# AN AQUATIC ASSESSMENT OF THE LOCAL RIVER SYSTEMS OF THE BRAKFONTEIN MINING OPERATION

**UNIVERSAL COAL**

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Digby Wells & Associates (Pty) Ltd. Co. Reg. No. 1999/05985/07. Fern Isle, Section 10, 359 Pretoria Ave Randburg Private Bag X10046, Randburg, 2125, South Africa

Tel: +27 11 789 9495, Fax: +27 11 789 9498, info@digbywells.com, www.digbywells.com

This document has been prepared by **Digby Wells Environmental**.

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| Name | Responsibility | Signature | Date |
|---|---|---|---|
| Russell Tate | Report compiler | | 13 August 2012 |
| Andrew Husted | Review | | 23 July 2012 |
| Danie Otto | Review | | |

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# EXECUTIVE SUMMARY

Digby Wells Environmental (Digby Wells) has been appointed, by Universal Coal Plc., to conduct an aquatic assessment at the proposed Brakfontein Coal Mine. The Brakfontein Coal Project is located in the Delmas district, on the western margin of the Witbank coalfield This report details the aquatic assessment for inclusion into the Environmental Impact Assessment (EIA)/Environmental Management Plan (EMP) reports for the project.

The proposed project area falls within the Olifants Water Management Area within the quaternary catchment B20E. The project area has 3 water courses draining the mining operation area. One of these courses is the Wilge River.

Rapid bioassessment techniques were applied at 6 sites to determine the overall ecostatus of the water courses associated with the proposed mining operation. The river courses were determined to be in a Class E ecostatus indicating that large anthropogenic modification has occurred. The Class E ecostatus was derived from biotic indices which gave an indication that the Class E score is probably due to poor water quality as a result of agricultural and mining activities upstream. These results are confirmed in a separate study done by Digby Wells which states several water quality parameters at twice to 11 times the magnitude of the Water Quality Objectives for the Wilge River.

The possible impacts of the proposed project were linked to a deterioration of water quality and quantity placing an emphasis on water quality. Mitigation measures have been recommended and a biomonitoring assessment plan developed.

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| | |
|---|---|
| ASPT | Average Score Per Taxon |
| DO | Dissolved Oxygen |
| Digby Wells | Digby Wells Environmental |
| DWA | Department of Water Affairs |
| ESIA | Environmental and Social Impact Assessment |
| FRAI | Fish Response Assessment Index |
| IHAS | Invertebrate Habitat Assessment System |
| IHI | Index of Habitat Integrity |
| MIRAI | Macro – Invertebrate Response Assessment Index |
| RHP | River Health Programme |
| SADC | Southern African Development Community |
| SASS | South African Scoring System |
| TDS | Total Dissolved Salts |
| USEPA | United States Environmental Protection Agency |
| WQO | Water Quality Objectives |

# 1 INTRODUCTION

It is clear that neither social and economic development, nor environmental diversity, can be sustained without water (Ashton *et al*., 2001). In South Africa water located in river systems provides the primary water supply for agricultural, domestic and industrial purposes (Aston, 2007). However due to an increasing demand and use of South African water resources the modification and pollution of local river systems is common (Crafford & Avenant-Oldewage, 2010).

The South African government has demonstrated a concern for the wellbeing of the countries water resources and as a means to fulfil this concern the Department of Water Affair (DWA) has established the National Water Act, Act 36 of 1998.

The location of the proposed project studied in this document is situated in South Africa within the Mpumalanga province. The province of Mpumalanga is renowned for its vast quantities of mineral deposits such as coal. The province is also seen as a large producer of South Africa's electricity and as such the province of Mpumalanga has widespread industrial activities which influence the management of the water resources contained within Mpumalanga (Ashton *et al*., 2001). The presence of mining activities near water courses creates the requirement for the establishment of baseline ecological conditions as to ascertain the present ecological status. Only once the baseline ecological status is known the effect mining activities has on these water courses can be determined.

The Olifants River is described as a very important river in southern Africa with its drainage basin comprising of two portions of Southern African Development Community (SADC) states (Mozambique and South Africa) (Ashton *et al*., 2001). A large proportion (85%) of the Olifants River drainage basin is contained in South Africa with an estimated basin area of 74,400 $km^2$. Historically the Olifants River was considered a strong – flowing perennial river but now is regarded as a weakly perennial river where flows frequently cease and, during drought periods, flows may be hardly discernible over large stretches of the lower reaches of the river (Ashton *et al*., 2001).

The Olifants River basin supports a very large population, including some of South Africa's poorest rural communities, as well as numerous urban areas and farming communities. The estimated population contained within the Olifants River catchment is 10.5 Million (Ashton *et al*., 2001). The demand for water throughout the Olifants basin is both high and unevenly spread with particularly high demands by industry, mining and formal agriculture (75%). Currently the Olifants River has been identified as a river of high silt loads, salinity and pollutant levels (Venter and Deacon, 1992). Due to anthropogenic impacts on water quality and quantity the need for monitoring arises.

The River Health Programme (RHP) is the national monitoring programme used to monitor and assess the freshwater resources within South Africa. Roux (2001) stated that the RHP methodology entails the selection and use of reference sites as opposed to monitoring sites. The monitoring focus when selecting sampling sites is based on the application of biological indicators and relevant drivers to assess the condition or "health" of the aquatic ecosystem.

The aim of the study was to establish the present ecological state of the aquatic ecosystems associated with the proposed Brakfontein mining area. In order to achieve this aim validated rapid aquatic biomonitoring methodologies were applied. The following objectives have been set out:

- Collect and review existing literature associated with the study area and current ecological state of the ecosystems in the area;
- Characterise the current ecological state of the aquatic ecosystem by making use if the selected driver indices which address available habitat and *in situ* water quality state; and
- Characterise the current ecological state of the aquatic ecosystem by making use of selected responder indices which address macro-invertebrate and ichthyofauna population attributes.

This report presents the results obtained from the surface aquatic ecosystem assessments conducted during August 2012. The report consists of an aquatic assessment which includes an assessment of *in situ* water quality, habitat availability, aquatic macro-invertebrates and ichthyofauna. These findings have been discussed in light of the proposed Brakfontein mining operation and the associated activities.

# 2 TERMS OF REFERENCE

Digby Wells Environmental (Digby Wells) was appointed by Universal Coal to investigate the environmental aspects of the proposed Brakfontein mining operation. Digby Wells has been commissioned to undertake an initial ecological state assessment of the local surface aquatic ecosystems in order to determine the condition or health of the river systems by implementing accredited fresh/surface-water biomonitoring assessment methodologies.

The project involves the South African authorities and as such, regulations and laws relating to the country are applied. This study addresses the following regulations and regulatory procedures of the South Africa Departments of Water and Environmental Affairs (National Water Act, Act 36, 1998 (South Africa).

# 3 KNOWLEDGE GAPS

## 3.1 Discussion

Owing to the allocated time frame for the study, a Level 1 RHP assessment was conducted and as such the confidence of the study should be compared to a RHP study of this level (Kleynhans & Louw, 2007). Only a single survey was carried out during the low flow period and it is suggested that an additional high flow survey (September - March) be carried out as to determine seasonal trends.

Due to the fact that seasonal trends have not been identified the results from this study may not provide an accurate representation of the current ecological integrity of the aquatic ecosystems surveyed, which has shown to vary according to seasonality, and thus confidence in the ecological state description of the system may be low. Due to weather constraints and periods of cold temperatures ichthyofauna was unable to be sampled effectively generating a low confidence in the overall ecostatus. The limited nature of the survey raised recommendations on how to improve the confidence of the study conducted.

## 3.2 Recommendations

Due to the nature of the study it is suggested that further studies are conducted during different seasons/periods in order to gain a comprehensive understanding and establishment of the aquatic systems associated with the proposed Brakfontein mining operation.

# 4 STUDY AREA

The project area is located in the Olifants River catchment and has a variety of surface water features associated with it. The project area is located within the Olifants WMA within the quaternary catchment B20E. The catchment B20E drains an area known as the Wilge River catchment. The perennial Wilge River and its associated water courses form tributaries to the Olifants River and their confluence is approximately 10km downstream from the proposed Brakfontein mining operation. The water supply of the Wilge River is sustained by groundwater aquifers and water from its tributaries. Where groundwater meets the surface a number of wetland areas exist.

The aquatic biodiversity associated with the Wilge River is classified as Class C (Moderately Modified) (Kleynhans, 2000) indicating that anthropogenic activities are potentially negatively influencing the aquatic biodiversity. The biodiversity of the upper reaches of the Wilge River has been described as important and necessary (Kleynhans, 2000). Additionally, according to Kleynhans (2000) the biodiversity found in the upper reaches is considered endangered. The sub-catchment of the project area according to the National Freshwater Ecological Protection Area (Driver *et al*., 2011) is CDEFZ. This catchment is has no associated FEPA associated with it and contains no protected species.

Upstream and around the project area a variety of mining activities occur. These activities include agricultural activities (chicken, maize, cattle and dairy farming as well as farm infrastructure), mining activities (Umbeko Mining, Keaton Mining), as well as recreational areas such as lodges.

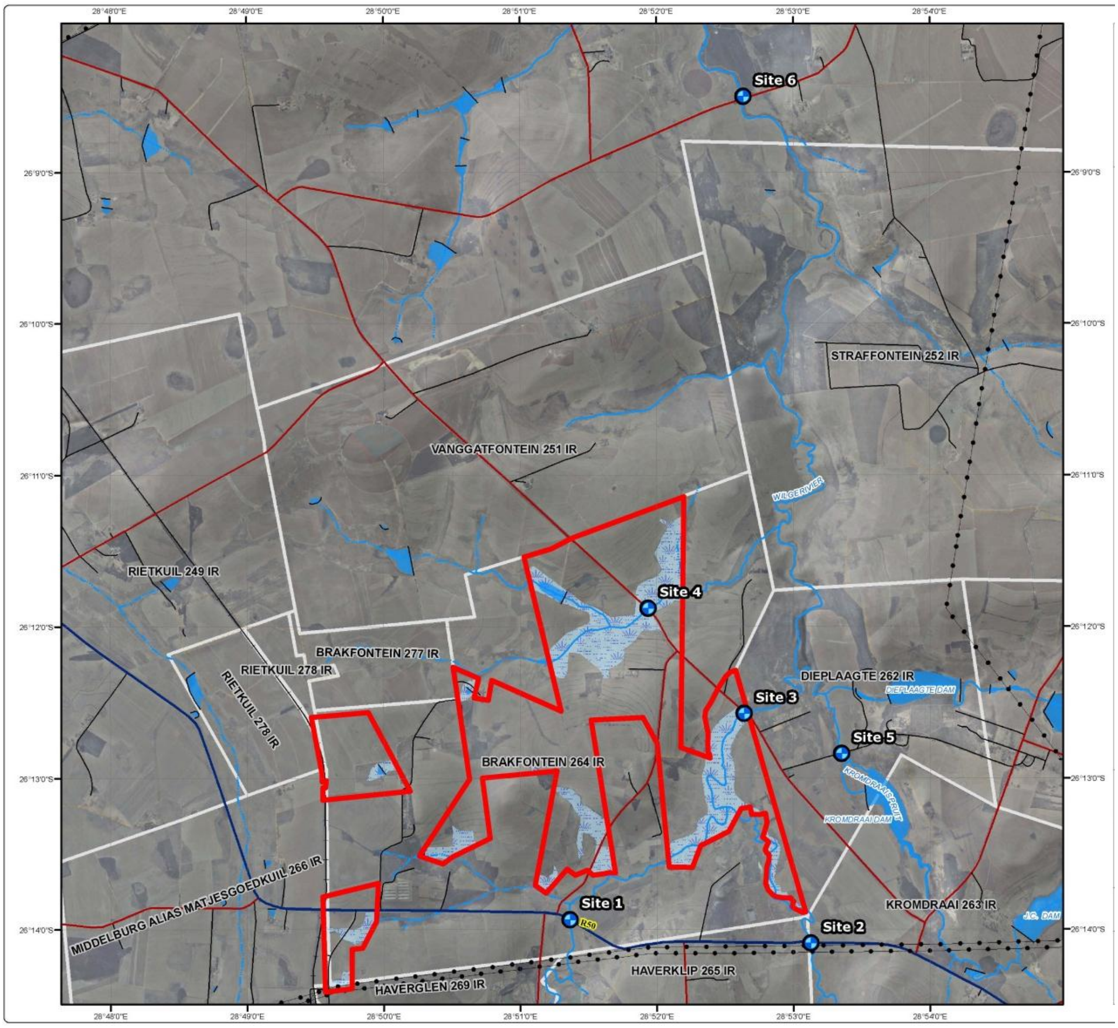
Six sites were selected as biomonitoring points in and around the mining operation. These sites are described in Table 4-1. The location of the sites is given in Figure 4-1.

**Table 4-1: Table depicting Global Positioning Systems points and site descriptions**

| Site Name | Coordinate | Description | Photograph |
|---|---|---|---|
| **Site 1** | 26 13 39.56 S<br>28 51 22.65 E | This site is located just off the R50 road. The site is located upstream the mining operation on a tributary of the Wilge River. The site is described as approximately 5m wide with the water surface being about 2m below that of the river banks. The flow type was characterised by slow flow (>0.1m/s) It must be noted that this site had excessive siltation and thus had a sandy substrate. The site's riparian vegetation was composed predominantly by grasses with a lack of large trees. |  |
| **Site 2** | 26 14 05.42 S<br>28 53 07.66 E | This site is located near to the R50 road above the mining operation. This stream forms a tributary of the Wilge River and is known as the Kromdraaispruit. The stream was approximately 2m wide and had a water surface about 1m away from the riverbanks top. The flow type would be described as slow (>0.1m/s) The stream is located near to agricultural activities and its dominant riparian vegetation was grasses and various aquatic macrophytes such as Bulrushes (*Taphia capensis*). |  |
| **Site 3** | 26 12 34.40 S<br>28 52 38.37 E | This site is located on the Wilge River immediately downstream mining operations. The river was approximately 3m wide and there were signs of erosion on the outer banks cutting a depth into the riverbanks of approximately 2m. The flow type of the river at the time sampled was slow (>0.1m/s). Riparian vegetation was dominated by grasses and aquatic macrophytes. |  |

| Site Name | Coordinate | Description | Photograph |
|---|---|---|---|
| **Site 4** | 26 11 52.71 S<br>28 51 56.27 E | This site forms a tributary of the Wilge River and is located within the mine operation area. At the time of sampling there was no flow observed and the predominant vegetation was wetland type species. |  |
| **Site 5** | 26 12 50.4 S<br>28 53 21.2 E | This site is located on a tributary of the Wilge River and is located approximately 1.34km up stream of the Wilge River confluence. The site is located downstream the Kromdraai Dam. The stream is approximately 1m wide with banks about ½m high. At the point of sampling there was no discernible flow with the formation of pools. Riparian vegetation was dominated by grasses. |  |
| **Site 6** | 26 08 30.0 S<br>28 52 38.6 E | This site is found on the Wilge River downstream of the Brakfontein mining operation as well as a variety of other mining operations. The river is about 8m wide and has riverbanks ±2m from the water surface. The flow type with identified to be slow (>0.1m/s). |  |

**Figure 4-1: Map indicating position of aquatic biomonitoring points.**



# 6 METHODOLOGY

## 6.1 Phase 1: Desktop Study

A desktop study involving the use of a literature review on the ecological state of the Olifants River was undertaken.

## 6.2 Phase 2: Ecological Integrity

In order to determine the ecological integrity of the aquatic environment, individual biophysical components of the streams in the study area were assessed. These biophysical attributes were considered by implementing selected biophysical tools or indices that refer to selected drivers and biological responses of an aquatic ecosystem. Methodologies formulated by the River Health Programme (RHP, 2001) were implemented. The selected drivers and biological responses include:

The abiotic driver assessment:

- *In situ* water quality (DWAF, 1996);
- The Index of Habitat Integrity (IHI) (Kleynhans, 1996); and
- The Invertebrate Habitat Assessment System (IHAS) (McMillan, 1999).

The biotic response indicator assessment:

- South African Scoring System 5 (SASS 5)
- Fish Response Assessment Index (FRAI); and
- Macro-Invertebrate Assessment Index (MIRAI)

According to Kleynhans and Louw (2007) the directional change in the attributes of the drivers and biota is referred to as trend. Generally, an assessment may be approached from a driver perspective (Kleynhans & Louw, 2007). The driver components will be considered in order to determine the degree of contribution towards the current state of the biological communities. The ultimate objective is to determine if the biota have adapted to the current habitat template or are still in a state of flux (Kleynhans & Louw, 2007).

### 6.2.1 Water Quality

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 refers to the quality of water (DWAF, 1996). The various water quality parameters were all taken *in situ*. These parameters include pH, oxygen content (DO (mg/l)) and oxygen saturation (DO %), temperature ($C^{o}$) and conductivity (µS/cm) using calibrated water quality meters.

The South African Water Quality Guidelines for Aquatic Ecosystems (DWAF, 1996) was applied to this study as the primary source of reference information. The South African Water Quality Guidelines contains information similar to that which is available in the international literature; however, the information provided is specifically formulated for Southern African aquatic ecosystems and water users (DWAF, 1996).

### 6.2.2 Habitat Quality

The assessment of the composition of the surrounding physical habitat which influences the quality of the water resource and the condition of the resident aquatic community is referred to as a habitat assessment (Barbour *et al*., 1996). An important factor which determines the survival of a species in an ecosystem is the state of the available habitat. As a result of habitat loss, alteration and degradation the number of species have declined (Karr, 1981). According to Karr (1981) the diversity of biota dependant on the habitat will decrease if the habitat integrity decreases.

The physical habitat of an aquatic ecosystem is a large component which affects the ecological integrity of an aquatic ecosystem and as a result of this, an assessment of the physical habitat should be included in all bioassessments to assist in interpreting the results (Uys *et al*., 1996; McMillan, 1999; Dickens and Graham, 2002; Vos *et al*., 2002).

#### 6.2.2.1 Index of Habitat Integrity

The quality and diversity of the available habitat was assessed by means of the IHI (Kleynhans, 1996). The IHI was applied on a systems basis. The IHI integrity classes and a description of each class are presented in Table 6-1. This index assesses the number and severity of anthropogenic perturbations and the damage they potentially inflict on the habitat integrity.

**Table 6-1: The IHI integrity classes and short descriptions of each class (Kleynhans, 1999)**

| Integrity Class | Description | IHI Score (%) |
|---|---|---|
| A | Natural | >90 |
| B | Largely Natural | 80 – 90 |
| C | Moderately Modified | 60 – 79 |
| D | Largely Modified | 40 – 59 |
| E | Seriously Modified | 20 – 39 |
| F | Critically Modified | 0 - 19 |

#### 6.2.2.2 Invertebrate Habitat Assessment System

The IHAS was specifically designed to be used in conjunction with the SASS5, benthic macro-invertebrate assessments. The IHAS assesses the availability of the biotopes at each site and expresses the availability and suitability of habitat for macro-invertebrates, this is determined as a percentage, where 100% represents "ideal" habitat availability. A description based on the IHAS percentage scores is presented in Table 6-2.

**Table 6-2: Description of IHAS scores with the respective percentage category (McMillan, 2002)**

| IHAS Score (%) | Description |
|---|---|
| >75 | Very Good |
| 65 – 74 | Good |
| 55 – 64 | Fair/Adequate |
| < 55 | Poor |

### 6.2.3 Aquatic Invertebrate Assessment

Macro-invertebrate assemblages are good indicators of localised conditions because many benthic macro-invertebrates have limited migration patterns or a sessile mode of life, they are particularly well-suited for assessing site-specific impacts (upstream and downstream studies) (USEPA, 2006). Macro-invertebrates respond to a combination of short term environmental variables. Benthic macro-invertebrate 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 (USEPA, 2006). The assessment and monitoring of benthic macro-invertebrates forms an integral part of the monitoring of the health of an aquatic ecosystem.

#### 6.2.3.1 South African Scoring System

The SASS5 is the current index being used to assess the status of riverine macro-invertebrates in South Africa. 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 show different sensitivities to pollution, these sensitivities range from highly tolerant families (e.g. Muscidae and Psychodidae) to highly sensitive families (e.g. Oligoneuridae). SASS results are expressed both as an index score (SASS score) and the average score per recorded taxon (ASPT value).

All SASS5 and ASPT scores are compared with the SASS5 Data Interpretation Guidelines (Dallas, 2007) for the relevant ecoregion, namely the Mpumalanga Highveld. 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.

Sampled invertebrates were then 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 & Graham, 2002; Gerber & Gabriel, 2002).

#### 6.2.3.2 Macro-Invertebrate Assessment Index

The aim of the MIRAI is to provide a habitat-based cause-and-effect foundation to interpret the deviation of the aquatic invertebrate community from the reference condition. This does not preclude the calculation of SASS scores if required (Thirion, 2007). The four major components of a stream system that determine productivity for aquatic organisms are as follows:

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

### 6.2.4 Fish Assessment

Information pertinent to this component is used in an index known as the Fish Response Assessment Index (FRAI) (Kleynhans, 2007); with the information gained being an indication of the present ecological state of the river based on the fish assemblage structures observed. All fish were identified in the field and released at the point of capture. Fish species were identified using the guide Freshwater Fishes of Southern Africa (Skelton, 2001). The identified fish species were compared to those expected to be present for the B20E quaternary catchment. The expected fish species list was developed from a literature survey and included sources such as (Kleynhans *et al*., 2007) and Skelton (2001).

### 6.2.5 Ecological Description

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). According to Iversen *et al*. (2000) EcoStatus may be defined as the totality of the features and characteristics of the system that bear upon its ability to support an appropriate natural flora and fauna. For the purpose of this study ecological classifications have been determined for biophysical attributes for the Olifants River.

# 7 FINDINGS

## 7.1 Site Selection

Six biomonitoring points were selected to identify trends within the aquatic systems associated with the proposed Brakfontein mining operation. Two sites were selected on the Wilge River (Site 1) and its tributary (Site 2) above the mining operation. A third site was selected immediately downstream of the mining operation on the Wilge River (Site 3). A fourth site was selected within the mining operation area on a tributary of the Wilge River (Site 4). Another site was selected on a tributary upstream the Wilge River on a point below Kromdraai Dam (Site 5). The final site was selected approximately 8.59 km downstream the proposed mining operation and downstream all tributaries flowing through the mining operation. Of the six sites selected in field observation found that only 4 out if the six sites were suitable for biomonitoring analyses. The suitability of the sites and sites chosen are indicated in Table 7-1. These sites will provide information which will allow for a comparative basis on which future impacts can be evaluated.

**Table 7-1: Table indicating suitability of sites for biomonitoring**

| Site | Suitable | Comments |
|---|---|---|
| **Site 1** | Yes | Sufficient habitat and flow |
| **Site 2** | Yes | Sufficient habitat and flow |
| **Site 3** | Yes | Sufficient habitat and flow |
| **Site 4** | No | Insufficient habitat available, unsuitable flow type |
| **Site 5** | No | Insufficient habitat available, unsuitable flow type |
| **Site 6** | Yes | Sufficient habitat and flow |

## 7.2 Water Quality

**Table 7-2: Water quality parameters 2012 survey**

| Site | Temp (°C) | pH | Conductivity (µS/cm) | DO% | DO (mg/l) |
|---|---|---|---|---|---|
| **Range** | 5 - 30 | 6.5 – 9.0 | 350 | 80 - 120 | > 5.0 |
| **Site 1** | 10 | 5.9 | 784 | 113 | 10.64 |
| **Site 2** | 10 | 6.26 | 918 | 105 | 10.11 |
| **Site 3** | 12.7 | 6.7 | 864 | 109 | 9.68 |
| **Site 4** | 13.8 | 7.03 | 551 | 117 | 9.98 |
| **Site 5** | 15.1 | 7.38 | 710 | 115 | 9.36 |
| **Site 6** | 11 | 7.62 | 367 | 105 | 9.81 |

The temperature of water plays an important role for aquatic ecosystems by affecting rates of chemical reactions and therefore also the metabolic rates of organisms (DWAF, 1996). The rate of development, reproductive periods and emergence time of organisms are all affected by temperature. The temperatures of inland waters in South Africa generally range from 5 - 30 ˚C (DWAF, 1996). At all sites the temperature was recorded to be within the Water Quality Guidelines for Aquatic Ecosystems (DWAF, 1996).

The pH of an aquatic system forms an important component in determining the integrity of the ecosystem. A low pH may allow for the increase in solubility of toxic elements and thus the monitoring of the pH is of utmost importance. According to Alabaster and Lloyd (1982) the pH target for fish health is presented as ranging between 6.5 and 9.0, as most species will tolerate and reproduce successfully within this pH range. The *in situ* pH at Sites 1 and 2 are below the range set out by Alabaster and Lloyd (1982) indicating that aquatic biota present at these sites may be experiencing toxic conditions. The *in situ* pH for the rest of the sites was determined to be within these guidelines and would not be seen as a limiting factor for biodiversity.

The conductivity of the sites was determined to range from 784 µS/cm (Site 1) to 367 µS/cm (Site 6) indicating that there is dilution occurring downstream of the study area. The electrical conductivity at Sites 1 to 5 was high indicating the presence of a high concentration of ions.

According to the South African Water Quality Guidelines for Aquatic Ecosystems (DWAF, 1996), the target water quality range for an aquatic ecosystem is between 80 – 120 % of DO saturation. The minimal allowable dissolved oxygen values according to DWAF (1996a) are not less than 60 % for sub-lethal effects and not less than 40 % for lethal effects. The DO saturation for the sites was determined to be in a good/healthy condition.

Mason (1991) discussed, dissolved oxygen (DO) is potentially the most important measure of water quality, especially for aquatic life. Both the survival and functioning of aquatic biota is dependent on the maintenance of aquatic DO concentrations because it is required for the respirations of all aerobic organisms. The median guideline for DO for the protection of aquatic biota is >5.0 mg/l (Kempster *et al*., 1980). The DO concentrations at the sampled sites were determined not a limiting factor for aquatic biota.

Overall the *in situ* water quality for all sites was determined to be fair. The fair quality of the water was derived by comparing the results to the Water Quality Objectives for the Wilge River set out by the DWA. The electrical conductivity of all the Sites was determined to be over the required concentration. It is for this reason the overall *in situ* water quality is described as fair. However further analysis of the constituents of the water column is required to obtain a confident description of the water quality.

## 7.3 Habitat Integrity

The structure and function of the aquatic community in a stream is influenced both by the quality and availability of the instream and riparian habitat; for this reason, evaluation of habitat quality and availability is critical to any assessment of aquatic biota.

### 7.3.1 Index of Habitat Integrity

The habitat integrity was determined during the aquatic assessment conducted in August 2012. The scores recorded for the catchment surveyed regarding IHI with an overall ecological classification is presented in Table 7-3.

**Table 7-3 : The habitat scores for IHI recorded for the study area**

| Habitat Assessed | Wilge River |
|---|---|
| **Instream Habitat Integrity Score** | 59.3 |
| **Riparian Zone Habitat Score** | 51.6 |
| **IHI** | Largely modified |
| **Ecoclassification** | Class C/D |

Based on the IHI scores, the instream and riparian habitat associated with the study catchment area are in a largely modified state which indicates large disturbances to the system. The assessment of the riparian vegetation and instream channel indicated that anthropogenic activities were having a considerable impact on the system. Land use patterns such as mining and extensive dry and irrigated agriculture had the largest impact on the IHI. Impacts associated with activites such as mining and agriculture will have impacts on the water quality (inputs from effluent and runoff) and water quality (abstraction of water). These were seen to effect the IHI in such a manner so as to ascertain a Ecoclassification of Class C/D.

### 7.3.2 Integrated Habitat Assessment System

The total IHAS values determined for the study area ranged from 46 (Site 1) to 74 (Site 3) and are presented in Table 7-4.

**Table 7-4: The habitat scores for IHAS recorded for the sampled sites**

| Biotope | Site | | | |
|---|---|---|---|---|
| | **Site 1** | **Site 2** | **Site 3** | **Site 6** |
| **Stones in Current** | 0 | 16 | 18 | 17 |
| **Vegetation** | 11 | 12 | 12 | 9 |
| **Other habitats** | 15 | 18 | 19 | 19 |
| **Stream condition** | 20 | 26 | 25 | 28 |
| **IHAS score (100)** | 46 | 72 | 74 | 73 |
| **EcoClassification** | Poor | Good | Good | Good |

Based on the IHAS scores, habitat availability was poor at Site 1 but was considered good at Site 2, 3 and 6. Habitat sampled and stream condition scores were low for Site 1. This low score may be attributed to the high degree of sedimentation and low flow conditions experienced during the low flow survey. Thus the modified habitat integrity may be as a result of habitat deterioration caused by the low flow conditions. In particular, the stones-in-current (SIC) biotope was absent or in low abundance from the site. Based on the assessment, habitat availability and quality at Site 1, the availability of habitat would be seen as a limiting factor of aquatic macro-invertebrate diversity especially. At Sites 2, 3 and 6 the habitat was determined to be good and therefore would not be considered a limiting factor for macro-invertebrate communities. A habitat is described as good when sufficient amounts/types of biotypes are found at the site. A good site would be described as having all the biotypes/habitats in sufficient amounts.

## 7.4 Aquatic macro-invertebrates

### 7.4.1 SASS 5

The total SASS scores in the study region ranged from 55 to 93 (Table 7-4). The ASPT values ranged from 3.8 to 4.1 (Table 7-5). The guidelines for the interpretation of SASS5 and ASPT scores according to Chutter (1998) are presented in Table 7-6. The guidelines for determining the ecological classes according to SASS5 and ASPT scores and a description thereof is given in Table 7-8 (Dallas, 2007).

**Table 7-5: SASS scores and ASPT values for the aquatic assessment (2012)**

| | Site 1 | Site 2 | Site 3 | Site 6 |
|---|---|---|---|---|
| SASS | 55 | 61 | 74 | 93 |
| No. Of Taxa | 14 | 16 | 18 | 23 |
| ASPT | 3.928 | 3.8125 | 4.111 | 4.04 |
| Ecoclassification | E | E | D | D |

SASS results show that the Sites 1 and 2 are in a seriously modified state (Class E0 and Sites 3 and 6 are in a largely modified state (Class D) (Table 7-5). At Site 1 it was noted that habitat was a factor contributing to the low SASS score, however at Sites 2 and 3 habitats was not a relevant factor and parameters such as water quality may have an influence on the SASS score. Additionally predominantly pollution tolerant taxa were sampled from all sites indicating that if good habitat types were available tolerant species would most likely be found.

**Table 7-6: The suggested SASS5 and ASPT interpretations (Chutter, 1998)**

| SASS 5 | ASPT | Suggested interpretation |
|---|---|---|
| **>100** | >6 | Water quality natural, habitat diversity high |
| **<100** | >6 | Water Quality natural, habitat diversity reduced |
| **>100** | <6 | Borderline case between water quality natural and some deterioration in water quality |

| SASS 5 | ASPT | Suggested interpretation |
|---|---|---|
| **50 - 100** | <6 | Some deterioration in water quality |
| **<50** | Variable | Major deterioration in water quality |

According to Chutter (1998) there may be some deterioration of water quality at all the sites. A study carried out by Digby Wells in June 2012 on the surface water quality suggests that there is agricultural and mining pollution affecting the water quality of the aquatic systems associated with the study area. These findings are presented in Table 7-7. The results of the water quality analyses were above the Water Quality Objectives (WQO) set out for the Wilge River. Only relevant data is included with relevance to the location of the sample. It is suggested that in depth water quality analyses are conducted as to quantify and identify the types of macro elements present in the water column as this may be impacting aquatic macro-invertebrates.

**Table 7-7: Findings from surface water quality analyses June 2012**

| Constituent | Relevance | Nitrate | Chloride | alklinity | Sulphate | Ammonia | flouride |
|---|---|---|---|---|---|---|---|
| **WQO Wilge River** | | **0.3** | **15** | **70** | **15** | **0.2** | **0.2** |
| **UCBW11** | Site 2 | 0.30 | 72.6 | 295 | 93.7 | 0.03 | 0.35 |
| **ECBW10** | Site 1 | 0.36 | 24.4 | 250 | 110 | 0.05 | 0.34 |
| **UCBW8** | Site 3 | 0.25 | 24.5 | 221 | 242 | 0.02 | 0.29 |
| **UCBW04** | Site 6 | 1.61 | 21.8 | 198 | 88 | 0.59 | 0.30 |

**Table 7-8: The ecological classes assigned to the SASS5 and ASPT scores and a description thereof as per the SASS5 Data Interpretation Guidelines (Dallas, 2007)**

| Class | SASS 5 Score | ASPT | Condition |
|---|---|---|---|
| **A** | >143 | >5.8 | Natural/unmodified |
| **B** | 115 – 143 | 5.5 – 5.8 | Minimally modified |
| **C** | 94 – 115 | 5.1 – 5.5 | Moderately modified |
| **D** | 72 – 94 | 4.6 – 5.1 | Largely modified |
| **E** | <72 | <4.6 | Seriously modified |

During the low flow survey a total of 18 invertebrate families were sampled. Low species diversity was recorded during the survey. At all sites in the study area the invertebrate community consisted largely of species tolerant to pollution. This observation is also reflected in the ASPT observed at the various sites. A low ASPT is generally an indication of poor water quality, whereby a low SASS score is largely an indication of poor habitat quality and availability. In this case the ASPT was <5 indicating that the low SASS score is not a reflection of poor habitat availability but is a reflection of poor water quality. The Study by Digby Wells in June 2012 confirms this. The low flow conditions experienced at all sites has a compounding effect on the invertebrate communities present and thus a modified class is given.

### 7.4.2 Macro-Invertebrate Response Assessment Index

The MIRAI was implemented for each of the sampled sites (August 2012) and the results of the assessment are presented in Table 7-9. The macro-invertebrate communities at all sites were determined to be in a seriously modified state (Class E). The various changes in the macro-invertebrate communities from reference conditions at all sites may be as a result of changes in water quality and low flows. Findings from this assessment are similar to findings of the SASS5.

**Table 7-9: The findings and ecological category for each sampled site for MIRAI**

| Component | Site 1 | Site 2 | Site 3 | Site 6 |
|---|---|---|---|---|
| **MIRAI (%)** | 27.995 | 33.2065 | 32.0983 | 34.8701 |
| **EC: MIRAI** | E | E | E | E |
| **Category** | Seriously modified | Seriously modified | Seriously modified | Seriously modified |

From these guidelines/findings it can be suggested that there is deterioration of water quality at all sites. This is a distinct possibility as anthropogenic activities such as mining operations and extensive agricultural practices appear to be impacting on water quality. Furthermore, the surface water quality analysis report completed by Digby Wells in June 2012 shows that there is evidence of potential agricultural and mining pollution with high levels of nitrates, ammonium and sodium salts. It is further hypothesised that low flow conditions have resulted in an alteration of community structure as species which are intolerant of low flows are not found in the sites sampled. It can be concluded that the low MIRAI values are a reflection of poor water quality however this requires further investigation.

In conclusion the results from SASS 5 indicate that there is a degradation of water quality. The results of MIRAI confirm these findings.

## 7.5 Fish Assessment

During the survey a variety of methods were applied to establish the fish assemblage of the systems associated with the study area. These methods included electroshocking and the placement of a number of fyke nets. The applied methods revealed no fish and as such no fish were captured during this survey.

An explanation of this may be due to the climatic conditions being experienced at the time of sampling. It must be noted that during the assessment air and water temperatures were low with water temperatures being 10 °C and the occurrence of snow creating conditions that are unfavourable for aquatic biota. The fish species community assemblages present in the catchment area are temperate species meaning they are not adapted to extreme cold temperatures. Organisms that are not adapted to cold conditions have shown to become less active during periods of low temperatures (Guderley, 2003). This is due to the lowering of the metabolic activities and reduced effectiveness of enzymes due to low temperatures (Guderley, 2003). Due to the fact that no fish were recorded and the possibility of the occurrence being climatically driven, the fish assessment components have been altered to include the expected fish species for the catchment area. The fish species expected to be found in this quaternary catchment according to Kleynhans *et al*., (2008) include the species described in Table 7-10.

**Table 7-10: Expected fish species of quaternary catchment B20E Kleynhans *et al*., (2008)**

| Species | Abbreviation | Common name |
|---|---|---|
| ***Barbus anoplus*** | BANO | Chubbyhead Barb |
| ***Barbus paludinosus*** | BPAU | Straightfin Barb |
| ***Pseudocrenilabrus philander*** | PPHI | Southern Mouth Brooder |

### 7.5.1 Ecological Description

In conclusion through these results it has been identified that the ecoclassification of the aquatic systems associated with the study area are in a seriously modified state (Class E) indicating that there is clear community modifications and impairment to ecosystem integrity. The classification of the ecosystems to a Class E was done through incorporation of all the biotic indices conducted during the assessment. The area of main concern and with the largest implications would be the occurrence of poor water quality as this is seen to have a serious effect on the total ecoclassification score. The explanations of these categories are given in Table 7-11.

**Table 7-11: The ecostatus categories, key colours and category descriptions (modified from Kleynhans, 2000)**

| Category | Score (%) | Rating | Category description |
|---|---|---|---|
| **A** | 90 - 100 | Excellent | Unmodified state – Un-impacted state, conditions natural. |
| **B** | 80 - 89 | Very good | Largely natural – Small change in community characteristics, most aspects natural. |
| **C** | 60 - 79 | Moderate | Moderately modified – Clear community modifications, some impairment of health evident. |

| Category | Score (%) | Rating | Category description |
|---|---|---|---|
| D | 40 - 59 | Low | Largely modified – Impairment of health clearly evident. Unacceptably impacted state. |
| E | 20 - 39 | Very low | Seriously modified – Most community characteristics seriously modified. Unacceptable state. |
| F | 0 - 19 | Critical | Critically modified – Extremely low species diversity. Unacceptable state. |

# 8 DISCUSSION

Biotic indices were determined to be in a seriously modified state largely as a result of poor water quality. When the results of this study are compared to the present ecological status (PES) derived by Kleynhans (2000) the current study suggests that there has been negative influences on the environmental integrity of the aquatic systems found in quaternary catchment B20E. The desired ecological status set out by Kleynhans (2000) is a Class C however the current study found that anthropogenic impacts are altering the current environment away from its desired condition. A report completed by Digby Wells entitled "Surface water specialist study for the Brakfontein area" indicated that there is a deterioration of water quality within the project area. Thus habitat quality is not the primary concern rather the focus is on water quality. It has been identified that sites downstream are experiencing dilution and as such an improvement in biotic indices was seen. This conclusion has been drawn but requires further investigation to determine the exact cause of the poor water quality.

# 9 IMPACT ASSESSMENT

This section presents the findings of the assessment of potential impacts to the aquatic environment associated with the Brakfontein mining operation.

The results of the impact assessment are presented as follows:

- *Sensitive and no-go areas* – The process to delineate areas that are considered sensitive in terms of the aquatic environment and will therefore have to be avoided, as well as maps delineating these areas are presented;
- *Significance assessment* – An assessment of the significance of anticipated positive and negative impacts to the aquatic environment associated with project activities is provided; and
- *Cumulative impacts* – The results of a high-level qualitative assessment of the potential cumulative impacts of the proposed project and existing and proposed developments in the reasonable future.

## 9.1 Perceived impacts

Upon completion of the aquatic assessment undertaken for the study area the following sensitive and no-go areas have been determined:

- Wilge River; and
- Wilge River tributary

## 9.2 Impact significance assessment

Activities associated with the construction, operation and decommissioning of each component of the Brakfontein mining operation will result in impacts on the aquatic environment.

In order to assess the significance of these impacts, use was made of a semi-quantitative impact assessment methodology which is based on an assessment of the following parameters:

- *Severity* – The magnitude of change from the current baseline status of the affected environmental, socio-economic or heritage aspect;
- *Spatial scale* – The physical area which is impacted on by the potential impact;
- *Duration* – The expected time period during which a potential impact will be experienced; and
- *Probability* – The likelihood of occurrence of the impact, based on knowledge of the operating conditions and the type of activities that will be undertaken.

The main impacts on the aquatic environment will occur during the operational and construction phases of the mining operation. These impacts were determined to have Medium - High significance. Activities that will result in changes to the aquatic environment and their significant impacts include:

- Close proximity of dumps/storage to water courses.
- Construction of workshops, washing plant and preparation of discard dump area;
- Establishment of infrastructure (i.e. construction laydown yard, vehicle parking area and contractor camps);
- Removal of vegetation and topsoil;
- Vehicular movement;
- Levelling and compaction of surfaces; and
- Box cut mining operation

*Tables summarising the significance of the potential impacts on the aquatic environment during the phases of the project are presented below.*

| **Nature of impact** | **The close proximity of dumps/storage to water courses allows for the introduction of pollutants during rainfall periods.** |
|---|---|
| **Phase** | Operational phase |
| **Description of impact** | Due to the close proximity of the dumps to the Wilge River, during rainfall period's water containing dissolved pollutants will be carried into the aquatic |

| **Nature of impact** | **The close proximity of dumps/storage to water courses allows for the introduction of pollutants during rainfall periods.** | | | | |
|---|---|---|---|---|---|
| | ecosystem.<br>The dumps/storage will contain substances which will be readily dissolved during periods of rainfall. These dissolved substances have the ability to alter the surface water chemistry and could be potentially harmful to aquatic biota. The specific elements which would contribute to reduced water/sediment quality would be an increase in the concentration of dissolved and suspended ions within the water column with specific increases in the concentrations of particular elements located within the dumps/storage. The groundwater report indicates that there is a potential for the storage/waste rock to generate acid mine drainage. For this reason it is essential that the placement of these storage/dumps is outside from the 1/100 year floodlines and at least 100m away from any water course.<br>If these processes were allowed to occur the following impacts on the aquatic systems will be observed:<br>■ Decreased water quality;<br>■ Decreased sediment quality; and<br>■ Reduction in ecosystem integrity. | | | | |
| **Mitigation required** | ■ Pollution control measures;<br>■ Construction of barriers (vegetation, barriers and berms) to prevent rain water runoff from the dumps into the nearby Wilge River;<br>■ Dumps and tailings should be vegetated to reduce runoff and subsequent pollution; and<br>■ A pollution control dam should be placed around storage areas and dumps to prevent any contaminated water from entering into the water courses. | | | | |
| ***Parameters*** | *Severity* | *Spatial scale* | *Duration* | *Probability* | |
| **Pre-Mitigation** | 5 | 3 | 5 | 4 | 52 (Medium - Low) |
| **Post-Mitigation** | 1 | 1 | 4 | 4 | 28 (Low) |
| **Difference pre- and post-mitigation** | -3 | -1 | -1 | 3 | 16 |
| | Comments: Through the creation of pollution control measures a reduced quantity of pollutants will enter into the aquatic ecosystem thus reducing the severity and spatial scales of the impacts. | | | | |
| **Residual impacts** | The surface water quality will be negatively affected during periods of rainfall for the life of the project. However, these impacts can be effectively managed if pollution control measures are implemented. | | | | |
| **Cumulative** | The overall water quality of the Olifants River will be influenced, thus should the | | | | |

| **Nature of impact** | **The close proximity of dumps/storage to water courses allows for the introduction of pollutants during rainfall periods.** |
|---|---|
| **impacts** | impacts occur, further degradation on the impacted Olifants River will occur. |

| **Nature of impact** | **Changes to surface water flow dynamics (quantity and quality) due to the presence of mining infrastructure.** |
|---|---|
| **Phase** | Operational phase, Construction phase |
| **Description of impact** | The clearing of naturally occurring vegetation, levelling of land, creation of hard surfaces and the creation of compacted surfaces to make way for development generates changes to the environment which allows for the alteration of normal drainage patterns. Altered drainage patterns serve to alter the aquatic ecosystems in the following manners:<br>■ Increased runoff due to presence of hard surfaces and removal of vegetation;<br>■ Decreased seepage due to increased runoff;<br>■ Increased erosion due to increased runoff; and<br>■ Increased sediment load of nearby aquatic systems.<br>Activities associated with the workshop and vehicular movements/maintenance creates the potential for substances such as oils and lubricants to leak into the surrounding environment. Once in the environment these substances can be carried into the aquatic ecosystem via water runoff. These substances are known to contain Poly Aromatic Hydrocarbons (PAH's) which have been shown to be persistent in nature. These substances have shown to decrease ecological integrity. The incidence of increased runoff may produce sedimentation in the local river systems thereby altering habitats in water chemistry thereby lowering the ecological status of the associated river systems.<br>If these impacts were to occur the following would be observed in the aquatic ecosystem:<br>■ Decreased water quality;<br>■ Altered flow dynamics; and<br>■ Negative impacts on biodiversity. |
| **Mitigation required** | ■ A storm water management plan should be implemented during the construction phase and operational phase;<br>■ No activities may be allowed within the 1:100 year flood line of the Wilge River and its tributary;<br>■ Clearing of vegetation should be supervised to ensure that no more than the minimum area of land that is needed is cleared; |

| Nature of impact | Changes to surface water flow dynamics (quantity and quality) due to the presence of mining infrastructure. | | | | |
|---|---|---|---|---|---|
| | ■ If erosion occurs, anti-erosion measures should be implemented (gabions);<br>■ Pollution control measures around areas where PAH contamination may occur; and<br>■ Areas around infrastructure should be well vegetated to reduce runoff of pollutants. | | | | |
| ***Parameters*** | *Severity* | *Spatial scale* | *Duration* | *Probability* | *Significant rating* |
| **Pre-Mitigation** | 4 | 3 | 6 | 6 | 72 (Medium-High) |
| **Post-Mitigation** | 2 | 2 | 5 | 5 | 54 (Medium-Low) |
| **Difference pre- and post-mitigation** | -2 | -1 | -1 | -1 | -18 |
| | Comments: By undertaking storm management procedures reduced runoff can be established. This will reduce erosion and reduce the impacts of altered flow dynamics thereby reducing the environmental significance of the impact as well as the spatial scale of the impact. If pollution control measures are implemented to reduce the impact of oils and lubricants no significant impact will occur. | | | | |
| **Residual impacts** | The surface water dynamics will be altered permanently during the life of the project; however, the resulting impacts (i.e. soil erosion and water chemistry) can be limited through the implementation of a storm water and pollution control management plan. | | | | |
| **Cumulative impacts** | Altered flow conditions, the introduction of pollutants and the alteration of water quantity entering into the Olifants River system will negatively impact the aquatic ecosystems thus adding to the already present stresses of low flow and poor water quality conditions. | | | | |

| Nature of impact | Box cut mining operation. |
|---|---|
| **Phase** | Construction and operation phases |
| **Description of impact** | The clearing of naturally occurring vegetation, levelling of land, creation of hard surfaces and the creation of compacted surfaces to make way for development generates changes to the environment which allows for the alteration of normal drainage patterns. Altered drainage patterns serve to alter the flow dynamics in the following manners:<br>■ Increased runoff due to presence hard surfaces and removal of vegetation;<br>■ Decreased seepage due to increased runoff;<br>■ Increased erosion due to increased runoff; and |

| Nature of impact | Box cut mining operation. | | | | |
|---|---|---|---|---|---|
| | ■ Increased sediment load of nearby aquatic systems.<br>Activities associated with vehicular movements/maintenance create the potential for substances such as oils and lubricants to leak into the surrounding environment. Once in the environment these substances can be carried into the aquatic ecosystem via water runoff. These substances are known to contain Poly Aromatic Hydrocarbons (PAH's) which have been shown to be persistent in nature. These substances have shown to decrease ecological integrity.<br>The presence of an open cast mining operation in close proximity to the Wilge River reduces the size of the catchment area and thus the amount of water available to enter into the river system thus adding to the reduced water flow conditions being experienced by the Wilge River system.<br>As rain water mixes into excavated areas the water is considered contaminated and has the potential to negatively affect the surface water quality.<br>If these impacts were to occur the following would be observed in the aquatic ecosystem:<br>■ Decreased water quality.<br>■ Altered flow dynamics.<br>■ Negative impacts on biodiversity. | | | | |
| **Mitigation required** | ■ A storm water management plan should be implemented during the construction phase and operational phase.<br>■ No activities may be allowed within the 1:100 year flood line of the Wilge River and its tributary.<br>■ Clearing of vegetation should be supervised to ensure that no more than the minimum area of land that is needed is cleared.<br>■ If erosion occurs, anti-erosion measures should be implemented (gabions).<br>■ Pollution control measures around areas where PAH contamination may occur.<br>■ Creation of berms and barriers to prevent contaminated water from entering into the surrounding aquatic systems.<br>■ Minimise disturbed areas to limit runoff.<br>■ Ensure backfilled areas are graded to original gradient. | | | | |
| ***Parameters*** | *Severity* | *Spatial scale* | *Duration* | *Probability* | |
| **Pre-Mitigation** | 4 | 7 | 5 | 6 | 90 (Medium - High) |
| **Post-Mitigation** | 4 | 3 | 5 | 6 | 72 (Medium - Low) |
| **Difference pre-** | 0 | 4 | 0 | 0 | -18 |

| Nature of impact | Box cut mining operation. |
|---|---|
| and post-mitigation | Comments: The impacts of the opencast mining operation will continue until rehabilitation has occurred. The impacts of the box cut mining have little to no mitigation measures to improve the impact on the surface water quality and quantity as the pit removes a significant portion of the catchment area. However impacts associated with open cast mining can be minimalized. |
| Residual impacts | The quantity and quality of water entering into the Olifants River system will be reduced thus enhancing low flow and poor water quality conditions the system is already experiencing. |
| Cumulative impacts | Due to the presence of a variety of water users large pressures are placed onto the Olifants River. This operation places further stress on the aquatic environment. |

# 10 MANAGEMENT PLAN

**Table 10-1: Aquatic management plan**

<table>
<tr><th colspan="4">AQUATIC MANAGEMENT PLAN</th></tr>
<tr><td>Context</td><td colspan="3">To maintain and preserve the integrity of the aquatic ecosystems associated with the project area the maintenance of water quality as well as quantity is of a significant nature.</td></tr>
<tr><td>Objectives</td><td colspan="3">The environmental objectives for the aquatic management plan are:<br>■ To prevent direct impacts on the Wilge River and associated river systems; and<br>■ To prevent indirect impacts on water quality and quantity of the river systems.</td></tr>
<tr><td>Risk sources</td><td colspan="3">The following risk sources have been identified:<br>■ The clearance of vegetation;<br>■ Creation of compacted surfaces;<br>■ Occurrence of persistent pollutants;<br>■ Reduction of drainage basin;<br>■ Potential contamination of surrounding aquatic ecosystems; and<br>■ Acid Mine Drainage.</td></tr>
<tr><td>Potential impacts</td><td colspan="3">The potential impacts on surface water systems include:<br>■ Deterioration of water quality and quantity; and<br>■ Negative influences on aquatic integrity.</td></tr>
<tr><td rowspan="2">Management and mitigation actions</td><td>Actions</td><td>Responsibility</td><td>Timeframe</td></tr>
<tr><td>■ Prevent unnecessary removal of vegetation.</td><td>Environmental</td><td>Continuous</td></tr>
</table>

| AQUATIC MANAGEMENT PLAN | | | |
|---|---|---|---|
| | | manager | |
| | ■ Exposed soils must be stabilised with vegetation. | Environmental manager | Continuous |
| | ■ A storm water management plan should be implemented during the construction and operation phases. | Environmental manager | Continuous |
| | ■ Creation of pollution control measures to prevent introduction of persistent/toxic pollutants into the aquatic systems from dumps and vehicular maintenance areas. | Environmental manager | Continuous |
| | ■ Ensure no mining activities occur within the 1:100 flood lines of the Wilge River and its tributary. | Environmental manager | Continuous |
| | ■ Ensure the integrity of the Riparian vegetation. | Environmental manager | Continuous |
| | ■ Design of pillars/supports of river crossings should be made to ensure adequate flow. | Environmental manager | Construction |
| | ■ 100 metre buffer zone from the Wilge River system. | Environmental manager | Continuous |
| | ■ Equipment shall be inspected daily to ensure that leaks or discharges of lubricants, fuels, or hydraulic fluids do not occur. All fuels, lubricants, and hydraulic fluids must be stored and dispensed at least 100m away from the stream bank or outside of the 100-year floodplain. | Environmental manager | Continuous |
| | ■ Minimalize in stream equipment activity. | Environmental manager | Continuous |
| | ■ Create berms and barriers to prevent flow of contaminated water into surrounding | Environmental | Continuous |

| AQUATIC MANAGEMENT PLAN | | | |
|---|---|---|---|
| | aquatic ecosystems. | manager | |
| | ■ Create pollution control measures which include the cultivation of vegetation which will slow down runoff from dumps. | Environmental manager | Continuous |
| | ■ Pollution control dam surrounding dumps/storage which may potentially cause acid mine drainage. The water from these can be used for dust suppression. | Environmental manager | Continuous |
| | ■ Aquatic biomonitoring programme should be implemented. | Environmental manager | Bi - annually |
| ***Performance indicators*** | The performance indicators are:<br>■ A proliferation of aquatic life within the Wilge River;<br>■ Increase in fish stocks common in reference conditions; and | | |
| ***Monitoring and evaluation*** | The following monitoring and evaluation actions are required:<br>■ The environmental manager must evaluate, approve, supervise and monitor the construction activities undertaken by the contractor;<br>■ An independent auditor will be responsible for auditing implementation of the EMP on a quarterly basis; and<br>■ A biomonitoring program must be implemented to monitor the aquatic integrity of the associated systems (Wilge River and its tributaries). | | |

# 11 MONITORING PROGRAMME

## 11.1 Location

The monitoring programme should include sites/locations where biological monitoring has occurred previously. The sites included in this study will be sufficient to include in future monitoring applications during the high flow season.

## 11.2 Parameters

The following parameters should be monitored by qualified specialists.

- *In situ* water quality constituents;
- Habitat integrity;
- Aquatic macro-invertebrates;
- Fish assemblages; and
- Riparian vegetation.

## 11.3 Objectives

The objectives of the monitoring would be to determine the current state of the aquatic ecosystem through the measurement of physical and biological properties. As of this study the baseline data is established and can be used to compare with in future studies as a means to determine if ecological degradation has occurred.

## 11.4 Key performance indicators

Key performance indicators would include the occurrence of particular fish species and abundance of species diversity.

## 11.5 Responsibility

Environmental manager to contract an accredited aquatic ecologist.

## 11.6 Frequency

Biomonitoring activities should occur bi-annually.

## 11.7 Resources

Aquatic specialist.

## 11.8 Reporting structure

A biomonitoring report should be provided annually on completion of the two surveys.

## 11.9 Threshold or limits

If modifications to the system occur a reduced biological diversity will be observed. Proliferation of pollution tolerant species may also be an indication of a deterioration of ecological integrity. If there is further reduction in species diversity further studies should be undertaken which should include water quality analysis as well as the accumulation of pollutants in the sediments.

### 11.10 Corrective action

Bi-annual biomonitoring should be undertaken to ascertain any effects caused by the mine. Should there be any deterioration discovered corrective action should be followed. However if mitigation measures are followed this may be avoided.

## 12 CONCLUSION

The aquatic ecosystems associated with the project area were determined to be in a seriously modified state. The primary concern of would be to prevent further degradation of water quality.

The impacts associated with the study area were determined to be medium – high before mitigation and low after mitigation. The main impacts associated with the project would be modifications of water quantity and quality. Due to the significance of the Olifants River system it is important that mitigation measures set out in this report are followed as to avoid further degradation of this resource. The data from this study will contribute to further studies and can be used to assess whether environmental degradation has occurred as a result of the project. It is further suggested that biomonitoring be conducted bi-annually.

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