

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:

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

Table 1: Olifants Water Management Area

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.

PES	PES Name	Description			
А	Natural	Unmodified natural			
В	Good	Largely natural with few modifications			
С	Fair	Moderately modified			
D	Poor	Largely modified			
Е	Severely Modified	Seriously modified			
F	Critically Modified	Critically or extremely modified			

Table 3: Present Ecological State

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 bioassessment 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 KMnO₄ 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.).

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

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



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.

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
В	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
с	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

Table 5: Summarised interpretation of the Highveld Ecoregion



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

Sample Point	Date	рН	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

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

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.



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		

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

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.

Taxon	QV	S	Veg	GSM	тот				
EPHEMEROPTERA (Mayflies)									
Baetidae 1sp	4	Α	Α		Α				
Caenidae (Squaregills/Cainflies)	6	Α	1		Α				
ODONATA (Dragonf	lies & D	amselfli	es)						
Coenagrionidae (Sprites and blues)	4		Α		Α				
TRICHOPTERA (Caddisflies)									
Hydropsychidae 1 sp	4	Α	Α		Α				
COLEOPTERA (Beetles)									
Dytiscidae/Noteridae* (Diving beetles)	5	1			1				
Gyrinidae* (Whirligig beetles)	5	1			В				
DIPTERA	(Flies)			-					
Chironomidae (Midges)	2		Α		Α				
GASTROPO	DA (Sna	ils)		-					
Lymnaeidae* (Pond snails)	3		1		1				
SASS Score					33				
No. of Taxa					8				
ASPT					4.1				

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



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

Sample Point	Date	рН	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

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

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.

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

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

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.

Taxon	QV	S	Veg	GSM	тот				
ANNELIDA									
Oligochaeta (Earthworms)	1			1	1				
CHELICERATA									
HYDRACARINA (Mites)	8		Α		Α				
EPHEMEROPTERA (Mayflies)									
Baetidae > 2 sp	12	В	В	В	В				
Caenidae (Squaregills/Cainflies)	6	Α	Α	Α	В				
ODONATA (Dragonflies & Damselflies)									
Coenagrionidae (Sprites and blues)	4		В	Α	В				
Aeshnidae (Hawkers & Emperors)	8		1		1				
Gomphidae (Clubtails)	6			Α	Α				
HEMIPTE	RA (Bug	IS)							
Belostomatidae* (Giant water bugs)	3		1		1				
TRICHOPTER	A (Cadd	isflies)							
Hydropsychidae 1 sp	4	В	В		В				
Hydropsychidae 2 sp	6			В	В				

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



Taxon	QV	S	Veg	GSM	тот			
Cased caddis:								
Hydroptilidae	6		Α		Α			
COLEOPTE	RA (Bee	tles)						
Dytiscidae/Noteridae* (Diving								
beetles)	5	Α	Α	Α	Α			
Gyrinidae* (Whirligig beetles)	5		Α	Α	В			
DIPTER	A (Flies)							
Ceratopogonidae (Biting midges)	5	Α	Α	Α	В			
Chironomidae (Midges)	2	В	В	В	В			
Simuliidae (Blackflies)	5	В	В	В	В			
GASTROPO	DDA (Sna	ails)						
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.



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

Sample Point	Date	рН	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

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

The free and total chlorine concentrations exceeded the DWAF guideline limits while all the other *insitu* 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

Sample Point	Date	рН	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

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

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.

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

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

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.

Taxon	QV	S	Veg	GSM	тот				
TURBELLARIA (Flatworms)	3	Α	1		Α				
ANNI	ELIDA								
Oligochaeta (Earthworms)	1	1		Α	Α				
CHELIC	ARATA								
HYDRACARINA (Mites)	8	Α	Α	Α	В				
EPHEMEROPTERA (Mayflies)									
Baetidae 1sp	4	Α			Α				
Baetidae 2 sp	6		Α		Α				
Caenidae (Squaregills/Cainflies)	6		Α		Α				
ODONATA (Dragon	flies & C	Damselfl	ies)						
Coenagrionidae (Sprites and blues)	4		B		В				
HEMIPTE	RA (Bug	is)							
Corixidae* (Water boatmen)	3		С		С				
TRICHOPTER	A (Cadd	isflies)							
Hydropsychidae 1 sp	4	Α		В	В				
Cased	caddis:								
Hydroptilidae	6		1		1				
COLEOPTE	RA (Bee	tles)							



Taxon	QV	S	Veg	GSM	тот				
Elmidae/Dryopidae* (Riffle beetles)	8	1	1		Α				
DIPTERA (Flies)									
Chironomidae (Midges)	2	Α	В	Α	В				
Simuliidae (Blackflies)	5	Α	Α		В				
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 S04⁻²-dominated habitats, especially MgS04 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.



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7.0 CERTIFICATION

This report was prepared and reviewed by the undersigned.



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APPENDIX A

Integrated Habitat Assessment System



RI 301-00183-48 Rev A 08 September 2020

INVERTEBRATE HABITAT ASSESSMENT S	SYSTEM	(IHAS)	ji.					
River Name: Vaalbankspruit	Date: 11/08/2020							
Site Code: Site 1								
		1		-				
SAMPLING HABITAT	0	1	2	3	4	6		
Stones-In-current (SIC)					-			
Total length (m) of broken water (riffies 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+	0		
Average size (om) of stones kieked (gravel*2, bedreek *20)	nono	<2,<20	2 10	11 20	2 20			
Amount to stone surface clear (of algae, sediment, silt etc)*	n/a	0-25	26-50	51-75	>75			
Protocal: time (mins) spent actually kicking SIC (grt/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					8		
Vanatation						-		
vegetation		0.1/	Sec. 4	260	~	0		
Lengin (m) or inniging vegeration sampled (carries)	none	0-24	2/2-1	31-6	- 1-	31		
Amount (m*) of aquatic vegetation / algae sampled	none	0-1/2	>>/2-2	>1	_			
Fringing vegetation sampled in (none, pool or still only, run only, mixture of both)	hone		run	pool	1 1	tnix		
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	2	-				5		
Stones-out-of-current (SOOC) sampled (protocol = 1m ²)	none	0 %	>15-1	1	>1			
Sand sampled: (protocol = 1min) (present, but only below stones)	none	below	0-35	2%-1	1	>1		
Mud sampled: (protocol = 1/2min) (present, but only below stones)	none	beiow	0-34	36	>3/4			
Gravel sampled: (protocol=1/2min) if all SIC stone size =<2)**	DODG	0.16	16	>15 **				
Bedrock sampled (ali=ng SIC, sand, gravel) (if all, SIC stone size > 20)**	none	SKITTER	1.	1	AL 44			
Algae present (1-2m2=algal bed_rocks=on rocks_isol=isolated citimos)	>2m ²	rocies	1-2m ²	<1m ²	Isol	none		
I ray identification (using time as per protocol)	-	under		Correct	Tarst.	over		
	Other Habitat Score							
** Note still fill in SIC section	(max. 20) 11							
	ABITAI	T TOTAL	(max.55	20				
ATOFAN ANADAATEDIATAA						-		
Bhusiani	U	1	2	3	4	0		
Physical Organization of Josef - stabilities each and achieves distills each different distinguished	The second	-		and cash	Chemist	(Janeter)		
rover make up (pool – pool/dam only, run only, rapid/inne only, zmx – 2 types etc)	DOOL	540	F 10	EDIG / TIT	2000	SINK		
Average stream widin (m)		210	3-10	- 51	4	26-3		
/werage sitean depri (in)	21	and the second	-72-1	73	n a.	- 12		
Approximate stream velocity (sow 5 m/s, tast 21m/s) Wildow advant (dian = discolar and with visible unlose but off alwayide)	Still	SIOW	nast	med		mix		
Water Cocor (disc = discocored with wsite coool but ser clearish)	Siry	opaque	Constr	other.	-	Clian		
Recent disurgances due to (consir = consiración, todr = (coordinagn)	Indi	lite	Conso.	cheuba	and by	none		
Damonpartan vegetation is: grass=includes reeds, shrubs=includes trees)	none	60.00	grass	SHI'UDS	1003			
aurrounding impacts, terosn – erosion/sneer bare barks, term – termand/settements	erosn.	marm	11965	other		open		
Left bank cover (%) (rocks and vegetabon; shear = 0%)	0-50	51-80	81-95	>95	-			
Right bank cover (%) (rocks and vegetation, shear = 0%)	0-50	51-00	01-95	×93				
	Tatel (may (5)							
171Moto: If more than one option : choose lawset	10	i qinax.	40)	1	20	-		
note, it may a man one option, choose lowest	TOTAL	ILLAS SC	OPEN	2	17			
5 C	TOTAL HAS SCORE %:			6.2	40			



INVERTEBRATE HABITAT ASSESSMENT S	SYSTEM	(IHAS)	ji.					
River Name: Vaalbankspruit	ult Date: 11/08/2020							
Site Code: SWR 3								
		1		-				
SAMPLING HABITAT	0	1	2	3	4	6		
Stones-In-current (SIC)					-			
Total length (m) of broken water (riffies 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 (em) of stones kielked (gravel+2, bedraek +20)	nono	<2,<20	2 10	11.20	2 20			
Amount to stone surface clear (of algae, sediment, silt etc)*	n/a	0-25	26-50	51-75	>75			
Protocal: time (mins) spent actually kicking SIC (grt/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					8		
				_		_		
Vegetation		1.00	202.00					
Length (m) of fringing vegetation sampled (baries)	hone	0.%	>%-1	>1-2	2	>2		
Amount (m ²) of aquatic vegetation / algae sampled	none	0-1/2	>1/2-2	>1				
Fringing vegetation sampled in (none, pool or still only; run only, mixture of both)	hone		TUR	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	2							
Stones out-of-content (SOOC) sampled (ordecol = 1m ²)	nane	0.%	216-1	1	>1			
Sand sempled: (protocol - tmin) (present, but only below stones)	none	helow	n.v.	2%-1	1	>1		
Mud sampled: (protocol = 1/2min) (present, but only below stones)	none	heime	av	36	54			
Gravel sampled: (protocol=1/2min) (prosent, but only before stories)	nano	0.16	36	516 #0	-/4			
Betrock sampled (all=no SIC, sand, resvel) (if all SIC since size > 20)**	none	SZETUS	16	- 12	AL 4			
Alson assessed (d. farQ, shad, bad, sanks, or statis, lask is also d always)	- 1mile	- ALLINE	4 0	den Z	last			
Agae present (1-2/h2=agai bed, rocks=on rocks, isol=isolated ciumps)	~210	TOCKS	1-200	Connet	ISOL.	none		
Tray identification Lusing otheras per protocon	Other Habitat Score							
** Note still fill in SIC section	(max, 20) 12							
	ABITA	TTOTAL	(max.55	5] 32				
	1				5	1		
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 / rift	2mix	3mtx		
Average stream width (m)	Constraint.	>10	5-10	<1	1.2	>2-5		
Average stream depth (m)	>1	1	2%-1	%	M-16	<16		
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	Sec. 10	disc		clear		
Recent disturbances due to (constr = construction, ft/dr = flood/drought)***	ß/dr	fire	Constr.	other		none		
Bank/ripartan 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				
48	Stream Conditions							
	Total (max.45) 20							
***Wote: If more than one option, choose lowest								
	TOTAL IHAS SCORE %:			8	52	8		



INVERTEBRATE HABITAT ASSESSMENT	SYSTER	(IHAS)						
River Name: Vaalbankspruit	Date: 11/08/2020							
Site Code: Site 3A								
	k -		k					
SAMPLING HABITAT	0	1	2	3	4	5		
Stones-in-current (SIC)	1	Marco	Auger	000	Sume	Cin as		
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	поле	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 to stone surface clear (of algae, sediment, sit etc)*	n'a	0-25	26-50	51-75	>75			
Protocal: time (mins) spent actually kicking SIC (grv/bedr=0)	0	<1	<1-2	2	>2-3	- 23		
"Note up to 25% of stones is usually embedded in stream bottom	SIC S	score (ma	ax. 20)		14			
Venetation	1		1					
Length (m) of frighting variation sempled (banks)	0006	0.26	54.1	51-2		57		
Lengur (m) or miging vegetation samples (panes)	none	0.14	- M - 1		1.5	-2		
Amount (m ⁺) of aquatic vegetation / algae sampled	none	0-72	213-2	>1		- Charles		
Fringing vegetation sampled in: (none; pool or still only; run only; mixture or both)	none		TUR	pool		mo		
Type of veg (% leafy vegetation vs stems/shoots) (aqv only = 49)	none	0	1.25	26.50	51.75	275		
15	Veg Score (max. 15) 7							
Other Habitat / General	2		2	10	3			
Stones-out-of-current (SOOC) sampled: (protocol = 1m ²)	none	0-1/2	>16-1	6 12	>1			
Sand sampled: (protocol = 1min) (present, but only below stones)	none	below	0-%	>>5-1	1	>1		
Mud sampled, (protocol = 1/2min) (present, but only below stones)	none	below	0.15	1/2	>%	- Costin		
Gravel sampled: (protocol=1/2min) if all. SIC stone size =<2)**	none	0-%	14	>>/2 **				
Bedrock sampled (all=no SIC, sand, gravel) (if all, SIC stone size > 20)**	none	some			All **			
Alose present (1.2m2=slost bed_rocks=on_rocks_isolated clumos)	>2012	meks	1-2102	<1m ²	leet	enne		
Trou identification (include time as ner protocol)	- 2-11	under	1.4411	Correct	Later.	over		
They reductive out to sing time as per processy.	Other Habitat Score							
** Note still fill in SIC section	(max. 20) 11							
	ABITAIT TOTAL ((max.66	1	32			
STREAM CHARACTERISTICS	0	1	2	3	4	5		
Physical	in and			1010100	Cristia	(Traile)		
River make up (pool = pool/dam only, run only, rapid/rime only, zmix = 2 types etc)	poor	240	Turi	apid / nit	2mix	Sinix		
Average stream width (m)	24	>10	5-10	51	1-2	P2-0		
Average stream depin (m)	>1	1	272-3	30	10 - 12	<.N		
Approximate stream velocity (slow ≤ 1m/s; tast ≥1m/s)	Shi	SION	tast	med		mox		
Water colour (disc = discoloured with visible colour but still clearish)	Silly	opaque	Sector Sector	disc.		clear		
Recent disturbances due to: (constr = construction; fl/dr = flood/drought)***	fildr	tire	Constr.	other		none		
Bank/nparian vegetation is: grass-includes reeds; shrubs-includes trees)	none		gress	shrubs	THE			
Surrounding impacts: (erosn = erosion/shear bare banks; farm = farmland/settlements	Crossi .	fatm	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			1 VI				
	Total (max.45) 28				28			
***Note: if more than one option, choose lowest		1	1		1	1		
	TOTAL IHAS SCORE %:			e	60			


APPENDIX B

Summarised Diatom Results



RI 301-00183-48 Rev A 08 September 2020





APPENDIX C

Invertebrate Results



RI 301-00183-48 Rev A 08 September 2020

Date (dd:mm:yr):	11/08/2	2020								(dd.ddd	ldd)	Biotopes Sampled (tick & rate)	Rating	Weight			
Site Code:	Site 1					Grid reference (dd mm ss.s) Lat:	S	#REF!		#RI	EF!	Stones In Current (SIC)	0	4.0			
Collector/Sampler:	Llovd I	vnch				Long	E	#REEI		#RI	EF!	Stones Out Of Current (SOOC)	2	4.0			
River:	Vaalba	nkonruit				Datum (WGS84/Cane):	. –	WCS 9	4			Padrock	2	1.5			
Level 1 Ecoregion:						Altitudo (m):		1030	-	ł		Aguatia Vag	2	1.0			
Oustermany Catalaments	TT: HIG	IVELD				Annude (III).						Aquatic veg	U	2.0			
Quaternary Catchment:	<u> </u>		_			Zonation:	٦	E: Low	er Footh	nills		MargVeg In Current	0	2.0			
	Temp (°C):		16.10		Routine or Project? (circle one)	Flow:					MargVeg Out Of Current	2	2.0			
Site Description:	pH:			6.90		Project Name:	Clarity	(cm):	64			Gravel	0	4.0			
	DO (mg	g/L):		8.59		MFC Aquatic Biomonitoring	Turbidi	ty:				Sand	2	2.0	1		
	Cond (mS/m):		80.00			Colour	:				Mud	2	1.0			
	Riparia	an Distur	bance:				_					Hand picking/Visual observation	Y			Category	^
	Instrea	m Distu	rbance:									OVERALL BIOTOPE SUITABILITY		0.0	20%	F	1
Tayon	OV	s	Veg	GSM	тот	Taxon	OV	s	Ven	GSM	TOT	Taxon	ov	s	Veg	GSM	TOT
PORIFERA (Sponge)	5	- U	vog	00111		HEMIPTERA (Bugs)		Ŭ	veg	00111		DIPTERA (Flies)			Vcg	00111	101
COEL ENTERATA (Chidaria)	1					Belostomatidae* (Giant water bugs)	3					Athericidae (Snipe flies)	10				-
TURBELLARIA (Flatworms)	3					Corixidae* (Water boatmen)	3					Blepharoceridae (Mountain midges)	15				1
	Ť					Gerridae* (Pond skaters/Water striders)	5					Ceratopogonidae (Biting midges)	5				1
Oligochaeta (Earthworms)	1					Hydrometridae* (Water measurers)	6					Chironomidae (Midges)	2		A		Δ
Hirudinea (Leeches)	3					Naucoridae* (Creening water bugs)	7					Culicidae* (Mosquitoes)	1				
	- v					Nepidae* (Water scorpions)	3					Dividae* (Divid midge)	10				+
Amphipoda (Scude)	13					Notopectidae* (Backswimmers)	3					Empididae (Dance flies)	6				+
Rotamonautidae* (Crabs)	3					Pleidae* (Pygmy backswimmers)	4					Enbudridae (Shore flies)	3				1
Atvideo (Freebuster Shrimpo)						Veliidae/M_veliidae* (Pipple buge)	5					Mussidas (House flips, Stable flips)	1				-
Released (Freshwater Shiftings)	10					MECALODTERA (Fishfling Deheanfling		(flice)				Reveladidae (Moth flice)	1				
	0					Conveloides (Fishflies & Debsonflies)		mes)				Simuliidaa (Riacifiica)	5				
PLECOPTERA (Stopoflice)	°					Siglidae (Alderflice)	6					Sumplidae* (Diacknies)	5				+
Netenemeuridee	14					Stalidae (Aldernies)	0					Sylphidae (Ratialied haggots)	5			<u> </u>	+
Destides	14					TRICHOPTERA (Caddistiles)	40					Tabanidae (Horse files)	5		┟────┦	<u> </u>	+
	12					Dipseudopsidae	10						5				
EPHEMEROPTERA (Mayflies)						Echomidae	8					GASTROPODA (Snails)					
Baelidae Isp	4	A	A		A	Hydropsychidae 1 sp	4	A	A		A	Ancylidae (Limpets)	6		┟────┦	<u> </u>	
Baetidae 2 Sp	10	-				Hydropsychidae 2 sp	10					Bulininae"	3				
Baetidae > 2 sp	12					Hydropsychidae > 2 sp	12					Hydroblidae"	3				-
Caenidae (Squaregilis/Cainfiles)	0	A	1		A	Philopotamidae	10					Lymnaeidae" (Pond snails)	3		┢──╹──┦	<u> </u>	1
Ephemeridae	15					Polycentropodidae	12					Physidae" (Pouch shalls)	3		┟────┦	<u> </u>	
Heptageniidae (Flatheaded mayfiles)	13					Psychomylidae/Xiphocentronidae	8					Planorbinae" (Orb snails)	3			<u> </u>	-
Cliner environmental and a construction of the	9	-				Cased caddis:	40					Iniaridae" (=ivielanidae)	3		┟────┦	<u> </u>	
Oligoneuridae (Brusniegged maynies)	15					Barbarochthohidae SWC	13						5				
Polymitarcyidae (Pale Burrowers)	10					Calamoceratidae ST	11					PELECYPODA (Bivalves)	-				4
Prosopistomatidae (Water specs)	15					Glossosomatidae SVVC	11					Corbiculidae (Clams)	5				-
Teloganodidae SWC (Spiny Crawlers)	12					Hydroptilidae	6					Sphaeriidae (Pill clams)	3			<u> </u>	
Tricorytridae (Stout Crawlers)	9	_				Hydrosaipingidae SwC	15					Unionidae (Perly mussels)	6				
ODONATA (Dragonflies & Damselflies)	1 40					Lepidostomatidae	10					SASS Score					33
Calopterygidae S1,1 (Demoiselles)	10					Leptoceridae	6					No. of Taxa					8
Chlorocyphidae (Jewels)	10	-				Petrothrincidae SWC	11					ASPI			L	L	4.1
Synlestidae (Chlorolestidae)(Sylphs)	8					Pisuliidae	10					Other biota:				<u> </u>	
Coenagrionidae (Sprites and blues)	4		A		A	Sericostomatidae SWC	13										
Lestidae (Emerald Damselflies/Spreadwir	10 8					COLEOPTERA (Beetles)	_										
Platycnemidae (Stream Damselflies)	10					Dytiscidae/Noteridae* (Diving beetles)	5	1			1						
Protoneuridae (Threadwings)	8					Elmidae/Dryopidae* (Riffle beetles)	8										
Aeshnidae (Hawkers & Emperors)	8		I	I	 	Gyrınidae* (Whirligig beetles)	5	1			В	Comments/Observations:					
Corduliidae (Cruisers)	8					Haliplidae* (Crawling water beetles)	5					4					
Gomphidae (Clubtails)	6					Helodidae (Marsh beetles)	12					4					
Libellulidae (Darters/Skimmers)	4					Hydraenidae* (Minute moss beetles)	8					4					
LEPIDOPTERA (Aquatic Caterpillars/Mo	ths)					Hydrophilidae* (Water scavenger beetle	s 5					4					
Crambidae (Pyralidae)	12					Limnichidae (Marsh-Loving Beetles)	10					1					
			1	1		Psephenidae (Water Pennies)	10	1			1						



Date (ddimm:yrit	11:00.7	1320								jas.de	cidd)	Biotopes Sampled (tick & rate)	Rating	Weight	8		
Sile Code:	10.5)				Grid reference (dri mm ss.s) Lat	8	-	6 ÷	1 53	1775	Stores in Current (SIC)	1	1400	22		
Collector/Sampler:	ildah I					Long	2 F.	Sec.11			122	Shares Lag Of Denner DERED	1.0	(are)			
Diver						Datum (Malaadaaaa)	801					Westweat	1.00	1400			
Land 4 Econology	11. 10	TIP TI D				Participant and and		nos		-		An other lines	-	a data data data data data data data da	ž.		
Customers Retainments	11111	ally LLO				Autor (m)						Hdrane And		Last.	2		
dualemary calciment.	and a		· · · · ·			Lownon.	1286	E LO	ver roog			Mandwed to conser		840			
and a second second	Samp	ea.		16.80		Realize or Project? (carde one)	FITA"		10			Molifyed concurrent	2	1983			
Site Description:	104			14		Project Name	Clour	Y Intel	61			Giosel	2	18,72			
11111610000000000000000000000000000000	DOIT	pLi:		7.20		MPC Aquatic Dismonitoring	Turci	dity:	£1.			Sand	1.1	CONTRACT.			
	Condi	mSam(:	ł., .,	04.00	1.	02 49	Colou	in l				Mud	2	120	2		
	Higheria	e thou				(16010	30				Hase ackep/isoof observation	×.	gard C		Calegore	
11100	LISEA	ni Dava	ristenin	in and							<u></u>	OVERALL DIOTOPE SUITAGIUTY		0	44%	0	dian.
Teson	av	5	Yep	GSN	TO-	Taxon	01	2	Vig	GSN	TOT	Teach	QV.	.5	.Veg .	E SN	TOT
PORFERA (sporge)	- 30 4 K	1,246	2474	0200	184	HEMPTERA (Bugs)	120	0.00	1	10000	1.000	DIP TERA (Films)	14	10000	100000		
CORLENTERATA (CALANA)	19	12		1		Boloman miden' gilland water mapsy-	- 14		-t / /	-	1	rannicidae (Srige files)	10		1	1	19
TURSELLARIA (Fistworms)	3					Consider'' (Near Docard)	3					Skyler occurate (Hour an integer)	19			1 225	100
ANNELIDA		- I come		a strange	-	Centoel" (Nec skdes/Weershelere)	1.3					Carabacgendes (Cargendes)	1.0.8	A.	A		
Cher Rout al entre sus	1.1	-		1		Carde residence d'Artes de promises	0			-		Colorentia - Plancol				1	
Section Questions						 Base collect: Simplify realize lengel 	1			1		Coloria: Margina	1				1
CINPACTALLA.						Billio Aduar (1966) and (1996)	- 24			1		Control (And in No. 2	E-1				1
Anthrise the Star day	T.					Néro a Secol (Carlord natary	- 3					Fig. Second Decision freque					
Coloron and Carl Statisty	-					Support (C-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1	. 1					Friendsteine Stanse (Con)					
Auto inclusion where	4	1		1		CARLON DOWNER ADDIVISION	-					interface (Procentics, String, day)	1				1
Privation for # informed (19744)				1		SCOPLOPTORA (PRIMINE, Oxformation	يا د د	o Tran				Payaliseinan (A. C. Inni)	1 N				1
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PLECOPTEX COLUMN						Stolen States	11					Repairies' services responses	1	_			—
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(There where you all as poly mythere)	-	+				Frankasseri Alexadders, Wilder	12			.		Non-miles No.					+
interfacebox side streams	15	1			•	Children (Printer VI)	11	1		I		27. 26. ansite e la sole e					
Name Strand Sec (1960) 100-02		1				Characteristic Lines (2015)		1		I		Called Mark Street Street St	Î A				
Information Sinth Call on Contractions	10	1		•	•	Defent lines			4	I	*	General as 1911 donai	5	I			•
Nor allow Static merch		 				Entertwicker (see Auto)	24			<u> </u>	- 0	Tadeoblog differing working					
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And a second to an establish	*	+				Conductor:	10	+		 		All surface from					
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40400 MALE 1999 1991 1	11					Contractions and the Property of the State	10	+		—		-					



Date (dd:mm:yr):	11/08/2	020								(dd.ddd	ldd)	Biotopes Sampled (tick & rate)	Rating	Weight			
Site Code:	Site 3A					Grid reference (dd mm ss.s) Lat:	S	#REF!		#RI	EF!	Stones In Current (SIC)	2	4.0			
Collector/Sampler:	Lloyd	vnch				Long	E	#DEEL		#RI	FFI	Stones Out Of Current (SOOC)	2	4.0			
Pivor:	Lioyu L	-yrich				Dotum (MCS84/Cono)	-			,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,		Badwards		1.5			
	Vaalba	nkspruit						wGS d	4	ł		Bearock		1.0			
Level 1 Ecoregion:	11: HIG	HVELD				Altitude (m):		-				Aquatic Veg	2	1.0			
Quaternary Catchment:						Zonation:	-	E: Low	er Footh	nills		MargVeg In Current	2	2.0			
	Temp (°C):		7.80		Routine or Project? (circle one)	Flow:		<u> </u>			MargVeg Out Of Current	2	2.0			
Site Description:	pH:			7.50		Project Name:	Clarity	(cm):	83			Gravel	2	4.0			
	DO (mg	g/L):		6.15		MFC Aquatic Biomonitoring	Turbidi	ity:				Sand	2	2.0			
Desumetroom of MEC	Cond (mS/m):		185.00			Colour	:				Mud	2	1.0			
Downstream of MPC	Riparia	n Distur	bance:				-					Hand picking/Visual observation	Y			Category	•
	Instrea	m Distu	rbance:									OVERALL BIOTOPE SUITABILITY		0.0	40%	E	1
Taxon	OV	s	Veg	GSM	тот	Taxon	OV	s	Veg	GSM	тот	Taxon	ov	s	Veg	GSM	TOT
PORIFERA (Sponge)	5	3	veg	COM					veg	0.011	101		<u></u>		veg	0.014	
COEL ENTERATA (Chidaria)	1					Belostomatidae* (Giant water bugs)	3					Athericidae (Snipe flies)	10				-
TURBELLARIA (Elatworme)	3	^	1		^	Corividae* (Water boatmen)	3		C		C	Blenharoceridae (Mountain middes)	15				-
	Ŭ				^	Gerridge* (Pond skaters/Water striders)	5		v		, v	Ceratopogopidae (Biting midges)	5				-
Oligochaeta (Earthworms)	1	1		<u>۸</u>	<u>۸</u>	Hydrometridae* (Water measurers)	6					Chiropomidae (Middes)	2	^	R	^	R
Hirudines (Leeches)	3			<u> </u>	^	Naucoridae* (Creening water bugs)	7					Culicidae* (Mosquitoes)	1	^			
						Nonidae* (Water coornigne)	2					Dividace (Niosquitoes)	10				
Amphipodo (Soudo)	12					Notopostidos* (Rockowimmore)	2					Empididae (Dance flice)	6				-
Amphipoda (Scuus)	2					Ploidoo* (Pygmy bookowimmoro)	- 3					Emploidae (Dance files)	2				-
Polarionautidae (Crabs)	3					Velidae (Pygny backswinners)	4					Ephydridae (Shore files)	3				
Atyldae (Freshwater Shrimps)	8			-		Velildae/MVelildae" (Ripple bugs)	5	<i>a</i> :)				Muscidae (House files, Stable files)	1				-
Palaemonidae (Freshwater Prawns)	10		-		_	MEGALOPTERA (Fishfiles, Dobsonfiles	s & Alder	rflies)				Psychodidae (Noth files)	-				
HYDRACARINA (Mites)	8	A	A	A	В	Corydalidae (Fishfiles & Dobsonfiles)	8					Simuliidae (Blackfiles)	5	A	A		В
PLECOPTERA (Stoneflies)						Sialidae (Alderflies)	6					Syrphidae* (Rat tailed maggots)	1				-
Notonemouridae	14			-		TRICHOPTERA (Caddisflies)						Tabanidae (Horse flies)	5				-
Perlidae	12					Dipseudopsidae	10					Tipulidae (Crane flies)	5				_
EPHEMEROPTERA (Mayflies)						Ecnomidae	8					GASTROPODA (Snails)					
Baetidae 1sp	4	Α				Hydropsychidae 1 sp	4	Α		В	В	Ancylidae (Limpets)	6				
Baetidae 2 sp	6		Α		Α	Hydropsychidae 2 sp	6					Bulininae*	3				_
Baetidae > 2 sp	12					Hydropsychidae > 2 sp	12					Hydrobiidae*	3				
Caenidae (Squaregills/Cainflies)	6		Α		Α	Philopotamidae	10					Lymnaeidae* (Pond snails)	3				_
Ephemeridae	15					Polycentropodidae	12					Physidae* (Pouch snails)	3				
Heptageniidae (Flatheaded mayflies)	13					Psychomyiidae/Xiphocentronidae	8					Planorbinae* (Orb snails)	3				
Leptophlebiidae (Prongills)	9					Cased caddis:						Thiaridae* (=Melanidae)	3				
Oligoneuridae (Brushlegged mayflies)	15					Barbarochthonidae SWC	13					Viviparidae* ST	5				
Polymitarcyidae (Pale Burrowers)	10					Calamoceratidae ST	11					PELECYPODA (Bivalves)					
Prosopistomatidae (Water specs)	15					Glossosomatidae SWC	11					Corbiculidae (Clams)	5				
Teloganodidae SWC (Spiny Crawlers)	12					Hydroptilidae	6		1		1	Sphaeriidae (Pill clams)	3				
Tricorythidae (Stout Crawlers)	9					Hydrosalpingidae SWC	15					Unionidae (Perly mussels)	6				
ODONATA (Dragonflies & Damselflies)						Lepidostomatidae	10					SASS Score					56
Calopterygidae ST,T (Demoiselles)	10					Leptoceridae	6					No. of Taxa					12
Chlorocyphidae (Jewels)	10					Petrothrincidae SWC	11					ASPT					4.7
Synlestidae (Chlorolestidae)(Sylphs)	8					Pisuliidae	10					Other biota:					
Coenagrionidae (Sprites and blues)	4		В		В	Sericostomatidae SWC	13										
Lestidae (Emerald Damselflies/Spreadwir	8					COLEOPTERA (Beetles)											
Platycnemidae (Stream Damselflies)	10					Dytiscidae/Noteridae* (Diving beetles)	5										
Protoneuridae (Threadwings)	8					Elmidae/Dryopidae* (Riffle beetles)	8	1	1		Α						
Aeshnidae (Hawkers & Emperors)	8					Gyrinidae* (Whirligig beetles)	5					Comments/Observations:					
Corduliidae (Cruisers)	8	1	1	1	1	Haliplidae* (Crawling water beetles)	5	1									-
Gomphidae (Clubtails)	6	1	i	1	1	Helodidae (Marsh beetles)	12	1				1					
Libellulidae (Darters/Skimmers)	4	1	1	1	1	Hvdraenidae* (Minute moss beetles)	8	1				1					
LEPIDOPTERA (Aquatic Caternillars/Mot	ths)					Hvdrophilidae* (Water scavenger beetle	s 5	1				1					
Crambidae (Pyralidae)	12					Limnichidae (Marsh-Loving Beetles)	10					1					
	·					Psephenidae (Water Pennies)	10					1					





AQUATIC BIO-MONITORING OF THE VAALBANKSPRUIT Wet Season Survey (November 2020)

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

13 January 2021



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Project Number **RI 301-00183-48**

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

Rev	Description	Date
А	Issued in Final	13 January 2021



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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APPENDICES

Appendix A Integrated Habitat Assessment System Appendix B Summarised Diatom Results Appendix C Summarised Invertebrate Results



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
		omanico	TT GLOI	managomont	/1104

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.

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

Table 3: Present Ecological State

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 bioassessment 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 KMnO₄ 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.).

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

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



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.

Category	Description	Average Score per Taxon (ASPT)	SASS Score
А	Unmodified or approximate natural conditions. High diversity of taxa with numerous sensitive taxa.	>5.6	> 123
В	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
с	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

Table 5: Summarised interpretation of the Highveld Ecoregion



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 /N-SITU WATER QUALITY

Sample Point	Date	рН	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

Table 6: In-situ water quality results for Site 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.



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

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

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.

Taxon	QV	S	Veg	GSM	тот		
CRUSTACEA							
Potamonautidae* (Crabs)	3				1		
EPHEMEROPT	ERA (Ma	yflies)		-			
Baetidae 1sp	4	Α	Α		В		
ODONATA (Dragon	flies & D	amselfli	es)				
Coenagrionidae (Sprites and blues)	4	Α	Α		Α		
Aeshnidae (Hawkers & Emperors)	8	1	1		Α		
Libellulidae (Darters/Skimmers)	4			В	В		
HEMIPTER	RA (Bugs	5)					
Belostomatidae* (Giant water bugs)	3		1		1		
Nepidae* (Water scorpions)	3		Α		Α		
Notonectidae* (Backswimmers)	3		Α		Α		
Pleidae* (Pygmy backswimmers)	4	Α	Α		В		
Veliidae/Mveliidae* (Ripple bugs)	5		Α		Α		
DIPTER	A (Flies)						
Chironomidae (Midges)	2	Α	Α	Α	В		
Culicidae* (Mosquitoes)	1	Α	Α	Α	В		
GASTROPO	DA (Sna	ils)					
Physidae* (Pouch snails)	3	1			1		
SASS Score					47		
No. of Taxa					13		
ASPT					3.6		

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



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

Sample Point	Date	рН	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

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

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..

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

Table	10: SWR	3 IHAS	Results	for	November	2020	Wet	Season	Survey
IUNIO	10.0111	0 11 17 10	1.00uito		11010111001			0000011	Guitey

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.

Taxon	QV	S	Veg	GSM	тот				
TURBELLARIA (Flatworms)	3	Α			Α				
ANNELIDA									
Oligochaeta (Earthworms)	1			Α	Α				
CRUS	CRUSTACEA								
Potamonautidae* (Crabs)	3				Α				
CHELICERATA									
Hydracarina (Mites)	8	Α	Α		В				
ODONATA (Dragor	nflies & I	Damself	lies)						
Coenagrionidae (Sprites and blues)	4		Α		Α				
НЕМІРТЕ	RA (Bug	gs)							
Belostomatidae* (Giant water bugs)	3		1		1				
Corixidae* (Water boatmen)	3	Α	Α		В				
TRICHOPTER	A (Cadd	isflies)							
Cased	Cased caddis:								
Hydroptilidae	6		1		1				
COLEOPTE	RA (Bee	tles)							
Gyrinidae* (Whirligig beetles)	5				В				

Table 11: SWP 3 Summ	any of SASS Result	s for November 202	Wet Season Survey
	ary of SASS Result	5 IOI NOVEIIIDEI 202	o wel Season Survey



DIPTERA (Flies)								
Ceratopogonidae (Biting midges)	5	Α		Α	В			
GASTROPODA (Snails)								
Physidae* (Pouch snails)	3	Α	Α		Α			
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

Sample Point	Date	рН	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

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

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

Sample Point	Date	рН	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

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

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

Sample Point	Date	рН	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

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

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.


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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: 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 (grv/bedr=0)	0	<1	<1-2	2	>2-3	>3						
*Note: up to 25% of stones is usually embedded in stream bottom.	SIC S	core (ma	ax. 20)	15								
	INVERTEBRATE HABITAT ASSESSMENT SYSTEM (IHAS) Vaalbankspruit Date: 17/11/2020 ite 1 Date: 17/11/2020 ite 1 Date: 17/11/2020 BITAT 0 1 2 3 4 5 Frent (SIC) none 0-1 2.2 >2.3 <3.5 >50 0 of submerged stones in current (run none 0.1 2.3 4.5 6+ origo forms kicked (gravel-2, bedrock > 20) none 0.2 >2.2 >5.5 10 10 or arte SIC areas kicked (gravel-2, bedrock > 20) none C.4 <1.2 2.2 2.3 >3 3 7 of stones is usually kicking SIC (grav/bedr=0) 0 <1 <1.2 2 >2.2 3 3 7 of stones is usually embedded in stream bottom. SIC Score (max. 20) 15 75 7 and use stems/shoots) (aqv only = 49) none 0.4'///2 24 2 2 2 2 2 2 2 2 2 2											
Vegetation												
Length (m) of fringing vegetation sampled (banks)	none	0-1/2	>1⁄2 - 1	>1-2	2	>2						
Amount (m ²) of aquatic vegetation / algae sampled	none	0-1/2	>1/2 - 2	>1								
Fringing vegetation sampled in: (none: pool or still only: run only: mixture of both)	none	- / -	run	loog		mix						
Type of yeg (% leafy vegetation vs stems/shoots) (agy only = 49)	none	0	1-25	26-50	51-75	>75						
	Vea S	core (ma	x. 15)		13							
			<u>, 10,</u>									
Other Habitat / General												
Stones-out-of-current (SOOC) sampled: (protocol = 1m ²)	none	0-1/2	>1⁄2-1	1	>1							
Sand sampled: (protocol = 1min) (present, but only below stones)	none	below	0-1/2	>1/2-1	1	>1						
Mud sampled: (protocol = 1/2min) (present, but only below stones)	none	below	0-1/2	1/2	>1/2							
Gravel sampled: (protocol=1/2min) if all. SIC stone size =<2)**	none	0-1/2	1/2	>1/2 **								
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						
	0 1 2 3 4 5 none 0-1 >1-2 >2-3 <3-5 >5 none 0-2 >2-5 >5-10 >10 0 0 1 2-3 4-5 6+ 0 0 1 2-3 4-5 6+ 0 0 1 2-3 4-5 6+ 0 0 1 2-3 4-5 6+ 0 0 1 2-20 0 10 0 1 2-20 0 10 0 1 2-10 2 2-20 0 0 1 2-12 2 2 2 0 0 1 2 >2 2 2 2 1 0 0 0 1 1 1 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 <t< th=""><th></th></t<>											
** Note still fill in SIC section	None 0-½ >½-1 1 >1 none below 0-½ >½-1 1 >1 none below 0-½ >½-1 1 >1 none below 0-½ ½ >½ i none below 0-½ ½ >½ i none some All ** isol. none 2m² rocks 1-2m² <1m² isol. none under Correct over over over Other Habitat Score (max. 20) 17 isol. isol.											
	IABITAI											
	none $0-\frac{1}{2}$ $>\frac{1}{2}-1$ $>1-2$ 2 none $0-\frac{1}{2}$ $>\frac{1}{2}-2$ >1 1 xture of both) none run pool 1 none 0 $1-25$ $26-50$ $51-75$ Veg Score (max. 15) 13 none 0 $1-25$ $26-50$ $51-75$ Veg Score (max. 15) 13 1 1 none $0-\frac{1}{2}$ $>\frac{1}{2}-1$ 1 >1 none $0-\frac{1}{2}$ $>\frac{1}{2}-1$ 1 >1 none $0-\frac{1}{2}$ $>\frac{1}{2}$ 3 4 20)** none some $All **$ ps >2m² rocks $1-2m²$ $3m²$ $4s$											
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	>1⁄2 - 1	1/2	1/2 - 1/4	<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								
	Strea	am Cond										
***Neto: if more than and ention, choose lowest	To	tal (max.	45)		25							
	TOTA											
	IUTAL	IHAS SC	OKE %:		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 S	core (ma	ax. 20)		12							
Vegetation												
Length (m) of fringing vegetation sampled (banks)	none	0-1/2	>1⁄2 - 1	>1-2	2	>2						
Amount (m ²) of aquatic vegetation / algae sampled	none	0-1/2	>1⁄2 - 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) (agv only = 49)	none	0	1-25	26-50	51-75	>75						
	Veg S	core (ma	x. 15)		9							
			, í									
Other Habitat / General												
Stones-out-of-current (SOOC) sampled: (protocol = 1m ²)	none	0-1/2	>1⁄2-1	1	>1							
Sand sampled: (protocol = 1min) (present, but only below stones)	none	below	0-1/2	>1⁄2-1	1	>1						
Mud sampled: (protocol = 1/2min) (present, but only below stones)	none	below	0-1/2	1/2	>1⁄2							
Gravel sampled: (protocol=1/2min) if all, SIC stone size =<2)**	none	0-1/2	1/2	>1/2 **								
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						
	Other Habitat Score											
** Note still fill in SIC section	0 1 2 3 4 5 none 0-1 >1-2 >2-3 <3-5 >5 none 0-2 >2-5 >5-10 >10 0 0 1 2-3 4-5 6+ none 0 1 2-20 none 0 1 2-20 none 0 1 2-20 2-10 11-20 2-20 none 0 1 -12 2 >2-3 >3 3 SIC Score (max. 20) 12											
	$\begin{array}{c c c c c c c c c c c c c c c c c c c $											
STREAM CHARACTERISTICS	0	1	2	3	4	5						
					0.1	o :						
River make up (pool = pool/dam only; run only; rapid/riffie only; 2mix = 2 types etc)	pool	>10	run	apid / rifi	2mix	3mix						
Average stream donth (m)	>1	>10	5-10	×1 1/	1-2	>2-5						
Average stream depth (m)	>1	1	>/2 - 1	⁷ /2	¹ / ₂ - ¹ / ₄	< 1/4						
Approximate stream velocity (slow < 1m/s; fast < 1m/s)	SUII	SIOW	Tast	mea.		mix						
Water colour (disc = discoloured with visible colour but still clearish)	SIIty	opaque	<u>O t-</u>	disc.		clear						
Recent disturbances due to: (constr = construction; 1/dr = 1000/drought)	TI/ dr	tire	Constr.	otner		none						
Dank/IIpanani vegetation is: grass=includes reeds; snrubs=includes trees)	none	form	grass	snrubs	mix	0000						
Surrounding impacts. (erosit – erosion/shear bare barks, rarm – farmland/settlements) Left bark cover $(%)$ (rocks and vegetation: cheer = 0%)		51 00	81.05			open						
Dight bank cover (%) (rocks and vegetation; choose = 0%)	0-50	51-00	01-95 01 0F	~90								
rught bank cover (%) (rocks and vegetation; snear = 0%)	U-50 Stres		itions	~90								
		Total (may 45)										
***Note: if more than one option, choose lowest			,									
······································	TOTAL	IHAS SC	ORE %:		53							
			/01	1	30							



APPENDIX B

Summarised Diatom Results







APPENDIX C

Invertebrate Results



Date (dd:mm:yr):	17/11/20	1/2020						(dd.ddddd)			Biotopes Sampled (tick & rate) Rating Weight					
Site Code:	Site 1				Grid reference (dd mm ss.s) Lat:	S	#REF!		#RI	EF!	Stones In Current (SIC)	3	4.0			
Collector/Sampler:	Lloyd Ly	/nch			Long:	Е	#REF!	#REF!		EF!	Stones Out Of Current (SOOC)	2	4.0			
River:	Vaalban	kspruit			Datum (WGS84/Cape):		WGS 8				Bedrock	2	1.5			
Level 1 Ecoregion:	11. HIGH				Altitude (m):				-			2	1.0			
Quaternary Catchment:					Zonation:		E: Low	er Footh	ville		MaraVag In Current	2	2.0			
guaternary outerment.		0			Douting or Project2 (circle one)	1	E. LOW		11115			-	2.0			
014 D	Temp (*C	<u>ے):</u>	26.7)	Routine or Project? (circle one)	Flow:					Margveg Out Of Current	3	2.0			
Site Description:	pH:		7.80		Project Name:	Clarity	(cm):	52			Gravel	2	4.0			
	DO (mg/	L):	#REF	1	MFC Aquatic Biomonitoring	Turbid	ity:				Sand	2	2.0			
	Cond (m	nS/m):	65.0)		Colour	:				Mud	2	1.0			
	Riparian	Disturbar	ce:								Hand picking/Visual observation	Y			Category	
	Instream	n Disturbar	ice:								OVERALL BIOTOPE SUITABILITY		0.0	46%	D	1
Taxon	ov	S V	eg GSM	тот	Taxon	ov	s	Veq	GSM	тот	Taxon	ov	s	Vea	GSM	то
PORIFERA (Sponge)	5		<u>og</u> oo.		HEMIPTERA (Bugs)			log			DIPTERA (Flies)			log		
COFLENTERATA (Cnidaria)	1				Belostomatidae* (Giant water bugs)	3		1		1	Athericidae (Snipe flies)	10				
TURBELLARIA (Flatworms)	3				Corixidae* (Water boatmen)	3					Blepharoceridae (Mountain midges)	15	1			
ANNELIDA					Gerridae* (Pond skaters/Water striders)	5					Ceratopogonidae (Biting midges)	5	1			
Oligochaeta (Earthworms)	1				Hydrometridae* (Water measurers)	6	1	1			Chironomidae (Midges)	2	Δ	Δ	Δ	R
Hirudinea (Leeches)	3				Naucoridae* (Creening water bugs)	7	1				Culicidae* (Mosquitoes)	1	Ā	Ā	Δ	R
CRUSTACEA					Nepidae* (Water scorpions)	3		Δ		Δ	Dixidae* (Dixid midge)	10				
Amphipoda (Scuds)	13				Notonectidae* (Backswimmers)	3				Â	Empididae (Dance flies)	6				
Potamonautidae* (Crabs)	3			1	Pleidae* (Pvgmy backswimmers)	4	Δ			R	Enbydridae (Shore flies)	3				
Atvidae (Freshwater Shrimps)	8			- ·	Veliidae/M veliidae* (Ripple bugs)	5				~	Muscidae (House flies, Stable flies)	1				
Palaemonidae (Freshwater Prawns)	10				MEGAL OPTERA (Fishflies Dobsonflies		rfligs)				Psychodidae (Moth flies)	1				
HYDRACARINA (Mites)	8				Corvdalidae (Fishflies & Dobsonflies)	8					Simuliidae (Blackflies)	5				
PLECOPTERA (Stoneflies)	Ű				Sialidae (Alderflies)	6					Symbidae* (Bat tailed maggots)	1				
Notonemouridae	14		_	-		0					Tabanidae (Horse flies)	5				
Perlidae	14				Dipseudopsidae	10					Tipulidae (Crape flies)	5				
	12				Enemidee	0					CASTROPODA (Speile)	5				
Poetideo 1ep	4	_	<u> </u>		Echomidae Hydropsychidae 1 ap	0					Anaviidaa (Limpata)	6				
Baetidae 2 an	4		A	P	Hydropsychidae 2 an	4					Ancylidae (Limpets)	0				
Baetidae 2 Sp	10			-	Hydropsychidae 2 Sp	10					Builtillae	3				
Baelidae / 2 sp	12				Rydropsychidae > 2 sp	12					Hydrobildae	3				
Caerindae (Squaregilis/Carrilles)	15				Philopotaniidae	10					Developet (Developeration)	3				
Epitementuae	10			_	Polycenti opodidae	12					Physidae (Pouch shalls)	3				1
Leptageniluae (Flatileaded Haynes)	0					0					Thiaridaet (=Malanidae)	3				
Oligonouridae (Problegged mauflice)	9			-	Cased caddis:	12					Visiporidoo* ST	5				
Delumitere video (Delo Burrovero)	10			_	Celemeneratides ST	10						5				
Polymitarcyldae (Pale Burrowers)	10				Classocomatidae ST	11					Corbioulidae (Clame)	5				
Tologopodidoo SWC (Spipy Crowlers)	10			-	Hudrontilidao	6	+	<u> </u>			Sphooriidae (Clams)	2	+			-
Tricorythidae (Stout Crowlers)	0			-	Hydrosalpingidae SM/C	15	+				Unionidae (Perly muscele)	6	+			+
ODONATA (Dragonfling & Damasifica)	3					10	+						+			1 17
Colontorygidae STT (Domaioallea)	10					6	+				SASS SCORE		+			4/
Chloropyphidae (Journal)	10				Potrothrippidoo SW/C	11	+						+			13
Suplectides (Chlorolectides)	0			-	Piculiidaa	10	+			-	AGE I					3.6
Cooperationidae (Childrolesudae)(Sylphs)	0					10	+				Other blota:					
Lostidoo (Emorold Domoolflice/Emocration	4		~	A		13										
Distronomidae (Stroom Domes ¹⁴¹	10				Dutiesides/Neteridest (Diving hards)	E										
Pratychemidae (Stream Damselfiles)	0			-	Elmidao/Dryopidao* (Diffle booffee)	5	+			-						
Accharidae (Inreadwings)	ð		_	-	Curinidaet (Whitiging heatles)	ð F					O					
Aesimicae (Hawkers & Emperors)	8	1	1	A	Gyrmude" (Whirigg beetles)	5					Comments/Observations:					
Cordulidae (Cruisers)	8			-	Haliplidae* (Crawing water beetles)	5	+				4					
Gomphidae (Clubtalis)	0			-	Helouidae (Marsh beetles)	12					4					
Libellulidae (Darters/Skimmers)	4		B	В	Hydraenidae [*] (Minute moss beetles)	8					4			D 1 0 5 1	00105	
LEPIDOPTERA (Aquatic Caterpillars/Mot	ins)				Hydrophilidae* (Water scavenger beetle	5	+				4			RI 301	-00183-4	48
	12				Limnichidae (Marsh-Loving Beetles)	10					4				10	

Date (dd:mm:yr):	17/11/2	.020								(dd.ddd	ldd)	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:	I lovd I	vnch				Lona:	Е	#REF!	4 #REF! 5		EF!	Stones Out Of Current (SOOC)	2	4.0			
River:	Vaalbar	nkenruit				Datum (WGS84/Cane):		WGS 8				Bedrock	-	1.5			
Lovel 1 Ecorogion:						Altitudo (m):						Aquatia Var		1.0			
Quaternary Catchmont	TT: HIG	IVELD				Annude (III).		E. Law	- East			Aquatic Veg	0	2.0			
Quaternary Catchinent.			-			Zonation:	1	E: LOW	er Footi	11115		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	J/L):		1.88		MFC Aquatic Biomonitoring	Turbidi	ity:				Sand	3	2.0			
	Cond (r	mS/m):		112.00			Colour	:				Mud	2	1.0			_
	Riparia	n Distur'	bance:									Hand picking/Visual observation	Y		1.12	Category	
	Instream	m Distur	rbance:									OVERALL BIOTOPE SUITABILITY		0.0	39%	E	
Taxon	QV	S	Veq	GSM	тот	Taxon	QV	S	Vea	GSM	тот	Taxon	QV	S	Vea	GSM	тот
PORIFERA (Sponge)	5					HEMIPTERA (Bugs)						DIPTERA (Flies)					
COELENTERATA (Cnidaria)	1					Belostomatidae* (Giant water bugs)	3		1		1	Athericidae (Snipe flies)	10				
TURBELLARIA (Flatworms)	3	Α			Α	Corixidae* (Water boatmen)	3	Α	Α		В	Blepharoceridae (Mountain midges)	15				
ANNELIDA						Gerridae* (Pond skaters/Water striders)	5					Ceratopogonidae (Biting midges)	5	Α		Α	В
Oligochaeta (Earthworms)	1			Α	Α	Hydrometridae* (Water measurers)	6					Chironomidae (Midges)	2				
Hirudinea (Leeches)	3	1				Naucoridae* (Creeping water bugs)	7	1	İ			Culicidae* (Mosquitoes)	1				
CRUSTACEA			1			Nepidae* (Water scorpions)	3	1	1			Dixidae* (Dixid midge)	10				1
Amphipoda (Scuds)	13					Notonectidae* (Backswimmers)	3					Empididae (Dance flies)	6				
Potamonautidae* (Crabs)	3				Δ	Pleidae* (Pygmy backswimmers)	4					Ephydridae (Shore flies)	3				
Atvidae (Freshwater Shrimps)	8	-				Veliidae/Mveliidae* (Ripple bugs)	5					Muscidae (House flies, Stable flies)	1				
Palaemonidae (Freshwater Prawns)	10					MEGALOPTERA (Eishflies Dobsonflies	& Alder	rflies)				Psychodidae (Moth flies)	1				
HYDRACARINA (Mites)	8	Δ	Δ		B	Corvdalidae (Eishflies & Dobsonflies)	8					Simuliidae (Blackflies)	5				
PLECOPTERA (Stoneflies)	Ŭ					Sialidae (Alderflies)	6					Syrphidae* (Bat tailed maggots)	1				
Notonemouridae	14						Ŭ					Tabanidae (Horse flies)	5				
Perlidae	12	-				Dinseudopsidae	10					Tipulidae (Crane flies)	5				
	12					Ecoomidae	8					GASTROPODA (Snaile)	Ŭ				
Baetidae 1sp	4					Hydronsychidae 1 sp	4					Ancylidae (Limnets)	6				
Baetidae 2 sp	6					Hydropsychidae 2 sp	6					Bulininge*	3				
Baetidae > 2 cp	12					Hydropsychidae > 2 sp	12					buinnae	2				
Caenidae / Squaregills/Cainflies)	6					Philopotamidae	10					Lympaeidae* (Pond spails)	3				
Enhomoridae	15	-				Polycontropodidoo	10					Develdee* (Pouch spails)	2	^	^		<u>۸</u>
Hentageniidae (Elatheaded mayflies)	13					Psychomyjidae/Xinbocentronidae	8					Planorbinge* (Orb snails)	3	^			
Loptophobiidae (Prongille)	0						0					Thiaridaa* (-Molanidaa)	2				
Oligonouridae (Prushlagged mayflice)	9					Parbaraphthanidaa SW/C	12						5				
Bolymiterovideo (Bolo Byrrowore)	10					Colomocoratidos ST	11					PELEC/PODA (Binchree)	5				
Prosonistomatidae (Water specs)	15	-				Clossosomatidae SV/C	11					Corbiculidae (Clams)	5				
Tologopodidoo SWC (Spipy Crowlerg)	10					Hydroptilidae	6				4	Sphaoriidae (Clarits)	2				
Tricorythidae (Stout Crawlers)	0					Hydropalningidae SW/C	15		-			Unionidae (Perly mussels)	6				
ODONATA (Dragonfligs & Damcolfligs)	3					L enidostomatidae	10					SASS Score					47
Colontarygidae STT (Demoiselles)	10					Leptocaridae	6					No. of Toxo					40
Calopterygidae 31,1 (Demoiselles)	10					Botrothrinoidae SW/C	11										2.0
Synlestidae (Chlorolastidae)(Sylabe)	9	├───┘					10	1				Other biota:				1	3.9
Cooperioridee (Sprites and blues)	0		•		^	Sorioostomatidae SW/C	10									l	
Lostidoo (Emorold Domoolflioo/Onroaduin	4	┥────	A		A		13										
Platyonomidae (Stroom Domes ¹⁶ ice)	10	<u> </u>				Duticoidoo/Notoridoo* (Diving bootloo)	5										
Protopouridae (Suream Damseillies)	10	I'				Elmidao/Druopidao* (Difflo bastics)	- D					1					
Asshridae (Haukara & Emparces)	0	───				Curinidae* (Whitelinia heatles)	8				_	O					
Aesinidae (Hawkers & Emperors)	ð	├ ──┤	-			Gynnidae" (vvniriigig beetles)	5				в	Comments/Observations:					
Cordulidae (Cruisers)	8	<u> </u>				Halplidae* (Crawing water beetles)	5					4					
Gompnidae (Clubtalis)	6	<u> </u>				Helodidae (Marsh beetles)	12					4					
Libeilulidae (Darters/Skimmers)	4				_	Hydraenidae [*] (Minute moss beetles)	8					4					
LEPIDOPTERA (Aquatic Caterpillars/Mot	ns)					Hydrophilidae (vvater scavenger beetle	5					4			RI 301	-00183-4	18
	12	1 1	1	1		Limnichidae (Marsh-Loving Beetles)	10	1	1	1		1					