Appendix D4

Mine Waste Solutions – Kareerand TSF Extension Project, Aquatic Fauna Impact Assessment

-Clean Stream Biological Services, 2017

ANGLO GOLD ASHANTI
- MINE WASTE SOLUTIONS –
KAREERAND TSF EXTENSION PROJECT

AQUATIC FAUNA IMPACT ASSESSMENT

2017

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1. INTRODUCTION

Background and objectives

Clean Stream Biological Services (CSBS) completed a comprehensive biodiversity assessment of the AngloGold Ashanti's (AGA) Mine Waste Solutions (MWS) area during 2015. The primary deliverable of the 2015 study was the compilation of a Biodiversity Management Plan (BMP) for the MWS section (CSBS, 2015a). As part of this study, various detailed specialist studies (vegetation, terrestrial fauna, aquatic fauna, and biodiversity risk assessment) were performed which provided the foundation for the BMP. A detailed aquatic fauna biodiversity assessment was also performed as part of this process (CSBS, 2015b). It included an assessment of fish, macroinvertebrates and diatoms and their relevant habitats, based on available information (especially previous biomonitoring survey) and a specialist survey conducted in 2015 at representative aquatic sites within this MWS study area.

Mine Waste Solutions (MWS) is a tailing dam reclamation operation situated in the North West Province of RSA, with tailings dams in the Klerksdorp, Orkney, Stilfontein and Hartbeesfontein area being processed. MWS is a subsidiary of AngloGold Ashanti (AGA). Currently tailings from the MWS plant are sent to the Kareerand Tailings Storage facility (TSF). The Kareerand TSF will become a constraint to the capacity of the operation as from the beginning of 2021; to keep within the designed rate of rise the tonnage deposited on the TSF will need to be reduced. In order to maintain operations, it is required to bring further TSF capacity into operation by the beginning of 2021.

It has been identified that the optimum strategy for creating additional TSF capacity is to construct an extension of the existing Kareerand TSF whilst at the same time increasing the final design height of the existing footprint. The extension will be constructed to the west of the existing footprint and the extension footprint will abut onto the existing footprint. In order to bring the TSF extension into operation it will be necessary to both design the TSF extension and to obtain the necessary permits for its construction and operation.

To support the permit applications various specialist studies need to be done and/or updated for the new footprint. The ecological assessment requires an update of the existing studies completed in 2015 by Clean Stream Biological Services. This will require an update of the characterization of the pre-development baseline faunal (including aquatic biota) environment and habitat, related biota and the extent of site related effects.

A vast amount of information on the aquatic fauna (fish and macroinvertebrates) is available for the study area, and especially the potentially receiving primary water body (Vaal River). Clean Stream Biological Services has been performing the aquatic biomonitoring surveys (bi-annually) for AGA since 2006. This information will be used together with information gained during an additional site visit (performed in 2017) to update the existing MWS aquatic biota report (CSBS, 2015b). This report aims to describe the Present Ecological Status (PES) of the aquatic fauna (fish and macroinvertebrates) of the reach of the primary receiving water body to be potentially impacted by the proposed development.

Aquatic ecosystems

An *aquatic ecosystem* can be defined as any unit that includes all of its organisms in a given area, interacting with the physical environment so that a flow of energy leads to clearly defined trophic structure, biotic diversity and material cycles within the system (Odum, 1971). It thus includes all the physical and chemical (abiotic) components in addition to the biological components. The *ecological integrity* of an ecosystem can be defined as the ability of the system to support and maintain a balanced, integrated composition of physico-chemical and habitat characteristics, as well as biotic components, on temporal and spatial scale, that are comparable to the natural or unimpacted state of that ecosystem. It thus refers to the structure and functioning of an ecosystem under natural conditions or a state unimpaired by anthropogenic stresses (Roux, 1999). From the above mentioned, it can therefore be deduced that the overall ecological integrity of a system is determined by four main aspects, namely its physical, physico-chemical and biological (biotic) integrity and energy source input. In nature, these aspects cannot be seen as separate entities, as they are inter-linked in a complicated system wherein they are affected, and to a great extent determined, by one another. If all these aspects were in balance, the biodiversity of the system would be at its optimum. If one component is however disturbed, the others will reflect it. If a fish species is for instant lost from an area, the invertebrate it feeds on can become over-abundant and dominate the system, having an effect on the other invertebrates. This can put extensive pressure on the food source of this particular species, which can result in unnatural high competition with other species, which may be detrimental to the overall biodiversity of the system.

Rivers are furthermore continuum systems, and a river section can be influenced by activities both upstream and downstream. Pollution incidences upstream of a site will have a negative impact not only locally, but can be detrimental to the entire ecosystem (depending on the extent of pollution). A downstream dam wall (physical barrier), or area of very poor water quality (chemical barrier) can prevent fish to migrate upstream for breeding, feeding and recolonisation, which may be detrimental to the upstream biodiversity.

Legal framework

The primary legislation for the protection of South Africa’s water resources is the *National Water Act, 1998 (Act No. 36 of 1998).* The *National Environmental Management Act (NEMA)* (Act 107 of 1998) and the associated Regulations (No R. 982), as amended in December 2014, states that prior to any development taking place within a wetland or riparian area, an environmental authorisation process needs to be followed. *The Environment Conservation Act, 1989 (No. 73 of 1989)* also includes aspects related to the protection of freshwater systems stating that appropriate environmental investigations (EIAs) are mandatory before approval for the “*construction or upgrading of dams, levees or weirs affecting the flow of a river”* will be given by the relevant authority. The new National Environmental Management: Biodiversity Act no. 10 of 2004 sets out a framework for planning the conservation and sustainable use of biological diversity within a broader framework of planning for sustainable development. It provides for the development, monitoring and review of a national biodiversity framework, which shall be a National Biodiversity Strategy and Action Plan (NBSAP) giving effect to the objectives of the Convention on Biological Diversity (CBD). The preparation of bioregional conservation plans, that embody the ecosystem approach of conservation in the context of climatic and geographical characteristics and interaction, is provided for as well as other conservation plans addressing specific components of biodiversity requiring special conservation attention.

2. DESCRIPTION OF PROPOSED ACTIVITY

As described above, Mine Waste Solutions (MWS) is a tailing dam reclamation operation situated in the North West Province, tailings dams in the Klerksdorp-Orkney –Stilfontein –Hartebeestfontein area are being processed. MWS is a subsidiary of AngloGold Ashanti (AGA). Currently tailings from the MWS plant are sent to the Kareerand Tailings Storage facility (TSF) (Figure 1). The Kareerand TSF will become a constraint to the capacity of the operation as from the beginning of 2021. In order to maintain operations, it is required to bring further TSF capacity into operation by the beginning of 2021.

It has been identified that the optimum strategy for creating additional TSF capacity is to construct an extension of the existing Kareerand TSF whilst at the same time increasing the final design height of the existing footprint (Kareerand TFS extension project). The extension will be constructed to the north-west of the existing footprint and the extension footprint will abut onto the existing footprint (Figure 1, yellow polygon). This will entail both increasing the height of the existing footprint and an increase in the area of the TSF (Figure 1). Due to the increase surface area of the extended TSF there will be additional storm water collection dams (Figure 1: blue polygons) to control run off from the dam. East and west drainage channels (unlined) for routing storm water around the TSF (draining to the Vaal River) will also be constructed (Figure 1: purple lines). Potential borrow pits for extraction of soils for rehabilitation of the TSF are also included in this project (Figure 1: brown polygons).

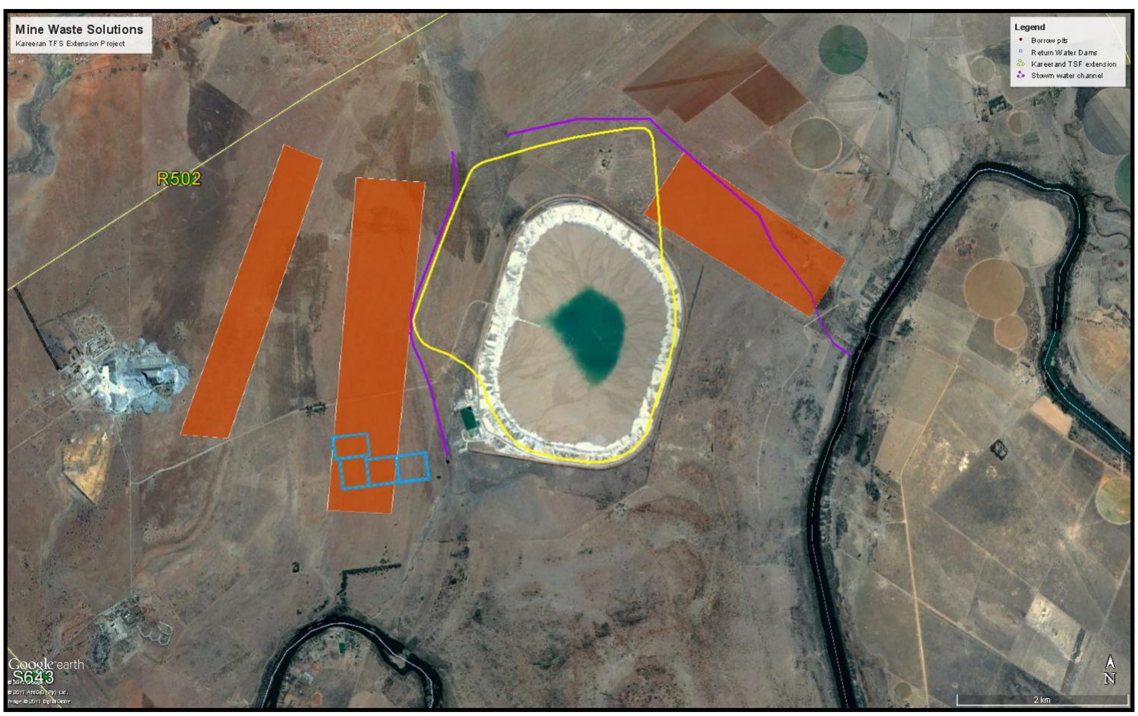

Figure 1: Activities related to proposed Kareerand TFS Expansion project.

3. METHODOLOGY

The assessment of the aquatic biodiversity of the AngloGold Ashanti's Mine Waste Solutions (MWS) operations, and the proposed Kareerand extension area was investigated on the basis of the following components:

3.1 *In-situ* water quality measurements (physico-chemical habitat)

A limited but pertinent suite of water quality variables were considered in order to gain a baseline perspective of water quality of the study area. This is especially important to gain a better understanding of the role of the physico-chemical habitat that forms part of the template for aquatic biota. The following parameters were assessed during biomonitoring surveys and are included in this assessment:

- Dissolved oxygen levels (percentage saturation and mg/l)
- Electrical conductivity
- pH
- Water temperature
- Chlorophyll-*a*

3.2 Environmental toxicity testing

Toxicity testing (as conducted as part of the AGA biomonitoring programme) is applied by exposing biota under laboratory conditions to water sources (pollution control dams and effluent sources) in order to determine the potential risk of such waters to the biota of the receiving water bodies. At least three trophic levels of biota i.e., vertebrates (*Poecilia reticulata*), invertebrates (*Daphnia magna*), bacteria (*Vibrio fischeri*) and/or primary producers (*Selenastrum capricornutum*) are exposed to the samples according to standard procedures under laboratory conditions and thereafter a risk/hazard category is determined by application of the latest DEEEP DWA recommended protocols and hazard classification. This risk category equates to the level of acute risk posed by the selected potential pollution sources on the receiving rivers/streams.

Selected samples are tested on a **screening**[1] level, while others are tested on a **definitive**[2] level. Toxicity testing is performed quarterly at this stage. The frequency and level of testing is guided by the level of toxicity of a sample. If toxicity levels increase, it may become relevant and useful to increase the frequency and level of testing. The frequency and level of toxicity testing (screening vs. definitive) required will be revised annually based on the outcome of the specific year's assessment.

[1] Screening = A screening toxicity test refers to an undiluted (100% concentration) sample. This is usually performed on a sample from the biomonitoring sites in the receiving water bodies (river/streams) to determine if any toxicity is present. This is performed both up- and downstream of the potential impacts to enable the determination of downstream increases or decreases in toxicity.

[2] Definitive = A definitive toxicity test refers to the exposure of test organisms to both the 100% concentration as well as a range of dilutions, generally used to determine the risk of a pollution source that may have a toxicity effect on the receiving water body (such as effluents and PCD's). The range of dilutions are therefore useful in the event that the 100% sample concentration presents acute toxicity, and allows for the determination of a safe dilution factor, to negate acute toxicity effects on the receiving water bodies.

Hazard classification for screening tests (undiluted sample)

(After the determination of the percentage effect[3] (EP), obtained with each of the ***battery of toxicity screening*** tests performed, the sample is ranked into one of the following five classes:

Class I	**No acute/chronic environmental toxicity hazard -** none of the tests shows a toxic effect
Class II	**Slight acute/chronic environmental toxicity hazard -** a statistically significant percentage effect is reached in at least one test, but the effect level is below 50%
Class III	**Acute/chronic environmental toxicity hazard -** the percentage effect level is reached or exceeded in at least one test, but the effect level is below 100%
Class IV	**High acute/chronic environmental toxicity hazard -** the 100% percentage effect is reached in at least one test
Class V	**Very high acute/chronic environmental toxictiy hazard -** the 100% percentage effect is reached in all the tests

Hazard classification system for definitive tests (undiluted sample plus range of dilutions)

The samples are classified into one of the following five classes on the basis of the highest toxicity unit (TUa) found in the ***battery of toxicity definitive tests*** performed. The toxicity unit is a function of the L(E)C50, where (TUa) = 100/L(E)C50. The 50% Lethal/Effective concentration (LC50 or LE50) is the linear calculated (derived) concentration at which a 50% mortality or inhibition rate can be expected. Hence, the lower this value is, the higher the acute toxicity level. Conversely, the higher the toxicity unit (TUa) is, the higher the acute toxicity level is. The conversion of L(E)C50 values to TUa values are therefore merely done to achieve a classification scale of increasing values related to increasing toxicity risks:

Class I	**No acute/chronic environmental toxicity hazard -** none of the tests shows a toxic effect
Class II	**Slight acute/chronic environmental toxicity hazard -** the percentage effect observed in at least one toxicity test is significantly higher than in the control, but the effect level is below 50% (TU is <1)
Class III	**Acute/chronic environmental toxicity hazard -** the L(E)C50 is reached or exceeded in at least one test, but in the 10 fold dilution of the sample the effect level is below 50% (TU is between 1 and 10)
Class IV	**High acute/chronic environmental toxicity hazard -** the L(E)C50 is reached in the 10 fold dilution for at least one test, but not in the 100 fold dilution (TU is between 10 and 100)
Class V	**Very high acute/chronic environmental toxcity hazard -** the L(E)C50 is reached in the 100 fold dilution for at least one test (TU is >100)

Weighting: Each sample is furthermore weighed according to its relative toxicity levels (out of 100%). Higher values indicate that more of the individual tests indicated toxicity within a specific class.

Selected samples are tested in the vicinity of the existing Kareerand TFS as –part of the AGA biomonitoring programme. This information will be provided in this report to gain insight into the current environmental toxicity hazards associated with the Kareerand

[3] EP (Percentage effect) = an effect measured either as a mortality rate or inhibition rate (depending on the type of test). A 10% effect is regarded as a slight acute toxicity for *Daphnia* and guppies, while a 20% effect is regarded as a slight acute toxicity for algae and bacteria (*Vibrio*). A 50% effect is regarded as an acute toxicity for all of the tests (daphnia, guppies, algae and bacteria)

TSF, and hence assist in predicting potential impacts associated with the proposed expansion project.

3.3 Aquatic habitats

The aquatic habitats form the template of the biological composition of any system. If both the physical and physico chemical (water quality) components are undisturbed, and in good condition, the biological composition of the system can be expected to be normal and one can expect a high biodiversity in the system. If one or both habitat components are however degraded, due to human activities, the biota of the system will reflect this by a loss firstly of the most intolerant species (Davies & Day, 1998). Under critical conditions, the biodiversity of a system can be reduced to nothing resulting in a sterile aquatic system.

The habitat requirements are different for each component of the aquatic ecosystem (e.g. fish vs. invertebrates) and also vary between different species of the same component (e.g. Sharptooth catfish vs. Largescale yellowfish). Each species may furthermore have different physical habitat preferences and water quality tolerances during different life stages (egg, larvae, juveniles, adults). The habitat diversity and quality are therefore assessed using different parameters or indices for different components of the aquatic ecosystem. Habitat Cover Ratings (HCR) and Site Habitat Integrity (SHI) indices were done to assess the habitat availability and condition in support of the interpretation of the Fish Response Assessment Index (FRAI). The Integrated Habitat Assessment System, ver.2 (IHAS) was also performed to supplement the SASS5 (macro-invertebrate) assessment and is discussed in the relevant section.

3.4 Diatoms

Diatoms are of great ecological importance because of their role as primary producers, and they form the base of the aquatic food web. They usually account for the highest number of species among the primary producers in aquatic systems. Diatoms have also been shown to be reliable indicators of specific water quality problems such as organic pollution, eutrophication, acidification and metal pollution, as well as for general water quality.

Epilithon (diatoms that inhabit gravel, stone and bedrock) were sampled at selected sites as part of biomonitoring and biodiversity assessments and spill investigation. Epilithic diatom samples were collected by scrubbing the substrate with a toothbrush and rinsing both the brush and the substrate with distilled water. The sample suspension was then poured into a container and preserved with Ethanol (70%) with a volume of 20% of the total sample. Diatom sample preparation for slide mounting and standard laboratory procedures were followed as outlined in Taylor *et al*. (2007b).

3.5 Macro-invertebrates

Aquatic macroinvertebrates are especially valuable indicators of water quality alteration in aquatic ecosystems. Macro-invertebrates were assessed with the use of the South African Scoring System Version 5 (SASS5) sampling protocol. The SASS5 protocol is a site-specific index, which, together with an associated habitat index (IHAS) gives a general perspective of the biotic integrity (based on macro-invertebrates) and the impact of water quality on the biotic integrity of the specific sites (Thirion *et al*., 1995; Dickens and Graham, 2001). Integrated Habitat Assessment System (IHAS version 2) (McMillan, 1998) takes into account the habitat sampled as well as the stream characteristics and is designed to pose very specific questions to operators. The IHAS scores were used during this assessment to provide an indication of the habitat availability and condition for invertebrates and hence to serve as a guide for expected taxa.

3.6 Fish

Fish species differ in their relative tolerance towards changes in the environment. They react to both changes in their physical as well as their physico-chemical (water quality) habitats, and are therefore good indicators of environmental condition. Fish assemblages are therefore also widely used to monitor changes in the environment. The study will aim to identify the presence/potential presence of any fish species with high conservation potential, or indicator species of ecological integrity.

Fish sampling was performed at representative sites in the study area using a SAMUS electrofisher. All representative habitat types (biotopes) were sampled to gain a representative fish sample of the site. All fish were identified up to species level and returned to the river.

The determination and description of the present ecological status (PES) of the aquatic ecosystems in the study area, in terms of fish, was done according to the methodology described for River EcoClassification during Reserve Determinations (Kleynhans & Louw, 2008) using the Fish Response Assessment Index (FRAI) (Kleynhans, 2008). The results were then used to classify the present state of the fish assemblage into a specific descriptive category (A to F) (Table A1).

3.7 Impact assessment

The potential impacts or risks (pre-mitigation and post-mitigation[4]) associated with the proposed development were assessed based on the following criteria (relative ranking proved in brackets):

- **Applicable phase: Construction, Operational, (Decommissioning/Closure).**
- **Nature of impact:** Provides a description of the expected impacts.

<u>CONSEQUENCE (considers extent, duration and intensity)</u>

- **Extent of impact:**
  - Site: Effect limited to site and its immediate surrounds (1).
  - Local: Effect limited to 3 to 5km of the site (2).
  - Regional: Effect will have an impact on a regional scale (3).
  - National: Effect will have an impact on national scale (4)
  - International: Effect will have an impact internationally (5).
- **Duration of impact:**
  - Short: Effect last for a period of 0 to 5 years (1).
  - Medium: Effect continues for a period between 5 and 10 years (2).
  - Long: Effect will cease after operational life of the activity either because of natural process or by human intervention (3).

[4] **Residual impacts** are defined as those **impacts** that remain following the implementation of the mitigation measures proposed.

  - Permanent: Where mitigation either by natural process or human intervention will not occur in such a way or in such a time span that the impact can be considered transient (4).
- **Intensity of impact:**
  - Low: The impact affects the environment in such a way that natural, cultural and social functions and processes are not affected (1).
  - Medium: Where the affected environment is altered but natural, cultural and social functions and processes continue albeit in a modified way (3).
  - High: Where the natural, cultural or social functions or processes are altered to the extent that it will temporarily or permanently cease (5).

<u>LIKELIHOOD (considers probability and frequency)</u>

- **Probability:**
  - Improbable: Less than 33% chance of occurrence (1)
  - Probable: Between 33 and 66% chance of occurrence (2).
  - Highly probable: Greater than 66% chance of occurrence (3).
  - Definite: Will occur regardless of any prevention measures (4).
- **Frequency**:
  - Annually or less: Impact occurs at least once a year or less frequently (1)
  - 6 Moths: Impact occurs at least once in 6 moths (2)
  - Monthly: Impact occurs at least once a month (3).
  - Weekly: Impact occurs at least once a week (4).
  - Daily: Impact occurs daily (5).

SIGNIFICANCE (considers consequence and likelihood):

  - Low: Where the impact will have a relatively small effect on the environment and will not have an influence on the decision.
  - Medium: Where the impact can have an influence on the environment and the decision and should be mitigated.
  - High: Where the impact definitely has an impact on the environment and decision regardless of any possible mitigation.
- **Status**:
  - Positive: Impact will be beneficial to the environment.
  - Negative: Impact will not be beneficial to the environment.
  - Neutral: Positive and negative impact.
- **Confidence:**
  - Low: It is uncertain whether the impact will occur
  - Medium: It is likely that the impact will occur.
  - High: It is relatively certain that the impact will occur.
- **Mitigation:** Provides recommendations for mitigation measures.
- **Significance post mitigation**: Describes the significance after mitigation.

The expected **Cumulative** impacts of the proposed activity is also described qualitatively.

4. RESULTS & DISCUSSION

4.1 Study Area

The initial 2015 biodiversity study comprised the entire AngloGold Ashanti's Mine Waste Solution operational area (Figure 2). The sites (and study area) assessed during the 2015 study is also applicable to the proposed Kareerand TSF extension project (Table 1, Figure 2). Additional sites were also included in the current report (from the biomonitoring programme and once-off specific survey for Kareerand extension TSF project) (Table 1, Figure 2). The primary aquatic ecosystems of concern within the MWS operational area (and the current and proposed Kareerand TSF activities) included the Vaal River and its Koekemoer Spruit tributary. An unnamed seasonal drainage line also drains towards the south away from the Kareerand TSF. This stream is referred to in this report as the Kareerand tributary, and sites were also selected within this stream. The Droë Spruit forming the most eastern boundary of the MWS study area is an ephemeral system with no notable aquatic biota, while the Schoon Spruit to the west falls outside of the MWS study area.

The MWS operational area falls within the water drainage region (water management area) C, and more specific in secondary catchment C2. According to the Ecoregion Classification for South African Rivers the river in the study area falls within the Highveld (11) category.

For the purpose of this aquatic biodiversity assessment, the aquatic ecosystems of the study area were divided into the following zones:

A) Vaal River ecosystem: Perennial lotic ecosystem
B) Koekemoer Spruit ecosystem: Non-perennial (seasonal) lotic ecosystem
C) Kareerand tributary: Non-perennial drainage line.

Table 1: Sites used for the assessment of MWS aquatic biodiversity and Kareerand TSF extension project.

Aquatic Zone	Site name	Other names*	Site description	Latitude	Longitude	Sub-quaternary (SQ) Reach	Eco Region
A) Vaal River	Vaal1	SR Drift	Vaal River in the upper reaches of the MWS study area. Upstream of all potential Kareerand TSF expansion impacts.	-26.888406°	26.926623°	C23L-1845	11.08
	Vaal1B		Vaal River between sites Vaal1 and Vaal2, area potentially impacted by proposed development (east channel, eastern borrow pit, TSF extension)	-26.951416°	26.908510°	C24B-1817	11.08
	Vaal2	VR-US	Vaal River in the middle reaches of the MWS study area, upstream of Koekemoer Spruit. Downstream of most proposed impacts.	-26.936502°	26.850588°	C24B-1817	11.01

	Vaal3		Vaal River downstream of the MWS operational area, downstream of Koekemoer Spruit and all potential impacts associated with proposed Kareerand TFS expansion project.	-26.963952°	26.752748°	C24B-1868	11.01
	Vaal 4	VR-DSA	Vaal River 8km downstream of site Vaal3, downstream of all MWS activities.	-27.010634°	26.698774°	C24B-1868	11.01
B) Koekemoer Spruit	KS1	KS-US	Koekemoer Spruit in the upper reaches of the MWS study area.	-26.804030°	26.825849°	C24A-1787	11.01
	KS2		Koekemoer Spruit, downstream of northern MWS portion operational area, upstream of Kareerand TSF activities.	-26.832857°	26.832383°	C24A-1787	11.01
	KS R502		Koekemoer Spruit, upstream of southern MWS portion operational area, upstream of Kareerand TSF activities.	-26.890656°	26.813598°	C24A-1787	11.01
	KS3		Koekemoer Spruit adjacent to MWS activities, including current and proposed Kareerand TSF activities.	-26.903059°	26.817949°	C24A-1787	11.01
	KS4	MWS-ISO4	Koekemoer Spruit downstream of most MWS activities, including current and proposed Kareerand TSF activities.	-26.926086°	26.815779°	C24A-1787	11.01
	KS5	KS-DS, KS-Vaal	Koekemoer Spruit in the lower reaches of the MWS study area just before Vaal River confluence (downstream of all MWS activities).	-26.937901°	26.815251°	C24A-1787	11.01
C) Kareerand tributary	Karee-RWD		Existing return water dam (RWD) at current Kareerand TSF (toxicity testing site)	-26.899672°	26.880924°	n/a	n/a
	Karee US Dam		Existing dam in Kareerand tributary downstream of current Kareerand TSF (toxicity testing site)	-26.902202°	26.877538°	n/a	n/a
	Karee DS Dam		Existing dam in Kareerand tributary downstream of current Kareerand TSF (toxicity testing site)	-26.905569°	26.876917°	n/a	n/a
	Karee-Vaal		Unnamed stream (Kareerand tributary) draining away from the Kareerand TSF, just before inflow into Vaal River.	-26.918286°	26.868002°	n/a	11.01

*As referred to in other reports (such as biomonitoring, spill investigations, etc.).

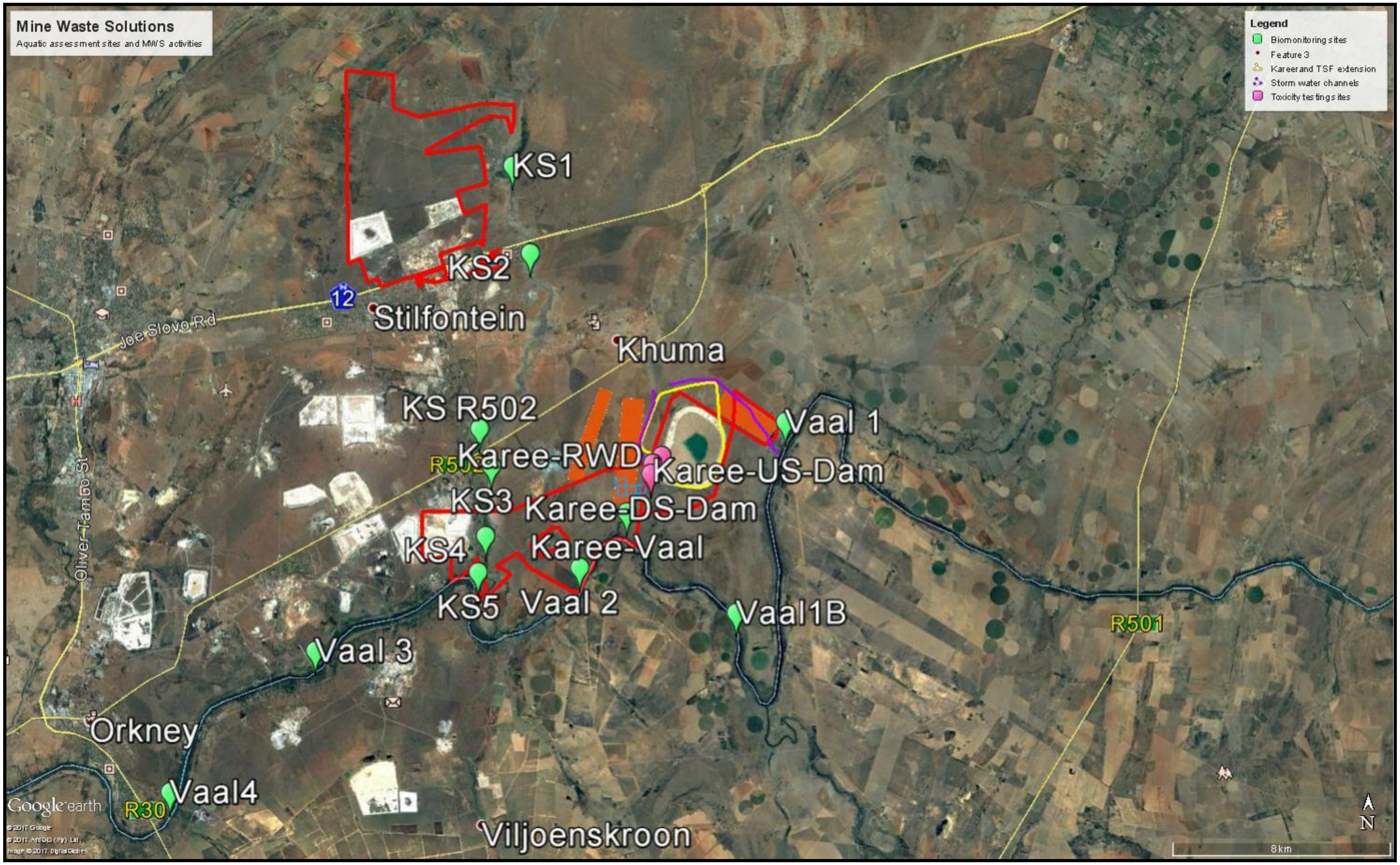

Figure 2: Aquatic ecosystems and sampling sites (Mine Waste Solutions, including current and proposed Kareerand TSF activities).

4.2 Background, PES and EI-ES

A) Vaal River

The Vaal River in the study area falls in the “Middle Vaal” water management area and flows in a westerly direction between the Upper and Lower Vaal water management areas, draining towards the Orange River. The climate over the Middle Vaal area is temperate with frost occurring in the winter and is generally semi-arid. Mean-annual rainfall in this area ranges between 700 mm (south-east) and 400 mm (west) and the potential evaporation can be as high as 1900 mm per annum, well in excess of the rainfall. Land-use in the area is characterised by extensive dry land cultivation, livestock farming in the natural grassland areas, some urban areas and numerous mines in some areas. About 40% of the total water requirements in the WMA are for irrigation, nearly 30% for urban and industrial use and about 20% for mining (DWAF, 2003).

The three Vaal River sub-quaternary reaches of concern in the MWS study area are C23L-1845, C24B-1817 and C24B-1868 (Table 1, Figure 2). Based on the recent desktop assessment (DWS, 2013) the present ecological status (PES) of the Vaal River reaches of concern in the study area range between a category B (largely natural) and D (Largely modified), while the ecological importance (EI[5]) and ecological sensitivity (ES[6]) range between moderate and high (Table 2). The PES decreases incrementally downstream (category B, then C and then D) within the study area, indicating downstream deterioration due to an increased gradient of impacts and users.

Table 2: Desktop PES, EI and ES results for reaches of concern in the MWS study area (DWS, 2013).

River	SQ	PES	EI	ES	Sites in reach
Vaal	C23L-1845	B (Largely natural)	Moderate	Moderate	Vaal1
	C24B-1817	C (Moderately modified)	High	High	Vaal1B, Vaal2
	C24B-1868	D (Largely modified)	Moderate	High	Vaal3, Vaal4
Koekemoer	C24A-1787	E (Seriously modified)	Moderate	High	KS1, KS2, KS3, KS4 and KS5

B) Koekemoer Spruit

The Koekemoer Spruit sub-quaternary (SQ) reach of concern in the MWS study area is C24A-1787. The desktop present ecological status (PES) of this reach (DWS, 2013) is an E (seriously modified), while the ecological importance (EI) is classified as moderate and the ecological sensitivity (ES) is high (Table 2).

The Koekemoer Spruit originates on the farms Rooipoort 354IP and Lustfontein 346IP about 28km north of the point where the Koekemoer Spruit crosses the N12, just to the east of the tailings dam complex. The Kromdraai Spruit, a tributary of the Koekemoer

[5] Ecological importance of a river as its importance in order to maintain biological diversity and ecological functioning on a local and wider scale.
[6] The ecological sensitivity (or fragility) refers to a river’s ability to resist disturbance and its capability to recover from disturbances once they have occurred.

Spruit originates to the north of the Koekemoer Spruit and drains to the east of the Koekemoer Spruit until it joins the latter stream about 3,5km to the north of the point where the Koekemoer Spruit crosses the N12. From the confluence with the Kromdraai Spruit no other stream of note joins the Koekemoer Spruit until it flows into the Vaal River about 16.5 km further downstream. The Koekemoer Spruit joins the Vaal River about 6km downstream of Vermaasdrift.

Indications are that the Koekemoer Spruit used to be predominately a non-perennial stream until 1959 when excess underground water from the gold mining operations was discharged into the stream, creating perennial stream sections. The Koekemoer Spruit upstream of the discharge points of excess mine water is still non-perennial. The lower reaches of the river are currently supplemented by underground mine water.

Treated or untreated sewage effluents from Stilfontein Municipality and Pioneer Sewerage Works, including effluent from Enviroclear are pumped in the Koekemoer Spruit where it crosses the Khuma road. These two discharges are the only perennial sources of water in the lower reaches of the Koekemoer Spruit (DWAF, 2006).

Untreated sewage effluent was being discharged at the Khuma road juncture into the Koekemoer Spruit during a biodiversity audit that was performed on 22 May 2015. A number of open manholes along the townships raw sewerage pipeline were also reported to overflow into the Koekemoer Spruit between KS2 and KS3. Partly cleaned spills of tailings material were also noted in the Koekemoer Spruit, especially in the area between KS3 and KS4. These spills emanated from the Buffels Gold Mine and its Tailings Dams 1 to 4. It is furthermore believed that this stream may receive a significant amount of affected sub-surface flow from old unrehabilitated mining areas, also notably between KS1 and KS2 from the MWS Tailings dams MWS2, MWS4 and MWS5 as well as the surrounding unrehabilitated areas as well as the Margaret shaft area.

Clean Stream Biological Services was commissioned to assess the potential impact and toxicity hazard associated with the pipeline spill on the Koekemoer Spruit that took place on the 27th of August 2013, following the theft of bolts at pipe joints from a water conveyance on the banks of the Koekemoer spruit. The pipe carries residue material from Mine Waste Solutions 1B Gold Plant to Kareerand TSF. The extent of the spillage is approximately 1.6 km of the Koekemoer Spruit covering an area of approximately 1 ha. The damaged pipe stopped leaking approximately 2 to 3 hours after the spillage commenced (personal communication, Mr. Joël Malan). AngloGold Ashanti expediently constructed a dam wall directly downstream from the spill in the Koekemoer Spruit, which allows the lateral passage of water but appears to have successfully contained the majority of the silty residue material. The following conclusions were made from the August 2013 aquatic ecosystem impact assessment, with reference to temporal variation as observed since February 2013:

- The impact of the spill, on the biotic integrity of the Koekemoer Spruit, was severe in the direct downstream vicinity. This section of the stream was completely devoid of fish and limited to only the most tolerant macro-invertebrate taxa.
- The impact appears to be both habitat related (sedimentation) and water quality related.
- It appears that the biotic integrity was fully restored, on a spatial scale, before the confluence of the Koekemoer Spruit and the Vaal River.

- The Koekemoer Spruit had no distinct impact to the biotic integrity of the Vaal River at the time of sampling.
- Water toxicity was acutely toxic directly downstream from the spill.
- The toxicity of water from the Koekemoer Spruit was restored to no acute/chronic hazard before its confluence with the Vaal River.
- Sediment had a high chronic toxicity in the direct vicinity of the spill and a chronic toxicity upstream and towards the temporary dam wall.
- Sediment toxicity was restored to no chronic hazard, on a spatial scale, before the confluence of the Koekemoer Spruit and the Vaal River.

4.3 *In-situ* Water quality

The primary purpose of this section is to provide a general indication of the prevailing physico-chemical habitat (water quality) as a template for sustaining aquatic biota diversity (this is not a comprehensive surface water quality assessment, which should be conducted as a separate specialist study). This assessment is primarily based on most recent biomonitoring studies (2017-03 and 2017-09) as well as the aquatic specialist survey conducted as part of the MWS Kareerand Extension project (2017-11).

A) Vaal River ecosystem

The Catchment Management Strategy for the Schoon Spruit and Koekemoer Spruit (DWAF, 2006) indicated that based on water quality guideline compliance (all users), the middle Vaal River (Orkney weir) are classified as *tolerable* for sulphates, *acceptable* for chlorine and *ideal* for pH, sodium, manganese, magnesium, iron, fluoride, aluminium and phosphorus.

Based on *in-situ* water quality measurements during recent surveys, the electrical conductivity (EC) ranged between 31.0 mS/m (Vaal 1: 2017-03) to 86.1 mS/m (Vaal 1B: 2017-11) in this reach of the Vaal River (Table 3). The EC levels generally remain mostly consistent on a spatial scale throughout this reach (regression line indicated slight downstream increase), not indicating specific areas of concern (inflow of high salinity sources) (Figure 3). Temporal variation is also notable, with salinity levels being lower during the wet season when higher flows dilute salt concentration (Table 3).

The pH in the reach ranged between 7.3 (Vaal2:2017-09) and 8.9 (Vaal 1B: 2017-11) during the 2017 monitoring period (Table 3). The pH also remained fairly constant on a spatial scale, with regression line indicating a slight downstream decrease in pH (Figure 4). All sites remained within the target for fish health (between 6.5 and 9.0) during the 2017 period and it is expected that most aquatic species will tolerate and reproduce successfully within this pH range (DWAF, 1996) (Figure 3).

The dissolved oxygen levels in this section of the Vaal River measured above the guideline (>5mg/l) as set by Kempster et al. (1982) and should therefore not be limiting to aquatic biota (Table 3, Figure 5). On a spatial scale the oxygen level indicated a general downstream increase between sites Vaal1 and Vaal1B, and again decreasing towards sites Vaal2 and Vaal4.

The Vaal River is a major resource in terms of drinking water supply and also supports farming. It is therefore important to quantify the effect of mining activities, in terms of nutrient enrichment, on this important resource. Chlorophyll-*a* was tested for the first time as part of the biomonitoring programme during the March 2015 survey and thereafter on a bi-annual schedule. From the data it appears that the Vaal River upstream from AGA-MWS activities is already in a trophic status of *eutrophic* (on 2 occasions) to hypertrophic (on three occasions) as measured at site Vaal1 (chlorophyll-*a* of 27, 51, 85, 85, 43 & 20 µg/l). A site further downstream of all AGA Vaal River operations (including MWS) indicated a general further increase towards hypertrophic levels. This is firstly an indication that activities upstream from MWS activities has already led to significant nutrient enrichment and that mining activities cannot be ruled out as a contributing factor to further increased levels. It must be noted that AGA (including MWS) is not the only water user between these sites and that these results are based on a single survey only. The nuisance factor of algal bloom activity in this reach is considered to be serious.

Table 3: *In-situ* water quality variables measured at the time of sampling at the selected sites in the Vaal River system (March, September and November 2017 surveys).

Monitoring site: Survey	EC (mS/m)	pH	Oxygen saturation (%)	Dissolved oxygen (mg/l)	Water temp (ºC)
Vaal 1:2017-03	34.8	8.5	101.6	7.6	22.2
Vaal 1:2017-09	81.2	8.8	108.1	9.1	21.2
Vaal1B: 2017-11	86.5	8.9	145.4	11.8	23.8
Vaal 2:2017-03	31.0	8.7	137.8	10.0	24.1
Vaal 2:2017-09	80.1	7.3	85.5	7.0	19.2
Vaal 4:2017-03	33.4	8.7	118.1	8.6	24.0
Vaal 4:2017-09	84.5	7.7	83.4	7.5	18.9

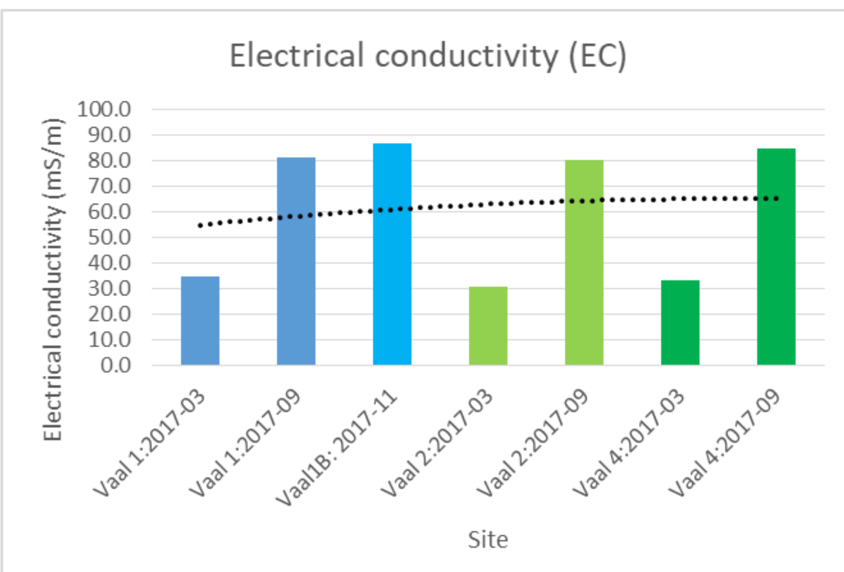

Figure 3: Electrical conductivity (EC) measurements at selected sites in the Vaal River reach (2017surveys)

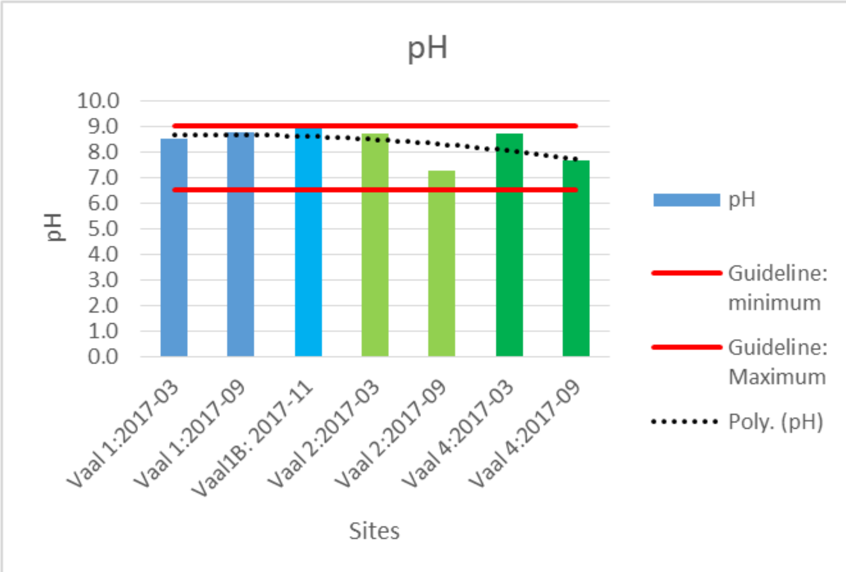

Figure 4: pH measurements at selected sites in the Vaal River reach (2017 surveys)

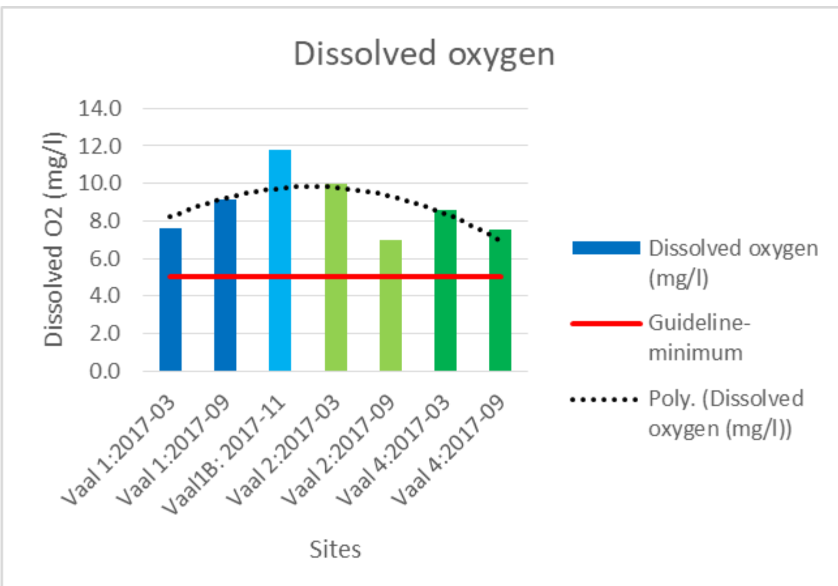

Figure 5: Dissolved oxygen measurements at selected sites in the Vaal River reach (2013 to 2015)

B) Koekemoer Spruit ecosystem

The Catchment Management Strategy for the Koekemoer Spruit (DWAF, 2006) indicated that based on water quality guideline compliance (all users), the Koekemoer Spruit ecosystem is classified as *unacceptable* for sulphate, and only *tolerable* for sodium, chloride, manganese and phosphorus while it is *acceptable* for magnesium and iron, and *ideal* for pH, fluoride and aluminium.

Due to the seasonal nature of the Koekemoer Spruit, many sites are often dry at the time of sampling. Based on the 2017 surveys *in-situ* water quality measurements the electrical conductivity (EC) ranges between 72.5 mS/m (KS2:2017-03) and 148.4 mS/m (KS R502:2017-11) in this reach of the Koekemoer Spruit indicating definite evidence of salinisation as a result of anthropogenic activities (Table 4, Figure 6). High EC levels were already evident in the upper reaches (site KS2), downstream of MWS northern section but upstream of the MWS southern section (including current Kareerand TSF). No further notable spatial increase in salinity (as measured in EC) was observed in the Koekemoer Spruit during 2017 (Figure 6). The pH in the reach is generally circum-neutral to alkaline, ranging between 6.7 and 8.1 during the 2017 surveys (Table 4). During this period it fell within the target for fish health (6.5 and 9.0) (DWAF, 1996). It can therefore be expected that pH levels should not have been limiting to aquatic biodiversity in this period. Regression analyses indicated that the pH levels generally decrease slightly downstream (Figure 7).

The dissolved oxygen levels of the Koekemoer Spruit often exceeded the guideline (>5mg/l) as set by Kempster *et al.* (1982) (especially in the upper reaches) and it can therefore be expected that this water quality variable will also result in limiting conditions for aquatic biodiversity (Figure 8). The low oxygen level is probably due to organic enrichment and/or the proliferation of algae. As previously noted, much untreated sewage water often enters the Koekemoer Spruit.

Table 4: *In-situ* water quality variables measured at the time of sampling at the selected sites in the Koekemoer Spruit system (March, September and November 2017 surveys).

Monitoring site: Survey	EC (mS/m)	pH	Oxygen saturation (%)	Dissolved oxygen (mg/l)	Water temp (ºC)
KS2:2017-03	72.5	8.1	52.2	4.1	20.1
KS2:2017-09	137.6	7.2	34.0	3.0	16.8
KS R502:2017-11	148.4	7.4	36.0	2.9	24.4
KS4:2017-03	131.4	6.7	81.3	7.1	17.7

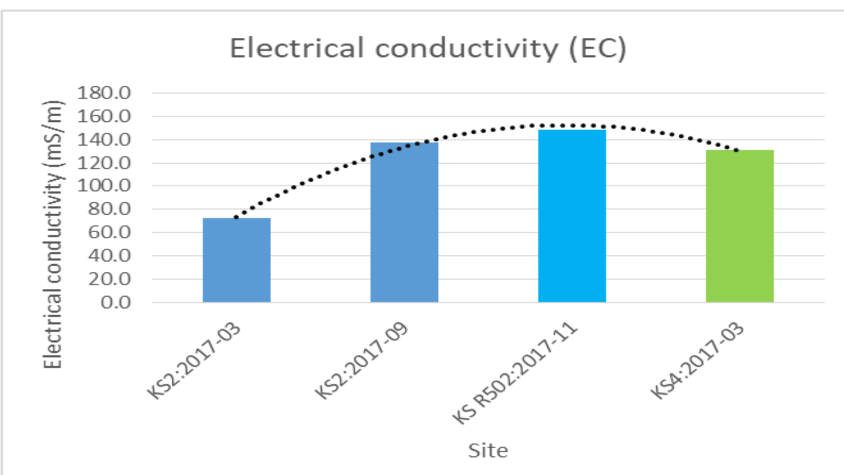

Figure 6: Electrical conductivity (EC) measurements at selected sites in the Koekemoer Spruit reach (2017surveys)

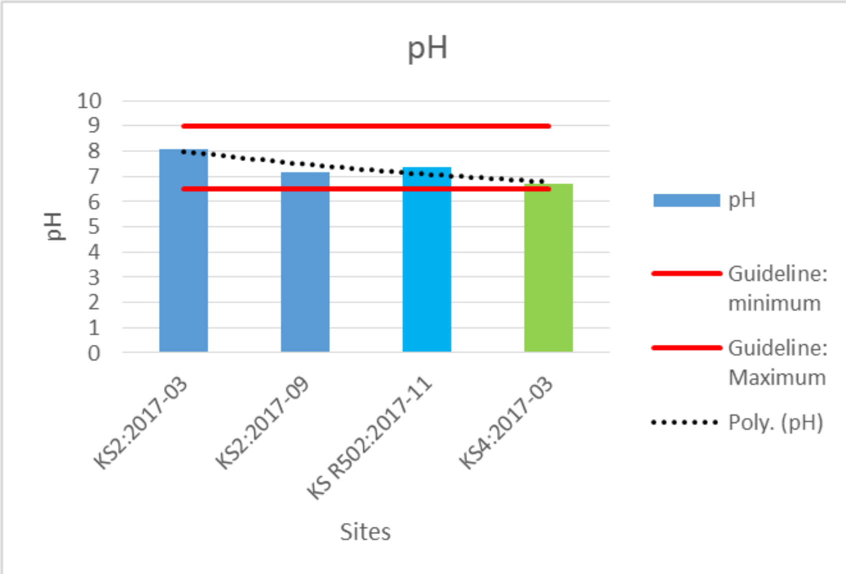

Figure 7: pH measurements at selected sites in the Koekemoer Spruit reach (2017 surveys)

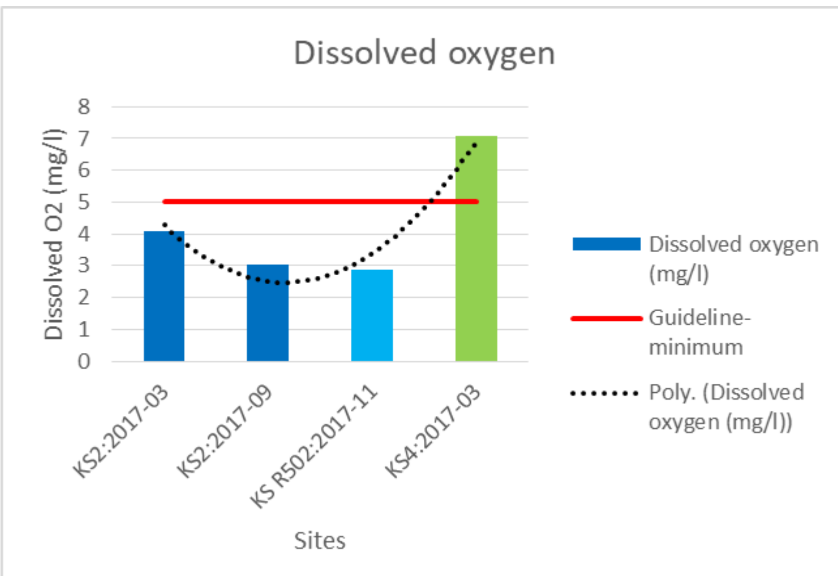

Figure 8: Dissolved oxygen measurements at selected sites in the Koekemoer Spruit reach (2013 to 2015)

C) Kareerand tributary

The Kareerand tributary is highly seasonal and therefore generally not suitable for the application of biomonitoring protocols. A single site (Karee-Vaal) was sampled in the lower reached close to the Vaal River during the 2017-11 survey to gain some insight into the conditions prevailing in this stream. Toxicity testing samples are also collected from some sites around the current Kareerand TSF, which is in close proximity to this drainage line (ref ro section 3.4 for more detail regarding these sites).

A very high EC level of 540 mS/m was measured at site Karee-Vaal during November 2017. This is an indication that some sources of high salinity is entering this drainage line, and that it then contributes to salt loads in the Vaal River. Some probable sources of pollution that may impact this stream include Khuma township and the existing Kareerand TSF (Figure 2). MWS should further investigae and ensure that no spills or seepage from the Kareerand TSF is reaching this stream. The high salinity of this stream may be a limiting factor to biotic integrity.

A pH level of 7.4 was measured at this site during November 2017, indicating that pH should not be limiting for aquatic fauna. Dissolved oxygen measured 6.9 mg/l during November 2017 and should also not be limiting to biotic integrity.

4.4 Environmental toxicity testing

The latest (September 2017) environmental toxicity testing survey indicated that the Kareerand operations return water dam (Karee-RWD) was of a very high acute/chronic environmental toxicity hazard (Class V), with a very high safe dilution ratio of 0.1% required to negate potential impacts. It appears that this hazard was largely mitigated at the time of sampling as the downstream dams measured no acute/chronic environmental toxicity hazard (Class I) at Karee-US-Dam and slight acute/chronic environmental hazard (Class II) at Karee-DS-Dam. Since the inception of toxicity testing at Kareerand TFS, hazards are consistently identified at Karee-RWD and Karee-US-Dam (Figure 9). It is however already clear that the hazards have mostly been negated at the most downstream pollution control dam (Karee-DS-Dam), which has only showed a few incidences of hazards since the onset of monitoring. High EC levels are also often measured at these sources (460 mS/m at site Karee-RWD during September 2017), indicating that they may be potential contributors to the high EC levels observed in the lower Kareerand tributary at site Karee-Vaal.

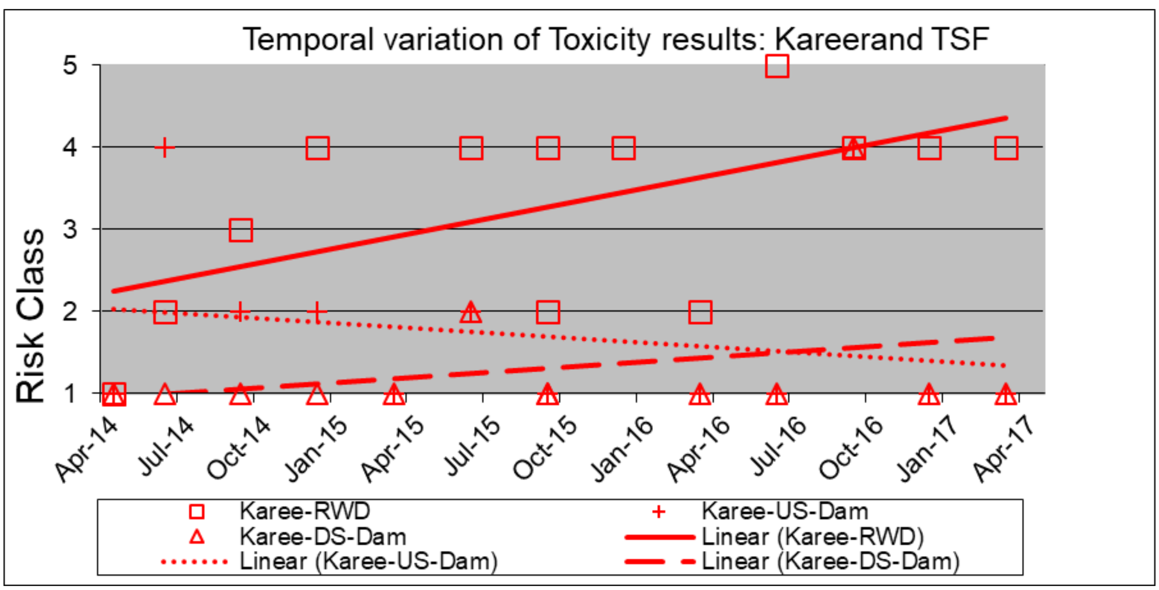

Figure 9: Temporal results of environmental toxicity tests (risk class) at existing Kareerand TSF.

4.5 Diatoms

Diatoms are of great ecological importance because of their role as primary producers, and they form the base of the aquatic food web. They usually account for the highest number of species among the primary producers in aquatic systems. Diatoms have also been shown to be reliable indicators of specific water quality problems such as organic pollution, eutrophication, acidification and metal pollution, as well as for general water quality.

Selected sites in the study area were assessed during March 2015 to gain some indication of the diatom diversity and assist in determining the general water quality of the reaches of concern. No additional diatom assessments were performed as part of the current (Kareerand TSF extension) of biomonitoring surveys, and the results reflected below therefore refers to the 2015 study.

The European numerical diatom index, the Specific Pollution sensitivity Index (SPI) was used to interpret results (Table 5). The results from the Trophic Diatom Index (TDI) (Kelly and Whitton, 1995) were also taken into account as this index provides the percentage pollution tolerant diatom valves (PTVs) in a sample and was developed for monitoring sewage outfall (orthophosphate-phosphorus concentrations), and not general stream quality (Table 5). The presence of more than 20% PTVs shows significant organic impact. The ecological characterisation of the samples in Table 6 was based on Van Dam *et al.* (1994). This work includes the preferences of 948 freshwater and brackish water diatom species in terms of pH, nitrogen, oxygen, salinity, humidity, saprobity and trophic state as provided by OMNIDIA (Le Cointe *et al*., 1993).

Table 5: Results of diatom analysis (2015).

Site name	No of species	SPI	Class	Category	PTV%
Vaal 1	26	8.5	Poor	D	19.7
Vaal 2	17	6.9	Poor	D/E	18.8
Vaal 3	14	7.3	Poor	D/E	25.5
KS 1	15	2.2	Very poor	F	41
KS 2	31	12.1	Moderate	C	3
KS 3	21	9.6	Poor	D	11.1

Table 6: Generic diatom based ecological classification.

Site	pH	Salinity	Organic nitrogen	Oxygen levels	Pollution levels	Trophic status
Vaal 1	Alkaline	Fresh brackish	Elevated concentrations of organically bound nitrogen	Fairly high (>50 % saturation)	Moderately polluted	Eutrophic
Vaal 2	Alkaline	Fresh brackish	Elevated concentrations of organically bound nitrogen	Fairly high (>50% saturation)	Moderately polluted	Eutrophic
Vaal 3	Alkaline	Fresh brackish	Elevated concentrations of organically bound nitrogen	Fairly high (>50% saturation)	Moderately polluted	Eutrophic

Site	pH	Salinity	Organic nitrogen	Oxygen levels	Pollution levels	Trophic status
KS 1	Alkaline	Fresh brackish	Continuous concentrations of organically bound nitrogen	Low (>30% saturation)	Very heavily polluted	Hyper eutrophic
KS 2	Circumneutral	Fresh brackish	Elevated concentrations of organically bound nitrogen	Continuously high (~100% saturation)	Unpolluted to slightly polluted	Eutrophic
KS 3	Alkaline	Fresh brackish	Elevated concentrations of organically bound nitrogen	Fairly high (>50% saturation)	Moderately polluted	Eutrophic

A) Vaal River ecosystem

Vaal 1

The *biological* water quality at this site was **Poor** (Category D) with a SPI score of 8.5 (Table 5). According to the ecological classification (Table 6) the water was characterized by **alkaline** condition with fairly **high oxygenation** rates, **elevated salinity and nutrient** levels with the potential of becoming more problematic. It also shows that this site was in an **eutrophic** state at time of sampling, this was also supported by the chlorophyll-a measurements (see section 3.3) and the fact that *Aulacoseira ambigua* and *Alaucoseira granulata* were both dominant (Table 6). According to Taylor *et al.* 2007b these species have affinities for eutrophic water.

Table 7: Dominant species that occurred at site Vaal 1 during April 2015

Dominant species at Vaal1	% Relative abundance
Aulacoseira ambigua (Grunow) Simonsen	23
Aulacoseira granulata (Ehr.) Simonsen	14
Cocconeis placentula Ehrenberg var. placentula	8
Nitzschia liebetruthii Rabenhorst var.liebetruthii	7
Nitzschia palea (Kützing) W.Smith	7
Navicula recens (Lange-Bertalot) Lange-Bertalot	7

Dominant species that occurred at this site are presented in the Table 7 and included species such as *Aulacoseira ambigua, Alaucoseira granulata, Coconeis placentula, Nitzschia liebruthii, Nitzschia palea* and *Navicula recens.* The dominance of *Cocconeis placentula* and *Nitzschia lieberuthii* alerts concern that the salinity may be elevated, as these species both occur in very electrolyte-rich to brackish waters. Organic indicator species were also present with *Nitzschia palea* and *Navicula recens* being tolerant to critical levels of pollution, which can also explain the score of the percentage pollution tolerant diatom valves (PTVs) of 19.7% that were fairly high (more than 20% indicates significant organic pollution).

Based on available diatom biomonitoring data for the Vaal 1 site, the study area is characterised by anthropogenic activities associated with high nutrient levels, which might be caused by sewerage discharges, mining operations or agricultural activities surrounding the system. Valve deformities were also present at this site, which indicates potential heavy metal pollution. Valve deformations have been associated with high metal solutions (Luis *et al.*, 2008) and the general threshold for valve deformities is usually considered between 1-2%. The occurrence of diatom valve deformities (1.5%) are of concern as it indicated that **metal toxicity** was entering the system and could affect the biological functioning of aquatic biota. The majority of diatom species present have a preference for eutrophic, organically enriched waters with high electrolyte content and is typically representative of industrially impacted waters. Organically bound nitrogen levels were very high indicating that nutrient loading was problematic at this site as reflected by the dominance of *Nitzschia palea* and *Navicula recens* (Taylor *et al.*, 2007b).

Vaal 2

The diatom based water quality at site Vaal 2 was *poor* (Category D/E) with a SPI score of 6.9 (Table 5). Again this site was more or less characterized as the upstream Vaal site but may receive discharges from the new Kareerand mega tailings dam. The dominant species (Table 8) *Aulacoseira ambigua* and *Aulacoseira granulata* were recorded and are known indicators of **eutrophic** conditions. The diatom based ecological classification (Table 6) indicated that **organic pollution** levels were elevated and PTVs made up 18.8% of the total count (>20% PTVs indicate significant organic pollution). The sub-dominant species *Stephanodiscus hantzschii* and *Hippodonta capitata* also indicated that **salinity** levels were elevated, for both these species has an affinity for brackish and high electrolyte content waters. The **nutrient** levels followed the same trend as salinity. Sub dominant species that indicate elevated nutrient levels were found to be elevated, notably *Eolimna subminuscula* and *Ghomphonema pavulum* that has an affinity for nutrient enriched waters and are tolerant of extremely polluted conditions. The SPI score and number of recorded diatom species decreased from the Vaal 1 site towards the downstream localities, indicating that water quality deteriorated downstream. Valve deformities (0.74%) were present at this site, which indicated that **heavy metal pollution** is entering into the system. Surface as well as sub-surface discharges of affected mine water from the Kareerand TSF towards the Vaal River was noted during a biodiversity risk audit on 22 May 2015. These discharges will enter the Vaal River between Vaal 1 and Vaal 2.

Table 8: Dominant species that occurred at site Vaal 2 during April 2015

Dominant species at site Vaal 2	Relative abundance %
Aulacoseira ambigua (Grunow) Simonsen	39,0
Aulacoseira granulata (Ehr.) Simonsen	21,0
Cyclotella meneghiniana Kützing	7,0
Nitzschia palea (Kützing) W.Smith	14,0

Vaal 3

Site Vaal 3 is located downstream of most of the potential impacts from the MWS study area and incorporates notable mining and agricultural activities. The diatom based water quality was ***poor** (category D/E)* with a SPI score of 7.3% calculated for this site (Table 5). **Nutrient** levels were very high as reflected by the dominance of *Nitzschia* species (Table 9). **Salinity** levels were very high and problematic as reflected by the dominant and sub-dominant species *Cyclotella meneghiniana and Nitzschia clausii*. According to Taylor *et al*. (2007b) this species becomes abundant in saline inland waters with very high electrolyte content and capable of tolerating critical to very heavy organic pollution. *Fragilaria* species indicated that there may have been recent elevated flows. The sub-dominant species *Nitzschia filiformis*, *Nitzschia clausii and Ghomphonema parvulum* indicated that the influx of water was **nutrient and electrolyte rich** as these species are usually abundant in saline inland waters with high electrolyte content to brackish waters impacted by industrial related activities and has got a high affinity for critically polluted and high electrolyte water. The sub-dominance of these species usually suggests that industry-related activities are the main source of pollution in an area. **Organic pollution levels** were high with PTVs making up 25.5% of the total count, which shows significant impact of organic pollution from the surrounding areas (Table 5). No deformities were noted, indicating that metal toxicity levels may have been below detection.

Table 9: Dominant species that occurred at site Vaal 3 during April 2015

Dominant species at Vaal 3	Relative abundance %
Aulacoseira ambigua (Grunow) Simonsen	33
Aulacoseira granulata (Ehr.) Simonsen	16
Cyclotella meneghiniana Kützing	10
Nitzschia palea (Kützing) W.Smith	13

B) Koekemoer Spruit

KS1

According to the ecological classification (Table 6) the water was characterized by **alkaline** waters with **low oxygenation** rates, **elevated salinity** and continuous concentrations of organically bound **nitrogen**. It also shows that this site was in a **hyper-eutrophic** state at the time of sampling. The diatom based water quality was **very poor** (Category F) with a SPI score of 2.2 (Table 5). The diatom community indicated that the majority of species had a preference for organically enriched waters with very high electrolyte content, typically of industrially related impacted waters. Nutrient levels were very high along with salinity and these levels were deemed problematic and would impact on the riverine aquatic biota. The major impact was however **organic pollution** levels with PTVs making up 41% of the total count. This was reflected by the dominant species *Ghomphonema parvulum* and *Nitzschia capitellata* (Table 10) both tolerant to heavily polluted waters (Taylor *et al.*, 2007b). The **high nutrient** levels were thought to be mainly due to sewerage discharges upstream from the study area. The sub dominant species *Nitzschia dissipata* is an indicator of calcium-based **salinity**. Abnormal valves were present and indicate that there are **heavy metals** present in the water which may affect the aquatic biota. Water levels were however low and it could be expected that elevated nutrient and salinity levels were exacerbated by the low water levels observed during sampling.

Table 10: Dominant species that occurred at site KS 1 during April 2015

Dominant species at Koekemoerspruit 1	Relative abundance %
Gomphonema parvulum (Kützing) Kützing	12
Nitzschia capitellata Hustedt	45
Nitzschia palea (Kützing) W.Smith	13

KS 2

The diatom-based water quality was *Moderate* (Category C) with a SPI score of 12.1. The dominance of *Achnanthidium saprophilum* and sub-dominance of *Achnanthidium eutrophilum* (Table 11) indicates that there were recent elevated flows in the system, with an influx of **organic pollutants** as these species have affinities for organically enriched and eutrophic waters.

It was evident from the diatom community composition that **salinity** was increased at the site along with **nutrient** levels (although these levels were already problematic). The dominant species *Nitzschia capitellata* prefers brackish to electrolyte rich waters and is able to tolerate extremely polluted conditions (Taylor *et al.*, 2007b). The co-dominance of *Gyrosigma attenuatum*, *Nitzschia obtusa, Nitzschia capitellata* and *Navicula microcari* indicated that conditions were deteriorating over time. According to Cholnoky (1968) and Hecky and Kilham (1973) these species are extremely tolerant of **salinity** and **high alkalinity**, and becomes abundant in brackish waters because competition from other diatom species is reduced. According to the Trophic Diatom Index (TDI) (Kelly and Whitton, 1995) organic pollution levels were low, with PTV making up 3% of the diatom count. Valve deformities were present (1%) indicating that **heavy metal pollution** is entering into the system.

Table 11: Dominant species that occurred at site KS 2 during April 2015

Dominant species at Koekemoerspruit 2	Relative abundance %
Achnanthidium saprophilum Round & Bukhtiyarova	6
Encyonopsis microcephala (Grun.)	7
Gyrosigma attenuatum (Kützing) Rabenhorst	12
Nitzschia capitellata Husted	45
Fragilaria tenera (W.Smith) Lange-Bertalot	5
Navicula heimansioides Lange-Bertalot	6
Navicula microcari Lange-Bertalot	16
Nitzschia obtusa W.M.Smith var. kurzii (Rabenhorst) Grunow	7
Tabularia fasciculata (Agardh)Williams et Round	8

KS 3

The biological water quality at this site was poor (category D) with a SPI score of 9.6 (Table 5). According to the ecological classification (Table 5) the water was characterized by **alkaline** waters with fairly high oxygenation rates, **elevated salinity** and **nutrient** levels with the potential of becoming more problematic. It also shows that this site was in a **eutrophic** state at time of sampling. According to the Trophic Diatom Index (TDI) (Kelly and Whitton, 1995) organic pollution levels were moderate, with PTV making up 11% of the diatom count. Furthermore, the organically bound **nitrogen** levels were found to be elevated. The dominant species *Fallacia pygmeae*, *Gyrosigma attenuatum, Mastogloia smithii* and *Tryblionella hungarica* (Table 12) all indicated that the salinity at this site was elevated and problematic as these species have an affinity for high electrolyte/brackish waters and can tolerate critical levels of pollution. Indicator species for industrial related impacts (*Gyrosigma attenuatum*) occurred at high abundance and the major anthropogenic impacts on the system could be originating from mining operations as well as sewerage discharges from the neighbouring township. Untreated sewage water was found discharging upstream from this locality on 22 May 2015. Valve deformities were noted, indicating the presence of **metal toxicity** at the time of sampling.

Table 12: Dominant species that occurred at site KS 3 during April 2015

Dominant species at Koekemoerspruit 3	Relative abundance %
Aulacoseira granulata (Ehr.) Simonsen	6
Fallacia pygmaea (Kützing) Stickle & Mann	7
Gyrosigma attenuatum (Kützing) Rabenhorst	26
Gyrosigma parkerii (Harrison) Elmore	7
Mastogloia smithii Thwaites	5
Navicula trivialis Lange-Bertalot abnormal form	8
Tryblionella hungarica (Grunow) D.G. Mann	8

4.6 Aquatic macro-invertebrates diversity

A) Vaal River ecosystem (BMU1)

According to the desktop PESEIS assessment (DWS, 2013) an estimated fifty (50) macro-invertebrate families may be expected to occur in this MWS Vaal River reach under present conditions (Table 13). The presence of forty-seven (47) macro-invertebrate taxa has been confirmed in this reach between the period 2013 to 2017 (Table 14). These taxa show great variation in their relative intolerance to water quality alteration and their preference for flow and cover features (Table 14).

Most of the invertebrate taxa sampled have a low (23) or very low (17) requirement for unmodified water quality (Table 14). This corresponds with the conclusions based on *in-situ* water quality (section 3.3) and diatoms (section 3.4) that the water quality of this reach is in a modified state. Eight of the sampled taxa (Atyidae, Hydracarina, Leptophlebiidae, Tricorythidae, Chlorocyphidae, Aeshnidae, Ecnomidae and Elmidae) have a moderate requirement for unmodified water quality. Only two indicators of very good water quality, namely Heptageniidae (Flat-headed mayflies) and more than two species of Baetidae (Small minnow flies) have been sampled in this reach (Table 14).

A large proportion (38 taxa) of the invertebrate taxa had a high preference for very slow flowing conditions (<0.1 m/s) and 46 taxa for slow (0.1-0.3 m/s) conditions. A moderate proportion (34 taxa) also preferred fast flow (0.3-0.6 m/s) and only 21 taxa had a preference for very fast (>0.6 m/s) conditions (Table 14). In terms of cover preference, the highest proportion of taxa (36 taxa) had a high preference for cobble substrates, 35 taxa had a preference for vegetation, 25 taxa for bedrock and 23 for water column as cover (Table 13) (See appendix 1 for common names and general description of invertebrate habitat).

Table 13: Macroinvertebrate taxa estimated to occur in the MWS Vaal River reach (DWS, 2013)

FAMILY/TAXON
TURBELLARIA, OLIGOCHAETA, HIRUDINEA, POTAMONAUTIDAE, ATYIDAE, HYDRACARINA, BAETIDAE, CAENIDAE, LEPTOPHLEBIIDAE, TRICORYTHIDAE, CHLOROCYPHIDAE, SYNLESTIDAE/CHLOROLESTIDAE, COENAGRIONIDAE, AESHNIDAE, CORDULIIDAE, GOMPHIDAE, LIBELLULIDAE, BELOSTOMATIDAE, CORIXIDAE, GERRIDAE, HYDROMETRIDAE, NAUCORIDAE, NEPIDAE, NOTONECTIDAE, PLEIDAE, VELIIDAE/MESOVELIIDAE, ECNOMIDAE, HYDROPSYCHIDAE, HYDROPTILIDAE, LEPTOCERIDAE, DYTISCIDAE,

ELMIDAE/DRYOPIDAE, GYRINIDAE, HALIPLIDAE, HYDRAENIDAE, HYDROPHILIDAE, CERATOPOGONIDAE, CHIRONOMIDAE, CULICIDAE, DIXIDAE, MUSCIDAE, SIMULIIDAE, TABANIDAE, TIPULIDAE, ANCYLIDAE, LYMNAEIDAE, PHYSIDAE, PLANORBINAE, CORBICULIDAE, SPHAERIIDAE AND UNIONIDAE.

Table 14: Macro-invertebrate taxa sampled in the Vaal River reach (2013 to 2017) and their relative requirement for unmodified water quality, flow and cover.

Taxon	Common name	Flow (in m/s) preference				Cover preference					WQ requirement
		<0.1	0.1-0.3	0.3-0.6	>0.6	BEDROCK	COBBLES	VEG	GSM	WATER COLUMN	
COELENTERATA	Cnidaria/Hydra	2	2	1	0	2	2	1	0	0	VERY LOW
TURBELLARIA	Flatworms	1	2	3	4	1	4	0	0	0	VERY LOW
Oligochaeta	Aquatic earthworms	2	2	2	1	0	1	0	4	0	VERY LOW
Leeches	Leaches	2	2	1	1	0	4	1	1	0	VERY LOW
Potamonautidae*	Crabs	1	1	3	2	0	3	1	1	0	VERY LOW
Atyidae	Freshwater shrimps	2	2	0	0	0	1	4	1	0	MODERATE
HYDRACARINA	Water mites	0	2	2	0	1	1	2	3	1	MODERATE
Baetidae 1 sp.	Small minnow flies	2	2	2	2	2	2	2	2	1	LOW
Baetidae 2 spp.	Small minnow flies										LOW
Baetidae > 2 spp.	Small minnow flies										HIGH
Caenidae	Cainflies	3	2	1	1	0	2	1	3	0	LOW
Heptageniidae	Flat-headed mayflies	1	1	3	2	1	4	1	0	0	HIGH
Leptophlebiidae	Prongills	3	2	2	1	1	3	2	0	0	MODERATE
Tricorythidae	Stout crawlers	0	1	1	4	1	4	1	0	0	MODERATE
Chlorocyphidae	Damselflies	2	3	1	0	1	4	1	0	0	MODERATE
Coenagrionidae	Damselflies	1	2	3	1	0	1	4	1	0	LOW
Aeshnidae	Dragonflies	1	2	2	2	0	3	2	0	0	MODERATE
Gomphidae	Dragonflies	0	2	3	0	0	1	0	5	0	LOW
Libelludae	Dragonflies	1	2	3	1	1	4	0	1	0	LOW
Belostomatidae*	Giant water bug	4	1	0	0	0	0	4	0	1	VERY LOW
Corixidae*	Water boatmen	2	3	1	0	1	1	1	1	4	VERY LOW
Gerridae*	Pond skater	4	1	0	0	0	0	0	0	5	MODERATE
Hydrometridae*	Marsh streaders	4	1	0	0	0	0	2	0	4	MODERATE
Naucoridae*	Creeping water bugs	2	2	3	0	1	1	1	1	4	LOW
Nepidae*	Water scorpions	4	1	0	0	0	0	5	0	0	VERY LOW
Notonectidae*	Back swimmers	4	1	0	0	0	0	2	0	4	VERY LOW
Pleidae*	Pigmy backswimmers	4	1	0	0	0	0	4	0	1	LOW
Veliidae*	Broad-shouldered water strid	5	1	1	0	0	0	0	0	5	MODERATE
Ecnomidae	Caseless caddisflies	1	5	0	0	2	3	2	0	0	MODERATE
Hydropsychidae 1sp.	Caseless caddisflies	0	1	2	4	2	3	1	0	0	LOW
Hydropsychidae 2 spp.	Caseless caddisflies										LOW
Hydroptilidae	Micro caddisflies	0	3	2	2	1	2	3	1	0	LOW
Leptoceridae	Cased caddisflies	0	1	3	2	2	2	2	2	0	LOW
Dytiscidae (adults*)	Predacious diving beetles	4	2	1	0	1	2	3	1	2	LOW
Elmidae / Dryopidae*	Riffle beetles	0	0	4	2	1	4	1	0	0	MODERATE
Gyrinidae (adults*)	Whirligig beetles	1	2	2	3	0	0	0	0	5	LOW
Hydrophilidae (adults*)	Water scavenger beetles	0	2	2	0	0	0	3	2	2	LOW
Ceratopogonidae	Biting midges	2	2	2	4	2	3	2	2	0	LOW
Chironomidae	Midges	1	3	2	2	2	2	2	2	0	VERY LOW
Culicidae*	Mosquitoes	3	1	0	0	0	0	0	0	5	VERY LOW
Muscidae	House flies	4	2	2	0	1	1	1	1	4	VERY LOW
Simuliidae	Black flies	0	2	2	4	2	3	2	0	0	LOW
Syrphidae*	Rat-tailed maggots	4	1	0	0	0	0	0	4	0	VERY LOW
Tabanidae	Horseflies	2	3	1	0	0	2	0	3	0	LOW
Ancylidae	Limpets	1	2	2	1	3	2	1	0	0	LOW
Lymnaeidae*	Pond snails	3	2	0	0	2	2	3	0	0	VERY LOW
Physidae*	Pouch snails	3	2	0	0	1	2	3	0	0	VERY LOW
Planorbinae*	Orb snails	3	2	0	0	2	2	3	0	0	VERY LOW
Corbiculidae	Clams	2	3	1	0	0	2	0	4	0	LOW
Sphaeridae	Pill clams	2	3	1	0	0	2	0	4	0	VERY LOW

Key: **Preference**

0 - No preference (does not occur)

1 - Very low preference Coincidental

2 - Low preference

3 - Moderate preference

4 - High preference

5 - Very high preference

High requirement for unmodified water quality

Moderate requirement for unmodified water quality

Low requirement for unmodified water quality

Very low requirement for unmodified water quality

Biotic integrity of Vaal River: macroinvertebrates (SASS5)

The application of the South African Scoring System (SASS5) macroinvertebrate index provides a tool for determining the relative biotic integrity of a site, and also allows for the assessment of spatial and temporal trends. The SASS5 index is applied at various sampling sites in the Vaal River as part of the AGA biomonitoring programme. The results gained during the 2017 monitoring period, together with the 2017-11 Kareerand project survey were used to provide an indication of the current biotic integrity of the Vaal River reach, based on the macroinvertebrate assemblage. The SASS5 values in the Vaal River reach ranged between 70 (site Vaal4: 2017-03) to 108 (sites Vaal2:2017-03 and Vaal4: 2017-09) (Table 15). The ASPT values ranged between 3.95 (site Vaal2:2017-09) and 5.38 (site Vaal2:2017-03) during the 2017 monitoring period (Table 15). The ASPT values are of lower confidence due to the generally low taxa diversity and hence more emphasis should be placed on the total SASS5 scores. The SASS5 scores indicate notable seasonal variation, which can be related to natural habitat variations as well as difference in water quality between seasons. When using the Dallas (2007) SASS5 interpretation guidelines for the Highveld (lower) ecoregion, the ecological category of this reach ranges between category B (slightly modified) and C (moderately modified) condition (Table 15). Temporal trends indicate notable variation over time, with all Vaal River sites indicating improvement over the latter part of the study period (Figure 10).

Table 15: SASS5 results for the Vaal River reach (2017).

Monitoring site	Survey	SASS5 score	ASPT	Ecological category*
Vaal1	2017-03	82	5.13	C
Vaal1	2017-09	105	5.00	B
Vaal1B	2017-11	80	4.71	C
Vaal2	2017-03	70	5.38	C
Vaal2	2017-09	79	3.95	C
Vaal4	2017-03	70	4.67	C
Vaal4	2017-09	108	4.70	B

Key:

ASPT - Average Score Pre Taxon

*Based on Dallas (2007) classification for Highveld (lower) ecoregion.

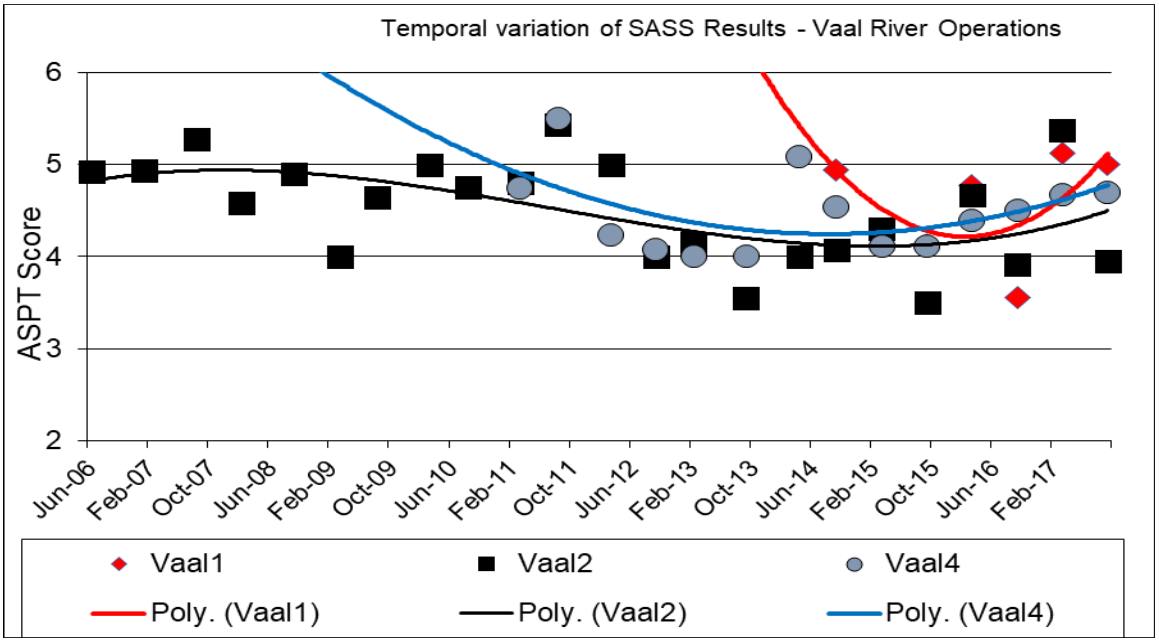

Figure 10: Temporal trends in SASS5 (ASPT values) results for the MWS Vaal River reach.

B) Koekemoer Spruit ecosystem

According to the desktop PESEIS assessment (DWS, 2013) an estimated twenty-nine (29) macro-invertebrate families may be expected to occur in the MWS Koekemoer Spruit reach under present conditions (Table 16). The lower diversity of macroinvertebrate taxa expected in the Koekemoer Spruit when compared to the Vaal River is especially attributed to the seasonal nature of the Koekemoer Spruit. Actual sampling of the Koekemoer Spruit revealed a higher diversity of invertebrates, with thirty-four (34) macro-invertebrate taxa confirmed in this reach between the period 2013 to 2017 (Table 17). These taxa also show great variation in their relative intolerance to water quality alteration and their preference for flow and cover features (Table 17).

Most of the invertebrate taxa sampled have a low (15) or very low (13) requirement for unmodified water quality (Table 17). This again corresponds with the conclusions based on *in-situ* water quality (section 3.3) and diatoms (section 3.4) that the water quality of this reach is in a poor state. Six taxa sampled in this reach (Atyidae, Hydracarina, Lestidae, Aeshnidae, Elmidae and Dixidae) have a moderate requirement for unmodified water quality and indicate that water quality may from time to time be better in some areas of the Koekemoer Spruit. No taxa with a very high requirement for unmodified water quality was sampled in the Koekemoer Spruit (Table 17).

A large proportion (28 taxa) of the invertebrate taxa again had a high preference for very slow flowing conditions (<0.1 m/s) and 32 taxa slow flowing (0.1-0.3 m/s), as expected in a seasonal system with generally low flows prevailing (Table 17). In terms of cover preference, the highest proportion of taxa (25 taxa) had a high preference for vegetation as cover, also evident of the seasonal nature of this stream.

Table 16: Macroinvertebrate taxa estimated to occur in the MWS Koekemoer Spruit SQ reach (DWS, 2013)

FAMILY/TAXON
TURBELLARIA, OLIGOCHAETA, HIRUDINEA, POTAMONAUTIDAE, BAETIDAE 1 SP, CAENIDAE, COENAGRIONIDAE, GOMPHIDAE, LIBELLULIDAE, BELOSTOMATIDAE, CORIXIDAE, GERRIDAE, HYDROMETRIDAE, NAUCORIDAENEPIDAE, NOTONECTIDAE, PLEIDAE, VELIIDAE/MESOVELIIDAE, LEPTOCERIDAE, DYTISCIDAE, GYRINIDAE, CERATOPOGONIDAE, CHIRONOMIDAE, CULICIDAE, MUSCIDAE, SIMULIIDAE, TABANIDAE, TIPULIDAE, LYMNAEIDAE, PHYSIDAE

Table 17: Macro-invertebrate taxa sampled in the Koekemoer Spruit reach (2013 to 2017) and their relative requirement for unmodified water quality, flow and cover.

Taxon	Common name	Flow (in m/s) preference				Cover preference					WQ requirement
		<0.1	0.1-0.3	0.3-0.6	>0.6	BEDROCK	COBBLES	VEG	GSM	WATER COLUMN	
TURBELLARIA	Flatworms	1	2	3	4	1	4	0	0	0	VERY LOW
Oligochaeta	Aquatic earthworms	2	2	2	1	0	1	0	4	0	VERY LOW
Leeches	Leaches	2	2	1	1	0	4	1	1	0	VERY LOW
Potamonautidae*	Crabs	1	1	3	2	0	3	1	1	0	VERY LOW
Atyidae	Freshwater shrimps	2	2	0	0	0	1	4	1	0	MODERATE
HYDRACARINA	Water mites	0	2	2	0	1	1	2	3	1	MODERATE
Baetidae 1 sp.	Small minnow flies	2	2	2	2	2	2	2	2	1	LOW
Baetidae 2 spp.	Small minnow flies										LOW
Caenidae	Cainflies	3	2	1	1	0	2	1	3	0	LOW
Coenagrionidae	Damselflies	1	2	3	1	0	1	4	1	0	LOW
Lestidae	Damselflies	4	1	0	0	0	1	4	1	0	MODERATE
Aeshnidae	Dragonflies	1	2	2	2	0	3	2	0	0	MODERATE
Libelludae	Dragonflies	1	2	3	1	1	4	0	1	0	LOW
Belostomatidae*	Giant water bug	4	1	0	0	0	0	4	0	1	VERY LOW
Corixidae*	Water boatmen	2	3	1	0	1	1	1	1	4	VERY LOW
Gerridae*	Pond skater	4	1	0	0	0	0	0	0	5	MODERATE
Hydrometridae*	Marsh streaders	4	1	0	0	0	0	2	0	4	MODERATE
Nepidae*	Water scorpions	4	1	0	0	0	0	5	0	0	VERY LOW
Notonectidae*	Back swimmers	4	1	0	0	0	0	2	0	4	VERY LOW
Pleidae*	Pigmy backswimmers	4	1	0	0	0	0	4	0	1	LOW
Veliidae*	Broad-shouldered water strid	5	1	1	0	0	0	0	0	5	MODERATE
Hydropsychidae 1sp.	Caseless caddisflies	0	1	2	4	2	3	1	0	0	LOW
Dytiscidae (adults*)	Predacious diving beetles	4	2	1	0	1	2	3	1	2	LOW
Elmidae / Dryopidae*	Riffle beetles	0	0	4	2	1	4	1	0	0	MODERATE
Gyrinidae (adults*)	Whirligig beetles	1	2	2	3	0	0	0	0	5	LOW
Hydrophilidae (adults*)	Water scavenger beetles	0	2	2	0	0	0	3	2	2	LOW
Ceratopogonidae	Biting midges	2	2	2	4	2	3	2	2	0	LOW
Chironomidae	Midges	1	3	2	2	2	2	2	2	0	VERY LOW
Culicidae*	Mosquitoes	3	1	0	0	0	0	0	0	5	VERY LOW
Dixidae*	Meniscus midges	3	2	2	0	0	0	0	0	5	MODERATE
Simuliidae	Black flies	0	2	2	4	2	3	2	0	0	LOW
Lymnaeidae*	Pond snails	3	2	0	0	2	2	3	0	0	VERY LOW
Physidae*	Pouch snails	3	2	0	0	1	2	3	0	0	VERY LOW
Planorbinae*	Orb snails	3	2	0	0	2	2	3	0	0	VERY LOW

Key: **Preference**

0 - No preference (does not occur)
1 - Very low preference Coincidental
2 - Low preference
3 - Moderate preference
4 - High preference
5 - Very high preference

High requirement for unmodified water quality
Moderate requirement for unmodified water quality
Low requirement for unmodified water quality
Very low requirement for unmodified water quality

Biotic integrity of Koekemoer Spruit: Macroinvertebrates (SASS5)

The South African Scoring System (SASS5) macroinvertebrate index was developed for perennial river systems and therefore its application to the Koekemoer Spruit should be viewed with circumspection. Due to the low diversity of taxa sampled, the ASPT values were also of very low confidence for interpretation purposes. Many of the sites also had no flow during the surveys. The results gained during the 2017 monitoring period, together with the 2017-11 Kareerand project survey were used to provide an indication of the current biotic integrity of the Koekemoer Spruit reach, based on the macroinvertebrate assemblage. The SASS5 values ranged between 6 (site KS R502: 2017-11) and 48 (site KS2:2017-03) (Table 18). When using the Dallas (2007) SASS5 interpretation guidelines for the Highveld (lower) ecoregion (with emphasis on total SASS5 values), the ecological category of this reach ranges between a category E (seriously modified) and F (critically modified) condition (Table 18). Only limited information is available and hence no temporal trends are established.

Table 18: SASS5 results for the Koekemoer Spruit reach (2017).

Monitoring site	Survey	SASS5 score	ASPT	Ecological category*
KS2	2017-03	48	3.43	E
KS2	2017-09	21	3.00	E
KS R502	2017-11	6	2.00	F
KS4	2017-09	43	4.78	E

ASPT - Average Score Pre Taxon (low confidence)

*Based on Dallas (2007) classification for Highveld (lower) ecoregion.

C) Karee tributary

The Karee tributary is a seasonal drainage line, and hence not suitable for the application of the SASS5 as a monitoring tool or ecological classification system. The SASS5 protocol was however applied during the Kareerand TSF expansion survey conducted in 2017-11 to gain an indication of the macroinvertebrate assemblage in the lower section of this stream (Table 19). During the 2017-11 survey conducted in the lower reaches of this stream as site Karee-Vaal, 15 macroinvertebrate taxa were sampled (Table 19). Most of the taxa sampled had a very low (6 taxa) and low (8 taxa) requirement for unmodified water quality, indicating that poor water quality is currently prevailing in this stream. Only one taxa (Hydracarina) with a moderate requirement for unmodified water quality was sampled, while no invertebrate taxa with a high requirement for unmodified water quality was present (Table 19).

Table 19: Macro-invertebrate taxa sampled in the Karee Tributary (sites Karee-Vaal) (2017-11) and their relative requirement for unmodified water quality, flow and cover.

Taxon	Common name	Flow (in m/s) preference				Cover preference					WQ requirement
		<0.1	0.1-0.3	0.3-0.6	>0.6	BEDROCK	COBBLES	VEG	GSM	WATER COLUMN	
Oligochaeta	Aquatic earthworms	2	2	2	1	0	1	0	4	0	VERY LOW
HYDRACARINA	Water mites	0	2	2	0	1	1	2	3	1	MODERATE
Coenagrionidae	Damselflies	1	2	3	1	0	1	4	1	0	LOW
Libelludae	Dragonflies	1	2	3	1	1	4	0	1	0	LOW
Belostomatidae*	Giant water bug	4	1	0	0	0	0	4	0	1	VERY LOW
Corixidae*	Water boatmen	2	3	1	0	1	1	1	1	4	VERY LOW
Gerridae*	Pond skater	4	1	0	0	0	0	0	0	5	MODERATE
Hydrometridae*	Marsh streaders	4	1	0	0	0	0	2	0	4	MODERATE
Notonectidae*	Back swimmers	4	1	0	0	0	0	2	0	4	VERY LOW
Pleidae*	Pigmy backswimmers	4	1	0	0	0	0	4	0	1	LOW
Dytiscidae (adults*)	Predacious diving beetles	4	2	1	0	1	2	3	1	2	LOW
Gyrinidae (adults*)	Whirligig beetles	1	2	2	3	0	0	0	0	5	LOW
Ceratopogonidae	Biting midges	2	2	2	4	2	3	2	2	0	LOW
Chironomidae	Midges	1	3	2	2	2	2	2	2	0	VERY LOW
Physidae*	Pouch snails	3	2	0	0	1	2	3	0	0	VERY LOW

Key: **Preference**

0 - No preference (does not occur)
1 - Very low preference Coincidental
2 - Low preference
3 - Moderate preference
4 - High preference
5 - Very high preference

High requirement for unmodified water quality
Moderate requirement for unmodified water quality
Low requirement for unmodified water quality
Very low requirement for unmodified water quality

4.7 Ichthyofauna (Fish) diversity

A) Vaal River

Based on the latest available information and distribution maps the following eleven *indigenous fish species* have a high probability to occur in the MWS Vaal River reach (Table 18):

- Vaal-Orange Smallmouth yellowfish (*Labeobarbus aeneus*)
- Vaal-Orange Largemouth yellowfish (*Labeobarbus kimberleyensis*)
- Orange River mudfish (*Labeo capensis*)
- Moggel (*Labeo umbratus*)
- Threespot barb (*Enteromius trimaculatus*)
- Chubbyhead barb (*Enteromius anoplus*)
- Straightfin barb (*Enteromius paludinosus*)
- Rock catfish (*Austroglanis sclateri*)
- Sharptooth catfish (*Clarias gariepinus*)
- Banded tilapia (*Tilapia sparrmanii*)
- Southern mouthbrooder (*Pseudocrenilabrus philander*)

During the surveys conducted for AGA biomonitoring programme (2012 to 2017) of selected sites within this reach, the presence of ten indigenous species was confirmed (Table 20). Three alien fish species, namely *Cyprinus carpio*, *Gambussia affinis and Micropterus salmoides* were also sampled in this reach (Table 20).

Table 20: Fish species sampled recently (2012 to 2017) at the various sampling sites in the MWS Vaal River section.

Locality name	Date sampled	*Labeobarbus aeneus*	*Enteromius anoplus*	*Labeobarbus kimberleyensis*	*Enteromius paludinosus*	*Enteromius trimaculatus*	*Cyprinus carpio*	*Clarias gariepinus*	*Gambussia affinis*	*Labeo capensis*	*Labeo umbratus*	*Micropterus salmoides*	*Pseudocrenilabrus philander*	*Tilapia sparrmanii*
Vaal1	01/09/2015	x								x			x	x
Vaal1	01/09/2016	x		x			x			x			x	x
Vaal1	01/09/2017	x			x			x		x			x	
Vaal1B	22/11/2017						x	x	x	x			x	x
Vaal2	01/03/2011	x				x		x	x	x			x	x
Vaal2	01/08/2011		x		x	x				x			x	x
Vaal2	01/09/2012	x								x	x		x	x
Vaal2	01/09/2013	x							x		x		x	x
Vaal2	01/09/2014				x	x		x	x	x			x	x
Vaal2	01/09/2015	x					x	x	x	x			x	x
Vaal2	01/09/2016	x		x		x				x			x	
Vaal2	01/09/2017				x	x				x			x	
Vaal4	01/03/2011	x	x		x	x		x	x	x			x	x
Vaal4	01/08/2011	x			x	x				x			x	x
Vaal4	01/09/2012	x					x				x		x	x
Vaal4	01/09/2013										x		x	x
Vaal4	01/09/2014								x	x			x	x
Vaal4	01/09/2015	x								x			x	x
Vaal4	01/09/2016									x			x	x
Vaal4	01/09/2017	x			x			x		x			x	x

Of the eleven expected indigenous fish species, only one have not been sampled in this reach during the field assessments to present:

- *Austroglanis sclateri* was absent during all sampling efforts. Although this species has an overall rating being moderately tolerant to environmental changes, it is a known fact that it is sensitive to habitat degradation (Niehaus *et.al*., 1997). Siltation of rocky substrates as a result of erosion as well as algal growth on these substrates may have caused a localized loss of this species.

Conservation status and intolerance/preference levels

One of the fish species present in this reach, namely the Vaal-Orange Largemouth yellowfish (*Labeobarbus Kimberleyensis*) are *red data listed*, being classified as *near-threatened*[7] (IUCN ver.3.1: 2017-02) and Vulnerable[8] (NEMBA:TOPS, 2007) (Table 21). A further five species, namely *L. aeneus, L. kimberleyensis, L. capensis, L. umbratus* and *A. sclateri* are endemic to the Orange-Vaal River system (Table 21). One species, namely the Threespot barb (*Enteromius trimaculatus*) is common in many South African River systems but thought to be vulnerable in the Orange-Vaal system.

Two species, namely *L. kimberleyensis* and *L. capensis* are classified as moderately intolerant to changes in the environment (Table 22). Five species are classified as being moderately tolerant (*L. aeneus, L. umbratus, B. trimaculatus, B. anoplus and A. sclateri*) while the rest falls within the tolerant category (Table 22). The fish species furthermore differ in their requirements for different habitats (Table 23) and it is therefore important to maintain a diverse system, as close to natural as possible, in an attempt to maintain species diversity.

Table 21: **Conservation status and relative intolerance of the expected indigenous fish species of the Vaal River main stem within the MWS study area.**

Scientific Name	Common Name	Conservation status	Relative intolerance
Labeobarbus aeneus	Vaal-Orange Smallmouth Yellowfish	Endemic to Orange-Vaal system.	Moderately tolerant
Labeobarbus kimberleyensis	Vaal-Orange Largemouth Yellowfish	**Near-threatened**, Endemic to Orange-Vaal system	Moderately intolerant
Labeo capensis	Orange River Mudfish	Endemic to Orange-Vaal system	Moderately intolerant
Labeo umbratus	Moggel	Endemic to Orange-Vaal system	Moderately tolerant
Enteromius trimaculatus	Threespot barb	Vulnerable in Orange-Vaal system.	Moderately tolerant
Enteromius anoplus	Chubbyhead barb	Widespread and common	Moderately tolerant
Enteromius paludinosus	Straightfin barb	Common	Tolerant
Austroglanis sclateri	Rock catfish	Endemic to Orange-Vaal system	Moderately tolerant
Clarias gariepinus	Sharptooth Catfish	Widespread and common	Tolerant
Tilapia sparrmanii	Banded tilapia	Common	Tolerant
Pseudocrenilabrus philander	Southern mouthbrooder	Common	Tolerant

[7] A taxon is **Near Threatened** when it has been evaluated against the criteria but does not qualify for Critically Endangered, Endangered or Vulnerable now, but is close to qualifying for or is likely to qualify for a threatened category in the near future.
[8] **Vulnerable Species** - Indigenous species facing a high risk of extinction in the wild in the medium-term future, although they are not a critically endangered species or an endangered species

Table 22: **The relative tolerance of each species towards changes in the environment (Kleynhans, 2003).**

Species	Trophic specialization	Habitat specialization	Flow requirement	Unmodified water quality requirement	OVERALL INTOLERANCE RATING
Labeobarbus aeneus	2.5	1.8	3.3	2.5	**2.5**
Labeobarbus kimberleyensis	3.8	3.4	3.8	3.6	**3.6**
Labeo capensis	3.4	3.1	3.5	2.8	**3.2**
Labeo umbratus	2.8	2.0	2.7	1.6	**2.3**
Enteromius trimaculatus	3.1	1.4	2.7	1.8	**2.2**
Enteromius anoplus	2.8	2.8	2.3	2.6	**2.6**
Enteromius paludinosus	1.6	1.4	2.3	1.8	**1.8**
Austroglanis sclateri	2.9	2.3	3.2	2.6	**2.7**
Clarias gariepinus	1.0	1.2	1.7	1.0	**1.2**
Tilapia sparrmanii	1.6	1.4	0.9	1.4	**1.3**
Pseudocrenilabrus philander	1.3	1.4	1.0	1.4	**1.3**

1-2 = Tolerant 2-3 = Moderate tolerant 3-4 = Moderately intolerant 4-5 = Intolerant

Table 23: **Species preference for specific habitat types/biotopes (Kleynhans, 2003).**

Species	Slow-Deep	Slow-Shallow	Fast-Deep	Fast-Shallow	Overhanging veg.	Undercut banks	Substrate	Aquatic macrophytes	Water column
Labeobarbus aeneus	3.5	2.5	3.5	4.0	0.7	1.5	4.0	2.0	4.0
Labeobarbus kimberleyensis	3.7	2.0	4.3	3.8	0	0	1.8	0	3.3
Labeo capensis	4.2	3.0	3.3	2.5	0.5	2.0	4.2	1.5	3.2
Labeo umbratus	4.5	2.7	1.0	0.9	0.6	0.1	4.2	0.8	2.5
Enteromius trimaculatus	3.9	3.2	2.3	2.7	3.9	2.6	2.3	2.8	2.8
Enteromius anoplus	4.1	4.3	0.9	2.5	4.0	2.7	2.3	3.2	1.1
Enteromius paludinosus	3.9	3.9	2.2	2.6	4.2	2.4	1.9	3.6	3.5
Austroglanis sclateri	3.4	2.3	2.3	3.8	0.3	3.5	4.4	0.1	0.9
Clarias gariepinus	4.3	3.4	1.2	0.8	2.8	2.9	2.8	3.0	2.6
Tilapia sparrmanii	3.0	4.3	0.9	1.5	4.5	1.9	2.5	3.6	1.1
Pseudocrenilabrus philander	2.6	4.3	0.5	0.9	4.5	3.2	3.0	2.7	0.3

0=NO PREFERENCE, IRRELEVANT >0 -1= VERY LOW PREFERENCE -COINCIDENTAL?
>1-2 = LOW REFERENCE >2-3=MODERATE PREFERENCE
>3-4=HIGH PREFERENCE >4-5=VERY HIGH PREFERENCE

Alien fish species

It is known that a number of exotic species are present in the Vaal River within the study area (Table 24). The presence of three exotic species, namely the Common carp (*Cyprinus carpio*), Largemouth bass (*Micropterus salmoides*) and Mosquito fish (*Gambusia affinis*) was confirmed during various surveys in this reach (Table 20). The exotic Grass carp (*Ctenopharyngodon idella*) was not sampled but has a high probability of occurrence within the study area. Mosquito fish (*Gambusia affinis*) has an impact on the naturally occurring fish communities by feeding on their eggs and young. The Largemouth Bass is an aggressive predator that feeds on other fish (and macroinvertebrates) and can have a significant impact on the populations of especially smaller species. The Common carp (*Cyprinus carpio*) causes habitat destruction by means of its behaviour in the bottom sediments, thereby also increasing turbidity levels.

It should therefore be encouraged to remove specimens of this species whenever caught by anglers.

Table 24: **Exotic/introduced fish species of the Vaal River main stem within the study area.**

Scientific Name	Common Name
Cyprinus carpio	Common carp
Micropterus salmoides	Largemouth bass
Gambusia affinis	Mosquito fish
Ctenopharyngodon idella	Grass carp

Biotic integrity of Vaal River: Fish

The general biotic integrity of the reach, based on its fish assemblage, was calculated by the application of the Fish Response Assessment Index (FRAI). Considering all available information on the current fish species richness, presence of alien fish species, migration barriers, and alterations to flow, water quality and habitats, a FRAI score of 72% was calculated. This indicated that the biotic integrity of this reach is currently altered from its natural conditions and can be classified in a category C (moderately modified (Table 25).

Table 25: Fish Response Assessment Index (FRAI) calculations for the MWS Vaal River section.

METRIC GROUP	METRIC	*RATING (CHANGE)	METRIC GROUP WEIGHT (%)
VELOCITY-DEPTH CLASSES METRICS	Response of species with high to very high preference for FAST-DEEP conditions	-1	99
	Response of species with high to very high preference for FAST-SHALLOW conditions	-2.5	
	Response of species with high to very high preference for SLOW-DEEP conditions	-1.5	
	Response of species with high to very high preference for SLOW-SHALLOW conditions	-0.5	
COVER METRICS	Response of species with a very high to high preference for overhanging vegetation	-0.5	100
	Response of species with a very high to high preference for undercut banks and root wads	-1.5	
	Response of species with a high to very high preference for a particular substrate type	-1.5	
	Response of species with a high to very high preference for instream vegetation	-0.5	
	Response of species with a very high to high preference for the water column	-1	
FLOW DEPENDANCE METRICS	Response of species intolerant of no-flow conditions	0	79
	Response of species moderately intolerant of no-flow conditions	-1.5	
	Response of species moderately tolerant of no-flow conditions	-2	
	Response of species tolerant of no-flow conditions	0	
PHYSICO-CHEMICAL METRICS	Response of species intolerant of modified physico-chemical conditions	0	63
	Response of species moderately intolerant of modified physico-chemical conditions	-2.5	
	Response of species moderately tolerant of modified physico-chemical conditions	-1.5	
	Response of species tolerant of modified physico-chemical conditions	-0.5	
MIGRATION METRICS	Response in terms of distribution/abundance of spp with catchment scale movements	0	62
	Response in terms of distribution/abundance of spp with requirement for movement between reaches or fish habitat segments	1	
	Response in terms of distribution/abundance of spp with requirement for movement within reach or fish habitat segment	0.5	
INTRODUCED SPECIES METRICS	The impact/potential impact of introduced competing/predaceous spp?	4	50
	How widespread (frequency of occurrence) are introduced competing/predaceous spp?	4	
	The impact/potential impact of introduced habitat modifying spp?	3	
	How widespread (frequency of occurrence) are habitat modifying spp?	3	
FRAI SCORE (%)		**72.0**	
FRAI CATEGORY		**C**	
FRAI CATEGORY DESCRIPTION		**Moderately modified**	

B) Koekemoer Spruit

Based on the latest available information and distribution maps the following ten indigenous species have a high probability to occur in the MWS Koekemoer Spruit reach:

- Vaal-Orange Smallmouth yellowfish (*Labeobarbus aeneus*)
- Vaal-Orange Largemouth yellowfish (*Labeobarbus kimberleyensis*)
- Orange River mudfish (*Labeo capensis*)
- Moggel (*Labeo umbratus*)
- Threespot barb (*Enteromius trimaculatus*)
- Chubbyhead barb (*Enteromius anoplus*)
- Straightfin barb (*Enteromius paludinosus*)
- Sharptooth catfish (*Clarias gariepinus*)
- Banded tilapia (*Tilapia sparrmanii*)
- Southern mouthbrooder (*Pseudocrenilabrus philander*)

During recent (2013 to 2017) surveys of selected sites within this stream, the presence of six indigenous species was confirmed (Table 26). One alien fish species, namely *Gambussia affinis* was also sampled in this reach. It is especially of concern that no fish was sampled after 2014, indicating recent deterioration in biotic conditions (based on fish). With this stream being naturally seasonal, the fish diversity would vary greatly over time and space. Under natural conditions the fish would seek refuge in the Vaal River and maybe also perennial pools within the system during low flow months and then recolonized the stream during the wet season. Due to the current radical change in water quality as well as flow regime of the Koekemoer Spruit, it is drastic that the fish diversity has been altered significantly from its natural condition. Most of the species previously sampled are generally tolerant to changes in the environment (Table 21). The exceptions were *Enteromius anoplus* and E*. trimaculatus* which are classified as moderately tolerant, and these species were only previously sampled in the upper reaches of the Koekemoer Spruit within the MWS study area (Table 26).

Table 26: Fish species sampled recently (2013 to 2017) at the various sampling sites in the MWS Koekemoer Spruit section.

Locality name	Date sampled	*Enteromius anoplus*	*Enteromius paludinosus*	*Enteromius trimaculatus*	*Clarias gariepinus*	*Gambussia affinis*	*Pseudocrenilabrus philander*	*Tilapia sparrmanii*
KS1	**09/2013**	X					X	X
KS1	**12/2013**	X	X				X	X
KS1	**09/2014**	X		X			X	X
KS4	**12/2013**							
KS4	**09/2014**					X		
KS5	**09/2013**							
KS5	**12/2013**		X		X	X	X	X
KS5	**09/2014**					X		X

Biotic integrity of Koekemoer Spruit: Fish

The general biotic integrity of the reach, based on its fish assemblage, was calculated by the application of the Fish Response Assessment Index (FRAI). This index was developed for application to perennial systems and the results should therefore be viewed with circumspection. Considering all available information on the current fish species richness, presence of alien fish species, migration barriers (physical and chemical), and alterations to flow, water quality and habitats, a FRAI score of 18.9% was calculated. This indicated that the biotic integrity of this reach, based on fish, is currently in a highly deteriorated state and can be classified in a category E/F (seriously/critically modified) (Table 27). This is also a deterioration form the previous MWS assessment when a FRAI score of 32.7% was calculated (category E), indicating recent deterioration in the fish assemblages of this stream.

Table 27: Fish Response Assessment Index (FRAI) calculations for the MWS Koekemoer Spruit section.

METRIC GROUP	METRIC	*RATING (CHANGE)	METRIC GROUP WEIGHT (%)
VELOCITY-DEPTH CLASSES METRICS	Response of species with high to very high preference for FAST-DEEP conditions	-5	99
	Response of species with high to very high preference for FAST-SHALLOW conditions	-5	
	Response of species with high to very high preference for SLOW-DEEP conditions	-4	
	Response of species with high to very high preference for SLOW-SHALLOW conditions	-3.5	
COVER METRICS	Response of species with a very high to high preference for overhanging vegetation	-3.5	100
	Response of species with a very high to high preference for undercut banks and root wads	-3	
	Response of species with a high to very high preference for a particular substrate type	-5	
	Response of species with a high to very high preference for instream vegetation	-3.5	
	Response of species with a very high to high preference for the water column	-4.5	
FLOW DEPENDANCE METRICS	Response of species intolerant of no-flow conditions	0	79
	Response of species moderately intolerant of no-flow conditions	-5	
	Response of species moderately tolerant of no-flow conditions	-4	
	Response of species tolerant of no-flow conditions	-3.5	
PHYSICO-CHEMICAL METRICS	Response of species intolerant of modified physico-chemical conditions	0	63
	Response of species moderately intolerant of modified physico-chemical conditions	-5	
	Response of species moderately tolerant of modified physico-chemical conditions	-4.5	
	Response of species tolerant of modified physico-chemical conditions	-3.5	
MIGRATION METRICS	Response in terms of distribution/abundance of spp with catchment scale movements	0	62
	Response in terms of distribution/abundance of spp with requirement for movement between reaches or fish habitat segments	3	
	Response in terms of distribution/abundance of spp with requirement for movement within reach or fish habitat segment	2	
INTRODUCED SPECIES METRICS	The impact/potential impact of introduced competing/predaceous spp?	3	50
	How widespread (frequency of occurrence) are introduced competing/predaceous spp?	2	
	The impact/potential impact of introduced habitat modifying spp?	0	
	How widespread (frequency of occurrence) are habitat modifying spp?	0	
FRAI SCORE (%)		**18.9**	
FRAI CATEGORY		**E/F**	
FRAI CATEGORY DESCRIPTION		**Seriously/critically modified**	

C) Karee tributary

No fish was detected at site Karee-Vaal at the time of sampling in November 2017. As this is a seasonal drainage line, the absence of fish from this site (stream) may be a natural phenomenon, as flow and hence habitats may not be suitable for the colonisation of any fish species.

4.8 Impacts assessment

Refer to Appendix 6 for aquatic biodiversity management tables that highlight the important biodiversity aspects, potential impact on these aspects and recommended management action that could be implemented (as included in the MWS Biodiversity Managament Plan).

The current section deals with the specific potential impacts of the proposed development (Kareerand TSF expansion projects as described in Section 2 of this report) on the aquatic fauna.

IMPACT 1: Altered hydrological regimes

CONSTRUCTION PHASE

Applicable activity: Expansion of Kareerand TSF, east and west storm water canals, return water dams, borrow pits.
Nature of impact: Alteration of natural runoff patterns due to alterations of catchments through construction of dams and infrastructure (including TSF and return water dam) and canals (east and west storm water canals), as well as borrow pits. The natural hydrology of the downstream rivers (Vaal River and to some extent lower Koekemoer Spruit) may be influenced in terms of volume and timing of flow that reach these receiving water bodies.
Extent of impact: Local: The impact will primarily occur between site Vaal1 (western storm water cannel inflow into Vaal River) and the Vaal-Koekemoer confluence, and depending on the extent of the impact, the downstream reach of the Vaal River. The impact would decrease with downstream distance form study area.
Duration of impact: Permanent: The impact will be occurring for the life of operation.
Intensity of impact: Medium: It is expected that ecological functioning of the receiving water bodies may be altered but they will be able to continue albeit in a modified way.
Probability: Definite.
Frequency: 6-Monthly (wet season)
Significance: MEDIUM
Status: Negative
Confidence: High
Mitigation: All actions must be taken to ensure that the runoff from the area to be impacted will be routed to the receiving water bodies, and that the volume as well as quality of this runoff is not jeopardised. Erosion control measures should be implemented.
Significance post mitigation: MEDIUM (refer to Table 28 below for detail regarding significance of residual impacts).

OPERATIONAL PHASE

Applicable activity: Operation of Kareerand Tailings Storage Facility, east and west storm water canals, return water dams, presence of borrow pits (even if rehabilitated).

Nature of impact: Alteration of natural runoff patterns due to alterations of catchments through construction of dams and infrastructure (including TSF and return water dam) and canals (east and west storm water canals), as well as borrow pits. The natural hydrology of the downstream rivers (Vaal River and to some extent lower Koekemoer Spruit) may be influenced in terms of volume and timing of flow that reach these receiving water bodies.

Extent of impact: Local: The impact will primarily occur between site Vaal1 (western storm water cannel inflow into Vaal River) and the Vaal-Koekemoer confluence, and depending on the extent of the impact, the downstream reach of the Vaal River. The impact would decrease with downstream distance form study area.

Duration of impact: Permanent: The impact will be occurring for the life of operation.

Intensity of impact: Medium: It is expected that ecological functioning of the receiving water bodies may be altered but they will be able to continue albeit in a modified way.

Probability: Definite.

Frequency: 6-Monthly (wet season)

Significance: MEDIUM

Status: Negative

Confidence: High

Mitigation: All actions must be taken to ensure that the runoff from the area to be impacted will be routed to the receiving water bodies, and that the volume as well as quality of this runoff is not jeopardised. Erosion control measures should be implemented. Borrow pits should be filled up and rehabilitated to restore natural runoff-patterns.

Significance post mitigation: MEDIUM (refer to Table 28 below for detail regarding significance of residual impacts).

Table 28: Predicted risk matrix for impact 1.

IMPACT 1:	**Altered hydrological regimes**				
	CRITERIA	**CONSTRUCTION**		**OPERATIONAL**	
		Rating	**Description**	**Rating**	**Description**
PRE-MITIGATION	Extent	2	Local	2	Local
	Duration	4	Permanent	4	Permanent
	Intensity	3	Medium	3	Medium
	CONSEQUENCE	**9**		**9**	
	Probability	4	Definite	4	Definite
	Frequency	2	6 mothly	2	6 mothly
	LIKELIHOOD	**6**		**6**	
	SIGNIFICANCE	**15**	**MEDIUM**	**15**	**MEDIUM**
POST-MITIGATION	Extent	2	Local	2	Local
	Duration	4	Permanent	4	Permanent
	Intensity	3	Medium	1	Low
	CONSEQUENCE	**9**		**7**	
	Probability	4	Definite	4	Definite
	Frequency	2	6 mothly	2	6 mothly
	LIKELIHOOD	**6**		**6**	
	SIGNIFICANCE	**15**	**MEDIUM**	**13**	**MEDIUM**

IMPACT 2: Habitat loss and deterioration

CONSTRUCTION PHASE

Nature of Impact: Increased erosion can be expected as result of the clearing of vegetation during construction. Erosion can also be aggravated by alien vegetation encroachment in disturbed areas. Increased input of sediment into the receiving water bodies (Vaal River, Koekemoer Spruit, Karee tributary) due to above mentioned activity may result in increased turbidity and sedimentation of bottom substrates. This is especially significant to fish and invertebrates that prefers clean rocky substrates (fish species that requires clean substrates for feeding and spawning (such as *Labeobarbus aeneus, Lb. kimberleyensis*, *Labeo capensis* that feeds and spawns in rocky areas, and various invertebrate species that have a high requirement for rocky habitats).
Extent of impact: Local: Depending on the level of disturbance, the primary impact can be expected 3 to 5km downstream of the disturbance.
Duration: Short: Effect will be primarily during and directly after construction.
Intensity of impact: medium
Probability: Definite
Significance: MEDIUM
Status: Negative.
Confidence: High
Mitigation:

- Limit construction to winter months (outside rainy season). Address erosion through applicable techniques (revegetation, gabions, etc.) to minimise erosion and hence sedimentation.
- Limit movement of construction vehicles and activities close to drainage lines and streams. Maintain riparian and wetland buffer zones.

Significance post mitigation: LOW (refer to Table 29 below for detail regarding significance of residual impacts).

OPERATIONAL PHASE

Nature of Impact: Increased erosion can be expected as result of the clearing of vegetation for construction (roads, infrastructure, canals, dams, borrow pits). Erosion can also be aggravated by alien vegetation encroachment in disturbed areas. Increased input of sediment into the receiving water bodies (Vaal River, Koekemoer Spruit, Karee tributary) due to above mentioned activity may result in increased turbidity and sedimentation of bottom substrates. This is especially significant to fish and invertebrates that prefers clean rocky substrates (fish species that requires clean substrates for feeding and spawning (such as *Labeobarbus aeneus, Lb. kimberleyensis*, *Labeo capensis* that feeds and spawns in rocky areas, and various invertebrate species that have a high requirement for rocky habitats).
Extent of impact: Local: Depending on the level of disturbance, the primary impact can be expected 3 to 5km downstream of the disturbance.
Duration: Long
Intensity of impact: Medium
Probability: Highly probable
Significance: MEDIUM
Status: Negative.
Confidence: High
Mitigation:

- Address erosion through applicable techniques (revegetation, gabions, etc.) during operational phase to minimise sedimentation.

- Limit movement of construction vehicles and activities close to drainage lines and streams.
- Implement alien plant control programme (especially riparian and wetland zones).

Significance post mitigation: LOW (refer to Table 29 below for detail regarding significance of residual impacts).

Table 29: Predicted risk matrix for impact 2.

IMPACT 2:	Habitat loss and deterioration				
	CRITERIA	CONSTRUCTION		OPERATIONAL	
		Rating	Description	Rating	Description
PRE-MITIGATION	Extent	2	Local	2	Local
	Duration	1	Short	3	Long
	Intensity	3	Medium	3	Medium
	CONSEQUENCE	**6**		**8**	
	Probability	4	Definite	3	Highly probable
	Frequency	2	6 mothly	2	6 mothly
	LIKELIHOOD	**6**		**5**	
	SIGNIFICANCE	**12**	**MEDIUM**	**13**	**MEDIUM**
POST-MITIGATION	Extent	2	Local	2	Local
	Duration	1	Short	3	Long
	Intensity	3	Medium	1	Low
	CONSEQUENCE	**6**		**6**	
	Probability	3	Highly probable	2	Probable
	Frequency	2	6 mothly	2	6 mothly
	LIKELIHOOD	**5**		**4**	
	SIGNIFICANCE	**11**	**LOW**	**10**	**LOW**

IMPACT 3: Water quality deterioration

CONSTRUCTION PHASE

Nature of impact: The proposed activity may impact on water quality in the following ways:

- Accidental spills (fuels, oils, cement, etc.) during construction (of TSF, return water dams, storm water canals). Depending on the nature and type of spill, these will impact significantly on the aquatic biota of the receiving water bodies (Vaal River, Koekemoer Spruit, Kareerand tributary). The intolerant biota will be most significantly impacted and may be eradicated due to such incidences.
- Increase turbidity of receiving river due to removal of vegetation during construction. Predatory species (such as Largemouth yellowfish and various invertebrates will especially be impacted as they require good visibility for feeding. The secondary impact of increased turbidity is sedimentation of bottom substrates (as described above for impact 2).

Extent of impact: Regional: Receiving river reaches (Vaal River, lower Koekemoer Spruit, lower Karee tributary). The extent will depend on the volume and type of spill/releases.
Duration: Short.
Intensity of impact: High
Probability: Probable

Significance: HIGH
Status: Negative.
Confidence: Low
Mitigation: Identify potential areas where seepage and spills can occur into the natural environment and take necessary precautions to prevent these. Prevent erosion (see mitigation for impact 2). It is essential that the aquatic biomonitoring programme should be maintained to detect any areas and aspects of concern (in terms of water quality deterioration).
Significance post mitigation: MEDIUM (refer to Table 30 below for detail regarding significance of residual impacts).

OPERATIONAL PHASE

Nature of impact: The proposed activity may impact on water quality in the following ways:

- Accidental spills (fuels, oils, etc.) from transport routes used to operate and maintain TSF and associated infrastructure (TSF, return water dams, storm water canals). Depending on the nature and type of spill, these will impact significantly on the aquatic biota of the receiving water bodies (Vaal River, Koekemoer Spruit, Kareerand tributary). The intolerant biota will be most significantly impacted and may be eradicated due to such incidences.
- Increase turbidity of receiving river due to erosion of bare soils (transport routes, etc.). Predatory species (such as Largemouth yellowfish and various invertebrates will especially be impacted as they require good visibility for feeding. The secondary impact of increased turbidity is sedimentation of bottom substrates (as described above for impact 2).
- Effluents/spills originating from TSF. Based on the current information it is evident that the water sources at the existing Kareerand TSF is of poor quality and generally pose a high acute and chronic environmental toxicity risk to potential receiving water bodies (as indicated by environmental toxicity testing results: Section 3.4). Although the monitoring data suggests that the toxicity is generally negated at the most downstream return water dam, the high EC measured at site Karee-Vaal indicate that some seepage/spills may be reaching this stream/drainage line, which flows into the Vaal River. The nature of the potential impacts effluents/seeps/spills will depend on the volume and quality. It can again be expected that the intolerant biota will be the most significantly impacted by such events, although the entire population may be altered.

Extent of impact: Regional: Receiving river reaches (Vaal River, lower Koekemoer Spruit, lower Karee tributary). The extent will depend on the volume and type of spill/releases.
Duration: Long: cease after operational life.
Intensity of impact: High
Probability: Probable
Significance: HIGH
Status: Negative.
Confidence: Low
Mitigation: Identify potential areas where seepage and spills can occur into the natural environment. Take necessary precautions to reduce potential spills and seepage. Toxicity testing should be performed on any effluent that may reach the natural ecosystem to determine their risk to the environment. Site Karee-Vaal should be included in the toxicity testing programme. It is essential that the aquatic biomonitoring programme should be maintained. Continually address erosion scars and incision of

wetlands (that act as natural filter systems for poor water quality). It is essential that the aquatic biomonitoring programme should be maintained to detect any areas and aspects of concern (in terms of water quality deterioration).
Significance post mitigation: MEDIUM (refer to Table 30 below for detail regarding significance of residual impacts).

Table 30: Predicted risk matrix for impact 3.

IMPACT 3:	**Water quality deterioration**				
	CRITERIA	**CONSTRUCTION**		**OPERATIONAL**	
		Rating	**Description**	**Rating**	**Description**
PRE-MITIGATION	Extent	3	Regional	3	Regional
	Duration	2	Medium	3	Long
	Intensity	5	High	5	High
	CONSEQUENCE	**10**		**11**	
	Probability	3	Highly probable	3	Highly probable
	Frequency	5	Daily	5	Daily
	LIKELIHOOD	**8**		**8**	
	SIGNIFICANCE	**18**	**HIGH**	**19**	**HIGH**
POST-MITIGATION	Extent	3	Regional	3	Regional
	Duration	2	Medium	3	Long
	Intensity	5	High	5	High
	CONSEQUENCE	**10**		**11**	
	Probability	2	Probable	2	Probable
	Frequency	3	Monthly	3	Monthly
	LIKELIHOOD	**5**		**5**	
	SIGNIFICANCE	**15**	**MEDIUM**	**16**	**MEDIUM**

Closure/Decommissioning Phase

No detail was available at this phase of the project regarding the exact processes that will be followed during closure/decommissioning. No detailed impact assessment can therefore be completed. This should be assessed and described in detail as part of the closure and rehabilitation plan for the mine. It is strongly recommended that the TSF, its content and associated infrastructure (storm water canals and dams) should be removed, all borrow pits should be completely rehabilitated (to resemble the baseline state as close as possible). Rehabilitated land use should primarily restore the pre-mining ecology and biodiversity, unless alternative land use is envisaged.

Cumulative impact of proposed development

The primary impacts that will have a cumulative impact in terms of aquatic fauna are *water quality deterioration* and *water quantity/hydrological alterations* as described above. The ***stability*** of a system could be described by concepts such as resilience (ability of system to recover from disturbance) and ***elasticity*** (speed with which the system returns to its original state after removal of the disturbance). The important issue is however, not whether an ecosystem can be classified as stable or fragile, but how much the particular ecosystem changes after a specific disturbance (Roux, 1999). Although these ecosystems have a limited ability to recover after pollution incidence or prolonged exposure to impacts, the overall ecological integrity of the system will generally be altered from its natural state and is unlikely to ever return to the pre-disturbance condition. The more severe and widespread (in spatial and temporal terms) an impact occurs, the lower the possibility of recovery [Such as the eradication of fish due to a spill in an area. Should there be dams and other migration barriers, physical or chemical, they are unlikely to return or recolonise the area again and may be lost with a radical impact on the aquatic ecosystem].

Water quality: Should the TSF contain all water of poor quality, and no polluted storm water reach the receiving water bodies, it is expected that the proposed activity will not have a significant cumulative contribution to water quality deterioration in downstream receiving river system (especially Vaal River). Should there be spills, seepage or releases from the new TSF or polluted storm water runoff, these will impact on the receiving water body (especially Vaal River reach). Due to the fact that the Vaal River (and especially the Koekemoer Spruit) is already in a deteriorated state (in terms of water quality), further deterioration could not be afforded as it will result in serious loss of ecological functioning (and detrimental to all other users of this resources). Continued monitoring (water quality and biomonitoring) should determine if the there is any signs of spatial or temporal deterioration in the receiving water bodies due to the proposed project. No water quality variables should be allowed to deteriorate further or fall outside the guideline values. The present ecological state (PES) of the receiving water bodies should also not be allowed to deteriorate towards a lower ecological category.

Water quantity: The proposed activity is not expected to have a significant impact on the flows in the receiving rivers. The ecological reserve of the receiving water body is therefore not expected to be notably impacted by the proposed development 9should clean water be allowed to reach the receiving water bodies)

4.9 Aquatic biodiversity monitoring programme

The current aquatic biomonitoring programme for AGA covers most of the important aquatic ecosystems of the MWS study area, as well as the areas to be potentially impacted by the proposed Kareerand TSF expansion project. It is recommended that the current AGA biomonitoring programme should be continued, and that additional sites be considered where applicable to specifically monitor the potential impact of the Kareerand TSF extension project (see Table 31 below for details of sites and protocols that should be considered for inclusion in AGA biomonitoring programme). It is especially strongly recommended that toxicity testing should be done at site Karee-Vaal (on Kareerand tributary) to monitor potential impacts (seepage/releases) from the Kareerand TSF towards the Vaal River. It is also strongly recommended that diatom sampling should be included as part of the routine aquatic biomonitoring programme. Toxicity assays of water types that may be discharged from the MWS area will greatly assist when applying for a discharge licence or when the need arises to decide on management actions pertaining to excess water.

Table 31: Recommended biomonitoring sites and protocols for AGA MWS Kareerand TSF Extension project (additional sites/protocols shaded).

Monitoring site	Description	Biomonitoring protocols		GPS coordinates	
		Protocol	Frequency	Latitude (South)	Longitude (East)
SR Drift* (Vaal1)	Vaal River in the upper reaches of the MWS study area. Upstream of all potential Kareerand TSF expansion impacts.	SASS5, FAII, habitat, *in-situ* water quality, chlorophyll-a, diatom analyses, screening toxicity testing.	twice per annum (fish once per annum)	-26.888406°	26.926623°
Vaal1B#	Vaal River between sites Vaal1 and Vaal2, area potentially impacted by proposed development (east channel, eastern borrow pit, TSF extension)	SASS5, FAII, habitat, *in-situ* water quality, chlorophyll-a, screening toxicity testing.	twice per annum (fish once per annum)	-26.951416°	26.908510°
VR-US* (Vaal2)	Vaal River in the middle reaches of the MWS study area, upstream of Koekemoer Spruit. Downstream of most TSF extension impacts.	SASS5, FAII, habitat, *in-situ* water quality,	twice per annum (fish once per annum)	-26.936502°	26.850588°
Vaal3#	Vaal River downstream of the MWS operational area, downstream of Koekemoer Spruit and all potential impacts associated with proposed Kareerand TFS expansion project.	SASS5, FAII, habitat, *in-situ* water quality, diatom analyses, screening toxicity testing.	twice per annum	-26.963952°	26.752748°
KS R502#	Koekemoer Spruit, upstream of southern MWS portion operational area, upstream of Kareerand TSF activities.	SASS5, habitat, *in-situ* water quality, diatom analyses, screening toxicity testing.	twice per annum	-26.963952°	26.752748°
MW-ISO4 (KS4)*	Koekemoer Spruit downstream of most MWS activities, including current and proposed Kareerand TSF activities.	SASS5, habitat, *in-situ* water quality, screening toxicity testing.	twice per annum	26.925800°	26.815700°
KS5#	Koekemoer Spruit in the lower reaches of the MWS study area just before Vaal River confluence (downstream of all MWS activities).	SASS5, habitat, *in-situ* water quality, diatom analyses, screening toxicity testing.	twice per annum	-26.937901°	26.815251°
Karee-BH16*	Kareerand Operations, borehole on southern side of slimes return dam	acute screening toxicity (DEEEP)	quarterly	-26.937901°	26.815251°
Karee-RWD*	Existing return water dam (RWD) at current Kareerand TSF (toxicity testing site)	acute screening toxicity (DEEEP)	quarterly	-26.899672°	26.880924°
Karee US Dam*	Existing dam in Kareerand tributary downstream of current Kareerand TSF (toxicity testing site)	acute screening toxicity (DEEEP)	quarterly	-26.902202°	26.877538°
Karee DS Dam*	Existing dam in Kareerand tributary downstream of current Kareerand TSF (toxicity testing site)	acute screening toxicity (DEEEP)	quarterly	-26.905569°	26.876917°
Karee-Vaal#	Unnamed stream (Kareerand tributary) draining away from the Kareerand TSF, just before inflow into Vaal River.	diatom analyses, acute screening toxicity (DEEEP)	quarterly	-26.918286°	26.868002°

*Existing biomonitoring site (AGA aquatic biomonitoring programme)
#Recommended site for inclusion as part of AGA biomonitoring programme.

4.10 Assumptions, uncertainties and gaps in knowledge

A vast amount of data pertaining to the aquatic biota of the study area is available, especially those gathered as part of the existing AngloGold Ashanti Biomonitoring Programme (2006 to 2017). The spatial gaps in knowledge was addressed during an aquatic survey conducted during 2017 as part of the current study. It is therefore concluded that there was no notable gaps in knowledge regarding the primary aquatic biota (fish and macroinvertebrates) of the study area.

The baseline (current) status of the study area was described, and the results is thought to be of high confidence. The expected impacts (risks) to the specialist component (aquatic biota) was conducted in detail for the construction and operational phase, looking at before and after mitigation scenarios. The detail regarding the actions that will be taken during closure/decommissioning and rehabilitation is not available at this early stage of the proposed development and therefore fall outside the scope of the current report. This should be further addressed as part of the closure and rehabilitation plans for the mine.

4.11 Conditions for inclusion in the environmental authorisation

It is recommended that the following should be considered for inclusion in the environmental authorisation of the proposed development.

- All recommended mitigation and management measures provided in this report should be considered.
- The impacts associated with the current TSF (especially seepage and water quality deterioration towards the Vaal River) should be addressed before the execution of any new developments.
- The recommended changes to the aquatic biomonitoring programme should be implemented.
- The management actions recommended in the latest Biodiversity Managament Plan for the Mine Waste Solutions study area should be implemented as a matter of urgency.
- No deterioration of the present ecological status (PES) of the potential receiving water bodies should be allowed (maintain within or improve PES categories).

4.12 Specialist opinion on proposed activity

- Should the proposed activity be conducted in the best environmental practice possible (considering all relevant mitigation measures), it could contribute to the prevention of further pollution related to mining activities in the area. Due to the fact that this study is an extension of an existing tailings storage facility with associated infrastructure, the location of the TSF extension makes sense and should be authorised (from an aquatic ecology perspective).
- The final decision regarding the borrow pit site should be guided by the terrestrial ecology (plants and animals) and preference should be given to those areas furthest away from aquatic ecosystems (streams, rivers and wetlands).

5. SUMMARY, CONCLUSIONS & RECOMMENDATIONS

A) Vaal River ecosystem:

- According to the DWS desktop classification system, the Vaal River reaches of concern falls within a *present ecological status* (PES) of B (slightly modified) to C (moderately modified) and are of moderate to ecological importance and sensitivity.
- The 2017 *in-situ water quality* monitoring results (physico-chemical habitat) did not detect any notable spatial deterioration within the Vaal River reach of concern. The EC levels generally remains consistent on a spatial scale throughout this reach while some temporal variation was noted (lower during the wet season when higher flows dilute salt concentration). The pH and dissolved oxygen levels were generally within guideline levels and should not be limiting to aquatic biota. Chlorophyll-*a* results indicated that the Vaal River upstream from MWS activities is already *eutrophic* to *hypertrophic* while a general further increase was noted towards hypertrophic levels downstream of the MWS study area. This is an indication that activities upstream from MWS activities has already led to significant nutrient enrichment and that mining activities cannot be ruled out as a contributing factor to further increased levels. The nuisance factor of algal bloom activity in this reach is considered to be serious.
- A total of 34 diatom species were identified from the Vaal River (2015 survey). The diatom-based water quality of the MWS Vaal River reach was classified as *poor*, with *salinity and organic pollution* levels being at unacceptable levels for the optimum functioning of aquatic biota. Nutrient levels were also very high. There were also concerns of *heavy metal pollution* that was picked up in the system during the analyses indicating that metal toxicity could affect the biological functioning of aquatic biota. The majority of diatom species present have a preference for *eutrophic*, organically enriched waters with high electrolyte content and is typically representative of industrially impacted waters. Organically bound nitrogen levels were very high indicating that nutrient loading was problematic at all sites.
- According to available literature an estimated fifty (50) *macro-invertebrate* families may be expected to occur in this MWS Vaal River reach under present conditions. The presence of forty-seven (47) macro-invertebrate taxa has been confirmed in this reach from 2013 to 2017. Overall this reach can be classified in a category B (slightly modified) to C (moderately modified) based on the aquatic macroinvertebrate composition. Temporal trends indicate notable variation over time, with all Vaal River sites indicating improvement over the latter part of the study period.
- Based on the latest available information and distribution maps the following eleven indigenous *fish* species have a high probability to occur in the MWS Vaal River reach. During recent (2012 to 2017) surveys of selected sites within this reach, the presence of ten indigenous species was confirmed. One of the fish species present in this reach, namely the Vaal-Orange Largemouth yellowfish (*Labeobarbus kimberleyensis*) is *red data listed* (IUCN and TOPS), being classified as *near-threatened.* A further five species, namely *L. aeneus, L. kimberleyensis, L. capensis, L. umbratus* and *A. sclateri* are endemic to the Orange-Vaal River system. A number of exotic species are also present in the Vaal River within the study area and may impact negatively on the indigenous

species. A FRAI score of 72% was calculated based on the latest available information, indicating that the biotic integrity (based on fish) of this reach is currently altered from its natural conditions and can be classified in a category C (moderately modified).

B) Koekemoer Spruit ecosystem

- According to the DWS desktop classification system, the Koekemoer Spruit reach of concern falls within a *present ecological status* (PES) of E (seriously modified) and are of moderate to ecological importance and sensitivity.
- Due to the seasonal nature of the Koekemoer Spruit, many sites of often dry at the time of sampling. The physico-chemical habitat (water quality) of the Koekemoer Spruit is very poor and will be greatly limiting to aquatic biodiversity of the area. Untreated sewage was found entering this stream and it can be expected that much surface and sub-surface affected mine water will reach this stream from the many mining operations in its vicinity. High EC levels were already evident in the upper reaches with no further notable spatial increase in salinity (as measured in EC) observed during 2017.
- A total of 61 diatom species were identified from the Koekemoer Spruit sites (2015 survey). The diatoms encountered in the Koekemoer Spruit indicated that there were concerns of *high salinity loads* within the system. There were valve deformities which indicated that *metal toxicity* was present and these might have an effect on the biological functioning of the aquatic biota in the river reach. The majority of diatom species present in the Koekemoer spruit have a preference for eutrophic, **organically enriched waters** with *high electrolyte content* and is typically representative of industrially, mining and agricultural activities.
- According to literature an estimated twenty-nine (29) **macro-invertebrate** families may be expected to occur in the MWS Koekemoer Spruit reach under present conditions. The lower expected diversity of macroinvertebrate taxa in the Koekemoer Spruit when compared to the Vaal River is especially attributed to the seasonal nature of the Koekemoer Spruit. Actual sampling of the Koekemoer Spruit revealed a higher diversity of invertebrates, with thirty-five (34) macro-invertebrate taxa confirmed in this reach between the period 2013 to 2017. The ecological category of this reach (based on macroinvertebrates) ranges between a category E (seriously modified) and F (critically modified) condition.
- Based on the latest available information and distribution maps ten indigenous species have a high probability to occur in the MWS Koekemoer Spruit reach. The 2013-2017 monitoring surveys confirmed the presence of six indigenous species. One alien fish species, namely *Gambussia affinis* was also sampled. A FRAI score of 18.9% was calculated indicating that the biotic integrity of this reach, based on fish, is currently in a highly deteriorated state and can be classified in a category E/F (seriously/critically modified). This is also a deterioration form the previous MWS assessment when a FRAI score of 32.7% was calculated (category E), indicating recent deterioration in the fish assemblages of this stream.

C) Karee tributary

- The Kareerand tributary is highly seasonal and therefore generally not suitable for the application of biomonitoring protocols. A single sites (Karee-Vaal) was sampled in the lower reached close to the Vaal River during the 2017-11 survey to gain some insight into the conditions prevailing in this stream. A very high EC level of 540 mS/m was measured at site Karee-Vaal during November 2017. This is an indication that some sources of high salinity is entering this drainage line, and that it then contributes to salt loads in the Vaal River. Some probable sources of pollution that may ompact this stream include Khuma township and the existing Kareerand TSF. MWS should further investigae and ensure that nou spills or seepage from the Kareerand TSF is reaching this stream.

- The latest (September 2017) environmental toxicity testing survey indicated that the Kareerand operations return water dam (Karee-RWD) was of a very high acute/chronic environmental toxicity hazard (Class V), with a very high safe dilution ratio of 0.1% required to negate potential impacts. It appears that this hazard was largely mitigated at the time of sampling as the downstream dams measured no acute/chronic environmental toxicity hazard (Class I) at Karee-US-Dam and slight acute/chronic environmental hazard (Class II) at Karee-DS-Dam. High EC levels are also often measured at these sources (460 mS/m at site Karee-RWD during September 2017), indicating that the may be potential contributors to the high EC levels observed in the lower Kareerand tributary at site Karee-Vaal.
- The Karee tributary is a seasonal drainage line, and hence not suitable for the application of the SASS5 as a monitoring tool or ecological classification system. During the 2017-11 survey conducted in the lower reaches of this stream as site Karee-Vaal, 15 *macroinvertebrate* taxa were sampled. Most of the taxa sampled had a very low (6 taxa) and low (8 taxa) requirement for unmodified water quality, indicating that poor water quality is currently prevailing in this stream.
- No fish was detected at site Karee-Vaal at the time of sampling in November 2017. As this is a seasonal drainage line, the absence of fish from this site (stream) may be a natural phenomenon, as flow and hence habitats may not be suitable for the colonisation of any fish species.

The potential impacts on the aquatic biota associated with the proposed Kareerand TSF expansion project include the following:

- Altered hydrological regimes
- Habitat loss and deterioration
- Water quality deterioration

The significance of these impacts on the aquatic fauna before and after mitigation can be summarised as follows:

SIGNIFICANCE OF IMPACTS		CONSTRUCTION		OPERATIONAL	
IMPACT		Pre-mitigation	Post-mitigation	Pre-mitigation	Post-mitigation
1	Altered hydrological regimes	MEDIUM	MEDIUM	MEDIUM	MEDIUM
2	Habitat loss and deterioration	MEDIUM	LOW	MEDIUM	LOW
3	Water quality deterioration	HIGH	MEDIUM	HIGH	MEDIUM

It is **recommended** that the above mentioned impacts should be mitigates (as described in the relevant section). The general impacts to aquatic biodiversity (as discussed in Appendix 6) should also be considered and appropriately managed. It is also emphasised that the current AGA biomonitoring programme should be maintained and additional sites and protocols as recommended in this report should be strongly considered for implementation.

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APPENDICES

Appendix 1: Specialist expertise and Declaration of independence.

Dr Pieter Kotze is currently a director of Clean Stream Biological Services and Biotox Laboratory Services and holds a Ph.D in Aquatic Ecology from the University of Johannesburg. From 1997 to 2002 conducted a Ph.D study on the assessment of ecological integrity of the Klip River aquatic ecosystem, during which time crucial experience was gained in the development and application of rapid biomonitoring protocols and multimetric indices. Relevant experience in the application of reserve determinations on intermediate and comprehensive levels was gained during several projects (Vaal River, Mokolo River, Olifants River, Letaba River, Orange River, Fish River, Sabie River, Crocodile River) since 2001. Dr Kotze was primarily responsible for the fish specialist component in the reserve determination and related projects. Dr. Kotze also attended reserve determination training courses in Eco-classification process, Habitat Flow Stressor Response and Yield modelling (2008) and he is a DWAF accredited SASS5 practitioner. Another field of expertise of Dr Kotze includes the compilation of Biodiversity Management Plans for especially the mining sector as well as performing of aquatic biomonitoring programmes for various clients. P. Kotze has been author, co-author and/or presenter of some papers, publications and courses on aquatic ecology. He has lectured post-graduate students on a part time basis at the Johannesburg University and served as a co-supervisor on M.Sc and Ph.D studies in freshwater ecology.

Declaration of Independence:

I act as an independent specialists in the environmental impact assessment process of the Amsterdam Dam project. I shall perform the work 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/our objectivity in performing such work. I have expertise in conducting the aquatic specialist study and report relevant to the environmental impact assessment. I confirm that I have knowledge of the relevant environmental Acts, Regulations and Guidelines that have relevance to the proposed activity and our field of expertise and will comply with the requirements therein.

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 ourselves for submission to the competent authority;

All particulars furnished by me/us in this report are true and correct. We realise that a false declaration is an offence in terms of regulation 48 of the National Environmental Management Act, 107 of 1998 (NEMA) and is punishable in terms of section 24F of the Act.

Dr. P. Kotze (15 December 2017)

Appendix 2: Aquatic macro-invertebrate taxa and their relative tolerance towards pollution (water quality deterioration) and generally preferred habitat (*from* DWAF, 2002).

TAXON	COMMON NAME	GENERALLY PREFERRED HABITAT
Phylum: PORIFERA	Freshwater sponges	On or under rocks, pebbles, any solid submerged substrate in unpolluted slow streams.
Taxon: COELENTERATA	Cnidaria/Hydra	n/a
Class: TURBELLARIA	Flatworms	Under stones or any other solid substrate.
Class: OLIGOCHAETA	Aquatic earthworms	Mud or bottom substrates in pools or quiet area of stream.
Class: HIRUDINAE	Leaches	Under stones, vegetation or debris in shallow pools or quiet areas of river.
Order: AMPHIPODA	Scuds, sideswimmers	Under stones, amongst vegetation or on bottom debris in unpolluted rivers.
Order: DECAPODA		
Potamonautidae*	Crabs	Under or amongst rocks.
Atyidae	Freshwater shrimps	Amongst vegetation on edges of pools and streams.
Palaemonidae	Freshwater prawns	Amongst stones, in rock crevices and in riffle areas.
Taxon: HYDRACARINA	Water mites	Submerged vegetation or bottom debris in slow streams or quiet pools.
Order: PLECOPTERA		
Notonemouridae	Stoneflies	Under stones, amongst dead leaves, fast flowing streams, mountain streams and coastal streams.
Perlidae	Stoneflies	Under stones, amongst dead leaves, fast flowing streams in Northern and Eastern half of country.
Order: EPHEMEROPTERA		
Baetidae	Small minnow flies	Rocks, plants or coarse sand in moderately fast streams
Caenidae	Cainflies	Stones or muddy areas in slow or very slow streams
Ephemeridae	n/a	n/a
Heptageniidae	Flat-headed mayflies	Stones or submerged pieces of wood in moderate to fast flowing streams
Leptophlebiidae	Prongills	Stones or submerged pieces of wood in gentle flowing streams
Oligoneuridae	Brushlegged mayfly	Coarse sand or sandy patches in very fast flowing streams
Polymitarcyidae	Pale burrowers	Muddy riverbanks in moderately fast flowing streams
Prosopistomatidae	Water specs	Stones or any floating substrate in fast flowing streams
Tricorythidae	Stout crawlers	Rocks or any solid submerged substrate in fast flowing streams
Order: HEMIPTERA		
Calopterygidae	Damselflies	Vegetation on edges of streams.
Chlorocyphidae	Damselflies	Under stones in backwater areas or slow streams.
Chlorolestidae	Damselflies	Vegetation on edges of slow streams.
Coenagrionidae	Damselflies	Vegetation on edges of streams.
Lestidae	Damselflies	Vegetation in backwaters and pools.
Platycnemidae	Damselflies	Under stones, on vegetation in headwater streams.
Protoneuridae	Damselflies	Vegetation in headwater of streams.
Order: ODONATA		
Aeshnidae	Dragonflies	Under stones in slow or fast streams.
Corduliidae	Dragonflies	Stones in slower areas of streams.
Gomphidae	Dragonflies	Sand banks, muddy patches on edges of streams.
Libelludae	Dragonflies	Stones, muddy patches in backwater areas or very slow streams.
Order: LEPIDOPTERA		
Pyralidae	Aquatic caterpillars	Exposed rock surfaces, on submerged plants or algae in rapid streams.
Order: HEMIPTERA		
Belostomatidae*	Giant water bug	Bottom of shallow pools in backwater areas or quiet areas of stream.
Corixidae*	Water boatmen	Shallow pools in quiet muddy areas of stream.
Gerridae*	Pond skater	On surface of ponds or streams in shaded areas.

Hydrometridae*	Marsh streaders	Floating vegetation in backwaters of streams
Naucoridae*	Creeping water bugs	Dense vegetation on edges of streams
Nepidae*	Water scorpions	Vegetation, trash or mud in shallow pools or slow streams.
Notonectidae*	Back swimmers	Pools and backwaters of streams
Pleidae*	Pigmy backswimmers	Dense vegetation in shallow, clear water.
Veliidae*	Broad-shouldered water striders	Generally pools, although some species prefer riffles in streams.
Order: MEGALOPTERA		
Corydalidae	Dobsonflies	Under stones, fast flowing streams of mountainous areas of Cape and Natal.
Sialidae	n/a	n/a
Order: TRICHOPTERA		
Dipseudopsidae	n/a	n/a
Ecnomidae	Caseless caddisflies	Stones, submerged aquatic vegetation in slow streams and quiet pools
Hydropsychidae	Caseless caddisflies	Under stones, living in shelters made of sand grains in fast flowing rivers
Philopotamidae	Caseless caddisflies	Narrow ilken tubes under stones in fast flowing streams
Psychomyiidae	Caseless caddisflies	Silk tunnels under stones on wet rocks, around waterfalls and head waters of streams
Polycentropodidae	Caseless caddisflies	Silken nets on stones in fast flowing water
Calamoceratidae	n/a	Sub-tropical
Hydroptilidae	Micro caddisflies	On or under stones in slow to very slow fowing streams
Hydrosalpingidae	n/a	South western cape
Lepidostomatidae	n/a	n/a
Leptoceridae	Cased caddisflies	Amongst vegetation (generally low pH streams)
Pisuliidae	Cased caddisflies	Leaf pockets, stream with overhanging trees, slow moving streams, backwaters or fast streams with areas where dead leaves gather.
Order: COLEOPTERA		
Dytiscidae (adults*)	Predacious diving beetles	Amongst plants on the edges of ponds/pools and backwater areas of streams.
Elmidae / Dryopidae*	Riffle beetles	Stones or any solid substrate in fast streams
Gyrinidae (adults*)	Whirligig beetles	Adults: On the surface of water in quit ponds or flowing water. Larvae: Under stones or other solid substrate, on vegetation in slow to moderately fast streams.
Haliplidae (adults*)	Crawling water beatles	n/a
Helodidae	Marsh beetles	On submerged vegetation, under stones in slow or fast streams with low pH.
Hydraenidae (adults*)	Minute moss beetles	Stagnant pools, wet rocks around waterfall and amongst plants on edge of streams.
Hydrophilidae (adults*)	Water scavenger beetles	Adults: Amongst vegetation, in muddy patches along riverbanks in quiet shallow pools or slow edges of streams. Larvae: Poolsand quiet, shallow edges of streams.
Limnichidae	n/a	n/a
Psephenidae	Water penny beetles	On rocks or other solid substrate in shallow fast streams.
Order: DIPTERA		
Athericidae	Snipe flies	Leaf pockets in mountain streams.
Blepharoceridae	Net-winged midges	Stones in mountain streams.
Ceratopogonidae	Biting midges	Sand, mud on edges of streams.
Chironomidae	Midges	Silk tubes on any type of substrates in pools and streams.
Culicidae*	Mosquitoes	Pools and any temporary puddle.
Dixidae*	Meniscus midges	Slow streams and backwater areas of fast streams.
Empididae	n/a	n/a
Ephydridae	Shore flies	Shallow pools, puddles, stagnant saline water.
Muscidae	House flies	Moss or massess of algae in shallow, still water.
Psychodidae	Moth flies	Streams and stagnant puddles with decaying organic matter.
Simuliidae	Black flies	Stones, plants or any solid surface in shallow, rapid streams.
Syrphidae*	Rat-tailed maggots	Water-filled holes, polluted streams, decaying vegetation on edges of ponds.

Tabanidae	Horseflies	Muddy areas of pools and streams.
Tipulidae	Crane flies	Species are habitat specific, bottoms of streams, muddy edges of streams, under algal scum or in aqutic mosses.
Phylum: MOLLUSCA		
Ancylidae	Limpets	On rocks or any solid submerged substrate in all streams countrywide.
Bulininea	n/a	n/a
Hydrobidae*	n/a	n/a
Lymnaeidae*	Pond snails	Gravel beds, or on aquatic vegetation.
Physidae*	Pouch snails	Gravel beds, or on aquatic vegetation.
Planorbinae*	Orb snails	Gravel beds, or on aquatic vegetation, in flowing streams.
Thiaridae*	Snails	Gravel beds in flowing streams, silty substrates in pools.
Viviparidae*	n/a	n/a
Corbiculidae	Clams	Sand or gravel beds in flowing streams.
Sphaeridae	Pill clams	Sand or gravel beds.
Unionidae	Pearly mussels	Deep muddy substrate.

Highly tolerant to pollution
Moderately tolerant to pollution
Very low tolerance to pollution

Appendix 3: Dominant diatoms sampled in the study area (2015-04).

Species name	Vaal 1	Vaal 2	Vaal 3	Koekemoer-spruit 1	Koekemoers-pruit 2	Koekemoer-spruit 3
Aulacoseira ambigua (Grunow) Simonsen	23,4	39,4	33,5			
Achnanthidium eutrophilum (Lange-Bertalot)Lange-Bertalot					4,9	
Achnanthidium saprophilum (Kobayasi et Mayama) Round & Bukhtiyarova					6,8	
Amphipleura pellucida Kützing					0,7	
Anomoeoneis sphaerophora (Ehr.) Pfitzer						1
Aulacoseira granulata (Ehr.) Simonsen	13,8	21,8	16			6
Aulacoseira subarctica fo.subborealis (Nygaard) Haworth	1,8					
Caloneis aequatorialis Hust.v. transitoria Manguin ex Kociolek& Revie					3,1	
Craticula ambigua (Ehrenberg) Mann						1,5
Cyclotella meneghiniana Kützing	1,3	7,4	10,5		0,7	
Craticula molestiformis (Hustedt) Lange-Bertalot	0,7			2,1	0,2	
Caloneis molaris (Grunow) Krammer						2,3
Cocconeis placentula Ehrenberg var. placentula	8,3					
Craticula buderi (Hustedt) Lange-Bertalot				2,3		
Craticula cuspidata (Kützing) Mann						0,5
Craticula vixnegligenda Lange-Bertalot					2,1	
Abnormal diatom valve (unidentified) or sum of deformities abundances	1,5	0,7		4,7	1	1,3
Denticula kuetzingii Grunow var.kuetzingii					2,3	
Diploneis oblongella (Naegeli) Cleve-Euler				2,3		
Diatoma vulgaris Bory	1,8					
Epithemia adnata (Kützing) Brebisson						0,7
Encyonema silesiacum (Bleisch in Rabh.) D.G. Mann				2,1		
Encyonopsis microcephala (Grun.) Kram. var. robusta (Hustedt) Krammer					7,6	
Eolimna subminuscula (Manguin) Moser Lange-Bertalot & Metzeltin		1,2	0,5	3,3		
Fragilaria bicapitata A.Mayer	1					
Fragilaria nanana Lange-Bertalot					3,6	
Fallacia pygmaea (Kützing) Stickle & Mann ssp.pygmaea Lange-Bertalot					1,8	7,9
Fragilaria tenera (W.Smith) Lange-Bertalot	1,3	1,7	1,5		5,7	
Fragilaria ulna (Nitzsch.)Lange-Bertalot var.acus (Kütz.) Lange-Berta			1,7			
Geissleria decussis(Ostrup) Lange-Bertalot & Metzeltin					0,5	
Gomphonema parvulum (Kützing) Kützing var. parvulum f. parvulum	2	1,4	4,7	12,4		
Gyrosigma acuminatum (Kützing)Rabenhorst					1	1
Gyrosigma attenuatum (Kützing) Rabenhorst					12,6	26,9
Gyrosigma parkerii (Harrison) Elmore					2,6	7,1
Hippodonta capitata (Ehr.)Lange-Bert.Metzeltin & Witkowski		0,5				

Species name	Vaal 1	Vaal 2	Vaal 3	Koekemoer-spruit 1	Koekemoers-pruit 2	Koekemoer-spruit 3
Mayamaea atomus (Kützing) Lange-Bertalot				0,4		
Mastogloia smithii Thwaites						5,8
Melosira varians Agardh	0,5					
Nitzschia amphibia Grunow f.amphibia	4,4	1,4	2,7	0,9		
Navicula arvensis Hustedt				0,9	1	
Nitzschia clausii Hantzsch			2	0,4		
Navicula capitatoradiata Germain abnormal fo.	0,5					
Navicula cryptotenella Lange-Bertalot		0,9				1
Nitzschia capitellata Hust.in A.S.var.tenuirostris(Grun.in V.H.) Bukh				45,5		
Navicula cryptotenelloides Lange-Bertalot						0,2
Nitzschia dissipata(Kützing)Grunow var.dissipata				0,2		
Navicula erifuga Lange-Bertalot				0,2	0,7	1,5
Nitzschia filiformis (W.M.Smith) Van Heurck var. filiformis			4,7		0,7	
Nitzschia hantzschiana Rabenhorst				3,1		
Navicula heimansioides Lange-Bertalot					6,8	
Nitzschia frustulum(Kützing)Grunow var.frustulum	4,1	1,4				
Navicula kotschyi Grunow					3,6	
Nitzschia desertorum Hustedt						3,6
Nitzschia liebetruthii Rabenhorst var.liebetruthii	7					2,3
Navicula microcari Lange-Bertalot		0,9			16,2	
Nitzschia obtusa W.M.Smith var. kurzii (Rabenhorst) Grunow					7	
Nitzschia palea (Kützing) W.Smith	6,5	14,6	13,5	11,2		
Navicula ranomafanensis (Manguin) Metzeltin & Lange-Bertalot	0,5					
Navicula recens (Lange-Bertalot) Lange-Bertalot	7,2		4,7			1,3
Navicula schroeteri Meister var. schroeteri		3,2				3,9
Navicula symmetrica Patrick		0,5				1,5
Navicula tripunctata (O.F.M.) Bory forme teratogene						1
Navicula trivialis Lange-Bertalot abnormal form						8,9
Nitzschia umbonata(Ehrenberg)Lange-Bertalot				7,1		
Navicula zanoni Hustedt	0,7					
Pinnularia borealis Ehrenberg var. borealis					0,7	
Pleurosigma salinarum (Grunow) Cleve & Grunow					0,7	
Reimeria uniseriata Sala Guerrero & Ferrario	2,6					
Stephanodiscus agassizensis Hakansson & Kling	1					
Staurosira elliptica (Schumann) Williams & Round	0,5					
Sellaphora pupula Kutzing						2.0
Stephanodiscus hantzschii fo.parva Grunow ex Cleve et Moller	1	1,2	3,2			
Tryblionella apiculata Gregory					0,7	
Tryblionella calida (grunow in Cl. & Grun.) D.G. Mann					0,5	1,8

Species name	Vaal 1	Vaal 2	Vaal 3	Koekemoer-spruit 1	Koekemoers-pruit 2	Koekemoer-spruit 3
Tabularia fasciculata (Agardh)Williams et Round					81,3	
Tryblionella hungarica (Grunow) D.G. Mann						8,4
Thalassiosira weissflogii (Grunow) Fryxell & Hasle	3,3	1,2				
Pleurosigma salinarum (Grunow) Cleve & Grunow						0.5
TOTAL	400	400	400	400	400	400

Appendix 4: View of selected aquatic survey sites in the MWS study area.

Plate A1: View of site Vaal 1 (Top:2015-04, Bottom:2017-09)

Plate A2: View of site Vaal 1B (2017-11)

Plate A3: View of site Vaal 2 (Top:2015-04, Bottom:2017-03)

Plate A4: View of site Vaal 3 (2015-04)

Plate A5: View of site Vaal 4 (2017-09)

Plate A6: View of site KS1 (Koekemoer Spruit) (Left: 2015-04, Right: 2017-03)

Plate A7: View of site KS2 (Koekemoer Spruit) (2015-04)

Plate A8: View of site KS R501 (Koekemoer Spruit) (2017-11)

Plate A9: View of site KS3 (Koekemoer Spruit) (2015-04)

Plate A10: View of site KS4 (Koekemoer Spruit) (Left: 2015-04, Right: 2017-03)

Plate A11: View of site Karee-Vaal (Karee tributary) (2017-11)

Appendix 5: Long term data of macroinvertebrates sampled within the MWS study area (2013 – 2017) (1 indicated presence).

Locality name	Date	COELENTERATA	TURBELLARIA	OLIGOCHAETA	HIRUDINEA	POTAMONAUTIDAE	ATYIDAE	HYDRACARINA	BAETIDAE 1 SP	BAETIDAE 2 SP	BAETIDAE > 2 SP	CAENIDAE	HEPTAGENIIDAE	LEPTOPHLEBIIDAE	TRICORYTHIDAE	CHLOROCYPHIDAE	COENAGRIONIDAE	LESTIDAE	AESHNIDAE	GOMPHIDAE	LIBELLULIDAE	CRAMBIDAE (PYRALIDAE)	BELOSTOMATIDAE	CORIXIDAE	GERRIDAE	HYDROMETRIDAE	NAUCORIDAE	NEPIDAE	NOTONECTIDAE	PLEIDAE	VELIIDAE/MESOVELIIDAE	ECNOMIDAE	HYDROPSYCHIDAE 1 SP	HYDROPSYCHIDAE 2 SP	HYDROPTILIDAE	LEPTOCERIDAE	DYTISCIDAE	ELMIDAE/DRYOPIDAE	GYRINIDAE	HYDROPHILIDAE	CERATOPOGONIDAE	CHIRONOMIDAE	CULICIDAE	DIXIDAE	MUSCIDAE	SIMULIIDAE	SYRPHIDAE	TABANIDAE	ANCYLIDAE	LYMNAEIDAE	PHYSIDAE	PLANORBINAE	CORBICULIDAE	SPHAERIIDAE
KS1	01/02/2013					1	1		1			1					1	1			1							1	1	1			1				1	1	1		1	1	1							1				
KS1	01/09/2013			1		1	1	1		1		1												1						1							1				1	1	1			1								
KS1	01/04/2014			1		1	1		1										1				1	1	1			1	1								1					1				1								
KS1	01/09/2014			1				1	1			1					1						1	1	1					1							1			1	1	1		1										
KS2	01/09/2017		1	1	1												1							1																	1	1												
KS2	01/03/2016			1					1								1		1				1	1	1				1		1						1				1	1												
KS2	01/09/2016			1																									1								1				1	1									1			
KS2	01/03/2017			1	1				1								1						1	1					1	1	1						1			1	1	1	1											
KS4	01/09/2014			1		1											1		1		1			1													1					1									1	1		
KS4	01/09/2017																							1	1						1						1			1		1		1		1					1			
KS4	01/03/2015																1		1																							1	1			1								
KS4	01/09/2015																																									1												
KS4	01/03/2016			1					1								1		1						1						1						1			1		1	1								1	1		
KS4	01/09/2016																																								1	1								1			
KS4	01/04/2014						1		1									1				1								1						1					1				1						1		
KS5	01/02/2013				1				1			1											1							1							1					1												
KS5	01/09/2013																																			1					1												
KS5	01/04/2014								1														1	1	1	1		1		1							1			1		1				1				1	1			
KS5	01/09/2014			1				1		1														1													1				1	1	1			1					1			
Vaal1	01/09/2014		1	1	1	1					1	1		1						1													1			1			1		1	1				1			1		1		1	1
Vaal1	01/09/2015			1	1					1		1	1				1						1	1									1			1			1			1	1		1	1					1			
Vaal1	01/03/2016			1	1	1		1		1		1		1	1		1						1	1							1			1	1				1	1	1	1				1				1		1	1	
Vaal1	01/09/2016			1	1				1			1					1																1									1				1					1			
Vaal1	01/03/2017			1	1		1			1		1		1	1		1				1		1	1			1						1					1				1				1								
Vaal1	01/09/2017			1	1		1	1	1			1		1	1		1		1	1			1										1					1	1			1			1	1					1		1	1
Vaal2	01/09/2012			1			1		1								1							1																		1				1					1			
Vaal2	01/02/2013			1	1		1		1						1		1						1	1					1	1	1		1									1				1								
Vaal2	01/09/2013		1	1	1					1							1							1									1						1			1				1					1			
Vaal2	01/04/2014			1			1			1							1						1	1																		1				1								
Vaal2	01/09/2014			1			1			1		1					1				1			1									1						1		1	1			1	1					1			
Vaal2	01/03/2015			1	1	1				1		1			1		1						1	1						1	1		1						1			1				1			1					
Vaal2	01/09/2015		1	1	1				1			1					1						1	1					1				1						1			1				1					1			
Vaal2	01/03/2016		1	1		1					1	1			1		1				1		1	1					1	1	1	1	1					1	1			1				1				1	1			
Vaal2	01/09/2016			1					1			1					1																						1		1	1				1				1	1		1	
Vaal2	01/03/2017			1			1			1		1		1	1		1						1								1		1					1				1				1								
Vaal2	01/09/2017			1	1		1		1			1			1		1						1	1									1						1			1	1		1	1			1		1		1	1
Vaal2	01/03/2012	1					1		1			1		1	1		1						1	1						1		1	1						1			1												
Vaal2	01/08/2011		1	1			1		1			1			1		1							1					1				1						1		1	1				1			1					
Vaal2	01/03/2011			1	1		1		1			1			1		1		1					1				1			1		1						1			1				1								
Vaal2	01/09/2010			1			1		1			1		1			1						1	1						1	1		1				1		1		1	1				1			1					
Vaal2	01/03/2010				1		1		1			1		1	1		1						1					1	1	1			1					1			1	1												
Vaal2	01/08/2009		1	1	1		1		1			1		1		1	1				1			1						1								1	1	1	1	1	1		1	1			1		1		1	
Vaal4	01/09/2012			1			1		1			1																			1		1								1	1	1			1					1		1	
Vaal4	01/02/2013			1		1			1			1			1		1						1	1						1	1		1				1		1			1			1	1					1			
Vaal4	01/09/2013			1						1													1											1					1		1	1				1					1			
Vaal4	01/04/2014			1			1			1													1								1		1				1		1			1				1								
Vaal4	01/09/2014			1	1					1		1		1										1										1			1		1		1	1				1					1			
Vaal4	01/03/2015			1	1	1	1		1			1					1						1	1				1		1	1			1			1				1	1				1								
Vaal4	01/09/2015			1	1		1	1				1					1						1	1									1				1		1		1	1				1	1			1	1		1	
Vaal4	01/03/2016			1	1		1				1	1			1		1				1		1	1							1		1									1				1				1				
Vaal4	01/09/2016			1			1			1		1					1				1												1				1		1		1	1				1					1		1	
Vaal4	01/03/2017			1	1	1	1		1			1			1		1			1			1								1			1								1				1							1	
Vaal4	01/09/2017			1	1	1	1	1				1		1	1		1			1	1		1										1					1	1		1	1			1	1				1	1		1	1
Vaal4	01/03/2012	1					1		1			1			1		1						1	1						1	1		1						1			1			1	1								1
Vaal4	01/08/2011			1					1			1			1		1			1				1	1								1						1	1	1	1				1							1	1
Vaal4	01/03/2011			1	1		1		1			1			1		1		1		1										1		1						1		1	1				1								
Vaal4	01/09/2010			1	1		1		1			1		1			1			1			1										1		1		1		1	1	1	1				1							1	

Appendix 6: Aquatic Biodiversity Management Tables

Table A1: Aquatic biodiversity management recommendations for the MWS Vaal River section

BIODIVERSITY ASPECTS	POTENTIAL IMPACTS	MANAGEMENT ACTIONS
A) Confirmed presence of **near-threatened fish species** Largemouth yellowfish (*Labeobarbus kimberleyensis*): • Moderately intolerant (overall) • Trophic specialist (top predator) • Habitat specialist (deep clean water and good quality riffles/rapids for breeding) • Predator: requires clean water/ good visibility for hunting. • Potamodromous species: Requires free movement/migration between river reaches to complete life cycle.	A1) Water quality (physico-chemical habitat) deterioration. Surface and sub-surface discharges from the Kareerand TSF. Contribution of poor water quality including untreated sewage water and mine process water from the Koekemoer Spruit.	• Prevent water quality deterioration (spills, seepage, releases). Identify potential areas where seepage and spills can occur into the natural environment. Take necessary precaution to reduce potential spills and seepage. • Ensure compliance to water quality guidelines. • Maintain ecological reserve (quality). • Do not allow increase turbidity (erosion, increased water column algae) that may influence feeding (predator). • Allow adequate quantity (flow) to ensure dilution of pollutants.
	A2) Water quantity / Flow modification	• Maintain ecological reserve (quantity) • Limit abstraction from resource during low flows/droughts.
	A3) Physical habitat deterioration (breeding habitats: rocky substrates in riffles and rapids)	• Prevent erosion (sedimentation) • Maintain adequate flows.
	A4) Reduced food source (invertebrates and fish)	• Maintain diversity and abundance of food source.
	A5) Over utilization (angling)	• Promote catch-and-release (sign boards, education/information, law enforcement) • Monitor reach for poaching activity (illegal use gill nets)

BIODIVERSITY ASPECTS	**POTENTIAL IMPACTS**	**MANAGEMENT ACTIONS**
	A6) Migration barriers (physical and chemical)	• Ensure free longitudinal connectivity. • No creation of new barriers (weirs, dams, water quality deterioration) • Contribute to implementation of fishways at existing barriers (also up- and downstream of study area)
	A7: Presence of alien fish species: • *Mosquito fish*: feed on fish eggs and larvae • Largemouth bass: Predator, compete for food. • Common carp: Bottom feeding increases water turbidity and disturb breeding grounds.	• Promote removal of alien species when caught. • Do not allow any stocking of fish (especially alien species)
B) Presence of biota with moderate to high requirement for **unmodified water quality**: • Fish: *Labeobarbus kimberleyensis* • Invertebrates: *Atyidae, Hydracarina, Leptophlebiidae, Tricorythidae, Chlorocyphidae, Aeshnidae, Ecnomidae and Elmidae*	B1) Water quality deterioration. Surface and sub-surface discharges from the Kareerand TSF. Contribution of poor water quality including untreated sewage water and mine process water from the Koekemoer Spruit.	See A1.
C) Presence of biota with a preference for flowing water (high flow requirement): • Fish: *Labeobarbus kimberleyensis, L. aeneus, Labeo capensis* • Invertebrates: Various (see Table 14). Indicators include *Heptageniidae*, *Tricorythidae, Hydropsychidae, Simulidae*	C1) Flow modification	See A2.

BIODIVERSITY ASPECTS	POTENTIAL IMPACTS	MANAGEMENT ACTIONS
D) Diverse aquatic biota: • Presence of ten of the expected 11 indigenous fish species confirmed. • Presence of 47 of an estimated 50 macro-invertebrate taxa confirmed. • 34 diatom species confirmed (Appendix 3)	D1) Water quality (physico-chemical habitat) deterioration	• See A1
	D2) Water quantity / Flow modification	• See A2
	D3) Physical habitat deterioration (especially sedimentation of rocky substrates, excessive algal growth)	• Maintain habitat diversity (deep, shallow, rocky substrate, vegetation). • Promote sustainable use of vegetation by local community. • Limit surface soil disturbance and manage erosion (especially previously disturbed areas) • Carrying capacity should not be exceeded. • Specialist aquatic assessments before and monitoring after disturbance of riverine areas. • Prevent further nitrification and organic enrichment due to WWTW effluents (leading to increased algal growth). • See also A3.
	D4) Reduced food source	• Maintain diversity and abundance of food source for all aquatic fauna.
	D5) Over utilization (fish)	• Promote catch-and-release of indigenous species. • Monitor reach for poaching activity (illegal use gill nets)
	D6) Migration barriers (physical and chemical)	• Ensure free longitudinal connectivity. • No creation of new barriers (weirs, dams, water quality deterioration) • Contribute to implementation of fishways at existing barriers (also up- and downstream of study area)
	D7) Presence of alien fish species	• See A7

Table A2: Aquatic biodiversity management recommendations for the MWS Koekemoer Spruit section

BIODIVERSITY ASPECTS	POTENTIAL IMPACTS	MANAGEMENT ACTIONS
E) Diversity of aquatic biota: • Presence of six (6) of the expected 10 indigenous fish species confirmed. • Presence of 34 macro-invertebrate taxa confirmed. • Presence of 61 diatom species confirmed (Appendix 3)	E1) Water quality (physico-chemical habitat) deterioration. Surface and sub-surface discharges of affected mine water.	• See A1
	E2) Water quantity / Flow modification	• See B1 • Maintain natural seasonality of this seasonal river (no releases during dry season)
	E3) Physical habitat deterioration. Spills of tailings material.	• See D3
	E4) Reduced food source (invertebrates and fish)	• See D4.
	E5) Over utilization (angling): Low probability of this happening in Koekemoer Spruit	• See D5
	A6) Migration barriers (physical and chemical)	• See D6
	A7: Presence of alien fish species:	• See D8
F) Presence of biota with moderate to high requirement for **unmodified water quality**: • Invertebrates: *Atyidae, Hydracarina, Lestidae, Aeshnidae, Elmidae and Dixidae*	F1) Water quality deterioration. Discharges of affected mine water and pipeline spills of tailings material.	See A1.