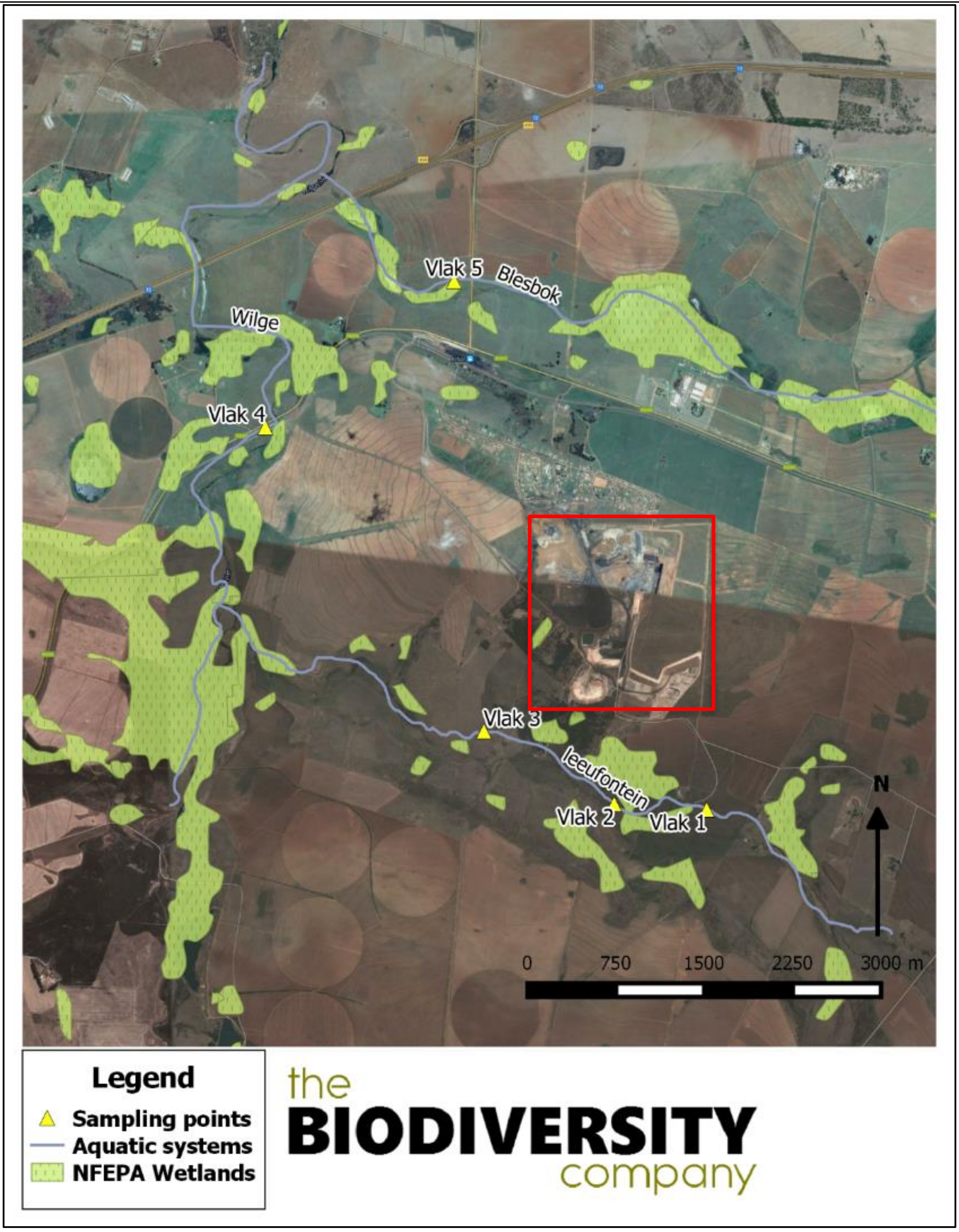


Figure 1: Locality map of the Vlakvarkfontein Coal Mine (red block) and five biomonitoring points

Table 1: Photos, co-ordinates and descriptions for the sites sampled

	Downstream (Low flow)	**Upstream (Low flow)**
Vlak1		
GPS coordinates	26° 4'31.04"S 28°54'18.44"E	
Site description	Site Vlak1 is situated on the Leeufontein River, a tributary of the Wilge River. Vlak1 is situated upstream of the mining operation. The site is characterized by deep slow moving waters over muddy substrate with marginal vegetation. Surrounded by agricultural land.	
Vlak2	**Upstream (High flow)**	**Upstream (Low flow)**
		
	Downstream (High flow)	**Downstream (Low flow)**
		
GPS coordinates	26° 4'29.51"S 28°53'50.19"E	

Site description	Site Vlak2 is situated on the Leeufontein River, a tributary of the Wilge River. Vlak2 is situated adjacent to Vlakvarkfontein Colliery. Vlak2 was characterised by slow moving waters over rocky and sandy substrate. A large pool is present upstream of the level crossing. Surrounded by agricultural land. Coal dust was noted in the sediment.	
Vlak3	**Upstream (High flow)**	**Upstream (Low flow)**
		
	Downstream (High flow)	**Downstream (Low flow)**
		
GPS coordinates	26° 4'9.55"S 28°53'10.39"E	
Site description	Site Vlak3 is situated on the Leeufontein River, a tributary of the Wilge River. Vlak3 is situated downstream of Vlakvarkfontein Colliery. This site was predominantly slow moving waters over scattered stones with sandy and muddy substrate. A small amount of algae was present during the high flow survey. White precipitate noted on the rocks.	

Vlak4	**Upstream (High flow)**	**Upstream (Low flow)**
		
	Downstream (High flow)	**Downstream (Low flow)**
		
GPS coordinates	26° 2'46.16"S 28°52'3.63"E	
Site description	Site Vlak4 is situated on the Wilge River, downstream of Leeufontein River confluence. Site Vlak4 had slow moving waters over sandy and rocky substrate. A large amount of algae and aquatic vegetation was observed during the high flow period. Some bank undercutting and sedimentation was present during the high flow. White precipitate noted on the rocks.	

Vlak5	**Upstream (High flow)**	**Upstream (Low flow)**
		
	Downstream (High flow)	**Downstream (Low flow)**

		
GPS coordinates	26° 2'6.04"S 28°53'1.28"E	
Site description	Site Vlak5 is situated on the Blesbok River, a tributary of the Wilge River. Vlak5 is situated downstream of Vlakvarkfontein Colliery. During the high flow, heavy sedimentation from the poorly maintained dirt road inundated the channel, suffocating much of the habitat. The recent low flow showed reconstruction of the channel. **ONLY** *in situ* water quality is carried out at this site.	

4 DESKTOP ASSESSMENT

4.1 National Freshwater Ecosystem Priority Area (NFEPA) Status

The National Freshwater Ecosystem Priority Areas (NFEPA) database forms part of a comprehensive approach to the sustainable and equitable development of South Africa's scarce water resources. This database provides guidance on how many rivers, wetlands and estuaries, and which ones, should remain in a natural or near-natural condition to support the water resource protection goals of the National Water Act (Act 36 of 1998). This directly applies to the National Water Act, which feeds into Catchment Management Strategies, water resource classification, reserve determination, and the setting and monitoring of resource quality objectives (Nel *et al*. 2011). The NFEPAs are intended to be conservation support tools and envisioned to guide the effective implementation of measures to achieve the National Environment Management Biodiversity Act's biodiversity goals (NEM:BA) (Act 10 of 2004), informing both the listing of threatened freshwater ecosystems and the process of bioregional planning provided for by this Act (Nel *et al*., 2011).

4.1.1 NFEPA's for the two sub-quaternary catchments

The two sub-quaternary catchments (B20E-1290 and B20F-1150) have a total of 8 freshwater priority areas designated to them (Table 2). Sites Vlak1, Vlak2 and Vlak3 fall under the Leeufontein sub-quaternary reach (SQR) B20E-1290. Site Vlak4 and Vlak5 fall under the Wilge sub-quaternary reach (SQR) B20F-1150.

Table 2: NFEPA's for the two sub-quaternary catchments

Type of FEPA map category	Biodiversity features
B20E-1290	
Number of wetland clusters	1 WetCluster FEPA
Wetland ecosystem type	Mesic Highveld Grassland Group 4_Unchannelled valley-bottom wetland
B20F-1150	
Number of wetland clusters	5 WetCluster FEPAs
Wetland ecosystem type	Mesic Highveld Grassland Group 4_Channelled valley-bottom wetland
Wetland ecosystem type	Mesic Highveld Grassland Group 4_Depression
Wetland ecosystem type	Mesic Highveld Grassland Group 4_Flat
Wetland ecosystem type	Mesic Highveld Grassland Group 4_Seep
Wetland ecosystem type	Mesic Highveld Grassland Group 4_Unchannelled valley-bottom wetland

4.2 Present Ecological Status for the Leeufontein Sub-quaternary reach B20E-1290

Present Ecological State		Ecological Importance		Ecological Sensitivity	
D (Largely Modified)		**Moderate**		**Moderate**	
Variable	**Status**	**Variable**	**Status**	**Variable**	**Status**
Modifications to Instream Habitat Continuity	Large	Fish species per sub quaternary catchment	6	Fish Physico-Chemical sensitivity description	High
Modifications to Riparian/ Wetland Zone Continuity	Moderate	Invertebrate taxa per sub quaternary catchment	27	Fish No-flow sensitivity description	High
Modifications to Riparian/ Wetland Zones	Moderate	Habitat Diversity Class	Moderate	Invertebrate Physico-Chemical sensitivity	Moderate
Potential Flow Modifications	Large	Instream Migration Link Class	Moderate	Invertebrate velocity sensitivity	High
Potential Physico-Chemical Modifications	Serious	Riparian-Wetland Zone Migration Link	High	Stream size sensitivity to modified flow/water level changes description	High
		Instream Habitat Integrity Class	Moderate	Riparian-Wetland Vegetation intolerance to water level changes description	High
Anthropogenic Impacts					
Anthropogenic impacts identified within the sub-quaternary catchment included bed stabilisation, low water crossings, erosion, alien vegetation, inundation, vegetation removal, irrigation, runoff/effluent from irrigation and mining, grazing and trampling, large amounts of abstraction and agricultural land.					

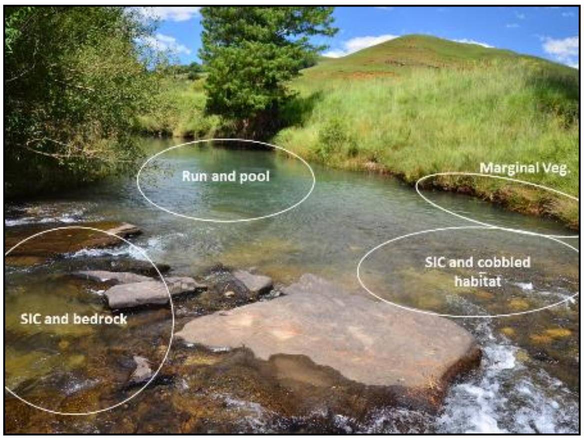
4.3 Present Ecological Status for the Wilge Sub-quaternary reach B20F-1150

Present Ecological State		Ecological Importance		Ecological Sensitivity	
C (Moderately Modified)		**High**		**Very High**	
Variable	**Status**	**Variable**	**Status**	**Variable**	**Status**
Modifications to Instream Habitat Continuity	Moderate	Fish species per sub quaternary catchment	11	Fish Physico-Chemical sensitivity description	Very High
Modifications to Riparian/ Wetland Zone Continuity	Small	Invertebrate taxa per sub quaternary catchment	52	Fish No-flow sensitivity description	Very High
Modifications to Riparian/ Wetland Zones	Moderate	Habitat Diversity Class	Moderate	Invertebrate Physico-Chemical sensitivity	Very High
Potential Flow Modifications	Large	Instream Migration Link Class	High	Invertebrate velocity sensitivity	Very High
Potential Physico-Chemical Modifications	Moderate	Riparian-Wetland Zone Migration Link	Very High	Stream size sensitivity to modified flow/water level changes description	High
		Instream Habitat Integrity Class	High	Riparian-Wetland Vegetation intolerance to water level changes description	High
Anthropogenic Impacts					
Anthropogenic impacts identified within the sub-quaternary catchment included bed stabilisation, recreational activities, grazing and trampling, chicken farming, low water crossings, runoff/effluent from irrigation, sedimentation, small farm dams, vegetation removal, large amounts of abstraction, alien vegetation, irrigation, roads and serious levels of agriculture.					

5 METHODOLOGY

Various assessments conducted during the survey are illustrated in Figure 2. Full methodology can be found in Appendix A.

***In situ* & *Ex situ* water quality analyses**



Habitat Assessments (IHAS)

Kick and sweep sampling method, SASS5 (South African Scoring System Version 5)

Figure 2: Methodologies applied during the aquatic survey

5.1 Biotic Integrity Based on SASS5 Results

Reference conditions reflect the best conditions that can be expected in rivers and streams within a specific area and also reflect natural variation over time. These reference conditions are used as a benchmark against which field data can be compared. Modelled reference conditions for the Highveld - upper Ecoregions were obtained from Dallas (2007) (Table 3). The biological bands for the Highveld - upper Ecoregion is presented in Figure 3.

It is important to note that the biological bands were reassigned from the Highveld – lower (used in previous biomonitoring reports) to the Highveld - upper Ecoregion (current report). This should be kept in mind when assessing previous biomonitoring reports

Table 3: Modelled reference conditions for the Highveld - upper ecoregion based on SASS5 and ASPT scores (adapted from Dallas, 2007)

SASS Score	ASPT*	Class	Description
> 240	> 6.8	A	Unimpaired. High diversity of taxa with numerous sensitive taxa.
189 - 240	6.3 – 6.8	B	Slightly impaired. High diversity of taxa, but with fewer sensitive taxa.
154 - 188	5.9 - 6.3	C	Moderately impaired. Moderate diversity of taxa.
120 - 153	5.3 – 5.9	D	Considerably impaired. Mostly tolerant taxa present.
< 120	< 5.3	E/F	Severely impaired. Only tolerant taxa present.

*** Average Score per Taxa**

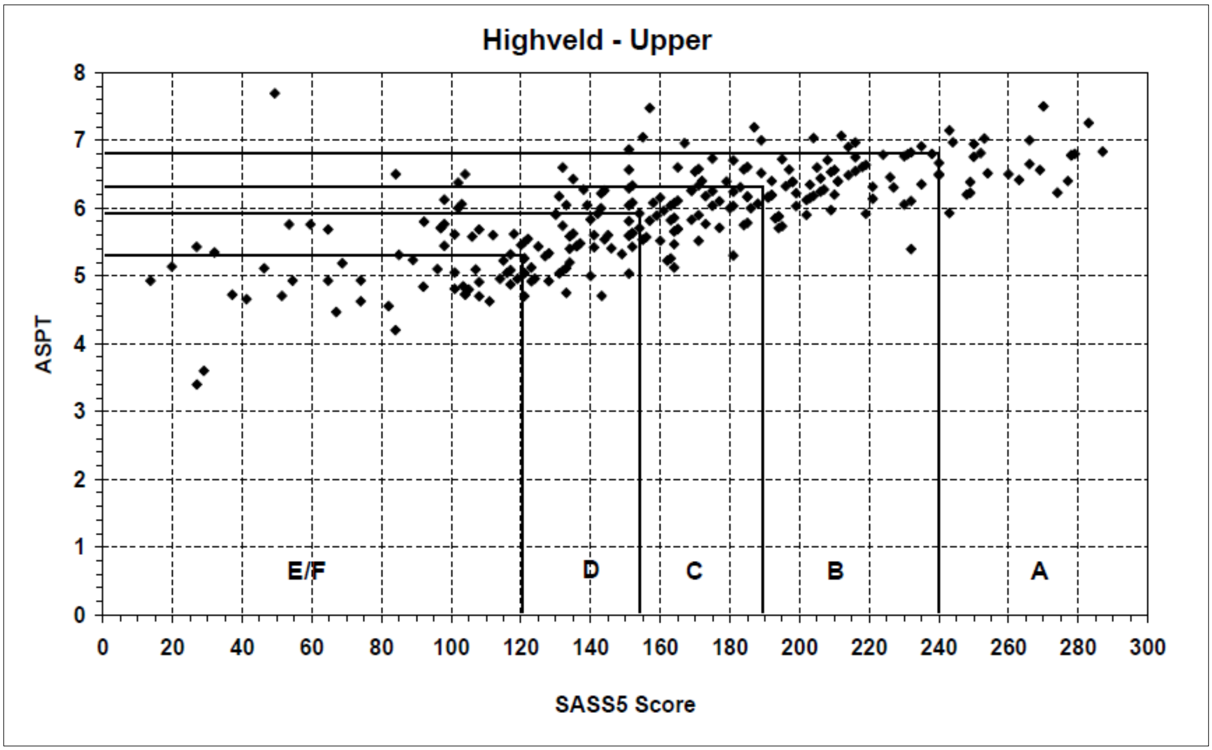


Figure 3: Biological Bands for the Highveld - Upper Ecoregion, calculated using percentiles

5.2 Expected Fish Species

A list of the eleven expected fish species is presented in Table 4 (Skelton, 2001; DWS, 2013). The species richness within the Leeufontein sub-quaternary catchment is considered moderate while high in the Wilge sub-quaternary catchment, and furthermore the species within the Wilge reach are generally considered to require largely unmodified physico-chemical conditions to survive and breed. Furthermore, species in the reach require flow during all phases of their life-cycle, often preferring fast flow clear waters for breeding and survival (DWAF, 2013).

Table 4: Expected species list for the project area

Scientific name	Common name	IUCN Status	Vlak1, 2 & 3	Vlak4 & 5
Amphilius uranoscopus	Stargazer (Mountain Catfish)	LC		X
Barbus anoplus	Chubbyhead Barb	LC	X	X
Barbus neefi	Sidespot Barb	LC	X	X
Barbus paludinosus	Straightfin Barb	LC	X	X
Barbus trimaculatus	Threespot Barb	LC		X
Chiloglanis pretoriae	Shortspine Suckermouth (Rock Catlet)	LC		X
Clarias gariepinus	Sharptooth catfish	LC	X	X
Labeobarbus marequensis	Largescale Yellowfish	LC		X
Labeobarbus polylepis	Smallscale Yellowfish	LC		X
Pseudocrenilabrus philander	Southern mouthbrooder	LC	X	X
Tilapia sparrmanii	Banded tilapia	LC	X	X

LC - Least Concern; X – Expected at site

5.2.1 Presence of Species of Conservation Concern

The conservation status of the indigenous fish species was assessed in terms of the IUCN Red List of Threatened Species (IUCN, 2014). Based on this assessment no species of special concern occur within the reach.

6 RESULTS & DISCUSSIONS

6.1 *In situ* water quality

In situ water quality analyses was conducted at all sites assessed during the 30th of August 2015 (low flow), 15th of January 2016 (high flow) and the 22nd of July 2016 (low flow) surveys. These results are important to assist in the interpretation of biological results due to the direct influence water quality has on aquatic life forms. The results of the survey are presented in Table 5.

Table 5: *In situ* water quality results for the Vlakvarkfontein sites

Site	pH	Conductivity (µS/cm)	DO (mg/l)	DO Saturation (%)	Temperature (°C)
TWQR*	**6.5-9.0**	**<700**	**>5.00**	**>80**	**5-30**
Low Flow 2015					
Vlak1	**6.01**	**906**	8.25	110.6	21.3
Vlak2	**6.31**	**821**	5.89	**73.9**	17.1
Vlak3	**6.42**	**882**	6.87	90.1	19.5
Vlak4	**6.49**	**1017**	7.73	106.8	22.4
Vlak5	6.62	331	7.01	93.6	20.3
High Flow 2016					
Vlak1	7.60	**1173**	**4.40**	**60.2**	22.6
Vlak2	7.78	**1123**	5.11	86.1	22.2
Vlak3	8.33	**915**	7.47	109.0	23.9
Vlak4	8.89	**1075**	5.84	96.8	29.1
Vlak5	7.28	197.4	**3.01**	**54.2**	**34.7**
Low Flow 2016					
Vlak1	8.65	**1109**	8.60	105.7	11.7
Vlak2	7.85	**1038**	9.75	98.3	10.5
Vlak3	8.73	**1010**	9.34	109.6	13
Vlak4	8.58	**980**	7.62	101.5	14.8
Vlak5	8.14	380	8.18	100.3	15.1

*Levels exceeding recommended guideline levels (DWAF, 1996) are indicated in red.

6.1.1 pH

Most fresh waters are usually relatively well buffered and more or less neutral, with a pH range from 6.5 to 8.5, and most are slightly alkaline due to the presence of bicarbonates of the alkali and alkaline earth metals (Barbour *et al*, 1996). The pH target for fish health is presented as ranging between 6.5 and 9.0 (Table 5). During the low flow survey which took place in August 2015, the pH levels at sites Vlak1 to Vlak4 fell outside of the recommended guideline levels of 6.5 to 9.0 (DWAF, 1996), which would have a negative effect on local aquatic biota at the time of the survey. A change took place with pH readings measuring more alkaline at all five sites and within the guideline levels during the high flow survey in January 2016. These recent readings are no reason for concern. The July 2016 survey showed pH levels to remain highly alkaline with readings measuring near the upper guideline limits. These readings are not a limiting factor for aquatic biota but should be monitored closely.

6.1.2 Electrical Conductivity (EC)

Electrical conductivity (EC) is a measure of the ability of water to conduct an electrical current. This ability is a result of the presence in water of ions such as carbonate, bicarbonate, chloride, sulphate, nitrate, sodium, potassium, calcium and magnesium, all of which carry an electrical charge. Conductivity levels at sites Vlak1 to Vlak4 exceeded the recommended guideline levels during all three surveys, indicating increased levels of dissolved salts. An increase occurred with higher readings measured in January 2016. These elevated levels may have a negative effect on local aquatic biota causing reason for concern and should be monitored.

6.1.3 Dissolved Oxygen (DO)

The maintenance of adequate Dissolved Oxygen (DO) is critical for the survival of aquatic biota as it is required for the respiration of all aerobic organisms (DWS, 1996). Therefore, DO concentration provides a useful measure of the health of an ecosystem (DWS, 1996). The median guideline for DO for the protection of freshwater fish, determined by a variety of fish faunas is > 4 - 5 mg/ℓ (Doudoroff & Shumway, 1970 and DWS, 1996). Exposure to DO concentrations below 2 mg/l will lead to death of most fishes (UNESCO, 1996). Percentage saturation (% sat) is the amount of oxygen (O_2) in a litre of water relative to the total amount of oxygen that the water can hold at that temperature. DO levels fluctuate seasonally and diurnally over a 24-hour period and vary with water temperature and altitude (DWS, 1996). The South African Water Quality Guidelines (1996), state that the target water quality range (TWQR) for DO to protect aquatic biota through most life stages is 80% - 120% of saturation, and that saturation levels below 40% would be lethal. All sites were within the recommended guideline DO levels during low flow, indicating DO would not have had a negative effect on local aquatic biota at the time of the survey. Readings were similar for the high flow survey with the exception of sites Vlak1 and Vlak5. These two sites were below the TWQR and may have a negative effect on local aquatic biota. All sites were within the recommended guideline DO levels during 2016 low flow, indicating DO would not have had a negative effect on local aquatic biota at the time of the survey.

6.1.4 Water Temperature

Water temperature plays an important role in aquatic ecosystems by affecting the rates of chemical reactions and therefore also the metabolic rates of organisms (DWS, 1996). Temperature affects the rate of development, reproductive periods and emergence time of organisms (DWS, 2005b). Temperature varies with season and the life cycles of many aquatic macroinvertebrates are cued to temperature (DWS, 2005b). During the low flow survey water temperatures at all five sites were within the guideline range and considered normal autumn temperatures. The high flow survey water temperatures at Vlak1 to Vlak4 were within the guideline range and considered normal summer temperatures showing an increase from the low flow survey temperatures. Water temperatures at site Vlak5 exceeded the TWQR with a reading of 34.7°C which may have a negative effect on local aquatic biota causing reason for concern. The 2016 low flow survey water temperatures at all five sites were within the guideline range and considered normal winter temperatures showing a decrease from the 2016 high flow survey temperatures.

The temporal trends for the *in situ* water quality were investigated based on recent results together with results from previous studies conducted by Digby Wells from 2013 to 2014. The results are displayed in the following figures:

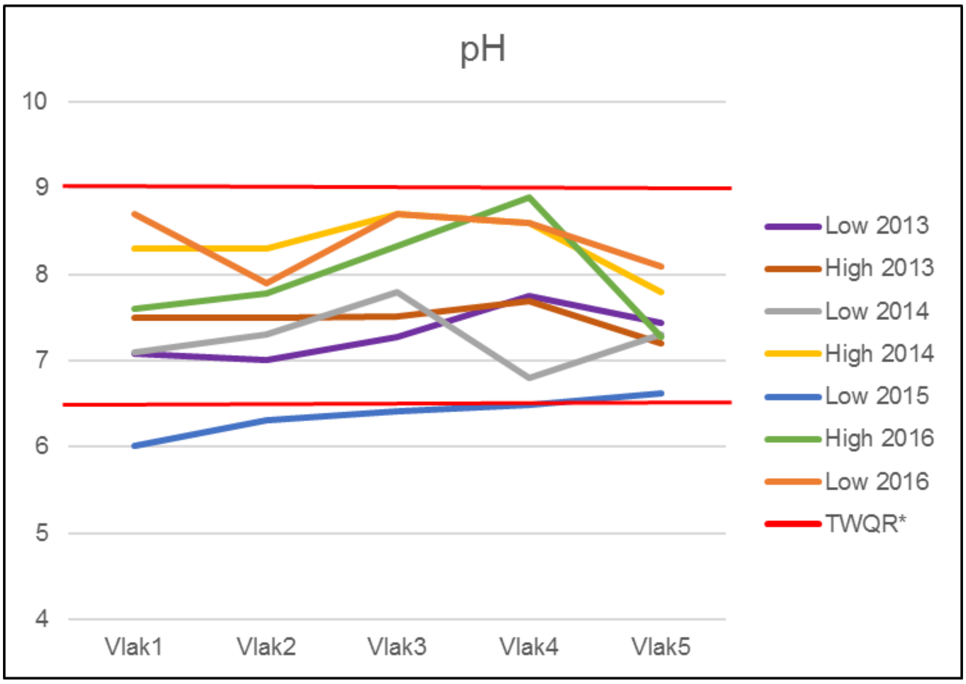


Figure 4: pH temporal trends for Vlakvarkfontein Colliery (2013-2016)

The pH remained relatively stable overtime only falling below the TWQR during the low flow 2015 survey. Site Vlak4 showed the most variation overtime but remained within guideline values. pH showed an increase downstream of the Vlakvarkfontein mining operation at sites Vlak3, Vlak4 and Vlak5. pH should be continued to be monitored.

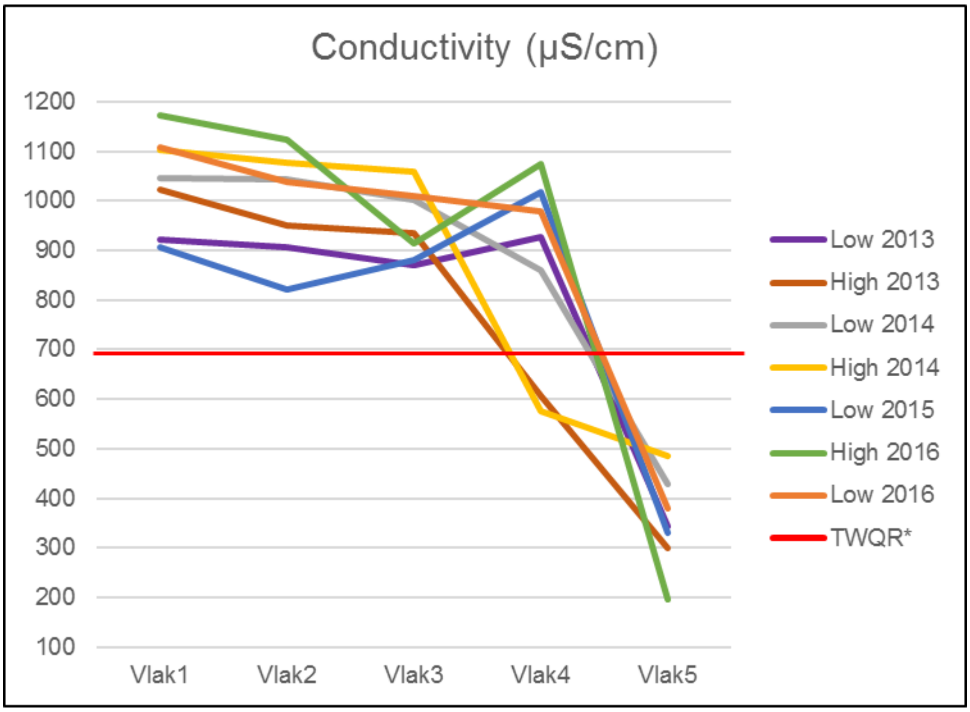


Figure 5: Conductivity temporal trends for Vlakvarkfontein Colliery (2013-2016)

Conductivity levels showed a steady decline downstream with the lowest levels recorded downstream of the mining operation at sites Vlak4 and Vlak5. The lower conductivity levels recorded downstream of the Vlakvarkfontein mining operation at sites Vlak4 and Vlak5 may be attributed to a dilution factor experienced with the Wilge River and Blesbok Rivers. Conductivity levels remained above guideline limits between sites Vlak1 and Vlak4 and should be monitored. These elevated levels may be a limiting factor to aquatic biota.

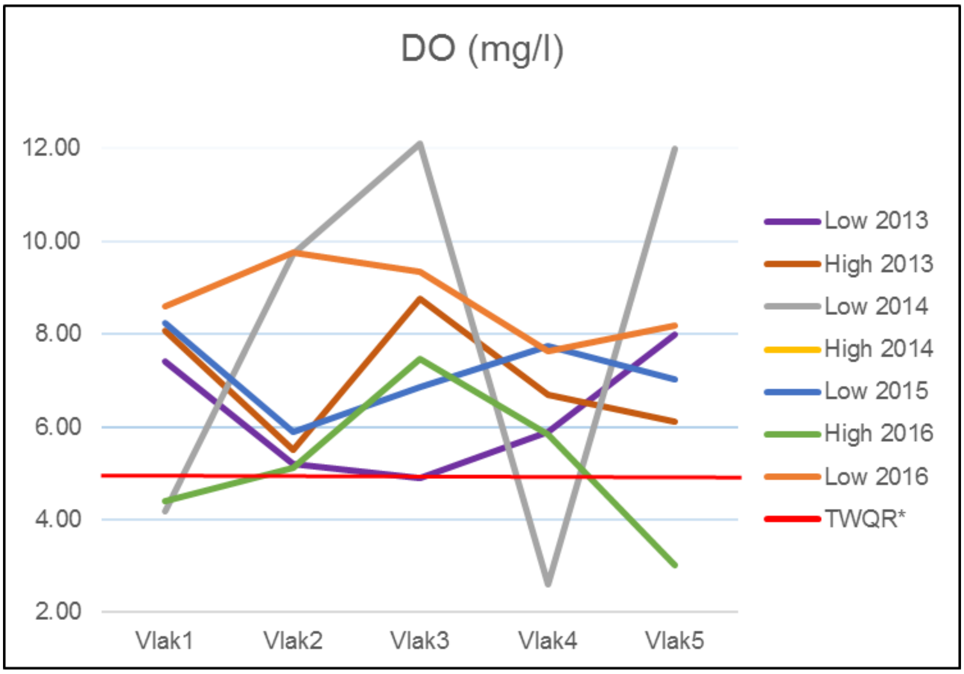


Figure 6: Dissolved Oxygen temporal trends for Vlakvarkfontein Colliery (2013-2016)

The DO concentration levels, although all over the place, showed a decrease at site Vlak2 and increased further downstream from sites Vlak3 to Vlak5 with some fluctuation. Generally, the DO concentration for the project area was adequate for aquatic biota with the exceptions of sites Vlak1 in 2014 low flow and 2016 high flow, Vlak4 during 2014 low flow and Vlak5 during the 2016 high flow. During these times the DO was below the TWQR with limiting effects on aquatic biota. Site Vlak2 showed the lowest levels of the three sites located on the Leeufontein River (Vlak1 to Vlak3) which may be due to the site located adjacent to the mining operation. DO concentration levels remained adequate in the Wilge River at site Vlak4 and Blesbok River at site Vlak5, both loacted downstream of Vlakvarkfontein mine.

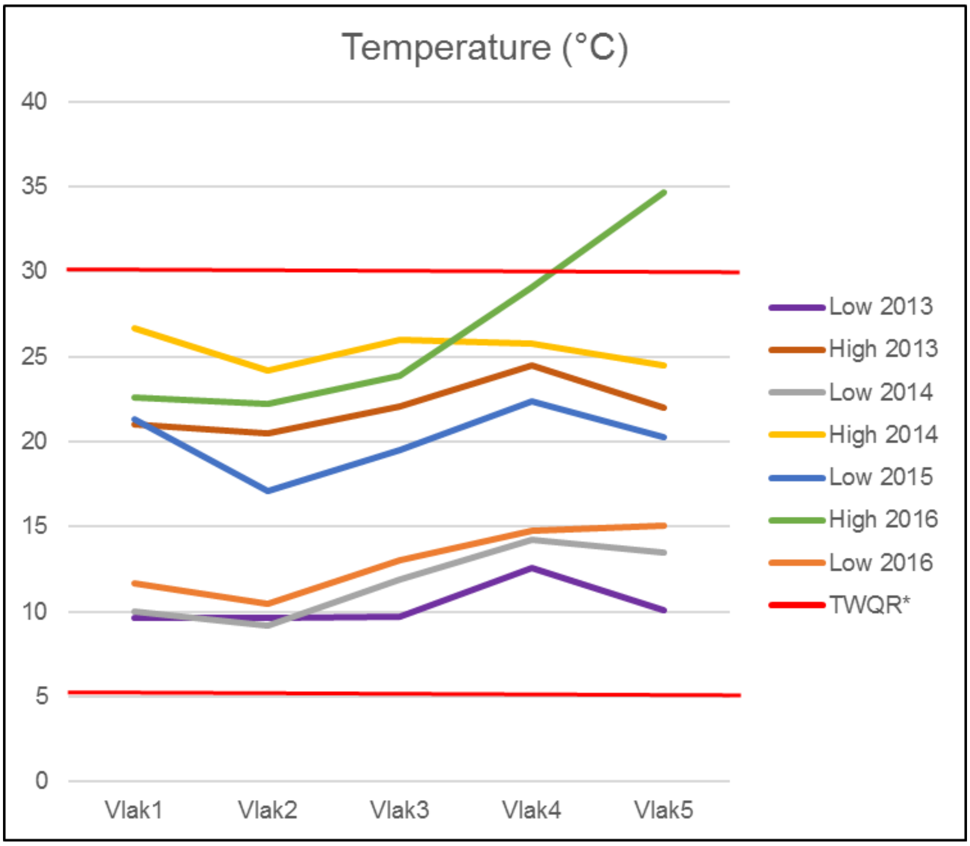


Figure 7: Temperature temporal trends for Vlakvarkfontein Colliery (2013-2016)

Temperature recordings were within guideline levels across the entire project area over time with the exception of the recent 2016 high flow. The temperatures recorded are considered normal seasonal temperatures and are of no concern to aquatic biota. The 2016 high flow reading of 34.7°C may have a negative effect (physiological stresses) on local aquatic biota causing reason for concern. No notable differences were noted in temperatures that may be attributed to the mining operation.

6.2 Habitat assessment

6.2.1 Invertebrate Habitat Assessment System (IHAS)

The IHAS index was developed by McMillan (1998) for use in conjunction with the SASS5 protocol. The IHAS results for the survey are presented in Table 6.

Table 6: IHAS Score at the four sites during the surveys

Season	Site	Score	Suitability
Low Flow 2015	Vlak1	52	Poor
	Vlak2	55	Adequate
	Vlak3	57	Adequate

	Vlak4	65	**Good**
High Flow 2016	**Vlak1**	54	**Poor**
	Vlak2	56	**Adequate**
	Vlak3	61	**Good**
	Vlak4	72	**Good**
Low Flow 2016	**Vlak1**	51	**Poor**
	Vlak2	55	**Adequate**
	Vlak3	53	**Poor**
	Vlak4	66	**Good**

Habitat at sites from poor at Vlak1 on the Leeufontein River, to Good at Vlak4 on the Wilge. Low IHAS scores were attributed to low water levels, sedimentation, and inundation of available habitat due to algae. Some suitable rocky substrate was present at site Vlak2, Vlak3 and Vlak4 which benefits aquatic biota. Although no IHAS or macroinvertebrate sampling was carried out at site Vlak5, it should be stressed that the poorly maintained dirt road crossing the site had serious damage after recent heavy rains. This resulted in the soil berms that keep the soils from flowing from the road collapsing, allowing heavy sedimentation and smothering of the instream channel (Figure 8).

Figure 8: Heavy sedimentation and smothering of instream channel from poorly maintained dirt road

IHAS scores over time showed that habitat at sites Vlak1 has remained poor, Vlak2 and Vlak3 alternated between poor and good, while Vlak4 was good occasionally scoring very good. Habitat showed a trend of improving downstream through the project area with the Wilge River and Blesbok River having better habitat availability than the Leeufontein River.

Low flow 2016

The main channel of the Blesbok River at Vlak5 has been reworked to cater for natural flow through the digging of the channel, removal of sediment build-up (noted in the 2016 high flow report) and installation of culverts under the road crossing (Figure 9). Additionally, side channels catering for stormwater from surface runoff from the road were created diagonal to the main channel (Figure 10). These activities will go a long way to re-establishing the biotic integrity of the Blesbok River. It is recommended that the side channels banks be reworked to create a gentle gradient. The steeper the bank, the more susceptible the embankments are to erosion. It is further recommended to plant vigorous growing indigenous grasses in these side channels to protect the soils (limiting erosion) while slowing the water and allowing infiltration of stormwater. Steep banks do not revegetate easily if at all, remaining exposed to erosion. Aggregate clumps can be placed across the stormwater channels (both the newly dug channels and the road side drainage leading into these channels) at regular intervals to attenuate flows and trap sediment. An example of a typical stormwater channel can be seen in Figure 11. The concreting of these channels will increase surface run-off velocity of the water entering the Blesbok River resulting in scouring and erosion of the Blesbok River at their confluence. Concreting of the side channel should be avoided.

Figure 9: Blesbok River at Vlak5 cleared of sediment build-up with recreation of channel

Figure 10: Side channel with steep banks catering for stormwater runoff at Vlak5

Figure 11: Example of a planted stormwater channel with aggregate attenuation dams recommended for Vlak5

6.3 Aquatic macroinvertebrates

The aquatic macroinvertebrate results for the 2015 low and 2016 high and low flow surveys are presented in Table 7.

Table 7: Macroinvertebrate assessment results recorded during the three survey periods

Season	**Low Flow 2015**				**High Flow 2016**				**Low Flow 2016**			
Site	**Vlak 1**	**Vlak 2**	**Vlak 3**	**Vlak 4**	**Vlak 1**	**Vlak 2**	**Vlak 3**	**Vlak 4**	**Vlak 1**	**Vlak 2**	**Vlak 3**	**Vlak 4**
SASS Score	89	91	112	140	43	88	84	95	60	49	66	63
No. of Taxa	19	20	22	25	10	21	17	18	13	13	16	14
ASPT*	**4.7**	**4.6**	**5.1**	**5.6**	**4.3**	**4.2**	**4.9**	**5.3**	**4.6**	**3.8**	**4.1**	**4.5**
Category	**E/F**	**E/F**	**E/F**	**D**	**E/F**	**E/F**	**E/F**	**E/F**	**E/F**	**E/F**	**E/F**	**E/F**

*ASPT: Average score per taxon

SASS scores recorded ranged from 89 to 140 at sites Vlak1 and Vlak4 respectively during the 2015 low flow survey. ASPT ranged between 4.6 and 5.6 at sites Vlak2 and Vlak4 respectively.

SASS5 scores recorded during the 2016 high flow survey ranged from 43 to 93 at sites Vlak1 and Vlak4 respectively. ASPT ranged between 4.3 and 5.3 at sites Vlak2 and Vlak4 respectively.

SASS scores recorded ranged from 49 to 66 at sites Vlak2 and Vlak3 respectively during the 2016 low flow survey. ASPT ranged between 3.8 and 4.6 at sites Vlak2 and Vlak1 respectively. The 2016 low flow survey showed much lower values compared to the previous low flow survey.

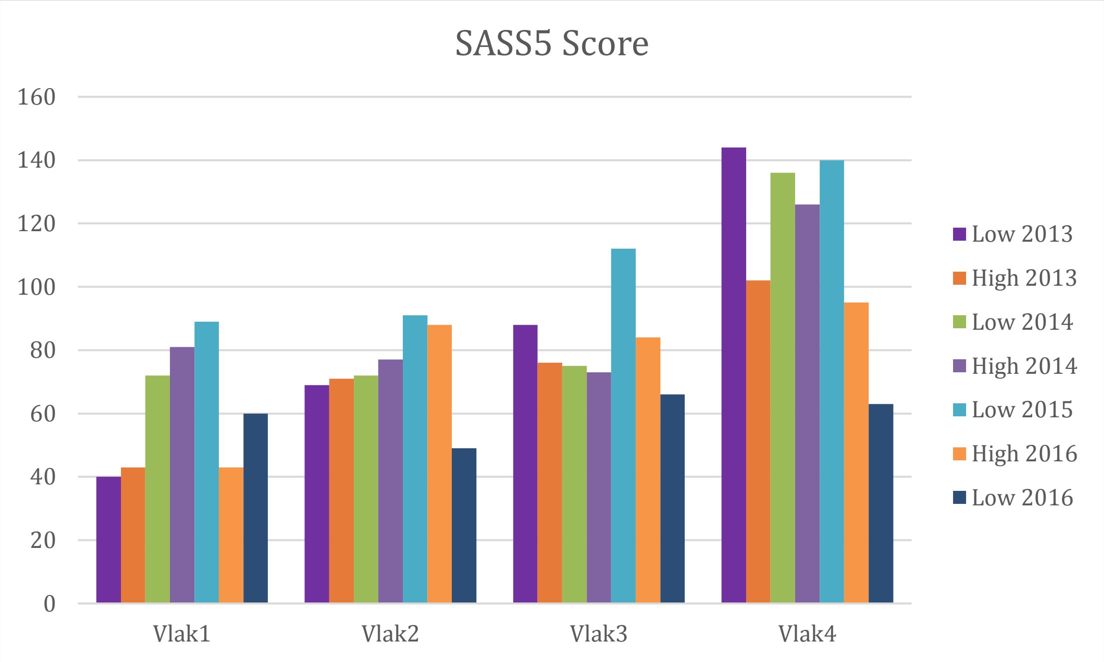


Figure 12: SASS5 scores for Vlakvarkfontein Colliery (2013-2016)

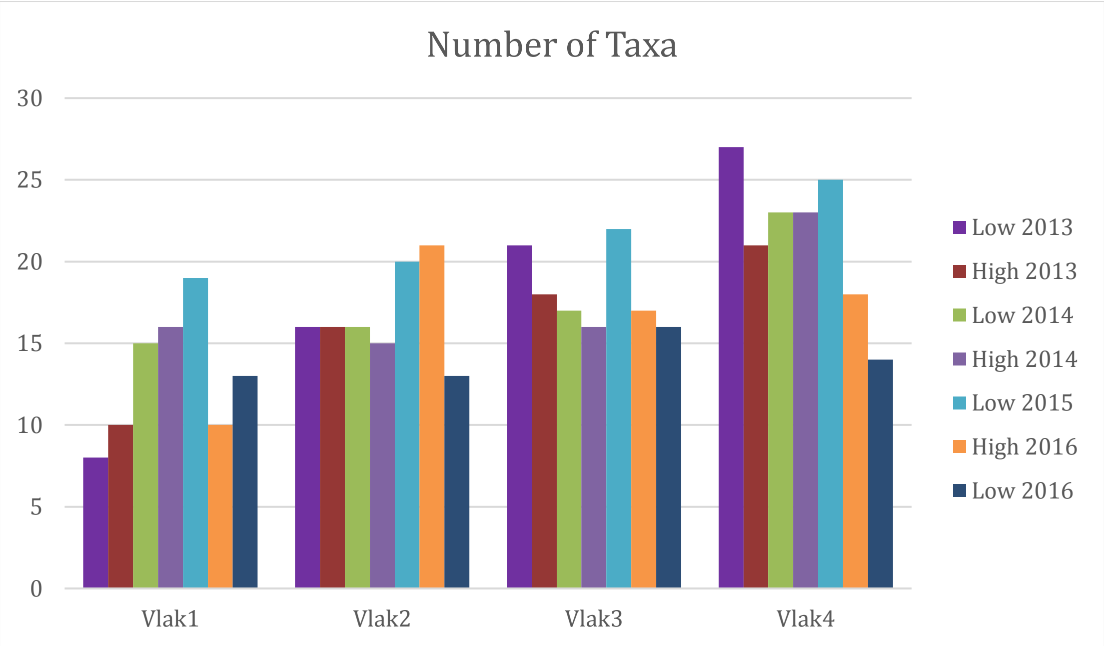


Figure 13: Number of invertebrate taxa for Vlakvarkfontein Colliery (2013-2016)

From Figure 12 and Figure 13 it can be seen that the 2015 low flow SASS5 scores and number of taxa is higher than previous surveys at all sites. The difference in SASS5 scores and number of taxa has changed the overall category of the site Vlak4 from a Class E/F to a Class D, with the other three sites changes not great enough to change the overall category. Since the 2015 low flow survey, Vlak4 has decreased back to Class E/F. The water quality and invertebrate trends indicate conditions over the period of 3 years in the Leeufontein River have improved slightly, whilst the Wilge River (Vlak4) has shown no particular trend.

6.4 Biotic Integrity based on SASS5 Results

Biotic integrity at sites all four sites were categorised as seriously modified (Class E/F) with only tolerant taxa present (Table 7). All sites showed a decrease in ASPT from the 2015 low flow survey. The results from the 2016 low flow survey indicate that the local aquatic biota in the aquatic systems associated with the Vlakvarkfontein colliery are in an impacted state. The impacts affecting the biotic integrity may relate to algal presence, limited riffle habitat, livestock impacts, sedimentation and reduced water quality.

During recent surveys, the diversity of Ephemeroptera, Plecoptera and Trichoptera (EPT) taxa at all four sites were low. These taxa are generally habitat specialists, with preference for diverse instream habitats and flows, such as stones in riffles, runs and pools. These taxa are also generally sensitive to physico-chemical water quality modifications. The poor EPT diversity indicates the low habitat and reduced water quality at the sampled sites. The ASPT scores at all four sites indicates that a high percentage of tolerant taxa were recorded during recent surveys.

Table 8: Category ratings based on SASS5 scores for Vlakvarkfontein Colliery (2013-2016)

	Season	Vlak1	Vlak2	Vlak3	Vlak4
Category	Low 2013	E/F	E/F	E/F	D
	High 2013	E/F	E/F	E/F	E/F
	Low 2014	E/F	E/F	E/F	D
	High 2014	E/F	E/F	E/F	D
	Low 2015	E/F	E/F	E/F	D
	High 2016	E/F	E/F	E/F	E/F
	Low 2016	E/F	E/F	E/F	E/F

Table 8 shows the general state of the aquatic systems associated with Vlakvarkfontein Colliery to be in a severely impaired state with only tolerant aquatic invertebrate taxa present on site.

6.5 Fish

Five species of fish were collected during the 2015 low, 2016 high and low flow surveys out of a possible 11 expected species for the two sub-quaternary catchments (Table 9). Fish were collected as by-catch during sampling of the aquatic macroinvertebrates with SASS5 methodology. Data is presented in Table 9:

Table 9: Fish species collected in the Vlakvarkfontein project area

Scientific name	Common name	Low Flow 2015	High Flow 2016	Low Flow 2016
Barbus anoplus	Chubbyhead barb	-	Vlak 1,2,3,4	Vlak 1
Barbus paludinosus	Straightfin barb	Vlak 2	-	-
Gambusia affinis	Mosquitofish	Vlak 2	Vlak 1,2,3,4	Vlak 1,3,4
Pseudocrenilabrus philander	Southern mouthbrooder	-	Vlak 2,3,4	-
Tilapia sparmanii	Banded tilapia	-	Vlak 2,4	-

Red - Exotic

All fish species collected during the Vlakvarkfontein biomonitoring surveys are tolerant of physico-chemical modifications with no particular sensitivity to bed or channel modification. *Gambusia affinis* is an exotic fish species that was found in abundance across the entire project area. The 2015 and 2016 biomonitoring fish results were compared to the previous biomonitoring results from 2013 and 2014 conducted by Digby Wells (Table 10).

Table 10: Fish species collected over time for Vlakvarkfontein Colliery

Scientific name	2013	Low Flow 2014	High Flow 2015	Low Flow 2015	High Flow 2016	Low Flow 2016
Barbus anoplus	X	X	X	-	X	X
Barbus paludinosus	X	-	X	X	-	-
Gambusia affinis	X	X	X	X	X	X
Pseudocrenilabrus philander	X	-	-	-	X	-
Tilapia sparrmanii	-	X	X	-	X	-

Red – Exotic X – captured - – Absent

A number of fish species were collected during the various Vlakvarkfontein biomonitoring surveys. These species include *Barbus anoplus*, *Barbus paludinosus, Pseudocrenilabrus philander, Tilapia sparrmanii* and the exotic species *Gambusia affinis*. *Barbus anoplus* shows a very high preference for slow-flowing water bodies and overhanging vegetation especially aquatic macrophytes (Kleynhans, 2003). Additionally, *B. anoplus* shows a moderate trophic and habitat specialisation, as well as a moderate need for flowing water and a moderate requirement for unmodified water quality (Kleynhans, 2003). Based on the relative tolerance of the sampled species to the surrounding environment as well as the absence of many of the expected fish species, it may be said that the aquatic systems surrounding Vlakvarkfontein Colliery are in an impacted state.

7 CONCLUSION & RECOMMENDATIONS

The desktop review revealed the Leeufontein River system to be in a largely impacted state and the Wilge River system to be in a moderately impacted state.

Pressures from poor bed stabilisation, low water crossings, erosion and sedimentation, alien vegetation, inundation, recreational activities, chicken farming, small farm dams, vegetation removal, irrigation, runoff/effluent from irrigation and mining, grazing and trampling by livestock, large amounts of water abstraction, roads and serious levels of agriculture. These impacts have resulted in impacts to instream habitat (flow, bed and channel modifications) within the two rivers, and have further compromised water quality.

Survey results indicate that the Leeufontein River, Wilge River and Blesbok River reaches assessed are in a poor condition. The water quality and habitat have shown little to no improvement with a decline in water quality at sites Vlak1 to Vlak5 from previous biomonitoring survey conditions negatively impacting on the aquatic biota. Water quality showed conductivity continuing at elevated levels due to salt in the systems. It is unlikely that water quality issues stem entirely from Vlakvarkfontein Colliery but may be attributed from a combination of impacts within the catchments.

The recent biomonitoring run results have not deviated from trends noted in previous biomonitoring results with the aquatic systems remaining in an impacted condition. Some recent reshaping of the Blesbok River channel was seen during the July 2016 low flow survey. This reshaping will result in the improvement of the biotic integrity in the long run. Some recommendations have been put forth regarding these reshaping activities and stormwater channels according best practice methodologies.

Continued biomonitoring should be carried out to monitor trends in ecological changes. Further biomonitoring programmes should include fish community structures as well as *ex situ* water quality analyses.

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9 Appendix A Methodology

9.1 *In Situ* Water Quality

During the survey a portable Exstick 2 multimeter was used to measure the following parameters *in situ*:

- pH;
- Conductivity;
- Dissolved Oxygen (DO); and
- Water Temperature.

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

9.2 Habitat Assessment

Habitat availability and diversity are major attributes for the biota found in a specific ecosystem, and thus knowledge of the quality of habitats is important in an overall assessment of ecosystem health. Habitat assessment can be defined as the evaluation of the structure of the surrounding physical habitat that influences the quality of the water resource and the condition of the resident aquatic community (Barbour *et al*. 1996). Both the quality and quantity of available habitat affect the structure and composition of resident biological communities (USEPA, 1998). Habitat quality and availability plays a critical role in the occurrence of aquatic biota. For this reason habitat evaluation is conducted simultaneously with biological evaluations to facilitate the interpretation of results.

9.2.1 Invertebrate Habitat Assessment System

The quality of the instream and riparian habitat influences the structure and function of the aquatic community in a stream; therefore assessment of the habitat is critical to any assessment of ecological integrity. The Invertebrate Habitat Assessment System (IHAS, version 2) was applied at each of the sampling sites in order to assess the availability of habitat biotopes for macroinvertebrates. The IHAS was developed specifically for use with the SASS5 index and rapid biological assessment protocols in South Africa (McMillan, 1998). The index considers sampling habitat and stream characteristics. The sampling habitat is broken down into three sub-sections namely Stones-In-Current (SIC), Vegetation (VEG), Gravel Sand & Mud (GSM) and other habitat/ general. It is presently thought that a total IHAS score of over 65% represents good habitat conditions, a score over 55% indicates adequate/fair habitat conditions (McMillan, 1998) (Table 18).

Table 11: Invertebrate Habitat Assessment System Scoring Guidelines

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

9.3 Aquatic Macroinvertebrates

The monitoring of aquatic macroinvertebrates forms an integral part of the monitoring of the health of an aquatic ecosystem as they are relatively sedentary and enable the detection of localised disturbances. Their relatively long life histories (±1 year) allow for the integration of pollution effects over time. Field sampling is easy and since the communities are heterogeneous and several phyla are usually represented, response to environmental impacts is normally detectable in terms of the community as a whole (Hellawell, 1977). Aquatic macroinvertebrates were sampled using the qualitative kick sampling method called SASS5 (South African Scoring System, version 5) (Dickens & Graham, 2002). The SASS5 protocol is a biotic index of the condition of a river or stream, based on the resident macroinvertebrate community, whereby each taxon is allocated a score according to its level of tolerance to river health degradation (Dallas, 1997). This method relies on churning up the substrate with your feet and sweeping a finely meshed SASS net (mesh size of 1000 micron), over the churned up area.

The SASS5 index was designed specifically for the assessment of perennial streams and rivers and is not suitable for assessment of impoundments, isolated pools, wetlands or pans (Dickens & Graham, 2002). In the Stones-In-Current (SIC) biotope the net is rested on the substrate and the area immediately upstream of the net disturbed by kicking the stones over and against each other to dislodge benthic invertebrates. The net is also swept under the edge of marginal and aquatic vegetation (VEG). Kick samples are collected from areas with gravel, sand and mud (GSM) substrates. Identification of the organisms is made to family level (Thirion *et al*., 1995; Davies & Day, 1998; Dickens & Graham, 2002; Gerber & Gabriel, 2002).

The endpoint of any biological or ecosystem assessment is a value expressed either in the form of measurements (data collected) or in a more meaningful format by summarising these measurements into one or several index values (Cyrus *et al*., 2000). The indices used for this study were SASS5 Score and Average Score per Taxon (ASPT). The ASPT score is calculated as follows: SASS5 Score/ No. of Taxa.