AQUATIC BIO-MONITORING OF THE VAALBANKSPRUIT

Dry Season Survey (August 2020)

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EXECUTIVE SUMMARY

Knight Piésold (Pty) Ltd was appointed by Middelburg Ferrochrome (MFC) to conduct the bi-annual aquatic bio-monitoring of the Vaalbankspruit in Mpumulanga. Aquatic bio-monitoring is the utilisation of methods that use living organisms as a proxy for deducing water quality and ecosystem health and was used to identify any possible impacts of the MFC operations on the Vaalbankspruit. This report provides feedback on the August 2020 dry season survey and the notable aspects considered for monitoring may be summarised as follows:

Site 1 (Upstream Control Point)

- The *in-situ* concentrations of free and total chlorine exceeded the DWAF guidelines.
- Site 1 provided poor habitat availability, with an IHAS score of 43 %
- The invertebrate PES was categorised as Category F (Critically Modified).
- The general diatom-based water quality ecological category for Site 1 was A (High Quality)

SWR 3 (Upstream)

- The *in-situ* concentration of dissolved oxygen (%) exceeded the DWAF guidelines.
- Poor habitat availability was provided at SWR 3, with an IHAS score of 52 %
- The invertebrate PES was categorised as Category B (Largely natural with few modifications)
- The general diatom-based water quality ecological category for SWR 3 was Category B (Good Quality)

Z 08 (Drainage Channel)

- The point was dry, therefore there was no sample collected.

Site 2B (Mid-stream Point)

- The *in-situ* concentrations of free and total chlorine exceeded the DWAF guidelines.
- This site was not suitable for bio-monitoring as there was no distinct channel
- The general diatom-based water quality ecological category for Site 2B was Category B (Good Quality)

Site 3A (Downstream)

- The *in-situ* concentrations of conductivity and dissolved oxygen (%) exceeded the DWAF guidelines.
- Site 3A provided adequate habitat availability as it recorded an IHAS score of 60 %
- The invertebrate PES was categorised as Category C/D (Moderately Modified to Largely Modified)
- The general diatom-based water quality ecological category for Site 3A was Category C/D (Moderate Quality)

General and Recommendations

The wet and dry season bio-monitoring surveys should continue to monitor the impacts of MFC on the Vaalbankspruit and to determine any trends and seasonal variation on the receiving aquatic environment.

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1.0 INTRODUCTION

1.1 PROJECT DESCRIPTION

Middelburg Ferrochrome (Pty) Ltd, hereafter referred to as MFC, is situated within Middelburg, Mpumalanga. To comply with the Water Use Licence conditions from the Department of Water and Sanitation (DWS) aquatic bio-monitoring should be undertaken during the dry and wet season at the upstream and downstream monitoring points to determine the potential impact of the MFC operations on the Vaalbankspruit.

1.2 BACKGROUND

Knight Piésold (Pty) Ltd (KP) was appointed by MFC to conduct the bi-annual aquatic bio-monitoring of the Vaalbankspruit. The MFC facility was established in 1964 as a Low Carbon Ferrochrome production facility. Charge chrome was first produced on this site in 1974 by Middelburg Steel and Alloys (Pty) Ltd, which was acquired by Samancor in 1991, making it one of only a few alloy plants in the world able to produce both charge chrome and low carbon ferrochrome, which it stopped producing in 2015. It currently produces charge chrome from two Submerged-Arc Furnaces (SAF's), two Direct-Current (DC) Furnaces, a Pelletising and Sintering plant (PSP) and a metal recovery plant.

1.3 SCOPE OF WORK

The scope of this report is as follows:

- To provide feedback on the Aquatic Bio-monitoring for the August 2020 dry season survey;
- To assess the impacts of the MFC operations on the Present Ecological State (PES) of the Vaalbankspruit; and
- To provide mitigation and early detection of any impacts on the aquatic ecosystem due to the MFC operations.

2.0 SITE DESCRIPTION

MFC is situated along the southern portion of Middelburg, within the industrial area of the town. The location is presented in Figure 1 below.

Figure 1: General Locality of Middelburg Ferrochrome

2.1 GENERAL SITE CHARACTERISTICS

2.1.1 CATCHMENT MANAGEMENT

MFC falls within the Olifants Water Management Area, which is characterised by the following:

Table 1: Olifants Water Management Area

Quaternary catchments	B12D
Level 1 Ecoregion	Highveld – Lower Ecoregion
Rivers	Vaalbankspruit
Present Ecological State	Category E (Seriously Modified)

2.1.2 SITES SELECTED FOR AQUATIC BIO-MONITORING

In accordance with the WUL conditions the bio-monitoring sites were provided by the client. The GPS co-ordinates of each site were pre-assessed using GIS imagery and confirmed during the ground truth process. Five monitoring sites were surveyed to assess the Present Ecological State (PES) and the possible impacts of MFC operations on the receiving aquatic environment.

The bio-monitoring sites are illustrated in Figure 2 and further described in Table 2 below.

Table 2: General Description of the Bio-monitoring Sites

Site Code	Description	Position UTM (WGS 84)
Site 1	Upstream Control Point – Located within a cattle farm, this site is upstream of all MFC operational activities and serves as a reference point	25°49'20.38"S 29°29'27.43"E
SWR 3	Upstream Impact Monitoring Point – Located alongside the southern border of the MFC property, this site serves as the upstream monitoring point.	25°49'7.16"S 29°29'25.68"E
Z 08	Drainage Channel – A drainage channel which flows east towards the Vaalbankspruit from the nearby Wastewater treatment works.	25°48'51.37"S 29°28'55.62"E
Site 2B	Impact Monitoring Point – Situated between the CRD Slimes and the Kloof Slag disposal sites, this point serves as a direct impact monitoring point.	25°48'5.64"S 29°29'7.99"E
Site 3A	Downstream Impact Monitoring Point – Located along the northern boundary of the MFC property, this site is situated alongside a low-level culvert and stream crossing.	25°47'40.14"S 29°29'1.95"E

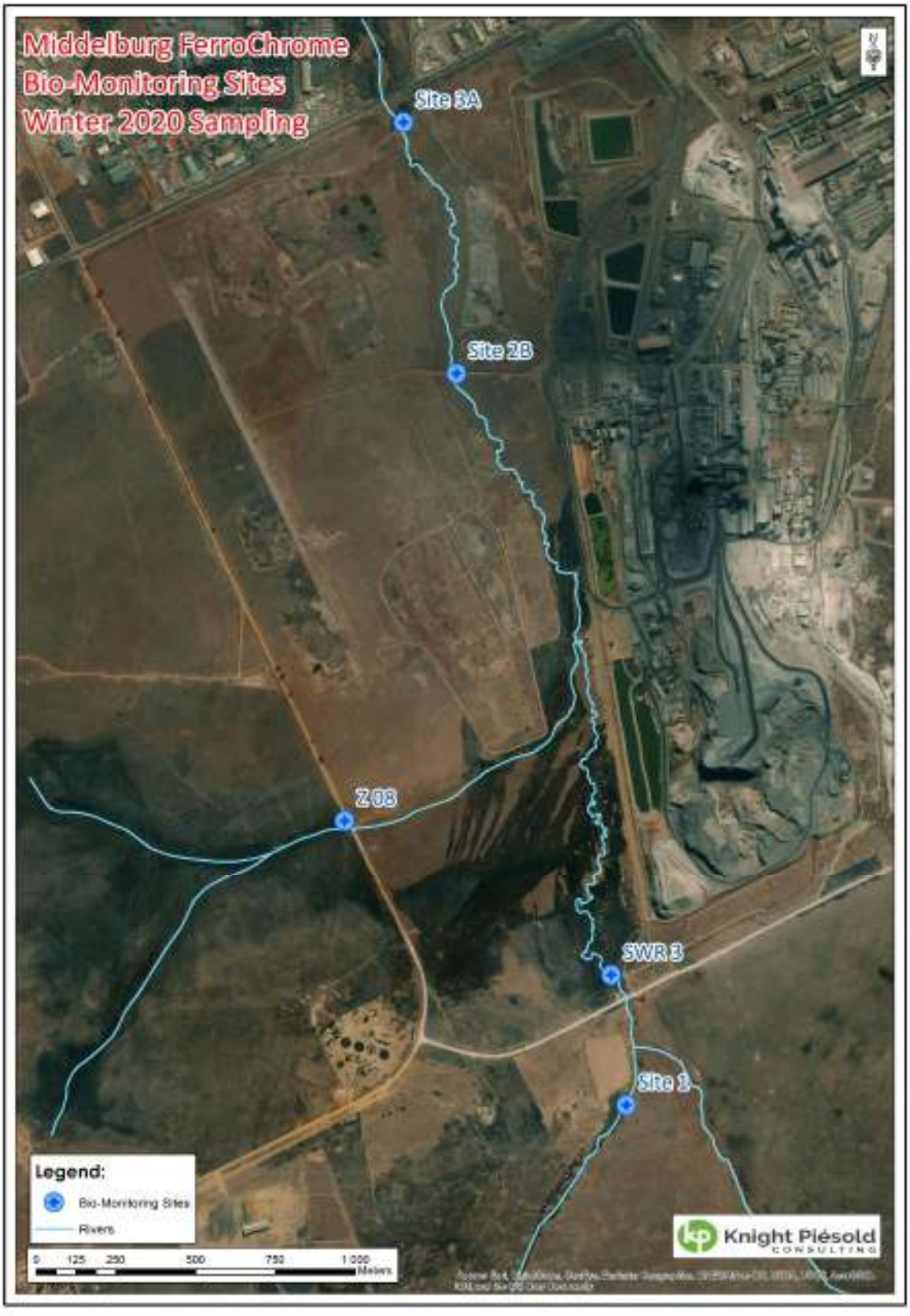

Figure 2: Locality of the Aquatic Bio-monitoring Sites

3.0 METHODOLOGY

Aquatic bio-monitoring was conducted to measure, assess and report on the general state of the receiving aquatic environment in order to provide an overview of the ecological health. Bio-monitoring incorporates the application of biological indicators and relevant non-biological indicators (indices) to assess the condition or "health" of the aquatic ecosystems. This assessment was based on selected abiotic and biotic components.

The results of these indices are presented in the form of one of six Present Ecological State (PES) categories. The categories range from an "A" to an "F" state. The categories and state descriptions are represented in Table 3 below.

Table 3: Present Ecological State

PES	PES Name	Description
A	Natural	Unmodified natural
B	Good	Largely natural with few modifications
C	Fair	Moderately modified
D	Poor	Largely modified
E	Severely Modified	Seriously modified
F	Critically Modified	Critically or extremely modified

The following ecological indicators were selected to represent the general ecological components involved in the aquatic environment:

- ***In situ* water quality** – pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS) and Temperature (°C).
- **Visual assessment** – In-stream habitat conditions include a general description of each site, GPS locations, photographs for future reference and surrounding features that may lead to pollution.
- **Invertebrate Habitat Assessment** – habitat suitability available for macro invertebrates such as Stone, Vegetation and GSM (Gravel, Sand and Mud).
- **Invertebrates** – Benthic aquatic invertebrates comprise of a wide range of taxa that live in streams and rivers. Abundance and compositions of invertebrate communities reflect water quality and in-stream habitat conditions.
- **Diatoms** – Provide biological water quality information for conditions on the day of biological component sampling regarding the aquatic health and functioning of the aquatic system and providing additional input to the physico-chemical component of the study as a response variable.

3.1 *IN-SITU* WATER QUALITY

Water quality is used to describe the physical, chemical, biological and aesthetic properties of water that determine its fitness for a variety of uses and for the protection of the health and integrity of aquatic ecosystems (DWAF, 1996).

The following water quality parameters were determined during the field survey using multi-parameter field instruments:

- pH
- Total Dissolved Solids (mg/l)
- Electrical Conductivity (mS/m)
- Temperature (°C)
- Dissolved Oxygen (DO) (mg/l)
- Dissolved Oxygen (DO) (%)
- Free and Total Chlorine

The above-mentioned parameters provide an *in-situ* of the current water quality at the time of the survey and can be used as an early detection system for any water quality changes.

3.2 VISUAL ASSESSMENT

Each site was assessed by in-stream conditions such as morphology, hydrology and general site description. Photographic evidence was taken at each site as a representation of the conditions during the survey. Visual assessment is essential as it can be used as a preventative measure that detects changes that may potentially impact the aquatic system at a later stage.

3.3 INVERTEBRATE HABITAT ASSESSMENT SYSTEM (IHAS)

IHAS evaluates the availability of suitable habitat for macro-invertebrates and expresses the availability and suitability as a percentage as described below. IHAS scores were interpreted according to the guidelines of McMillan 2002 as follows:

- <55% inadequate habitat
- 55-65% adequate habitat
- >65% good habitat.

The IHAS has been tested and found to be an unsatisfactory method of quantifying invertebrate habitat suitability (Ollis *et al*., 2006). As this study forms part of WUL conditions, IHAS will still be utilised and compared to a suitable simple five points scale as per the SASS 5 sheet.

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.

3.4 AQUATIC INVERTEBRATES

The South African Scoring System Version 5 (SASS 5) (Dickens and Graham, 2002) is a rapid bio-assessment method used to assess the integrity of macro-invertebrates in flowing aquatic ecosystems. Aquatic bio-monitoring utilises this index to detect the water quality of ecosystems. The index assigns each taxon with a sensitivity score that is used to indicate an overall average score per taxon (ASPT).

Benthic macro-invertebrates, in particular, are recognised as valuable organisms for bio-assessments, due largely to their visibility to the naked eye, ease of identification, rapid life cycle often based on the seasons and their largely sedentary habits (Dickens and Graham, 2002). Sampling was conducted using a standard size SASS net with mesh <1mm, dislodging macro invertebrates from their habitat substrates into the water column and catching the invertebrates in the net.

SASS Data Interpretation Guidelines (Dallas, 2007) were used to interpret the SASS 5 information collected during the survey. The guidelines method utilises natural variation in SASS 5 scores and ASPT to determine preliminary biological bands. The study area falls within the Level 1 Ecoregion for the Highveld and the SASS5 score and ASPT values were evaluated according to these bands.

3.5 DIATOMS

3.5.1 SAMPLING AND ANALYSIS

The diatom analysis was conducted in South Africa by Shael Koekemoer of Koekemoer Aquatic Services. Epiphyton substrate was sampled as outlined in Taylor *et al.* (2007a). Diatom samples were taken at the site by scrubbing the substrate with a small brush and rinsing both the brush and the substrate with distilled water.

Preparation of diatom slide followed the Hot HCl and $KMnO_4$ method as outlined in Taylor *et al.* (2007a). A Nikon Eclipse E100 microscope with phase contrast optics (1000x) was used to identify diatom valves on slides. The aim of the data analysis was to count 400 diatom valves to produce semi-quantitative data from which ecological conclusions can be drawn (Taylor *et al*., 2007a). This range is supported by Prygiel *et al.* (2002), Schoeman (1973) and Battarbee (1986) as satisfactory for the calculation of relative abundance of diatom species. Nomenclature followed Krammer and Lange-Bertalot (1986-91). Diatom index values were calculated in the database programme OMNIDIA (Lecointe *et al.*, 1993) for epilithon data in order to generate index scores to general water quality variables.

The referenced diatom data which was sampled prior to the August 2020 survey was not collected by Knight Piésold (Pty). However, Koekemoer Aquatic Services made references based on their database, as they have analysed diatom samples from the sampled points of the Vaalbankspruit.

3.5.2 DIATOM BASED WATER QUALITY SCORE

The European numerical diatom index, the Specific Pollution sensitivity Index (SPI) was used to assign biological water quality Ecological Categories (ECs) and associated water quality classes. Classes based on the class limits provided in Table 4. Other indices housed within the OMNIDIA programme used to characterise biological water quality included:

- Biological Diatom Index (BDI): Primarily a practical index, as it treats morphologically related taxa as one group and composes so-called associated taxa eliminating species that are difficult to identify.
- The ecological characterisation of diatom species based on Van Dam et al. (1994): Includes the preferences of 948 freshwater and brackish water diatom species in terms of pH, nitrogen, oxygen, salinity, humidity, saprobity and trophic state.
- Trophic Diatom Index (TDI) (Kelly and Whitton, 1995): This index provides the percentage pollution tolerant diatom valves (PTVs) in a sample and was developed for monitoring sewage outfall (orthophosphate-phosphorus concentrations), and not general stream quality. The presence of more than 20% PTVs shows significant organic impact.
- Valve deformities were also noted as it is an indication of possible metal toxicity that may be present within the system. According to Luís et al. (2008) several studies on metal polluted rivers have shown that diatoms respond to perturbations not only at the community but also at the individual level with alteration in cell wall morphology. In particular, size reduction and frustule deformations have been sometimes associated with high metal concentrations. The general threshold for the occurrence of valve deformities in a sample is usually considered between 1 - 2% and is regarded as potentially hazardous (Taylor, pers. comm.).

Table 4: Adjusted Class Limit Boundaries for the SPI Index Applied in this Study

Interpretation of Index Scores		
Ecological Category (EC)	**Class**	**Index Score (SPI Score)**
A	High Quality	18 – 20
A/B		17 – 18
B	Good Quality	15 – 17
B/C		14 – 15
C	Moderate Quality	12 – 14
C/D		10 – 12
D	Poor Quality	8 – 10
D/E		6 – 8
E	Bad Quality	5 – 6
E/F		4 – 5
F		>4

4.0 RESULTS AND DISCUSSION

This section provides feedback on the recent aquatic bio-monitoring survey of the Vaalbankspruit The results for the August 2020 survey will be presented according to Table 5 below which summarises the SASS interpretation for the Highveld – Lower Ecoregion.

Table 5: Summarised interpretation of the Highveld Ecoregion

Category	Description	Average Score per Taxon (ASPT)	SASS Score
A	Unmodified or approximate natural conditions. High diversity of taxa with numerous sensitive taxa.	>5.6	> 123
B	Largely natural with few modifications. A change in community characteristics may have taken place but species richness and presence of intolerant species indicate little modification	>4.8	>81
C	Moderately Modified. A lower than expected species richness and presence of most intolerant species. Some impairment of health may be evident at the lower limit of this class.	>4.6	>64
D	Largely Modified. A clearly lower than expected species richness and absence or much lowered presence of intolerant and moderately intolerant species. Impairment of health may become more evident at the lower limit of this class.	>4.2	>51
E	Seriously Modified. A strikingly lower than expected species richness and general absence of intolerant and moderately intolerant species. Impairment of health may become very evident.	<4.2	<51
F	Critically Modified. An extremely lowered species richness and absence of intolerant species. Only tolerant species may be present with a complete loss of species at the lower limit of the class. Impairment of health generally very evident		<19

4.1 SITE 1 (UPSTREAM CONTROL POINT)

Plate 1: Upstream view of Site 1

Plate 2: Downstream view of Site 1

Site 1, the long-term bio-monitoring site, is located within a privately fenced livestock farm. During the survey the site experienced low to no flow and the clarity was recorded as 64 cm.

4.1.1 *IN-SITU* WATER QUALITY

Table 6: *In-situ* water quality results for Site 1

Sample Point	Date	pH	Temp	TDS (mg/l)	Conductivity (mS/m)	DO (mg/l)	DO (%)	Free Chlorine (mg/l)	Total Chlorine (mg/l)
DWAF Ecosystem Guidelines		**6.5 – 9.0**	**5 – 30**	**<1100**	**<154**	**>5.0**	**80 – 120**	**<0.2**	**<0.2**
Site 1	11/08/2020	6.9	16.1	390	80	8.59	84.7	0.73	0.53

The recorded *in-situ* parameters fell within guideline values, except for free and total chlorine concentrations which deviated from the DWAF guideline limits.

4.1.2 IHAS

Site 1 provided inadequate or poor habitat availability, as it obtained an IHAS score of 43 % (Table 7). It had a SASS biotope score of 20 % which placed Site 1 into an EC of Category F (Critically Modified). The site does not provide any aquatic vegetation, nor does it provide distinct Gravel Sand and Mud (GSM) biotopes for sampling, there was some sand and mud below stones. No stone or stone in-current available within the stretch of the river. The site is dominated by boulders, with some marginal vegetation (dominantly reeds) available for sampling and stones (out-of-current) between these boulders.

Table 7: Site 1 IHAS Results for August 2020 Dry Season Survey

Biotope	Score
	Site 1
Stones (out of 20 points)	0
Vegetation (out of 15 points)	9
Other/General (out of 20 points)	11
Total out of 55	20
Physical aspects and Conditions (out of 45 points)	23
Total IHAS Score	43
IHAS Description	Poor

4.1.3 AQUATIC INVERTEBRATES

A total of 8 taxa were observed at Site 1. The site obtained a SASS score of 33 and an ASPT of 4.1. These results placed the site into a Present Ecological State (PES) of Category F (Critically Modified). The SASS results could be impacted due to the low water levels and flow as the limited habitat available for macro invertebrates. The most sensitive taxa recorded during the survey include Caenidae (Squaregills/Cainflies), Dytiscidae/Noteridae (Diving beetles) and Gyrinidae (Whirligig beetles). A summary of the SASS results for the August 2020 survey is presented below.

Table 8: Summary of Site 1 SASS Results for August 2020 Dry Season Survey

Taxon	QV	S	Veg	GSM	TOT
EPHEMEROPTERA (Mayflies)					
Baetidae 1sp	4	A	A		A
Caenidae (Squaregills/Cainflies)	6	A	1		A
ODONATA (Dragonflies & Damselflies)					
Coenagrionidae (Sprites and blues)	4		A		A
TRICHOPTERA (Caddisflies)					
Hydropsychidae 1 sp	4	A	A		A
COLEOPTERA (Beetles)					
Dytiscidae/Noteridae* (Diving beetles)	5	1			1
Gyrinidae* (Whirligig beetles)	5	1			B
DIPTERA (Flies)					
Chironomidae (Midges)	2		A		A
GASTROPODA (Snails)					
Lymnaeidae* (Pond snails)	3		1		1
SASS Score					33
No. of Taxa					8
ASPT					4.1

4.1.4 DIATOMS

The biological water quality at Site 1 improved from November 2019. In August 2020, the SPI score was 18.1 (A Ecological Category) with high water quality prevailing. Further analysis of the various indices within OMNIDIA suggested that decreased nutrient and organic pollution levels were the main reason for water quality improvement between November 2019 and August 2020. No significant change in salinity concentrations was observed during this time. Pollution levels remained stable from November 2019 with slight levels prevailing in August 2020.

As observed in November 2019, dominant species still consisted of pioneer species that are influenced by water temperature and water level fluctuations, preferring low to moderate nutrient levels and included *Achnanthidium* species and *Synedra rumpens* (Sánchez-Castillo, 2008; Craticula, 2011) and suggests a stressed environment. Although the SPI score indicates and improvement in biological water quality between November 2019 and August 2020; the high SPI score can mainly be ascribed to the dominance of *Brachysira neoexilis* and *Achnanthidium minutissima*. Both species are found in clean, olig- to mesotrophic waters and therefore have a high indicator value in determining the SPI score. However, both species are closely associated with mining effluent containing heavy metals. *Brachysira neoexilis* is tolerant to mining effluents, especially effluents containing Uranium (Cattaneo *et al*. 2004; Herlory, 2013). *Achnanthidium minutissima* is able to tolerate waters of low pH and high metal concentrations (Cattaneo *et al*. 2004) while Yoshiaki *et al*. (2004) showed that the relative abundance of *Achnanthidium minutissima* increased when Cu, Zn and Pb concentrations were high. From previous and current studies in the Mpumalanga mining industry area it has been noted that *Achnanthidium minutissima* occurs in high abundance in critically polluted streams across the province which is associated with coal mining. These two species have been consistently present at dominant and sub-dominant abundance since November 2017, suggesting that mining effluent could have been present. No valve deformities were noted in August 2020 which was similar to November 2019.

4.2 SWR 3 (UPSTREAM MONITORING POINT)

Plate 3: Upstream view of Site SWR 3

Plate 4: Downstream view of Site SWR 3

This site is located upstream of the MFC, in close proximity to the southern edge of the MFC property. The site is accessed from a nearby road crossing, downstream of a livestock farm and is frequently visited for water abstraction. The site is comprised of multiple pools connected by a run. There was low flow present at the site, which can be attributed to a leaking pipe, presumed to be flowing to or from the nearby wastewater works. The water clarity at the site was recorded as 91 cm.

4.2.1 *IN-SITU* WATER QUALITY

Table 9: *In-situ* water quality results for SWR 3

Sample Point	Date	pH	Temp	TDS (mg/l)	Conductivity (mS/m)	DO (mg/l)	DO (%)	Free Chlorine (mg/l)	Total Chlorine (mg/l)
DWAF Ecosystem Guidelines		**6.5 – 9.0**	**5 – 30**	**<1100**	**<154**	**>5.0**	**80 – 120**	**<0.2**	**<0.2**
SWR 3	11/08/2020	7.4	15.9	410	84	7.2	71.4	0.19	0.18

The dissolved oxygen saturation (%) deviated from the DWAF guidelines, while all the other *in-situ* parameters are within the guideline limits.

4.2.2 IHAS

Site SWR 3 recorded an IHAS score of 52 % as it provided poor habitat in the August 2020 survey. The site had multiple deep pools which were undercut by embankments. The SASS biotope score of 44 % placed SWR 3 into an EC of Category D (Largely Modified). The site was dominated by the stone

biotope throughout the run and pools, with a small region of stones within riffles present at the V-cut within the concrete upstream at the site. The GSM biotopes were limited to the undercut banks present at the site. Marginal vegetation was dominated by *Typha* sp. at the site, located along the banks as well as instream at the upstream portion.

Table 10: SWR 3 IHAS Results for August 2020 Dry Season Survey

Biotope	Score
	SWR 3
Stones (out of 20 points)	12
Vegetation (out of 15 points)	8
Other/General (out of 20 points)	12
Total out of 55	32
Physical aspects and Conditions (out of 45 points)	20
Total IHAS Score	52
IHAS Description	Poor

4.2.3 AQUATIC INVERTEBRATES

Site SWR 3 recorded a SASS score of 85 and 16 taxa were observed. This resulted in an ASPT of 5.3 and placed the site into a Present Ecological State (PES) of Category B (Largely natural with few modifications).. The most sensitive taxa recorded during the survey include Baetidae > 2 sp, Hydracarina (Mites) and Aeshnidae (Hawkers & Emperors). A summary of the SASS results for the August 2020 survey is presented below.

Table 11: SWR 3 Summary of SASS Results for August 2020 Dry Season Survey

Taxon	QV	S	Veg	GSM	TOT
ANNELIDA					
Oligochaeta (Earthworms)	1			1	1
CHELICERATA					
HYDRACARINA (Mites)	8		A		A
EPHEMEROPTERA (Mayflies)					
Baetidae > 2 sp	12	B	B	B	B
Caenidae (Squaregills/Cainflies)	6	A	A	A	B
ODONATA (Dragonflies & Damselflies)					
Coenagrionidae (Sprites and blues)	4		B	A	B
Aeshnidae (Hawkers & Emperors)	8		1		1
Gomphidae (Clubtails)	6			A	A
HEMIPTERA (Bugs)					
Belostomatidae* (Giant water bugs)	3		1		1
TRICHOPTERA (Caddisflies)					
Hydropsychidae 1 sp	4	B	B		B
Hydropsychidae 2 sp	6			B	B

Taxon	QV	S	Veg	GSM	TOT
Cased caddis:					
Hydroptilidae	6		A		A
COLEOPTERA (Beetles)					
Dytiscidae/Noteridae* (Diving beetles)	5	A	A	A	A
Gyrinidae* (Whirligig beetles)	5		A	A	B
DIPTERA (Flies)					
Ceratopogonidae (Biting midges)	5	A	A	A	B
Chironomidae (Midges)	2	B	B	B	B
Simuliidae (Blackflies)	5	B	B	B	B
GASTROPODA (Snails)					
Lymnaeidae* (Pond snails)	3		1		1
SASS Score					85
No. of Taxa					16
ASPT					5.3

4.2.4 DIATOMS

The diatom based water quality in August 2020 was good with a SPI score of 15.5 (B Ecological Category). Organic pollution, nutrient levels and salinity concentrations were low to moderate. Further analysis of the various indices within OMNIDIA suggested that general pollution were moderate in August 2020.

As observed at Site 1, dominant species consisted of pioneer species that are influenced by water temperature and water level fluctuations, preferring low to moderate nutrient levels and included *Achnanthidium* species and *Synedra rumpens* (Sánchez-Castillo, 2008; Craticula, 2011) and suggests a stressed environment. Species diversity increased at Site SWR 3 in comparison to Site 1 suggesting an increased measure of impact. Species with an affinity for higher nutrient and organic pollution increased and were associated with mainly sewage effluent. These species were prolific but occurred at low abundance. Valve deformities were noted at an abundance of 0.25%, and although within general threshold limits, suggested some level of bio-availability.

4.3 Z 08 (DRAINAGE CHANNEL)

Plate 5: Upstream view of Site Z 08

Plate 6: Downstream view of Site Z 08

Monitoring point Z 08 is located within a drainage channel which flows towards the Vaalbankspruit. No water was present within the channel during the August 2020 survey, therefore no aquatic biomonitoring or *in-situ* analysis was conducted at this site.

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4.4 SITE 2B (MID-STREAM MONITORING POINT)

Plate 7: Upstream view of Site 2B

Plate 8: Downstream view of Site 2B

Monitoring point Site 2B is located at a low-level crossing, which separates a densely vegetated wetland. Upstream of the crossing, the wetland remains densely vegetated with dried reeds, whilst downstream of the crossing the vegetation had burnt away. There was no distinct channel present at this point, with limited habitat available due to the low water levels present. This site was therefore not suitable for bio-monitoring, however, *in-situ* analysis was conducted and a diatom sample was collected for analysis.

4.4.1 *IN-SITU* WATER QUALITY

Table 12: *In-situ* water quality results for Site 2B

Sample Point	Date	pH	Temp	TDS (mg/l)	Conductivity (mS/m)	DO (mg/l)	DO (%)	Free Chlorine (mg/l)	Total Chlorine (mg/l)
DWAF Ecosystem Guidelines		**6.5 – 9.0**	**5 – 30**	**<1100**	**<154**	**>5.0**	**80 – 120**	**<0.2**	**<0.2**
Site 2B	11/08/2020	7.5	11.6	660	133	9.05	81.7	0.28	0.24

The free and total chlorine concentrations exceeded the DWAF guideline limits while all the other *in-situ* parameters were within the limits.

4.4.2 DIATOMS

The biological water quality at Site 2B improved from November 2019 and in August 2020, the SPI score was 15.3 (B Ecological Category) with good water quality prevailing at the time of sampling. Improvement was mainly due to improved organic pollution and salinity concentrations while nutrient levels increased during this time. Further analysis of the various indices within OMNIDIA suggested that pollution levels remained stable from November 2019 with moderate levels prevailing in August 2020.

Dominant species consisted of pioneer species that are influenced by water temperature and water level fluctuations, preferring low to moderate nutrient levels and included *Achnanthidium* and Ulnaria species as well as *Synedra rumpens* (Sánchez-Castillo, 2008; Craticula, 2011) which suggested a stressed environment. The dominant species, *Fragilaria vaucheriae* and *Achnanthidium minutissima* are both tolerant to metals and increase in abundance in treated streams (Medley and Clements, 1998), suggests and possibly reflects the impact of mining activities in the area. The abundance of species associated with high nutrient and salinity concentrations observed in November 2019 generally decreased in abundance when compared to August 2020, reflecting generally improved conditions. *Gomphonema parvulum* was dominant and indicates organic enrichment, which is usually associated with sedimentation, both organic and inorganic sediment (Teply and Bahls, 2006). According to Davey *et al.* (2008) it has an optimum filterable Phosphorus between 0.35 and 1 mg/L, restricted to a narrow concentration range which suggests that Phosphorus concentrations were elevated and increased from Site SWR 3. Valve deformities were noted at an abundance of 1.25%, falling within upper threshold limits and suggested the possible bio-availability of metals. This was a notable increase from November 2019.

4.5 SITE 3A (DOWNSTREAM MONITORING POINT)

Plate 9: Upstream view of Site 3A

Plate 10: Downstream view of Site 3A

Site 3A is located towards the northern boundary of the MFC property, situated at a culvert with a raised crossing. It is within a channelled wetland, with a dense population of fibrous algae present. The available survey area was limited to the open channelled region where adequate depth and flow was present. The flow at the site was slow during the time of the survey, with water clarity at the site recorded at 83 cm.

4.5.1 *IN-SITU* WATER QUALITY

Table 13: *In-situ* water quality results for Site 3A

Sample Point	Date	pH	Temp	TDS (mg/l)	Conductivity (mS/m)	DO (mg/l)	DO (%)	Free Chlorine (mg/l)	Total Chlorine (mg/l)
DWAF Ecosystem Guidelines		**6.5 – 9.0**	**5 – 30**	**<1100**	**<154**	**>5.0**	**80 – 120**	**<0.2**	**<0.2**
Site 3A	11/08/2020	7.5	7.8	920	185	6.15	51.9	0.16	0.14

The conductivity and dissolved oxygen saturation (%) exceeded the DWAF guideline limits while all the other *in-situ* parameters were within the limits.

4.5.2 IHAS

Site 3A provided adequate habitat availability, as it obtained an IHAS score of 60 % (Table 12). It had a SASS biotope score of 40 % which placed Site 3A into an EC of Category E (Seriously Modified). Site 3A is situated within a wetland with a defined channel, which is dominated by the stone biotope with an established, dense algal community dominated by *Spirogyra* sp. algae. The GSM biotopes were present

between and beneath stones within the channel. Marginal vegetation was comprised of reeds which had died back for the winter.

Table 14: Site 3A IHAS Results for August 2020 Dry Season Survey

Biotope	Score
	Site 3A
Stones (out of 20 points)	14
Vegetation (out of 15 points)	7
Other/General (out of 20 points)	11
Total out of 55	32
Physical aspects and Conditions (out of 45 points)	28
Total IHAS Score	60
IHAS Description	Adequate

4.5.3 AQUATIC INVERTEBRATES

Twelve taxa were observed at Site 3A. The SASS score was recorded as 56, resulting in an of 4.7 which placed the site into a Present Ecological State (PES) of Category C/D (Moderately Modified to Largely Modified). The most sensitive taxa recorded during the survey include Hydracarina (Mites), Elmidae/Dryopidae (Riffle beetles), Hydroptilidae and Caenidae (Squaregills/Cainflies). A summary of the SASS results for the August 2020 survey is presented below.

Table 15: Summary of SASS Results for August 2020 Dry Season Survey

Taxon	QV	S	Veg	GSM	TOT
TURBELLARIA (Flatworms)	3	A	1		A
ANNELIDA					
Oligochaeta (Earthworms)	1	1		A	A
CHELICARATA					
HYDRACARINA (Mites)	8	A	A	A	B
EPHEMEROPTERA (Mayflies)					
Baetidae 1sp	4	A			A
Baetidae 2 sp	6		A		A
Caenidae (Squaregills/Cainflies)	6		A		A
ODONATA (Dragonflies & Damselflies)					
Coenagrionidae (Sprites and blues)	4		B		B
HEMIPTERA (Bugs)					
Corixidae* (Water boatmen)	3		C		C
TRICHOPTERA (Caddisflies)					
Hydropsychidae 1 sp	4	A		B	B
Cased caddis:					
Hydroptilidae	6		1		1
COLEOPTERA (Beetles)					

Taxon	QV	S	Veg	GSM	TOT
Elmidae/Dryopidae* (Riffle beetles)	8	1	1		A
DIPTERA (Flies)					
Chironomidae (Midges)	2	A	B	A	B
Simuliidae (Blackflies)	5	A	A		B
SASS Score					56
No. of Taxa					12
ASPT					4.7

4.5.4 DIATOMS

The biological water quality at Site 3A remained stable from November 2019. In August 2020, the SPI score was 11.5 (C/D Ecological Category) with moderate water quality prevailing. Further analysis of the various indices within OMNIDIA suggested that nutrient and organic pollution levels decreased from November 2019 while salinity concentrations increased notably during this time. Pollution levels remained stable from November 2019 with moderate levels prevailing in August 2020.

Achnanthidium species still dominated the diatom community in August 2020, reflecting ongoing disturbance at the site. As observed in November 2019, sulphate-based salinity concentrations increased notably between Site 2B and Site 3A, based on the increased abundance of *Fragilaria fasciculata*. *Fragilaria fasciculata* has been reported from critically polluted industrial wastewater (Taylor *et al*., 2007), has a preference for SO_4^{-2}-dominated habitats, especially $MgSO_4$ and characterised as most indicative of habitats with high specific conductance and euryhaline conditions. According to Wilson *et al.* (2011) salinity optima is approximately 8.93 g/L and Beldowska *et al*. (2018) also found this species to be a good accumulator of Mercury (Hg). Key indicator species associated with industrial effluent increased in abundance between Site 2B and Site 3A reflecting an increased measure of impact between the sites,but remaining relatively stable when compared to November 2019. Valve deformities were noted at an abundance of 0.5% which was an increase from November 2019. Although within general threshold limits, the presence of valve deformities throughout 2019 and 2020, suggests that impact is present for prolonged periods although toxicity may not be biologically availably to diatoms.

5.0 CONCLUSION

5.1 SITE 1 (UPSTREAM CONTROL POINT)

- The *in-situ* concentrations of free and total chlorine exceeded the DWAF guidelines.
- Site 1 provided poor habitat availability, with an IHAS score of 43 %
- The invertebrate PES was categorised as Category F (Critically Modified).
- The general diatom-based water quality ecological category for Site 1 was A (High Quality)

5.2 SWR 3 (UPSTREAM)

- The *in-situ* concentration of dissolved oxygen (%) exceeded the DWAF guidelines.
- Poor habitat availability was provided at SWR 3, with an IHAS score of 52 %
- The invertebrate PES was categorised as Category B (Largely natural with few modifications)
- The general diatom-based water quality ecological category for SWR 3 was Category B (Good Quality)

5.3 Z 08 (DRAINAGE CHANNEL)

- The point was dry, therefore there was no sample collected.

5.4 SITE 2B (MID-STREAM POINT)

- This site was not suitable for bio-monitoring as there was no distinct channel
- The *in-situ* concentrations of free and total chlorine exceeded the DWAF guidelines.
- The general diatom-based water quality ecological category for Site 2B was Category B (Good Quality)

5.5 SITE 3A (DOWNSTREAM)

- The *in-situ* concentrations of conductivity and dissolved oxygen (%) exceeded the DWAF guidelines.
- Site 3A provided adequate habitat availability as it recorded an IHAS score of 60 %
- The invertebrate PES was categorised as Category C/D (Moderately Modified to Largely Modified)
- The general diatom-based water quality ecological category for Site 3A was Category C/D (Moderate Quality)

5.6 GENERAL AND RECOMMENDATIONS

The wet and dry season bio-monitoring surveys should continue to monitor the impacts of MFC on the Vaalbankspruit and to determine any trends and seasonal variation on the receiving aquatic environment.

6.0 REFERENCES

Battarbee, R.W. 1986. Diatom Analysis. In Berglund BE (ed) Handbook of Holocene Paleoecology and Paleohydrology. John Wiley & Sons Ltd. Chichester. Great Briton. pp 527-570.

Bełdowska, M., Zgrundo, A. & Kobos, J. 2018. Mercury in the Diatoms of Various Ecological Formations. *Water, Air, & Soil Pollution*, 229 (5): 168. [https://doi.org/10.1007/s11270-018-3814-1].

Cattaneo, A., Couillard, Y., Wunsam, S., and Courcelles, M. 2004. Diatom taxonomic and morphological changes as indicators of metal pollution and recovery in Lac Dufault Québec, *Canada. Journal of Paleolimnology* 32: 163-175.

Craticula. 2011. Common Freshwater Diatoms of Britain and Ireland. A multiaccess key. [Web: http://craticula.ncl.ac.uk/EADiatomKey/html/taxa.html].

Dallas H F (2007). River Health Programme: South African Scoring System (SASS) Data Interpretation Guidelines. Report produced for the Department of Water Affairs and Forestry (Resource Quality Services) and the Institute of Natural Resources.

Davey, A., Gardner, M., Johnson, I., Nixon, S., Payne, m. and Smith, H. 2008. Understanding the Impact of Farming on Aquatic Ecosystems. Defra Project WQ0112.

Dickens, C. W. S. and Graham, P. M. (2002). The South African Scoring System (SASS) Version 5 Rapid bioassessment method for rivers. African Journal of Aquatic Science 27(1): 1-10.

DWAF (1996). South African Water Quality Guidelines Volume 7: Aquatic Ecosystems. - Pretoria : Department of Water Affairs and Forestry.

Herlory, O., Bonzom, J-M., Gilbin, R., Frelon, S., Fayolle, S., Delmas, F. and Coste, M. 2013. Use of diatom assemblages as biomonitor of the impact of treated uranium mining effluent discharge on a stream: Case study of the Ritord watershed (Center-West France). *Ecotoxicology* 22:1186–1199 DOI 10.1007/s10646-013-1106-5.

Kelly M. G., Whitton B. A., (1995). The Trophic Diatom Index: a new index for monitoring eutrophication in rivers, Journal of Applied Phycology 7, 433- 444.

Krammer, K and Lange-Bertalot, H (1986-1991). Bacillario-phyceae. Süßwasserflora von Mitteleuropa 2 (1-4). Spektrum Akademischer Verlag, Heidelberg. Berlin.

Lecointe, C, Coste, M and Prygiel, J (1993). “Omnidia”: Software for taxonomy, calculation of diatom indices and inventories management. Hydrobiologia 269/270: 509-513.

Luís, A.T., Teixeira, P., Almeida, S.F.P., Ector, L., Matos, J.X. and Ferreira da Silva, A. (2008). Impact of Acid Mine Drainage (AMD) on Water Quality, Stream Sediments and Periphytic Diatom Communities in the Surrounding Streams of Aljustrel Mining Area (Portugal). Water Air Soil Pollution. DOI 10.1007/s11270-008-9900-z.

McMillan P H (1998). An Invertebrate Habitat Assessment System (IHASv2), for the Rapid Biological Assessment of Rivers and Streams. [Report]: Research Project / Water Resources Management Program. - [s.l.] : CSIR, 1998. - pp. Ii, 44. - number ENV-P-I 98132.

Medley, C.M. and Clements, H.C. 1998. Responses of Diatom communities to Heavy Metals in Streams: The Influence of Longitudinal Variation. *Ecological Applications*, 8(3), pp. 63 1-644.

Prygiel J, Carpentier P, Almeida S, Coste M, Druart JC, Ector L, Guillard D, Honoré MA, Iserentant R, Ledeganck P, Lalanne-Cassou C, Lesniak C, Mercier I, Moncaut P, Nazart M, Nouchet N, Peres F, Peeters V, Rimet F, Rumeau A, Sabater S, Straub F, Torrisi M, Tudesque L, Van der Vijver B, Vidal H, Vizinet J and Zydek N (2002). Determination of the biological diatom index (IBD NF T 90-354): results of an inter-comparison exercise. Journal of Applied Phycology 14: 27-39.

Sánchez-Castillo, PM, Linares-Cuesta, JE and Fernández-Moreno, D. 2008. Changes in epilithic diatom assemblages in a Mediterranean high mountain lake (Laguna de La Caldera, Sierra Nevada, Spain) after a period of drought. *J. Limnol.,* 67(1): 49-55.

Schoeman, FR (1973). A systematical and ecological study of the diatom flora of Lesotho with special reference to water quality. V&R Printers, Pretoria, South Africa.

Tan, X., Xia, X., Zhao, Q. and Zhang, Q., 2014. Temporal variations of benthic diatom community and its main influencing factors in a subtropical river, China. Environmental Science and Pollution Research, 21(1), pp.434-444.

Taylor, JC, Harding, WR and Archibald, CGM (2007). A methods manual for the collection, preparation and analysis of diatom samples. Water Research Commission Report TT281/07. Water Research Commission. Pretoria.

Teply, M. and Bahls, L. 2006. Interpretation of Periphyton Samples for Montana Streams - Middle Rockies Ecoregion. Prepared for the Montana Department of Environmental Quality. Water Quality Monitoring Section. Rosie Sada. Project Manager.1520 E 6th Avenue. Helena, MT 59620.

Van Dam, Mertens A and Sinkeldam J (1994). A coded checklist and ecological indicator values of freshwater diatoms from the Netherlands. Netherlands Journal of Aquatic Ecology 28(1): 177-133.

Wilson, S.E., Cumming, B and Smol, J.P. 2011. Assessing the reliability of salinity inference models from diatom assemblages: an examination of a 219-lake data set from western North America. *Canadian Journal of Fisheries and Aquatic Sciences*. 53: 1580-1594. 10.1139/f96-094.

Yoshiaki, N., Michiaki, S., Kaoru, Y., Takashi, Y., & Takaharu, H. 2004. Heavy-Metal pollution and its state in algae in Kakehashi River and Godani River at the Foot of Ogoya Mine, Ishikawa. *Analytical Sciences*, 20: 73–78.

7.0 CERTIFICATION

This report was prepared and reviewed by the undersigned.

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APPENDIX A

Integrated Habitat Assessment System

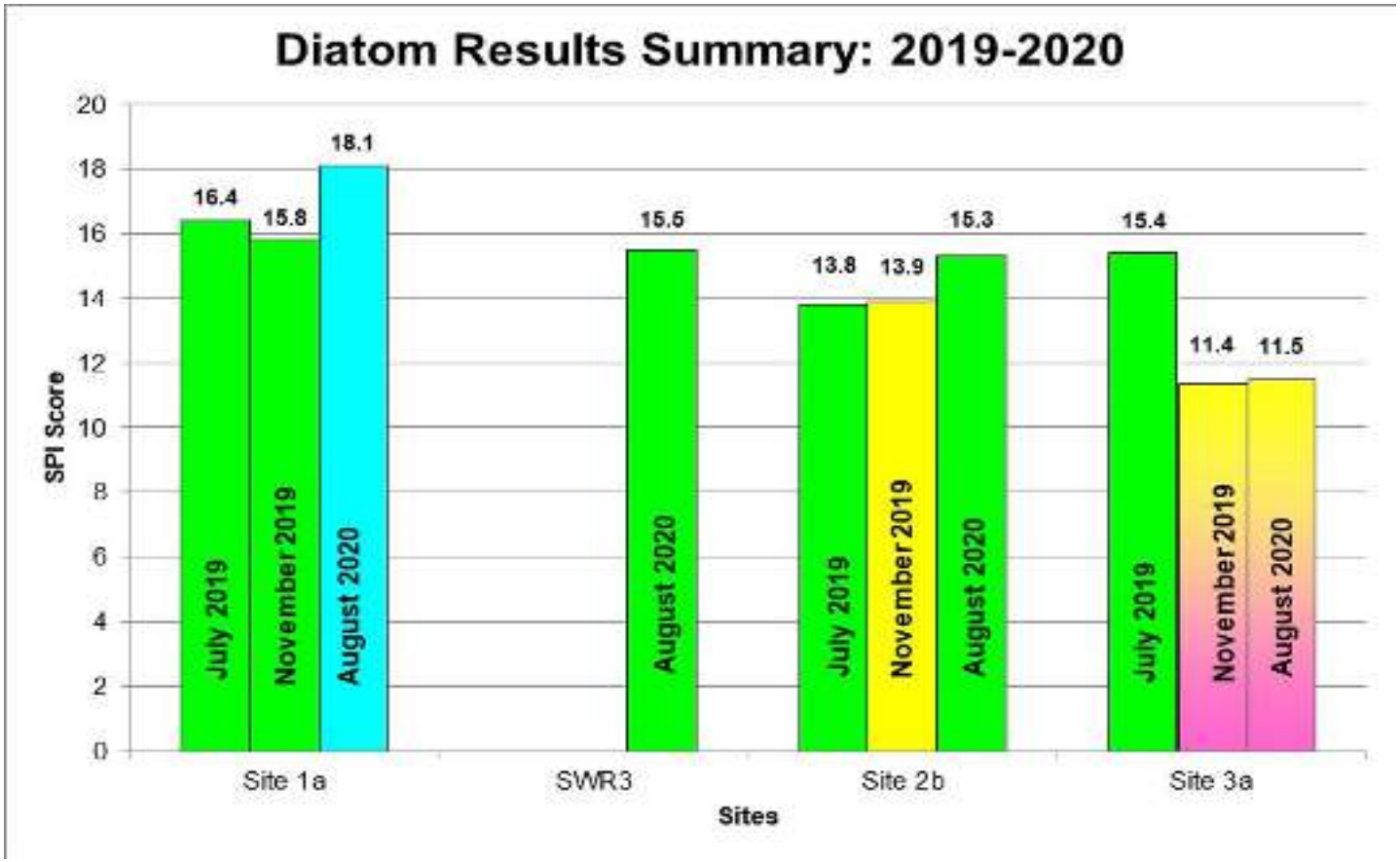
INVERTEBRATE HABITAT ASSESSMENT SYSTEM (IHAS)						
River Name: Vaalbankspruit	**Date: 11/08/2020**					
Site Code: Site 1						
SAMPLING HABITAT	**0**	**1**	**2**	**3**	**4**	**5**
Stones-in-current (SIC)						
Total length (m) of broken water (riffles or rapids)	none	0-1	>1-2	>2-3	<3-5	>5
Total length (m) of submerged stones in current (run	none	0-2	>2-5	>5-10	>10	
Number of separate SIC areas kicked (not individual stones)	0	1	2-3	4-5	6+	
Average size (cm) of stones kicked (gravel<2, bedrock >20)	none	<2, <20	2-10	11-20	2-20	
Amount of stone surface clear (of algae, sediment, silt etc)*	n/a	0-25	26-50	51-75	>75	
Protocol: time (mins) spent actually kicking SIC (grv/bedr=0)	0	<1	<1-2	2	>2-3	>3
**Note: up to 25% of stones is usually embedded in stream bottom*	**SIC Score (max. 20)**				**0**	
Vegetation						
Length (m) of fringing vegetation sampled (banks)	none	0-½	>½ - 1	>1-2	2	>2
Amount (m^2) of aquatic vegetation / algae sampled	none	0-½	>½ - 2	>1		
Fringing vegetation sampled in: (none; pool or still only; run only; mixture of both)	none		run	pool		mix
Type of veg (% leafy vegetation vs stems/shoots) (aqv only = 49)	none	0	1-25	26-50	51-75	>75
	Veg Score (max. 15)				**9**	
Other Habitat / General						
Stones out-of-current (SOOC) sampled: (protocol = $1m^2$)	none	0-½	>½-1	1	>1	
Sand sampled: (protocol = 1min) (present, but only below stones)	none	below	0-½	>½-1	1	>1
Mud sampled: (protocol = 1/2min) (present, but only below stones)	none	below	0-½	½	>½	
Gravel sampled: (protocol=1/2min) if all, SIC stone size =<2)**	none	0-½	½	>½ **		
Bedrock sampled (all=no SIC, sand, gravel) (if all, SIC stone size > 20)**	none	some			All **	
Algae present (1-2m2=algal bed, rocks=on rocks, isol=isolated clumps)	>$2m^2$	rocks	1-$2m^2$	<$1m^2$	Isol.	none
Trav identification (using time as per protocol)		under		Correct		over
*** Note still fill in SIC section*	**Other Habitat Score (max. 20)**				**11**	
	HABITAIT TOTAL (max.55)				**20**	
STREAM CHARACTERISTICS	**0**	**1**	**2**	**3**	**4**	**5**
Physical						
River make up (pool = pool/dam only; run only; rapid/riffle only; 2mix = 2 types etc)	pool		run	rapid / rff	2mix	3mix
Average stream width (m)		>10	5-10	<1	1-2	>2-5
Average stream depth (m)	>1	1	>½ - 1	½	¼ - ½	<¼
Approximate stream velocity (slow ≤ 1m/s; fast ≥1m/s)	still	slow	fast	mod		mix
Water colour (disc = discoloured with visible colour but still clearish)	silty	opaque		disc		clear
Recent disturbances due to: (constr = construction, fl/dr = flood/drought)***	fl/dr	fire	Constr	other		none
Bank/riparian vegetation is: (grass=includes reeds; shrubs=includes trees)	none		grass	shrubs	mix	
Surrounding impacts: (erosn = erosion/shear bare banks; farm = farmland/settlements	erosn.	farm	trees	other		open
Left bank cover (%) (rocks and vegetation; shear = 0%)	0-50	51-80	81-95	>95		
Right bank cover (%) (rocks and vegetation; shear = 0%)	0-50	51-80	81-95	>95		
	Stream Conditions Total (max.45)				**23**	
****Note: if more than one option, choose lowest*						
	TOTAL IHAS SCORE %:				**43**	

INVERTEBRATE HABITAT ASSESSMENT SYSTEM (IHAS)						
River Name: Vaalbankspruit	**Date: 11/08/2020**					
Site Code: SWR 3						
SAMPLING HABITAT	**0**	**1**	**2**	**3**	**4**	**5**
Stones-in-current (SIC)						
Total length (m) of broken water (riffles or rapids)	none	0-1	>1-2	>2-3	<3-5	>5
Total length (m) of submerged stones in current (run	none	0-2	>2-5	>5-10	>10	
Number of separate SIC areas kicked (not individual stones)	0	1	2-3	4-5	6+	
Average size (cm) of stones kicked (gravel<2, bedrock >20)	none	<2, <20	2-10	11-20	2-20	
Amount of stone surface clear (of algae, sediment, silt etc)*	n/a	0-25	26-50	51-75	>75	
Protocol: time (mins) spent actually kicking SIC (grv/bedr=0)	0	<1	<1-2	2	>2-3	>3
**Note: up to 25% of stones is usually embedded in stream bottom*	**SIC Score (max. 20)**				**12**	
Vegetation						
Length (m) of fringing vegetation sampled (banks)	none	0-½	>½ - 1	>1-2	2	>2
Amount (m^2) of aquatic vegetation / algae sampled	none	0-½	>½ - 2	>1		
Fringing vegetation sampled in: (none; pool or still only; run only; mixture of both)	none		run	pool		mix
Type of veg (% leafy vegetation vs stems/shoots) (aqv only = 49)	none	0	1-25	26-50	51-75	>75
	Veg Score (max. 15)				**8**	
Other Habitat / General						
Stones out-of-current (SOOC) sampled: (protocol = $1m^2$)	none	0-½	>½-1	1	>1	
Sand sampled: (protocol = 1min) (present, but only below stones)	none	below	0-½	>½-1	1	>1
Mud sampled: (protocol = 1/2min) (present, but only below stones)	none	below	0-½	½	>½	
Gravel sampled: (protocol=1/2min) if all, SIC stone size =<2)**	none	0-½	½	>½ **		
Bedrock sampled (all=no SIC, sand, gravel) (if all, SIC stone size > 20)**	none	some			All **	
Algae present (1-2m2=algal bed, rocks=on rocks, isol=isolated clumps)	>$2m^2$	rocks	1-$2m^2$	<$1m^2$	Isol.	none
Trav identification (using time as per protocol)		under		Correct		over
*** Note still fill in SIC section*	**Other Habitat Score (max. 20)**				**12**	
	HABITAIT TOTAL (max.55)				**32**	
STREAM CHARACTERISTICS	**0**	**1**	**2**	**3**	**4**	**5**
Physical						
River make up (pool = pool/dam only; run only; rapid/riffle only; 2mix = 2 types etc)	pool		run	rapid / rff	2mix	3mix
Average stream width (m)		>10	5-10	<1	1-2	>2-5
Average stream depth (m)	>1	1	>½ - 1	½	¼ - ½	<¼
Approximate stream velocity (slow ≤ 1m/s; fast ≥1m/s)	still	slow	fast	mod		mix
Water colour (disc = discoloured with visible colour but still clearish)	silty	opaque		disc		clear
Recent disturbances due to: (constr = construction, fl/dr = flood/drought)***	fl/dr	fire	Constr	other		none
Bank/riparian vegetation is: (grass=includes reeds; shrubs=includes trees)	none		grass	shrubs	mix	
Surrounding impacts: (erosn = erosion/shear bare banks; farm = farmland/settlements	erosn.	farm	trees	other		open
Left bank cover (%) (rocks and vegetation; shear = 0%)	0-50	51-80	81-95	>95		
Right bank cover (%) (rocks and vegetation; shear = 0%)	0-50	51-80	81-95	>95		
	Stream Conditions Total (max.45)				**20**	
****Note: if more than one option, choose lowest*						
	TOTAL IHAS SCORE %:				**52**	

INVERTEBRATE HABITAT ASSESSMENT SYSTEM (IHAS)						
River Name: Vaalbankspruit	**Date: 11/08/2020**					
Site Code: Site 3A						
SAMPLING HABITAT	**0**	**1**	**2**	**3**	**4**	**5**
Stones-in-current (SIC)						
Total length (m) of broken water (riffles or rapids)	none	0-1	>1-2	>2-3	<3-5	>5
Total length (m) of submerged stones in current (run	none	0-2	>2-5	>5-10	>10	
Number of separate SIC areas kicked (not individual stones)	0	1	2-3	4-5	6+	
Average size (cm) of stones kicked (gravel=2, bedrock >20)	none	<2,<20	2-10	11-20	2-20	
Amount fo stone surface clear (of algae, sediment, silt etc)*	n/a	0-25	26-50	51-75	>75	
Protocol: time (mins) spent actually kicking SIC (grvl/bedr=0)	0	<1	<1-2	2	>2-3	>3
**Note: up to 25% of stones is usually embedded in stream bottom*	**SIC Score (max. 20)**				**14**	
Vegetation						
Length (m) of fringing vegetation sampled (banks)	none	0-¼	>¼ - 1	>1-2	2	>2
Amount (m^2) of aquatic vegetation / algae sampled	none	0-½	>½ - 2	>1		
Fringing vegetation sampled in: (none; pool or still only; run only; mixture of both)	none		run	pool		mix
Type of veg (% leafy vegetation vs stems/shoots) (aqv only = 49)	none	0	1-25	26-50	51-75	>75
	Veg Score (max. 15)				**7**	
Other Habitat / General						
Stones-out-of-current (SOOC) sampled: (protocol = $1m^2$)	none	0-½	>½-1	1	>1	
Sand sampled: (protocol = 1min) (present, but only below stones)	none	below	0-½	>½-1	1	>1
Mud sampled: (protocol = 1/2min) (present, but only below stones)	none	below	0-½	½	>½	
Gravel sampled: (protocol=1/2min) if all, SIC stone size =<2)**	none	0-½	½	>½ **		
Bedrock sampled (all=no SIC, sand, gravel) (if all, SIC stone size > 20)**	none	some			All **	
Algae present (1-2m2=algal bed, rocks=on rocks, isol=isolated clumps)	>$2m^2$	rocks	1-$2m^2$	<$1m^2$	Isol.	none
Tray identification (using time as per protocol)		under		Correct		over
*** Note still fill in SIC section*	**Other Habitat Score (max. 20)**				**11**	
	HABITAT TOTAL (max.65)				**32**	
STREAM CHARACTERISTICS	**0**	**1**	**2**	**3**	**4**	**5**
Physical						
River make up (pool = pool/dam only; run only; rapid/riffle only; 2mix = 2 types etc)	pool		run	rapid / riff	2mix	3mix
Average stream width (m)		>10	5-10	<1	1-2	>2-5
Average stream depth (m)	>1	1	>¼ - 1	¼	½ - ¾	<¼
Approximate stream velocity (slow ≤ 1m/s; fast ≥1m/s)	still	slow	fast	med		mix
Water colour (disc = discoloured with visible colour but still clearish)	silty	opaque		disc		clear
Recent disturbances due to: (constr = construction; fl/dr = flood/drought)***	fl/dr	fire	Constr.	other		none
Bank/riparian vegetation is: (grass=includes reeds; shrubs=includes trees)	none		grass	shrubs	mix	
Surrounding impacts: (erosn = erosion/shear bare banks; farm = farmland/settlements	erosn	farm	trees	other		open
Left bank cover (%) (rocks and vegetation; shear = 0%)	0-50	51-80	81-95	>95		
Right bank cover (%) (rocks and vegetation; shear = 0%)	0-50	51-80	81-95	>95		
	Stream Conditions Total (max.45)				**28**	
****Note: if more than one option, choose lowest*						
	TOTAL IHAS SCORE %:				**60**	

APPENDIX B

Summarised Diatom Results


Diatom Results Summary: 2019-2020
SPI Score
20
18
16
14
12
10
8
6
4
2
0
16.4
15.8
18.1
15.5
13.8
13.9
15.3
15.4
11.4
11.5
July 2019
November 2019
August 2020
August 2020
July 2019
November 2019
August 2020
July 2019
November 2019
August 2020
Site 1a
SWR3
Site 2b
Site 3a
Sites

APPENDIX C

Invertebrate Results

Date (dd:mm:yr):	11/08/2020			(dd.ddddd)	
Site Code:	Site 1	**Grid reference (dd mm ss.s) Lat:**	**S**	#REF!	#REF!
Collector/Sampler:	Lloyd Lynch	**Long:**	**E**	#REF!	#REF!
River:	Vaalbankspruit	**Datum (WGS84/Cape):**		WGS 84	
Level 1 Ecoregion:	11: HIGHVELD	**Altitude (m):**			
Quaternary Catchment:		**Zonation:**		E: Lower Foothills	
	Temp (°C): 16.10	**Routine or Project? (circle one)**	**Flow:**		
Site Description:	**pH:** 6.90	**Project Name:**	**Clarity (cm):**	64	
	DO (mg/L): 8.59	MFC Aquatic Biomonitoring	**Turbidity:**		
	Cond (mS/m): 80.00		**Colour:**		
	Riparian Disturbance:				
	Instream Disturbance:				

Biotopes Sampled (tick & rate)	**Rating**	**Weight**
Stones In Current (SIC)	0	4.0
Stones Out Of Current (SOOC)	2	4.0
Bedrock	2	1.5
Aquatic Veg	0	1.0
MargVeg In Current	0	2.0
MargVeg Out Of Current	2	2.0
Gravel	0	4.0
Sand	2	2.0
Mud	2	1.0
Hand picking/Visual observation	Y	
OVERALL BIOTOPE SUITABILITY		**20%**

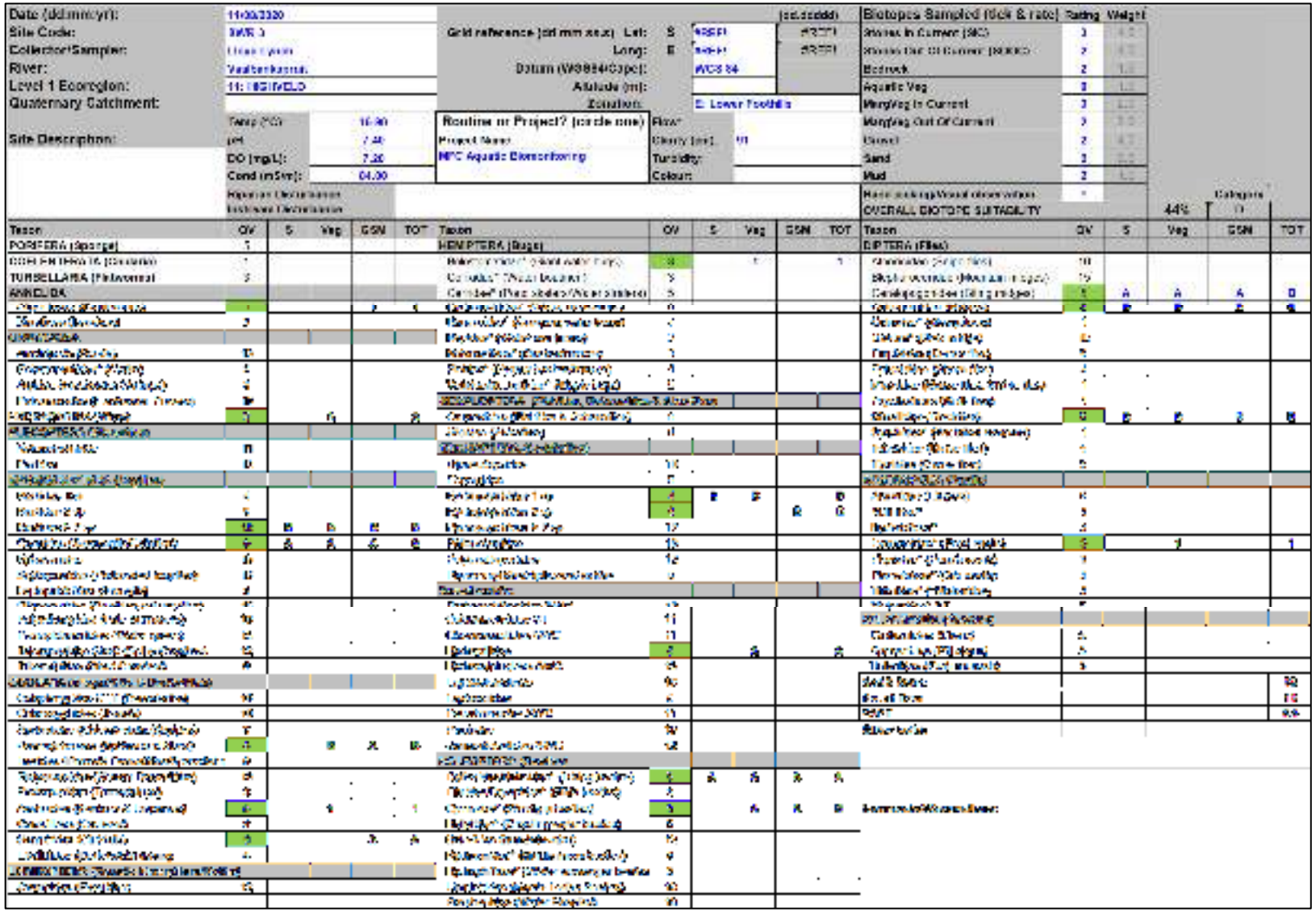
Category F

Taxon	QV	S	Veg	GSM	TOT
PORIFERA (Sponge)	5				
COELENTERATA (Cnidaria)	1				
TURBELLARIA (Flatworms)	3				
ANNELIDA					
Oligochaeta (Earthworms)	1				
Hirudinea (Leeches)	3				
CRUSTACEA					
Amphipoda (Scuds)	13				
Potamonautidae* (Crabs)	3				
Atyidae (Freshwater Shrimps)	8				
Palaemonidae (Freshwater Prawns)	10				
HYDRACARINA (Mites)	8				
PLECOPTERA (Stoneflies)					
Notonemouridae	14				
Perlidae	12				
EPHEMEROPTERA (Mayflies)					
Baetidae 1sp	4	A	A		A
Baetidae 2 sp	6				
Baetidae > 2 sp	12				
Caenidae (Squaregills/Cainflies)	6	A	1		A
Ephemeridae	15				
Heptageniidae (Flatheaded mayflies)	13				
Leptophlebiidae (Prongills)	9				
Oligoneuridae (Brushlegged mayflies)	15				
Polymitarcyidae (Pale Burrowers)	10				
Prosopistomatidae (Water specs)	15				
Teloganodidae SWC (Spiny Crawlers)	12				
Tricorythidae (Stout Crawlers)	9				
ODONATA (Dragonflies & Damselflies)					
Calopterygidae ST,T (Demoiselles)	10				
Chlorocyphidae (Jewels)	10				
Synlestidae (Chlorolestidae)(Sylphs)	8				
Coenagrionidae (Sprites and blues)	4		A		A
Lestidae (Emerald Damselflies/Spreadwin	8				
Platycnemidae (Stream Damselflies)	10				
Protoneuridae (Threadwings)	8				
Aeshnidae (Hawkers & Emperors)	8				
Corduliidae (Cruisers)	8				
Gomphidae (Clubtails)	6				
Libellulidae (Darters/Skimmers)	4				
LEPIDOPTERA (Aquatic Caterpillars/Moths)					
Crambidae (Pyralidae)	12				

Taxon	QV	S	Veg	GSM	TOT
HEMIPTERA (Bugs)					
Belostomatidae* (Giant water bugs)	3				
Corixidae* (Water boatmen)	3				
Gerridae* (Pond skaters/Water striders)	5				
Hydrometridae* (Water measurers)	6				
Naucoridae* (Creeping water bugs)	7				
Nepidae* (Water scorpions)	3				
Notonectidae* (Backswimmers)	3				
Pleidae* (Pygmy backswimmers)	4				
Veliidae/M...veliidae* (Ripple bugs)	5				
MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)					
Corydalidae (Fishflies & Dobsonflies)	8				
Sialidae (Alderflies)	6				
TRICHOPTERA (Caddisflies)					
Dipseudopsidae	10				
Ecnomidae	8				
Hydropsychidae 1 sp	4	A	A		A
Hydropsychidae 2 sp	6				
Hydropsychidae > 2 sp	12				
Philopotamidae	10				
Polycentropodidae	12				
Psychomyiidae/Xiphocentronidae	8				
Cased caddis:					
Barbarochthonidae SWC	13				
Calamoceratidae ST	11				
Glossosomatidae SWC	11				
Hydroptilidae	6				
Hydrosalpingidae SWC	15				
Lepidostomatidae	10				
Leptoceridae	6				
Petrothrincidae SWC	11				
Pisuliidae	10				
Sericostomatidae SWC	13				
COLEOPTERA (Beetles)					
Dytiscidae/Noteridae* (Diving beetles)	5	1			1
Elmidae/Dryopidae* (Riffle beetles)	8				
Gyrinidae* (Whirligig beetles)	5	1			B
Haliplidae* (Crawling water beetles)	5				
Helodidae (Marsh beetles)	12				
Hydraenidae* (Minute moss beetles)	8				
Hydrophilidae* (Water scavenger beetles	5				
Limnichidae (Marsh-Loving Beetles)	10				
Psephenidae (Water Pennies)	10				

Taxon	QV	S	Veg	GSM	TOT
DIPTERA (Flies)					
Athericidae (Snipe flies)	10				
Blepharoceridae (Mountain midges)	15				
Ceratopogonidae (Biting midges)	5				
Chironomidae (Midges)	2		A		A
Culicidae* (Mosquitoes)	1				
Dixidae* (Dixid midge)	10				
Empididae (Dance flies)	6				
Ephydridae (Shore flies)	3				
Muscidae (House flies, Stable flies)	1				
Psychodidae (Moth flies)	1				
Simuliidae (Blackflies)	5				
Syrphidae* (Rat tailed maggots)	1				
Tabanidae (Horse flies)	5				
Tipulidae (Crane flies)	5				
GASTROPODA (Snails)					
Ancylidae (Limpets)	6				
Bulininae*	3				
Hydrobiidae*	3				
Lymnaeidae* (Pond snails)	3		1		1
Physidae* (Pouch snails)	3				
Planorbinae* (Orb snails)	3				
Thiaridae* (=Melanidae)	3				
Viviparidae* ST	5				
PELECYPODA (Bivalves)					
Corbiculidae (Clams)	5				
Sphaeriidae (Pill clams)	3				
Unionidae (Perly mussels)	6				
SASS Score					33
No. of Taxa					8
ASPT					4.1
Other biota:					

Comments/Observations:



Date (dd:mm:yr):	11/08/2020				(dd.ddddd)
Site Code:	Site 3A	**Grid reference (dd mm ss.s) Lat:**	**S**	#REF!	#REF!
Collector/Sampler:	Lloyd Lynch	**Long:**	**E**	#REF!	#REF!
River:	Vaalbankspruit	**Datum (WGS84/Cape):**		WGS 84	
Level 1 Ecoregion:	11: HIGHVELD	**Altitude (m):**			
Quaternary Catchment:		**Zonation:**		E: Lower Foothills	
	Temp (°C): 7.80	**Routine or Project? (circle one)**	**Flow:**		
Site Description:	**pH:** 7.50	**Project Name:**	**Clarity (cm):**	83	
	DO (mg/L): 6.15	MFC Aquatic Biomonitoring	**Turbidity:**		
Downstream of MFC	**Cond (mS/m):** 185.00		**Colour:**		
	Riparian Disturbance:				
	Instream Disturbance:				

Biotopes Sampled (tick & rate)	Rating	Weight
Stones In Current (SIC)	2	4.0
Stones Out Of Current (SOOC)	2	4.0
Bedrock	2	1.5
Aquatic Veg	2	1.0
MargVeg In Current	2	2.0
MargVeg Out Of Current	2	2.0
Gravel	2	4.0
Sand	2	2.0
Mud	2	1.0
Hand picking/Visual observation	Y	

OVERALL BIOTOPE SUITABILITY	40%	Category E

Taxon	QV	S	Veg	GSM	TOT
PORIFERA (Sponge)	5				
COELENTERATA (Cnidaria)	1				
TURBELLARIA (Flatworms)	3	A	1		A
ANNELIDA					
Oligochaeta (Earthworms)	1	1		A	A
Hirudinea (Leeches)	3				
CRUSTACEA					
Amphipoda (Scuds)	13				
Potamonautidae* (Crabs)	3				
Atyidae (Freshwater Shrimps)	8				
Palaemonidae (Freshwater Prawns)	10				
HYDRACARINA (Mites)	8	A	A	A	B
PLECOPTERA (Stoneflies)					
Notonemouridae	14				
Perlidae	12				
EPHEMEROPTERA (Mayflies)					
Baetidae 1sp	4	A			
Baetidae 2 sp	6		A		A
Baetidae > 2 sp	12				
Caenidae (Squaregills/Cainflies)	6		A		A
Ephemeridae	15				
Heptageniidae (Flatheaded mayflies)	13				
Leptophlebiidae (Prongills)	9				
Oligoneuridae (Brushlegged mayflies)	15				
Polymitarcyidae (Pale Burrowers)	10				
Prosopistomatidae (Water specs)	15				
Teloganodidae SWC (Spiny Crawlers)	12				
Tricorythidae (Stout Crawlers)	9				
ODONATA (Dragonflies & Damselflies)					
Calopterygidae ST,T (Demoiselles)	10				
Chlorocyphidae (Jewels)	10				
Synlestidae (Chlorolestidae)(Sylphs)	8				
Coenagrionidae (Sprites and blues)	4		B		B
Lestidae (Emerald Damselflies/Spreadwin	8				
Platycnemidae (Stream Damselflies)	10				
Protoneuridae (Threadwings)	8				
Aeshnidae (Hawkers & Emperors)	8				
Corduliidae (Cruisers)	8				
Gomphidae (Clubtails)	6				
Libellulidae (Darters/Skimmers)	4				
LEPIDOPTERA (Aquatic Caterpillars/Moths)					
Crambidae (Pyralidae)	12				

Taxon	QV	S	Veg	GSM	TOT
HEMIPTERA (Bugs)					
Belostomatidae* (Giant water bugs)	3				
Corixidae* (Water boatmen)	3		C		C
Gerridae* (Pond skaters/Water striders)	5				
Hydrometridae* (Water measurers)	6				
Naucoridae* (Creeping water bugs)	7				
Nepidae* (Water scorpions)	3				
Notonectidae* (Backswimmers)	3				
Pleidae* (Pygmy backswimmers)	4				
Veliidae/M...veliidae* (Ripple bugs)	5				
MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)					
Corydalidae (Fishflies & Dobsonflies)	8				
Sialidae (Alderflies)	6				
TRICHOPTERA (Caddisflies)					
Dipseudopsidae	10				
Ecnomidae	8				
Hydropsychidae 1 sp	4	A		B	B
Hydropsychidae 2 sp	6				
Hydropsychidae > 2 sp	12				
Philopotamidae	10				
Polycentropodidae	12				
Psychomyiidae/Xiphocentronidae	8				
Cased caddis:					
Barbarochthonidae SWC	13				
Calamoceratidae ST	11				
Glossosomatidae SWC	11				
Hydroptilidae	6		1		1
Hydrosalpingidae SWC	15				
Lepidostomatidae	10				
Leptoceridae	6				
Petrothrincidae SWC	11				
Pisuliidae	10				
Sericostomatidae SWC	13				
COLEOPTERA (Beetles)					
Dytiscidae/Noteridae* (Diving beetles)	5				
Elmidae/Dryopidae* (Riffle beetles)	8	1	1		A
Gyrinidae* (Whirligig beetles)	5				
Haliplidae* (Crawling water beetles)	5				
Helodidae (Marsh beetles)	12				
Hydraenidae* (Minute moss beetles)	8				
Hydrophilidae* (Water scavenger beetles	5				
Limnichidae (Marsh-Loving Beetles)	10				
Psephenidae (Water Pennies)	10				

Taxon	QV	S	Veg	GSM	TOT
DIPTERA (Flies)					
Athericidae (Snipe flies)	10				
Blepharoceridae (Mountain midges)	15				
Ceratopogonidae (Biting midges)	5				
Chironomidae (Midges)	2	A	B	A	B
Culicidae* (Mosquitoes)	1				
Dixidae* (Dixid midge)	10				
Empididae (Dance flies)	6				
Ephydridae (Shore flies)	3				
Muscidae (House flies, Stable flies)	1				
Psychodidae (Moth flies)	1				
Simuliidae (Blackflies)	5	A	A		B
Syrphidae* (Rat tailed maggots)	1				
Tabanidae (Horse flies)	5				
Tipulidae (Crane flies)	5				
GASTROPODA (Snails)					
Ancylidae (Limpets)	6				
Bulininae*	3				
Hydrobiidae*	3				
Lymnaeidae* (Pond snails)	3				
Physidae* (Pouch snails)	3				
Planorbinae* (Orb snails)	3				
Thiaridae* (=Melanidae)	3				
Viviparidae* ST	5				
PELECYPODA (Bivalves)					
Corbiculidae (Clams)	5				
Sphaeriidae (Pill clams)	3				
Unionidae (Perly mussels)	6				
SASS Score					56
No. of Taxa					12
ASPT					4.7
Other biota:					

Comments/Observations:

AQUATIC BIO-MONITORING OF THE VAALBANKSPRUIT

Wet Season Survey (November 2020)

Prepared for:	Middleburg Ferrochrome (Pty) Ltd
Prepared by:	Knight Piésold (Pty) Ltd.
Project Number:	RI 301 00183/48
Revision Number:	A
Date:	13 January 2021

Knight Piésold CONSULTING

Prepared for
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South Africa, 2128

Project Number
RI 301-00183-48

AQUATIC BIO-MONITORING OF THE VAALBANK SPRUIT
WET SEASON SURVEY (NOVEMBER 2020)

Rev	Description	Date
A	Issued in Final	13 January 2021

Knight Piésold CONSULTING

EXECUTIVE SUMMARY

Knight Piésold (Pty) Ltd was appointed by Middelburg Ferrochrome (MFC) to conduct the bi-annual aquatic bio-monitoring of the Vaalbankspruit in Mpumulanga. Aquatic bio-monitoring is the utilisation of methods that use living organisms as a proxy for deducing water quality and ecosystem health and was used to identify any possible impacts of the MFC operations on the Vaalbankspruit. This report provides feedback on the November 2020 wet season survey and the notable aspects considered for monitoring may be summarised as follows:

Site 1 (Upstream Control Point)

- The *in-situ* dissolved oxygen saturation and dissolved oxygen concentration fell below the DWAF guidelines.
- Site 1 provided good habitat availability, with an IHAS score of 70 %
- The invertebrate PES was categorised as Category E (Seriously Modified).
- The general diatom-based water quality ecological category for Site 1 was A/B (High Quality)

SWR 3 (Upstream)

- The dissolved oxygen concentration and saturation values fell below the minimum threshold value stipulated within the DWAF guidelines.
- Inadequate habitat availability was provided at SWR 3, with an IHAS score of 53 %
- The invertebrate PES was categorised as E (Seriously Modified)
- The general diatom-based water quality ecological category for SWR 3 was Category C (Moderate Quality)

Z 08 (Drainage Channel)

- The dissolved oxygen saturation and dissolved oxygen concentration fell below the DWAF guidelines.
- The general diatom-based water quality ecological category for Site 2B was Category B (Good Quality)

Site 2B (Mid-stream Point)

- This site was not suitable for bio-monitoring as there was no distinct channel
- The dissolved oxygen concentration and saturation values fell below the minimum threshold value stipulated within the DWAF guidelines.
- The general diatom-based water quality ecological category for Site 2B was Category B (Good Quality)

Site 3A (Downstream)

- This site is a wetland and there was no distinct channel making it unsuitable for bio-monitoring. The previously surveyed site was covered by the reed bed which had grown dense.
- The *in-situ* value of conductivity exceeded the DWAF guidelines, while the dissolved oxygen saturation and dissolved oxygen concentration fell below the DWAF guidelines.
- The general diatom-based water quality ecological category for Site 3A was Category B (Good Quality)

General and Recommendations

The wet and dry season bio-monitoring surveys should continue to monitor the potential impacts of MFC on the Vaalbankspruit and to determine any trends and seasonal variation on the receiving aquatic environment.

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1.0 INTRODUCTION

1.1 PROJECT DESCRIPTION

Middelburg Ferrochrome (Pty) Ltd, hereafter referred to as MFC, is situated within Middelburg, Mpumalanga. To comply with the Water Use Licence conditions from the Department of Water and Sanitation (DWS) aquatic bio-monitoring should be undertaken during the dry and wet season at the upstream and downstream monitoring points to determine the potential impact of the MFC operations on the Vaalbankspruit.

1.2 BACKGROUND

Knight Piésold (Pty) Ltd (KP) was appointed by MFC to conduct the bi-annual aquatic bio-monitoring of the Vaalbankspruit. The MFC facility was established in 1964 as a Low Carbon Ferrochrome production facility. Charge chrome was first produced on this site in 1974 by Middelburg Steel and Alloys (Pty) Ltd, which was acquired by Samancor in 1991, making it one of only a few alloy plants in the world able to produce both charge chrome and low carbon ferrochrome, which it stopped producing in 2015. It currently produces charge chrome from two Submerged-Arc Furnaces (SAF's), two Direct-Current (DC) Furnaces, a Pelletising and Sintering plant (PSP) and a metal recovery plant.

1.3 SCOPE OF WORK

The scope of this report is as follows:

- To provide feedback on the Aquatic Bio-monitoring for the November 2020 wet season survey
- To assess the potential impacts of the MFC operations on the Present Ecological State (PES) of the Vaalbankspruit
- To provide mitigation and early detection of any potential impacts on the aquatic ecosystem due to the MFC operations.

2.0 SITE DESCRIPTION

MFC is situated along the southern portion of Middelburg, within the industrial area of the town. The location is presented in Figure 1 below.

Figure 1: General Locality of Middelburg Ferrochrome

2.1 GENERAL SITE CHARACTERISTICS

2.1.1 CATCHMENT MANAGEMENT

MFC falls within the Olifants Water Management Area, which is characterised by the following:

Table 1: Olifants Water Management Area

Quaternary catchments	B12D
Level 1 Ecoregion	Highveld – Lower Ecoregion
Rivers	Vaalbankspruit
Present Ecological State	Category E (Seriously Modified)

2.1.2 SITES SELECTED FOR AQUATIC BIO-MONITORING

In accordance with the WUL conditions the bio-monitoring sites were provided by the client. The GPS co-ordinates of each site were pre-assessed using GIS imagery and confirmed during the ground truth process. Five monitoring sites were surveyed to assess the Present Ecological State (PES) and the possible impacts of MFC operations on the receiving aquatic environment.

The bio-monitoring sites are illustrated in Figure 2 and further described in Table 2 below.

Table 2: General Description of the Bio-monitoring Sites

Site Code	Description	Position UTM (WGS 84)
Site 1	Upstream Control Point – Located within a cattle farm, this site is upstream of all MFC operational activities and serves as a reference point	25°49'20.38"S 29°29'27.43"E
SWR 3	Upstream Impact Monitoring Point – Located alongside the southern border of the MFC property, this site serves as the upstream monitoring point.	25°49'7.16"S 29°29'25.68"E
Z 08	Drainage Channel – A drainage channel which flows east towards the Vaalbankspruit from the nearby Wastewater treatment works.	25°48'51.37"S 29°28'55.62"E
Site 2B	Impact Monitoring Point – Situated between the CRD Slimes and the Kloof Slag disposal sites, this point serves as a direct impact monitoring point.	25°48'5.64"S 29°29'7.99"E
Site 3A	Downstream Impact Monitoring Point – Located along the northern boundary of the MFC property, this site is situated alongside a low-level culvert and stream crossing.	25°47'40.14"S 29°29'1.95"E

Figure 2: Locality of the Aquatic Bio-monitoring Sites

3.0 METHODOLOGY

Aquatic bio-monitoring was conducted to measure, assess and report on the general state of the receiving aquatic environment in order to provide an overview of the ecological health. Bio-monitoring incorporates the application of biological indicators and relevant non-biological indicators (indices) to assess the condition or "health" of the aquatic ecosystems. This assessment was based on selected abiotic and biotic components.

The results of these indices are presented in the form of one of six Present Ecological State (PES) categories. The categories range from an "A" to an "F" state. The categories and state descriptions are represented in Table 3 below.

Table 3: Present Ecological State

PES	PES Name	Description
A	Natural	Unmodified natural
B	Good	Largely natural with few modifications
C	Fair	Moderately modified
D	Poor	Largely modified
E	Severely Modified	Seriously modified
F	Critically Modified	Critically or extremely modified

The following ecological indicators were selected to represent the general ecological components involved in the aquatic environment:

- ***In situ* water quality** – pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS) and Temperature (°C).
- **Visual assessment** – In-stream habitat conditions include a general description of each site, GPS locations, photographs for future reference and surrounding features that may lead to pollution.
- **Invertebrate Habitat Assessment** – habitat suitability available for macro invertebrates such as Stone, Vegetation and GSM (Gravel, Sand and Mud).
- **Invertebrates** – Benthic aquatic invertebrates comprise of a wide range of taxa that live in streams and rivers. Abundance and compositions of invertebrate communities reflect water quality and in-stream habitat conditions.
- **Diatoms** – Provide biological water quality information for conditions on the day of biological component sampling regarding the aquatic health and functioning of the aquatic system and providing additional input to the physico-chemical component of the study as a response variable.

3.1 *IN-SITU* WATER QUALITY

Water quality is used to describe the physical, chemical, biological and aesthetic properties of water that determine its fitness for a variety of uses and for the protection of the health and integrity of aquatic ecosystems (DWAF, 1996).

The following water quality parameters were determined during the field survey using multi-parameter field instruments:

- pH
- Total Dissolved Solids (mg/l)
- Electrical Conductivity (mS/m)
- Temperature (°C)
- Dissolved Oxygen (DO) (mg/l)
- Dissolved Oxygen (DO) (%).

The above-mentioned parameters provide an *in-situ* of the current water quality at the time of the survey and can be used as an early detection system for any water quality changes.

3.2 VISUAL ASSESSMENT

Each site was assessed by in-stream conditions such as morphology, hydrology and general site description. Photographic evidence was taken at each site as a representation of the conditions during the survey. Visual assessment is essential as it can be used as a preventative measure that detects changes that may potentially impact the aquatic system at a later stage.

3.3 INVERTEBRATE HABITAT ASSESSMENT SYSTEM (IHAS)

IHAS evaluates the availability of suitable habitat for macro-invertebrates and expresses the availability and suitability as a percentage as described below. IHAS scores were interpreted according to the guidelines of McMillan 2002 as follows:

- <55% inadequate habitat
- 55-65% adequate habitat
- >65% good habitat.

The IHAS has been tested and found to be an unsatisfactory method of quantifying invertebrate habitat suitability (Ollis *et al*., 2006). As this study forms part of WUL conditions, IHAS will still be utilised and compared to a suitable simple five points scale as per the SASS 5 sheet.

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.

3.4 AQUATIC INVERTEBRATES

The South African Scoring System Version 5 (SASS 5) (Dickens and Graham, 2002) is a rapid bio-assessment method used to assess the integrity of macro-invertebrates in flowing aquatic ecosystems. Aquatic bio-monitoring utilises this index to detect the water quality of ecosystems. The index assigns each taxon with a sensitivity score that is used to indicate an overall average score per taxon (ASPT).

Benthic macro-invertebrates, in particular, are recognised as valuable organisms for bio-assessments, due largely to their visibility to the naked eye, ease of identification, rapid life cycle often based on the seasons and their largely sedentary habits (Dickens and Graham, 2002). Sampling was conducted using a standard size SASS net with mesh <1mm, dislodging macro invertebrates from their habitat substrates into the water column and catching the invertebrates in the net.

SASS Data Interpretation Guidelines (Dallas, 2007) were used to interpret the SASS 5 information collected during the survey. The guidelines method utilises natural variation in SASS 5 scores and ASPT to determine preliminary biological bands. The study area falls within the Level 1 Ecoregion for the Highveld and the SASS5 score and ASPT values were evaluated according to these bands.

3.5 DIATOMS

3.5.1 SAMPLING AND ANALYSIS

The diatom analysis was conducted in South Africa by Shael Koekemoer of Koekemoer Aquatic Services. Epiphyton substrate was sampled as outlined in Taylor *et al.* (2007a). Diatom samples were taken at the site by scrubbing the substrate with a small brush and rinsing both the brush and the substrate with distilled water.

Preparation of diatom slide followed the Hot HCl and $KMnO_4$ method as outlined in Taylor *et al.* (2007a). A Nikon Eclipse E100 microscope with phase contrast optics (1000x) was used to identify diatom valves on slides. The aim of the data analysis was to count 400 diatom valves to produce semi-quantitative data from which ecological conclusions can be drawn (Taylor *et al*., 2007a). This range is supported by Prygiel *et al.* (2002), Schoeman (1973) and Battarbee (1986) as satisfactory for the calculation of relative abundance of diatom species. Nomenclature followed Krammer and Lange-Bertalot (1986-91). Diatom index values were calculated in the database programme OMNIDIA (Lecointe *et al*., 1993) for epilithon data in order to generate index scores to general water quality variables.

The referenced diatom data which was sampled prior to the August and November 2020 survey was not collected by Knight Piésold (Pty). However, Koekemoer Aquatic Services made references based on their database, as they have analysed diatom samples from the sampled points of the Vaalbankspruit.

3.5.2 DIATOM BASED WATER QUALITY SCORE

The European numerical diatom index, the Specific Pollution sensitivity Index (SPI) was used to assign biological water quality Ecological Categories (ECs) and associated water quality classes. Classes based on the class limits provided in Table 4. Other indices housed within the OMNIDIA programme used to characterise biological water quality included:

- Biological Diatom Index (BDI): Primarily a practical index, as it treats morphologically related taxa as one group and composes so-called associated taxa eliminating species that are difficult to identify.
- The ecological characterisation of diatom species based on Van Dam et al. (1994): Includes the preferences of 948 freshwater and brackish water diatom species in terms of pH, nitrogen, oxygen, salinity, humidity, saprobity and trophic state.
- Trophic Diatom Index (TDI) (Kelly and Whitton, 1995): This index provides the percentage pollution tolerant diatom valves (PTVs) in a sample and was developed for monitoring sewage outfall (orthophosphate-phosphorus concentrations), and not general stream quality. The presence of more than 20% PTVs shows significant organic impact.
- Valve deformities were also noted as it is an indication of possible metal toxicity that may be present within the system. According to Luís et al. (2008) several studies on metal polluted rivers have shown that diatoms respond to perturbations not only at the community but also at the individual level with alteration in cell wall morphology. In particular, size reduction and frustule deformations have been sometimes associated with high metal concentrations. The general threshold for the occurrence of valve deformities in a sample is usually considered between 1 - 2% and is regarded as potentially hazardous (Taylor, pers. comm.).

Table 4: Adjusted Class Limit Boundaries for the SPI Index Applied in this Study

Interpretation of Index Scores		
Ecological Category (EC)	**Class**	**Index Score (SPI Score)**
A	High Quality	18 – 20
A/B		17 – 18
B	Good Quality	15 – 17
B/C		14 – 15
C	Moderate Quality	12 – 14
C/D		10 – 12
D	Poor Quality	8 – 10
D/E		6 – 8
E	Bad Quality	5 – 6
E/F		4 – 5
F		>4

4.0 RESULTS AND DISCUSSION

This section provides feedback on the recent aquatic bio-monitoring survey of the Vaalbankspruit. The results for the November 2020 survey will be presented according to Table 5 below which summarises the SASS interpretation for the Highveld – Lower Ecoregion.

Table 5: Summarised interpretation of the Highveld Ecoregion

Category	Description	Average Score per Taxon (ASPT)	SASS Score
A	Unmodified or approximate natural conditions. High diversity of taxa with numerous sensitive taxa.	>5.6	> 123
B	Largely natural with few modifications. A change in community characteristics may have taken place but species richness and presence of intolerant species indicate little modification	>4.8	>81
C	Moderately Modified. A lower than expected species richness and presence of most intolerant species. Some impairment of health may be evident at the lower limit of this class.	>4.6	>64
D	Largely Modified. A clearly lower than expected species richness and absence or much lowered presence of intolerant and moderately intolerant species. Impairment of health may become more evident at the lower limit of this class.	>4.2	>51
E	Seriously Modified. A strikingly lower than expected species richness and general absence of intolerant and moderately intolerant species. Impairment of health may become very evident.	<4.2	<51
F	Critically Modified. An extremely lowered species richness and absence of intolerant species. Only tolerant species may be present with a complete loss of species at the lower limit of the class. Impairment of health generally very evident		<19

4.1 SITE 1 (UPSTREAM CONTROL POINT)

Plate 1: Upstream view of Site 1

Plate 2: Downstream view of Site 1

Site 1 is located within a privately fenced livestock farm. The water levels were higher compared to the last survey, and the habitat had improved as aquatic vegetation was available for sampling. During the survey the site experienced low to no flow and the clarity was recorded as 52 cm.

4.1.1 *IN-SITU* WATER QUALITY

Table 6: *In-situ* water quality results for Site 1

Sample Point	Date	pH	Temp	TDS (mg/l)	Conductivity (mS/m)	DO (mg/l)	DO (%)
DWAF Ecosystem Guidelines		**6.5 – 9.0**	**5 – 30**	**<1100**	**<154**	**>5.0**	**80 – 120**
Site 1	17/11/2020	7.8	26.7	320	65	2.15	27.1

The recorded *in-situ* parameters fell within guideline values, except for dissolved oxygen concentration and saturation which deviated from the DWAF guideline limits.

4.1.2 IHAS

Site 1 obtained an IHAS score of 70 %, indicating that it provided good habitat availability (Table 7). It had a SASS biotope score of 46 % which placed Site 1 into an EC of Category D (Largely Modified), which is an improvement from the Category F (Critically Modified) obtained during the previous dry season. Populations of aquatic vegetation were available for sampling during this survey which were not available during the previous dry season survey. The site provided all biotopes; however, the GSM biotopes were limited to the banks and underneath the stones present in the survey area. The site also had boulders, stones, and marginal vegetation (dominantly reeds) available for sampling.

Table 7: Site 1 IHAS Results for November 2020 Wet Season Survey

Biotope	Score
	Site 1
Stones (out of 20 points)	15
Vegetation (out of 15 points)	13
Other/General (out of 20 points)	17
Total out of 55	45
Physical aspects and Conditions (out of 45 points)	25
Total IHAS Score	70
IHAS Description	Good

4.1.3 AQUATIC INVERTEBRATES

The site obtained a SASS score of 47 and an ASPT of 3.6, as a total of 13 taxa were observed. These results placed the site into a Present Ecological State (PES) of Category E (Seriously Modified), an improvement from the Category F (Critically Modified) obtained during the previous dry survey. The PES obtained of Category E complies with the RQO for the Vaalbankspruit. The most sensitive taxa recorded during the survey include Aeshnidae (Hawkers & Emperors) and Veliidae (Ripple bugs). A summary of the SASS results for the November 2020 survey is presented below.

Table 8: Summary of Site 1 SASS Results for November 2020 Wet Season Survey

Taxon	QV	S	Veg	GSM	TOT
CRUSTACEA					
Potamonautidae* (Crabs)	3				1
EPHEMEROPTERA (Mayflies)					
Baetidae 1sp	4	A	A		B
ODONATA (Dragonflies & Damselflies)					
Coenagrionidae (Sprites and blues)	4	A	A		A
Aeshnidae (Hawkers & Emperors)	8	1	1		A
Libellulidae (Darters/Skimmers)	4			B	B
HEMIPTERA (Bugs)					
Belostomatidae* (Giant water bugs)	3		1		1
Nepidae* (Water scorpions)	3		A		A
Notonectidae* (Backswimmers)	3		A		A
Pleidae* (Pygmy backswimmers)	4	A	A		B
Veliidae/M...veliidae* (Ripple bugs)	5		A		A
DIPTERA (Flies)					
Chironomidae (Midges)	2	A	A	A	B
Culicidae* (Mosquitoes)	1	A	A	A	B
GASTROPODA (Snails)					
Physidae* (Pouch snails)	3	1			1
SASS Score					47
No. of Taxa					13
ASPT					3.6

4.1.4 DIATOMS

The biological water quality at Site 1 deteriorated slightly from August 2020. In December 2020, the SPI score was 17.8 (A/B Ecological Category) with high water quality prevailing. Further analysis of the various indices within OMNIDIA suggested that organic pollution levels increased slightly between August and December 2020 while no significant change in salinity concentrations and nutrient loading was observed during this time. Pollution levels remained stable from August 2020 with slight levels prevailing in December 2020.

No notable change in diatom species composition was observed between August and December 2020. *Brachysira neoexilis* and *Achnanthidium minutissima* still dominated the diatom community and are found in clean, oligo- to mesotrophic waters and therefore have a high indicator value in determining the SPI score. However, as noted in August 2020, both species are closely associated with mining effluent containing heavy metals. From previous and current studies in the Mpumalanga mining industry area it has been noted that *Achnanthidium minutissima* occurs in high abundance in critically polluted streams across the province, which is associated with coal mining. These two species have been consistently present at dominant and sub-dominant abundance since November 2017, suggesting that mining effluent could have been present. The abundance of aerophilic species increased between August and December 2020, suggesting that water level fluctuation was more pronounced in December 2020. No valve deformities were noted in December 2020 which was similar to August 2020.

4.2 SWR 3 (UPSTREAM MONITORING POINT)

Plate 3: Upstream view of Site SWR 3

Plate 4: Downstream view of Site SWR 3

This site is located upstream of MFC, in close proximity to the southern edge of the MFC property. The site is accessed from a nearby road crossing, downstream of a livestock farm. The site is comprised of multiple pools connected by a run. The marginal vegetation had grown, and the flow reduced compared to the last survey. The water clarity at the site was recorded as 76 cm.

4.2.1 *IN-SITU* WATER QUALITY

Table 9: *In-situ* water quality results for SWR 3

Sample Point	Date	pH	Temp	TDS (mg/l)	Conductivity (mS/m)	DO (mg/l)	DO (%)
DWAF Ecosystem Guidelines		**6.5 – 9.0**	**5 – 30**	**<1100**	**<154**	**>5.0**	**80 – 120**
SWR 3	17/11/2020	7.3	23.1	550	112	1.88	23.1

The dissolved oxygen saturation and concentration deviated from the DWAF guidelines, while all the other *in-situ* parameters are within the guideline limits.

4.2.2 IHAS

Site SWR 3 obtained an IHAS score of 53 % indicating that it provided poor habitat availability during the November 2020 survey. The SASS biotope score of 39 % placed SWR 3 into an EC of Category E (Seriously Modified). Although variable, all three biotopes were available for sampling. The site was dominated by the stone biotope throughout the run and pools. The GSM biotopes were limited to the

undercut banks present at the site, whilst the marginal vegetation was located along the banks and dominated by *Typha* sp..

Table 10: SWR 3 IHAS Results for November 2020 Wet Season Survey

Biotope	Score
	SWR 3
Stones (out of 20 points)	12
Vegetation (out of 15 points)	9
Other/General (out of 20 points)	13
Total out of 55	34
Physical aspects and Conditions (out of 45 points)	19
Total IHAS Score	53
IHAS Description	Poor

4.2.3 AQUATIC INVERTEBRATES

A SASS score of 47 and a total of 12 taxa were observed at site SWR 3, resulting in an ASPT of 3.9, which placed the site into a Present Ecological State (PES) of Category E (Seriously Modified), which is a deterioration from the Category B (Largely natural with few modifications) obtained during the previous dry survey. The PES obtained of Category E complies with the RQO for the Vaalbankspruit. The most sensitive taxa recorded during the survey include Hydracarina (Mites) and Hydroptilidae (Cased Caddisflies). A summary of the SASS results for the November 2020 survey is presented below.

Table 11: SWR 3 Summary of SASS Results for November 2020 Wet Season Survey

Taxon	QV	S	Veg	GSM	TOT
TURBELLARIA (Flatworms)	3	A			A
ANNELIDA					
Oligochaeta (Earthworms)	1			A	A
CRUSTACEA					
Potamonautidae* (Crabs)	3				A
CHELICERATA					
Hydracarina (Mites)	8	A	A		B
ODONATA (Dragonflies & Damselflies)					
Coenagrionidae (Sprites and blues)	4		A		A
HEMIPTERA (Bugs)					
Belostomatidae* (Giant water bugs)	3		1		1
Corixidae* (Water boatmen)	3	A	A		B
TRICHOPTERA (Caddisflies)					
Cased caddis:					
Hydroptilidae	6		1		1
COLEOPTERA (Beetles)					
Gyrinidae* (Whirligig beetles)	5				B

DIPTERA (Flies)					
Ceratopogonidae (Biting midges)	5	A		A	B
GASTROPODA (Snails)					
Physidae* (Pouch snails)	3	A	A		A
Planorbinae* (Orb snails)	3		1		1
SASS Score					47
No. of Taxa					12
ASPT					3.9

4.2.4 DIATOMS

The biological water quality at site SWR 3 deteriorated from August 2020. In December 2020, the SPI score was 12.3 (C Ecological Category) with moderate water quality prevailing. Further analysis of the various indices within OMNIDIA suggested that organic pollution levels and nutrient loading increased between August and December 2020, while no significant change in salinity concentrations was observed during this time. Pollution levels remained stable from August 2020 with slight levels prevailing in December 2020.

As observed in August 2020, species diversity increased at Site SWR 3 in comparison to Site 1 suggesting an increased measure of potential impact. Increased nutrient and organic loading associated with sewage effluent was the main reason for biological water quality deterioration in December 2020 and reflected by the decreased abundance of species with an affinity for good water quality between August and December 2020. Increased enrichment and eutrophication, especially increased total phosphorous was reflected by the dominance of *Aulacoseira granulata* and *Aulacoseira granulata* var. *angustissima*. *Nitzschia nana* was also dominant and is a halophilic epipelic (sediment dwelling) species occurring in Phosphate enriched waters, and being epipelic, suggested that sedimentation was elevated. This species also has an affinity for elevated Copper concentration with an optimal tolerance of 0.57 ±2.73 mg/L (Von Falkenhayen, 2010). The stressed environment at Site SWR 3 was further reflected by the high abundance of *Pseudostaurosira brevistriata*, a r-strategist species (small fast reproducing), able to tolerate harsh and frequently changing conditions. No valve deformities were noted in December 2020 which was an improvement from August 2020.

4.3 Z 08 (DRAINAGE CHANNEL)

Plate 5: Upstream view of Site Z 08

Plate 6: Downstream view of Site Z 08

Monitoring point Z 08 is located within a drainage channel which flows towards the Vaalbankspruit. There was water present during this round, unlike the previous survey (August) where the channel was dry. The site was unsuitable for biomonitoring, as it was a standing pool of water. *In-situ* analysis was conducted at this site and a sample was collected for diatom analysis.

4.3.1 *IN-SITU* WATER QUALITY

Table 12: *In-situ* water quality results for Z 08

Sample Point	Date	pH	Temp	TDS (mg/l)	Conductivity (mS/m)	DO (mg/l)	DO (%)
DWAF Ecosystem Guidelines		**6.5 – 9.0**	**5 – 30**	**<1100**	**<154**	**>5.0**	**80 – 120**
Z 08	17/11/2020	7.2	22.8	640	129	2.77	32.5

The analysed *in-situ* parameters were within the DWAF guideline limits, except for dissolved oxygen saturation (%) and concentration (mg/l) which deviated from the DWAF guidelines.

4.3.2 DIATOMS

Diatoms were sampled for the first time at this site in December 2020. Biological water quality was good with a SPI score of 15 (B Ecological Category). Further analysis of the various indices within OMNIDIA suggested that organic pollution, nutrient levels and salinity concentrations were elevated with slight levels prevailing in December 2020.

The diatom community composition at Site Z 08 was very similar to Site 1, with *Brachysira neoexilis* and *Achnanthidium minutissima* dominating the diatom community. These species are found in clean, oligo- to mesotrophic waters and therefore have a high indicator value in determining the SPI score. However, both species are closely associated with mining effluent containing heavy metals. Aerophilic species were also prolific suggesting that water level fluctuation impacted the site. No valve deformities were noted in December 2020 suggesting that metal toxicity was below detection limits.

4.4 SITE 2B (MID-STREAM MONITORING POINT)

Plate 7: Upstream view of Site 2B

Plate 8: Downstream view of Site 2B

Monitoring point Site 2B is densely vegetated with reeds and is located at a low-level crossing. The site had low flow and the dense reedbed limited access to the site. Monitoring point Site 2B was therefore not suitable for bio-monitoring, however, *in-situ* analysis was conducted and a diatom sample was collected for analysis.

4.4.1 *IN-SITU* WATER QUALITY

Table 13: *In-situ* water quality results for Site 2B

Sample Point	Date	pH	Temp	TDS (mg/l)	Conductivity (mS/m)	DO (mg/l)	DO (%)
DWAF Ecosystem Guidelines		**6.5 – 9.0**	**5 – 30**	**<1100**	**<154**	**>5.0**	**80 – 120**
Site 2B	17/11/2020	7.2	18.9	730	150	1.35	15.6

The dissolved oxygen saturation and concentration deviated from the DWAF guideline limits while all the other *in-situ* parameters were within the limits.

4.4.2 DIATOMS

The biological water quality at Site 2B improved slightly from August 2020. In December 2020, the SPI score was 16.5 (B Ecological Category) with good water quality prevailing at the time of sampling. Improvement was mainly due to improved organic pollution while salinity concentrations and nutrient

levels remained stable. Further analysis of the various indices within OMNIDIA suggested that pollution levels remained stable from August 2020 with moderate levels prevailing in December 2020.

Achnanthidium species dominated the diatom community by 70 % in December 2020. The increase in this pioneer species either indicates increased flow at the time of sampling or accumulative impact within the Vaalbankspruit as this species is metal tolerant and generally increases in abundance in treated streams. The abundance of *Gomphonema parvulum* decreased between August and December 2020 reflecting improved organic loads, sedimentation and Phosphorus concentrations. *Rhoicosphenia curvata* was also dominant and suggested that salinity concentration was higher in December 2020 compared to August 2020. The latter species is frequently found as an epiphyte on the green filamentous algae such as *Cladophora* species (blanket weed), and typifies electrolyte-rich to brackish waters, tolerating pollution. According to Wilson *et al*. (2011) it has a salinity optima of 1.32 g/L. No valve deformities were noted in December 2020 which was a notable improvement from August 2020.

4.5 SITE 3A (DOWNSTREAM MONITORING POINT)

Plate 9: Upstream view of Site 3A

Plate 10: Downstream view of Site 3A

Site 3A is located towards the northern boundary of the MFC property. It is situated at a culvert with a raised crossing. The monitoring point was covered by reeds, closing the limited open area that was sampled during the last survey. Bio-monitoring was therefore not conducted during this survey due to the dense reed bed that had taken over the previously sampled stretch of the Vaalbankspruit.

4.5.1 *IN-SITU* WATER QUALITY

Table 14: *In-situ* water quality results for Site 3A

Sample Point	Date	pH	Temp	TDS (mg/l)	Conductivity (mS/m)	DO (mg/l)	DO (%)
DWAF Ecosystem Guidelines		**6.5 – 9.0**	**5 – 30**	**<1100**	**<154**	**>5.0**	**80 – 120**
Site 3A	17/11/2020	7.1	19.3	930	189	1.69	18.3

The conductivity, dissolved oxygen saturation and dissolved oxygen concentration deviated from the DWAF guideline limits while all the other *in-situ* parameters were within the limits.

4.5.2 DIATOMS

The biological water quality at Site 3A improved from August 2020. In December 2020, the SPI score was 15.4 (B Ecological Category), with good water quality prevailing. Although improvement in the SPI score was evident, further analysis of the various indices within OMNIDIA suggested that organic pollution levels increased slightly between August and December 2020, while increased nutrient loading

was also observed during this time. Pollution levels remained stable from August 2020 with moderate levels prevailing in December 2020.

Achnanthidium species still dominated the diatom community in December 2020, reflecting ongoing disturbance at the site. Sulphate-based salinity concentrations decreased between August and December 2020 at the site, based on the decreased abundance of *Fragilaria fasciculata*. Key indicator species associated with industrial effluent occurred at similar abundance between Site 2B and Site 3A and suggested an overall stable measure of impact between the sites, they are improving when compared to 2019. *Nitzschia amphibia* increased in abundance at this site between August and December 2020, suggesting that the measure of sewage related impact increased during this time. *Nitzschia amphibia* is often associated with organic pollution being a tolerant species, typically part of the silt flora and is often abundant in recovery zones close to sewage treatment works and prefers warm, brackish, sodium sulphate waters. No valve deformities were noted in December 2020 which was an improvement from August 2020.

5.0 CONCLUSION

5.1 SITE 1 (UPSTREAM CONTROL POINT)

- The *in-situ* dissolved oxygen saturation and dissolved oxygen concentration fell below the DWAF guidelines.
- Site 1 provided good habitat availability, with an IHAS score of 70 %
- The invertebrate PES was categorised as Category E (Seriously Modified).
- The general diatom-based water quality ecological category for Site 1 was A/B (High Quality)

5.2 SWR 3 (UPSTREAM)

- The dissolved oxygen concentration and saturation values fell below the minimum threshold value stipulated within the DWAF guidelines.
- Inadequate habitat availability was provided at SWR 3, with an IHAS score of 53 %
- The invertebrate PES was categorised as E (Seriously Modified)
- The general diatom-based water quality ecological category for SWR 3 was Category C (Moderate Quality)

5.3 Z 08 (DRAINAGE CHANNEL)

- The dissolved oxygen saturation and dissolved oxygen concentration fell below the DWAF guidelines.
- The general diatom-based water quality ecological category for Site 2B was Category B (Good Quality)

5.4 SITE 2B (MID-STREAM POINT)

- This site was not suitable for bio-monitoring as there was no distinct channel
- The dissolved oxygen concentration and saturation values fell below the minimum threshold value stipulated within the DWAF guidelines.
- The general diatom-based water quality ecological category for Site 2B was Category B (Good Quality)

5.5 SITE 3A (DOWNSTREAM)

- This site is a wetland and there was no distinct channel making it unsuitable for bio-monitoring. The previously surveyed site was covered by the reed bed which had grown dense.
- The *in-situ* value of conductivity exceeded the DWAF guidelines, while the dissolved oxygen saturation and dissolved oxygen concentration fell below the DWAF guidelines.
- The general diatom-based water quality ecological category for Site 3A was Category B (Good Quality)

5.6 GENERAL AND RECOMMENDATIONS

The wet and dry season bio-monitoring surveys should continue to monitor the impacts of MFC on the Vaalbankspruit and to determine any trends and seasonal variation on the receiving aquatic environment.

6.0 REFERENCES

Battarbee, R.W. 1986. Diatom Analysis. In Berglund BE (ed) Handbook of Holocene Paleoecology and Paleohydrology. John Wiley & Sons Ltd. Chichester. Great Briton. pp 527-570.

Bełdowska, M., Zgrundo, A. & Kobos, J. 2018. Mercury in the Diatoms of Various Ecological Formations. *Water, Air, & Soil Pollution*, 229 (5): 168. [https://doi.org/10.1007/s11270-018-3814-1].

Cattaneo, A., Couillard, Y., Wunsam, S., and Courcelles, M. 2004. Diatom taxonomic and morphological changes as indicators of metal pollution and recovery in Lac Dufault Québec, *Canada. Journal of Paleolimnology* 32: 163-175.

Craticula. 2011. Common Freshwater Diatoms of Britain and Ireland. A multiaccess key. [Web: http://craticula.ncl.ac.uk/EADiatomKey/html/taxa.html].

Dallas H F (2007). River Health Programme: South African Scoring System (SASS) Data Interpretation Guidelines. Report produced for the Department of Water Affairs and Forestry (Resource Quality Services) and the Institute of Natural Resources.

Davey, A., Gardner, M., Johnson, I., Nixon, S., Payne, m. and Smith, H. 2008. Understanding the Impact of Farming on Aquatic Ecosystems. Defra Project WQ0112.

Dickens, C. W. S. and Graham, P. M. (2002). The South African Scoring System (SASS) Version 5 Rapid bioassessment method for rivers. African Journal of Aquatic Science 27(1): 1-10.

DWAF (1996). South African Water Quality Guidelines Volume 7: Aquatic Ecosystems. - Pretoria : Department of Water Affairs and Forestry.

Herlory, O., Bonzom, J-M., Gilbin, R., Frelon, S., Fayolle, S., Delmas, F. and Coste, M. 2013. Use of diatom assemblages as biomonitor of the impact of treated uranium mining effluent discharge on a stream: Case study of the Ritord watershed (Center-West France). *Ecotoxicology* 22:1186–1199 DOI 10.1007/s10646-013-1106-5.

Kelly M. G., Whitton B. A., (1995). The Trophic Diatom Index: a new index for monitoring eutrophication in rivers, Journal of Applied Phycology 7, 433- 444.

Krammer, K and Lange-Bertalot, H (1986-1991). Bacillario-phyceae. Süßwasserflora von Mitteleuropa 2 (1-4). Spektrum Akademischer Verlag, Heidelberg. Berlin.

Lecointe, C, Coste, M and Prygiel, J (1993). "Omnidia": Software for taxonomy, calculation of diatom indices and inventories management. Hydrobiologia 269/270: 509-513.

Luís, A.T., Teixeira, P., Almeida, S.F.P., Ector, L., Matos, J.X. and Ferreira da Silva, A. (2008). Impact of Acid Mine Drainage (AMD) on Water Quality, Stream Sediments and Periphytic Diatom Communities in the Surrounding Streams of Aljustrel Mining Area (Portugal). Water Air Soil Pollution. DOI 10.1007/s11270-008-9900-z.

McMillan P H (1998). An Invertebrate Habitat Assessment System (IHASv2), for the Rapid Biological Assessment of Rivers and Streams. [Report]: Research Project / Water Resources Management Program. - [s.l.] : CSIR, 1998. - pp. Ii, 44. - number ENV-P-I 98132.

Medley, C.M. and Clements, H.C. 1998. Responses of Diatom communities to Heavy Metals in Streams: The Influence of Longitudinal Variation. *Ecological Applications*, 8(3), pp. 63 1-644.

Prygiel J, Carpentier P, Almeida S, Coste M, Druart JC, Ector L, Guillard D, Honoré MA, Iserentant R, Ledeganck P, Lalanne-Cassou C, Lesniak C, Mercier I, Moncaut P, Nazart M, Nouchet N, Peres F, Peeters V, Rimet F, Rumeau A, Sabater S, Straub F, Torrisi M, Tudesque L, Van der Vijver B, Vidal H, Vizinet J and Zydek N (2002). Determination of the biological diatom index (IBD NF T 90-354): results of an inter-comparison exercise. Journal of Applied Phycology 14: 27-39.

Sánchez-Castillo, PM, Linares-Cuesta, JE and Fernández-Moreno, D. 2008. Changes in epilithic diatom assemblages in a Mediterranean high mountain lake (Laguna de La Caldera, Sierra Nevada, Spain) after a period of drought. *J. Limnol.,* 67(1): 49-55.

Schoeman, FR (1973). A systematical and ecological study of the diatom flora of Lesotho with special reference to water quality. V&R Printers, Pretoria, South Africa.

Tan, X., Xia, X., Zhao, Q. and Zhang, Q., 2014. Temporal variations of benthic diatom community and its main influencing factors in a subtropical river, China. Environmental Science and Pollution Research, 21(1), pp.434-444.

Taylor, JC, Harding, WR and Archibald, CGM (2007). A methods manual for the collection, preparation and analysis of diatom samples. Water Research Commission Report TT281/07. Water Research Commission. Pretoria.

Teply, M. and Bahls, L. 2006. Interpretation of Periphyton Samples for Montana Streams - Middle Rockies Ecoregion. Prepared for the Montana Department of Environmental Quality. Water Quality Monitoring Section. Rosie Sada. Project Manager.1520 E 6th Avenue. Helena, MT 59620.

Van Dam, Mertens A and Sinkeldam J (1994). A coded checklist and ecological indicator values of freshwater diatoms from the Netherlands. Netherlands Journal of Aquatic Ecology 28(1): 177-133.

Von Falkenhayen, L. 2010. Monitors of heavy meal pollution in Australian tropical streams. Ph.D. dissertation. Department of Geographical and Environmental Studies. The University of Adelaide.

Wilson, S.E., Cumming, B and Smol, J.P. 2011. Assessing the reliability of salinity inference models from diatom assemblages: an examination of a 219-lake data set from western North America. *Canadian Journal of Fisheries and Aquatic Sciences*. 53: 1580-1594. 10.1139/f96-094.

Yoshiaki, N., Michiaki, S., Kaoru, Y., Takashi, Y., & Takaharu, H. 2004. Heavy-Metal pollution and its state in algae in Kakehashi River and Godani River at the Foot of Ogoya Mine, Ishikawa. *Analytical Sciences*, 20: 73–78.

7.0 CERTIFICATION

This report was prepared and reviewed by the undersigned.

Prepared:

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Senior Environmental Scientist

Approval that this document adheres to Knight Piésold Quality Systems: NN

APPENDIX A

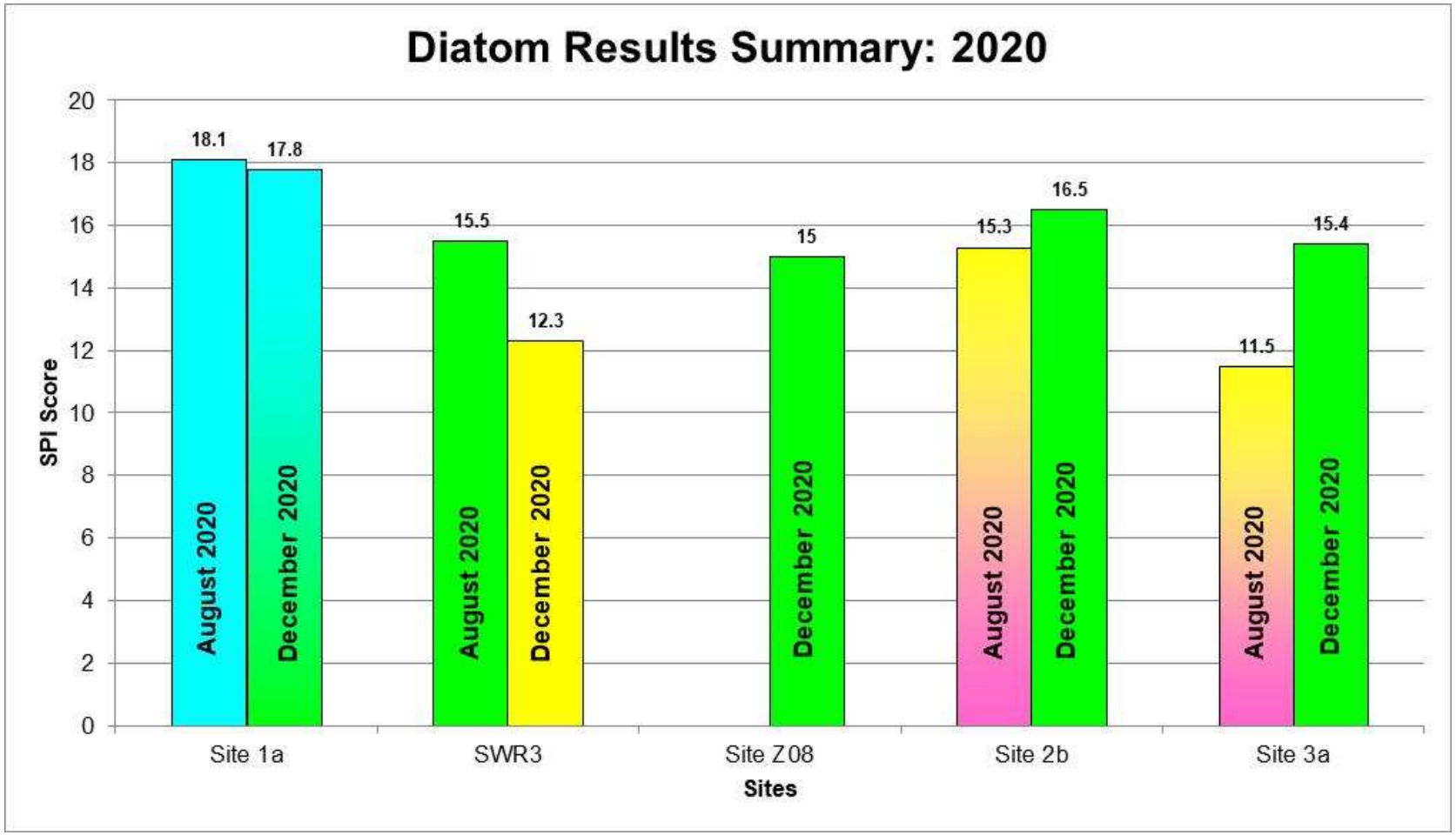
Integrated Habitat Assessment System

INVERTEBRATE HABITAT ASSESSMENT SYSTEM (IHAS)						
River Name: Vaalbankspruit	**Date: 17/11/2020**					
Site Code: Site 1						
SAMPLING HABITAT	**0**	**1**	**2**	**3**	**4**	**5**
Stones-in-current (SIC)						
Total length (m) of broken water (riffles or rapids)	none	0-1	>1-2	>2-3	<3-5	>5
Total length (m) of submerged stones in current (run	none	0-2	>2-5	>5-10	>10	
Number of separate SIC areas kicked (not individual stones)	0	1	2-3	4-5	6+	
Average size (cm) of stones kicked (gravel<2, bedrock >20)	none	<2,<20	2-10	11-20	2-20	
Amount fo stone surface clear (of algae, sediment, silt etc)*	n/a	0-25	26-50	51-75	>75	
Protocal: time (mins) spent actually kicking SIC (grvl/bedr=0)	0	<1	<1-2	2	>2-3	>3
**Note: up to 25% of stones is usually embedded in stream bottom.*	**SIC Score (max. 20)**				**15**	
Vegetation						
Length (m) of fringing vegetation sampled (banks)	none	0-½	>½ - 1	>1-2	2	>2
Amount (m^2) of aquatic vegetation / algae sampled	none	0-½	>½ - 2	>1		
Fringing vegetation sampled in: (none; pool or still only; run only; mixture of both)	none		run	pool		mix
Type of veg (% leafy vegetation vs stems/shoots) (aqv only = 49)	none	0	1-25	26-50	51-75	>75
	Veg Score (max. 15)				**13**	
Other Habitat / General						
Stones-out-of-current (SOOC) sampled: (protocol = $1m^2$)	none	0-½	>½-1	1	>1	
Sand sampled: (protocol = 1min) (present, but only below stones)	none	below	0-½	>½-1	1	>1
Mud sampled: (protocol = 1/2min) (present, but only below stones)	none	below	0-½	½	>½	
Gravel sampled: (protocol=1/2min) if all, SIC stone size =<2)**	none	0-½	½	>½ **		
Bedrock sampled (all=no SIC, sand, gravel) (if all, SIC stone size > 20)**	none	some			All **	
Algae present (1-2m2=algal bed, rocks=on rocks, isol=isolated clumps)	>$2m^2$	rocks	1-$2m^2$	<$1m^2$	Isol.	none
Tray identification (using time as per protocol)		under		Correct		over
*** Note still fill in SIC section*	**Other Habitat Score (max. 20)**				**17**	
	HABITAIT TOTAL (max.55)				**45**	
STREAM CHARACTERISTICS	**0**	**1**	**2**	**3**	**4**	**5**
Physical						
River make up (pool = pool/dam only; run only; rapid/riffle only; 2mix = 2 types etc)	pool		run	apid / riff	2mix	3mix
Average stream width (m)		>10	5-10	<1	1-2	>2-5
Average stream depth (m)	>1	1	>½ - 1	½	½ - ¼	<¼
Approximate stream velocity (slow ≤ 1m/s; fast ≥1m/s)	still	slow	fast	med.		mix
Water colour (disc = discoloured with visible colour but still clearish)	silty	opaque		disc.		clear
Recent disturbances due to: (constr = construction; fl/dr = flood/drought)***	fl/dr	fire	Constr.	other		none
Bank/riparian vegetation is: grass=includes reeds; shrubs=includes trees)	none		grass	shrubs	mix	
Surrounding impacts: (erosn = erosion/shear bare banks; farm = farmland/settlements	erosn.	farm	trees	other		open
Left bank cover (%) (rocks and vegetation; shear = 0%)	0-50	51-80	81-95	>95		
Right bank cover (%) (rocks and vegetation; shear = 0%)	0-50	51-80	81-95	>95		
	Stream Conditions Total (max.45)				**25**	
****Note: if more than one option, choose lowest*						
	TOTAL IHAS SCORE %:				**70**	

INVERTEBRATE HABITAT ASSESSMENT SYSTEM (IHAS)						
River Name: Vaalbankspruit	**Date: 17/11/2020**					
Site Code: SWR 3						
SAMPLING HABITAT	**0**	**1**	**2**	**3**	**4**	**5**
Stones-in-current (SIC)						
Total length (m) of broken water (riffles or rapids)	none	0-1	>1-2	>2-3	<3-5	>5
Total length (m) of submerged stones in current (run	none	0-2	>2-5	>5-10	>10	
Number of separate SIC areas kicked (not individual stones)	0	1	2-3	4-5	6+	
Average size (cm) of stones kicked (gravel<2, bedrock >20)	none	<2,<20	2-10	11-20	2-20	
Amount fo stone surface clear (of algae, sediment, silt etc)*	n/a	0-25	26-50	51-75	>75	
Protocal: time (mins) spent actually kicking SIC (grvl/bedr=0)	0	<1	<1-2	2	>2-3	>3
**Note: up to 25% of stones is usually embedded in stream bottom.*	**SIC Score (max. 20)**				**12**	
Vegetation						
Length (m) of fringing vegetation sampled (banks)	none	0-½	>½ - 1	>1-2	2	>2
Amount (m^2) of aquatic vegetation / algae sampled	none	0-½	>½ - 2	>1		
Fringing vegetation sampled in: (none; pool or still only; run only; mixture of both)	none		run	pool		mix
Type of veg (% leafy vegetation vs stems/shoots) (aqv only = 49)	none	0	1-25	26-50	51-75	>75
	Veg Score (max. 15)				**9**	
Other Habitat / General						
Stones-out-of-current (SOOC) sampled: (protocol = $1m^2$)	none	0-½	>½-1	1	>1	
Sand sampled: (protocol = 1min) (present, but only below stones)	none	below	0-½	>½-1	1	>1
Mud sampled: (protocol = 1/2min) (present, but only below stones)	none	below	0-½	½	>½	
Gravel sampled: (protocol=1/2min) if all, SIC stone size =<2)**	none	0-½	½	>½ **		
Bedrock sampled (all=no SIC, sand, gravel) (if all, SIC stone size > 20)**	none	some			All **	
Algae present (1-2m2=algal bed, rocks=on rocks, isol=isolated clumps)	>$2m^2$	rocks	1-$2m^2$	<$1m^2$	Isol.	none
Tray identification (using time as per protocol)		under		Correct		over
*** Note still fill in SIC section*	**Other Habitat Score (max. 20)**				**13**	
	HABITAIT TOTAL (max.55)				**34**	
STREAM CHARACTERISTICS	**0**	**1**	**2**	**3**	**4**	**5**
Physical						
River make up (pool = pool/dam only; run only; rapid/riffle only; 2mix = 2 types etc)	pool		run	apid / riff	2mix	3mix
Average stream width (m)		>10	5-10	<1	1-2	>2-5
Average stream depth (m)	>1	1	>½ - 1	½	½ - ¼	<¼
Approximate stream velocity (slow ≤ 1m/s; fast ≥1m/s)	still	slow	fast	med.		mix
Water colour (disc = discoloured with visible colour but still clearish)	silty	opaque		disc.		clear
Recent disturbances due to: (constr = construction; fl/dr = flood/drought)***	fl/dr	fire	Constr.	other		none
Bank/riparian vegetation is: grass=includes reeds; shrubs=includes trees)	none		grass	shrubs	mix	
Surrounding impacts: (erosn = erosion/shear bare banks; farm = farmland/settlements	erosn.	farm	trees	other		open
Left bank cover (%) (rocks and vegetation; shear = 0%)	0-50	51-80	81-95	>95		
Right bank cover (%) (rocks and vegetation; shear = 0%)	0-50	51-80	81-95	>95		
	Stream Conditions Total (max.45)				**19**	
****Note: if more than one option, choose lowest*						
	TOTAL IHAS SCORE %:				**53**	

APPENDIX B

Summarised Diatom Results


Diatom Results Summary: 2020
SPI Score
20
18
16
14
12
10
8
6
4
2
0
18.1
17.8
15.5
12.3
15
15.3
16.5
11.5
15.4
August 2020
December 2020
Site 1a
SWR3
Site Z08
Site 2b
Site 3a
Sites

APPENDIX C

Invertebrate Results

Date (dd:mm:yr):	17/11/2020			(dd.ddddd)	
Site Code:	Site 1	**Grid reference (dd mm ss.s) Lat:**	S	#REF!	#REF!
Collector/Sampler:	Lloyd Lynch	**Long:**	E	#REF!	#REF!
River:	Vaalbankspruit	**Datum (WGS84/Cape):**		WGS 84	
Level 1 Ecoregion:	11: HIGHVELD	**Altitude (m):**			
Quaternary Catchment:		**Zonation:**		E: Lower Foothills	

Site Description:	Temp (°C):	26.70	**Routine or Project? (circle one)**	Flow:	
	pH:	7.80	Project Name:	Clarity (cm):	52
	DO (mg/L):	#REF!	MFC Aquatic Biomonitoring	Turbidity:	
	Cond (mS/m):	65.00		Colour:	
	Riparian Disturbance:				
	Instream Disturbance:				

Biotopes Sampled (tick & rate)	Rating	Weight
Stones In Current (SIC)	3	4.0
Stones Out Of Current (SOOC)	2	4.0
Bedrock	2	1.5
Aquatic Veg	2	1.0
MargVeg In Current	2	2.0
MargVeg Out Of Current	3	2.0
Gravel	2	4.0
Sand	2	2.0
Mud	2	1.0
Hand picking/Visual observation	Y	
OVERALL BIOTOPE SUITABILITY	46%	Category D

Taxon	QV	S	Veg	GSM	TOT
PORIFERA (Sponge)	5				
COELENTERATA (Cnidaria)	1				
TURBELLARIA (Flatworms)	3				
ANNELIDA					
Oligochaeta (Earthworms)	1				
Hirudinea (Leeches)	3				
CRUSTACEA					
Amphipoda (Scuds)	13				
Potamonautidae* (Crabs)	3				1
Atyidae (Freshwater Shrimps)	8				
Palaemonidae (Freshwater Prawns)	10				
HYDRACARINA (Mites)	8				
PLECOPTERA (Stoneflies)					
Notonemouridae	14				
Perlidae	12				
EPHEMEROPTERA (Mayflies)					
Baetidae 1sp	4	A	A		B
Baetidae 2 sp	6				
Baetidae > 2 sp	12				
Caenidae (Squaregills/Cainflies)	6				
Ephemeridae	15				
Heptageniidae (Flatheaded mayflies)	13				
Leptophlebiidae (Prongills)	9				
Oligoneuridae (Brushlegged mayflies)	15				
Polymitarcyidae (Pale Burrowers)	10				
Prosopistomatidae (Water specs)	15				
Teloganodidae SWC (Spiny Crawlers)	12				
Tricorythidae (Stout Crawlers)	9				
ODONATA (Dragonflies & Damselflies)					
Calopterygidae ST,T (Demoiselles)	10				
Chlorocyphidae (Jewels)	10				
Synlestidae (Chlorolestidae)(Sylphs)	8				
Coenagrionidae (Sprites and blues)	4	A	A		A
Lestidae (Emerald Damselflies/Spreadwin	8				
Platycnemidae (Stream Damselflies)	10				
Protoneuridae (Threadwings)	8				
Aeshnidae (Hawkers & Emperors)	8	1	1		A
Corduliidae (Cruisers)	8				
Gomphidae (Clubtails)	6				
Libellulidae (Darters/Skimmers)	4			B	B
LEPIDOPTERA (Aquatic Caterpillars/Moths)					
Crambidae (Pyralidae)	12				

Taxon	QV	S	Veg	GSM	TOT
HEMIPTERA (Bugs)					
Belostomatidae* (Giant water bugs)	3		1		1
Corixidae* (Water boatmen)	3				
Gerridae* (Pond skaters/Water striders)	5				
Hydrometridae* (Water measurers)	6				
Naucoridae* (Creeping water bugs)	7				
Nepidae* (Water scorpions)	3		A		A
Notonectidae* (Backswimmers)	3		A		A
Pleidae* (Pygmy backswimmers)	4	A	A		B
Veliidae/M...veliidae* (Ripple bugs)	5		A		A
MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)					
Corydalidae (Fishflies & Dobsonflies)	8				
Sialidae (Alderflies)	6				
TRICHOPTERA (Caddisflies)					
Dipseudopsidae	10				
Ecnomidae	8				
Hydropsychidae 1 sp	4				
Hydropsychidae 2 sp	6				
Hydropsychidae > 2 sp	12				
Philopotamidae	10				
Polycentropodidae	12				
Psychomyiidae/Xiphocentronidae	8				
Cased caddis:					
Barbarochthonidae SWC	13				
Calamoceratidae ST	11				
Glossosomatidae SWC	11				
Hydroptilidae	6				
Hydrosalpingidae SWC	15				
Lepidostomatidae	10				
Leptoceridae	6				
Petrothrincidae SWC	11				
Pisuliidae	10				
Sericostomatidae SWC	13				
COLEOPTERA (Beetles)					
Dytiscidae/Noteridae* (Diving beetles)	5				
Elmidae/Dryopidae* (Riffle beetles)	8				
Gyrinidae* (Whirligig beetles)	5				
Haliplidae* (Crawling water beetles)	5				
Helodidae (Marsh beetles)	12				
Hydraenidae* (Minute moss beetles)	8				
Hydrophilidae* (Water scavenger beetles	5				
Limnichidae (Marsh-Loving Beetles)	10				
Psephenidae (Water Pennies)	10				

Taxon	QV	S	Veg	GSM	TOT
DIPTERA (Flies)					
Athericidae (Snipe flies)	10				
Blepharoceridae (Mountain midges)	15				
Ceratopogonidae (Biting midges)	5				
Chironomidae (Midges)	2	A	A	A	B
Culicidae* (Mosquitoes)	1	A	A	A	B
Dixidae* (Dixid midge)	10				
Empididae (Dance flies)	6				
Ephydridae (Shore flies)	3				
Muscidae (House flies, Stable flies)	1				
Psychodidae (Moth flies)	1				
Simuliidae (Blackflies)	5				
Syrphidae* (Rat tailed maggots)	1				
Tabanidae (Horse flies)	5				
Tipulidae (Crane flies)	5				
GASTROPODA (Snails)					
Ancylidae (Limpets)	6				
Bulininae*	3				
Hydrobiidae*	3				
Lymnaeidae* (Pond snails)	3				
Physidae* (Pouch snails)	3	1			1
Planorbinae* (Orb snails)	3				
Thiaridae* (=Melanidae)	3				
Viviparidae* ST	5				
PELECYPODA (Bivalves)					
Corbiculidae (Clams)	5				
Sphaeriidae (Pill clams)	3				
Unionidae (Perly mussels)	6				
SASS Score					47
No. of Taxa					13
ASPT					3.6
Other biota:					

Comments/Observations:

Date (dd:mm:yr):	17/11/2020			(dd.ddddd)	**Biotopes Sampled (tick & rate)**	**Rating**	**Weight**
Site Code:	SWR 3	**Grid reference (dd mm ss.s) Lat:**	**S** #REF!	#REF!	**Stones In Current (SIC)**	2	4.0
Collector/Sampler:	Lloyd Lynch	**Long:**	**E** #REF!	#REF!	**Stones Out Of Current (SOOC)**	2	4.0
River:	Vaalbankspruit	**Datum (WGS84/Cape):**	WGS 84		**Bedrock**	0	1.5
Level 1 Ecoregion:	11: HIGHVELD	**Altitude (m):**			**Aquatic Veg**	0	1.0
Quaternary Catchment:		**Zonation:**	E: Lower Foothills		**MargVeg In Current**	3	2.0
	Temp (°C): 23.10	**Routine or Project? (circle one)**	**Flow:**		**MargVeg Out Of Current**	2	2.0
Site Description:	**pH:** 7.30	**Project Name:**	**Clarity (cm):**	76	**Gravel**	2	4.0
	DO (mg/L): 1.88	MFC Aquatic Biomonitoring	**Turbidity:**		**Sand**	3	2.0
	Cond (mS/m): 112.00		**Colour:**		**Mud**	2	1.0
	Riparian Disturbance:				**Hand picking/Visual observation**	Y	**Category**
	Instream Disturbance:				**OVERALL BIOTOPE SUITABILITY**	39%	E

Taxon	QV	S	Veg	GSM	TOT
PORIFERA (Sponge)	5				
COELENTERATA (Cnidaria)	1				
TURBELLARIA (Flatworms)	3	A			A
ANNELIDA					
Oligochaeta (Earthworms)	1			A	A
Hirudinea (Leeches)	3				
CRUSTACEA					
Amphipoda (Scuds)	13				
Potamonautidae* (Crabs)	3				A
Atyidae (Freshwater Shrimps)	8				
Palaemonidae (Freshwater Prawns)	10				
HYDRACARINA (Mites)	8	A	A		B
PLECOPTERA (Stoneflies)					
Notonemouridae	14				
Perlidae	12				
EPHEMEROPTERA (Mayflies)					
Baetidae 1sp	4				
Baetidae 2 sp	6				
Baetidae > 2 sp	12				
Caenidae (Squaregills/Cainflies)	6				
Ephemeridae	15				
Heptageniidae (Flatheaded mayflies)	13				
Leptophlebiidae (Prongills)	9				
Oligoneuridae (Brushlegged mayflies)	15				
Polymitarcyidae (Pale Burrowers)	10				
Prosopistomatidae (Water specs)	15				
Teloganodidae SWC (Spiny Crawlers)	12				
Tricorythidae (Stout Crawlers)	9				
ODONATA (Dragonflies & Damselflies)					
Calopterygidae ST,T (Demoiselles)	10				
Chlorocyphidae (Jewels)	10				
Synlestidae (Chlorolestidae)(Sylphs)	8				
Coenagrionidae (Sprites and blues)	4		A		A
Lestidae (Emerald Damselflies/Spreadwin	8				
Platycnemidae (Stream Damselflies)	10				
Protoneuridae (Threadwings)	8				
Aeshnidae (Hawkers & Emperors)	8				
Corduliidae (Cruisers)	8				
Gomphidae (Clubtails)	6				
Libellulidae (Darters/Skimmers)	4				
LEPIDOPTERA (Aquatic Caterpillars/Moths)					
Crambidae (Pyralidae)	12				

Taxon	QV	S	Veg	GSM	TOT
HEMIPTERA (Bugs)					
Belostomatidae* (Giant water bugs)	3		1		1
Corixidae* (Water boatmen)	3	A	A		B
Gerridae* (Pond skaters/Water striders)	5				
Hydrometridae* (Water measurers)	6				
Naucoridae* (Creeping water bugs)	7				
Nepidae* (Water scorpions)	3				
Notonectidae* (Backswimmers)	3				
Pleidae* (Pygmy backswimmers)	4				
Veliidae/M...veliidae* (Ripple bugs)	5				
MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)					
Corydalidae (Fishflies & Dobsonflies)	8				
Sialidae (Alderflies)	6				
TRICHOPTERA (Caddisflies)					
Dipseudopsidae	10				
Ecnomidae	8				
Hydropsychidae 1 sp	4				
Hydropsychidae 2 sp	6				
Hydropsychidae > 2 sp	12				
Philopotamidae	10				
Polycentropodidae	12				
Psychomyiidae/Xiphocentronidae	8				
Cased caddis:					
Barbarochthonidae SWC	13				
Calamoceratidae ST	11				
Glossosomatidae SWC	11				
Hydroptilidae	6		1		1
Hydrosalpingidae SWC	15				
Lepidostomatidae	10				
Leptoceridae	6				
Petrothrincidae SWC	11				
Pisuliidae	10				
Sericostomatidae SWC	13				
COLEOPTERA (Beetles)					
Dytiscidae/Noteridae* (Diving beetles)	5				
Elmidae/Dryopidae* (Riffle beetles)	8				
Gyrinidae* (Whirligig beetles)	5				B
Haliplidae* (Crawling water beetles)	5				
Helodidae (Marsh beetles)	12				
Hydraenidae* (Minute moss beetles)	8				
Hydrophilidae* (Water scavenger beetles	5				
Limnichidae (Marsh-Loving Beetles)	10				
Psephenidae (Water Pennies)	10				

Taxon	QV	S	Veg	GSM	TOT
DIPTERA (Flies)					
Athericidae (Snipe flies)	10				
Blepharoceridae (Mountain midges)	15				
Ceratopogonidae (Biting midges)	5	A		A	B
Chironomidae (Midges)	2				
Culicidae* (Mosquitoes)	1				
Dixidae* (Dixid midge)	10				
Empididae (Dance flies)	6				
Ephydridae (Shore flies)	3				
Muscidae (House flies, Stable flies)	1				
Psychodidae (Moth flies)	1				
Simuliidae (Blackflies)	5				
Syrphidae* (Rat tailed maggots)	1				
Tabanidae (Horse flies)	5				
Tipulidae (Crane flies)	5				
GASTROPODA (Snails)					
Ancylidae (Limpets)	6				
Bulininae*	3				
Hydrobiidae*	3				
Lymnaeidae* (Pond snails)	3				
Physidae* (Pouch snails)	3	A	A		A
Planorbinae* (Orb snails)	3		1		1
Thiaridae* (=Melanidae)	3				
Viviparidae* ST	5				
PELECYPODA (Bivalves)					
Corbiculidae (Clams)	5				
Sphaeriidae (Pill clams)	3				
Unionidae (Perly mussels)	6				
SASS Score					47
No. of Taxa					12
ASPT					3.9
Other biota:					

Comments/Observations: