Riverine Ecology Assessment for the Proposed Pure Source Mine Project

Parys, Free State Province

February 2019

Client

Shango Solutions

Prepared for:

Van Wyk Development Corporation (Pty) Ltd

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Report Name	**Riverine Ecology Assessment for the Proposed Pure Source Mine Project**	
Submitted to	Shango Solutions	
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	Russell Tate is a published, registered Professional Scientist (Pr. Sci. Nat Aquatic Health: 400089/15) with an MSc in aquatic eco-toxicology. Russell Tate has completed specialist projects in South Africa, Mozambique, Botswana, Zambia, Ivory Coast, Ghana, Mali, Liberia, Sierra Leone, Senegal, Cameroon and throughout north eastern and central Democratic Republic of Congo. Considering the wide geographical range of the projects completed, Russell Tate has a good technical understanding on the variable conditions within African landscapes as well as their biological compositions. Russell has worked on numerous mining related assessments which include the monitoring of the impacts of existing surface mines. Russell therefore has a knowledge of the potential impacts arising from the proposed project.	
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	Andrew Husted is Pr Sci Nat registered (400213/11) in the following fields of practice: Ecological Science, Environmental Science and Aquatic Science. Andrew is an Aquatic, Wetland and Biodiversity Specialist with more than 12 years' experience in the environmental consulting field. Andrew has completed numerous wetland training courses, and is an accredited wetland practitioner, recognised by the DWS, and also the Mondi Wetlands programme as a competent wetland consultant.	
Declaration	The Biodiversity Company and its associates operate as independent consultants under the auspice of the South African Council for Natural Scientific Professions. We declare that we have no affiliation with or vested financial interests in the proponent, other than for work performed under the Environmental Impact Assessment Regulations, 2017. We have no conflicting interests in the undertaking of this activity and have no interests in secondary developments resulting from the authorisation of this project. We have no vested interest in the project, other than to provide a professional service within the constraints of the project (timing, time and budget) based on the principals of science.	

Malachite Kingfisher, *Corythornis cristatus*, on the Vaal River (July 2018)

Executive Summary

The Biodiversity Company was commissioned by the Van Wyk Development Corporation (Pty) Ltd to conduct a riverine ecology assessment to support the Mining Right Application and Environmental Authorisation process for the proposed Pure Source Mine project.

The proposed project will involve the development of an open pit mine, a processing plant and associated infrastructure. Commodities to be mined will include sand (silica), gravel and diamonds (alluvial).

This report aims to provide a detailed baseline ecological assessment of the riverine ecology which may be potentially affected through the proposed mining operation. Standard River Ecosystem Monitoring Programme methods were applied to determine the baseline Present Ecological Status (PES) of the abovementioned watercourses.

The proposed project is located approximately 20 km northeast of Parys in the Free State Province. The project area is situated within the Vaal Water Management Area in the C23B quaternary catchment. The catchment of the project area drains into the C23B-01731 Sub Quaternary Reach (SQR) of the Vaal River system. The C23B-01731 SQR is 27.52 km in length and is within the Highveld Ecoregion.

Baseline Condition

The results of the PES assessment derived a largely/seriously modified ecological category (class D/E) for the Vaal River reach. This PES is below the attainable ecological management class (class B) and not currently meeting the gazetted Resource Quality Objectives for the reach. The modified status can be attributed to persistent cumulative modifications within the reach, including a myriad of instream impoundments and acutely toxic ammonia concentrations impact on water quality, resulting in significant instream condition modification.

Risk Assessment

The proposed project activities were determined to have two primary potential impacts to the associated riverine ecology. The first was determined to be related to the conditions within the physical make-up of the considered river reaches. This includes the riverine substrates, banks, riparian vegetation and water column. These physical components of a water course determine the quality of the aquatic habitats. Therefore, modification of these physical components would result in a habitat quality impact. The second impact was determined to be related to the chemical properties of water. Considering aquatic biota have requirements for habitat, as well as sensitivity to changes in water chemistry, a change to water quality is anticipated to have negative impacts to local aquatic biota.

The central anticipated impacts associated with the proposed project are related to increased suspended solids and sedimentation. The proposed open pit mining methods, without mitigation, will strip vegetation resulting in increased runoff velocities and subsequent erosion, sedimentation and increased suspended solids. In addition, processing activities make use of water. Water utilised in the process activities will contain elevated suspended solids, mitigation actions have been provided. The proposed project will alter the topography of the catchment feeding the C23B-01731 SQR which will result in the permanent alteration of the hydrology within the considered river reach. However, this may be negated through effective water resource management.

Conclusion

The outcomes of this study have indicated a considerably modified riverine environment. The results of the impact assessment did not identify any significant fatal flaws for the proposed project should mitigation actions be effectively implemented. However, additional water resource studies have been recommended for the abstraction of water and the identification of hydrological impacts attributed to the final voids and effective mitigation actions.

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DECLARATION

I, Russell Tate declare that:

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

Russell Tate

Aquatic Specialist

The Biodiversity Company

10/04/2019

1 Introduction

The Biodiversity Company was commissioned by the Van Wyk Development Corporation (Pty) Ltd to conduct a riverine ecology assessment to support the Mining Right Application and Environmental Authorisation process for the proposed Pure Source Mine project.

The proposed project will involve the development of an open pit mine, a processing plant and associated infrastructure. Commodities to be mined will include sand (silica), gravel and diamonds (alluvial).

This report aims to provide a detailed baseline ecological assessment of the riverine ecology which may be potentially affected through the proposed mining operation. In addition, this report aims to provide delineated buffer zones and sensitive riverine landscapes. Furthermore, this report aims to identify potential fatal flaws for the proposed project. The overall aim of the riverine ecology study was to complete the following objectives:

- Determining the Present Ecological Status (PES) of the local watercourses;
- The delineation and assessment of riparian areas within 500 m of the project area;
- A risk assessment for the proposed development; and
- The prescription of mitigation measures and recommendations for identified risks.

2 Project Area

The proposed project is located approximately 20 km northeast of Parys in the Free State Province. The project area is situated within the Vaal Water Management Area in the C23B quaternary catchment. The catchment of the project area drains into the C23B-01731 Sub Quaternary Reach (SQR) of the Vaal River system. The C23B-01731 SQR is 27.52 km in length and is within the Highveld Ecoregion. The gradient of the watercourse within the project area was determined to be a class F Geoclass which is indicative of a low gradient-gentle slope watercourse (DWS, 2018). The specific reach of the SQR is located downstream of the Vaal River Barrage and upstream of the Goosebay gauging weir near to the town of Vaal Oewer.

The catchment draining the project area consists of typical undulating, hygrophilous vegetation. Frost, fire and grazing maintain the dominance of grasslands in the region with the considered catchment being accurately defined by this broad description.

Aquatic fauna of the Vaal River system, particularly in this zone, are threatened by extensive agriculture, urban development and industrial activities in Vanderbijlpark/Vereeniging. This landuse has resulted in the sedimentation and modification of instream and wetland habitats associated with the Vaal River. In addition, the Ermelo Coal field is largely located within the overall source zone of the Vaal River basin which has resulted in several point source contaminants from coal mining and power generation activities. The Vaal River basin supports a critical commercial and industrial area in South Africa, supplying water for a multitude of activities and services.

According to Nel *et al*. (2011) the catchment of the watercourses in the project area are not National Freshwater Priority Areas (NFEPA). The Vredefort Dome World Heritage Site is located approximately 33 km downstream of the proposed project area. The Vredefort Dome area presents unique instream habitat as a result of the geological formations in the area. The instream habitats include extensive cobbled substrate runs which support high quality spawning sites for the various Cyprinid species.

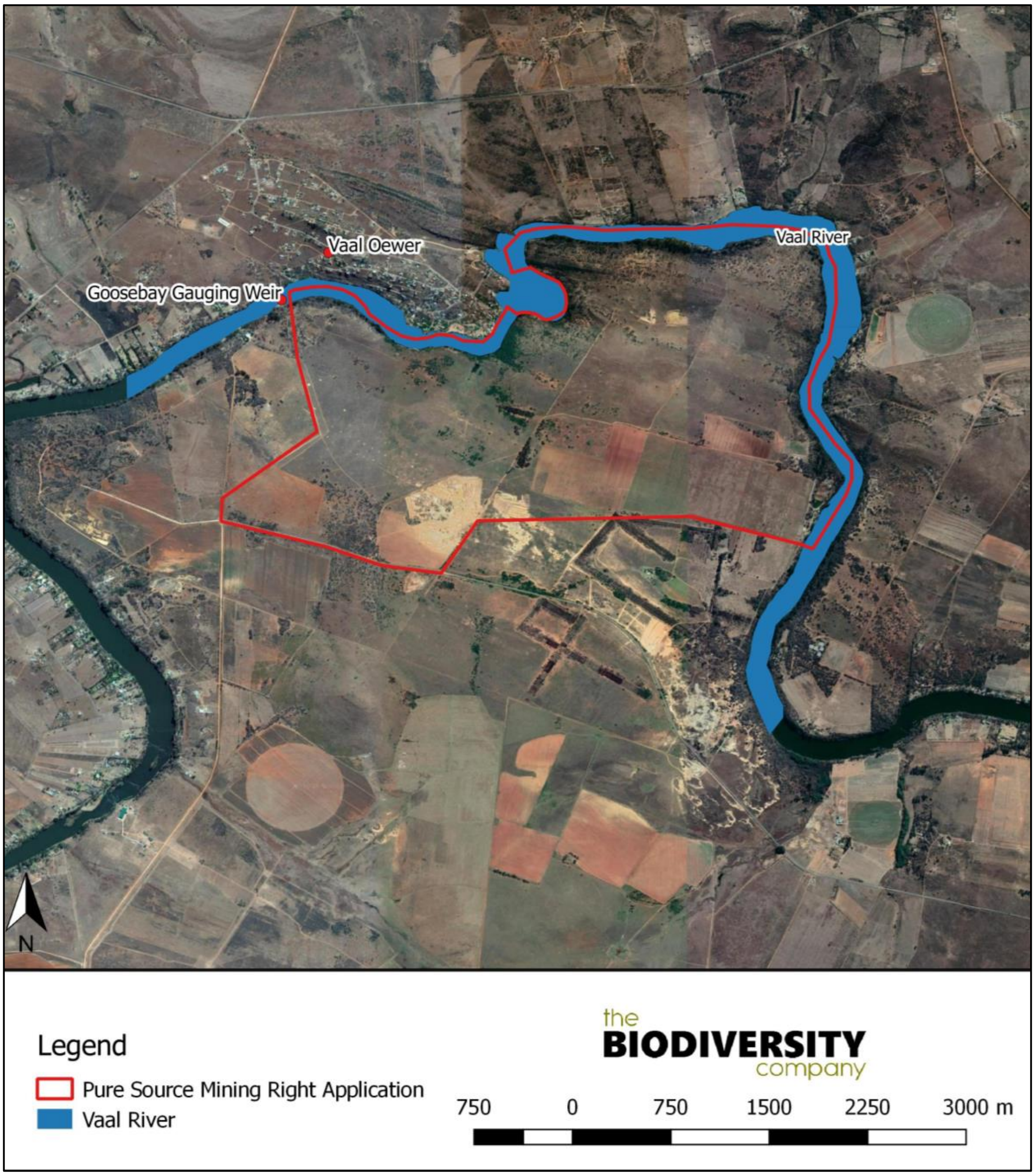

Figure 2-1: Location of the proposed project

3 Condition and Composition of the Aquatic Fauna

The project area considered in this assessment is located within the Southern Temperate Highveld Freshwater Ecoregion (Abel *et al*., 2008). In comparison to northern African river systems, the aquatic fauna of the considered ecoregion is "lacking in diversity" (Abel *et al*., 2008). This ecoregion is known to contain approximately 67-101 freshwater fish species of which 1-11 are known to be endemic (Figure 3-1). The ecoregion is known to have increased flow rates during the spring and summer seasons (September to March) and the indigenous fish species breed during this period.

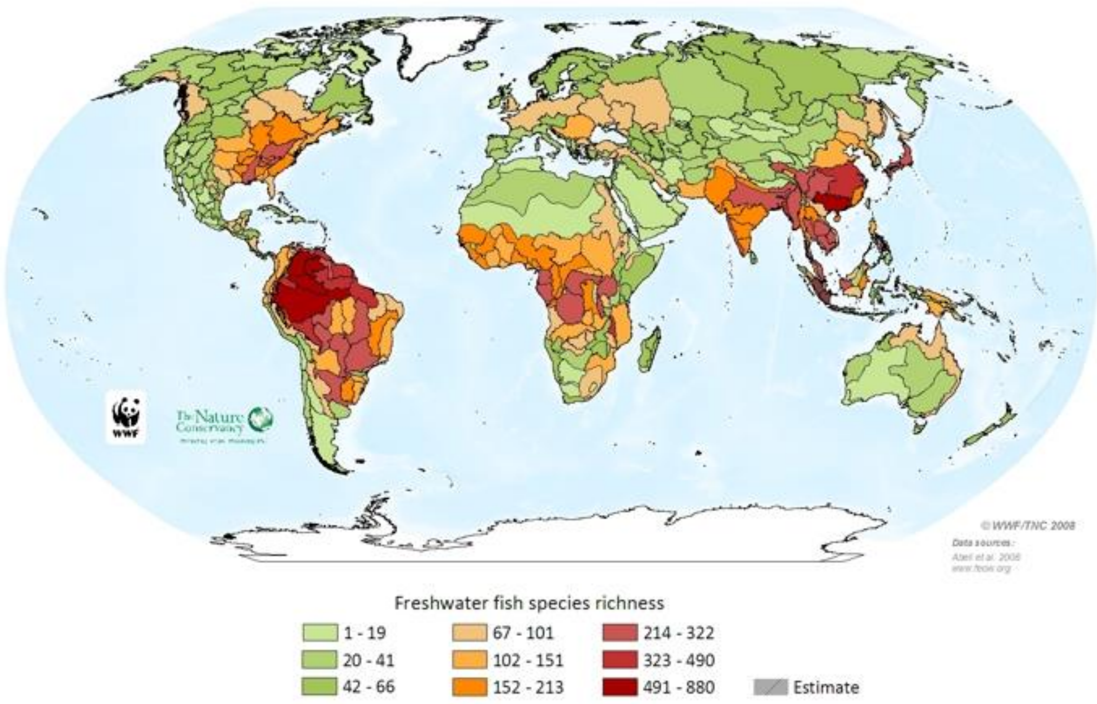

Figure 3-1: Freshwater Fish Species Richness of the Freshwater Ecoregions of the World (Abel et al., 2008)

Notable aquatic ecology in the Vaal River basin are the several endemic Cyprinid species such as *Labeo capensis* (Least Concern), *L. umbratus* (Least Concern), *Labeobarbus kimberleyensis* (Near Threatened), *Labeobarbus aeneus* (Least Concern) and the Rock Catlet, *Austroglanis sclateri* (Least Concern). In addition to the above species, *Enteromius cf. palidus* is undergoing systematic revision and likely represents several species. In the case of this assessment, *E. cf. palidus* is regarded as a listed species as a precautionary approach. The desktop ecological status of the C23B-01731 SQR is presented in Table 3-1.

Table 3-1: Desktop Ecological Status of the Vaal River within the C23B-01731 Sub Quaternary Reach (DWS, 2018)

Present Ecological Status	Largely Modified (class D)
Ecological Importance	Moderate
Ecological Sensitivity	High
Default Ecological Category	Largely Natural (Class B)

The desktop data for the Vaal River SQR considered in this assessment indicates that the PES of the watercourse is Largely Modified (class D). The central factors negatively effecting the PES were water quality deterioration, in the form of excessive sewerage input compounded by industrial, agricultural and urban runoff, habitat quality degradation, in the form of extensive flow regulation and riparian habitat modification. The ecological importance of the watercourse at a desktop level was determined to be moderate. The moderate rated level of importance can be attributed to the wide distribution of aquatic fauna throughout the Orange-Vaal River Basins. The ecological sensitivity was derived to be high. The presence of flow and water quality sensitive taxa renders the fauna sensitive to changes to the physical components of the watercourse. The default ecological category was rated as Largely Natural (class B). Management of landuse must be completed in a manner which aims to improve the PES class of the watercourse. However, the extensive and permanent nature of the existing impacts renders the management of the watercourse to this level implausible. The default ecological category should therefore be revised.

3.1 Resource Quality Objectives

The resource quality objectives for the considered river reach are provided in Table 3-2.

Table 3-2: Resource quality objectives for river water quality in the Vaal River (RSA Government, 2016)

IUA	RQO	Numerical Limits
UM: Vaal River reach from Vaal Dam to C23L	Instream habitat must be in moderately modified or better condition to support the ecosystem. Water hyacinth should be at levels that do not lower instream habitat conditions to less than moderately modified. Instream biota must be in a moderately modified or better condition. The requirement of fish species of ecological importance should be provided for. Flows must be moderately modified or better condition. High flows must be sufficient to support ecosystem functions. <u>Water Quality:</u> The nutrient concentrations must be decreased for ecosystem condition and other users. Salt concentrations must be at levels that do not threaten the ecosystem function and are detrimental to fish species and are suitable for users. Pathogens must be at levels safe for human use (excluding direct consumption)	Instream Habitat Integrity category ≥ C (≥ 62) Fish ecological category: ≥ C (≥ 62) Macro-invertebrate ecological category: ≥ C (≥ 62) Instream ecostatus category ≥ C (≥ 62) Hydrological category ≥ C (≥ 62) Water Quality category: ≥ C (≥ 62) Riparian zone habitat integrity category ≥ C (≥ 62) Riparian ecostatus category ≥ C (≥ 62)

4 Methodology

Standard methods used in the River Ecosystem Monitoring Programme were used to determine the PES of the considered watercourse. The various sections provided below elaborate on the various methods/indexes which were applied for this study.

The survey was completed between the 10th and 12th of July 2018.

4.1 Water Quality

Water quality was measured *in situ* using a handheld calibrated Extech ExStik II meter. The constituents considered that were measured included: pH, conductivity (µS/cm), temperature (°C) and Dissolved Oxygen (DO) in mg/l.

4.2 Aquatic Habitat Integrity and Riparian Zone Delineation

The Intermediate Habitat Assessment Index (IHIA) as described in the Procedure for Rapid Determination of Resource Directed Measures for River Ecosystems (Section D), 1999 were used to define the ecological status of the river reach.

The area covered in this assessment included a 10 km reach of the Vaal River. This habitat assessment model compares current conditions with reference conditions that are expected to have been present.

The IHIA model was used to assess the integrity of the habitats from a riparian and instream perspective. The habitat integrity of a river refers to the maintenance of a balanced composition of physico-chemical and habitat characteristics on a temporal and spatial scale that are comparable to the characteristics of natural habitats of the region (Kleynhans, 1996). The criteria and ratings utilised in the assessment of habitat integrity in the current study are presented in Table 4-1 and Table 4-2.

Table 4-1: Criteria used in the assessment of habitat integrity (Kleynhans, 1996)

Criterion	Relevance
Water abstraction	Direct impact on habitat type, abundance and size. Also implicated in flow, bed, channel and water quality characteristics. Riparian vegetation may be influenced by a decrease in the supply of water.
Flow modification	Consequence of abstraction or regulation by impoundments. Changes in temporal and spatial characteristics of flow can have an impact on habitat attributes such as an increase in duration of low flow season, resulting in low availability of certain habitat types or water at the start of the breeding, flowering or growing season.
Bed modification	Regarded as the result of increased input of sediment from the catchment or a decrease in the ability of the river to transport sediment. Indirect indications of sedimentation are stream bank and catchment erosion. Purposeful alteration of the stream bed, e.g. the removal of rapids for navigation is also included.
Channel modification	May be the result of a change in flow, which may alter channel characteristics causing a change in marginal instream and riparian habitat. Purposeful channel modification to improve drainage is also included.
Water quality modification	Originates from point and diffuse point sources. Measured directly or alternatively agricultural activities, human settlements and industrial activities may indicate the likelihood of modification. Aggravated by a decrease in the volume of water during low or no flow conditions.
Inundation	Destruction of riffle, rapid and riparian zone habitat. Obstruction to the movement of aquatic fauna and influences water quality and the movement of sediments.
Exotic macrophytes	Alteration of habitat by obstruction of flow and may influence water quality. Dependent upon the species involved and scale of infestation.
Exotic aquatic fauna	The disturbance of the stream bottom during feeding may influence the water quality and increase turbidity. Dependent upon the species involved and their abundance.
Solid waste disposal	A direct anthropogenic impact which may alter habitat structurally. Also, a general indication of the misuse and mismanagement of the river.
Indigenous vegetation removal	Impairment of the buffer the vegetation forms to the movement of sediment and other catchment runoff products into the river. Refers to physical removal for farming, firewood and overgrazing.
Exotic vegetation encroachment	Excludes natural vegetation due to vigorous growth, causing bank instability and decreasing the buffering function of the riparian zone. Allochtonous organic matter input will also be changed. Riparian zone habitat diversity is also reduced.
Bank erosion	Decrease in bank stability will cause sedimentation and possible collapse of the river bank resulting in a loss or modification of both instream and riparian habitats. Increased erosion can be the result of natural vegetation removal, overgrazing or exotic vegetation encroachment.

Table 4-2: Descriptions used for the ratings of the various habitat criteria

Impact Category	Description	Score
None	No discernible impact or the modification is located in such a way that it has no impact on habitat quality, diversity, size and variability.	0
Small	The modification is limited to very few localities and the impact on habitat quality, diversity, size and variability are also very small.	1-5
Moderate	The modifications are present at a small number of localities and the impact on habitat quality, diversity, size and variability are also limited.	6-10
Large	The modification is generally present with a clearly detrimental impact on habitat quality, diversity, size and variability. Large areas are, however, not influenced.	11-15
Serious	The modification is frequently present and the habitat quality, diversity, size and variability in almost the whole of the defined area are affected. Only small areas are not influenced.	16-20
Critical	The modification is present overall with a high intensity. The habitat quality, diversity, size and variability in almost the whole of the defined section are influenced detrimentally.	21-25

The riparian delineation was completed according to Department of Water Affairs and Forestry (DWAF, 2005). Typical riparian cross sections and structures are provided in Figure 4-1. Indicators such as topography and vegetation were the primary indicators used to define the riparian zone. One metre contour data obtained from topography spatial data was also utilised to support the infield assessment.

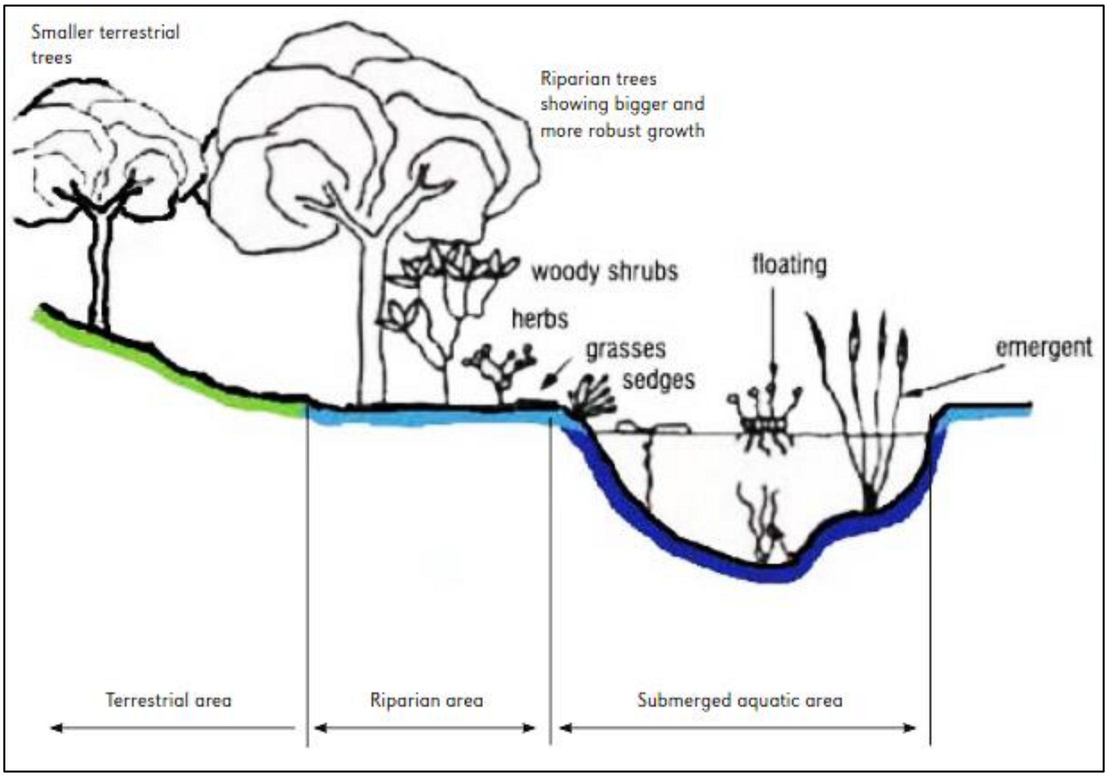

Figure 4-1: Riparian Habitat Delineations (DWAF, 2005)

4.3 Aquatic Macroinvertebrate Assessment

Macroinvertebrate assemblages are good indicators of localised conditions because many benthic macroinvertebrates have limited migration patterns or a sessile mode of life. They are particularly well-suited for assessing site-specific impacts (upstream and downstream studies)

(Barbour *et al.,* 1999). Benthic macroinvertebrate assemblages are made up of species that constitute a broad range of trophic levels and pollution tolerances, thus providing strong information for interpreting cumulative effects (Barbour *et al.,* 1999). The assessment and monitoring of benthic macroinvertebrate communities forms an integral part of the monitoring of the health of an aquatic ecosystem.

4.3.1 South African Scoring System

The South African Scoring System version 5 (SASS5) is the current index being used to assess the status of riverine macroinvertebrates in South Africa and was used for this study (Figure 4-3) .According to Dickens and Graham (2002), the index is based on the presence of aquatic invertebrate families and the perceived sensitivity to water quality changes of these families. Different families exhibit different sensitivities to pollution, these sensitivities range from highly tolerant families (e.g. Chironomidae) to highly sensitive families (e.g. Perlidae). SASS results are expressed both as an index score (SASS score) and the Average Score Per recorded Taxon (ASPT value).

Sampled invertebrates were identified using the “Aquatic Invertebrates of South African Rivers” Illustrations book, by Gerber and Gabriel (2002). Identification of organisms was made to family level (Thirion *et al.,* 1995; Dickens and Graham, 2002; Gerber and Gabriel, 2002).

All SASS5 and ASPT scores are compared with the SASS5 Data Interpretation Guidelines (Dallas, 2007) for the North Eastern Coastal Belt - upper ecoregion (Figure 4-2). This method seeks to develop biological bands depicting the various ecological states and is derived from data contained within the Rivers Database and supplemented with other data not yet in the database.

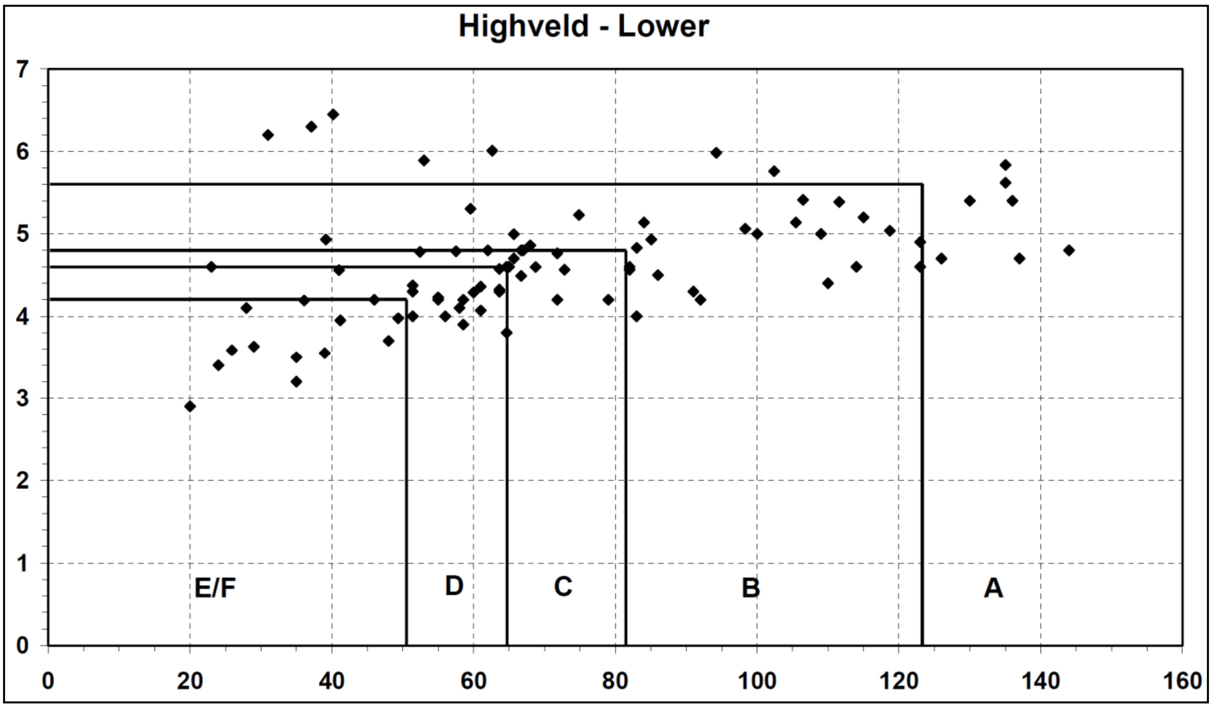

Figure 4-2: Biological Bands for the Highveld Lower Ecoregion (Dallas, 2007)

Figure 4-3: Standard kick and sweep invertebrate sampling in the Vaal River (July 2018)

The assessment of the watercourse was completed using standard invertebrate sampling methods which have been adapted to suit the nature of the considered watercourse. In the case of this study, the wide and deep nature of the Vaal River system has presented poor invertebrate biotopes. In order to compensate for this and provide a high level assessment of the current conditions, an adapted method which will provide an overall data set which can withstand robust statistical analysis was conducted in this study. This involved the selection of four sampling points which represented a single grouped site. Standard SASS5 sampling methods were completed at a total of four sites which represent the larger macro site.

4.3.2 Macroinvertebrate Response Assessment Index

The Macroinvertebrate Response Assessment Index (MIRAI) was used to provide a habitat-based cause-and-effect foundation to interpret the deviation of the aquatic invertebrate community from the calculated reference conditions for the SQR. This does not preclude the calculation of SASS5 scores if required (Thirion, 2007). The four major components of a stream system that determine productivity for aquatic macroinvertebrates are as follows:

- Flow regime;
- Physical habitat structure;
- Water quality;
- Energy inputs from the watershed; and
- Riparian vegetation assessment.

The results of the MIRAI will provide an indication of the current ecological category and therefore assist in the determination of the PES.

4.4 Fish Community Assessment

A standard qualitative fish assessment was completed for this study. Electrofishing techniques, fyke and cast netting methods were applied to determine the reach based fish community during the survey for comparative purposes and interpretation. The Fish Response Assessment Index will be applied for this study.

4.5 Present Ecological Status

Ecological classification refers to the determination and categorisation of the integrity of the various selected biophysical attributes of ecosystems compared to the natural or close to natural reference conditions (Kleynhans and Louw, 2007). For the purpose of this study ecological classifications have been determined for biophysical attributes for the associated water course. This was completed using the river ecoclassification manual by Kleynhans and Louw (2007).

4.6 Impact Assessment

The impact assessment methodology is guided by the requirements of the NEMA EIA Regulations (2014). The broad approach to the significance rating methodology is to determine the environmental risk (ER) by considering the consequence (C) of each impact (comprising Nature, Extent, Duration, Magnitude, and Reversibility) and relate this to the probability/likelihood (P) of the impact occurring. This determines the environmental risk. In addition other factors, including cumulative impacts, public concern, and potential for irreplaceable loss of resources, are used to determine a prioritisation factor (PF) which is applied to the ER to determine the overall significance (S).

Table 4-3: Description of Impact Categories

Value	Description
< -20	High Negative (i.e. where the impact must have an influence on the decision process to develop in the area)
-20 to -10	Medium Negative (i.e. where the impact could influence the decision to develop in the area)
0 to -10	Low Negative (i.e. where this impact would not have a direct influence on the decision to develop in the area)
0 to 10	Low Positive (I.e. where this impact would not have a direct influence on the decision to develop in the area)
10 to 20	Medium Positive (i.e. where the impact could influence the decision to develop in the area)
> 20	High Positive (i.e. where the impact must have an influence on the decision process to develop in the area)

5 Limitations

The following limitations form a component of this assessment:

- A single dry season survey was completed for this study, therefore temporal trends have not been considered;
- Water volumes to be abstracted and the location of the abstraction point from the Vaal River have not been defined, this has therefore not been included in this study;
- The decommissioning/closure phase activities for this project have already been granted environmental approval. Therefore, only activities whereby the rehabilitation of open cast areas and surface infrastructure were considered in this study.

- The survey completed for this study was completed during a period of excessive sewage discharge in the Vaal River. It is therefore likely that the ecological condition would be considerably worse than what is typically observed in the watercourse.
- The closure objective is to develop the farm portions as an eco-estate with residential and hospitality facilities on the banks of the Vaal River. The development of the eco-estate and associated facilities was not considered in this report.

6 Site Selection

To define the PES of the river reach for 2018 a total of 12 sampling points, making up three macro sites were selected. These sites were selected upstream, adjacent and immediately downstream of the proposed project area. During the July 2018 survey, it was found that there was insufficient habitat to support an effective monitoring study at the selected downstream sites (DR1-DR4). The location of the various sampling points in presented in Table 6-1 and Figure 6-1.

Table 6-1: Photos, co-ordinates and descriptions for the riverine and wetland sites sampled (July 2018 low flow)

Upstream Site	Upstream	Downstream
Low Flow		
Adjacent Site	**Upstream**	**Downstream**
Low Flow		

Downstream Site	Upstream	Downstream
Low Flow		

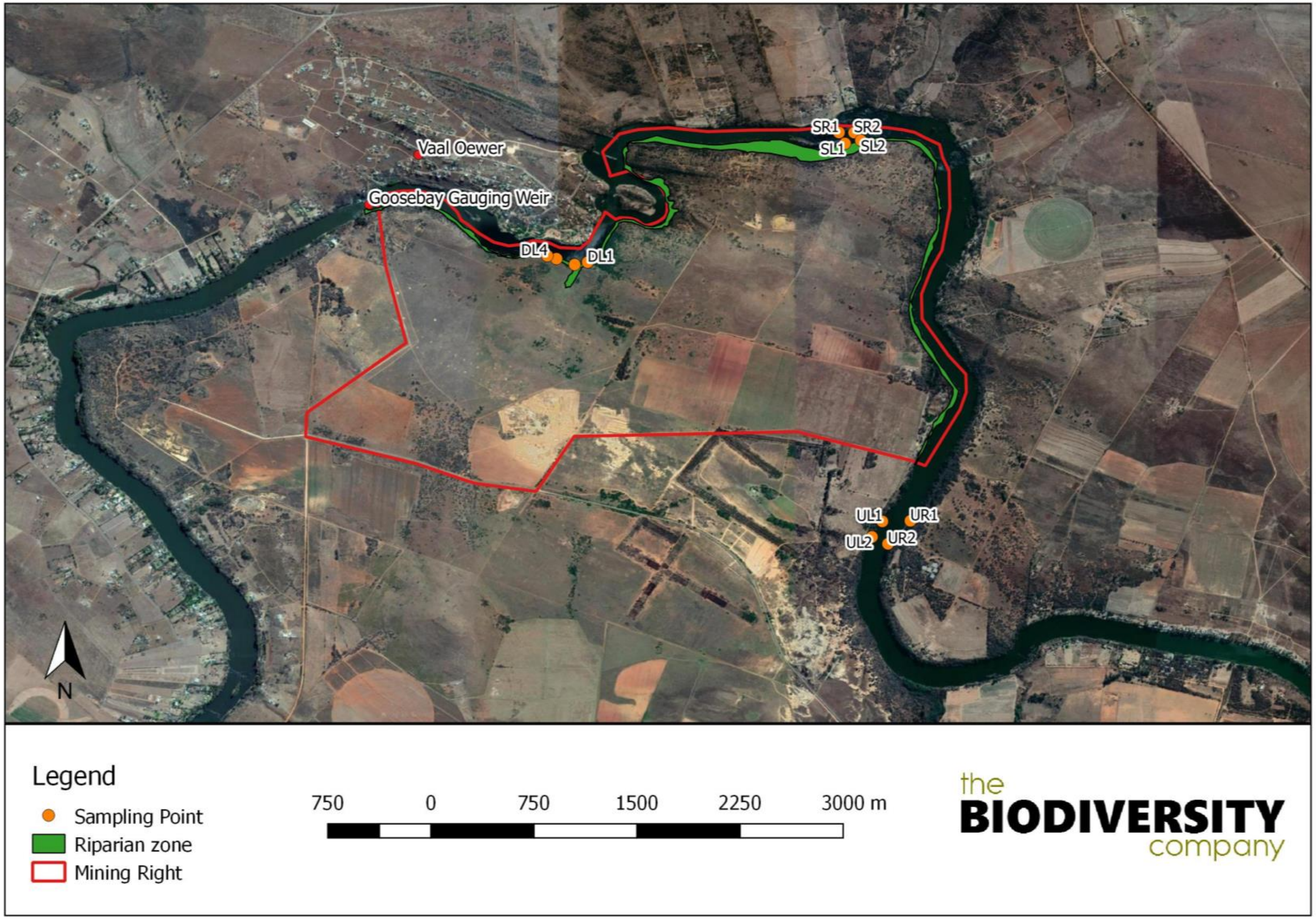

Figure 6-1: Location of the various selected sampling points in relation to the mining right area

7 Results

7.1 Water Quality

In situ water quality analysis was conducted at all study sites during the surveys. These results are important to assist in the interpretation of biological results due to the direct influence water quality has on aquatic life forms. The results of the surveys are presented in Table 7-1. Results were compared to the Target Water Quality Range (TWQR) for aquatic ecosystems (DWS, 1996). The chemical sample data was obtained from Hydrospatial (2019) at sites located upstream and downstream of the project area, these results are presented in

Table 7-2.

Table 7-1: In situ water quality results for the low flow survey (July 2018)

Site	pH	Conductivity (µS/cm)	DO (mg/l)	Temperature (°C)
TWQR*	**6.0-9.0**	**-**	**>5.00**	**5-30**
		Site 1		
UL1	8.8	792	4.3	15
UL2	8.8	788	4.3	13
UR1	9.0	740	4.2	12
UR2	8.9	793	4.3	13
Mean and SEM	8.8±0.1	778±12.8	4.2±0.2	13±0.6
		Site 2		
AL1	8.5	774	4.5	13
AL2	8.4	760	4.6	13
AR1	8.6	775	4.5	14
AR2	8.0	781	4.8	14
Mean and SEM	8.3±0.1	772±4.44	4.6±0.1	13±0.2
		Site 3		
DR1	8.5	759	3.0	14
DR2	8.7	800	3.8	14
DR3	9.0	785	4.9	15
DR4	9.0	753	4.1	14
Mean and SEM	8.8±0.1	774±11.0	**3.9**±0.4	14±0.3

Table 7-2: Chemical water quality results for the low flow survey (August 2018)

Constituent	Unit	Upstream Mining Right	Downstream Mining Right
pH – Value at 25°C	pH Units	8.04	8.11
Electrical Conductivity (EC) at 25°C	mS/m	79.9	79.3
Total Dissolved Solids (TDS) at 180°C	mg/l	493	488
Total Suspended Solids (TSS)	mg/l	21	15
Turbidity	NTU	14.7	11.9
Total Alkalinity as CaCO3	mg/l	149	146
Total Hardness as CaCO3	mg/l	260	255
Chloride as Cl	mg/l	45.5	45.6
Sulphate as SO_4	mg/l	175	174
Fluoride as F	mg/l	0.27	0.286
Nitrate as N	mg/l	3.87	4.41
Ammonium as N	mg/l	1.48	0.875
Orthophosphate as P	mg/l	0.262	0.274
Sodium as Na	mg/l	62.7	61
Potassium as K	mg/l	10	9.78
Magnesium as Mg	mg/l	23.4	23
Aluminium as Al	mg/l	<0.002	<0.002
Cadmium as Cd	mg/l	<0.002	<0.002
Total Chromium as Cr	mg/l	<0.003	<0.003
Copper as Cu	mg/l	<0.002	<0.002
Iron as Fe	mg/l	<0.004	<0.004
Lead as Pb	mg/l	<0.004	<0.004
Manganese as Mn	mg/l	0.027	<0.001
Nickel as Ni	mg/l	0.002	<0.002
Cobalt as Co	mg/l	<0.003	<0.003
Zinc as Zn	mg/l	0.008	0.01

The results of the water quality analyses indicate largely uniform conditions upstream, adjacent and downstream of the project area with limited fluctuations (Standard Error Mean) observed between the sampling points. The pH of the Vaal River was determined to be basic

(>7). Dissolved solid content was determined to be elevated (>400 µS/cm) above what would be expected in a natural system.

Nutrient concentrations were determined to be at eutrophic levels, with nitrates observed above the 2.5 mg/l threshold (2.5-10 mg/l, DWAF, 1996). It is noted that the analysis did not include the nitrite and ammonia concentrations in the total interpretation and therefore it is anticipated that the level of eutrophication is likely greater. The incidence of eutrophication was confirmed through the direct observation of extensive algal matts covering rocks and foam during the survey (Figure 7-1 and Figure 7-2).

Figure 7-1: Algae observed in the Vaal River (Adjacent Site, July 2018)

Figure 7-2: Foam observed in the Vaal River as a resultant effect of sewage discharge (Downstream, July 2018)

Ammonia concentrations determined during the August 2018 surface water assessment indicated levels of 1.48-0.88 mg/l. Using the interpretation guidelines stipulated in DWAF (1996), the concentrations of un-ionised ammonia was observed at an estimated value of 0.074 and 0.05 mg/l for the respective sites. At a pH level of approximately 8.0, the New Zealand and Australian governments recommend a level of >30 µg/l (0.03 mg/l) to protect 95% of freshwater species. Considering this, the current levels of un-ionised ammonia observed in the Vaal River during the survey were above the threshold effect concentrations and would therefore exert an acutely toxic effect to freshwater organisms. The source of the eutrophication and excessively high ammonia levels were attributed to extensive sewage discharge in the Vaal River system upstream of the project area. In addition to high concentrations of nitrogen, elevated levels of orthophosphate were also observed to be within the Vaal River and were above the hypertrophic conditions of >250 µg/l as depicted in DWAF (1996).

Further and corroborating evidence for the eutrophic conditions were the lowered levels of dissolved oxygen measured at all sites during the survey. These low levels of oxygen have likely been caused as a direct result of the higher chemical and biological oxygen demand as a result of the presence of excessive nutrients.

Aside for the acutely toxic concentrations of un-ionised ammonia, high levels of nitrates and phosphate, the levels of metals were determined to be below threshold effect concentrations. Overall, the water quality of the Vaal River during the survey period can be concluded as acutely toxic.

7.2 Habitat Quality and Riparian Delineation

The results of the IHIA for the Vaal River reach assessed during the July 2018 survey are presented below (Table 7-3).

Table 7-3: IHIA for the Vaal River reach (July 2018)

Instream	Average	Score
Water abstraction	10	5,6
Flow modification	20	10
Bed modification	15	7,8
Channel modification	15	7,8
Water quality	20	11
Inundation	10	4
Exotic macrophytes	15	5,4
Exotic fauna	15	4,8
Solid waste disposal	10	2,4
Total Instream		**40**
Category		**class D**
Riparian	**Average**	**Score**
Indigenous vegetation removal	15	7,8
Exotic vegetation encroachment	17	8,4
Bank erosion	5	2,8
Channel modification	10	4,8
Water abstraction	15	7,8
Inundation	10	4,4
Flow modification	20	9,6
Water quality	20	10
Total Riparian		**44**
Category		**class D**

The results of the IHIA for the Vaal River reach considered in this study indicated largely modified instream and riparian habitat. The instream habitat of the Vaal River has been extensively modified through the development of instream barriers and water transfers which have ultimately resulted in the direct modification of the natural flows in the Vaal River system. Although the watercourse largely emulates natural hydrological patterns, artificial releases from the Vaal barrage have ultimately modified natural flow patterns and subsequently negatively effected the instream condition of the watercourse. As noted in the water quality component of this assessment, significant water quality impacts were observed during the survey, this has acted to cumulatively reduce the instream habitat condition of the river reach considered. The incidence of the Goosebay gauging weir has resulted in the inundation of aquatic habitats in the project area and has further altered natural instream habitats (Figure 7-3).

Figure 7-3: Goosebay gauging weir (Hydrospatial, 2019)

Riparian habitat was extensively modified through the presence of alien invasive species (Figure 7-3 and Figure 7-5) and this was compounded by the complete loss of riparian habitat within the Goosebay way inundation zone which has significantly altered riparian habitats (Figure 7-6).

Figure 7-4: Marginal habitat modification and the presence of alien vegetation species Myriophyllum aquaticum (July 2018)

Figure 7-5: Riparian habitat modification showing extent of alien invasive plant species, Eucalyptus globulus (July 2018)

Figure 7-6: Extensive riparian and marginal habitat modification through direct modification (July 2018)

7.2.1 Riparian Delineation

The riparian assessment was completed during the winter period with limited emergent vegetation available for the confirmation of the riparian area. The macro-channel of the Vaal River system was delineated via desktop data and confirmed in the field. The riparian zone of the Vaal River within the project area was confined to the macro-channel with the delineation provided in Figure 7-8. The marginal and lower riparian zones of the Vaal River are extensively populated with alien vegetation, including *Eucalyptus globulus* and *Salix babylonica* in the lower zone and *Eichhornia crassipes, Myriophyllum aquaticum* and *Nasturtium officinale* in the marginal and instream zone.

Figure 7-7: Typical Riparian Vegetation along the Vaal River within the Project Area (July 2018)

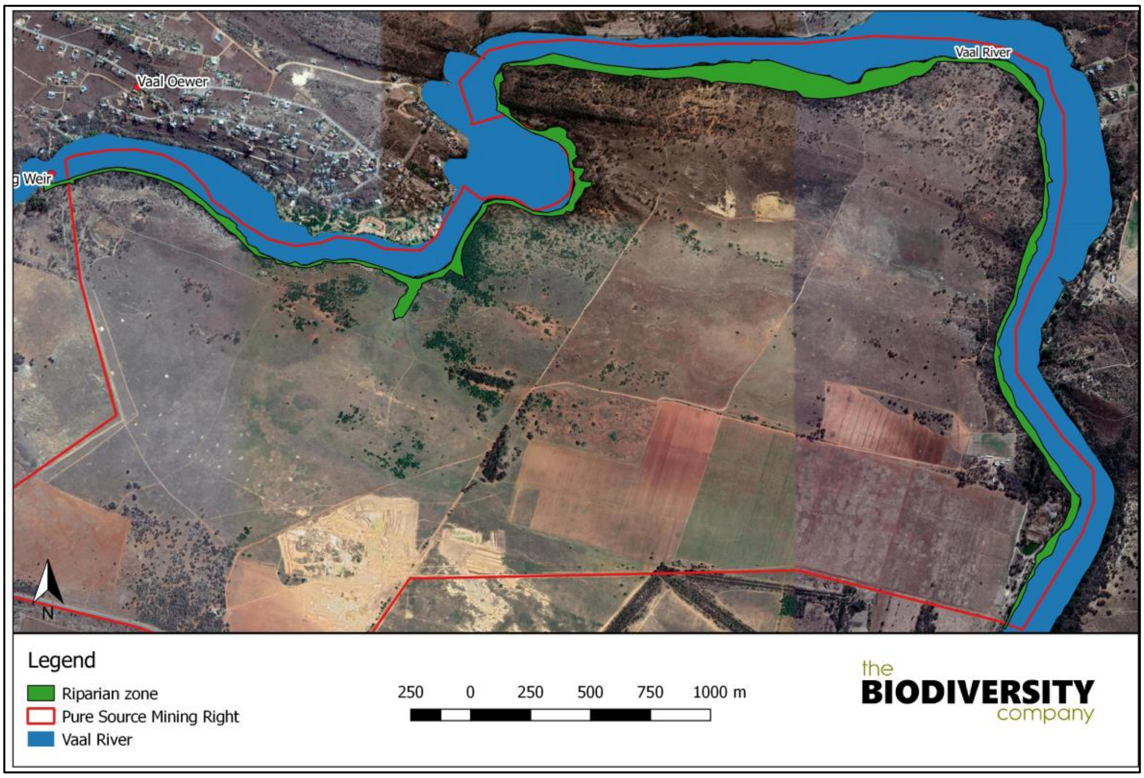

Figure 7-8: Riparian Zone Delineation for the proposed Pure Source Mine

7.3 Aquatic Macroinvertebrates

An indication of the available biotopes is presented in Table 7-4. A rating system of 0 to 5 was applied, 0 being not available, while 5 indicates an abundant and diverse biotope. The river reach assessed in this study were classed as lower foothills (class E). The weightings for the biotope ratings are adjusted accordingly.

Table 7-4: Biotope availability at the selected sampling sites (Rating 0-5)

Biotope	Weight	UL1	UL2	UR1	UR2	AR1	AR2	AL1	AL2	DL1	DL2	DL3	DL4
Stones in current (SIC)	5	0	0	0	0	2,5	4	4	8	0	0	0	0
Stones out of current (SOOC)	5	1,5	0	0	0	2,5	1	3	6	0	0	0	0
Bedrock	3	3	0	0	0	3,5	4	2	1,2	0	0	2	1
Aquatic vegetation	10	0	0	1	0	2	3	3	3	1	1,5	0	0
Marginal vegetation in current	5	0	0	0	0	3,5	2	2	2	0	0	0	0
Marginal vegetation out of current	10	1	2	2	2	3	3	4	4	2,5	3,5	1	2
Gravel	4	0,5	0	0	0	1	1	2	1,6	0	0	0	0
Sand	2	0	0	0	0	2	3	2	0,8	0	2,5	1	0
Mud	1	1	2	3	3	2	3	3	0,6	3	1	2	2
Biotope Score (X / 45)		7	4	6	5	22	24	25	22	6,5	8,5	6	5
Weighted Biotope Score (%)		6,4	2,4	3,6	2,6	22	23	27	20	4,1	6,2	3.0	3.0
Biotope Category (Tate and Husted, 2015)		F	F	F	F	C	C	B	D	F	F	F	F

The invertebrate habitat observed during the sites ranged from poor at in the slow flowing deep reaches such as the upstream and downstream sampling sites, to fair at the sites in the flowing cobbled areas at the adjacent site.

Within the upstream and downstream sampling points, biotopes available were typically marginal and aquatic vegetation as depicted in Figure 7-9, and muddy substrates with an absence of fast/moderate flowing water and stone biotopes. Within the Adjacent Site, the invertebrate biotopes were well represented and would not be a limiting factor for aquatic biodiversity (Figure 7-10).

Figure 7-9: Typical vegetation biotopes in the Vaal River (July 2018)

Figure 7-10: Typical instream habitat diversity in the Vaal River (July 2018)

The aquatic macroinvertebrate results for the 2018 survey are presented in Table 7-5.

Table 7-5: Macroinvertebrate assessment results recorded during the 2018 study

Site	SASS Score	No. of Taxa	ASPT*	Category (Dallas, 2007)
UL1	53	13	4,1	**D**
UL2	48	13	3,7	**E/F**
UR1	31	8	3,9	**E/F**
UR2	26	8	3,3	**E/F**
Mean and SEM	39.5±6.5	-	3.7±0.2	**E/F**
AR1	61	13	4,7	**D**
AR2	49	11	4,5	**E/F**
AL1	54	13	4,2	**D**
AL2	69	13	5,3	**C**
Mean and SEM	58.2±4.3	-	4.6±0.2	**D**
DL1	42	11	3.8	**E/F**
DL2	42	11	3.8	**E/F**
DL3	49	12	4,1	**E/F**
DL4	64	15	4,3	**C**
Mean and SEM	49.2±5.1	-	4.0±0.1	**E/F**

The results of the SASS5 assessment indicate SASS5 score variations between 26 at UR2 to 69 at AL2. The calculated ASPT values obtained ranged from 3.3 at UR2 to 5.3 at AL2. Overall ecological classes derived ranged from class C (moderately modified) to class E/F (seriously modified). Overall the invertebrate diversity ranged according to the available habitats, showing an increase in diversity at the Adjacent Site. Overall the mean SASS5 scores obtained were lowest at the upstream site but did not differ significantly at the downstream sampling point which had similar habitat types. The mean SASS5 and ASPT values resulted in classification of the up and downstream sites as seriously modified (class E/F) whilst the Adjacent Site was derived to be largely modified. The results of the MIRAI for the two considered river reaches are provided in Table 7-6.

Table 7-6: MIRAI for the Vaal River (July 2018)

Invertebrate Metric Group	Score Calculated
Flow modification	34.9
Habitat	44.6
Water Quality	37.3
Ecological Score	**38**
Invertebrate Category	**class D/E**

The MIRAI classification for the Vaal River indicated largely/seriously modified conditions (class D/E). The primary driver was derived to be flow modification. However, given the level of degradation in water quality observed it is anticipated that the driver factors are skewed.

Several key taxa were noted to be absent or significantly reduced in frequency during the survey. These included various families from the orders Hemiptera, Coeleoptera, Ephemeroptera, Trichoptera and Odonata. No taxa considered to be sensitive to water quality were observed during the survey. Taxa observed during the survey were either air-breathing or had reduced exposure to the open water via lifecycle adaptations, such as the presence of Hydrophyschidae in cases within microhabitats, thus reducing their exposure.

Overall, a significant proportion of invertebrate taxa were absent from the assessed watercourse, corroborating the acute toxicity levels as depicted in the water quality assessment.

7.4 Fish Community

The sampling effort applied at each of the macro sampling points is provided in Table 7-7. The results of the qualitative fish assessment are depicted in Table 7-8, with photographs of the observed species depicted in Table 7-9.

Table 7-7: Fish species collected/observed during the July 2018 survey

Site	Method Applied	Effort
Upstream Site	Electroshocking, Cast Netting, Dip Netting, Minnow Trap and Fyke Net	16 Hours
Adjacent Site	Electroshocking, Cast Netting, Dip Netting, Minnow Trap and Fyke Net	10 Hours
Downstream Site	Electroshocking, Cast Netting, Dip Netting	4 Hours

Table 7-8: Fish species collected/observed during the July 2018 survey

Fish Species/Site	Upstream	Adjacent	Downstream	FROC
Austroglanis sclateri	0	0	0	0,0
Clarias gariepinus	1	1	1	5,0
Enteromius anoplus	0	1	0	1,7
Enteromius cf. pallidus	0	0	0	0,0
Enteromius paludinosus	0	1	0	1,7

Fish Species/Site	Upstream	Adjacent	Downstream	FROC
Labeo capensis	1	1	0	3,3
Labeo umbratus	1	1	0	3,3
Labeobarbus aeneus	0	1	0	1,7
Labeobarbus kimberleyensis	0	0	0	0,0
Pseudocrenilabrus philander	1	1	1	5,0
Tilapia sparrmanii	1	1	1	5,0
*Cyprinus carpio**	1	1	1	5,0
*Gambusia affinis**	1	1	1	5,0

Table 7-9: Selected photographs of fish species collected during the 2018 study

Species	Photograph
Clarias gariepinus	
Enteromius anoplus	
Enteromius paludinosus	
Labeo umbratus	

Species	Photograph
Labeo capensis	
Labeobarbus aeneus	
Pseudocrenilabrus philander	
Tilapia sparrmanii	
*Cyprinus carpio**	

Despite the presence of acutely toxic conditions, a total of 10 fish species were observed during the survey. It is noted that the assessment was qualitative and therefore the presence of a single individual would indicate presence. However, it was noted during the survey that fish abundance was reduced, whereby extensive sampling would result in the observation of a single individual of a species. This was the case for *Enteromius anoplus, E. paludinosus Labeobarbus aeneus, Labeo umbratus* and *Labeo capensis*, the conclusion drawn in this case is that toxic water quality had reduced the abundance and biomass within the fish community. The most abundant fish observed during the survey were *Cyprinus carpio (*Figure 7-11*)*, a species known to be resistant to ammonia toxicity (USEPA, 2013).

Figure 7-11: Alien taxa Cyprinus carpio observed in July 2018 throughout the project area

The overall results indicate that two listed taxa were absent from the sampling effort conducted during this study. However, anecdotal evidence suggests the presence of *Labeobarbus kimberlyensis* in the river reach directly associated with the proposed project. Considering this, the taxa is regarded as present in the watercourse. The results of the FRAI are provided in Table 7-10.

Table 7-10: Fish Response Assessment Index (July 2018)

Species	Reference FROC	2018 FROC
Austroglanis sclateri	5.0	0,0
Clarias gariepinus	5.0	5,0
Enteromius anoplus	5.0	1,7
Enteromius cf. pallidus	5.0	0,0
Enteromius paludinosus	5.0	1,7
Labeo capensis	3.0	3,3
Labeo umbratus	5.0	3,3
Labeobarbus aeneus	3	1,7
Labeobarbus kimberleyensis	3	0,0
Pseudocrenilabrus philander	5.0	5,0
Tilapia sparrmanii	5.0	5,0
FRAI% (Automated)		53.7
EC FRAI		class D
FRAI: Fish Response Assessment Index **FROC: Frequency of Occurence**		

As noted in the FRAI results, a largely modified (class D) fish community was present during the sampling activities for the July 2018 survey. A number of taxa had reduced overall Frequencies of Occurrence (FROC) or were completely absent from the survey. The impacted fish community can be attributed to impacted instream habitat conditions compounded by poor water quality.

7.5 Present Ecological Status

The results for the reach-based PES assessment of the reach of the Vaal River is presented in Table 7-11.

Table 7-11: PES of the Vaal River from the 2018 study period

Aspect assessed	Ecological Score	Ecological Category
Instream Ecological Category	40	Class D
Riparian Ecological Category	44	Class D
Aquatic Invertebrate Ecological Category	38	Class D/E
Fish Community Ecological Category	53	Class D\E
Ecostatus	**Class D**	

The results of the PES assessment derived a largely/seriously modified ecological category (class D/E) for the Vaal River reach. This PES is below the attainable ecological management class (class B). The modified status can be attributed to persistent cumulative modifications within the reach, including a myriad of instream impoundments and acutely toxic water quality, resulting in significant instream condition modification.

As can be observed the overall classification, none of the current ecological classifications are meeting the gazetted Resource Quality Objectives (Table 3-2).

8 Aquatic Ecological Important and Sensitivity (No-Go Area's)

The results of the EIS for the watercourse in the project area are presented in Table 8-1.

Table 8-1: Ecological Importance and Sensitivity Ratings for the Watercourses in the Project area *located in the Vaal Water Management Area*

Biological Determinants		
Determinant	**Rating**	**Comment**
Rare and endangered biota	3	More than one taxon rare or endangered at a local scale
Unique biota	2	The aquatic fauna is distributed widely throughout the Vaal WMA
Intolerant biota	2	Flow intolerant taxa make up the majority of the aquatic fauna
Species richness	2	On a local scale the species richness is moderate
Habitat Determinants		
Diversity of aquatic habitat	2	Impacted system, most of which are reversible impacts associated with water quality deterioration
Refuge value of habitat types	2	Important area for fish species between Bloemhof Damand Vaal Barrage.
Sensitivity of habitat to flow modification	1	Flow is heavily modified, but organisms are still sensitive.

Sensitivity to flow related water quality changes	2	A loss of flow will further concentrate the current pollutants making the watercourse sensitive to flow related water quality changes
Migration route corridor for instream and riparian biota	1	This portion of the Vaal River would be regarded as a migratory corridor for fish migrating upstream.
National parks and wilderness areas	1	NFEPA listing with no nature reserves associated with the watercourses.
Mean	**1.8**	
EIS class	**Moderate**	

The results of the EIS assessment derived a moderate EIS for the Vaal River reach assessed.

8.1 Spatial Sensitivity Assessment

The layout of sensitive environments in respect to aquatic ecology is presented in Figure 9-1, it is noted that this layout should be considered with the hydrology report as well as the wetland ecology report. It is noted that a 100 m buffer has been presented in these figures based on the delineated watercourses in the project area. As observed, limited direct impacts to riverine habitat can be anticipated as a result of the proposed project.

9 Potential Impacts from the Proposed Project

9.1 The Current Scenario/ Initial Impact

The baseline assessment conducted in this study indicated large scale, catchment wide cumulative impacts which have rendered the riverine ecosystems in the project area seriously modified. It is anticipated that there will be a further deterioration in the water quality in the Vaal River. This will further exacerbate the current poor water quality in the river reaches which would likely further degrade the PES of the river system. In conclusion, the no-go scenario indicates further degradation of the assessed watercourse considered in this study.

9.2 The Proposed Project / Additional Impact

9.2.1 Proposed Activities

Mining under the Mining Right will be undertaken by a “truck and shovel” method utilising suitably sized diesel driven equipment. A 363.5 ha area will be demarcated for phased open pit mining and associated infrastructure. The area containing the sand deposit will be mined in portions of on average 6.8 ha each year (in most years, however, the area to be mined will not exceed 5 ha), with continuous roll-over rehabilitation. The area containing the aggregate resource will be mined in portions of on average 4.6 ha, per year (in most years, however, the area to be mined will not exceed 4 ha). The planned open pit mine will comprise three distinct areas for the silica sand (main pit, north pit and east pit) and four areas for the aggregate (northern pit, central pit, south eastern pit and south western pit). Each area considers an estimated maximum depth of 12 m but may exceed a depth of 12 m in certain areas. The entire application area could have potential for diamond bearing gravels. The anticipated life of the mine is 30 years. An overview of the mining method for the three commodities is described below.

Prior to commencement of sand mining, topsoil will be removed from the area demarcated for mining and stockpiled next to the pit for the purpose of rehabilitation. The sand will be mined in benches and reject material will be backfilled into the void as mining advances. Opencast benches will be established with a maximum height between 1.5 m to 3 m. Sand will either be screened in the pit or transported by truck or conveyer to the washing plant.

In the absence of sand, topsoil will be stripped to expose aggregate and stockpiled prior to excavating the aggregate. The excavated aggregate will be crushed in the pit by a mobile crusher and reject material will be backfilled into the void as mining advances. A total sand resource of 21 910 291 million m3 is estimated for the application area. The average depth of the sand deposit is 10.64 m. All of the outcropping and underlying sediments on this property could be used for aggregate. From test pits dug on the application area, the total volume of fresh aggregate to an average depth 6.98 m is calculated at 9 565 043 million m3 and approximately 7.67 m for oxidised aggregate with a total volume of 10 498 882 million m3. Silica sand is present on the Farm Woodlands and has been mined historically on the property. The types of sand present on Portions 1, 3 and the Remaining Extent of the Farm Woodlands 407 vary from light yellow plaster, dark yellow plaster, white plaster, grey plaster, building to red sand. Oxidised aggregate is suitable for decorative purposes, but not for use in the civil construction industry. The anticipated life of the mine is 30 years with an option to renew if the mining programme is not yet completed. The closure objective is to develop the farm portions as an eco-estate with residential and hospitality facilities on the banks of the Vaal River. The application area is currently utilised as a game farm and this will continue to remain the primary land use with other agricultural activities such as crop production.

The layout of the proposed project with the delineated riparian zones and 100 m buffer are presented in Figure 9-1. As can be seen in the figure, the layout of the proposed project is largely outside the delineated riparian areas and buffer zones. Considering this, no direct impacts to the riparian habitat of the Vaal River can be anticipated. However, several indirect impacts can be expected as a result of the proposed project.

9.2.2 Primary Impacts

The proposed project activities were determined to have two primary potential impacts to the associated riverine ecology. The first was determined to be related to the conditions within the physical make-up of the considered river reaches. This includes the riverine substrates, banks, riparian vegetation and water column. These physical components of a water course determine the quality of the aquatic habitats. Therefore, modification of these physical components would result in a habitat quality impact. The second impact was determined to be related to the chemical properties of water. Considering aquatic biota have requirements for habitat, as well as sensitivity to changes in water chemistry, a change to water quality is anticipated to have negative impacts to local aquatic biota.

The central anticipated impacts associated with the proposed project are related to increased suspended solids and sedimentation. The proposed open pit mining methods, without mitigation, will strip vegetation resulting in increased runoff velocities and subsequent erosion, sedimentation and increased suspended solids. This may have an impact to aquatic habitat and to fine sediment sensitive instream aquatic ecology. The proposed project will alter the topography of the catchment feeding the C23B-01731 SQR which will result in the alteration of the hydrology within the considered river reach.

The weathered nature of the commodities being mined will likely result in the negligible leaching of water contaminants. Nonetheless, it can be anticipated that salt content within the mineral resources will become exposed to further weathering. This subsequently may result in the increase of dissolved solid content downstream of the proposed project should runoff/seepage from the mineral resources enter into the watercourse. It is therefore recommended that a leachate test is completed for the mineral resource to define the potential contaminants which may emanate from this source.

The proposed project will utilise water from the Vaal River for the processing of the mineral resources. The utilisation of water will inevitably have impacts to the immediate local hydrology and this may subsequently have a negative impact on local instream biology. The volumes of water which are proposed to be extracted have not been provided and therefore the significance of this impact cannot be defined, and the risk has not been included in this study.

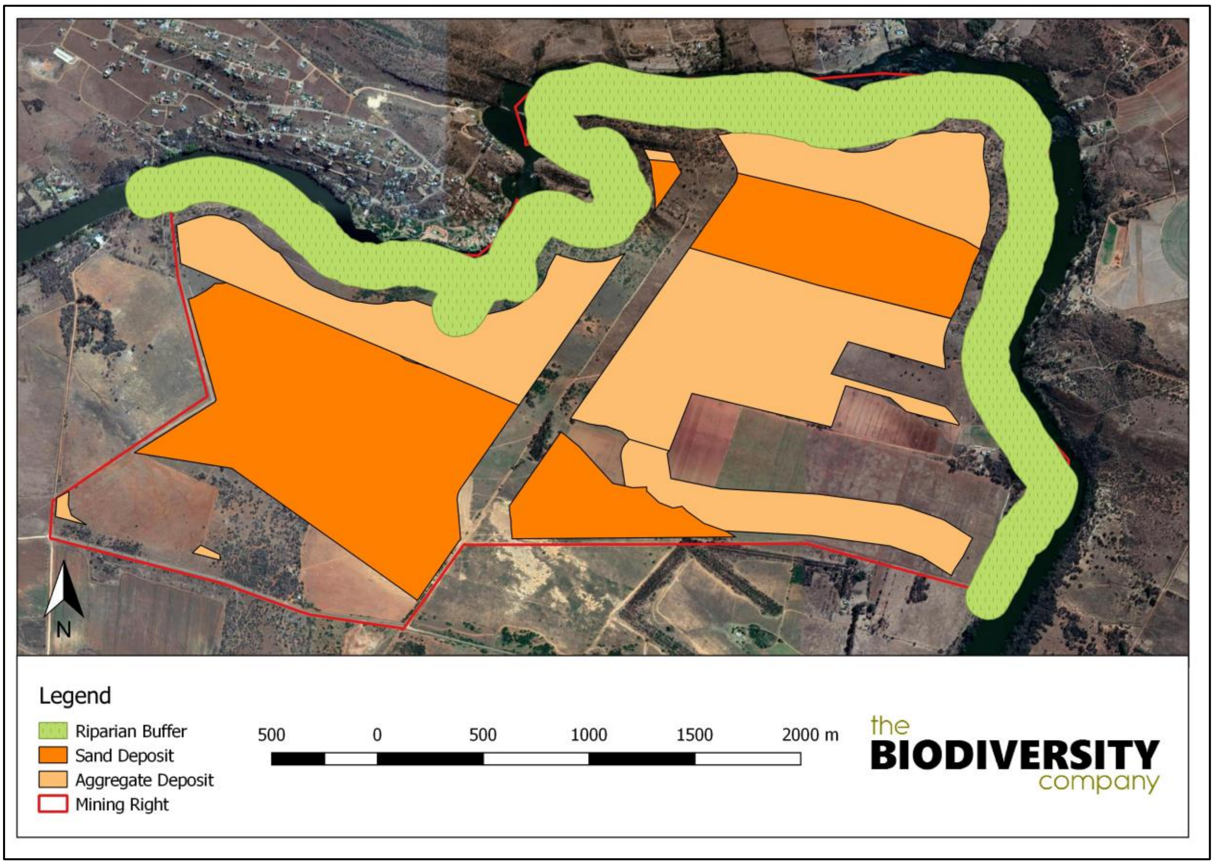

Figure 9-1: Project Deposits and Riparian Buffer Zone

9.2.3 Alternative Assessment

The alternatives considered for this assessment was the location of the product processing facility as indicated in Figure 9-2.

A rated criteria options assessment was completed for the proposed project. The method utilises selected criteria and rates them according to suitability on a 1-5 scale with 1 being unsuitable and 5 being suitable. The various selected criteria as well as the results of their specific ratings are presented in the table below (Table 9-1).

Aspects taken into consideration include the presence of wetlands and drainage which may lead into the Vaal River. The second factor taken into consideration was the distance of the infrastructure from the Vaal River itself, which would increase buffer capacity. The third factor considered in the alternative assessment was the required linear infrastructure such as roadways, pipelines and electricity cables which would increase the area of disturbed land in the catchment.

As observed in the table, the assessment indicated that alternative 3 would be the least destructive to local riverine ecology.

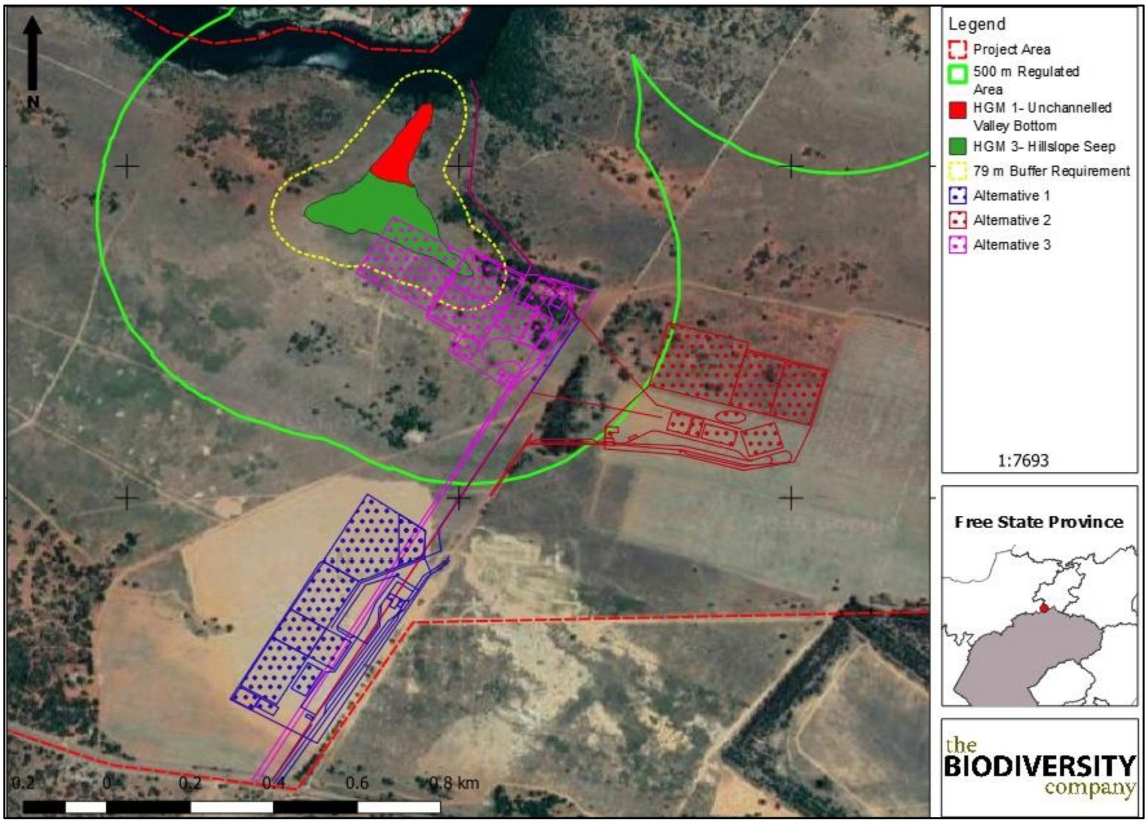

Figure 9-2: Project processing plant alternatives

Table 9-1: Alternative Assessment

Criteria/Option	Site Alternative 1	Site Alternative 2	Site Alternative 3
Presence of Drainage flowing into the Vaal River	5	3	1
Distance from River	5	3	1
Linear infrastructure requirements	3	3	1
Total Suitability	13	9	3

9.2.4 Surface Infrastructure (Roads, Processing Plants and Product Handling)

This section of the report considered the various activities surrounding the placement, operation and decommissioning of the surface infrastructure within the project area.

9.2.4.1 Planning Phase

No impacts to riverine ecology can be anticipated during the planning phase.

9.2.4.2 Construction Phase

No direct losses to riverine resources are anticipated as a result of the construction of the surface infrastructure. The construction activities shall reduce the catchment area through clearing and the placement of the structures, this may have resultant impacts on the water and habitat quality in the downstream reaches. In addition, the storage and utilisation of construction materials (concrete, fuel, stockpiles) present risk to degrade local water quality. The storage and handling of waste such as domestic and miscellaneous construction waste, also presents risk to local water and habitat quality.

The construction of access roads is anticipated to have an in-direct impact to local riverine ecological conditions. Should activities take place in an uncontrolled manner, the activities proposed during this phase have the potential to degrade water and habitat quality within the Vaal River. It is likely that grading of the existing roadways will take place. In addition, the activity is likely to construct drainage on the roadway and other surface infrastructure. The exposure and movement of top and sub-soils therefore present risk to altering chemical and physical conditions in local watercourses. The impact of the construction of the surface infrastructure is presented in Table 9-2. Overall, a low negative impact was derived and can be anticipated as a result of the construction activities for surface infrastructure.

Although the PES (baseline) of the river reach assessed was derived to be modified from reference conditions, further deterioration is possible and thus a potential decline in the PES could be observed without mitigation.

Table 9-2: Impact Assessment for the Construction of Surface Infrastructure

Impact Name	**Surface Infrastructure**				
Alternative	**-**				
Phase	**Construction**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	3	3
Extent of Impact	2	2	Reversibility of Impact	2	2
Duration of Impact	2	2	Probability	3	2
Environmental Risk (Pre-mitigation)					-6,75
Mitigation Measures					
See below.					
Environmental Risk (Post-mitigation)					-4,50
Degree of confidence in impact prediction:					High
Impact Prioritisation					
Public Response					3
Issue has received an intense meaningful and justifiable public response					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1,33
Final Significance					-6,00

9.2.4.2.1 Mitigation

- Areas where construction is to take place must be clearly demarcated. Any areas not demarcated must be completely avoided;
- Basic stormwater structures such as berms must be designed and implemented prior to and throughout the duration of the construction activities;
- Stockpiling or storage of materials and/or waste must be placed beyond the defined buffers for each respective activity;
- Tarps must be used to cover stockpiles when not in use;
- No vehicles are to enter buffer zones;
- No vehicles are to be serviced on site, a suitable workshop with appropriate pollution control facilities should be utilised offsite;
- Small volumes of hydrocarbons for refuelling purposes must be stored in a suitable storage device on an impermeable surface outside of the delineated wetland buffer zone;
- Disturbed areas must be revegetated after completion of the phase;
    - A one-month timeframe for the initiation of this mitigation;
    - Ripping of the soils should occur in two directions; and

- Removed vegetation and topsoil can be harvested and applied here.

- Drainage channels constructed for the access roads must be constructed so as not to result in erosion;
- Energy dissipation, such as stones or blocks should be placed where water leaves the access roads;
- An inspection of the drainage channels must be completed within 1 week following the end of upgrading activities and within a week after the first rainfall event. Should excessive sediment be transported down the channels it is recommended that sediment screens are implemented;
- Sediment screens must be inspected, maintained and cleared every month or after significant rainfall (>50mm/24hrs);
- An alien vegetation removal and management plan must be implemented along the verges of the access road as well as the construction footprint area;
- Suitable toilets must be provided whereby no untreated discharge into the environment is permissible;
- As mentioned above, general stormwater management practices should be included in the design phase and implemented during the construction phase of this project; and
- Following the completion of the phase, all construction materials and debris should be removed and disposed of in a suitable area off-site. An inspection should be completed within a week after the phase is completed.

9.2.4.3 Operation Phase

Similarly to the construction phase, no direct loss of riverine resources are anticipated during the operational phase of surface infrastructure. The impacts that can be anticipated during the operational phase are typically associated with habitat modification, whereby runoff from the altered catchment modify the hydrology and sediment equilibrium of the downstream watercourse. In addition, direct hydrological impacts through reduced seepage as a result of the presence of an artificial surface can also be anticipated. Impacts related to the operation and maintenance of the various existing access roads are also anticipated to have an impact to water chemistry and habitat quality. The central impacts that can be anticipated from the access/roads and processing plant would be erosion and sedimentation impacts with resultant modifications to riverine instream and riparian habitat.

Discharge and seepage of contaminated water via the processing plant activities can also be anticipated. Water utilised in the processing activities will likely contain elevated dissolved and suspended solids, this water would therefore need to be contained. Impacts that can be anticipated in the Vaal River should this water be allowed to enter will result in negative effects to fine sediment sensitive aquatic biota. The impact of the operational phase surface infrastructure on local riverine ecology is presented in Table 9-3.

Table 9-3: Impact Assessment for the Operation of Surface Infrastructure

Impact Name	**Surface Infrastructure**
Alternative	**-**
Phase	**Operation**
Environmental Risk	

Attribute	Pre-mitigation	Post-mitigation	Attribute	Pre-mitigation	Post-mitigation
Nature of Impact	-1	-1	Magnitude of Impact	4	4
Extent of Impact	3	3	Reversibility of Impact	3	3
Duration of Impact	4	4	Probability	4	3
Environmental Risk (Pre-mitigation)					-14,00
Mitigation Measures					
See below.					
Environmental Risk (Post-mitigation)					-10,50
Degree of confidence in impact prediction:					High
Impact Prioritisation					
Public Response					3
Issue has received an intense meaningful and justifiable public response					
Cumulative Impacts					2
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1,50
Final Significance					-15,75

9.2.4.3.1 Mitigation

- Diversion trench and berm systems which diverts clean stormwater around pollution sources and convey and contain dirty water to central pollution control impoundments;
- Barrier systems, including synthetic, clay and geological or other approved mitigation methods to minimise contaminated seepage and runoff from stockpiles and pollution control facilities from entering the local aquatic systems;
- Where stormwater enters river systems from disturbed sites, sediment and debris trapping, as well as energy dissipation control measures must be put in place; and
- The planting of indigenous vegetation around pollution control impoundments and structures should be completed as this has been shown to be effective in erosion and nutrient control;
- Sediment screens must be inspected, maintained and cleared every month or after significant rainfall (>50mm/24hrs);
- Suitable toilets must be provided whereby no untreated discharge into the environment is permissible;
- An alien vegetation removal and management plan must be implemented along the verges of the access road as well as the operation footprint area;
- No water can be discharged into the environment from the processing plant without suitable treatment;
- An annual adaptive water resource monitoring programme, whereby recommendations must be suitable implemented; and
- Bi-annual aquatic biomonitoring studies.

9.2.4.4 Decommissioning Phase

Impacts anticipated to occur during the decommission phase will be similar to those observed during the construction phase, whereby land will be disturbed and vegetation removed along with the surface infrastructure. As with the construction phase, the overall impact during the decommissioning phase is anticipated to be low. The results of the impact assessment are provided in Table 9-4.

Table 9-4: Impact Assessment for the Decommissioning of Surface Infrastructure

Impact Name	**Surface Infrastructure**				
Alternative	**-**				
Phase	**Decommissioning**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	3	3
Extent of Impact	2	2	Reversibility of Impact	2	2
Duration of Impact	2	2	Probability	3	2
Environmental Risk (Pre-mitigation)					-6,75
Mitigation Measures					
See below					
Environmental Risk (Post-mitigation)					-4,50
Degree of confidence in impact prediction:					High
Impact Prioritisation					
Public Response					3
Issue has received an intense meaningful and justifiable public response					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1,33
Final Significance					-6,00

9.2.4.4.1 Mitigation

- Areas where decommissioning is to take place must be clearly demarcated. Any areas not demarcated must be completely avoided;
- Basic stormwater structures such as berms must be designed and implemented prior to and throughout the duration of the construction activities;
- Stockpiling or storage of materials and/or waste must be placed beyond the defined wetland buffers for each respective activity;
- Tarps must be used to cover stockpiles when not in use;
- No vehicles are to enter buffer zones;
- No vehicles are to be serviced on site, a suitable workshop with appropriate pollution control facilities should be utilised offsite;

- Hydrocarbons for refuelling purposes must be stored in a suitable storage device on an impermeable surface outside of the delineated wetland buffer zone;
- Disturbed areas must be revegetated after completion of the phase;
  - A one-month timeframe for the initiation of this mitigation;
  - Ripping of the soils should occur in two directions; and
  - Removed vegetation and topsoil can be harvested and applied here.
- Energy dissipation, such as stones or blocks should be placed where erosion is likely to take place following the decommissioning activities;
- An inspection of the drainage channels must be completed within 1 week following the end of upgrading activities and within a week after the first rainfall event. Should excessive sediment be transported down the channels it is recommended that additional erosion control measures are implemented;
- As mentioned above, general stormwater management practices should be included in the design phase and implemented during the construction phase of this project; and
- Following the completion of the phase, all materials and debris should be removed and disposed of in a suitable area off-site. An inspection should be completed within a week after the phase is completed.

9.2.4.5 Rehabilitation and Closure

Considering that rehabilitation will take place concurrently with the ongoing mining activities, a limited extent of impact is anticipated for the various roadways. During the rehabilitation activities impacts can be primarily associated with the earthworks and removal of vegetation. The impact assessment for this phase is presented in Table 9-5.

Table 9-5: Impact Assessment for the rehabilitation and closure of surface infrastructure

Impact Name	**Surface Infrastructure**				
Alternative	**-**				
Phase	**Rehab and closure**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	2	2
Extent of Impact	2	2	Reversibility of Impact	2	2
Duration of Impact	2	2	Probability	3	2
Environmental Risk (Pre-mitigation)					-6,00
Mitigation Measures					
See below					
Environmental Risk (Post-mitigation)					-4,00
Degree of confidence in impact prediction:					High
Impact Prioritisation					
Public Response					3
Issue has received an intense meaningful and justifiable public response					
Cumulative Impacts					1

Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.	
Degree of potential irreplaceable loss of resources	1
The impact is unlikely to result in irreplaceable loss of resources.	
Prioritisation Factor	1,33
Final Significance	-5,33

9.2.5 Opencast Mining

9.2.5.1 Planning Phase

No impacts to the riverine environment are anticipated during the planning phase.

9.2.5.2 Construction Phase

During the construction phase vegetation and topsoil will be cleared and moved over the proposed open pit areas. This will be completed in a sequential basis and therefore the entire area will not be exposed within the same timeframe. Given that this phase would be the stripping vegetation and removal of topsoil, impacts anticipated can be associated with increased runoff velocities and the subsequent erosion and sedimentation of local waterbodies. In addition, runoff from topsoil stockpiles are anticipated to contain high levels of suspended material. The impact assessment for this phase is presented in Table 9-6. Overall, a low impact to riverine ecology after mitigation actions can be anticipated during this phase.

Table 9-6: Impact Assessment for the construction of the open cast mining areas

Post-mitigatio+C4:H25 n	**Open Cast Mining**				
Alternative	**-**				
Phase	**Construction**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	4	3
Extent of Impact	2	2	Reversibility of Impact	2	3
Duration of Impact	3	3	Probability	5	2
Environmental Risk (Pre-mitigation)					-13,75
Mitigation Measures					
See below.					
Environmental Risk (Post-mitigation)					-5,50
Degree of confidence in impact prediction:					High
Impact Prioritisation					
Public Response					3
Issue has received an intense meaningful and justifiable public response					
Cumulative Impacts					2
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1,50
Final Significance					-8,25

9.2.5.2.1 Mitigation

- In-line with the mitigation hierarchy, the wetland and riparian buffer areas must be avoided through the implantation of mitigation provided in TBC (2019);
- Areas where construction is to take place must be clearly demarcated. Any areas not demarcated must be completely avoided;
- Stockpiling or storage of materials and/or waste must be placed beyond the defined d buffers for each respective activity;
- Barriers and berms to capture runoff from both the construction areas as well as the topsoil stockpiles must be implemented;
- No vehicles are to be serviced on open site, a suitable workshop with appropriate pollution control facilities should be utilised offsite;
- Suitable stormwater and groundwater management, which will reduce erosion and sedimentation, must be established and implemented for each individual pit. The implementation of said plans should be audited annually; and
- Hydrocarbons for refuelling purposes must be stored in a suitable storage device on an impermeable surface outside of the delineated buffer zones.

9.2.5.3 Operation Phase

The impact of the open cast mining during the operational phase will likely present habitat quality impacts to local riverine conditions. The alteration of the catchment area will result in altered hydrology, this will have an impact to local instream and riparian conditions, through shifts in the nature and volumes of flows. In addition, drawdown of groundwater into the open pits can be anticipated during this phase, this will have an additional impact on the hydrology of the associated watercourse. However, given the localised extent of the opencast activities and distance from the Vaal River, it is anticipated that limited reduced water volumes can be expected. The exact groundwater interactions are detailed in the groundwater specialist report for this application (NOA, 2019). Following the ingress of groundwater into the open pit, water will be required to be pumped to allow for the continuation of mining activities, it is therefore recommended that this water is utilised in the processing plant or in dust suppression activities.

Moderate potential impacts were determined for this phase of the project and will likely have a moderate cumulative impact on hydrology. The impact assessment for this component of the proposed project is presented din Table 9-7.

Table 9-7: Impact Assessment for the operation phase of open cast mining

Impact Name	**Opencast Mining**				
Alternative	**-**				
Phase	**Operation**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	5	5
Extent of Impact	3	3	Reversibility of Impact	3	3
Duration of Impact	4	4	Probability	4	3

Environmental Risk (Pre-mitigation)	-15,00
Mitigation Measures	
See below.	
Environmental Risk (Post-mitigation)	-11,25
Degree of confidence in impact prediction:	High
Impact Prioritisation	
Public Response	3
Issue has received an intense meaningful and justifiable public response	
Cumulative Impacts	2
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cumulative change.	
Degree of potential irreplaceable loss of resources	1
The impact is unlikely to result in irreplaceable loss of resources.	
Prioritisation Factor	1,50
Final Significance	-16,88

9.2.5.3.1 Mitigation

- Complete avoidance of buffer zones stipulated in the wetland study and this report;
- The implementation of concurrent rehabilitation with roll-over mining methods;
- The maintenance of the buffer zone during the open pit mining activities;
- Alien vegetation removal in areas surrounding the open pit areas. This must be completed on a continuous basis;
- Effective stormwater and management to divert water around the open pit areas;
- No discharge of contaminated water to occur via open pit pumping;
- Implementation of sedimentation and erosion control in drainage surrounding the open cast areas;
- An annual adaptive water resource monitoring programme, whereby recommendations must be suitable implemented; and
- Bi-annual aquatic biomonitoring studies.

9.2.5.4 Decommissioning Phase

During the decommissioning activities the backfilling of the open pits will take place. Limited disturbance to new areas can be anticipated during this time and therefore the impact of this phase is limited. The impact assessment for this phase is presented in Table 9-8.

Table 9-8: Impact Assessment for the decommissioning of the open cast pits

Impact Name	**Opencast Mining**				
Alternative	**-**				
Phase	**Decommissioning**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	3	3

Extent of Impact	2	2	Reversibility of Impact	2	2
Duration of Impact	2	2	Probability	3	2
Environmental Risk (Pre-mitigation)					-6,75
Mitigation Measures					
See below.					
Environmental Risk (Post-mitigation)					-4,50
Degree of confidence in impact prediction:					High
Impact Prioritisation					
Public Response					3
Issue has received an intense meaningful and justifiable public response					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1,33
Final Significance					-6,00

9.2.5.4.1 Mitigation

- Contouring for a free draining landscape must be completed;
- Erosion and sedimentation control must be in place within 1 month of completing the decommissioning phase for each pit;
- Complete avoidance of buffer zones stipulated in this report; and
- Alien vegetation removal in areas surrounding the open pit areas. This must be completed on a continuous basis.

9.2.5.5 Closure and Rehabilitation Phase

Given the absence of overburden material to backfill the open pits, the closure and rehabilitation of the open pit activities will likely result in the development of a permanent void. This void will fill with groundwater and an equilibrium will be reached whereby diffuse flows enter into the Vaal River. However, considering the open nature of the waterbody, loss of water volume via evaporation is anticipated. In addition, should water be attenuated in the depressions created from the pits, a change in hydrology can be anticipated. The impact assessment for this phase is presented in Table 9-9. Given the overall extent of the open cast activities, a large impact can be anticipated should no backfilling take place. In addition, it is noted that this impact can be mitigated through implementation of a free-flowing landscape design.

Table 9-9: Impact assessment for the rehabilitation and closure of the open cast mining activities

Post-mitigatio+C4:H25n	**Open Cast Mining**
Alternative	**-**
Phase	**Rehab and closure**
Environmental Risk	

Attribute	Pre-mitigation	Post-mitigation	Attribute	Pre-mitigation	Post-mitigation
Nature of Impact	-1	-1	Magnitude of Impact	3	5
Extent of Impact	2	2	Reversibility of Impact	3	3
Duration of Impact	5	5	Probability	4	3
Environmental Risk (Pre-mitigation)					-13,00
Mitigation Measures					
See Below					
Environmental Risk (Post-mitigation)					-11,25
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					3
Issue has received an intense meaningful and justifiable public response					
Cumulative Impacts					2
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1,50
Final Significance					-16,88

9.2.5.5.1 Mitigation

- Final voids must be free flowing;
- Erosion and sedimentation control must be in place and an annual survey should be completed until at-least complete vegetation rehabilitation (as determined by an appropriate specialist); and
- Alien invasive plant management plan must be in place.

10 Recommendations

The following additional studies are recommended:

- Hydrological study to assess loss of catchment to closure voids;
- Water resource assessment study to assess impact of abstraction against stipulated RQO's; and
- Water resource assessment to provide final recommendations of final void areas following the completion of mining activities.

11 Conclusion

The outcomes of this study have indicated a considerably modified riverine environment. The results of the impact assessment did not identify any significant fatal flaws for the proposed project should mitigation actions be effectively implemented. However, additional water resource studies have been recommended for the abstraction of water and identification of hydrological impacts attributed to the final voids.

12 References

Abel R, Thieme ML, Revenga C, Bryer M, Kottelat M, Bogutskaya N, Coad B, Mandrak N, Contreras Balderas S, Biussing W, Stiassny MLJ, Skelton P, Allen GR, Unmack P, Naseka A, Ng R, Sindorf N, Robertson J, Armijo E, Higgins JV, Heibel TJ, Wikramanayake E, Olson D, Lopez HL, Reis RE, Lundberg JG, Mark H, Perez S, Petry P. 2008. Freshwater Ecoregions of the World: A new map for biogeographic units for freshwater biodiversity conservation. Bioscience. 58:403–414.

Barbour MT, Gerritsen J, White JS. 1999. Development of a stream condition index (SCI) for Florida. Prepared for Florida Department of Environmental Protection: Tallahassee, Florida.

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

Department of Water and Sanitation (DWS). 2005. A practical field procedure for identification and delineation of wetlands and riparian areas. Pretoria: Department of Water Affairs and Forestry.

Department of Water and Sanitation (DWS). 2018. A Desktop Assessment of the Present Ecological State, Ecological Importance and Ecological Sensitivity per Sub Quaternary Reaches for Secondary Catchments in South Africa. Draft. Compiled by RQS-RDM.

Dickens CWS, Graham PM.2002. The South African Scoring System (SASS), Version 5, Rapid bioassessment method for rivers. *African Journal of Aquatic Science*. 27**:** 1–10.

Gerber A, Gabriel MJM. 2002. Aquatic Invertebrates of South African Rivers Field Guide. Institute for Water Quality Studies. Department of Water Affairs and Forestry.

Hydrospatial. 2019. The hydrological assessment for the Pure Source Mine.

Kleynhans CJ, Louw MD. 2007. Module A: EcoClassification and EcoStatus determination in River EcoClassification: Manual for EcoStatus Determination (version 2). Joint Water Resource Commission and Department of Water Affairs and Forestry report. WRC Report No. TT 329/08.

Kleynhans CJ. 1996. A qualitative procedure for the assessment of the habitat integrity status of the Luvuvhu River (Limpopo System, South Africa) Journal of Aquatic Ecosystem Health 5:41-54.

Nel JL, Snaddon K, Murray K, Roux DJ, Hill L, Swartz ER, Manuel J, Funke N. 2011. Implementation Manual for Freshwater Ecosystem Priority Areas. Water Research Commission. Report Number 1801/1/11, ISBN 978-1-4312-0147-1.

Republic of South Africa Government (RSA Government). 2016. Classes and Resource Quality Objectives of Water Resources for Catchments in the Upper Vaal. Government Gazette, 22 April 2016. No. 39943.

TBC. 2019. Wetland assessment for the Pure Source Mine.

Thirion C. 2007. Module E: Macroinvertebrate Response Assessment Index in River EcoClassification: Manual for EcoStatus Determination (version 2). Joint Water Research

Commission and Department of Water Affairs and Forestry report. WRC Report No. TT 332/08.

Thirion CA, Mocke A, Woest, R. 1995. Biological monitoring of streams and rivers using SASS4. A User's Manual. Internal Report No. N 000/00REQ/1195. Institute for Water Quality Studies. Department of Water Affairs and Forestry. 46.