

# **SPECIALIST ASSESSMENT: AQUATIC ECOSYSTEMS**

**For the proposed Volspruit Mine**

For:  
San Oosthuizen  
EcoPartners  
[san@ecopartners.co.za](mailto:san@ecopartners.co.za)  
[www.ecopartners.co.za](http://www.ecopartners.co.za)

Compiled by:  
Norma Sharratt (*Pr. Sci. Nat*) 400088/15  
Pieter Kotze (*Pr. Sci. Nat*) 400413/04  
Tel: 082 890 6452 / 082 779 0734  
Email: [Norma@cleanstream-bio.co.za](mailto:Norma@cleanstream-bio.co.za)  
[Pieter@cleanstream-bio.co.za](mailto:Pieter@cleanstream-bio.co.za)



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## Abbreviations and Acronyms

| Abbreviation | Description                                                     |
|--------------|-----------------------------------------------------------------|
| ASPT         | Average (SASS) score per taxon                                  |
| DO           | Dissolved Oxygen                                                |
| DWAF         | (Former) Department of Water Affairs and Forestry               |
| DWS          | Department of Water and Sanitation                              |
| EC           | Electrical Conductivity                                         |
| EIA          | Environmental Impact Assessment                                 |
| EIS          | Ecological Importance and Sensitivity                           |
| EWR          | Ecological Water Requirement                                    |
| EMP          | Environmental Management Plan                                   |
| FD           | Fast Deep                                                       |
| FS           | Fast Shallow                                                    |
| FEPA         | Freshwater Ecosystem Priority Areas                             |
| FRAI         | Fish Response Assessment Index                                  |
| FROC         | Frequency of Occurrence (fish species)                          |
| GNR          | General Notice Regulation                                       |
| GPS          | Global Positioning System                                       |
| GSM          | Gravel, Sand and Mud                                            |
| IHI          | Index of Habitat Integrity                                      |
| IUCN         | International Union for Conservation of Nature                  |
| IHAS         | Integrated Habitat Assessment System                            |
| IWULA        | Integrated Water Use Licence Application                        |
| IWWMP        | Integrated Water and Waste Management Plan                      |
| MIRAI        | Macroinvertebrate Response Assessment Index                     |
| MPRDA        | Mineral and Petroleum Resources Development Act, 28 of 2002     |
| NEMA         | National Environmental Management Act, 107 of 1998              |
| NEMBA        | National Environmental Management: Biodiversity Act, 10 of 2004 |
| NEMWA        | National Environmental Management: Waste Act, 59 of 2008        |
| NFEPA        | National Freshwater Ecosystem Priority Areas                    |
| NPS          | Non-point source                                                |
| NWA          | National Water Act, 36 of 1998                                  |
| PCD          | Pollution Control Dam                                           |
| PES          | Present Ecological State                                        |
| SASS5        | South African Scoring System, Version 5                         |
| SD           | Slow Deep                                                       |
| SQ           | Sub-quaternary reach                                            |
| SS           | Slow Shallow                                                    |
| TDS          | Total Dissolved Salts                                           |
| WUL          | Water Use Licence                                               |

## **Executive Summary**

### **1.1 Baseline Assessment**

Based on the aquatic assessment conducted in 2011 and 2021/2022, the Present Ecological State (PES) is considered to be Largely Natural /Slightly Modified (category B) to Moderately Modified (category C) for fish and aquatic macroinvertebrates in this reach of the Nyl River.

It is important to note that the Nyl River is a floodplain wetland with a seasonal flow regime and a high diversity of aquatic macroinvertebrates is not expected under natural conditions. Reference should also be made to the wetland specialist report for a more comprehensive description of wetland habitat integrity.

#### *Habitat Integrity*

The instream habitats within this reach of the Nyl River have been impacted mainly by farm dams and road crossings (inundation and flow modifications), with minor impacts to water quality from agricultural activities (cattle watering and return flows from irrigation). The impacts to aquatic ecosystems due to irrigation in the sub-catchment has been assumed to be low due to a thick, impermeable clay layer which underlies the Nyl River floodplain, preventing loss of surface water to groundwater. The PES (for instream habitats and marginal aquatic habitats) was considered Moderately Modified (PES C).

#### *Water Quality*

Water quality was considered relatively good with a low salinity (as measured by EC) and circum-neutral pH. This was confirmed by the diatom assessment.

#### *Aquatic macroinvertebrates*

Four aquatic macroinvertebrate taxa with a moderate or high requirement for good water quality were recorded, suggesting relatively good water quality. During March 2022, there was an improvement in SASS score and diversity in a downstream direction, with the highest score (104) and number of taxa (21) being recorded from the most downstream site in the study area (site 6B). The average (SASS) score per taxon (ASPT) remained fairly consistent between the upstream and downstream sites (Site 1 and 6B), indicating no loss of taxa with a requirement for good water quality and therefore fairly stable water quality conditions within the study area. The main activities between the sites are agricultural (cattle watering and cultivated fields). The Nyl River within the study area was classified as PES B/C (Largely Natural to Moderately Modified).

As expected for a wetland system, no stones or in-current biotopes were present within the study area and only the vegetation and mud biotopes were sampled using SASS. The ASPT and diversity were therefore (naturally) low, as would be expected in a wetland such as this. This means that the SASS5 protocol is more responsive to habitat availability, and it is questionable whether SASS5 is the most appropriate method for assessing aquatic macroinvertebrates in this floodplain wetland. A species-level assessment using a surrogate (indicator) group (such as dragonflies and damselflies) should be conducted provide additional information on aquatic biodiversity within the floodplain. Amphibian diversity could also be considered.

### *Fish*

Seven of an expected ten indigenous fish species were sampled in the study area during the 2011 and 2021/22 surveys. All ten fish species are expected to still occur in this reach under present conditions, albeit in altered abundance and frequency of occurrence. One of the observed species, namely the Mozambique tilapia, is a species of conservation concern and is classified as Vulnerable (IUCN) due to the threat of hybridization with the alien Nile tilapia.

Two alien fish species, the Common carp and Mosquito fish, were also sampled in the study area during the January 2011 and November 2021/22 surveys. The presence of these species is concerning, and they may have a significant impact on the indigenous fish of the study area.

The indigenous fish species of this reach of the Nyl River are classified as tolerant to moderately tolerant to changes in the environment. The most intolerant of all species is the Johnston's topminnow, which are intolerant to habitat alterations and water quality deterioration. This species, if still present, will be the most important indicator fish species to use in future to detect changes as a result of activities such as mining operations.

The biological integrity, based on fish, of this reach of the Nyl River was determined to be in a good condition during 2011, with a FRAI score of 83.1% (descriptive category B). The most important alterations identified at the time (2011) to influence the biotic integrity in terms of fish in this river reach included changes in hydrology (mainly due to farm dams), sedimentation (due to erosion), presence of migration barriers (dams and road crossings, resulting in scenarios where fish cannot conduct natural dispersal or recolonise areas after unfavourable conditions (such as droughts) and the presence of alien fish species (Common carp disturb bottom substrates, compete for food and habitat and create turbid waters).

The application of the FRAI model based on the 2021/22 survey results indicate that the present ecological state may have deteriorated from a category B in 2011 to a category C in 2021/22 with a FRAI score of 66.3% calculated (Table 21). The temporal decrease in FRAI and hence biotic integrity as reflected by the fish assemblage was related to the following results and observations:

- Decreased occurrence, and potential absence of the Johnston's topminnow (*M. johnstoni*): This species was absent during November 2021 and March 2022 although adequate habitat was available. This species is intolerant to habitat and water quality changes and most probably highly susceptible to be impacted by the predatory alien *G. affinis* (in terms of competition for habitats, food and predation). It is strongly advised that a biomonitoring programme should be implemented as a matter of urgency to further expand the knowledge on the fish species composition and to verify the presence/absence of this species within this reach.
- *Enteromius bifrenatus* was also not sampled during 2021/22 surveys and was also very scarce (only 1 individual sampled at site Nyl 1) during January 2011. There is a probability that this species may have become even scarcer or may now be absent from this reach. This species will also be influenced by alterations in habitat (sedimentation, flow), water quality deterioration and the presence of alien fish species.
- Increase in alien fish species, with *G. affinis* not being sampled in 2011 and now (2021/22) being very abundant and widespread throughout the study area. The impact of alien fish species in indigenous species have therefore increased notably over this period resulting in an overall deterioration in the indigenous fish species assemblage.

## **1.2 Impact Assessment**

The Nyl River is a floodplain wetland with a seasonal flow regime. The proposed mining development includes open-cast mining within the major floodlines (1:10, 1:50 and 1:100 years).

Typically, the risks associated with mining within buffer zones or major flood lines are:

1. water will enter the pit during flood events, therefore being lost from the river,
2. water will be lost from the surface to the groundwater during dewatering,
3. after closure, contaminated water will migrate into the adjacent groundwater and potentially emerge at the surface, causing water quality impacts,
4. decant post-closure, causing impacts to water quality.

However, for Volspruit Mine, a flood protection berm will be constructed around the North Pit to prevent flood water from entering the pit. In addition, it has been found that a thick clay layer beneath the Nyl River prevents any linkages between groundwater and surface water (Geo Pollution Technologies 2023). It is reported that this clay layer will reduce impacts due to dewatering and contamination via groundwater. The risks associated with decant and AMD have also been described as low. While this reduces the major risks associated with mining within major floodlines, the following impacts were identified:

Groundwater will increase in salinity, metal concentrations and alkalinity (pH) due to mine drainage from the tailings facility and waste rock dump and migration of salts from the open-cast pits post-closure. However, the impacts are not considered significant (GPT 2023) and sulphates are expected to remain within guideline limits. As there are not expected to be linkages between surface and groundwater (due to the clay layer), this water will not directly impact on the Nyl River.

However, should this groundwater be used to irrigate crops there may be indirect impacts to the Nyl River via agricultural return flows. While this is an existing impact due to current irrigation in the sub-catchment, the quality of the return flows will gradually decline due to the increased salinity and metal concentrations in the abstracted groundwater.

The prediction is that groundwater will become more alkaline (to an average of approximately 8, GPT 2023). Warm, alkaline conditions can lead to the reduction of nitrates to ammonia, ammonia being toxic to sensitive aquatic species. Nitrate concentrations are expected to increase due to mining and algae are likely to proliferate in the river due to increased salt and nutrient concentrations. This will compromise habitats and cause oxygen levels to fluctuate (low at night, high during the day) and may be limiting to aquatic biota and certain fish. These conditions will favour alien invasive Mosquito fish, while indigenous sensitive species will become less abundant.

These impacts will be exacerbated by the usual surface water impacts associated with mining activities (spills, leaks, dust, seepage and erosion). The proximity of the Waste Rock Dump, its PCD and the tailings storage facility to the Nyl River, increases the likelihood of spills, dust and leaks.

It should additionally be noted that the groundwater is already of poor quality and the river is already impacted by agricultural activities (farm dams, abstraction and irrigation) and that impacts due to mining will merely exacerbate existing conditions.

It is therefore expected that there will be a gradual decline in water quality and habitat integrity within the Nyl River. This will be followed by a decline in the abundance of sensitive species (such as Johnston's topminnow) and an increase in hardy species (including alien mosquito fish). This may not be immediately evident but will progress gradually over time. The PES is expected to decline over time to category C/D or D, although conditions may vary seasonally.

The above conclusion is based on these assumptions:

- The clay layer remains intact and is not excavated (without authorisation) within or adjacent to the study area at any time in the future (including post-closure)
- The berm will be effectively impermeable and structurally stable in the long term (beyond mine closure).
- Climate change will not significantly alter flows and flood levels in the Nyl River, at least until the water quality impacts related to mining have returned to acceptable levels.
- Ground water will not emerge at the surface during or in the years following closure (e.g., if irrigation and dewatering were to cease).

These assumptions reduce the margin of error for managing risks. Considering that the effectiveness of proposed mitigation cannot be predicted with 100% certainty and the Nyl River is a sensitive ecosystem with good water quality, the conditions for approval should be conservative and should include regular monitoring.

Recommended conditions of approval are listed below.

- The RQO of the Nyl River must be met in terms of quality and quantity (as advised by DWS).
- Construction of the flood protection berm should be overseen by an engineer to ensure the impermeability of the clay core and stability of the structure.
- The impermeability of the berm should be tested during the first major flood event.
- Mining should commence in the east and progress westwards to allow the effectiveness of the berm to be tested during summer rainfall periods.
- A maintenance, monitoring and emergency preparedness plan must be compiled and implemented for the flood protection berm, and its associated service road. This should extend beyond closure.
- The northern pit must be rehabilitated to be free draining towards the wetland.
- No further activities within the delineated floodplain and its buffer that might cause disturbance or excavation of the clay layer.
- A biodiversity and wetland management plan must be compiled. This should include water quality improvement and habitat conservation measures for wetland biota.
- Irrigation of crops should be informed by groundwater levels and ground water quality, as advised by DWS.
- The tailings dam and waste rock dump must be appropriately lined.
- Ground water levels as well as surface water levels in the Nyl River should be regularly monitored to ensure that ground water does not reach the surface, and that surface water is not lost to groundwater. The extent, duration and frequency of flood events must be recorded.
- Culverts beneath the N1 should be inspected for blockages and debris, which should be removed, at the start of the rainy season each year, to prevent changes to flood levels.
- Water quality monitoring should include nitrates, ammonia, pH and toxicity testing in the Nyl River, the waste rock dump PCD, tailings RWD/PCD and boreholes within and adjacent to the floodplain. Non-compliances should be followed by remedial action.

# 1 Introduction

This impact report for Aquatic Ecosystems has been compiled for San Oosthuizen of EcoPartners who are managing application process for infrastructural developments at the Volspruit Mine.

In 2011 a baseline aquatic specialist assessment was conducted of the Nyl River, the primary lotic aquatic ecosystems associated with the proposed mining area (Report reference: WCS/A/11).

The design and layout for the tailing storage facility and the location and design of the waste rock dump for the proposed Volspruit mine development have changed. This has necessitated an update of specialist assessments.

The terms of reference for the EIA include:

- Conduct a desktop assessment of existing information;
- Identify gaps in existing information relative to new and proposed activities;
- Characterise the aquatic ecosystems and establish the baseline status (present ecological status) of aquatic ecosystems within the study area based on existing and new data;
- Compile a report to describe the baseline environment and to provide reliable data against which future changes can be measured.
- Assess the potential impacts to the biodiversity associated with the opencast pits and associated infrastructures.
- Provide mitigation and/or management recommendations, as well as future monitoring suggestions (where applicable).

## 1.1 Background

The proposed Volspruit Mine will be located on the Farms Volspruit 326-KP and Zoetveld 294-KR in the Limpopo Province (Figure 1). The study area, as illustrated in the map below, is located along the eastern bank of the Nyl River, approximately 17 km to the south of the town of Mokopane (as the crow flies). The N1 highway passes through the extreme north of the site, while an un-surfaced public road traverses the study area from north to south. Roughly 35km upstream of the site is the Nylsvley Nature Reserve Ramsar Site, while the abandoned Grass Valley Chrome Mine is just outside the site to the north-east. The study area covers 2 840 ha and falls within quarter degree square (QDS) 2428BD.

In 2011 a baseline aquatic specialist assessment was conducted of the Nyl River, the primary lotic aquatic ecosystems associated with the proposed mining area (Report reference: WCS/A/11). The mining right was granted but various infrastructural and layout changes have been proposed, which require new authorisations.

The layout changes, together with the length of time since the initial assessments and reports (2011), necessitated an updated assessment of aquatic ecosystems. Changes in legislation, potential changes in conservation status of species and the present ecological status of the potential receiving water bodies are likely. These may influence impact ratings and management recommendations.

New information was made available by the groundwater specialists (GPT) in June 2023, necessitating a revision of impacts.

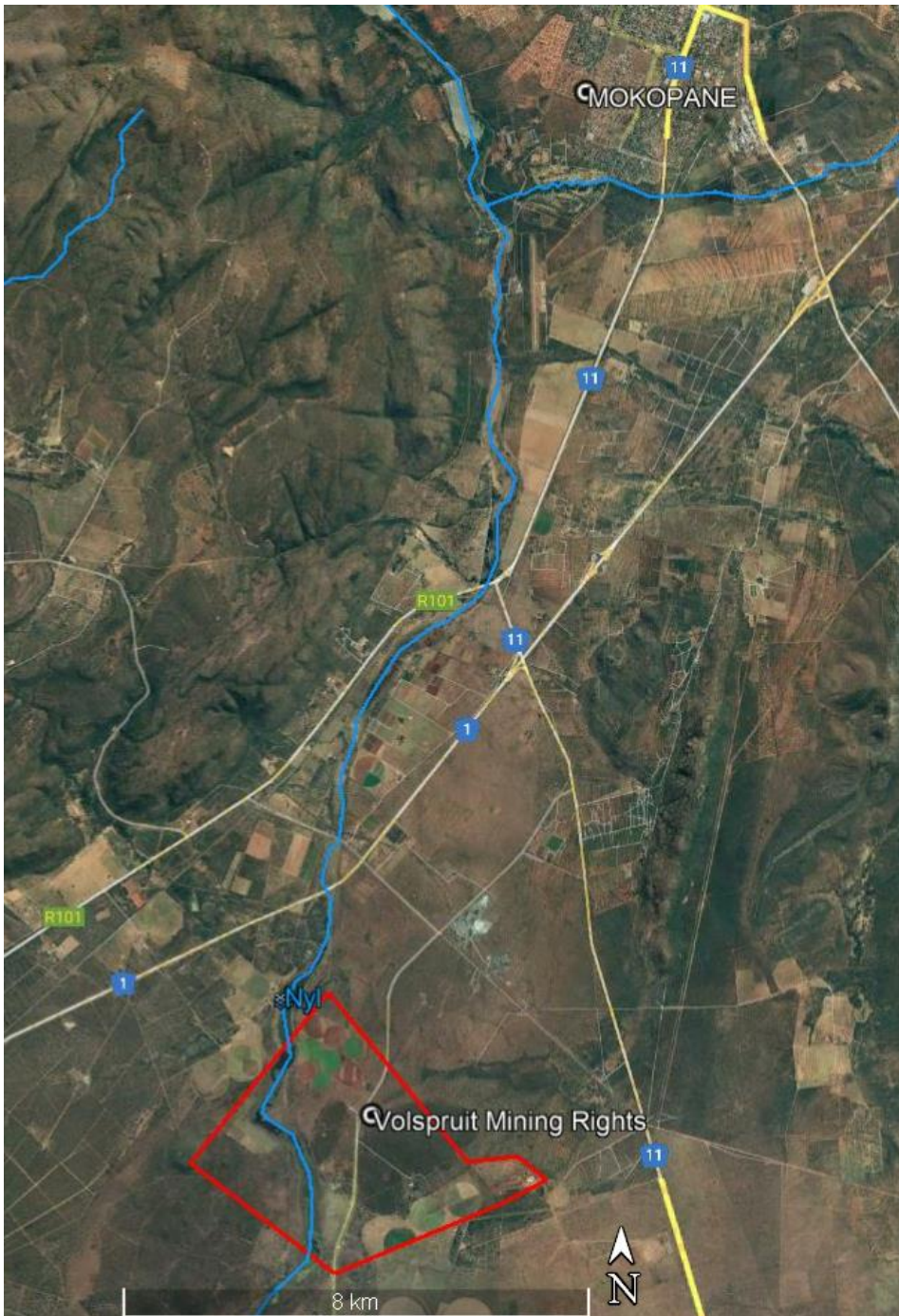


**Figure 1. Location of the study area along the Nyl River due South of Mokopane.**

## **1.2 Specialist Details**

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.

Norma Sharratt is an aquatic ecologist with 15 years' experience in aquatic specialist assessments, mainly within the mining industry. She is registered with the South African Council for Natural Scientific Professions as an Aquatic Science Professional (registration number 400088/15). She holds two M.Sc degrees - in Ecological Assessment (*Cum laude* 2005) and in Entomology (1998). Her 2005 thesis dealt with the recovery of aquatic invertebrate assemblages following the removal of alien trees from riparian zones. A number of co-authored papers followed each thesis. Since then she has worked on rivers across South Africa (including the Breede, Komati, Vaal, Crocodile, Olifants, Olifants/Doorn, Usuthu-Mhlathuze, Luvuvhu and Umgeni primary catchments), as well as in Swaziland and Mozambique. She has extensive experience undertaking specialist aquatic assessments for Environmental Impact Assessments and has developed mitigation and management measures for a range of developments. She has also contributed to Biodiversity Management Plans and has been involved intensively in a number of biomonitoring projects, mainly within the mining sector.

### **1.3 Declaration of Independence**

I Norma Joan Sharratt as the appointed specialist hereby declare/affirm the correctness of the information provided as part of the application, and that:

- I act as the independent specialist in this application;
- I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favorable to the applicant;
- I declare that there are no circumstances that may compromise my objectivity in performing such work;
- I have expertise in conducting the specialist report relevant to this application, including knowledge of the Act, Regulations and any guidelines that have relevance to the proposed activity;
- I will comply with the Act, Regulations and all other applicable legislation;
- I have no, and will not engage in, conflicting interests in the undertaking of the activity;
- I undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing any decision to be taken with respect to the application by the competent authority; and - the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority;
- all the particulars furnished by me in this form are true and correct; and
- am aware that it is an offence in terms of Regulation 48 to provide incorrect or misleading information and that a person convicted of such an offence is liable to the penalties as contemplated in section 49B(2) of the National Environmental Management Act, 1998 (Act 107 of 1998).



Signature of the Specialist

Clean Stream Biological Services (Pty) Ltd)  
Name of Company

16 October 2023  
Date

## **1.4 Legislation**

### **1.4.1 The National Water Act**

The National Water Act (Act No. 36 of 1998) (NWA) allows for the protection of water resources, which includes:

maintenance of the quality of the water resource to the extent that the water resource may be used in an ecologically sustainable way;  
prevention of the degradation of the water resource;  
the rehabilitation of the water resource;  
the protection of aquatic ecosystems and diversity

A watercourse means:

- A river or spring;
- A natural channel in which water flows regularly or intermittently;
- A wetland, lake or dam into which, or from which, water flows; and
- Any collection of water which the Minister may, by notice in the Gazette, declare to be a watercourse, and a reference to a watercourse includes, where relevant, its bed and banks.

The Act imposes 'duty of care' on all landowners, to ensure that water resources are not polluted. The following Clause in terms of the National Water Act is applicable in this case:

- 19 (1) "An owner of land, a person in control of land or a person who occupies or uses the land on which (a) any activity or process is or was performed or undertaken; which causes, has caused or likely to cause pollution of a water resource, must take all reasonable measures to prevent any such pollution from occurring, continuing or recurring"

The NWA recognises the entire ecosystem, and not just the water itself, as part of the water resource. Chapter 4 of the National Water Act addresses the use of the resource and effectively stipulates that all uses and activities with a potential impact on a watercourse (or, for wetlands, within a distance of 500m upstream or downstream of a wetland) must be authorized by the DWS.

### ***The Resource Quality Objectives***

Sections 16-18 of the Act stipulate the determination of the Reserve. The ecological reserve relates to the water required to protect the aquatic ecosystem of the water resource in order to secure ecological sustainability. The reserve pertains to both the quantity and quality of the water required to achieve this.

### ***General Authorisations***

These have been promulgated under the National Water Act and were published under GNR 398 of 26 March 2004. Any use of water that does not meet the requirements of Schedule 1 or the General Authorisations, requires a license obtained from the Department of Water and Sanitation (DWS).

#### **1.4.2 National Environmental Management Act (Act 107 of 1998)**

NEMA (Act 107 of 1998) and the associated Regulations (No R. 982), as amended in December 2017, states that prior to any development taking place within a wetland or riparian area, an environmental authorisation process needs to be followed. NEMA promotes sustainable development and principles such as the 'precautionary approach' and 'polluter pays'. NEMA requires responsibility for impacts to be taken throughout the life cycle of a project.

#### **1.4.3 National Environmental Management: Biodiversity Act No. 10 of 2004 (NEMBA)**

The intention of this Act is to protect species and ecosystems and promote the sustainable use of indigenous biological resources. It addresses aspects such as protection of threatened ecosystems.

#### **1.4.4 Mineral and Petroleum Resource Development Act, 2002 (Act No. 28 of 2002)**

The MPRDA is the central Act governing mining in South Africa and the preamble to the MPRDA affirms the State's obligation to protect the environment for the benefit of present and future generations, to ensure ecologically sustainable development of mineral and petroleum resources and to promote economic and social development.

#### **1.4.5 International Standards, Guidelines and Requirements**

The International Finance Corporation provides a set of eight performance standards (PS) that guide the implementation of the Equator Principles. PS6 (Biodiversity Conservation and Sustainable Natural Resource Management) recognizes that protecting and conserving biodiversity is fundamental to sustainable development. This Performance Standard reflects the objectives of the Convention on Biological Diversity to conserve biological diversity and promote use of renewable natural resources in a sustainable manner.

## 2 Approach

### 2.1 Assumptions and Limitations

- Reference conditions are not known with certainty and comparison with reference conditions is based on available information.
- A field survey was conducted in the study area during mid-November 2021 to update the 2011 survey results. Conditions were, however, too dry for sampling from most sites. It was recommended that a follow-up survey be conducted at the end of the wet season (February/March, or after a prolonged period of wetness) for greater accuracy. This follow-up survey was conducted in March 2022 at the end of the wet season.
- It should be noted that the Nyl River is essentially a floodplain wetland with a seasonal flow regime. Many of the Indices used in the aquatic assessment (e.g. IHI, SASS5, FRAI, MIRAI) were developed for *flowing rivers*. As such, it is very important to take seasonal fluctuations (e.g. in flow, pool depth and associated diversity of aquatic biota) and conditions prevailing at the time of sampling into consideration.
- In addition, the aquatic specialist report should be considered supplementary to the wetland specialist report, which considers, amongst others, wetland functional and structural integrity, wetland fauna and flora and wetland eco-services provided by the Nyl floodplain

### 2.2 Study Area

The study area is located within the Limpopo River Catchment (Primary Catchment A), and more specifically within quaternary catchment A61E. The catchment is drained by the Nyl River, which becomes the Mogalakwena River which feeds into the Glen Alpine Dam and eventually drains into the Limpopo River approximately 50km upstream of the Mapungubwe National Park.

The study area falls within sub-quaternary reach A61E-386 of the Nyl River, draining northwards towards sub-quaternary reach is A61F-353. Figure 3 indicates the position of the study area in relation to the affected quaternary catchment.

### 2.3 Sampling Sites

Sampling sites were selected to be representative of all the surface water ecosystems within the study area, aiming to assess an upstream scenario (upstream of potential impacts associated with the proposed mining activity), directly impacted (area in close proximity of mining with highest probability to be directly impacted by the activities, and downstream scenario (area downstream of all potential impacts from mining area). The location, rationale and photos of each sampling site are provided in Figure 3 and Table 1.

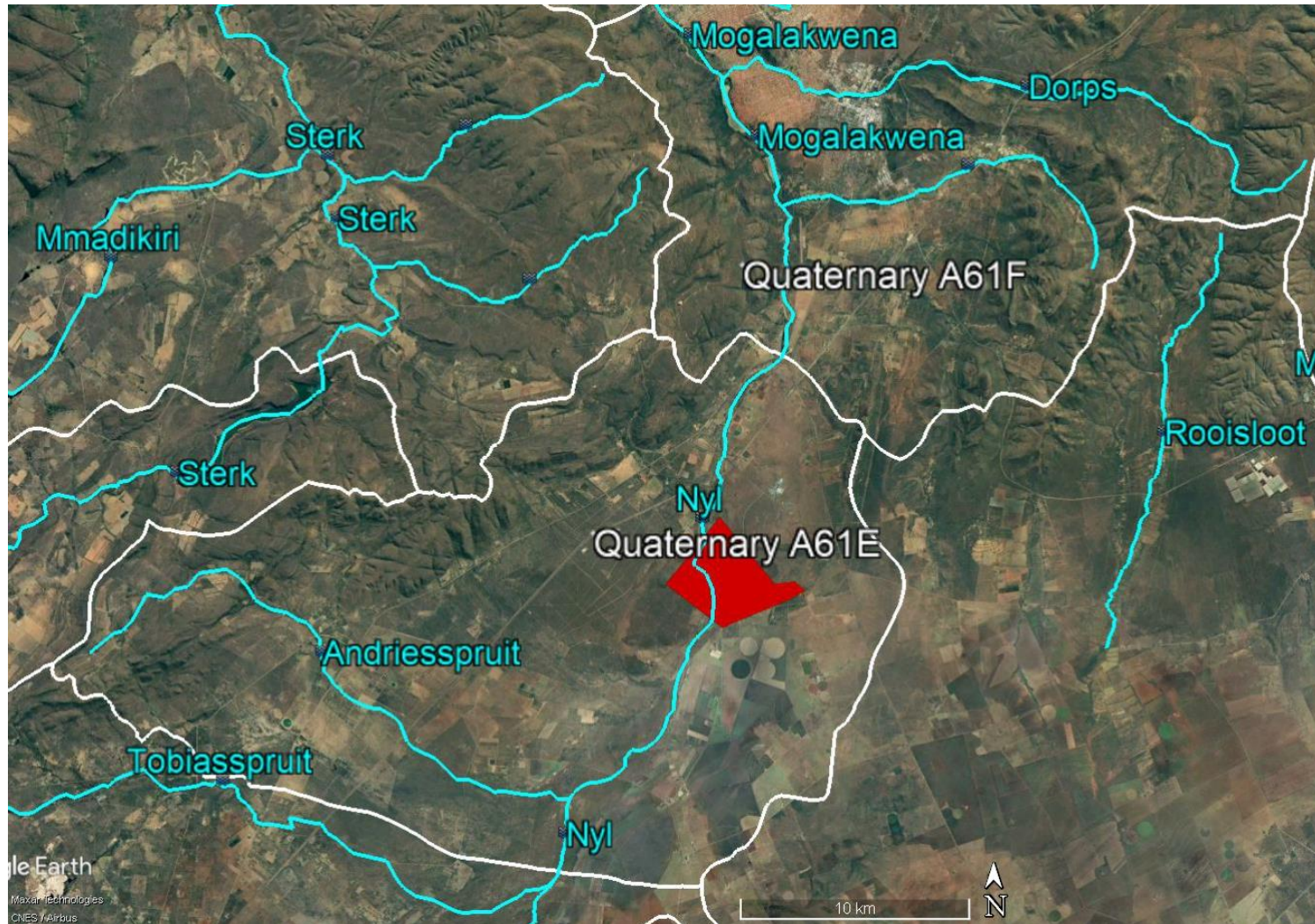


Figure 2. Location of the study area (in red) relative to rivers (turquoise) and catchments (white).

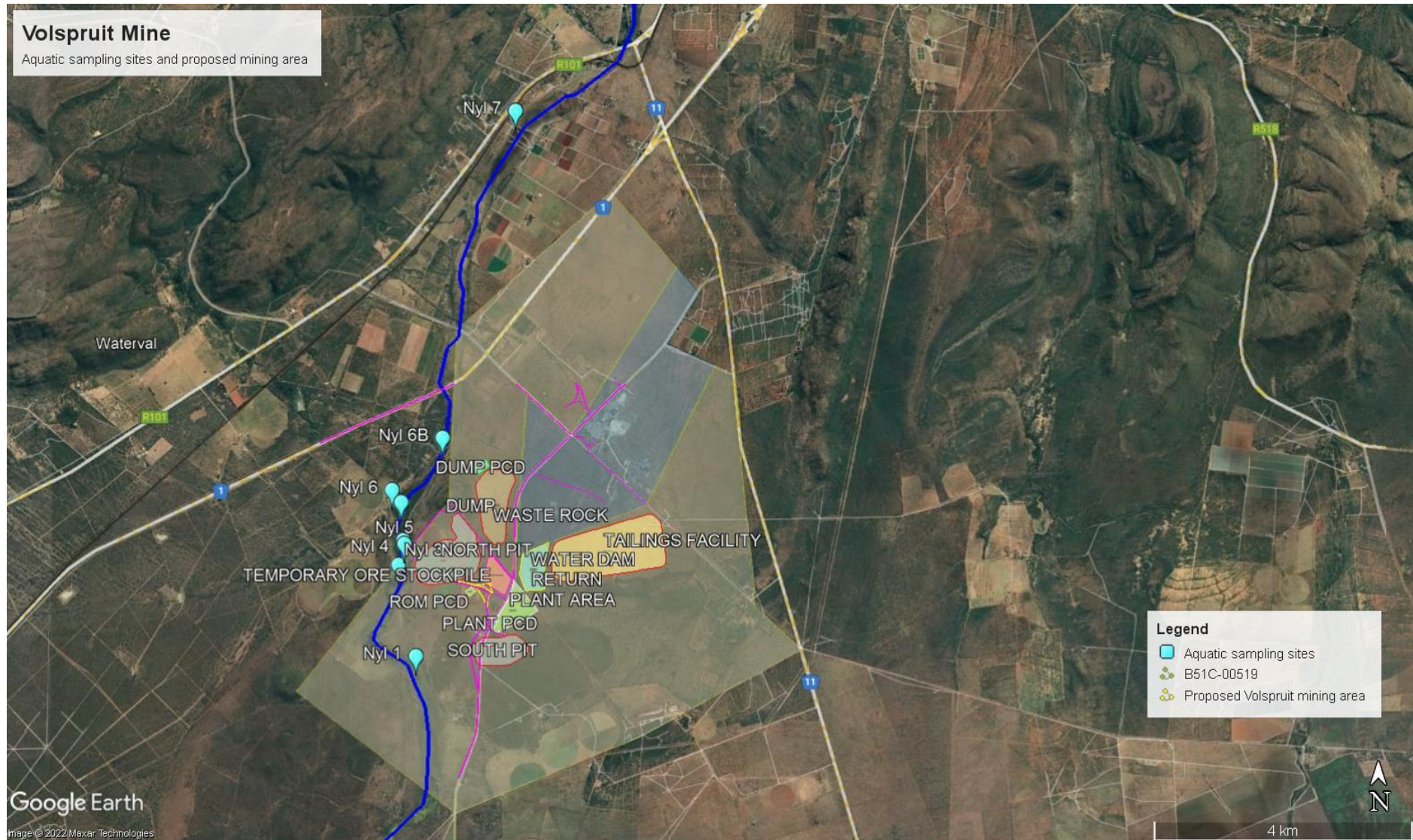


Figure 3: Google Earth™ image of entire study area indicating aquatic sampling sites (blue icons) sampled for the purpose of the January 2011, November 2021 and March 2022 surveys as well as the approximate Volspruit mining area (shaded).

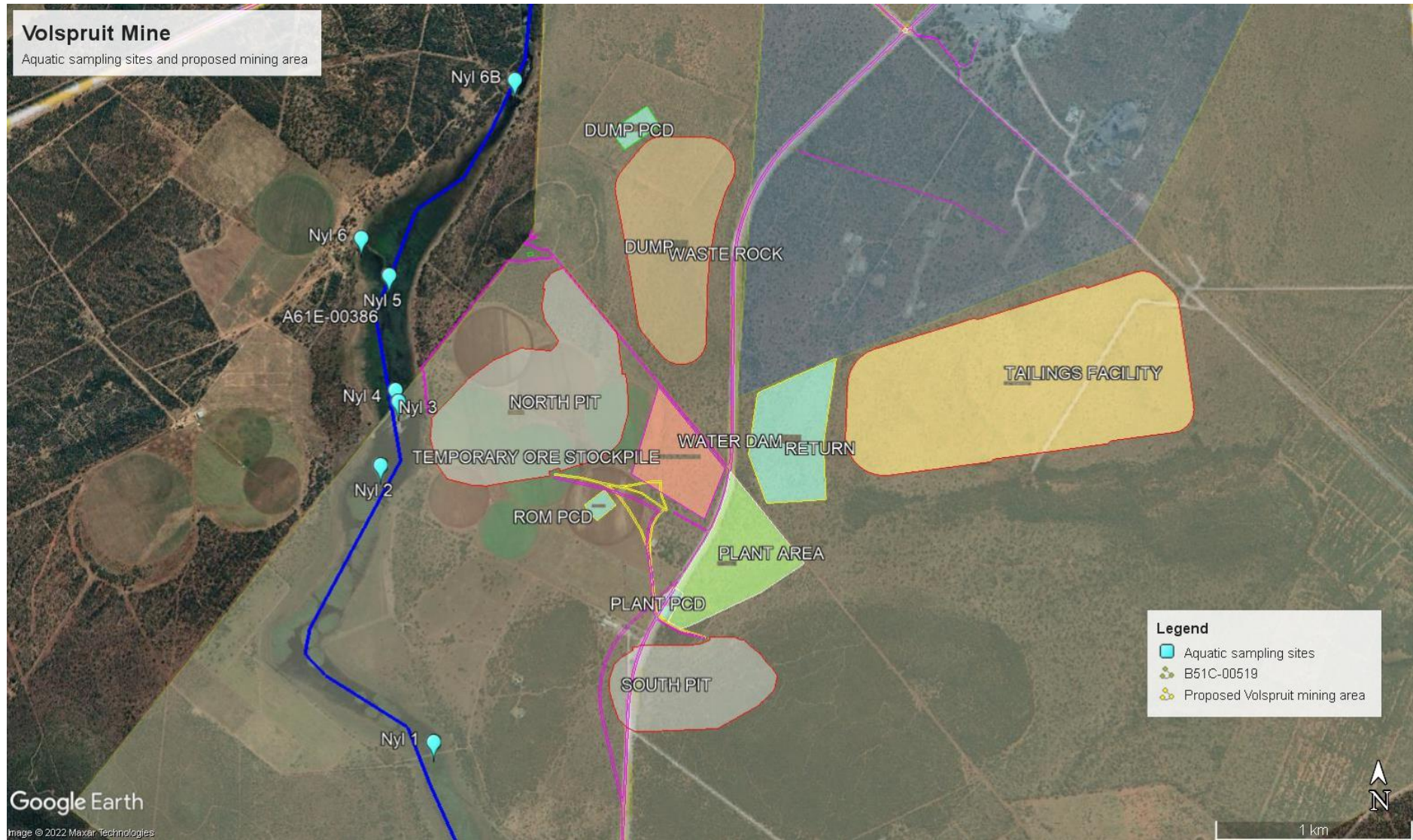


**Figure 4: Google Earth™ image of primary study area indicating aquatic sampling sites (blue icons) and Volspruit mining area detail (shaded).**

**Table 1: Fish sampling sites selected for the purpose of the baseline study (2011, 2021 and 2022).**

| Site Name | Latitude/ Longitude           | Description/ Rationale                                                                                                       | Photo                                                                               |                                                                                      |                                                                                     |
|-----------|-------------------------------|------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
| Nyl 1     | -24.362672° S<br>28.944097° E | Site in Nyl River inside mining area, but upstream of most potential impacts related to proposed mine (including South pit). |   |   |  |
|           |                               |                                                                                                                              | January 2011                                                                        | November 2021                                                                        | March 2022                                                                          |
| Nyl 2     | -24.350034° S<br>28.941436° E | Site in Nyl River in upper reaches of area to be directly impacted by proposed mining.                                       |  |  |                                                                                     |
|           |                               |                                                                                                                              | January 2011                                                                        | November 2021                                                                        |                                                                                     |

Volspruit Mine Impact Report – Aquatic Ecosystems – October 2023

|       |                               |                                                                                                            |                                                                                     |                                                                                      |                                                                                      |
|-------|-------------------------------|------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
| Nyl 3 | -24.347120° S<br>28.942333° E | Site in inundated section (dammed area) of Nyl River. Close proximity of proposed mining area (North pit). |   |   |   |
|       |                               |                                                                                                            | January 2011                                                                        | November 2021                                                                        | March 2022                                                                           |
| Nyl 4 | -24.346606° S<br>28.942183° E | Site downstream of dam in Nyl River. Close proximity of proposed mining area.                              |   |   |   |
|       |                               |                                                                                                            | January 2011                                                                        | November 2021                                                                        | March 2022                                                                           |
| Nyl 5 | -24.341364° S<br>28.941872° E | Site in Nyl River, downstream of most potential mining impacts (North pit).                                |  |  |  |
|       |                               |                                                                                                            | January 2011                                                                        | November 2021 (close proximity)                                                      | March 2022                                                                           |

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|        |                               |                                                                                                                                              |                                                                                     |                                                                                     |
|--------|-------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
| Nyl 6  | -24.339664° S<br>28.940469° E | Site in another small, dammed section of Nyl River, downstream of most potential mining impacts.                                             |   |                                                                                     |
|        |                               |                                                                                                                                              | January 2011                                                                        |                                                                                     |
| Nyl 6B | -24.332443° S<br>28.948171° E | Site downstream of most mining impacts. (including Waste Rock Dump PCD and residual stockpiles)                                              |   |  |
|        |                               |                                                                                                                                              | November 2021                                                                       | March 2022                                                                          |
| Nyl 7  | -24.287153° S<br>28.959269° E | Site in Nyl River, further downstream of potential mining impacts in vicinity of previous National River Health monitoring site A6NYL-JAAGB. |  |                                                                                     |
|        |                               |                                                                                                                                              | January 2011                                                                        |                                                                                     |

## 2.4 Desktop Assessment

The data obtained during the 2011 Assessment (Wetland Consulting Services, 2011) were reviewed to identify gaps in knowledge.

A desktop review of available databases was conducted, including the NFEPA (Nel et al 2011) and the desktop assessment of aquatic ecosystems conducted by DWS (2014).

## 2.5 Ecstatus Determination

The description of the present ecological status (PES) of the aquatic ecosystems in the study area was broadly conducted according to the methodology described for River Eco-Classification during Reserve Determinations (Kleynhans & Louw, 2008) (Table 2).

**Table 2. Descriptive categories used to describe the present ecological status (PES) of biotic components (adapted from Kleynhans, 1999).**

| CATEGORY | BIOTIC INTEGRITY | DESCRIPTION OF GENERALLY EXPECTED CONDITIONS                                                                                                                                                                                                                                                                                                                                                       |
|----------|------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| A        | Excellent        | Unmodified, or approximates natural conditions closely. The biotic assemblages compare to that expected under natural, unperturbed conditions.                                                                                                                                                                                                                                                     |
| B        | Good             | Largely natural with few modifications. A change in community characteristics may have taken place but species richness and presence of intolerant species indicate little modifications. Most aspects of the biotic assemblage as expected under natural unperturbed conditions.                                                                                                                  |
| C        | Fair             | Moderately modified. A lower than expected species richness and presence of most intolerant species. Most of the characteristics of the biotic assemblages have been moderately modified from its naturally expected condition. Some impairment of health may be evident at the lower end of this class.                                                                                           |
| D        | Poor             | Largely modified. A clearly lower than expected species richness and absence or much lowered presence of intolerant and moderately intolerant species. Most characteristics of the biotic assemblages have been largely modified from its naturally expected condition. Impairment of health may become evident at the lower end of this class.                                                    |
| E        | Very Poor        | Seriously modified. A strikingly lower than expected species richness and general absence of intolerant and moderately tolerant species. Most of the characteristics of the biotic assemblages have been seriously modified from its naturally expected condition. Impairment of health may become very evident.                                                                                   |
| F        | Critical         | Critically modified. Extremely lowered species richness and an absence of intolerant and moderately tolerant species. Only intolerant species may be present with complete loss of species at the lower end of the class. Most of the characteristics of the biotic assemblages have been critically modified from its naturally expected conditions. Impairment of health generally very evident. |

It must be emphasised that the A→F scale represents a continuum, and that the boundaries between categories are notional, artificially-defined points along the continuum. This situation falls within the concept of a fuzzy boundary, where a particular entity may potentially have membership of both classes (Robertson et al. 2004). These boundary categories are denoted as B/C, C/D, etc.

## **2.6 Water Quality**

On-site water quality variables, including temperature, electrical conductivity, dissolved oxygen, oxygen saturation and pH levels were measured at the sampling sites to assist in the interpretation of the biological data.

## **2.7 Habitat Integrity Assessment**

A modified version of the Index of Habitat Integrity (IHI) was used to determine habitat condition. This approach is based on the assessment of physical habitat disturbance (Kleynhans, 1997) and classifies the present ecological state of instream and riparian habitat integrity according to the Present Ecological State (PES) categories given in Table 2, ranging from pristine/undisturbed to critically modified. The IHI was developed specifically for flowing rivers and was therefore modified for the Nyl River, which is essentially a floodplain wetland with a seasonal flow regime.

## **2.8 Aquatic Macroinvertebrates**

Aquatic macroinvertebrates were assessed using the SASS 5 (South African Scoring System) methodology. SASS5 is based on the presence or absence of sensitive aquatic macroinvertebrates collected and analysed according to the methods outlined in Dickens and Graham (2002). A high relative abundance and diversity of sensitive taxa present indicates a relatively healthy system with good water quality. Disturbance to water quality and habitat results in the loss of sensitive taxa. Macroinvertebrates reflect overall changes in ecosystem health, including loss of diversity and abundance.

An assessment of the suitability and availability of habitats for aquatic invertebrates was based on Integrated Habitat Assessment System (IHAS) index (McMillan 1998).

The MIRAI (Macroinvertebrate Response Assessment Index) (Thirion 2008) is a response, habitat and stressor indicator which classifies the PES of a river reach according to a comparison between expected and observed taxa, as obtained from the SASS5 results, to assess the response of the macroinvertebrate assemblage to stressors (including changes in flow, water quality and habitats).

The description of the present ecological status (PES) of the aquatic ecosystems in the study area was broadly conducted according to the methodology described for River Eco-Classification during Reserve Determinations (Kleynhans & Louw, 2008) (Table 2).

## 2.9 Fish/Ichthyofauna

### 2.9.1 Fish Habitat Cover Rating (HCR) (Kleynhans, 1997)

This approach was developed to assess habitats according to different attributes that are surmised to satisfy the habitat requirements of various fish species (Kleynhans, 1997).

At each site, the following depth-flow (df) classes are identified, namely:

- Slow (<0.3m/s), shallow (<0.5m) - Shallow pools and backwaters.
- Slow, deep (>0.5m) - Deep pools and backwaters.
- Fast (>0.3m/s), shallow - Riffles, rapids and runs.
- Fast, deep - Usually rapids and runs.

The relative contribution of each of the above-mentioned classes at a site is estimated and indicated as:

- 0 = Absent
- 1 = Rare (<5%)
- 2 = Sparse (5-25%)
- 3 = Moderate (25-75%)
- 4 = Extensive (>75%)

For each depth-flow class, the following cover features (cf), considered to provide fish with the necessary cover to utilize a particular flow and depth class, are investigated:

- Overhanging vegetation
- Undercut banks and root wads
- Stream substrate
- Aquatic macrophytes

The amount of cover present at each of these cover features (cf) is noted as:

- 0 = absent
- 1 = Rare/very poor (<5%)
- 2 = Sparse/poor (5-25%)
- 3 = Moderate/good (25-75%)
- 4 = Extensive/excellent (>75%)

The fish habitat cover rating (HCR) is calculated as follows:

$$HCR = df/\Sigma df \times \Sigma cf$$

- The contribution of each depth-flow class at the site is calculated ( $df/\Sigma df$ ).
- For each depth-flow class, the fish cover features (cf) are summed ( $\Sigma cf$ ).

### 2.9.2 Fish Response Assessment Index (FRAI)

Fish sampling was performed at each site 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 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 2).

## 3 Findings

### 3.1 Background and Objectives

#### 3.1.1 Objective

The objective of an Aquatic Ecosystem Assessment is to assess the **response** of the aquatic fauna and flora to changes in water quality, flow and habitats. Therefore, it is **not** an assessment of water quantity and quality **per se**, but an assessment of the effect of **changes in water quantity, quality and habitat availability/suitability** on the biota and the health of the aquatic ecosystem.

A healthy ecosystem is one that is sustainable – “it has the ability to maintain its structure (organization) and function (vigor) over time in the face of external stress (resilience)” (Costanza and Mageau 1999). It generally has a high diversity of taxa and the presence of habitat specialists, including endemics and rare/threatened species. After external stress (such as a contamination event) it can recover to its former functional and structural integrity. A decline in water quality and quantity (flow and habitats) will result in a loss of taxa and a decline in the structural and functional health of the ecosystem.

Generally, ecosystems can tolerate a certain level of disturbance from human activities. However, if the stressors are prolonged (continue for an extended period of time) or are acute/catastrophic (a large-scale spill for example), the disturbance may exceed the ecosystem’s ability to recover without costly interventions (e.g. there may be localised extinctions and loss of endemic or rare species, or there may be a loss of structural integrity/connectivity that prevents former processes from becoming re-established) (Stella and Bendix 2019).

Biota generally take days to weeks to respond to changes in water quality and quantity and are therefore useful to show the overall effect of human disturbance on aquatic ecosystem health and sustainability. Contamination events can be missed if water quality sampling does not coincide with the exact incident (i.e. contaminated water may have been flushed by rainwater), whereas biota will continue to show the effects well beyond the contamination event. Similarly, changes in habitat integrity (e.g. pool size, availability of marginal vegetation) are not detected by water quality monitoring and can only be assessed as part of a habitat survey and biomonitoring.

It is therefore important to assess the response of the biota (including fish and aquatic macroinvertebrates) to a range of biological stressors (including water quality, flows and habitat availability and suitability– which would include availability of overhanging vegetation, depth of pools, clarity of water and suitability of preferred substrate types, for example).

### **3.1.2 Inter-relationship between surface water quality and quantity in a mining scenario**

To understand the impacts of mining on aquatic ecosystems, it is important to note that both quantity and quality of water are affected by mining.

1. Water Quantity: Dewatering causes a drawdown cone of depression which could lower the ground water table. Depending on the linkages between surface water and ground water, this could lower the base flow during low flow periods and result in longer flow cessation as well as shallower pools. The degree with which this happens is influenced by the linkages between surface water and groundwater (e.g. whether the soils are clay or sandy).
2. Surface water quality could be affected directly by discharges from pollution control facilities, seepage via groundwater and decant.

There is a complex relationship between surface water quality and water quantity;

- A decline in water quantity affects habitats and water quality. For example, loss of in-current habitats, shallower pools which lead to higher water temperatures, reduced dilution due to evapotranspiration (and therefore higher concentrations in nutrients and salts) and a proliferation of algae in response to warmer temperatures and higher nutrient concentrations.
- A decline in water quality renders the aquatic habitats less suitable for species with a higher requirement for good water quality, and can be harmful to fish health, encourage the proliferation of algae, including toxic blue green algae. Erosion can result in high turbidity and suspended solids which can block the gills of fish and filter feeders. Where sediments settle out, they alter the suitability of benthic substrates, cause pools to become shallower and are colonised by monospecific stands of reeds which reduce biodiversity and availability of suitable marginal habitats.

Sinclair Knight Merz (2013) summarises this relationship as follows:

“Water quality has a close but complex relationship with water quantity. The nature of the relationship depends strongly on the individual catchment and type of aquatic ecosystem. Changes in the quality or quantity of water may result in immediate changes in the structure and function of ecosystems, including the numbers and types of organisms that can survive in the altered environment.

River regulation, catchment land use and water extraction alter the natural flow/watering regimes and associated water quality characteristics. Depending on circumstances, any combination of these factors can give rise to water quality issues such as eutrophication (and associated algal blooms), contamination with toxins, increasing salinity.”

They conclude that management of water resources should take into effect the relationship between water quantity (flow) and water quality. The Nyl River is non-perennial – i.e. it ceases to flow during the drier months, comprising a series of pools

which become increasingly warmer and more concentrated due to evapotranspiration. Should the water table be lowered due to dewatering or subsidence, the biota will respond to both a decline in water quantity, and an associated decline in water quality.

Therefore, to determine the risks of mining to aquatic ecosystems, it is essential to consider changes in quantity (base flows and water table) and quality, as well the relationship between them.

### **3.1.3 Desktop Present Ecological State (PES), Ecological Sensitivity (ES) and Ecological Importance (EI) (DWS 2014)**

Kleynhans & Louw (2008) defined ecological importance of a river as its importance to maintain biological diversity and ecological functioning on a local and wider scale. The ecological sensitivity (or fragility) on the other hand refers to a river's ability to resist disturbance and its capability to recover from disturbances once it has occurred (Resh *et al.* 1988; Milner 1994; Kleynhans 1999).

The Department of Water Affairs and Sanitation (DWS) conducted a desktop review and update of the present ecological status (PES), Ecological Sensitivity (ES) and Ecological Importance (EI) of all South African rivers (DWS, 2013). The desktop assessment was done on a sub-quaternary reach scale. The study also provided a description of the current land-use activities in each sub-quaternary catchment, as well as a desktop assessment of the present ecological state (PES), ecological importance (EI) and ecological sensitivity (ES) (DWS, 2014).

- The desktop overall (instream and riparian zone) PES of the Nyl River reach in the study area (sub-quaternary reach A61E-386) was classified as Category D (Largely modified).
- The desktop assessment classified that the ecological importance (EI) and ecological sensitivity (ES) of this reach is moderate.

The immediate downstream receiving sub-quaternary reach in the Nyl River (A61F-353) received the same classification for PES, EI and ES.

It should be noted that the indices used for the desktop assessment (IHI, MIRAI and FRAI) were designed specifically for flowing rivers. The Nyl River is essentially **a floodplain wetland with a seasonal flow regime**. As such, it is very important to take these seasonal fluctuations (e.g. in flow, pool depth and associated diversity of aquatic biota) and conditions prevailing at the time of sampling into consideration, rather than relying solely on generalized desktop-level indices. In addition, the aquatic specialist report should be considered supplementary to the wetland specialist report, which considers, amongst others, wetland functional and structural integrity, wetland fauna and flora and wetland eco-services provided by the Nyl floodplain.

### **3.1.4 National Freshwater Ecosystem Priority Area (NFEPA)**

NFEPA's are rivers, together with their associated catchment, that are currently in a good to pristine state and are important in terms of maintaining threatened or near-threatened fish species. NFEPA Rivers should be maintained in a high level of biotic integrity in order to contribute to national biodiversity goals (Nel *et al.*, 2011). The river and its surrounding catchment, including tributaries, need to be managed in a way that maintains the good condition of the receiving river (A or B ecological category) (Nel *et al.*, 2011).

The Nyl River sub-quaternary reach A61E-386 is not classified as a NFEPA river reach in terms of fish.

This reach is, however, highlighted as a wetland FEPA containing various wetland ecosystem types (refer to wetland specialist study for detail).

## **3.2 Water Quality**

The results of the water quality analyses are shown in Tables 3 - 5. Please note that these limited water quality analyses were only interpreted in terms of ecological responses and do not constitute a detailed surface water assessment.

During the January 2011 survey, electrical conductivity (EC – as a measure of salinity) was very low, ranging from 15.7 mS/m (Nyl 1) to 38.0 mS/m (Nyl 5) (Table 3). These levels reflected good water quality in terms of dissolved salts, with a slight downstream increase due to the concentrating effect of evaporation and evapo-transpiration. The decrease observed in the EC level at the most downstream site (Nyl 7) is thought to be related to dilution as a result of rainfall and tributaries.

During March 2022, the salinity levels resembled those measured in 2011, with a decrease in salt concentrations in a downstream direction.

The EC measured during November 2021 at site Nyl 3 (47.5 mS/m) and 6B (61.5 mS/m) was notably higher than that recorded at this site in January 2011 (28.5 mS/m). Although this could be an indication of temporal deterioration in water quality, it is most likely to be a reflection of dilution (during the wetter survey in January 2011) and the concentrating effect of evaporative losses during this drier survey (November 2021) and suggests large temporal variation in salt concentrations in the river.

The EC levels observed during all surveys would not be particularly limiting to fish or aquatic macroinvertebrates expected to occur in the study area.

The pH of the study sites ranged between 7.8 and 8.9 in January 2011 and 7.3 to 8.3 in March 2022 and should not be limiting to aquatic biota. These levels fell within the target for fish health of between 6.5 and 9.0 as it is expected that most species will tolerate and reproduce successfully within this pH range (DWAf, 1996).

Oxygen levels were also high at all the sites during both surveys, and due to the wetland nature of the sites with vast amounts of vegetation present, oxygen, as well as pH levels, can be expected to vary greatly over a 24-hour period due to the photosynthesis process.

The clarity of the water was mostly clear, with some increase in turbidity being mostly associated with livestock drinking and damming.

Water temperatures ranged between 21.5°C and 29.1°C in January 2011 and 24.4°C to 29.5°C in March 2022 (Tables 3 and 5).

**Table 3: *In-situ* water quality variables measured at the time of sampling at aquatic sampling sites (January 2011 survey).**

| Monitoring site | Conductivity (mS/m) | pH  | Oxygen saturation (%) | Dissolved oxygen (mg/l) | Water Temp. (°C) | Clarity (visual) |
|-----------------|---------------------|-----|-----------------------|-------------------------|------------------|------------------|
| Nyl 1           | 15.7                | 7.8 | 80                    | 6.5                     | 21.5             | Clear            |
| Nyl 2           | 20.3                | 7.8 | 76                    | 5.6                     | 24.0             | Clear            |
| Nyl 3           | 28.5                | 7.8 | 70                    | 5.5                     | 26.7             | Turbid           |
| Nyl 4           | 32.4                | 7.8 | 79                    | 6.2                     | 26.3             | Turbid           |
| Nyl 5           | 38.0                | 8.2 | 80                    | 6.5                     | 28.1             | Clear            |
| Nyl 6           | 37.0                | 8.2 | 75                    | 5.8                     | 28.0             | Slightly turbid  |
| Nyl 7           | 19.7                | 8.9 | 102                   | 7.5                     | 29.1             | Clear            |

**Table 4: *In-situ* water quality variables measured at the time of sampling at aquatic sampling sites (November 2021 survey).**

| Monitoring site | Conductivity (mS/m) | pH  | Oxygen saturation (%) | Dissolved oxygen (mg/l) | Water temp (°C) | Turbidity (visual) | Flow (visual) |
|-----------------|---------------------|-----|-----------------------|-------------------------|-----------------|--------------------|---------------|
| Nyl 3           | 47.5                | 8.4 | 102.8                 | 6.6                     | 24.7            | Turbid             | No flow       |
| Nyl 6B          | 61.5                | 8.7 | 240.0                 | 13.4                    | 32.6            | Turbid             | No flow       |

**Table 5: *In-situ* water quality variables measured at the time of sampling at aquatic sampling sites (March 2022 survey).**

| Monitoring site | Conductivity (mS/m) | pH  | Oxygen saturation (%) | Dissolved oxygen (mg/l) | Water Temp. (°C) | Clarity (visual) |
|-----------------|---------------------|-----|-----------------------|-------------------------|------------------|------------------|
| Nyl 1           | 19.6                | 8.1 | 88.9                  | 6.2                     | 29.5             | Clear            |
| Nyl 2           | 20.6                | 8.3 | 78.1                  | 5.5                     | 27.4             | Clear            |
| Nyl 3           | Not re-sampled      |     |                       |                         |                  |                  |
| Nyl 4           | 20.0                | 7.8 | 90.0                  | 6.9                     | 29.5             | Clear            |
| Nyl 5           | 11.9                | 7.3 | 91.6                  | 6.6                     | 25.4             | Clear            |
| Nyl 6B          | 14.1                | 8.1 | 73.4                  | 5.6                     | 24.4             | Clear            |
| Nyl 7           | Not Re-sampled      |     |                       |                         |                  |                  |

### 3.2.1 Diatom Assessment

During 2011, a diatom assessment was conducted to assess the biological water quality of the Nyl River within the vicinity of the study area. No obvious new activities were evident during the 2021 survey (Wetland Consulting Services 2012) and it is thought that conditions would be largely unchanged. The findings of the 2011 survey are summarised below:

- The overall species assemblages displayed the ecological conditions typical of a floodplain wetland system ranging from acidic, eutrophic (high level of nutrients), fresh waters at the upstream site to circumneutral, mesotrophic (moderate level of nutrients), fresh to brackish conditions at the downstream site; both were highly oxygenated.
- The ecological water quality was of good condition at sites sampled.
- Dominant species *Achnanthes minutissimum* recorded at both sites has been frequently identified as a mesotrophic taxon indicating good water quality (Slàdecek, 1986; Leclercq and Maquet, 1987; Prygiel and Coste, 2000).
- At the downstream site, there was an increase in *Nitzschia* taxa which tend to be more tolerant to environmental change, probably in response to increased agricultural impacts (including salts and nutrients from irrigation of cultivated crops in adjacent fields).
- The ordination plot showed diatom assemblages clustering along a gradient of nutrients and salts. The Nyl River samples were grouped with samples taken from healthy, natural temporarily inundated pan systems which, similar to a floodplain system, are also characterized by fluctuating conditions.

## 3.3 Habitat Integrity

It is important to note that the Nyl floodplain is essentially a floodplain wetland with a non-perennial flow regime. As such, it is more important to consider the integrity of the wetland structure and function rather than consider aquatic habitats in isolation. Please refer to the wetland specialist study for a more comprehensive assessment of habitat integrity.

For the purposes of the aquatic assessment (in terms of aquatic macroinvertebrates and fish), a modified version of the IHI (Index of Habitat Integrity) was used to assess physical disturbances to instream and marginal aquatic habitats within the floodplain (including impacts to flow, water quality and benthic/marginal/instream habitats).

The overall habitat integrity of the Nyl River on site was considered Moderately Modified (PES Category C), with most of the variables assessed having a small to moderate impact on habitat integrity (Table 5). However, larger impacts that were evident are summarised below.

Farm dams and road crossings were associated with the following impacts:

- Reduced flows during high flow periods

- Migration barriers, which limit natural dispersal of fish and prevent recolonisation after unfavourable conditions (such as droughts)
- Inundation of aquatic habitats upstream of the road/impoundment resulting in altered habitats (conversion of wetlands with subsurface seepage and wetland vegetation to pools with surface water and aquatic vegetation, including aquatic weeds)
- Erosion and channelization of the floodplain downstream of the road/impoundment, where water is released through culverts, causing concentrated flows and erosion along preferential flow paths.
- Where eroded sediments settle out, they reduce pool depth and tend to be colonized by monospecific stands of *Typha* reeds (thus reducing diversity of plants).
- Wetland extent is reduced downstream of the road/impoundment as diffuse subsurface flow is converted to more constricted surface flows. This results in marginal wetland areas becoming drier and being colonized by alien vegetation (including weeds and invasive alien species). *Persicaria* (knotweed), in particular, was abundant at most of the sites.

The extent to which irrigation in the catchment has contributed to lower flows (and longer low flow periods) is uncertain. While surface water abstraction from farm dams has almost certainly affected flows within the Nyl River, the effects of groundwater abstraction are less clear. According to Geo Pollution Technologies (2023), the Nyl floodplain is underlain by a thick impermeable clay layer which maintains separation between the surface water and groundwater. Therefore, based on this information, the lowering of the water table through irrigation (from groundwater sources) is unlikely to affect flows at the surface (GPT 2023).

Water quality has, however, been affected by irrigation, which generally cause an increase in salinity and nutrients (from fertilisers) due to agricultural return flows from cultivated fields.

Trampling by cattle has altered the suitability of substrates and has contributed to water quality impacts, including increased nutrients and turbidity.

Aquatic weeds, most notably the invasive *Lemna* (duckweed), were evident in pools and dams. The presence of alien carp in farm dams has been reported. These disturb bottom substrates, compete for food and habitat and increase the turbidity of water.

The greatest impacts on habitat integrity were related to farm dams and road crossings (along the dam walls) (affecting sites 2, 3, 4 and 6b), with only minor impacts being associated with agriculture. Impacts from abstraction (from surrounding boreholes and the river itself) are likely although the significance of this impact is uncertain.

Concerns have been raised that the N1 crossing, which is located immediately downstream of the study area, has caused an increase in flood levels **within the study**

**area**, as water is backed up during high flow periods (AED 2022). The bridge essentially acts as a dam wall, causing flow constrictions and increased inundation upstream of it during high flow periods. It is important to note that this only occurs seasonally in the rainy season (and probably not every year). This inundation upstream of the bridge also creates a depositional environment for sediments, which may result in sediments building up on the upstream side of the bridge. These sediments are typically colonised by reeds.

The bridge also obstructs flows during high flow periods, causing flows to be more concentrated and **more erosive downstream** of the N1 bridge and hence downstream of the study area. The flow pattern is therefore altered downstream of the bridge to be confined to a channel and more erosive.



**Figure 5. Physical disturbances to aquatic habitats within the study area. Top row: inundation due to impoundments, accompanied by increase erosion, turbidity and erosion downstream of outlets/culverts. Bottom row: Invasion by wetland and aquatic weeds in response to disturbance (trampling by cattle) and eutrophication.**

**Table 6. Index of Habitat Integrity (modified from Kleynhans 1997) describing the magnitude of physical disturbances within the overall study area.**

|                                          | Nyl River |
|------------------------------------------|-----------|
| WATER ABSTRACTION                        | 5         |
| FLOW MODIFICATION                        | 14        |
| BED MODIFICATION                         | 5         |
| CHANNEL MODIFICATION                     | 10        |
| WATER QUALITY                            | 8         |
| INUNDATION                               | 8         |
| VEGETATION REMOVAL                       | 5         |
| BANK EROSION                             | 5         |
| EXOTIC MACROPHYTES                       | 8         |
| EXOTIC FAUNA                             | 1         |
| RUBBISH DUMPING                          | 0         |
| <b>HABITAT INTEGRITY SCORE 2021</b>      | 74        |
| <b>PES Category: Moderately Modified</b> | <b>C</b>  |

## 3.4 Aquatic Macroinvertebrates

### 3.4.1 SASS5

The results of the SASS assessment are summarised in Table 6. It should be noted that SASS5 was developed for flowing rivers and interpretation of the results need to be modified for wetland ecosystems. The Nyl River is a floodplain wetland with a seasonal flow regime, rendering the SASS5 protocol more responsive to habitat availability and variability than to water quality *per se*.

As expected for a wetland, no stone or in-current biotopes were present within the study area and only the vegetation, stones-out-of-current and mud biotopes were sampled. Flows were absent from all sites and only pools with marginal vegetation were sampled.

Table 6 shows that the diversity and SASS5 scores were relatively low, which is not unexpected considering the wetland nature of the aquatic ecosystems (no stones-in-current biotopes). However, the SASS score and ASPT were largely stable within the study area.

Four taxa with a moderate or high requirement for good water quality were recorded during March 2022. More than two species of Baetidae (mayflies) were recorded from the upstream and downstream sites, indicating good water quality. Three taxa with a moderate requirement for good water quality were recorded - Aeshnidae dragonflies, Lestidae damselflies and Hydracarina water mites). Aeshnidae and Hydracarina were sampled from all sites, while Lestidae was recorded from the most downstream site.

During March 2022, there was an improvement in SASS score and diversity in a downstream direction, with the highest score (104) and number of taxa (21) being recorded from the most downstream site in the study area (site 6B). The ASPT remained fairly consistent between the upstream and downstream sites (Site 1 and 6B) during March 2022, indicating no loss of taxa with a requirement for good water quality and therefore fairly stable water quality conditions within the study area. This is consistent with the findings from 2011. (The survey conducted in 2021 yielded unreliable results due to low water levels and seasonal differences and were therefore disregarded.)

This low diversity of aquatic macroinvertebrates with a moderate or high requirement for good water quality renders the SASS5 protocol less responsive to changes in water quality, and more responsive to habitat availability, suitability and variability. The MIRAI (The Macroinvertebrate Response Assessment Index) (Table 7) confirmed that the aquatic macroinvertebrate assemblage responded mostly to habitat availability, with a secondary response to water quality. Habitat was also considered the primary driver of assemblage patterns.

The Nyl River within the study area was classified by the MIRAI as PES Category B/C (Largely Natural/Moderately Modified), based on the results of the March 2022 survey.

**Table 7. SASS5 results for the 2011 and 2022 surveys. Taxa with a moderate or high requirement for good water quality (sensitivity score of 8 or more) are highlighted green.**

| SITE                                       |                       | Nyl1                     | Nyl1 | Nyl2 | Nyl3 | Nyl4 | Nyl5 | Nyl5 | Nyl6B |
|--------------------------------------------|-----------------------|--------------------------|------|------|------|------|------|------|-------|
| Sampling Date                              |                       | 2011                     | 2022 | 2011 | 2022 | 2022 | 2011 | 2022 | 2022  |
| Biotopes Sampled (Rated 1-5)               | Stones out of current | 0                        | 1    | 0    | 0    | 1    | 0    | 0    | 0     |
|                                            | Marginal vege         | 3                        | 3    | 4    | 4    | 3    | 4    | 3    | 4     |
|                                            | Sediment              | 1                        | 1    | 1    | 1    | 2    | 1    | 1    | 2     |
| TOTAL No.TAXA                              |                       | 13                       | 15   | 15   | 19   | 15   | 16   | 14   | 21    |
| SASS Score                                 |                       | 30                       | 75   | 77   | 85   | 74   | 76   | 73   | 104   |
| ASPT                                       |                       | 2,3                      | 5,0  | 5,1  | 4,5  | 4,9  | 4,8  | 5,2  | 5,0   |
| SASS5 Taxon                                |                       | SASS5 Sensitivity Score* |      |      |      |      |      |      |       |
| ANNELIDA                                   |                       |                          |      |      |      |      |      |      |       |
| Hirudinea (Leeches)                        |                       | 3                        |      |      | A    |      | A    |      | A     |
| CRUSTACEA                                  |                       |                          |      |      |      |      |      |      |       |
| HYDRACARINA (Mites)                        |                       | 8                        | A    | A    | B    | A    | A    | A    | A     |
| EPHEMEROPTERA (Mayflies)                   |                       |                          |      |      |      |      |      |      |       |
| Baetidae 1sp                               |                       | 4                        | A    |      |      |      |      |      |       |
| Baetidae 2 sp                              |                       | 6                        |      | A    | A    |      | A    |      |       |
| Baetidae > 2 sp                            |                       | 12                       | B    |      |      | B    |      | A    | B     |
| ODONATA (Dragonflies & Damselflies)        |                       |                          |      |      |      |      |      |      |       |
| Coenagrionidae (Sprites and blues)         |                       | 4                        | A    | A    | A    | A    | A    |      | A     |
| Lestidae (Emerald Damselflies/Spreadwings) |                       | 8                        |      |      |      |      |      | 1    | A     |
| Aeshnidae (Hawkers & Emperors)             |                       | 8                        |      | A    |      | A    | A    | A    | A     |
| Gomphidae (Clubtails)                      |                       | 6                        |      |      |      |      |      |      | 1     |
| Libellulidae (Darters/Skimmers)            |                       | 4                        | A    | A    | A    | A    | A    | A    | A     |
| HEMIPTERA (Bugs)                           |                       |                          |      |      |      |      |      |      |       |
| Belostomatidae* (Giant water bugs)         |                       | 3                        | A    | A    | A    | 1    | A    |      | B     |
| Corixidae* (Water boatmen)                 |                       | 3                        | A    |      | B    |      |      | A    | B     |
| Gerridae* (Pond skaters/Water striders)    |                       | 5                        | B    | A    | A    | 1    | A    |      | 1     |
| Hydrometridae* (Water measurers)           |                       | 6                        |      | 1    |      |      |      |      |       |
| Naucoridae* (Creeping water bugs)          |                       | 7                        | 1    | A    |      |      |      |      |       |
| Nepidae* (Water scorpions)                 |                       | 3                        | A    | A    | A    | B    | A    | A    | B     |
| Notonectidae* (Backswimmers)               |                       | 3                        | B    | B    | A    | 1    | A    | A    | A     |
| Pleidae* (Pygmy backswimmers)              |                       | 4                        |      |      |      | A    |      | A    | B     |
| Veliidae/M...veliidae* (Ripple bugs)       |                       | 5                        | A    | A    | A    | A    | A    |      | A     |
| COLEOPTERA (Beetles)                       |                       |                          |      |      |      |      |      |      |       |
| Dytiscidae* (Diving beetles)               |                       | 5                        | A    | B    | A    | A    | B    | A    | A     |
| Noteridae*                                 |                       | 5                        |      | A    | A    |      | A    |      |       |
| Halplidae* (Crawling water beetles)        |                       | 5                        | A    |      | A    |      |      |      |       |
| Hydrophilidae* (Water scavenger beetles)   |                       | 5                        |      | 1    | A    | 1    | A    | 1    | 1     |
| DIPTERA (Flies)                            |                       |                          |      |      |      |      |      |      |       |
| Ceratopogonidae (Biting midges)            |                       | 5                        |      | A    | A    |      | A    | 1    | A     |
| Chironomidae (Midges)                      |                       | 2                        | A    |      | A    | B    | A    | B    | A     |
| Tabanidae (Horse flies)                    |                       | 5                        |      |      | 1    |      |      |      |       |
| Tipulidae (Crane flies)                    |                       | 5                        | A    |      | A    |      |      |      | 1     |
| GASTROPODA (Snails)                        |                       |                          |      |      |      |      |      |      |       |
| Physidae* (Pouch snails)                   |                       | 3                        |      | A    |      | A    |      | B    | B     |
| Planorbinae* (Orb snails)                  |                       | 3                        |      |      |      | 1    |      |      |       |

**Table 8. Result of the MIRAI assessment (most downstream site, March 2022)**

|                                         | Score      | Rank |
|-----------------------------------------|------------|------|
| <b>FLOW MODIFICATION</b>                | 74,1       | 3    |
| <b>HABITAT</b>                          | 76.3       | 1    |
| <b>WATER QUALITY</b>                    | 75,8       | 2    |
| <b>SEASONALITY</b>                      | 80,0       | 4    |
| <b>Overall Score</b>                    | 77,0       |      |
| <b>INVERTEBRATE ECOLOGICAL CATEGORY</b> | <b>B/C</b> |      |

## 3.5 Fish Assessment

### 3.5.1 Habitat Covers for Fish

The Habitat Cover Ratings (HCR's) approach was used to evaluate the amount and diversity of cover (habitat) available for fish at each of the sites in the study area (Tables 9 to 11). The habitat diversity or biotopes available for fish at the different sites were typical of those expected in a valley-bottom wetland ecosystem. No fast habitats were present at any of the sites in the study area, and it is expected that this may be the case during all seasons (even wet season) as a result of the wetland nature of the system. The January 2011 survey was conducted during the wet season with heavy rains experienced prior to and during the survey, and yet no fast habitats were present at any of the sites. The absence of fast habitats can therefore exclude the presence of fish species with a preference for this habitat type.

During the January 2011, November 2021 and March 2022 surveys the dominant velocity-depth category (habitat) available for fish at all sites was slow (<0.3m/s)-shallow (<0.5m) and slow-deep (Tables 9 to 11). Fish species with a preference or requirement for slow (lentic) habitats can therefore be expected to occur at these sites. The primary cover feature available to fish during both surveys was provided in the form of macrophytes and overhanging vegetation (also typical valley bottom wetland habitats) (Table 9 to 11). The absence of substrates in the form of cobbles and boulders that could serve as cover for fish in the area is expected to be reflective of natural conditions, and the presence of this cover feature at sites Nyl 3 and Nyl 4 is the result of farm dam walls constructed with rocks.

**Table 9: Habitat composition and diversity for fish at different sampling sites (January 2011)**

| Sites                                      | NYL 1 | NYL 2 | NYL 3 | NYL 4 | NYL 5 | NYL 6 | NYL 7 |
|--------------------------------------------|-------|-------|-------|-------|-------|-------|-------|
| <b>SLOW-DEEP (&gt;0.5m; &lt;0.3m/s)</b>    |       |       |       |       |       |       |       |
| Abundance                                  | 0     | 4     | 4     | 4     | 2     | 2     | 4     |
| Overhanging vegetation                     | 0     | 2     | 2     | 2     | 2     | 1     | 2     |
| Undercut banks and Root-wads               | 0     | 0     | 0     | 0     | 0     | 0     | 1     |
| Substrate                                  | 0     | 0     | 2     | 1     | 0     | 0     | 0     |
| Macrophytes                                | 0     | 3     | 3     | 4     | 3     | 4     | 4     |
| <b>SLOW-SHALLOW (&lt;0.5m; &lt;0.3m/s)</b> |       |       |       |       |       |       |       |
| Abundance                                  | 4     | 2     | 1     | 2     | 3     | 4     | 3     |
| Overhanging vegetation                     | 1     | 2     | 2     | 2     | 2     | 1     | 2     |
| Undercut banks and Root-wads               | 1     | 0     | 0     | 0     | 0     | 0     | 1     |
| Substrate                                  | 1     | 0     | 2     | 1     | 0     | 0     | 0     |
| Macrophytes                                | 4     | 3     | 3     | 4     | 3     | 4     | 4     |
| <b>FAST-DEEP (&gt;0.3m; &gt;0.3m/s)</b>    |       |       |       |       |       |       |       |
| Abundance                                  | 0     | 0     | 0     | 0     | 0     | 0     | 0     |
| Overhanging vegetation                     | 0     | 0     | 0     | 0     | 0     | 0     | 0     |
| Undercut banks and Root-wads               | 0     | 0     | 0     | 0     | 0     | 0     | 0     |
| Substrate                                  | 0     | 0     | 0     | 0     | 0     | 0     | 0     |
| Macrophytes                                | 0     | 0     | 0     | 0     | 0     | 0     | 0     |
| <b>FAST-SHALLOW (&lt;0.3m; &gt;0.3m/s)</b> |       |       |       |       |       |       |       |
| Abundance                                  | 0     | 0     | 0     | 0     | 0     | 0     | 0     |
| Overhanging vegetation                     | 0     | 0     | 0     | 0     | 0     | 0     | 0     |
| Undercut banks and Root-wads               | 0     | 0     | 0     | 0     | 0     | 0     | 0     |
| Substrate                                  | 0     | 0     | 0     | 0     | 0     | 0     | 0     |
| Macrophytes                                | 0     | 0     | 0     | 0     | 0     | 0     | 0     |

Abundance of velocity-depth classes and cover are estimated according to: 0 – absent; 1 – rare; 2 – sparse; 3 – common; 4 – very abundant

**Table 10: Habitat composition and diversity for fish at different sampling sites (November 2021)**

| Velocity-depth class                | Sites                        | Nyl 2 | Nyl 3 | Nyl 6B |
|-------------------------------------|------------------------------|-------|-------|--------|
| SLOW-DEEP<br>(>0.5m;<br><0.3m/s)    | Abundance                    | 0     | 4     | 1      |
|                                     | Overhanging vegetation       | 0     | 0     | 1      |
|                                     | Undercut banks and Root-wads | 0     | 0     | 0      |
|                                     | Substrate                    | 0     | 1     | 0      |
|                                     | Macrophytes                  | 0     | 2     | 2      |
| SLOW-SHALLOW<br>(<0.5m;<br><0.3m/s) | Abundance                    | 4     | 2     | 3      |
|                                     | Overhanging vegetation       | 3     | 0     | 2      |
|                                     | Undercut banks and Root-wads | 3     | 0     | 0      |
|                                     | Substrate                    | 0     | 1     | 0      |
|                                     | Macrophytes                  | 4     | 2     | 3      |
| FAST-DEEP<br>(>0.3m;<br>>0.3m/s)    | Abundance                    | 0     | 0     | 0      |
|                                     | Overhanging vegetation       | 0     | 0     | 0      |
|                                     | Undercut banks and Root-wads | 0     | 0     | 0      |
|                                     | Substrate                    | 0     | 0     | 0      |
|                                     | Macrophytes                  | 0     | 0     | 0      |
| FAST-SHALLOW<br>(<0.3m;<br>>0.3m/s) | Abundance                    | 0     | 0     | 0      |
|                                     | Overhanging vegetation       | 0     | 0     | 0      |
|                                     | Undercut banks and Root-wads | 0     | 0     | 0      |
|                                     | Substrate                    | 0     | 0     | 0      |
|                                     | Macrophytes                  | 0     | 0     | 0      |

Abundance of velocity-depth classes and cover are estimated according to: 0 – absent; 1 – rare; 2 – sparse; 3 – common; 4 – very abundant

**Table 11: Habitat composition and diversity for fish at different sampling sites (March 2022)**

| Velocity-depth class                | Sites                        | Nyl 1 | Nyl 2 | Nyl 4 | Nyl 5 | Nyl 6B |
|-------------------------------------|------------------------------|-------|-------|-------|-------|--------|
| SLOW-DEEP<br>(>0.5m;<br><0.3m/s)    | Abundance                    | 4     | 4     | 3     | 0     | 4      |
|                                     | Overhanging vegetation       | 0     | 0     | 0     | 0     | 0      |
|                                     | Undercut banks and Root-wads | 0     | 0     | 0     | 0     | 0      |
|                                     | Substrate                    | 0     | 0     | 0     | 0     | 0      |
|                                     | Macrophytes                  | 4     | 4     | 4     | 0     | 3      |
| SLOW-SHALLOW<br>(<0.5m;<br><0.3m/s) | Abundance                    | 4     | 3     | 3     | 4     | 4      |
|                                     | Overhanging vegetation       | 3     | 0     | 1     | 0     | 2      |
|                                     | Undercut banks and Root-wads | 0     | 0     | 0     | 0     | 1      |
|                                     | Substrate                    | 4     | 0     | 2     | 0     | 0      |
|                                     | Macrophytes                  | 4     | 4     | 3     | 4     | 3      |
| FAST-DEEP<br>(>0.3m;<br>>0.3m/s)    | Abundance                    | 0     | 0     | 0     | 0     | 0      |
|                                     | Overhanging vegetation       | 0     | 0     | 0     | 0     | 0      |
|                                     | Undercut banks and Root-wads | 0     | 0     | 0     | 0     | 0      |
|                                     | Substrate                    | 0     | 0     | 0     | 0     | 0      |
|                                     | Macrophytes                  | 0     | 0     | 0     | 0     | 0      |
| FAST-SHALLOW<br>(<0.3m;<br>>0.3m/s) | Abundance                    | 0     | 0     | 0     | 0     | 0      |
|                                     | Overhanging vegetation       | 0     | 0     | 0     | 0     | 0      |
|                                     | Undercut banks and Root-wads | 0     | 0     | 0     | 0     | 0      |
|                                     | Substrate                    | 0     | 0     | 0     | 0     | 0      |
|                                     | Macrophytes                  | 0     | 0     | 0     | 0     | 0      |

### 3.5.2 Fish species composition

During the January 2011 baseline aquatic fauna study performed in the study area, seven indigenous fish species were sampled at seven sites (Table 12). These included the Johnston's topminnow (*Micropanchax johnstoni*), Hyphen barb (*Enteromius bifrenatus*), Straightfin barb (*Enteromius paludinosus*), Sharptooth catfish (*Clarias gariepinus*), Mozambique tilapia (*Oreochromis mossambicus*), Southern mouthbrooder (*Pseudocrenilabrus philander*) and Banded tilapia (*Tilapia sparrmanii*) (Table 12).

During the November 2021 (early wet season) survey only four indigenous species (*E. paludinosus*, *C. gariepinus*, *O. mossambicus* and *P. philander*) were sampled at three sites (Table 13). The end of wet season survey conducted in March 2022 reflected very similar results with five indigenous species sampled, namely *E. paludinosus*, *C. gariepinus*, *O. mossambicus*, *P. philander* and *T. sparrmanii* (Table 14). *Enteromius paludinosus* was by far the most abundant and most widespread and most abundant indigenous fish species in the study area during 2011 and 2021/22 surveys. The relative abundance of *Pseudocrenilabrus philander* and *Oreochromis mossambicus* was moderate while the rest of the species had a generally low abundance.

One alien fish species, namely the Common carp (*Cyprinus carpio*) was sampled within the study area at Site Nyl 6 during January 2011, and although none were sampled in 2021/22 it is still present within this reach (confirmed by locals). During the 2021 and 2022 surveys another alien species, namely the Mosquito fish (*Gambusia affinis*) (absent in 2011) was also sampled in the study area and its high abundance is especially of concern (Tables 13 and 14).

**Table 12: Fish species (no. of individuals) sampled during January 2011 at the selected sampling sites.**

| SPECIES                                |                       | Fish Sampling Sites |       |       |       |       |       |       |
|----------------------------------------|-----------------------|---------------------|-------|-------|-------|-------|-------|-------|
| SCIENTIFIC NAME                        | ENGLISH COMMON NAME   | Nyl 1               | Nyl 2 | Nyl 3 | Nyl 4 | Nyl 5 | Nyl 6 | Nyl 7 |
| <i>Micropanchax johnstoni</i>          | Johnston's Topminnow  | 4                   | 2     |       | 1     | 12    | 7     |       |
| <i>Enteromius bifrenatus</i>           | Hyphen Barb           | 1                   |       |       |       |       |       |       |
| <i>Enteromius paludinosus</i>          | Straightfin Barb      | 12                  | 100+  | 500+  | 500+  | 150+  | 300+  | 200+  |
| <i>Clarias gariepinus</i>              | Sharptooth Catfish    |                     |       | 2     | 2     |       |       |       |
| <i>Oreochromis mossambicus</i>         | Mozambique Tilapia    |                     |       | 30    | 5     |       | 2     |       |
| <i>Pseudocrenilabrus philander</i>     | Southern mouthbrooder | 8                   | 12    | 20    | 7     | 12    | 30    | 50    |
| <i>Tilapia sparrmanii</i>              | Banded Tilapia        | 2                   |       |       |       | 3     | 7     |       |
| <i>Cyprinus carpio</i> *               | Common carp           |                     |       |       |       |       | 1     |       |
| Sampling time (minutes electrofishing) |                       | 20                  | 15    | 30    | 25    | 20    | 20    | 23    |

\*Alien species

**Table 13: Fish species (no. of individuals) sampled during November 2021 at the selected sampling sites.**

| SCIENTIFIC NAME                        | ENGLISH COMMON NAME   | Nyl 2 | Nyl 3 | Nyl 6B |
|----------------------------------------|-----------------------|-------|-------|--------|
| <i>Enteromius paludinosus</i>          | Straightfin Barb      | 200+  | 500+  | 130+   |
| <i>Clarias gariepinus</i>              | Sharptooth Catfish    | 1     | 5     | 0      |
| <i>Oreochromis mossambicus</i>         | Mozambique Tilapia    | 1     | 5     | 10     |
| <i>Pseudocrenilabrus philander</i>     | Southern mouthbrooder | 50+   | 0     | 80+    |
| <i>Gambusia affinis</i> *              | Mosquitofish          | 100+  | 0     | 100+   |
| Sampling time (minutes electrofishing) |                       | 74    | 28    | 12     |

\*Alien species

**Table 14: Fish species (no. of individuals) sampled during March 2022 at the selected sampling sites.**

| SCIENTIFIC NAME                    | ENGLISH COMMON NAME   | Nyl 1 | Nyl 2 | Nyl 4 | Nyl 5 | Nyl 6B |
|------------------------------------|-----------------------|-------|-------|-------|-------|--------|
| <i>Enteromius paludinosus</i>      | Straightfin Barb      | 8     | 2     | 111   | 3     | 65     |
| <i>Clarias gariepinus</i>          | Sharptooth Catfish    | 4     | 3     | 0     | 1     | 0      |
| <i>Oreochromis mossambicus</i>     | Mozambique Tilapia    | 0     | 0     | 0     | 0     | 32     |
| <i>Pseudocrenilabrus philander</i> | Southern mouthbrooder | 1     | 0     | 3     | 0     | 10     |
| <i>Tilapia sparrmanii</i>          | Banded Tilapia        | 0     | 0     | 3     | 0     | 2      |
| <i>Gambusia affinis</i> *          | Mosquitofish (Ex)     | 1     | 0     | 2     | 0     | 19     |

\*Alien species

To enable the determination of the biotic integrity (present state in relation to those expected under natural conditions) of the study area in terms of its fish assemblage, it is necessary to determine which species would have occurred under natural (pre-disturbance) conditions. No historic (pre-disturbance) information is known to exist, or have been published, for the exact study area. The approach therefore used to determine the expected species follows the use of all available fish information of the region.

Two National River Health biomonitoring sites (A6NYL-TOBIA and A6NYL-JAAGB) are present within close proximity of the study area (site Nyl 7 exact site of A6NYL-JAAGB), of which reference frequency of occurrence (FROC) information is also available that was utilised for the purpose of this study (Kleynhans *et al.*, 2007). The desktop PES (DWS, 2013) also includes a list of species that could be expected to be present within each sub-quaternary reach that was used to verify expected reference species. The known species pool of the area was then narrowed down based on the habitat composition within the study area expected under natural conditions.

Apart from the unnatural habitats created by dams and road crossings over the stream, the current habitat compositions in the undammed sections of most of the sites are expected to be mostly similar to those under natural conditions, although the hydrological

regime may have been altered to some extent (reduced flows due to abstraction and damming).

**Table 15: Probability of occurrence of fish species and their expected frequency of occurrence under natural (pre-disturbed), 2011 and present (2021/22) conditions.**

| SCIENTIFIC NAME                    | Natural / Pre-disturbed | 2011 | Present (2021/22) |
|------------------------------------|-------------------------|------|-------------------|
| <i>Micropanchax johnstoni</i>      | 5                       | 4    | 1                 |
| <i>Enteromius bifrenatus</i>       | 3                       | 2    | 1                 |
| <i>Labeobarbus marequensis</i>     | 0                       | 0    | 0                 |
| <i>Enteromius paludinosus</i>      | 5                       | 5    | 5                 |
| <i>Enteromius trimaculatus</i>     | 2                       | 1    | 1                 |
| <i>Enteromius unitaeniatus</i>     | 2                       | 1    | 1                 |
| <i>Enteromius viviparus</i>        | 3                       | 1    | 1                 |
| <i>Clarias gariepinus</i>          | 2                       | 2    | 2                 |
| <i>Labeo molybdinus</i>            | 0                       | 0    | 0                 |
| <i>Marcusenius macrolepidotus</i>  | 0                       | 0    | 0                 |
| <i>Oreochromis mossambicus</i>     | 3                       | 3    | 3                 |
| <i>Pseudocrenilabrus philander</i> | 5                       | 5    | 5                 |
| <i>Tilapia sparrmanii</i>          | 3                       | 3    | 2                 |
| <i>Gambusia affinis</i> *          | 0                       | 0    | 4                 |
| <i>Cyprinus carpio</i> *           | 0                       | 2    | 2                 |

Spatial Fish Frequency of Occurrence (FROC): \*1=Present at very few sites (<10% of sites); 2=Present at few sites (>10-25%); 3=Present at about >25-50 % of sites; 4=Present at most sites (>50- 75%); 5=Present at almost all sites (>75%)

\*Alien species

Italics: not sampled but estimated to potentially still be present.

Based on all available information, thirteen indigenous fish species have a known distribution range in the Nyl River system in the vicinity of the study area (Table 15). Due to the absence of fast habitats, and especially rocky bottom substrates, at least two species can be excluded from the study area, namely *Labeobarbus marequensis* (Largescale yellowfish) and *Labeo molybdinus* (Leaden labeo). *Marcusenius macrolepidotus* (Bulldog) can be excluded based on its preference for deep pools and undercut banks and rootwads, being absent from the sites surveyed and the reach in general. There is a very low probability that these species occurred in the reach under natural conditions.

Ten indigenous fish species therefore have a moderate to high probability of occurrence in the Nyl River study reach under natural conditions (Table 15). The presence of seven of these species was confirmed during the January 2011, November 2021 and March 2022 surveys.

### 3.5.3 Habitat preference and intolerance to environmental degradation

The fish species of the study area differ in their preferences for different habitat types (Table 16). All the fish species observed in the study area have a preference for slow habitats with overhanging vegetation, aquatic macrophytes and water column as cover (Table 17).

It is therefore essential that especially these habitat features should not be altered by any future activities in the area (including mining). Examples of activities often responsible for degradation in different fish habitat features are given in Table 17 and caution should therefore be taken with any of these activities, especially those that may influence the preferred habitats of the fish species known to occur in the study area.

**Table 16: Habitat preferences (flow-depth and cover features) of the expected fish species (Kleynhans, 2003).**

| ABBREVIATION | ENGLISH COMMON NAME   | SLOW-DEEP (<0.3 m/s; >0.5 m) | SLOW-SHALLOW (<0.3 m/s; <0.5 m) | FAST-DEEP (>0.3 m/s; >0.3 m) | FAST-SHALLOW (>0.3 m/s; <0.3 m) | OVERHANGING VEGETATION | BANK UNDERCUT | SUBSTRATE | AQUATIC MACROPHYTES | WATER COLUMN |
|--------------|-----------------------|------------------------------|---------------------------------|------------------------------|---------------------------------|------------------------|---------------|-----------|---------------------|--------------|
| AJOH         | JOHNSTON'S TOPMINNOW  | 3.3                          | 4                               | 0                            | 0                               | 3.5                    | 1             | 2         | 3                   | 3            |
| BBIF         | HYPHEN BARB           | 3.3                          | 4.7                             | 0.7                          | 0.8                             | 4.4                    | 2.7           | 2.7       | 1.6                 | 0            |
| BPAU         | STRAIGHTFIN BARB      | 3.9                          | 3.9                             | 2.2                          | 2.6                             | 4.2                    | 2.4           | 1.9       | 3.6                 | 3.5          |
| BTRI         | THREESpot BARB        | 3.9                          | 3.2                             | 2.3                          | 2.7                             | 3.9                    | 2.6           | 2.3       | 2.8                 | 2.8          |
| BUNI         | LONGBEARD BARB        | 5                            | 4.3                             | 0.9                          | 1.3                             | 4.6                    | 2.7           | 2.9       | 1.3                 | 2.2          |
| BVIV         | BOWSTRIPE BARB        | 2.1                          | 4.8                             | 0.4                          | 0.6                             | 4.9                    | 2.1           | 1.5       | 3.2                 | 0.3          |
| CGAR         | SHARPTOOTH CATFISH    | 4.3                          | 3.4                             | 1.2                          | 0.8                             | 2.8                    | 2.9           | 2.8       | 3                   | 2.6          |
| OMOS         | MOZAMBIQUE TILAPIA    | 4.6                          | 3.8                             | 1.4                          | 0.8                             | 3                      | 1.9           | 2.1       | 2.8                 | 3.9          |
| PPHI         | SOUTHERN MOUTHBROODER | 2.6                          | 4.3                             | 0.5                          | 0.9                             | 4.5                    | 3.2           | 1.9       | 2.9                 | 0.3          |
| TSPA         | BANDED TILAPIA        | 3                            | 4.3                             | 0.9                          | 1.5                             | 4.5                    | 1.9           | 2.5       | 3.6                 | 1.1          |

0 = NO PREFERENCE, IRRELEVANT;

>0 -0.9 = VERY LOW PREFERENCE -COINCIDENTAL?

>1-1.9 = LOW PREFERENCE

>2-2.9 = MODERATE PREFERENCE

>3-3.9 = HIGH PREFERENCE

>4-5 = VERY HIGH PREFERENCE

**Table 17: Human activities that are often responsible for degradation in specific fish habitat features (important habitats for fish in study area shaded)**

| Velocity depth class or Habitat feature | General impacts and activities.                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|-----------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Slow deep & slow shallow                | Increased flows as result of regulation, water transfer schemes, irrigation releases. Sedimentation of pools as a result of catchment and bank erosion.                                                                                                                                                                                                                                                                                                                                                      |
| Fast deep and fast shallow              | Decreased flows a result of water abstraction (for agriculture, domestic, mining or industry), flow modification as a result of dams, weirs and channelization.                                                                                                                                                                                                                                                                                                                                              |
| Overhanging vegetation                  | Clearing of vegetation on stream banks for the purpose of stream crossings (conveyer belts, roads, haul roads), clearing of riparian zones for construction activities, exotic vegetation encroachment replacing natural vegetation and also causing increased bank erosion, and to a lesser extent water quality deterioration (increased toxins could result in decreased availability of vegetation while increased nutrients could result in excessive growth or domination by single or a few species). |
| Undercut banks                          | Alteration of natural water levels (through water abstraction, flow alterations, etc.). Physical disturbance of banks through construction or agricultural activities.                                                                                                                                                                                                                                                                                                                                       |
| Substrate                               | Increased sedimentation (related to erosion), excessive algal growth (especially associated with irrigation return flows and WWTW effluents), sand mining, trampling by livestock, disturbance by bottom feeding alien species such as Common carp, etc.                                                                                                                                                                                                                                                     |
| Aquatic macrophytes                     | Altered flow regimes, use of herbicides, presence of alien Grass carp.                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| Water column                            | Decreased flows (through abstraction, constructions of dams, etc.)                                                                                                                                                                                                                                                                                                                                                                                                                                           |

### 3.5.4 Relative intolerance of fish to environmental change

The fish species of the study area also differ in their tolerance level to disturbance of the environment (Table 18). All the fish species expected or observed within the study area are classified as being overall tolerant to moderately tolerant to environmental change (Table 18).

The most intolerant of all species expected in the study area is the Johnston's topminnow, which are intolerant to habitat alterations and water quality deterioration (Table 18). This species will be the most important indicator fish species to use in future to detect changes as a result of activities such as mining operations (if still present). The Threespot barb is also moderately intolerant to changes in trophic structure, but this species was not sampled during the 2011 and 2021/22 surveys, and it is assumed that it is not abundant in this river reach. *Enteromius paludinosus* (Straightfin barb) was the most intolerant species confirmed in the study area during 2021/22 (Table 18).

**Table 18: Relative intolerance ratings of expected fish species (Kleynhans, 2003)**

| ABBREVIATION | ENGLISH COMMON NAME   | TROPHIC SPECIALIZATION | HABITAT SPECIALIZATION | FLOW REQUIREMENT | REQUIREMENT: UNMODIFIED WATER QUALITY | AVERAGE OVERALL INTOLERANCE RATING |
|--------------|-----------------------|------------------------|------------------------|------------------|---------------------------------------|------------------------------------|
| AJOH         | JOHNSTON'S TOPMINNOW  | 3                      | 3.3                    | 1.5              | 3.8                                   | 2.9                                |
| BBIF         | HYPHEN BARB           | 3                      | 2.5                    | 2.5              | 3                                     | 2.8                                |
| BPAU         | STRAIGHTFIN BARB      | 1.6                    | 1.4                    | 2.3              | 1.8                                   | 1.8                                |
| BTRI         | THREESpot BARB        | 3.1                    | 1.4                    | 2.7              | 1.8                                   | 2.2                                |
| BUNI         | LongBEARD BARB        | 1.1                    | 1.3                    | 2.3              | 2.2                                   | 1.7                                |
| BVIV         | BOWSTRIPE BARB        | 2                      | 2.3                    | 2.3              | 3                                     | 2.4                                |
| CGAR         | SHARPTOOTH CATFISH    | 1                      | 1.2                    | 1.7              | 1                                     | 1.2                                |
| OMOS         | MOZAMBIQUE TILAPIA    | 1.2                    | 1.9                    | 0.9              | 1.3                                   | 1.3                                |
| PPHI         | SOUTHERN MOUTHBROODER | 1.3                    | 1.4                    | 1                | 1.4                                   | 1.3                                |
| TSPA         | BANDED TILAPIA        | 1.6                    | 1.4                    | 0.9              | 1.4                                   | 1.3                                |

0-1.9 = TOLERANT; >2-2.9 = MODERATELY TOLERANT

>3-3.9 = MODERATELY INTOLERANT

>4-5.0 = INTOLERANT

### 3.5.5 Conservation status

The only fish species of the study area classified as threatened on any scale (international, national or regional) is the Mozambique tilapia (*Oreochromis mossambicus*), classified as being Vulnerable with a decreasing population trend (IUCN) (Table 19). Although this species is relatively widespread and common, it is threatened by hybridization with the rapidly spreading alien Nile tilapia (*Oreochromis niloticus*). *Oreochromis niloticus* is being spread by anglers and for aquaculture purposes. Hybridization is already occurring throughout the northern part of the species' range, with most of the evidence coming from the Limpopo River system. (IUCN, 2011). The other fish species of the study area are mostly widespread and common (Table 19).

**Table 19: Conservation status of indigenous fish species expected in the Volspruit Mine study area**

| SCIENTIFIC NAME                    | ENGLISH COMMON NAME   | CONSERVATION STATUS / GENERAL COMMENTS                                                 |
|------------------------------------|-----------------------|----------------------------------------------------------------------------------------|
| <i>MICROPANCHAX JOHNSTONI</i>      | JOHNSTON'S TOPMINNOW  | IUCN: Least concern. Widespread                                                        |
| <i>ENTEROMIUS BIFRENATUS</i>       | HYPHEN BARB           | IUCN: Least concern. Relatively widespread in Limpopo, became very rare in Mpumalanga. |
| <i>ENTEROMIUS PALUDINOSUS</i>      | STRAIGHTFIN BARB      | IUCN: Least concern. Widespread and common                                             |
| <i>ENTEROMIUS TRIMACULATUS</i>     | THREESpot BARB        | IUCN: Least concern. Widespread and common                                             |
| <i>ENTEROMIUS UNITAENIATUS</i>     | LongBEARD BARB        | W IUCN: Least concern. Widespread and common                                           |
| <i>ENTEROMIUS VIVIPARUS</i>        | BOWSTRIPE BARB        | IUCN: Least concern. Widespread and common                                             |
| <i>CLARIAS GARIEPINUS</i>          | SHARPTOOTH CATFISH    | IUCN: Least concern. Widespread and common                                             |
| <i>OREOCHROMIS MOSSAMBICUS</i>     | MOZAMBIQUE TILAPIA    | Vulnerable (decreasing) (IUCN 2021). Widespread and common                             |
| <i>PSEUDOCRENILABRUS PHILANDER</i> | SOUTHERN MOUTHBROODER | IUCN: Least concern. Widespread and common                                             |
| <i>TILAPIA SPARRMANII</i>          | BANDED TILAPIA        | IUCN: Least concern. Widespread and common                                             |

### 3.5.6 Alien fish species

One alien fish species, the Common carp (*Cyprinus carpio*) was sampled in the study area (Site Nyl 6) during the 2011 study and although not sampled in November 2021/22 its presence was confirmed by locals. Common carp have a negative impact on the environment they occur in, but are valued by certain interest groups such as sport fishermen. They are widely regarded as a pest and are held responsible for the introduction of numerous fish parasites. They compete with other fish for food, they eat the spawn of other fish and disrupt nest-building activities of some fish. Furthermore, they cause habitat degradation by their feeding behaviour of grubbing in the mud for food, which causes the destruction of vegetation, rooting up of marginal vegetation and disturbing of the bottom sediments which increases turbidity (de Moor & Bruton, 1988).

Another alien fish species, namely the Mosquito fish (*Gambusia affinis*) was sampled in the study area during November 2021 and March 2022. This species was not present in 2011 and it is therefore evident that it was introduced since the 2011 survey. The very high abundance observed for this species during the November 2021 and March 2022 surveys is especially of concern as this aggressive predatory species may impact negatively on the indigenous fish species. *Gambusia affinis* has been introduced to aquatic systems as a biological control method for mosquitoes and is also spread by anglers/landowners as fodder for predatory fish (such as Largemouth bass). This species feeds on living animals, including mosquito- and fish larvae, and therefore impact natural fish populations as a result of predation of eggs and larvae.

Another alien fish species, namely the Largemouth bass (*Micropterus salmoides*) has a low probability of occurrence within this quaternary catchment. The potential presence of this species is always alarming and the expected impact can be detrimental, as this aggressive predator can have a large impact on the indigenous fish species, especially small species and juveniles of larger species. It should be encouraged to remove specimens of this species whenever caught by anglers to keep their numbers as low as possible. These species should also not be allowed to be stocked in the river or within dams that are situated in tributaries of the rivers in the area.

### **3.5.7 Migration**

Most of the fish species expected or observed in the study area are all classified as potadromous<sup>1</sup> in terms of migratory life history. Most of the *Enteromius species*, *C. gariepinus* and *T. sparrmanii* all require movement between reaches, while *P. philander* and *A. johnstoni* primarily migrates within a reach. Currently, migration of the fish in the study area is influenced by the presence of various existing dams and road crossings. It is recommended that all redundant dams should be removed from streams in the study area (and region where applicable) and no new instream dams or bridges that obstruct free movement of fish should be constructed as part of any proposed developments or mining activities. A fish migration assessment should be conducted as part of any planned future dams or bridges (and if possible, also for existing dams and bridges).

### **3.5.8 Biotic integrity based on fish**

The present ecological status (PES) or biotic integrity, based on fish, of the Nyl River reach of the study area was determined through the application of the Fish Response Assessment Index (FRAI) (Kleynhans, 2007). It provides an indication of the status of the fish assemblage, in relation to what could be expected under natural or unmodified conditions. The FRAI was done for the entire Nyl River reach (Sites Nyl 1 to Nyl 7).

According to the FRAI calculation done in 2011, the fish assemblage of the Nyl River reach was still in a good condition, with a FRAI score of 83.1% calculated (Table 20). This classified ecological status based on fish in a category B, indicating that the reach was only slightly modified from its natural state in 2011. Although a change in community characteristics has taken place, species richness and presence of intolerant species indicated little modifications. Most aspects of the fish assemblage were similar to that expected under natural unperturbed conditions. The primary impacts responsible for the observed condition in 2011 were related to habitat deterioration. The most important

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<sup>1</sup> **Potadromous:** Truly migratory species whose entire life cycle is completed within freshwater and that undertake migrations within freshwater zones of rivers for a variety of reasons, such as for spawning, feeding, dispersion after spawning, colonisation after droughts, for over-wintering, etc.

alterations that influenced the biotic integrity in terms of fish at the time (2011) included the following:

- Reduced flows resulted in loss of habitat diversity and availability (associated with presence of various dams within and upstream of the study area).
- Slightly reduced water quality (associated with agricultural and livestock farming activities).
- Sedimentation of bottom substrates (associated with erosion due to agriculture and livestock farming).
- Presence of migration barriers (dams and road crossings, resulting in scenarios where fish cannot conduct natural dispersal or recolonise areas after unfavourable conditions (such as droughts)).
- Presence of alien fish species (Common carp disturb bottom substrates, compete for food and habitat and create turbid waters).

The application of the FRAI model based on the 2021/22 survey results indicate that the present ecological state may have deteriorated from a category B in 2011 to a category C in 2021/22 with a FRAI score of 66.3% calculated (Table 21). The temporal decrease in FRAI and hence biotic integrity as reflected by the fish assemblage was related to the following results and observations:

- Decreased occurrence, and potential absence of the Johnston's topminnow (*M. johnstoni*): This species was absent during November 2021 and March 2022 although adequate habitat was available. This species is intolerant to habitat and water quality changes (Table 18) and most probably highly susceptible to be impacted by the predatory alien *G. affinis* (in terms of competition for habitats, food and predation). It is strongly advised that a biomonitoring programme should be implemented as a matter of urgency to further expand the knowledge on the fish species composition and to verify the presence/absence of this species with this reach.
- *Enteromius bifrenatus* was also not sampled during 2021/22 surveys, and was also very scarce (only 1 individual sampled at site Nyl 1) during January 2011. There is a probability that this species may have become even scarcer or may now be absent from this reach. This species will also be influenced by alterations in habitat (sedimentation, flow), water quality deterioration and the presence of alien fish species.
- Increase in alien fish species, with *G. affinis* not being sampled in 2011 and now (2021/22) being very abundant and widespread throughout the study area. The impact of alien fish species on indigenous species have therefore increased notably over this period resulting in an overall deterioration in the indigenous fish species assemblage.

**Table 20: Fish Response Assessment Index (FRAI) results for Nyl River Reach (2011).**

| METRIC GROUP                         | METRIC                                                                                                                    | *RATING<br>(CHANGE) | METRIC<br>GROUP<br>WEIGHT<br>(%) |
|--------------------------------------|---------------------------------------------------------------------------------------------------------------------------|---------------------|----------------------------------|
| VELOCITY-DEPTH<br>CLASSES<br>METRICS | Response of species with high to very high preference for FAST-DEEP conditions                                            | 0.0                 | 84                               |
|                                      | Response of species with high to very high preference for FAST-SHALLOW conditions                                         | 0.0                 |                                  |
|                                      | Response of species with high to very high preference for SLOW-DEEP conditions                                            | -0.5                |                                  |
|                                      | 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                                  | 0.0                 |                                  |
|                                      | Response of species with a high to very high preference for a particular substrate type                                   | 0.0                 |                                  |
|                                      | 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                                              | 0.0                 |                                  |
| FLOW<br>DEPENDENCE<br>METRICS        | Response of species intolerant of no-flow conditions                                                                      | 0.0                 | 63                               |
|                                      | Response of species moderately intolerant of no-flow conditions                                                           | 0.0                 |                                  |
|                                      | Response of species moderately tolerant of no-flow conditions                                                             | -1.5                |                                  |
|                                      | Response of species tolerant of no-flow conditions                                                                        | 0.0                 |                                  |
| PHYSICO-CHEMICAL<br>METRICS          | Response of species intolerant of modified physico-chemical conditions                                                    | 0.0                 | 63                               |
|                                      | Response of species moderately intolerant of modified physico-chemical conditions                                         | -1.0                |                                  |
|                                      | Response of species moderately tolerant of modified physico-chemical conditions                                           | -2.0                |                                  |
|                                      | Response of species tolerant of modified physico-chemical conditions                                                      | -0.5                |                                  |
| MIGRATION<br>METRICS                 | Response in terms of distribution/abundance of spp with catchment scale movements                                         |                     | 55                               |
|                                      | Response in terms of distribution/abundance of spp with requirement for movement between reaches or fish habitat segments | 2.0                 |                                  |
|                                      | Response in terms of distribution/abundance of spp with requirement for movement within reach or fish habitat segment     | 1.0                 |                                  |
| INTRODUCED<br>SPECIES<br>METRICS     | The impact/potential impact of introduced competing/predaceous spp?                                                       |                     | 37                               |
|                                      | How widespread (frequency of occurrence) are introduced competing/predaceous spp?                                         |                     |                                  |
|                                      | The impact/potential impact of introduced habitat modifying spp?                                                          | 1.5                 |                                  |
|                                      | How widespread (frequency of occurrence) are habitat modifying spp?                                                       | 0.5                 |                                  |
| FRAI SCORE (%)                       |                                                                                                                           | 83.1                |                                  |
| FRAI CATEGORY                        |                                                                                                                           | B                   |                                  |
| FRAI CATEGORY DESCRIPTION            |                                                                                                                           | Good                |                                  |

\*GUIDELINES FOR RATING/CHANGE (0-->5)

-5=Extreme loss from reference (absent); -4=Serious loss from reference; -3=Large loss from reference; -2=Moderate loss from reference, -1= Small loss from reference; 0=No change from reference; 1= Small increase from reference; 2=Moderate increase from reference; 3=Large increase from reference; 4=Serious increase from reference; 5=Extreme increase from reference (completely dominant).

**Table 21: Fish Response Assessment Index (FRAI) results for Nyl River Reach (2021/22 results).**

| METRIC GROUP                   | METRIC                                                                                                                      | *RATING (CHANGE)    | METRIC GROUP WEIGHT (%) |
|--------------------------------|-----------------------------------------------------------------------------------------------------------------------------|---------------------|-------------------------|
| VELOCITY-DEPTH CLASSES METRICS | Response of species w ith high to very high preference for FAST-DEEP conditions                                             | ↑ 0                 | 84                      |
|                                | Response of species with high to very high preference for FAST-SHALLOW conditions                                           | ↑ 0                 |                         |
|                                | Response of species with high to very high preference for SLOW-DEEP conditions                                              | ↓ -1.5              |                         |
|                                | Response of species w ith high to very high preference for SLOW-SHALLOW conditions                                          | ↓ -1.5              |                         |
| COVER METRICS                  | Response of species with a very high to high preference for overhanging vegetation                                          | ↓ -1.5              | 100                     |
|                                | Response of species with a very high to high preference for undercut banks and root wads                                    | ↑ 0                 |                         |
|                                | Response of species with a high to very high preference for a particular substrate type                                     | ↑ 0                 |                         |
|                                | Response of species with a high to very high preference for instream vegetation                                             | → -1                |                         |
|                                | Response of species with a very high to high preference for the water column                                                | ↑ 0                 |                         |
| FLOW DEPENDANCE METRICS        | Response of species intolerant of no-flow conditions                                                                        | ↑ 0                 | 64                      |
|                                | Response of species moderately intolerant of no-flow conditions                                                             | ↑ 0                 |                         |
|                                | Response of species moderately tolerant of no-flow conditions                                                               | ↓ -1.5              |                         |
|                                | Response of species tolerant of no-flow conditions                                                                          | ↓ -1.5              |                         |
| PHYSICO-CHEMICAL METRICS       | Response of species intolerant of modified physico-chemical conditions                                                      | ↑ 0                 | 64                      |
|                                | Response of species moderately intolerant of modified physico-chemical conditions                                           | ↓ -4                |                         |
|                                | Response of species moderately tolerant of modified physico-chemical conditions                                             | → -2.5              |                         |
|                                | 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                 | 56                      |
|                                | Response in terms of distribution/abundance of spp w ith requirement for movement betw een reaches or fish habitat segments | ↓ 2                 |                         |
|                                | Response in terms of distribution/abundance of spp with requirement for movement w ithin reach or fish habitat segment      | → 1                 |                         |
| INTRODUCED SPECIES METRICS     | The impact/potential impact of introduced competing/predaceous spp?                                                         | ↓ 3                 | 38                      |
|                                | How widespread (frequency of occurrence) are introduced competing/predaceous spp?                                           | ↓ 4                 |                         |
|                                | The impact/potential impact of introduced habitat modifying spp?                                                            | ↑ 1.5               |                         |
|                                | How widespread (frequency of occurrence) are habitat modifying spp?                                                         | ↑ 0.5               |                         |
| FRAI SCORE (%)                 |                                                                                                                             | 66.3                |                         |
| FRAI CATEGORY                  |                                                                                                                             | C                   |                         |
| FRAI CATEGORY DESCRIPTION      |                                                                                                                             | Moderately modified |                         |

\*GUIDELINES FOR RATING/CHANGE (0-->5)

-5=Extreme loss from reference (absent); -4=Serious loss from reference; -3=Large loss from reference; -2=Moderate loss from reference, -1= Small loss from reference; 0=No change from reference; 1= Small increase from reference; 2=Moderate increase from reference; 3=Large increase from reference; 4=Serious increase from reference; 5=Extreme increase from reference (completely dominant).

## 4 Identification of sensitive areas.

The entire Nyl River and its adjacent floodplain is considered of HIGH sensitivity in terms of aquatic ecosystems. This includes the buffer zones as delineated in the Wetland Assessment Specialist Report.

## 5 Potential Impacts to Aquatic Ecosystems

The impact assessment for aquatic ecosystems considers:

1. The physical disturbances which act as the drivers of change (e.g. pollution, erosion, changes in hydrology, etc.)
2. The response of the biota to these stressors (i.e., how does the biota react to the physical disturbance?).

**As such, the sensitivity of the receiving ecosystems is considered, not just the physical disturbances. Impact ratings will therefore depend on the response of the biota (with sensitive biota generally having a more pronounced response – through, for example, mortality, reduced health or migration away from the affected area), and may not coincide with ratings given in other specialist reports.**

### 5.1 DESCRIPTION OF IMPACTS

#### ***5.1.1 Northern pit (potential loss of water from the Nyl River)***

The North Pit will extend into the floodplain of the Nyl River, falling within the 100-, 50- and 10-year flood lines. A flood barrier (or berm) will be constructed to protect the mine from a 100-year flood event. The risk of water being intercepted by the pit (and thus lost from the river) will therefore depend on how effective this berm is in terms of impermeability and structural integrity in the long term. Should water be lost from the river, it will cause reduced flows and a decline in water quality in the river (where contaminated water discharges back into the river) and, therefore, a decline in the ecological integrity and presence of sensitive species. This risk will continue post closure as the structure will be permanent. The need for maintenance and repairs to the structure would therefore need to be continued post closure.

The position of this berm in relation to the Nyl floodplain wetland is described in the wetland specialist report. The position of the berm, north pit and waste rock PCD in relation to the 1:10, 1:50 and 1:100-year flood lines is shown in Figure 6. The berm is situated along the western wall of the north pit and extends approximately 50 metres beyond the 1:100 meter floodline on either side of the pit. The berm and associated service road will extend into wetland area and within approximately 12 metres of the Nyl channel.

While this area is already disturbed by a farm dam and a road, the proximity of the pit to the Nyl River channel, together with the high sensitivity of the aquatic ecosystems in the Nyl floodplain means that the margin for error is small, and the risks are greater, particularly when considering the good water quality and relatively undisturbed conditions currently encountered on site. The accuracy and confidence with which impacts are assessed becomes more important in order to avoid unforeseen impacts.

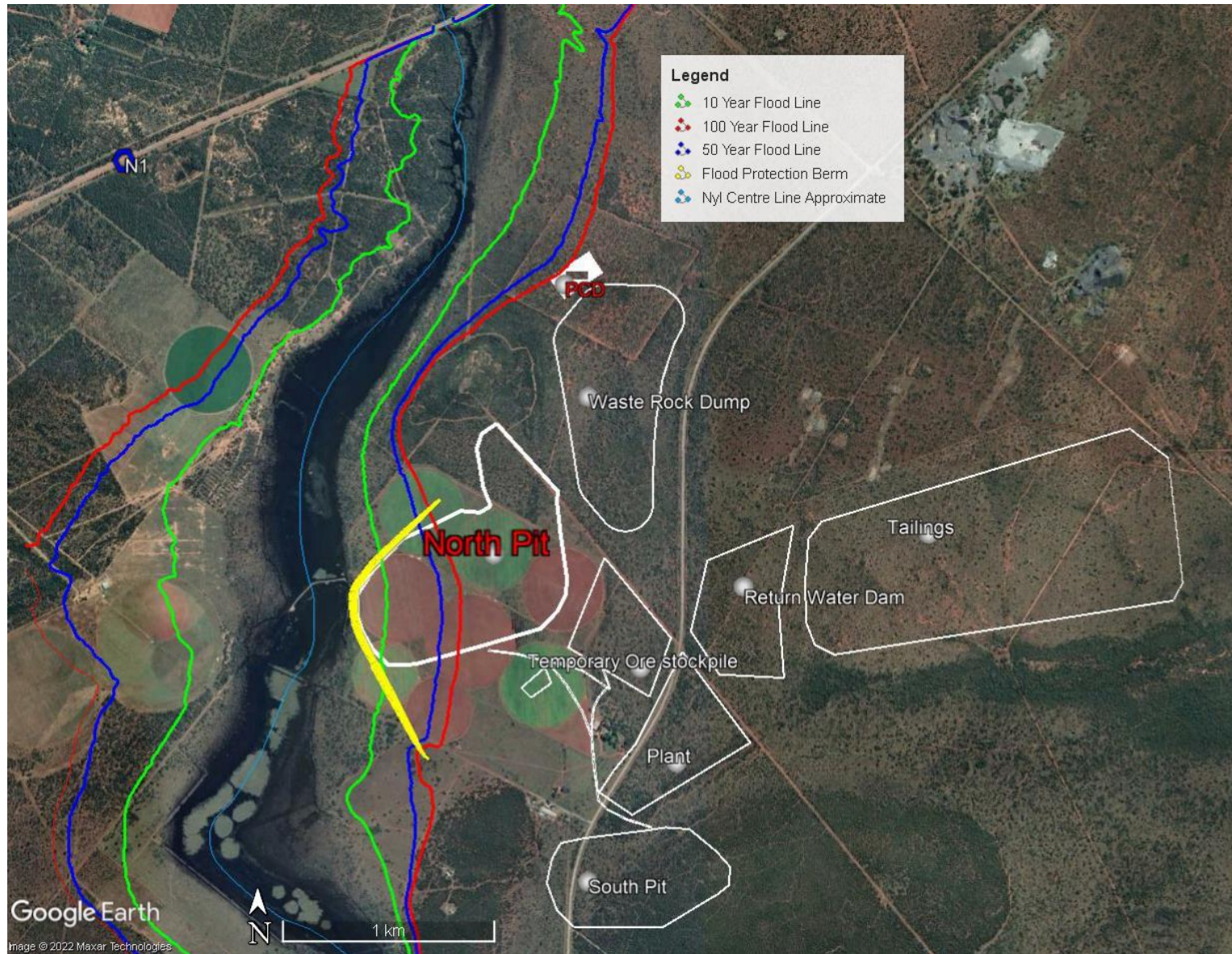
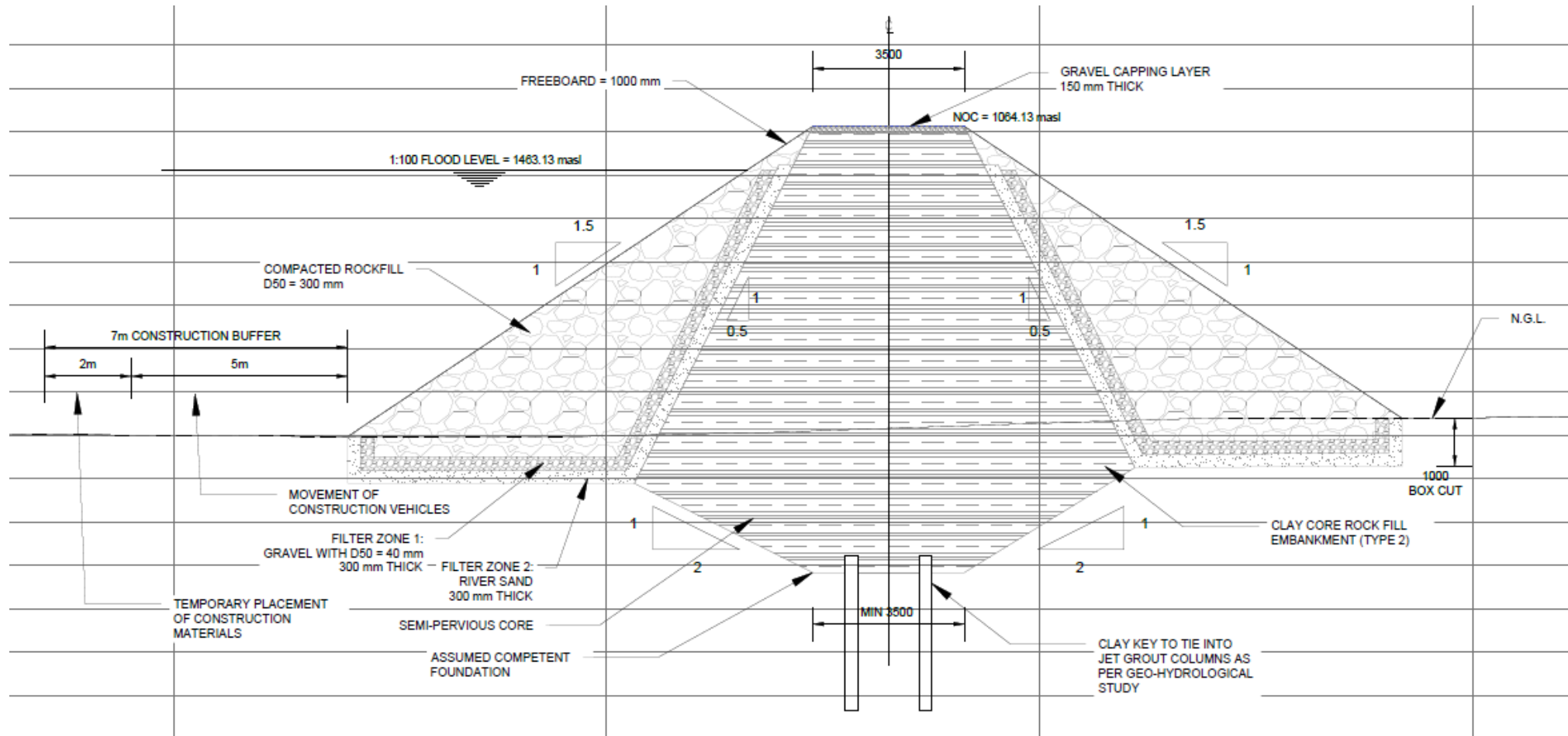


Figure 6 location of the north pit, protection berm and waste rock PCD relative to 10, 50 and 100-year flood lines.



## SECTION A-A TYPE 2 FLOOD DIVERSION BERM

SCALE 1:100

“

Figure 7. Cross-sectional diagram provided of the flood protection berm (Eco Elementum 2021)

A diagram showing the cross section of the berm (Eco Elementum 2021) was provided (Figure 7). The berm will have a “semi-porous clay core” (which will extend approximately 7 metres above ground and approximately 2.5 metres below the surface of the ground) surrounded by compacted rockfill slopes with a gradient of 1:1,5. The base of the berm will therefore be approximately 10 metres wide (based on a 1: 1,5 gradient). The slopes will be vegetated. The berms will be approximately 7 metres in height with a freeboard of 1m above the 1:100 year flood level. There will be a 5m-wide service road with a 2m-wide verge (7 metres in total) for vehicles and construction along the wetland-side of the berm.

Based on the above information, it seems likely that impacts due to mining within the major flood lines can be mitigated.

However, this report assesses impacts to aquatic ecosystems (not water quality *per se*). Considering that the Nyl River is relatively unimpacted with a high biodiversity and good water quality, even small disturbances can translate into significant impacts for sensitive species. As such, it would be important to ensure that impacts are precisely predicted.

Uncertainties are discussed below:

- How will the flood lines be altered upstream of the study area (where will water be displaced to)? According to AED (2022) *“If a barrier is constructed on one side of a river, the flood line on the opposite side is effectively pushed up, elevating the flood line on that side of the river.”* However, in the same AED report, it is stated that *“This flood barrier will narrow the 50- and 100-year floodplain of the Nyl River, but due to the backwater of the N1 road bridge, the flood barrier will not alter the 50- or 100- year flood line on the opposite side of the Nyl River.”* It seems likely therefore that, provided the culverts, structure and route of the N1 freeway remain unchanged, the flood lines will be minimally altered within the study area.
- However, should water be displaced beyond the edge of the clay layer of the floodplain (within the study area or upstream of it), there may be some loss to groundwater during flood events. This is only likely to occur during bigger flood events.
- The impact of climate change on flood levels in say 50, 100 or 200 years from now is not known.
- Construction activities and possible changes to the culverts, length or position of the N1 post-closure cannot be ruled out. The N1 currently causes flood water to be backed up, If the culverts become obstructed by debris, water levels will rise upstream of the obstruction.
- The long-term stability and structural integrity of the flood protection berm (50, 100 or 200 years from now) cannot be predicted with 100% certainty. As flooding of the Nyl River is usually seen as a gradual rise in water levels rather than an increase in flow velocity, it seems that erosion of the side slopes will be minor. However, ongoing inspections and maintenance of the berm will be required to:
  - gauge its effectiveness relative to flood levels
  - detect erosion nick points and repair them
  - monitor impacts of climate change and the effectiveness of the berm height and length in relation to changes in rainfall frequency and intensity.

The structural integrity of the berm will also need to be ensured well beyond closure, taking not consideration climate change.

- The effectiveness and impermeability of the flood berm has not been tested in practice. While the design may be sound, the clay core will be constructed from clay removed from overburden. The consistency and impermeability of this clay is assumed. However, as water levels are unlikely to remain above the 1:10 year levels for extended periods, the volume of water lost from the river is expected to be relatively small.

Of the above uncertainties, the effects of climate change and structural damage to the berm are most likely to impact upon aquatic ecosystems. These impacts are most likely to occur many years post-closure.

### 5.1.2 Mine dewatering (potential loss of water from the Nyl River).

Dewatering of the Northern pit to allow for mining during the operational phase, is likely to cause a drawdown cone of depression - a lowering of the groundwater table in the vicinity of the dewatering. This drawdown cone of depression will extend below the Nyl River.

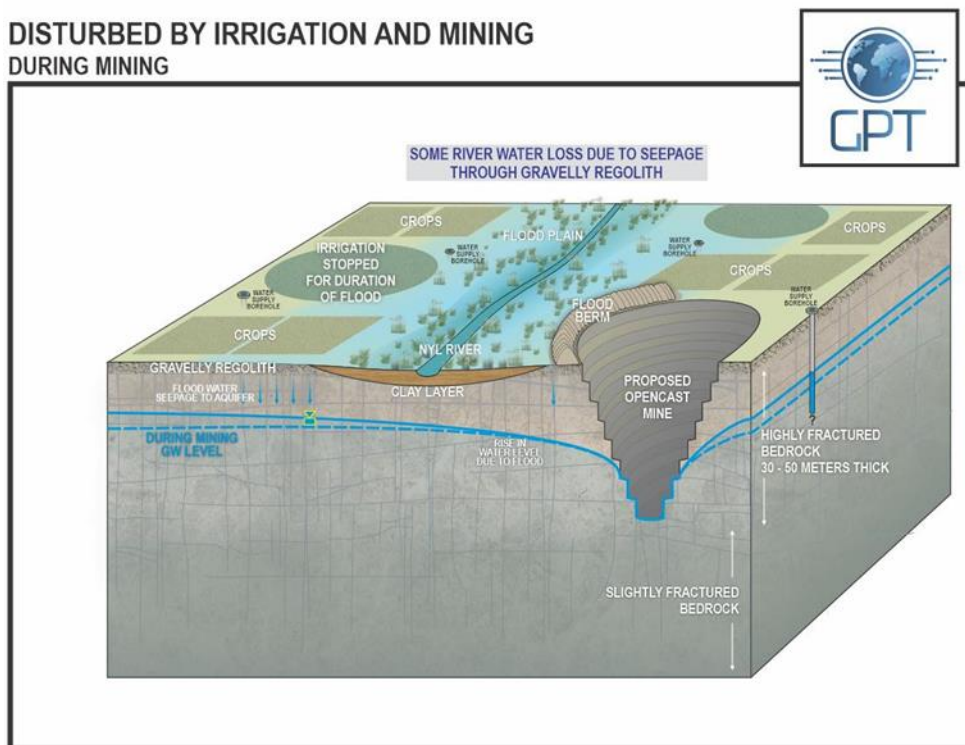


**Figure 8. Schematic to illustrate groundwater drawdown due to irrigation and mining (during flood conditions) (Sourced from GPT 2022).**

In sandy alluvial soils, this lowering of the water table usually leads to a loss of surface water to groundwater, causing a loss of habitats for aquatic biota in overlying wetlands and watercourses.

However, the Nyl River is unusual in this regard because it has a clay layer beneath the alluvial soils. This clay layer is relatively impermeable and therefore limits linkages between the surface water and groundwater. Water from rainfall and runoff therefore tends to pool at the surface, forming extensive wetlands, with surface water spread across the floodplain after heavy rainfall. This has been confirmed by the groundwater surveys and water quality results which show very different salt concentrations in groundwater and surface water (GPT2023). According to GPT, the unsaturated zone underneath the river

is filled from below, and not from the river. The deduction is that the clay layer in this area is indeed impermeable and that infiltration can only occur at the edges of the clay layer during large flood events.

As such, it is anticipated that water will not be lost to groundwater provided that both the impermeable berm and the clay layer remain intact and flood levels do not “over-top” the edge of the clay layer.

By the same token, ground water will not emerge at the surface during wet years post-closure. Groundwater is therefore not likely to significantly impact on surface water quality. In addition, existing irrigation activities have already lowered the water table by “5 to 10 metres” (GPT 2023). The groundwater report states, “Drawdown of groundwater below the Nyl River is in the same order as those observed currently due to irrigation extraction” (GPT 2023). The Groundwater assessment (GPT 2023) monitored groundwater levels in close proximity to the floodplain between about 2013 and 2019 and did not observe groundwater reaching the surface during this period, remaining 5-12 mbgl (GPT 2022).

For the hydropedological survey (WCS 2022), transects of the soil profile across the Nyl floodplain were analysed. Their conclusions are extracted below:

“The floodplain section within the study area is therefore understood to be mainly driven by surface runoff generated upstream of the study area. The hillslope adjacent to the floodplain (study area) is to contribute water to the floodplain in the form of surface runoff during high intensity rainfall events. Such surface runoff occurs predominantly as sheet flow, with no drainage lines or watercourses identified within the study area, other than the floodplain.”

The transmission losses are expected to be relatively high when the flooding extent exceeds the clay rich floodplain soils where permeability is higher. It is important to note that during large floods where flooding takes place beyond the clay rich soils and into the adjacent sandy terrestrial soils the loss through transmission losses is relatively small compared to the large volume floodwater mostly originating from the upstream catchment. It is possible that the local transmission losses will reduce the flooding extent and duration slightly under this scenario.”

Therefore, during wet years, there may be surface-groundwater linkages towards the edges of the floodplain, where the clay layer thins. However, the loss of water from the surface will be limited and of limited duration, and the volume of groundwater emerging at the surface is likely to be minimal.

A flood in the Nyl River in February 2014 was documented by GPT (2023). It resulted in a sudden rise in the groundwater levels, synchronised with the flood, but at different rates in different locations. Initially it was thought to be a response to clay thickness. However, it was since shown that “the unsaturated zone underneath the river is filled from below, and not from the river. The deduction is that the clay layer in this area is indeed impermeable and that the flood needed to overtop the clay before infiltrating.”

Therefore, the risks of drawdown affecting flooding and surface flows seem to be low. The greatest risk is associated with potential disturbance of the clay layer, particularly along the edges of the floodplain where the layer is already thin (e.g. excavation for dam, berm or road construction).

The clay layer report compiled by Prof Andries Claassens for E-sciences (2013) states, *“it was found that on the eastern side [of Mr De Klerk’s Dam] near the edge of the river, a substantial amount of topsoil was removed and used to construct the wall. Especially at the edges where the clay layer become quite thin, most of it was probably removed and water may now move quite rapidly through the exposed underlying material which is much more porous than clays associated with wetland.”*

### **5.1.3 Mine Drainage and Seepage from the Tailings and Waste Rock Dump.**

Seepage from the tailings dam, waste rock dump and other stockpiles is likely to be high in salts such as sulphates, nitrates and calcium and certain metals, such as aluminium. These may impact upon groundwater quality. Should this contaminated groundwater emerge within watercourses, it could cause a deterioration in water quality and a decline in ecological integrity. Contaminated water could also reach watercourses directly as surface water runoff, causing increased salinity and increased pH. In the Nyl River, this could, in turn, impact upon sensitive species (such as Johnston's Topminnow).

However, as discussed in section 5.1.2, the likelihood of ground water emerging at the surface is limited by the impermeability of the clay layer underlying the floodplain. It is more likely therefore, that contaminated water will reach the Nyl River via surface flows, which may include runoff containing contaminants from leaks, spills, dust and seepage from the Waste Rock Dump, its PCD and the tailings facility and its associated PCD.

During mining Nitrogen containing minerals in the bedrock comes into contact with water and the atmosphere resulting in the formation of nitrate ( $\text{NO}_3$ ) (Bosman 2010). This is exacerbated by ammonia-containing explosives during mining. As Patel (2016) comments, "Nitrates are not usually found on the list of concerns associated with the mining. Resulting from this oversight, the effects on the world population resulting from mining related nitrification of water sources are neglected."

An increase in nitrate concentrations promotes the growth of algae and cause fluctuations in oxygen concentrations (low at night and elevated during the day). Supersaturated conditions during the day can cause gas bubble disease in fish and promote the growth of blue-green algae, which may be harmful to livestock and humans). Of greater concern, is that inorganic nitrogen (nitrites and nitrates), when reduced, can form ammonia. Ammonia can cause toxicity to sensitive aquatic species. High pH values and temperatures promote this reduction. The pH within the Nyl River is likely to increase (mainly in response to elevated calcium). Therefore, the risk of occasional ammonia toxicity to sensitive species cannot be ignored.

According to the groundwater report (GPT 2023), mine drainage is likely to be slightly alkaline (causing groundwater to remain slightly elevated at an average pH of 8) and saline, but the increase in sulphates is expected to fall within guideline limitless. In addition, the separation of the surface water from the groundwater will ensure that seepage will be confined to the groundwater and will therefore not impact directly on water quality in the Nyl River.

*"From the ABA undertaken by Escience Associates (Pty) Ltd, it was found that both the waste rock and the tailings samples have virtually no potential for AMD formation, but instead have the tendency to neutralise AMD generation. The Proposed Volspruit mine residues themselves are, therefore, expected to have no risk of acid mine drainage formation due to the results obtained through the representative sampling and analyses undertaken."* Geo Pollution technologies (2022)

According to the groundwater report, groundwater flow direction is determined by groundwater abstraction rather than topographical features (GPT 2022). The most likely scenario is that the groundwater will be used for crop irrigation, thus eventually reaching the Nyl River as runoff or agricultural return flows.

The quality of the water eventually reaching the Nyl River cannot be determined currently, and ongoing monitoring would be essential. It is likely that there will be some impact to water quality in the Nyl River,

albeit indirectly and/or at lower concentrations. Agricultural return flows may contain fertilisers which are likely to exacerbate impacts due to nitrates. According to GPT (2023) the current quality of groundwater is poor and already has high nitrate concentrations (as well as magnesium, calcium and chloride) exceeding guideline limits in certain boreholes. Boreholes with high nitrate concentrations also had higher ammonium concentrations (although these were within guideline limits). As pH of the groundwater is likely to increase, the interaction between nitrates and pH are also likely to increase. Should this water find its way to the Nyl River, the combined effect of warmer temperatures and pH may result in periodic problems due to ammonia, exacerbated by a deterioration in habitats due to algal proliferation.

It should be remembered that disturbance of the clay layer (e.g. excavations) cannot be completely ruled out and may result in surface – groundwater linkages post-closure. However, the impacts due to sulphates in ground water are considered minor and within guideline limits (GPT 2022). Impacts due to nitrates may be more complex due to interactions with pH and temperature.

In summary, impacts to water quality in the Nyl River are mainly likely to be due to contaminated surface runoff (spills, leaks, dust etc.) as well as indirectly via agricultural return flows, rather than mine drainage, provided the clay later remains intact in the long term. The increase in pH, together with high temperatures, is in fact likely to exacerbate algal proliferation and ammonia production in the Nyl River, which could cause toxicity to sensitive aquatic species and compromise habitat availability and diversity. Careful management and monitoring of surface water would be required to manage this impact, as well as preservation of the clay layer in the floodplain.

#### **5.1.4 Migration of salts and metals from the pit post-closure**

After mining, groundwater levels will rebound, and the open-cast pits tend to fill with water. The north pit at Volspruit will therefore be backfilled. The South pit will be left open and may therefore fill with water. Although there will be a pollution plume from the North pit, waste rock dump and tailings facility concentrations of sulphate is predicted to be low and within DWA Class I groundwater quality standards. In addition, there will be no contamination of surface water due to the impermeable clay layer (GPT 2022).

*“Since the sulphides in the ore are of low concentration and consist mostly of chalcopyrite and pentlandite, which are not reactive enough for long term acid generation, is very unlikely that the pit backfill material will produce acid rock drainage. This interpretation is supported by acid base accounting and leach testing of various bedrock samples at both the South and North Pits.*

*“Geochemical modelling indicates that sulphate concentration emanating from the backfilled pit could reach 60mg/L in the initial stages and then decline slowly with time. Elevated amounts of Ca (up to 200 mg/L) are also liberated into the groundwater environment, which may aid in the precipitation of gypsum. Groundwater pH is predicted to remain slightly elevated to an approximate value of 8.”*

Nitrates may become problematic under warm and alkaline conditions (when nitrates are reduced to toxic ammonia) (as discussed in 5.1.3). The pH of groundwater is expected to remain elevated at approximately 8. In addition, Chromium, which is associated with PGM (Platinum Group Minerals) can be toxic to aquatic biota as hexavalent Chromium. However, this is unlikely to be a risk under alkaline conditions.

According to the groundwater report (Geo Pollution Technologies 2023), the clay layer beneath the alluvial soils of the Nyl River, will prevent the salts and metals in groundwater from emerging at the surface. The risk of surface water contamination via groundwater sources is therefore considered low, provided the clay

layer remains intact in the long term and crop irrigation continues to keep the water table below ground level.

A more likely scenario is that the groundwater will be used for crop irrigation, thus eventually reaching the Nyl River as runoff or agricultural return flows. The quality of the water eventually reaching the Nyl River cannot be determined, and ongoing monitoring would be essential. It is likely that there will be some impact to water quality in the Nyl River (particularly in terms of pH and salinity), albeit indirectly and/or at lower concentrations.

It should be noted that groundwater quality is already considered poor, with exceedances in nitrate, magnesium, calcium and chloride concentrations recorded in certain boreholes (GPT 2023). Results given in the surface water report (AED 2022), showed low nitrate concentrations in the Nyl River during a winter survey in July 2011. Ammonia concentrations were not recorded. With the likely increase in pH and calcium due to mining, the risk of ammonia toxicity cannot be ruled out completely and may pose a slight and periodic risk under warm and alkaline conditions. Increased salt concentrations in agricultural return flows will additionally contribute to the proliferation of algae and associated oxygen fluctuations and decline in habitat suitability.

#### **5.1.5 Interception of surface runoff**

Some surface water runoff from upslope areas will be intercepted by the pits and mining infrastructure, resulting in less water reaching the floodplain. This may result in a drop in water levels in the Nyl River (especially during drier months) and longer no-flow periods, ultimately having a negative effect on aquatic biota, particularly sensitive species. A drop in water levels will affect the availability of habitats for aquatic species and will also exacerbate water quality impacts due to conditions being more concentrated (i.e. less dilution). This amount of surface water intercepted is likely to be minimal (based on the surface water report by AEG 2022).

*“The surface run-off in the vicinity of the proposed mine is insignificant in relation to the flow in the Nyl River and its associated wetland, possibly also its associated alluvial aquifer. Apart from very localised changes, it is expected that the mine will not have much effect on the hydrology of the Nyl River or the associated wetland.”*

#### **5.1.6 Decant**

Eventually, the pit may fill with water and may start decanting. According to the groundwater report (GPT 2023), “direct surface decanting of the pits is unlikely” and “in addition, the pit water is predicted to be of acceptable quality”. Should it occur, decant could potentially have a significant negative effect on water quality in the receiving Nyl River, with negative consequences for sensitive species, such as Jonston's Topminnow.

It would therefore be essential to monitor ground water levels and implement management actions to prevent decant. The flood berm will also need to remain intact and structurally stable in the long term to intercept potential decant post closure, unless it can be shown that the water is of acceptable quality in terms of the RQO of the Nyl River.

#### **5.1.7 Overall Decline in water quality**

The water quality in the Nyl River is currently of excellent quality. There is likely to be some decline in water quality associated with mining activities, including seepage, drainage, spills or leaks containing fuels, oils,

greases, sewage or mine water. Spills or leaks from PCDs is an additional risk. These impacts can be mitigated to a large extent with effective management action, thus reducing the significance of the impact.

The diversity of fish in the receiving Nyl River could decline due to a decline in water quality. In particular, sensitive species such as Johnston's Topminnow, could be lost from this reach of the river.

#### **5.1.8 Decrease in biodiversity and ecological integrity**

Even with mitigation, there is likely to be some decline in ecological integrity due to elevated nitrates, salts and pH, together with a proliferation of algae. This will have a negative impact on certain sensitive species, most notably Johnston's Topminnow which is highly sensitive to these changes.

Alien fish species, being more tolerant, will have the competitive advantage over indigenous species and therefore become more dominant, while indigenous species become progressively less abundant, ultimately resulting in a depauperate fish community and a low ecological integrity.

However, should there be damage to either the flood barrier, or the clay layer, there could be a loss of surface water to groundwater, which could alter the hydrology (longer dry periods) and habitats (shallower pools). However, the likelihood of this occurring is low (and can be reduced with effective mitigation) (GPT 2023).

A full description and assessment of potential impacts during each phase of mining is included below.

## **5.2 IMPACT ASSESSMENT**

### **5.2.1 Impact Assessment Methodology**

Impacts were assessed in terms of the following criteria:

The **magnitude / severity**, quantified on a scale from 0-10, where:

- 0 is small and will have no effect on the environment,
- 2 is minor and will not result in an impact on processes,
- 4 is low and will cause a slight impact on processes,
- 6 is moderate and will result in processes continuing but in a modified way,
- 8 is high (processes are altered to the extent that they temporarily cease), and
- 10 is very high and results in complete destruction of patterns and permanent cessation of processes.

The **scale / extent**, wherein it is indicated whether the impact will be site only (limited to the immediate area or site of development), local, regional, national or international and a value between 1 and 5 was assigned as appropriate (with 1 being localized and 5 being extensive):

The **duration**, wherein it was indicated whether:

- the lifetime of the impact will be immediate – assigned a score of 1;
- of a very short duration (0–5 years) – assigned a score of 2;
- medium-term (5–15 years) – assigned a score of 3;

- long term (> 15 years), ceases with operational life - assigned a score of 4; or
- permanent - assigned a score of 5;

The **probability of occurrence**, which describes the likelihood of the impact actually occurring. Probability was estimated on a scale of 1–5, where:

- 0 is none,
- 1 is very improbable (probably will not happen),
- 2 is improbable (some possibility, but low likelihood),
- 3 is probable (distinct possibility),
- 4 is highly probable (most likely) and
- is definite (impact will occur regardless of any prevention measures) or don't know.

The significance was calculated by combining the criteria in the following formula:  $S=(E+D+M)*P$

S = Significance weighting E = Extent

D = Duration M = Magnitude P = Probability

The **significance weightings** for each potential impact are as follows:

- < 30 points: Low (i.e. where this impact would not have a direct influence on the decision to develop in the area),
- 30-60 points: Medium (i.e. where the impact could influence the decision to develop in the area unless it is effectively mitigated),
- 60 points: High (i.e. where the impact must have an influence on the decision process to develop in the area).

## **5.2.2 CONSTRUCTION PHASE**

### **5.2.2.1 Construction – Increased turbidity and sedimentation**

Clearing of vegetation and soil disturbance could lead to increased erosion (especially during wet season) and increased dust that may enter the receiving water bodies. This would lead to increased turbidity (decreased water quality) which may have a negative impact on aquatic fauna, especially visual predators and filter feeders. The impact would vary in intensity between different species and different life stages and processes (spawning, feeding, etc.). When the suspended solids (soil/dust particles) settle out on the substrates in the aquatic ecosystems, it leads to shallower pool depths and colonisation of the sediments by monospecific stands of reeds which, in turn, decrease the availability of open pools and water column biotopes. Benthic substrates are transformed which may lead to deterioration in biotic integrity and loss of species.

#### *Mitigation*

- No unnecessary development or disturbance should occur within the 1:100 year flood line of any drainage line or any wetland, together with its buffer. As far as possible, these areas should be cordoned off and considered no-go zones.
- The flood protection berm should be constructed prior to the commencement of construction and during the dry season (May-September) to limit the impact to the floodplain.
- Limit vegetation clearing to the actual footprint of the proposed development.
- No excavation or construction in wetland areas. Clay to be sourced from the development

footprint.

- Fence off wetland areas prior to construction activities commencing to prevent access into the wetland areas by heavy machinery and vehicles.
- Undertake construction activities in winter to minimise sediment transport due to runoff after rainfall events.
- Re-vegetate all bare areas not directly within the footprint of the developments as soon as possible. The extent of the disturbance should be limited to a minimum.
- Shallow berms should be constructed between construction areas and the delineated wetland to prevent sediment rich runoff from the construction site entering the wetlands.
- Anti-erosion mitigation to diffuse and attenuate flows should be implemented where storm water is diverted around construction activities.
- Implement a water quality monitoring programme. Where target endpoints are not met, recommendations should translate directly into follow-up action that is recorded and auditable.

This impact is likely to be of **High** significance but can be effectively mitigated to a Medium level of significance if mitigation measures are effectively applied.

#### **5.2.2.2 Construction – Altered hydrology**

Construction of pits, dams, trenches, berms and infrastructure, will intercept surface runoff, preventing it from reaching the Nyl River. Surface flows in the Nyl River can be impacted where surface runoff has been intercepted. This can change both the timing and duration of surface flows, as well as overall volumes of water within the channel. Alien vegetation encroachment due to disturbances can also have a significant impact on water levels in streams and rivers.

Reduced flows will have an impact on the habitat availability for aquatic fauna. Because flows within the Nyl River are extremely low during dry periods and fish rely heavily on the availability of pool habitats at these times, a further reduction in volumes could have severe impacts on fish populations within and downstream of this reach.

##### *Mitigation:*

- Water must be diverted around construction areas and allowed to flow into the floodplain in an attenuated fashion. Effective means must be found to prevent ingress of surface water runoff from upslope areas into the pits during construction.
- Clean water should be allowed to enter natural water bodies, with appropriate storm water attenuation.
- Pumping of surface water from the Nyl River (for mining and irrigation) should be restricted reduce impacts on flow volumes. Abstraction should comply with Water Use Licence conditions and the ecological water requirements of the Nyl River System.
- Implement an alien vegetation control programme and continuously manage alien vegetation encroachment.
- Implement water quality and biomonitoring programmes to detect any deterioration in aquatic integrity.
- Detailed flow monitoring (water depth) must be implemented for the Nyl River on commencement of the construction phase and maintained throughout the Life of Mine.

The significance of this impact is likely to be **Medium** and could be reduced with mitigation.

### 5.2.2.3 Construction – Spread of alien fish species

Alien fish species are often spread through the introduction of people to an area. The introduction of alien species is most often for angling/recreational purposes but can also be driven by subsistence needs for protein. Alien fish species compete with indigenous fish species for habitat and food and can have a devastating impact on natural aquatic biota through predation and habitat destruction. Hardy exotic species (such as mosquito fish) are likely to increase in abundance, while more sensitive indigenous species will decrease in abundance and prevalence.

#### *Mitigation*

- Prohibit the stocking of any alien fish species into dams or rivers within the mining area. If alien fish species are present or observed within the study area in future, they should be removed.
- Prevent deterioration in habitats by managing stormwater runoff, erosion at outlets and transport of eroded sediments into the floodplain.

This impact is likely to be of **Medium significance** but can be effectively mitigated to a **Low** level of significance if mitigation measures are effectively applied.

### 5.2.2.4 Construction – Increased pressure on fish stock

Increased number of people in an area often results in increased fishing pressure on the aquatic ecosystems, as it is often a free and readily available source of food. Except for the Sharptooth catfish, indigenous fish species observed in the study area have low importance as angling species. Smaller species are however sometimes netted for subsistence. The abundance of catfish is furthermore as a result of existing alteration (creation of dams) related to agriculture in the area.

#### *Mitigation*

- Prohibit the illegal harvesting of fish with nets, fish traps etc (especially from rivers). Control angling (if allowed). Remove unnatural habitats (created by unauthorised dams/roads) from the Nyl River wetland ecosystem.

This impact is likely to be of **Medium significance** but can be effectively mitigated to a **Low** level of significance if mitigation measures are effectively applied.

### 5.2.2.5 Construction – Water quality deterioration

Water quality deterioration resulting from spills/leaks during general construction activities (oil, diesel, cement, etc). Storm water flushing construction areas, as well as dust, can carry additional pollutants into water bodies. Water quality deterioration will especially affect fish species intolerant to water quality alteration (especially Johnston's topminnow) but can have an impact on all aquatic fauna (e.g., fuel spills).

#### *Mitigation*

- All mitigation for erosion prevention and control should be applied.
- Ensure separation of clean and dirty water and allow clean water to enter natural waterbodies.
- Apply best practice as per Best Practice Guidelines for stormwater (DWAf 2006-2008)

- To prevent spillages and leaks:
  - Vehicles should be well maintained
  - Diesel and oil/grease should be stored in bunded areas that will allow any spillages to be easily and quickly isolated and prevent contamination of any soils or water.
  - Spills should be cleaned up with approved absorbent material such as “Drizit” or “Spillsorb”. These should be kept in sufficient quantities on site to deal with small spills. Absorbent material and contaminated soil should be disposed of at a registered hazardous waste site.
  - An emergency preparedness plan should be compiled and all construction staff aware of procedures in event of a spill.
  - Hazardous waste should be stored in bunded/impermeable areas and disposed of appropriately at a registered landfill site. Potential spills or seepage of hazardous waste must be anticipated and prevented.
- Should cement be used on site, the following guidelines apply:
  - Carefully control all on-site Operations that involve the use of cement and concrete (this applies to areas other than the batching plant).
  - Limit cement and concrete mixing to single sites where possible.
  - Use plastic trays or liners when mixing cement and concrete: Do not mix cement and concrete directly on the ground.
  - Dispose of all visible remains of excess cement and concrete after the completion of tasks. Dispose of in the approved manner (solid waste concrete may be treated as inert construction rubble, but wet cement and liquid slurry, as well as cement powder must be treated as hazardous waste).
- An aquatic biomonitoring and water quality programme should be implemented. Where target endpoints are not met, recommendations should translate directly into follow-up action that is recorded and auditable. Johnston's topminnow may be important indicator species in terms of water quality deterioration.

This impact is likely to be of **Medium** significance but can be effectively mitigated to a Low level of significance if mitigation is effectively applied.

### **5.2.3 OPERATIONAL PHASE**

#### **5.2.3.1 Operational – Loss of water from the Nyl River to the North Pit during floods**

The northern pit is located within the 10-, 50- and 100-year flood lines. An impermeable barrier will therefore be constructed around the pit to prevent water from entering during flood events.

This impact is described and discussed fully in Section 5.1.1. The berm will be constructed with a semi-permeable clay core surrounded by rockfill slopes. It will be approximately 7 metres in height.

Based on the groundwater report (GPT 2023), surface water report (AED 2022) and engineering drawings provided (Eco Elementum), the flood protection berm should be able to prevent (or at least minimise) water entering the pit. As flows in the Nyl River are slow, the risk of large-scale structural failure or scouring is also unlikely. Should this occur, however, flood levels will be reduced, with negative consequences for fish spawning and migration. Considering that the Nyl River is relatively

unimpacted with a high biodiversity and good water quality, even small disturbances can translate into significant impacts for sensitive species.

However, the impermeability and structural integrity of the flood protection berm would need to be demonstrated. The berm will need to remain permanently in place post-closure and will need to be regularly monitored and rigorously maintained. The berm has been designed for the 1:100 year flood event and the effects of climate change are uncertain in the long term. Long term monitoring of flood levels and flood lines in the Nyl River will be required. This will include monitoring culverts beneath the N1 to maintain the status quo. While many of these mitigation and management measures are possible during the operational phase, the long-term effectiveness of the berm cannot be predicted with 100% accuracy.

#### *Mitigation*

- The flood protection berm must be inspected bi-annually during the dry season and wet season to detect and repair possible damage/erosion and ensure structural stability.
- Construction must take place in the dry season and must be overseen by a qualified engineer.
- Erosion nick points (e.g. at the base of the berm or along service roads) must be immediately stabilised to prevent subsequent damage to the berm.
- The berm must be well protected by rockfill, sloped and revegetated.
- During the first major flood event (>1:5 year), the berm must be assessed by an engineer to ensure impermeability and structural integrity.
- Water levels in the Nyl River and flood lines must be monitored from the inception of the development and changes reported to the DWS.
- Mining should progress sequentially, starting in the east and progressing towards the west, so that potential problems can be detected and addressed timeously.
- A maintenance and monitoring plan should ensure regular inspections to detect possible damage or weakness, which should be repaired timeously.
- An emergency preparedness plan should be compiled for potential breaches during storm events.

The significance of this impact is likely to be **High** but could be reduced to Medium if effective mitigation and monitoring measures are implemented correctly and diligently. It is important that the impermeability of the berm be tested during the first major flood event.

#### **5.2.3.2 Operational – Water quality deterioration: Mine Drainage and seepage from Tailings and Waste Rock Dump**

Water quality deterioration related to seepage from the waste rock dump, tailings facility and stockpiles will cause increased salts (particularly sulphates), metals and changes in pH in the groundwater. Acid Base accounting has identified the neutralisation potential as being high so that acidification is likely to be limited (E-Science Associates 2012), while increases in sulphate concentrations will fall within guideline limits (GPT 2023). This impact is also discussed under Section 5.2.3.

According to Geo Pollution technologies (2023), this mine drainage is likely to be alkaline and saline, although the increase in sulphates is expected to fall within guideline limits. Calcium is also

expected to become elevated and the pH of the leachate is predicted to be slightly alkaline at a value of approximately 8.

However, the separation of the surface water from the groundwater by the clay layer that underlies the Nyl floodplain will ensure that seepage will be confined to the groundwater and will therefore have limited impact on water quality on the Nyl River.

Impacts to the Nyl River will therefore primarily be via surface water runoff (e.g. leaks/spills from PCDs and shallow subsurface seepage from the waste rock dump or tailings).

In addition, it is anticipated that groundwater will be used for crop irrigation. As such, contaminated groundwater will ultimately reach the Nyl River as runoff or agricultural return flows. The quality of the water eventually reaching the Nyl River cannot be accurately determined. However, it is likely that there will be some impact to water quality in the Nyl River, albeit indirectly, at relatively low concentrations and over an extended period of time (increasing cumulatively with ongoing evapotranspiration from irrigated fields).

Of concern, is that the pH in the Nyl River is likely to increase if this high-calcium high-pH runoff were to reach the river. Under warm, alkaline conditions, nitrates become reduced to form ammonia. Ammonia can be highly toxic to aquatic biota, including fish. Nitrates can also cause a proliferation of algae and changes to oxygen fluctuations which can be limiting to fish (low concentrations at night when photosynthesis stops or supersaturated during the day when the algae photosynthesise). The concentrations of nitrates may be exacerbated by fertilisers used on cultivated fields.

Salts, such as calcium, chlorides and sulphates in surface runoff and agricultural return flows (with concentrations increasing with ongoing evapotranspiration from irrigated fields) may also affect salt concentrations in the receiving Nyl River.

While these increased concentrations may not directly impact on aquatic biota (and may well fall within guideline limits), there are likely to be indirect effects via algal proliferation (which will affect habitat availability and oxygen concentrations) and toxicity (under alkaline conditions). The effects of algae on oxygen concentrations and ammonia on toxicity are likely to have the greatest impact on aquatic biota. This will mainly affect fish species intolerant to water quality alteration (especially Johnston's topminnow) but will have an impact on all aquatic fauna.

This impact is likely to result in a gradual deterioration over time and may not be immediately noticeable.

#### *Mitigation*

- pH, nitrate and ammonia concentrations must be included in routine surface water and groundwater monitoring programmes.
- Toxicity testing should be conducted on water sampled from pollution control facilities, boreholes and potential sewage effluents. Toxicity testing should also be performed on water sampled from the Nyl River upstream and downstream of the mine.
- Irrigation should not be permitted where nitrate and ammonia concentrations exceed guideline limits for aquatic ecosystems, or when a toxicity hazard of Class III or higher is recorded for borehole water. Water used for irrigation must comply with Water Use

Licence conditions and the ecological water requirements of the Nyl River.

- Biannual biomonitoring should assess impacts to ecological integrity within the river. This should include an assessment of algal proliferation and oxygen concentrations. Johnston's topminnow may be the most relevant fish to use as indicator of water quality deterioration, although the entire fish assemblage should be monitored to detect changes. Officials from DWS should conduct regular site visits to the mining area.
- The soils in the Nyl River floodplain and adjoining buffer may not be disturbed or excavated to disturb or remove the clay layer.
- Appropriate liners should be used for the tailings dam and WRD, as well as their associated PCDs and RWDs.
- Implement and maintain monitoring programme (biomonitoring, groundwater or surface water monitoring or environmental audits). Should any signs of pollution be detected, immediate actions should be taken to rectify the problems.
- Waste dumps and soil stockpiles should be located well outside of wetland areas and their buffers. Runoff from these areas should be treated as dirty water.
- Ensure adequate precautions are taken to prevent/limit spills or seepage of polluted water (e.g. lining of dams, trenches, separation of clean and dirty water).
- Groundwater levels must be regularly monitored to ensure no linkages with surface water. Piezometer borehole transects should be established across the edge of the floodplain downslope of each proposed opencast pit to monitor shallow groundwater levels.

The significance of this impact is expected to be **High** in the long term as it is likely to increase over time. It will however fluctuate with water levels in the river (due to dilution) and irrigation return flows. With mitigation, the significance of this impact may be reduced to Medium. Ongoing ground and surface water quality monitoring will need to continue well beyond closure.

#### **5.2.3.3 Operational – Dewatering causing decreased/altered flows in the Nyl River**

This impact is discussed in detail in Section 5.1.2. To summarise:

Dewatering of the Northern pit to allow for mining during the operational phase, is likely to cause a drawdown cone of depression - a lowering of the groundwater table in the vicinity of the dewatering. This drawdown cone of depression will extend below the Nyl River. In sandy alluvial soils, this lowering of the water table usually leads to a loss of surface water to groundwater. However, the Nyl River has a clay layer beneath the alluvial soils. This clay layer is impermeable and therefore prevents linkages between the surface water and groundwater (GPT 2023).

Therefore, impacts to aquatic ecosystems is considered to be low. The only loss of water is likely to occur if the flood levels extend beyond the edge of the clay layer in the floodplain. This will only occur during big flood events and will not result in the loss of large volumes of water. This assumes that the clay layer will remain intact and that the existing flood lines are not significantly altered.

#### *Mitigation*

- The soils in the Nyl floodplain and adjacent buffer zones may not be disturbed or excavated in any way.
- No construction within the floodplain.
- The Ecological Water Requirements of the Nyl River should be met, in consultation with the DWS.

- Clean water should be directed around mining activities and infrastructure and released back into the Nyl River in an attenuated manner. This will reduce further loss of surface water.
- Surface water and groundwater levels in and around the Nyl River should be monitored throughout the development and beyond closure.

The significance of this impact has been classified as **Medium** but can be mitigated by preventing disturbance of the clay layer. It would be important to monitor groundwater and surface water levels throughout the operational phase of the mine.

#### **5.2.3.4 Operational – Deterioration in water quality from pollution control facilities.**

Pollution control facilities and pipelines carrying mine water pose a considerable risk of contamination through spills, leaks and subsurface seepage. This applies to mining PCDs/ pipelines/infrastructure and sewage effluent and infrastructure. The worst-case scenario would be structural failure, which would result in a large-scale pollution event in the Nyl River. The waste rock dump PCD is located on the edge of the 1:100 year flood line and poses the greatest risk.

Contaminants are likely to include sulphates, calcium and nitrates. Nitrates can promote the growth of algae and cause fluctuations in oxygen concentrations (low at night and elevated during the day). Supersaturated conditions during the day can cause gas bubble disease in fish and promote the growth of blue-green algae, which may be harmful to livestock and humans). Of greater concern, is that inorganic nitrogen (nitrites and nitrates), when reduced, can form ammonia. Ammonia can cause toxicity to aquatic biota. High pH values and temperatures promote this reduction. The pH within the Nyl River is likely to increase (mainly in response to elevated calcium). Therefore, the risk of ammonia toxicity cannot be ignored.

#### *Mitigation*

- The PCDs for the mine must be appropriately lined and of adequate capacity to cater for a 50-year storm event or more.
- The placement of the waste rock dump PCD should take into consideration possible changes in flood lines due to climate change, as well as the flood protection berm.
- PCDs must be well maintained, not overfilled (allowing for sufficient freeboard) and should be regularly inspected for structural weaknesses and faults.
- An emergency preparedness plan should be prepared to manage large-scale spills of mine water or hazardous substances.
- Toxicity testing should be conducted quarterly in return water dams and PCDs to determine the risk of toxicity to receiving watercourses. A toxicity hazard of three or higher should prompt management intervention.
- Toxicity testing and biomonitoring in the Nyl River floodplain must take place biannually upstream and downstream of the mine. A class III toxicity hazard or higher should trigger management action.
- Apply best practice as per Best Practice Guidelines for PCDs and stormwater (DWAf 2006-2008)

The significance of this impact is expected to be **High** but can be effectively mitigated to **Medium** if all mitigation measures are strictly applied. However, some decline in water quality is likely.

#### 5.2.3.5 Operational – Disturbance from Blasting

Blasting in close proximity to aquatic ecosystems may also have a direct impact on fish assemblages through disturbance.

In addition, nitrates from explosives can cause increased nitrate concentrations in groundwater and surface water (through runoff from storage and transport areas). Nitrates promote the growth of algae and cause fluctuations in oxygen concentrations (low at night and elevated during the day). Supersaturated conditions during the day can cause gas bubble disease in fish and promote the growth of blue-green algae, which may be harmful to livestock and humans). Of greater concern, is that inorganic nitrogen (nitrites and nitrates), when reduced, can form ammonia. Ammonia can cause toxicity to aquatic biota. High pH values and temperatures promote this reduction. The pH within the Nyl River is likely to increase (mainly in response to elevated calcium). Therefore, the risk of ammonia toxicity cannot be ignored.

##### Mitigation:

- Limit blasting in close vicinity to aquatic ecosystems (e.g. where mining takes place within the 1:100 floodline).
- Use electronic detonation systems to manage vibration output from blasting.
- Ensure explosives are responsibly stored and transported.
- Toxicity testing and biomonitoring in the Nyl River floodplain must take place biannually upstream and downstream of the mine. A class III toxicity hazard or higher should trigger management action.
- Monitor pH, nitrates and ammonia in surface water and groundwater.

This impact is likely to be of **Medium** significance but can be effectively mitigated to a **Low** level of significance.

#### 5.2.3.6 Operational – Sedimentation

Soil erosion and dust (especially from blasting and ore transportation) may lead to the input of sediment into the wetland system. In addition, dust and eroded sediments from mining activities, stockpiles, waste dumps and roads contain metals and salts that can contaminate surface water and also cause increases in turbidity. Sedimentation within the wetland may lead to changes in wetland vegetation as sediments are colonised by species such as *Typha capensis* or *Phragmites australis*, often in monospecific stands. Disturbed areas are also more susceptible to colonisation by alien vegetation within the wetlands. In addition, pool habitats may become shallower and warmer, with lower oxygen concentrations, due to deposition of sediments on pool substrates, thus affecting certain fish species. Sedimentation may cause pool habitats to be silted up, with a consequent displacement of water into a more pronounced channel. Water may also 'back up' behind the deposited sediments, which may obstruct surface flows. These changes are likely to impact on habitat availability for aquatic biota.

##### Mitigation

- Development and disturbance should be minimised within the 1:100 year flood line and wetland (including its buffer). In particular, infrastructure that may release dust or sediments (e.g. roads, stockpiles, waste dumps, tailings dams) should be located well outside of wetland areas (including wetland buffer zones). Blasting should be kept to a minimum within the 1:100 year floodline.

- Mitigation measures should include the construction of a low berm, approximately 1m high by 2-3m wide between the mining activities and the wetlands. These berms would serve to intercept flows containing suspended sediments and create a depositional environment. They should be located outside the wetland boundaries and should be created prior to construction and vegetation clearing on the stockpile footprint commencing. The topsoil stockpiles should also be vegetated.
- The service road that will run between the wetland and the flood protection berm, in particular, should be protected from erosion as erosion along this road could affect the stability of the berm. It is recommended that the road be gravelled or cemented to prevent erosion.
- Install effective flow attenuation, sediment trapping and erosion protection measures along stormwater drains and at stormwater outlets.
- Limit surface soil disturbance (including vegetation removal) across the site.
- Trucks should use tarpaulins to prevent spillage/dust from loads.
- Dust suppression of roads will assist in keeping dust levels down.

This impact is likely to be of **Medium significance** but can be effectively mitigated to a **Low** level of significance if mitigation is effectively applied.

#### **5.2.3.7 Operational - Erosion and sedimentation**

Storm water runoff will increase in velocity and volume following rainfall events due to a decrease in infiltration (resulting from vegetation clearance and infrastructure) causing erosion at storm water outlets. Where these occur in wetland areas, vertical incision of the floodplain may alter the flow characteristics, from diffuse, mainly subsurface flows to a more channelised overland flow with decreased lateral connectivity.

##### *Mitigation*

Apply all mitigation measures to ensure effective storm water attenuation as well as sediment-trapping and erosion control measures.

This impact is likely to be of **Medium** significance but can be effectively mitigated to a **Low** level of significance if mitigation is effectively applied.

#### **5.2.3.8 Operational – Abstraction and impoundments**

Dams, road crossings and abstraction of water from dams are likely to exacerbate existing impacts to water quality, quantity and flow regimes (e.g. prolonged no-flow periods). Dams and road crossings also impact fish migration patterns.

##### *Mitigation:*

Ensure compliance to water use licence. Return clean water to natural aquatic ecosystems (without storage) to limit impact on natural hydrological regime of streams. Remove all redundant unauthorised dams and river crossings.

This impact is likely to be of **Medium significance** but can be effectively mitigated to a **Low** level of significance if mitigation is effectively applied.

#### **5.2.3.9 Operational – Increased pressure on fish stock**

Increased numbers of people in an area often results in increased fishing pressure on the aquatic ecosystems, as it is often a free and readily available source of food. Except for the Sharptooth catfish, indigenous fish species observed in the study area have low importance as angling species. Smaller species are however sometimes netted for subsistence. The abundance of catfish is furthermore as a result of existing alteration (creation of dams) related to agriculture in the area. Ideally these river-crossing and dams should be removed.

##### *Mitigation*

Prohibit the illegal harvesting of fish with nets, fish traps etc (especially from rivers). Control angling (if allowed). Remove unnatural habitats (created by unauthorised dams) from the Nyl River wetland ecosystem.

This impact is likely to be of **Medium** significance but can be effectively mitigated to a **Low** level of significance if mitigation is effectively applied.

#### **5.2.3.10 Operational – Water quality deterioration related to operational activities**

Water quality deterioration related to hazardous waste, accidental spills and leaks during general operational activities (fuels, cement, PVC, tyres etc). Storm water flushing areas that contain contaminated sediments as well as dust can also carry pollutants into water bodies. Water quality deterioration will especially affect aquatic fauna intolerant to water quality alteration but can have an impact on all aquatic fauna (e.g. fuel and sewage spills).

In addition, nitrates can cause increased nitrate concentrations which promote the growth of algae and cause fluctuations in oxygen concentrations (low at night and elevated during the day). Supersaturated conditions during the day can cause gas bubble disease in fish and promote the growth of blue-green algae, which may be harmful to livestock and humans). The target water quality range specified in the DWAF (1996) guidelines for aquatic ecosystems specifies a maximum increase of inorganic nitrogen by no more than 15% from baseline, unimpacted levels.

Of greater concern, is that inorganic nitrogen (nitrites and nitrates), when reduced, can form ammonia. Ammonia can cause toxicity to aquatic biota. High pH values and temperatures promote this reduction. The pH within the Nyl River is likely to increase (mainly in response to elevated calcium). Therefore, the risk of ammonia toxicity cannot be ignored.

Chromium can sometimes become problematic in certain mining effluents, particularly when oxidised to form hexavalent chromium which is toxic to aquatic biota. However, this is most likely to occur under acidic conditions which are not expected in the Nyl River.

Various surface activities could potentially affect water quality in receiving watercourses. These are summarised below:

- Leaks/spills from pipelines containing mine water or sewage
- Seepage or spills from pollution control dams (including mining contaminants or sewage)
- Storm water runoff containing contaminants from workshops (oils, greases) and product storage or transport areas.
- Erosion at storm water outlets
- Seepage or runoff from waste disposal areas

- Leaks or spills from storage areas for hazardous waste and hazardous substances (such as fuel and greases).

These impacts to water quality are likely to impact upon sensitive aquatic species, in particular, Johnston's Topminnow.

#### *Mitigation*

- Identify potential areas where seepage and spills can occur into the natural environment and take necessary precautions to reduce potential spills and seepage.
- Designated waste handling and storage facilities must be put in place at the start of the construction phase. Hazardous waste and products must be located on bunded areas of sufficient capacity to contain spills and that do not allow seepage of pollutants into the ground or the run-off of polluted water. All waste must be disposed of in registered waste disposal facilities. The waste facilities should be located within the dirty water area of the mine.
- Compile an emergency preparedness plan in case of spillages, especially in wetland areas. Employees should be made aware of pollution prevention measures as well as procedures to follow in case of emergencies.
- Ensure that silt, lime, cement, paint, chemicals, etc. do not wash into drains or nearby watercourses.
- Toxicity testing should be conducted in PCDs to determine the risk of toxicity to aquatic ecosystems, in the event of leaks or spills. This applies particularly to return water dams the tailings PCDs.
- Regular biomonitoring should be conducted according to recommended target endpoints. Recommendations should be regarded as incidents, with recorded, auditable follow-up actions taken for each recommendation.
- Surface water monitoring should include monitoring points within the Nyl River upstream and downstream of the mine.
- Nitrates, ammonia, chromium and pH measurements should be included in water quality monitoring programmes.
- Apply best practice as per Best Practice Guidelines (DWA 2006-2008)

This impact is likely to be of **Medium** significance but can be effectively mitigated to a **Low** level of significance if mitigation is effectively applied.

#### **5.2.3.11 Operational - Interception of surface runoff**

Some surface water runoff from upslope areas will be intercepted by the pits and mining infrastructure, resulting in less water reaching the floodplain. This may result in a drop in water levels in the Nyl River (especially during drier months) and longer no-flow periods, ultimately having a negative effect on aquatic biota, particularly sensitive species. A drop in water levels will affect the availability of habitats for aquatic species and will also exacerbate water quality impacts due to conditions being more concentrated (i.e. less dilution). This amount of surface water intercepted is likely to be minimal (based on the surface water report by AEG 2022).

*"The surface run-off in the vicinity of the proposed mine is insignificant in relation to the flow in the Nyl River and its associated wetland, possibly also its associated alluvial aquifer. Apart from very*

*localised changes, it is expected that the mine will not have much effect on the hydrology of the Nyl River or the associated wetland.”*

#### *Mitigation*

- Clean stormwater should be diverted around the mine and released into the Nyl River in an attenuated way.
- Flow attenuation and erosion protection structures must be used within the stormwater drains and at stormwater outlets to prevent sediments from being transported into the river.
- Apply best practice as per Best Practice Guidelines for stormwater (DWA 2006-2008)

This impact is likely to be of **Medium significance** but can be effectively mitigated to a **Low** level of significance if mitigation is effectively applied.

#### **5.2.3.12 Operational – Loss of Biodiversity and decline in ecological integrity**

It is likely that there will be a loss of sensitive species from the system due to altered water quality, altered flows and a decline in habitat availability (due to erosion, sedimentation and altered hydrology) as well as colonisation of sediments by monospecific stands of reeds, typically *Typha* or *Phragmites*, which then outcompete other species. Pool habitats are also likely to support fewer fish due to sedimentation, while water quality deterioration will affect fish species intolerant to water quality alteration (especially Johnston's topminnow) but will also have an impact on all aquatic fauna. These impacts are likely to be carried downstream and may impact on other animals higher up in the food chain (e.g. frogs, birds, otter).

#### *Mitigation*

- Implement all mitigation relating to water quality, hydrology, erosion and sedimentation.
- Regular biomonitoring should be conducted according to recommended target end-points. Recommendations should be regarded as incidents, with recorded, auditable follow-up actions taken for each recommendation.
- A biodiversity management plan and programme should be compiled and implemented for the floodplain, including a species-level assessment of Odonata.

Even with effective application of all mitigation measures, it is likely that there will be some decline in ecological integrity and a lower prevalence in sensitive taxa, with an increased abundance of alien fish species (particularly Mosquito fish). The main impact is likely to be due to water quality although impacts to water quantity (and therefore habitats) cannot be entirely ruled out. The PES category is likely to decline to a C/D. The significance of this impact is therefore likely to remain **Medium**.

#### **5.2.4 DECOMMISSIONING AND CLOSURE**

##### **5.2.4.1 Decommissioning & Closure – Reduced flows in the Nyl River**

The Northern pit is located within the 10-, 50- and 100-year flood lines. A flood protection berm will therefore be constructed around the pit to prevent water from entering during flood events.

This berm and the associated impacts are discussed in Section 5.1.1. and 5.2.1. The berm has been designed to cater for a 1:100-year flood, will consist of a semi-permeable clay core and surrounded by rockfill to prevent scouring.

It is anticipated that the berm will be a permanent structure and will not be removed during decommissioning. It is also understood that the pit will be backfilled. However, the risk during this phase – and beyond closure – is that the berm will be damaged, overtopped, or that flood levels will rise due to climate change.

There is therefore a risk that water will be lost from the Nyl River post-closure. This could have a severe impact upon flood volumes in the river as well as pool depth during low flow periods. Fish migration and spawning may be affected, while colonisation by alien species will be favoured. There may also be impacts to water quality.

It would therefore be essential that the pit is properly rehabilitated to be free draining and that the structural integrity of the berm be maintained well beyond closure. Topsoil should be re-shaped to have a gently sloping, free-draining topography and should be re-vegetated to prevent erosion. A clay layer should be included along the wetland edge of the rehabilitated slope.

#### *Mitigation*

- A maintenance and monitoring plan should ensure regular inspections to detect possible damage or erosion of the flood protection berm and associated service road. Erosion nick points should be stabilized immediately.
- The berm must remain in place well beyond closure.
- An emergency preparedness plan should be compiled for possible breaches during storm events post-closure.
- The backfilled pit must be thoroughly rehabilitated to be free draining. Topsoil should be re-shaped to have a gently sloping, free-draining topography and should be re-vegetated to prevent erosion. A clay layer should be included along the wetland edge of the rehabilitated slope.
- All clean stormwater runoff should be directed towards the river in a non-erosive and attenuated manner.

The significance of this impact is likely to be **High** but could possibly be reduced to Medium if the closure plan is comprehensive, detailed and responsibly implemented. The feasibility of long-term monitoring of the barrier is uncertain, which means that responsible rehabilitation will be critical.

#### **5.2.4.2 Decommissioning & Closure – Water quality deterioration: Mine Drainage and seepage from Tailings**

Water quality deterioration related to seepage from the tailings facility will cause increased salts, metals and changes in pH (increased alkalinity) in the groundwater.

This impact is also discussed in Section 5.1.3.

Acid Base accounting has identified the neutralisation potential as being high so that acidification is likely to be limited (E-Science Associates 2012), while increases in sulphate concentrations will fall within guideline limits (GPT 2022). According to Geo Pollution technologies (2022), this mine

drainage is likely to be alkaline and saline, although the increase in sulphates is expected to fall within guideline limitless. Calcium is also expected to become elevated and the pH of the leachate is predicted to be slightly alkaline at a value of approximately 8.

However, the separation of the surface water from the groundwater by a thick clay layer will ensure that seepage will be confined to the groundwater and will therefore have limited direct impacts on water quality on the Nyl River. Impacts to the Nyl River will therefore primarily be via surface water runoff (e.g. leaks/spills from PCDs and shallow subsurface seepage from the waste rock dump or tailings).

An additional scenario is that the ground water will be used for irrigation of crops, thus indirectly reaching surface water in the Nyl River as agricultural return flows. There may therefore be a gradual increase in nitrate and salt concentrations in the receiving Nyl River over time. An increase in nitrate concentrations promotes the growth of algae which causes fluctuations in oxygen concentrations (low at night and elevated during the day). Supersaturated conditions during the day can cause gas bubble disease in fish and promote the growth of blue-green algae, which may be harmful to livestock and humans). Of greater concern, is that inorganic nitrogen (nitrites and nitrates), when reduced, can form ammonia. Ammonia can cause toxicity to aquatic biota. High pH values and high temperatures promote this reduction. The pH of ground water is expected to increase (GPT 2022). Therefore, should this alkaline water reach the river, there will be a risk of ammonia toxicity.

Water quality deterioration will especially affect fish species intolerant to water quality alteration but will have an impact on all aquatic fauna, causing a decline in diversity.

#### *Mitigation*

- Nitrate and ammonia concentrations must be included in routine surface water and groundwater monitoring programmes.
- Toxicity testing should be conducted on water sampled from pollution control facilities and boreholes. Toxicity testing should also be performed on water sampled from the Nyl River upstream and downstream of the mine.
- Irrigation should not be permitted where nitrate and ammonia concentrations in groundwater exceed guideline limits for aquatic ecosystems, or when a toxicity hazard of Class III or higher is recorded for borehole water. Water used for irrigation must comply with Water Use Licence conditions and the ecological water requirements of the Nyl River.
- Biannual biomonitoring should assess impacts to ecological integrity within the river. This should include an assessment of algal proliferation and oxygen concentrations. Johnston's topminnow may be the most relevant fish to use as indicator of water quality deterioration, although the entire fish assemblage should be monitored to detect changes. Officials from DWS should conduct regular site visits to the mining area.
- The soils in the Nyl River floodplain and adjoining buffer may not be disturbed so as not to disturb or excavate the clay layer. Disturbance or excavation of the clay layer would need to be prevented well beyond closure, until groundwater quality complies with the RQO for this reach of the Nyl River, as advised by the DWS.
- Appropriate liners should be used for the tailings dam and WRD, as well as their associated PCDs and RWDs, and must ensure long-term effectiveness.
- Ensure responsible rehabilitation and removal of all pollution sources from site (stockpiles, PCDs, waste dumps).
- The risks associated with the tailings facility should continue to be monitored until they

are considered to be of negligible risk to surface and groundwater.

- Implement and maintain monitoring programme well beyond closure. Should any signs of pollution be detected, immediate actions should be taken to rectify the problems.
- Ensure adequate precautions are taken to prevent/limit spills or seepage of polluted water (e.g. lining of dams, trenches, separation of clean and dirty water).
- Groundwater levels must be regularly monitored to ensure no linkages with surface water. Piezometer borehole transects should be established across the edge of the floodplain downslope of each proposed opencast pit to monitor shallow groundwater levels.

This impact is likely to be of **High** significance but can be effectively mitigated to a **Medium** level of significance if mitigation is effectively applied.

#### **5.2.4.3 Decommissioning & Closure – Water quality deterioration (due to Ingress)**

After closure, the open pits are likely to fill with water (from groundwater recharge, surface runoff or direct inflows from the Nyl River under flood conditions). Water within the pits will become contaminated, notably by salts (especially sulphates, nitrates and chlorides) and metals (especially iron and aluminium) (GeoPollution Technologies, 2022). Contaminated water could potentially migrate from the pit into surrounding groundwater causing a pollution plume.

However, according to Geo Pollution Technologies (2022), the clay layer below the Nyl River will prevent groundwater from emerging at the surface and is therefore not likely to affect water quality in the river. In addition, sulphate levels will remain relatively low and the water will be slightly alkaline.

*“Since the sulphides in the ore are of low concentration and consist mostly chalcopyrite and pentlandite, which are not reactive enough for long term acid generation, is very unlikely that the pit backfill material will produce acid rock drainage. Geochemical modelling indicates that sulphate concentration emanating from the backfilled pit could reach 60mg/L in the initial stages and then decline slowly with time. Elevated amounts of Ca (up to 200 mg/L) are also liberated into the groundwater environment, which may aid in the precipitation of gypsum. Groundwater pH is predicted to remain slightly elevated to an approximate value of 8.”*

An additional scenario is that groundwater will be used for crop irrigation adjacent to the river, thus eventually reaching the Nyl River as agricultural return flows. The quality of the water reaching the Nyl River cannot be determined currently, and ongoing monitoring would be essential. It is likely that there will be some impact to water quality in the Nyl River, albeit indirectly and/or at lower concentrations. With ongoing irrigation over many years, there is likely to be a gradual accumulation of salts and metals at the soil surface, with ongoing evapotranspiration from irrigated fields. These may be washed into the Nyl River in surface runoff. This is likely to be accompanied by a proliferation in algae due to increased salts and nutrients (already evident in sections of the river). Toxic ammonia could potentially become problematic should the pH become too alkaline.

Therefore, while there is likely to be some decline in water quality in the Nyl River, this will mainly result in the proliferation in algae, which may affect oxygen concentrations and be harmful to sensitive fish. The formation of toxic ammonia under alkaline conditions cannot be ruled out during dry periods. This is less likely to be problematic during wet periods due to dilution.

#### *Mitigation*

- Nitrate and ammonia concentrations must be included in routine surface water and groundwater monitoring programmes.
- Toxicity testing should be conducted on water sampled from boreholes. Toxicity testing should also be performed on water sampled from the Nyl River upstream and downstream of the mine.
- Irrigation should not be permitted where nitrate and ammonia concentrations in groundwater exceed guideline limits for aquatic ecosystems, or when a toxicity hazard of Class III or higher is recorded for borehole water. Water used for irrigation must comply with Water Use Licence conditions and the ecological water requirements of the Nyl River.
- Biannual biomonitoring should assess impacts to ecological integrity within the river. This should include an assessment of algal proliferation and oxygen concentrations. Johnston's topminnow may be the most relevant fish to use as indicator of water quality deterioration, although the entire fish assemblage should be monitored to detect changes. Officials from DWS should conduct regular site visits to the mining area.
- The flood berm must remain intact to prevent water from entering the north pit and continually monitored and maintained to prevent damage or erosion.
- The pits, in particular the north pit, must be responsibly and completely rehabilitated to prevent surface water from being intercepted. After backfilling, top spoil must be shaped to be gently sloping and free draining towards the wetland. No pooling of water should occur over the rehabilitated pit. The slopes should be grassed to reduce erosion.
- Existing stormwater structures should remain intact until rehabilitation is complete.
- Ensure continued water quality and biomonitoring programmes post-closure.

The significance of this impact is likely to be **High** considering the long-term nature of the impact and the current good water quality in the river. However, the magnitude can be reduced with effective implementation of mitigation and management measures.

#### **5.2.4.4 Decommissioning & Closure – Water quality deterioration (due to Decant)**

After closure, the open pits may fill with water (from groundwater recharge, surface runoff or direct inflows from the Nyl River under flood conditions). Water within the pits will become contaminated, notably by salts (especially sulphates, nitrates and chlorides) and metals (especially iron and aluminium) (Geo Pollution Technologies, 2022). There is a possibility that the pit will fill with water and eventually start decanting towards the Nyl River.

However, according to the groundwater report (GPT 2022), "direct surface decanting of the pits is unlikely".

Should it occur, decant could potentially have a significant negative effect on water quality in the receiving Nyl River, with negative consequences for sensitive species, such as Johnston's Topminnow.

It would be important to prevent ingress into the pit by retaining the berm and ensuring its structural integrity, as well as rehabilitating the pit fully so that it is free draining and does not intercept surface water.

#### *Mitigation*

- The likelihood of decant should be precisely determined and constantly monitored

- The flood berm must remain intact to prevent water from entering the north pit and continually monitored and maintained to prevent damage or erosion.
- The pits, in particular the north pit, must be thoroughly and completely rehabilitated to prevent surface water from being intercepted. After backfilling, top spoil must be shaped to be gently sloping and free draining towards the wetland. No pooling of water should occur over the rehabilitated pit. The slopes should be grassed to reduce erosion.
- Existing stormwater structures should remain intact until rehabilitation is complete.
- Groundwater levels must be monitored and managed in the long term to ensure that decant cannot occur. Dewatering must take place when the risk of decant is high.

This impact is likely to be of **Medium** significance but can be mitigated to a **Low** level of significance with effective monitoring and management.

#### **5.2.4.5 Decommissioning & Closure – Erosion and Sedimentation**

Deconstruction of infrastructure and rehabilitation will cause mobilisation of sediments and erosion. This will result in increased sediment loads being carried downstream. The consequences of this include:

- Increased turbidity;
- Increased settling out of sediments in downstream reaches, causing changes in benthic habitat suitability and colonisation by monospecific reed beds;
- Change in instream and marginal habitats from slow-moving dispersive flows to an increasingly incised channel with higher flow velocities and fewer pool habitats

##### *Mitigation*

- Demolition activities should be confined to a minimum area, which should be clearly demarcated. Delineated wetlands should be considered no-go areas as far as possible.
- Sediment trapping mechanisms should prevent soils from being washed into wetlands.
- Movement of machinery and vehicles during the infrastructure removal process must be strictly controlled to prevent disturbance to wetland areas. Rehabilitated areas should be re-vegetated as soon as possible to minimise erosion.
- The affected landscape should be rehabilitated in such a way that overland flow is diffuse and free-draining, with no constrictions or risk of preferential flow paths being created. Within rehabilitated areas, steep slopes and concentrated run-off should also be avoided to prevent erosion. The rehabilitated areas should be re-vegetated as soon as possible following completion of the earthworks to minimise erosion. Regular long-term follow up of rehabilitated areas will be required to ensure the successful establishment of vegetation and to survey for any erosion damage on site. Erosion damage should be repaired immediately.

This impact is likely to be of **Medium** significance but can be mitigated to a **Low** level of significance with effective management.

#### **5.2.4.6 Decommissioning & Closure – Water quality deterioration due to spills/leaks.**

It is likely that residual seepage of pollutants will take place from contaminated soils left on site. Dust and sediments may contain contaminants that can pollute surface water. Storm water flushing old

stockpile areas, as well as dust, can also carry pollutants into receiving water bodies. Spills or leaks from vehicles and storage areas during decommissioning also pose a risk to water quality.

*Mitigation:*

- Ensure separation of clean and dirty water and allow clean water to enter natural water bodies.
- Ensure adequate rehabilitation and removal of all pollution sources (stockpiles, tailings, waste dumps).
- To prevent spillages, vehicles should be well maintained
- Diesel and oil/grease should be stored in bunded areas that will allow any spillages to be easily and quickly isolated and prevent contamination of any soils or water.
- Spills should be cleaned up with approved absorbent material such as “Drizit” or “Spillsorb”. These should be kept in sufficient quantities on site to deal with small spills. Absorbent material and contaminated soil should be disposed of at a registered hazardous waste site.
- An emergency preparedness plan should be compiled and all construction staff aware of procedures in event of a spill.
- Hazardous waste should be stored in bunded/impermeable areas and disposed of appropriately at a registered landfill site. Potential spills or seepage of hazardous waste must be anticipated and prevented.
- Implement an ongoing aquatic biomonitoring and water quality programme. Where target endpoints are not met, recommendations should translate directly into follow-up action that is recorded and auditable.

This impact is likely to be of **Medium** significance but can be mitigated to a **Low** level of significance with effective management.

**5.2.4.7 Decommissioning & Closure – Biodiversity Loss and decline in ecological integrity**

Where contaminated water reaches the Nyl River, there is likely to be a loss of sensitive species (such as Johnston’s Topminnow) and an increase in abundance of more hardy species and exotic fish species (such as predatory mosquito fish). Predators higher up in the food chain (e.g. frogs, birds) may also be affected. Furthermore, the decline in habitats due to ongoing deposition of sediments, may result in continued declines in abundance and species composition. These impacts may be carried downstream, affecting ecosystems downstream of the study site.

*Mitigation*

- Implement all mitigation measures given for erosion, sedimentation and water quality.
- Implement all mitigation measures regarding effective rehabilitation.
- Ensure continued water quality and biomonitoring programmes post-closure. Should any monitoring (biomonitoring, groundwater or surface water monitoring or environmental audits) detect any signs of deterioration or pollution, rectifying actions should be taken.
- A biodiversity management plan and programme should be implemented for the floodplain, including a species-level assessment of Odonata.

Even with effective application of all mitigation measures, it is likely that there will be some decline in ecological integrity and a lower prevalence in sensitive taxa, with an increased abundance of alien fish species (particularly Mosquito fish). The main impact is likely be due to

water quality although impacts to water quantity (and therefore habitats) cannot be entirely ruled out. The PES category is likely to decline from a B/C to a C/D. The significance of this impact is therefore likely to remain **Medium**.

### **5.3 CUMULATIVE IMPACTS**

A cumulative impact is defined in GNR 982 (EIA Regulations of 4 December 2014) as amended, as:

“Cumulative impact’ in relation to an activity, means the past, current and reasonably foreseeable impact of an activity, considered with the impact of activities associated with that activity, that in itself may not be significant, but may become significant when added to the existing and reasonable foreseeable impacts eventuating from similar or diverse activities”

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, however, is 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 likely to never 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:* The limited water quality variables measured on-site, together with the good biotic integrity indicated by the fish assemblage, and the potential presence of the Johnston’s topminnow, a species moderately intolerant to water quality alteration, indicate that the water quality of this reach of the Nyl River is currently in a good condition. Water quality in these catchments generally deteriorates downstream as more pollutants enter the streams. With an increase in development (mining, agriculture and other land uses) in the catchment, water quality can be expected to deteriorate in future, which will not only impact on the area within direct vicinity of the mine, but also further downstream.

*Water quantity:* Influx of people into an area, together with socio-economic development activities (such as mining, industry, agriculture) puts pressure on the water resources of an area. Should water resources not be adequate to sustain the present and potential future mining activities in the area, water transfers may be required. This has a highly negative and irreversible impact on the ecological integrity of aquatic ecosystems. It is therefore important that the availability of water for present and future mining activities in the area be considered. Water use should be limited as far as possible, and it should be ensured that the ecological water requirements of the Nyl River are met.

It is also important to consider the effects of climate change on rainfall patterns and, therefore, flow volumes and flow rates in the Nyl River. An increase in the magnitude or frequency of storm events may result in more frequent flood events and potential overtopping of the clay layer or flood berm.

The cumulative impact of the proposed development was assessed in terms of the potential impact of the proposed Volspruit mining project on the Nyl River floodplain as well as the river downstream of the study area.

The current impacts within the study area, as well as upstream and downstream of the study area, are agricultural, with farm dams, road crossings abstraction from farm dams and irrigation return flows having the greatest impact on the river. Centre pivot irrigation upstream of the study area has already affected the hydrology of the river. Water quality has been affected to some extent, but mainly from agricultural activities.

The groundwater assessment (GPT 2023) found that the groundwater quality is “poor”, There will be a decline in the quality of the groundwater due to mining (increased salts, pH and metals) although the decline will be within guideline limits.

It is anticipated that mining at Volspruit, considered alone, will not significantly add to these existing impacts. However, it will contribute to salt loads in the river to some extent, as well as the alkalinity of the water (due to general surface water impacts associated with mining such as leaks, spills, dust and runoff from the mine, as well as from agricultural return flows where groundwater is used for irrigation).

Based on the information provided (GPT 2023, Eco Elementum 2022), it is anticipated that the flood protection berm around the northern pit, together with the clay layer beneath the floodplain, will significantly reduce the impacts on flows in the Nyl River, as well as surface-groundwater linkages.

However, when considered on a temporal scale, agricultural return flows will have an ongoing and cumulative effect on salt concentrations in the soils, and therefore in the runoff. As calcium concentrations in the soil (and runoff) increase over time, there may be a progressive increase in salinity and pH in the river. Under warm, alkaline conditions, nitrates may become reduced to form ammonia which could cause toxicity to aquatic biota. The increasing concentrations of salts and nutrients is also likely to cause proliferation of algae, which will further affect aquatic biota through low oxygen concentrations (or supersaturated conditions during the day) and decreased habitat suitability and availability. There will therefore be cumulative impacts to aquatic ecosystems, with a gradual decline in the abundance of sensitive species and increased colonisation by alien fish species (most notably, Mosquito fish). These impacts will not be immediately evident and will increase cumulatively over time. Fish tend to respond to environmental changes more slowly than aquatic macroinvertebrates.

With each future development within the sub-catchment, these impacts will be exacerbated. Each new development will have incremental impacts on water quality and hydrology, ultimately impacting on the Limpopo, an international river. The impacts of the Volspruit mine development on the aquatic biodiversity (as provided in this report and subsequent monitoring reports) need to be considered in any future Environmental Impact Assessments that would be required for developments in the area.

The cumulative impacts are therefore considered to be High. However, with effective mitigation (i.e. ensuring the flood berm remains impermeable in the long term, the clay layer is not disturbed and the culverts beneath the N1 are maintained to be free flowing and unobstructed), the cumulative impacts can be reduced to Medium.

## 6 Proposed Biomonitoring Programme

### 6.1 Biomonitoring protocols, sites and schedule

It is recommended that a biomonitoring programme should be implemented as soon as possible in the study area, which should be part of the water use licence conditions. This programme should be implemented to improve the baseline information (a low flow/dry season survey is of special importance to ensure adequate seasonal coverage for baseline information). The baseline information is critical in enabling detection of future changes associated with the development.

Recommendations on a proposed biomonitoring programme for the study area are made in Table 19. This is based on the observations and results gained from the current and previous studies. The sites recommended for inclusion in the biomonitoring programme are those that should provide a good measure of potential impacts associated with the proposed activity, and that allow the application of generally recommended biomonitoring protocols.

**Table 22: Proposed biomonitoring sites, protocols and schedule recommended for the Volspruit Mine study area.**

| <b>Sites</b>                                                                                         | <b>Biomonitoring Protocol</b>                                                                                                   | <b>Frequency</b>                         |
|------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------|------------------------------------------|
| <b>Nyl 1 to Nyl 7</b>                                                                                | Habitat assessment, SASS5 and fish surveys, PES assessment using MIRAI and FRAI                                                 | Bi-annually (wet and dry season surveys) |
| <b>Nyl 1 and Nyl 7</b>                                                                               | DWS's DEEEP protocol: Whole effluent toxicity testing using four different biota (fish, daphnia, algae and bacteria).           | Quarterly (4 times per annum)            |
| <b>Boreholes within and adjacent to the floodplains and irrigated fields.</b>                        | DWS's DEEEP protocol: Whole effluent toxicity testing using at least three different biota (fish, daphnia, algae and bacteria). | Quarterly (4 times per annum)            |
| <b>Pollution control dams, Sewage Treatment Plant effluent, any other potential pollution source</b> | DWS's DEEEP protocol: Whole effluent toxicity testing using at least three different biota (fish, daphnia, algae and bacteria). | Quarterly (4 times per annum)            |

## 7 SUMMARY AND CONCLUSION

### 7.1 Baseline Assessment of Aquatic Ecosystems

Based on the aquatic assessment conducted in 2011 and 2021/2022, the Present Ecological State (PES) is considered to be Largely Natural /Slightly Modified (category B) to Moderately Modified (category C) for fish and aquatic macroinvertebrates in this reach of the Nyl River.

It is important to note that the Nyl River is a floodplain wetland with a seasonal flow regime and a high diversity of aquatic macroinvertebrates is not expected under natural conditions. Reference should also be made to the wetland specialist report for a more comprehensive description of wetland habitat integrity.

#### *Habitat Integrity*

The instream habitats within this reach of the Nyl River have been impacted mainly by farm dams and road crossings (inundation and flow modifications), with minor impacts to water quality from agricultural activities (cattle watering and return flows from irrigation). The impacts to aquatic ecosystems due to irrigation in the sub-catchment has been assumed to be low due to a thick, impermeable clay layer which underlies the Nyl River floodplain, preventing loss of surface water to groundwater. The PES (for instream habitats and marginal aquatic habitats) was considered Moderately Modified (PES C).

#### *Water Quality*

Water quality was considered relatively good with a low salinity (as measured by EC) and circum-neutral pH. This was confirmed by the diatom assessment.

#### *Aquatic macroinvertebrates*

Four aquatic macroinvertebrate taxa with a moderate or high requirement for good water quality were recorded, suggesting relatively good water quality. During March 2022, there was an improvement in SASS score and diversity in a downstream direction, with the highest score (104) and number of taxa (21) being recorded from the most downstream site in the study area (site 6B). The ASPT remained fairly consistent between the upstream and downstream sites (Site 1 and 6B), indicating no loss of taxa with a requirement for good water quality and therefore fairly stable water quality conditions within the study area. The Nyl River within the study area was classified as PES B/C (Largely Natural to Moderately Modified).

As expected for a wetland system, no stones or in-current biotopes were present within the study area and only the vegetation and mud biotopes were sampled using SASS. The ASPT and diversity were therefore (naturally) low, as would be expected in a wetland such as this. This means that the SASS5 protocol is more responsive to habitat availability, and it is questionable whether SASS5 is the most appropriate method for assessing aquatic macroinvertebrates in this floodplain wetland. A species-level assessment using a surrogate (indicator) group (such as dragonflies and damselflies) should be conducted provide additional information on aquatic biodiversity within the floodplain. Amphibian diversity could also be considered.

#### *Fish*

Seven of an expected ten indigenous fish species were sampled in the study area during the 2011 and 2021/22 surveys. All ten fish species are expected to still occur in this reach under present

conditions, albeit in altered abundance and frequency of occurrence. One of the observed species, namely the Mozambique tilapia, is a species of conservation concern and is classified as Vulnerable (IUCN) due to the threat of hybridization with the alien Nile tilapia.

Two alien fish species, the Common carp and Mosquito fish, were also sampled in the study area during the January 2011 and November 2021/22 surveys. The presence of these species is concerning, and they may have a significant impact on the indigenous fish of the study area.

The indigenous fish species of this reach of the Nyl River are classified as tolerant to moderately tolerant to changes in the environment. The most intolerant of all species is the Johnston's topminnow, which are intolerant to habitat alterations and water quality deterioration. This species, if still present, will be the most important indicator fish species to use in future to detect changes due to activities such as mining operations.

The biological integrity, based on fish, of this reach of the Nyl River was determined to be in a good condition during 2011, with a FRAI score of 83.1% (descriptive category B). The most important alterations identified at the time (2011) to influence the biotic integrity in terms of fish in this river reach included changes in hydrology (mainly due to farm dams), sedimentation (due to erosion), presence of migration barriers (dams and road crossings, resulting in scenarios where fish cannot conduct natural dispersal or recolonise areas after unfavourable conditions (such as droughts) and the presence of alien fish species (Common carp disturb bottom substrates, compete for food and habitat and create turbid waters).

The application of the FRAI model based on the 2021/22 survey results indicate that the present ecological state may have deteriorated from a category B in 2011 to a category C in 2021/22 with a FRAI score of 66.3% calculated. The temporal decrease in FRAI and hence biotic integrity as reflected by the fish assemblage was related to the following results and observations:

- Decreased occurrence, and potential absence of the Johnston's topminnow (*M. johnstoni*): This species was absent during November 2021 and March 2022 although adequate habitat was available. This species is intolerant to habitat and water quality changes and most probably highly susceptible to be impacted by the predatory alien *G. affinis* (in terms of competition for habitats, food and predation). It is strongly advised that a biomonitoring programme should be implemented as a matter of urgency to further expand the knowledge on the fish species composition and to verify the presence/absence of this species with this reach.
- *Enteromius bifrenatus* was also not sampled during 2021/22 surveys and was also very scarce (only 1 individual sampled at site Nyl 1) during January 2011. There is a probability that this species may have become even scarcer or may now be absent from this reach. This species will also be influenced by alterations in habitat (sedimentation, flow), water quality deterioration and the presence of alien fish species.
- Increase in alien fish species, with *G. affinis* not being sampled in 2011 and now (2021/22) being very abundant and widespread throughout the study area. The impact of alien fish species in indigenous species have therefore increased notably over this period resulting in an overall deterioration in the indigenous fish species assemblage.

## **7.2 Anticipated Impacts**

The Nyl River is a floodplain wetland with a seasonal flow regime. The proposed mining development includes open-cast mining within the major floodlines (1:10, 1:50 and 1:100 years).

Typically, the risks associated with mining within buffer zones or major flood lines are:

- water will enter the pit during flood events, therefore being lost from the river,
- water will be lost from the surface to the groundwater during dewatering,
- after closure, contaminated water will migrate into the adjacent groundwater and potentially emerge at the surface, causing water quality impacts,
- decant post-closure, causing impacts to water quality.

However, for Volspruit Mine, a flood protection berm will be constructed around the North Pit to prevent water from entering the pit during major floods or decanting into the Nyl River post-closure.

In addition, it has been found that a thick clay layer beneath the Nyl River prevents any linkages between groundwater and surface water (Geo Pollution Technologies 2023), reducing impacts due to dewatering and ingress.

Therefore, provided the berm remains structurally stable and its clay core remains impermeable in the long term, there should be no (or limited) loss of flood water from the floodplain. The berm will, however, require constant monitoring and maintenance to detect possible damage or erosion, either of the berm itself, or the service road which will run alongside it. Erosion from the service road may additionally cause increased sedimentation within the Nyl River.

During the operational phase, mine dewatering will cause a drawdown cone of depression that will affect groundwater levels. However, according to the GPT (2023), WCS (2022) and E-science (2013), there is an impermeable clay layer that underlies the Nyl River which effectively separates the surface and ground water. As such impacts to ground water levels or quality are unlikely to affect the surface hydrology and water quality. This is likely to remain the case provided the clay layer remains intact and the ground water levels remain relatively stable.

Therefore, impacts to the Nyl River and its aquatic biota will mostly consist of water quality impacts derived from the sources discussed below:

Surface water runoff containing sediments (from erosion and dust) and contaminants (from leaks, spills, dust and subsurface seepage). Because of the proximity of the infrastructure to the river, it would be essential to manage these very carefully to avoid impacts. The proximity of infrastructure to the Nyl River, together with the sensitivity of the biota and the currently good quality of the water, increase the likelihood of these impacts occurring, as well as their expected severity.

It is expected that groundwater will be abstracted for crop irrigation. Surface water quality may therefore also be affected by agricultural return flows. While current irrigation activities are not causing serious impacts to water quality in the river, it is anticipated that the ground water will become increasingly saline and alkaline due to gradual mine drainage from the tailings dam, waste rock dump and the pit (post-closure). Should this ground water then be used to irrigate crops within the vicinity of the mine, the salts will accumulate at the soil surface and potentially reach the river in

stormwater runoff and subsurface seepage. Therefore, with ongoing irrigation, there is likely to be a gradual decline in water quality in the Nyl River.

This impact is not expected to be particularly significant, with sulphates falling within guideline limits (GPT 2023). However, over a period of time, salt and nitrate concentrations in the river will start to increase. Should the water become alkaline, there is a risk that nitrates will become reduced to form ammonia which is toxic to aquatic biota. In addition, there will be a proliferation of algae which will compromise habitat suitability and availability and affect oxygen concentrations (low at night, supersaturated during the day). These conditions are favoured by hardy species, including alien and predatory mosquito fish, which will become more abundant, while the more sensitive indigenous species will decline in abundance, or be lost from the sub-catchment altogether.

The river within this reach is currently considered to be PES B/C, with good water quality. Despite the implementation of stringent mitigation measures, it is likely that there will be a gradual decrease in aquatic biodiversity, a decline in the abundance or prevalence of sensitive taxa and an increase in the abundance of hardy and exotic species due to the above impacts to water quality. This will have a negative impact on certain fish species, most notably Johnston's Topminnow which is highly sensitive to these changes.

It is important to note that conditions are already compromised by agricultural activities (including dams, cattle watering, abstraction and irrigation). It is likely that mining activities will exacerbate these existing impacts. This gradual and cumulative decline in habitat suitability and sensitive taxa (such as Johnston's topminnow) means that the cumulative impacts are likely to be significant in the long term. It is estimated that, overall, there will be a gradual decline in ecological integrity by approximately one category (i.e., to a PES C/D or D). These impacts may affect downstream reaches.

The above description of impacts assumes that the clay layer and flood lines will remain intact (i.e. no unauthorised excavations will occur within the floodplain within or adjacent to the study area) and there will be no damage to the flood protection berm during storm events. Should there be unauthorised construction or excavation of the clay layer, or if the flood lines are altered (e.g. construction on the N1) or the flood protection berm is breached at some point in the future (during the operational phase or at any time after closure), there may be significant impacts to the hydrology of the flood plan, most notably the loss of surface water to groundwater and the subsequent decline in habitats for aquatic biota. These impacts would be highly significant and would cause irreversible impacts to the aquatic ecosystems on site.

### **7.3 Assumptions and Gaps in Knowledge**

The extent to which irrigation schemes upstream of the study area have affected surface flows (including low flows and duration of low flow periods) in the Nyl River is not precisely known, nor can future impacts be precisely predicted.

The impact of agricultural return flows on water quality in the Nyl River in the long term is unknown. While the short-term impacts appear to be relatively low, there may be longer term impacts due to complex interactions (such as the formation of ammonia under alkaline conditions).

The risk of future unauthorised excavations within the floodplain cannot be predicted. These could potential damage the clay layer or cause it to become thinner in places.

The impermeability of the flood protection berm has not been tested.

The maintenance that will be required to prevent erosion or damage to the berm is not known with 100% certainty. The risk of failure many years post-closure cannot be ruled out.

An assessment of flows and water quality in the Nyl River will need to take into consideration the Resource Quality Objectives and Recommended Ecological Categories provided in consultation with the DWS. These are not currently available for the sub-catchment.

An assessment of the biodiversity of the Nyl River and associated floodplain within the study area is considered incomplete without an assessment of wetland vegetation, aerial odonates (dragonflies and damselflies), amphibians, water birds and a more comprehensive fish survey during high flows.

## **7.4 Reasoned Opinion**

The Nyl River is a floodplain wetland with a seasonal flow regime. The proposed mining development includes open-cast mining within the major floodlines (1:10, 1:50 and 1:100 years).

Typically, the risks associated with mining within buffer zones or major flood lines are:

- water will enter the pit during flood events, therefore being lost from the river,
- water will be lost from the surface to the groundwater during dewatering,
- after closure, contaminated water will migrate into the adjacent groundwater and potentially emerge at the surface, causing water quality impacts,
- decant post-closure, causing impacts to water quality.

However, for Volspruit Mine, a flood protection berm will be constructed around the North Pit to prevent flood water from entering the pit.

In addition, it has been found that a thick clay layer beneath the Nyl River prevents any linkages between groundwater and surface water (Geo Pollution Technologies 2023). It is reported that this clay layer will reduce impacts due to dewatering and contamination via groundwater. The risks associated with decant and AMD have also been described as low.

While this reduces the major risks associated with mining within major floodlines, the following impacts were identified:

Groundwater will increase in salinity, metal concentrations and alkalinity (pH) due to mine drainage from the tailings facility and waste rock dump and migration of salts from the open-cast pits post-closure. However, the impacts are not considered significant (GPT 2023) and sulphates are expected to remain within guideline limits. As there are not expected to be linkages between surface and groundwater (due to the clay layer), this water will not directly impact on the Nyl River.

However, should this groundwater be used to irrigate crops there may be indirect impacts to the Nyl River via agricultural return flows. While this is an existing impact due to current irrigation in the sub-

catchment, the quality of the return flows will gradually decline due to the increased salinity and metal concentrations in the abstracted groundwater.

The prediction is that groundwater will become more alkaline (to an average of approximately 8, GPT 2023). Warm, alkaline conditions can lead to the reduction of nitrates to ammonia, ammonia being toxic to sensitive aquatic species. Nitrate concentrations are expected to increase due to mining and algae are likely to proliferate in the river due to increased salt and nutrient concentrations. This will compromise habitats and cause oxygen levels to fluctuate (low at night, high during the day) and may be limiting to aquatic biota and certain fish. These conditions will favour alien invasive Mosquito fish, while indigenous sensitive species will become less abundant.

These impacts will be exacerbated by the usual surface water impacts associated with mining activities (spills, leaks, dust, seepage and erosion). The proximity of the Waste Rock Dump, its PCD and the tailings storage facility to the Nyl River, increases the likelihood of spills, dust and leaks.

It should additionally be noted that the groundwater is already of poor quality and the river is already impacted by agricultural activities (farm dams, abstraction and irrigation) and that impacts due to mining will merely exacerbate existing conditions.

It is therefore expected that there will a gradual decline in water quality and habitat integrity within the Nyl River. This will be followed by a decline in the abundance of sensitive species (such as Johnston's topminnow) and an increase in hardy species (including alien mosquito fish). This may not be immediately evident but will progress gradually over time. The PES is expected to decline over time to category C/D or D, although conditions may vary seasonally.

The above conclusion is based on these assumptions:

- The clay layer remains intact and is not excavated (without authorisation) within or adjacent to the study area at any time in the future (including post-closure)
- The berm will be effectively impermeable and structurally stable in the long term (beyond mine closure).
- Climate change will not significantly alter flows and flood levels in the Nyl River, at least until the water quality impacts related to mining have returned to acceptable levels.
- Ground water will not emerge at the surface during or in the years following closure (e.g., if irrigation and dewatering were to cease).

These assumptions reduce the margin of error for managing risks. Considering that the effectiveness of proposed mitigation cannot be predicted with 100% certainty and the Nyl River is a sensitive ecosystem with good water quality, the conditions for approval should be conservative and should include regular monitoring.

Recommended conditions of approval are listed below.

- The RQO of the Nyl River must be met in terms of quality and quantity (or as advised by DWS).
- Construction of the flood protection berm should be overseen by an engineer to ensure the impermeability of the clay core and stability of the structure.

- A maintenance, monitoring and emergency preparedness plan must be compiled and implemented for the flood protection berm, and its associated service road. This should extend beyond closure.
- The impermeability of the berm should be tested during the first major flood event.
- Mining should commence in the east and progress westwards to allow the effectiveness of the berm to be tested during summer rainfall periods.
- Culverts beneath the N1 should be inspected for blockages and debris, which should be removed, at the start of the rainy season each year, to prevent changes to flood levels.
- The northern pit must be rehabilitated to be free draining towards the wetland.
- No further activities within the delineated floodplain and its buffer that might cause disturbance or excavation of the clay layer.
- A biodiversity and wetland management plan must be compiled for the study area. This should include water quality improvement and habitat conservation measures for wetland biota.
- Irrigation of crops should be informed by groundwater levels and ground water quality, as advised by DWS.
- The tailings dam and waste rock dump must be appropriately lined to mitigate impacts to groundwater.
- Water quality monitoring should include nitrates, ammonia, pH and toxicity testing in the Nyl River, the waste rock dump PCD, tailings RWD/PCD and boreholes within and adjacent to the floodplain. Non-compliances should be followed by remedial action.
- Ground water levels as well as surface water levels in the Nyl River should be regularly monitored to ensure that ground water does not reach the surface, and that surface water is not lost to groundwater. The extent, duration and frequency of flood events must be recorded.

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## APPENDIX A: Impact Assessment Tables

### 7.5 Construction Phase

| POTENTIAL ENVIRONMENTAL IMPACTS - FAUNA                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION |          |       |             |       |     | RECOMMENDED MITIGATION MEASURES/ REMARKS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION |          |       |             |       |     |
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| Description of Impact                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Magnitude                                    | Duration | Scale | Probability | TOTAL | S P |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Magnitude                                   | Duration | Scale | Probability | TOTAL | S P |
| Erosion and sedimentation: Clearing of vegetation and soil disturbance could lead to increased erosion of sediments (especially during wet season) and increased dust that may enter the receiving water bodies. This would lead to increased turbidity (decreased water quality) which may have a negative impact on aquatic fauna, especially visual predators and filter feeders. The impact would vary in intensity between different species and different life stages and processes (spawning, feeding, etc.). When the suspended solids (soil/dust particles) settle out on the substrates in the aquatic ecosystems, it leads to shallower pool depths and colonisation of the sediments by monospecific stands of reeds which, in turn, decrease the availability of open pools and water column biotopes. Benthic substrates are transformed which may lead to deterioration in biotic integrity and loss of species. | 8                                            | 3        | 2     | 5           | 65    | H   | <ul style="list-style-type: none"> <li>No unnecessary development or disturbance should occur within the 1:100 year flood line of any drainage line or any wetland, together with its buffer. As far as possible, these areas should be cordoned off and considered no-go zones.</li> <li>The flood protection berm should be constructed prior to the commencement of construction and during the dry season (May-September) to limit the impact to the floodplain.</li> <li>Limit vegetation clearing to the actual footprint of the proposed development.</li> <li>No excavation or construction in wetland areas. Clay to be sourced from the development footprint.</li> <li>Fence off wetland areas prior to construction activities commencing to prevent access into the wetland areas by heavy machinery and vehicles.</li> <li>Undertake construction activities in winter to minimise sediment transport due to run-off after rainfall events.</li> <li>Re-vegetate all bare areas not directly within the footprint of the developments as soon as possible. The extent of the disturbance should be limited to a minimum.</li> <li>Shallow berms should be constructed between construction areas and the delineated wetland to prevent sediment rich runoff from the construction site entering the wetlands.</li> <li>Anti-erosion mitigation to diffuse and attenuate flows should be implemented where storm water is diverted around construction activities.</li> <li>Implement a water quality monitoring programme. Where target endpoints are not met, recommendations should translate directly into follow-up action that is recorded and auditable.</li> </ul> | 6                                           | 3        | 3     | 4           | 48    | M   |

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| POTENTIAL ENVIRONMENTAL IMPACTS<br>- FAUNA                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION |          |       |             |       |    | RECOMMENDED MITIGATION MEASURES/<br>REMARKS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION |          |       |             |       |    |
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| Description of Impact                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Magnitude                                    | Duration | Scale | Probability | TOTAL | SP |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Magnitude                                   | Duration | Scale | Probability | TOTAL | SP |
| Altered flows: Construction of pits, dams, trenches, berms and infrastructure, will intercept surface runoff, preventing it from reaching the Nyl River. Surface flows in the Nyl River can be impacted where surface runoff has been intercepted. This can change both the timing and duration of surface flows, as well as overall volumes of water within the channel. Alien vegetation encroachment due to disturbances can also have a significant impact on water levels in streams and rivers.                                           | 4                                            | 4        | 3     | 5           | 55    | M  | <ul style="list-style-type: none"> <li>Water must be diverted around construction areas and allowed to flow into the floodplain in an attenuated fashion. Effective means must be found to prevent ingress of surface water runoff from upslope areas into the pits during construction.</li> <li>Clean water should be allowed to enter natural water bodies, with appropriate storm water attenuation.</li> <li>Pumping of surface water from the Nyl River (for mining and irrigation) should be restricted reduce impacts on flow volumes. Abstraction should comply with Water Use Licence conditions and the ecological water requirements of the Nyl River System.</li> <li>Implement an alien vegetation control programme and continuously manage alien vegetation encroachment.</li> <li>Implement water quality and biomonitoring programmes to detect any deterioration in aquatic integrity.</li> <li>Detailed flow monitoring (water depth) must be implemented for the Nyl River on commencement of the construction phase and maintained throughout the Life of Mine.</li> </ul> | 4                                           | 4        | 3     | 3           | 33    | M  |
| <b>Spread of alien fish species:</b> alien fish species are often spread through the introduction of people to an area. The introduction of alien species is most often for angling/recreational purposes, but can also be driven by subsistence needs for protein. Alien fish species compete with indigenous fish species for habitat and food, and can have a devastating impact on natural aquatic biota through predation and habitat destruction.                                                                                         | 4                                            | 5        | 3     | 3           | 42    | M  | Prohibit the stocking of any alien fish species into dams or rivers within the mining area. If alien fish species are present or observed within the study area in future, they should be removed (One alien fish species, namely Common carp, observed during baseline survey).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 4                                           | 5        | 3     | 1           | 12    | L  |
| <b>Increased pressure on fish stock.</b> Increased number of people in an area often results in increased fishing pressure on the aquatic ecosystems, as it is often a free and readily available source of food. Except for the Sharptooth catfish, indigenous fish species observed in the study area have low importance as angling species. Smaller species are however sometimes netted for subsistence. The abundance of catfish is furthermore as a result of existing alteration (creation of dams) related to agriculture in the area. | 4                                            | 4        | 3     | 3           | 33    | M  | Prohibit the illegal harvesting of fish with nets, fish traps etc (especially from rivers). Control angling (if allowed). Remove unnatural habitats (created by dams/roads) from the Nyl River wetland ecosystem.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 2                                           | 4        | 2     | 1           | 8     | L  |

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| POTENTIAL ENVIRONMENTAL IMPACTS<br>- FAUNA                                                                                                                                                                                                                                                                                                                                                                                                                     | ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION |           |          |       |             |       | RECOMMENDED MITIGATION MEASURES/<br>REMARKS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION |           |          |       |             |       |
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|                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Description of Impact                        | Magnitude | Duration | Scale | Probability | TOTAL |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | S P                                         | Magnitude | Duration | Scale | Probability | TOTAL |
| <p><b>Water quality deterioration resulting from spills/leaks during general construction activities</b> (oil, diesel, cement, etc). Storm water flushing construction areas, as well as dust, can carry additional pollutants into water bodies. Water quality deterioration will especially affect fish species intolerant to water quality alteration (especially Johnston's topminnow) but can have an impact on all aquatic fauna (e.g. fuel spills).</p> | 8                                            | 5         | 3        | 3     | 48          | M     | <ul style="list-style-type: none"><li>• All mitigation for erosion prevention and control should be applied.</li><li>• Apply best practice as per Best Practice Guidelines for stormwater (DWAF 2006-2008)</li><li>• Ensure separation of clean and dirty water and allow clean water to enter natural water bodies.</li><li>• To prevent spillages and leaks:<ul style="list-style-type: none"><li>○ vehicles should be well maintained</li><li>○ Diesel and oil/grease should be stored in bunded areas that will allow any spillages to be easily and quickly isolated and prevent contamination of any soils or water.</li><li>○ Spills should be cleaned up with approved absorbent material such as “Drizit” or “Spillsorb”. These should be kept in sufficient quantities on site to deal with small spills. Absorbent material and contaminated soil should be disposed of at a registered hazardous waste site.</li><li>○ An emergency preparedness plan should be compiled and all construction staff aware of procedures in event of a spill.</li><li>○ Hazardous waste, should be stored in bunded/impermeable areas and disposed of appropriately at a registered landfill site. Potential spills or seepage of hazardous waste must be anticipated and prevented.</li></ul></li><li>• Should cement be used on site, the following apply:<ul style="list-style-type: none"><li>○ Carefully control all on-site operations that involve the use of cement and concrete (this applies to areas other than the batching plant).</li><li>○ Limit cement and concrete mixing to single sites where possible.</li><li>○ Use plastic trays or liners when mixing cement and concrete: Don’t mix cement and concrete directly on the ground.</li><li>○ Dispose of all visible remains of excess cement and concrete after the completion of tasks. Dispose of in the approved manner (solid waste concrete may be treated as inert construction rubble, but wet cement and liquid slurry, as well as cement powder must be treated as hazardous waste).</li></ul></li><li>• An aquatic biomonitoring and water quality programme should be implemented. Where target endpoints are not met, recommendations should translate directly into follow-up action that is recorded and auditable. Johnston's topminnow may be important indicator species in terms of water quality deterioration</li></ul> | 6                                           | 5         | 3        | 2     | 28          | L     |

## 7.6 Operational Phase

| POTENTIAL ENVIRONMENTAL IMPACTS - FAUNA                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION |          |       |             |       |    | RECOMMENDED MITIGATION MEASURES/ REMARKS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION |          |       |             |       |    |
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| Description of Impact                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Magnitude                                    | Duration | Scale | Probability | TOTAL | SP |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Magnitude                                   | Duration | Scale | Probability | TOTAL | SP |
| <p><b>Loss of water to the northern pit:</b> The northern pit is located within the 10-, 50- and 100-year flood lines. An impermeable barrier will therefore be constructed around the pit to prevent water from entering during flood events. The berm will be constructed with a semi-permeable clay core surrounded by rockfill slopes. It will be approximately 7 metres in height.</p> <p>Based on GPT (2022), the flood protection berm should be able to prevent (or at least minimise) water entering the pit. As flows in the Nyl River are slow, the risk of large-scale structural failure or scouring is also unlikely. Should this occur, however, flood levels will be reduced, with negative consequences for fish spawning and migration. Considering that the Nyl River is relatively unimpacted with a high biodiversity and good water quality, even small disturbances can translate into significant impacts for sensitive species.</p> <p>However, the impermeability and structural integrity of the flood protection berm has not yet been demonstrated. The berm will need to remain permanently in place post-closure and will need to be regularly monitored and rigorously maintained. The berm has been designed for the 1:100 year flood event and the effects of climate change are uncertain in the long term. Long term monitoring of flood levels and flood lines in the Nyl River will be required. This will include monitoring culverts beneath the N1 to maintain the status quo. While many of these mitigation and management measures are possible during the operational phase, the long term effectiveness of the berm cannot be predicted with 100% accuracy.</p> <p>Please refer to section 5.1.1 of the report for a more detailed description of this berm.</p> | 6                                            | 5        | 4     | 5           | 80    | H  | <ul style="list-style-type: none"> <li>The flood protection berm must be inspected bi-annually during the dry season and wet season to detect and repair possible damage/erosion and ensure structural stability.</li> <li>Construction must take place in the dry season and must be overseen by a qualified engineer.</li> <li>Erosion nick points (e.g. at the base of the berm or along service roads) must be immediately stabilised to prevent subsequent damage to the berm.</li> <li>The berm must be well protected by rockfill, sloped and revegetated.</li> <li>During the first major flood event (&gt;1:5 year), the berm must be assessed by an engineer to ensure impermeability and structural integrity.</li> <li>Water levels in the Nyl River and flood lines must be monitored from the inception of the development and changes reported to the DWS.</li> <li>Mining should progress sequentially, starting in the east and progressing towards the west, so that potential problems can be detected and addressed timeously.</li> <li>A maintenance and monitoring plan should ensure regular inspections to detect possible damage or weakness, which should be repaired timeously.</li> <li>An emergency preparedness plan should be compiled for potential breaches during storm events.</li> </ul> | 6                                           | 5        | 3     | 4           | 56    | M  |

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| POTENTIAL ENVIRONMENTAL IMPACTS - FAUNA                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION |          |       |             |       |    | RECOMMENDED MITIGATION MEASURES/ REMARKS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION |          |       |             |       |    |
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| Description of Impact                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Magnitude                                    | Duration | Scale | Probability | TOTAL | SP |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Magnitude                                   | Duration | Scale | Probability | TOTAL | SP |
| <p><b>Water quality deterioration</b> related to seepage from the waste rock dump, tailings facility and stockpiles will cause increased salts (particularly sulphates), metals and changes in pH in the groundwater. However, the separation of the surface water from the groundwater by the clay layer that underlies the Nyl floodplain will ensure that seepage will be confined to the groundwater and will therefore have limited impact on water quality on the Nyl River.</p> <p>Impacts to the Nyl River will therefore primarily be via surface water runoff (e.g. leaks/spills from PCDs and shallow subsurface seepage from the waste rock dump or tailings). In addition, it is anticipated that groundwater will be used for crop irrigation. As such, contaminated groundwater will ultimately reach the Nyl River as runoff or agricultural return flows. The quality of the water eventually reaching the Nyl River cannot be accurately determined. However, it is likely that there will be some impact to water quality in the Nyl River, albeit indirectly, at relatively low concentrations and over an extended period of time (increasing cumulatively with ongoing evapotranspiration from irrigated fields).</p> <p>Of concern, is that the pH in the Nyl River is likely to increase if this high-calcium high-pH runoff were to reach the river. Under alkaline conditions, nitrates become reduced to form ammonia. Ammonia can be highly toxic to aquatic biota, including fish. Nitrates can also cause a proliferation of algae and changes to oxygen fluctuations which can be limiting to fish (low concentrations at night when photosynthesis stops or supersaturated during the day when the algae photosynthesise). The concentrations of nitrates may be exacerbated by fertilisers used on cultivated fields. Salts, such as calcium, chlorides and sulphates in surface runoff and agricultural return flows (with concentrations increasing with ongoing evapotranspiration from irrigated fields) may also affect salt concentrations in the receiving Nyl River.</p> <p>While these increased concentrations may not directly impact on aquatic biota (and may well fall within guideline limits), there are likely to be indirect effects via algal proliferation (which will affect habitat availability and oxygen concentrations) and toxicity (under alkaline conditions). The</p> | 6                                            | 5        | 3     | 5           | 70    | H  | <ul style="list-style-type: none"> <li>pH, nitrate and ammonia concentrations must be included in routine surface water and groundwater monitoring programmes.</li> <li>Toxicity testing should be conducted on water sampled from pollution control facilities, boreholes and potential sewage effluents. Toxicity testing should also be performed on water sampled from the Nyl River upstream and downstream of the mine.</li> <li>Irrigation should not be permitted where nitrate and ammonia concentrations exceed guideline limits for aquatic ecosystems, or when a toxicity hazard of Class III or higher is recorded for borehole water. Water used for irrigation must comply with Water Use Licence conditions and the ecological water requirements of the Nyl River.</li> <li>Biannual biomonitoring should assess impacts to ecological integrity within the river. This should include an assessment if algal proliferation and oxygen concentrations. Johnston's topminnow may be the most relevant fish to use as indicator of water quality deterioration, although the entire fish assemblage should be monitored to detect changes. Officials from DWS should conduct regular site visits to the mining area.</li> <li>The soils in the Nyl River floodplain and adjoining buffer may not be disturbed or excavated to disturb or remove the clay layer.</li> <li>Appropriate liners should be used for the tailings dam and WRD, as well as their associated PCDs and RWDs, and must ensure long-term effectiveness.</li> <li>Implement and maintain monitoring programme (biomonitoring, groundwater or surface water monitoring or environmental audits). Should any signs of pollution be detected, immediate actions</li> </ul> | 6                                           | 5        | 3     | 4           | 56    | M  |

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| POTENTIAL ENVIRONMENTAL IMPACTS - FAUNA                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION |          |       |             |       |    | RECOMMENDED MITIGATION MEASURES/ REMARKS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION |          |       |             |       |    |
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| Description of Impact                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Magnitude                                    | Duration | Scale | Probability | TOTAL | SP |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Magnitude                                   | Duration | Scale | Probability | TOTAL | SP |
| effects of algae on oxygen concentrations and ammonia on toxicity are likely to have the greatest impact on aquatic biota. This will mainly affect fish species intolerant to water quality alteration (especially Johnston's topminnow) but will have an impact on all aquatic fauna.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                              |          |       |             |       |    | should be taken to rectify the problems. <ul style="list-style-type: none"> <li>Waste dumps and soil stockpiles should be located well outside of wetland areas and their buffers. Runoff from these areas should be treated as dirty water.</li> <li>Ensure adequate precautions are taken to prevent/limit spills or seepage of polluted water (e.g. lining of dams, trenches, separation of clean and dirty water).</li> <li>Groundwater levels must be regularly monitored to ensure no linkages with surface water. Piezometer borehole transects should be established across the edge of the floodplain downslope of each proposed opencast pit to monitor shallow groundwater levels.</li> </ul>                                                                                                                                          |                                             |          |       |             |       |    |
| <b>Dewatering may cause decreased/altered flows in the Nyl River</b><br>Dewatering of the Northern pit to allow for mining during the operational phase, is likely to cause a drawdown cone of depression - a lowering of the groundwater table in the vicinity of the dewatering. This drawdown cone of depression will extend below the Nyl River. In sandy alluvial soils, this lowering of the water table usually leads to a loss of surface water to groundwater. However, the Nyl River has a clay layer beneath the alluvial soils. This clay layer is relatively impermeable and therefore limits linkages between the surface water and groundwater. Therefore, impacts to aquatic ecosystems is considered to be low. The only loss of water is likely to occur if the flood levels extend beyond the edge of the clay layer in the floodplain. This will only occur during big flood events and will not result in the loss of large volumes of water. This assumes that the clay layer will remain intact and that the existing flood lines are not significantly altered. | 6                                            | 4        | 4     | 4           | 56    | H  | <ul style="list-style-type: none"> <li>No construction within the floodplain.</li> <li>All activities within the floodplain and its buffer that might cause disturbance or excavation of the clay layer must be prohibited</li> <li>Long term monitoring of water levels in the Nyl River and the groundwater will be essential to detect changes and potential loss of surface water to groundwater</li> <li>The Ecological Water Requirements of the Nyl River should be met, in consultation with the DWS.</li> <li>Clean water should be directed around mining activities and infrastructure and released back into the Nyl River in an attenuated manner. This will reduce further loss of surface water.</li> <li>Continuous monitoring of both surface and groundwater levels should be made throughout the operational phase.</li> </ul> | 5                                           | 4        | 3     | 3           | 36    | M  |

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| POTENTIAL ENVIRONMENTAL IMPACTS - FAUNA                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION |          |       |             |       |    | RECOMMENDED MITIGATION MEASURES/ REMARKS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION |          |       |             |       |    |
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| Description of Impact                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Magnitude                                    | Duration | Scale | Probability | TOTAL | SP |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Magnitude                                   | Duration | Scale | Probability | TOTAL | SP |
| <b>Deterioration in water quality from mining activities and pollution control facilities.</b><br>Pollution control facilities and pipelines carrying mine water pose a considerable risk of contamination through spills, leaks and subsurface seepage. This applies to mining PCDs/ pipelines/infrastructure and sewage effluent and infrastructure. The worst-case scenario would be structural failure, which would result in a large-scale pollution event in the Nyl River. The waste rock dump PCD is located on the edge of the 1:100 year flood line and poses the greatest risk.<br>Contaminants are likely to include sulphates, calcium and nitrates. Nitrates can promote the growth of algae and cause fluctuations in oxygen concentrations (low at night and elevated during the day). Supersaturated conditions during the day can cause gas bubble disease in fish and promote the growth of blue-green algae, which may be harmful to livestock and humans). Of greater concern, is that inorganic nitrogen (nitrites and nitrates), when reduced, can form ammonia. Ammonia can cause toxicity to aquatic biota. High pH values and temperatures promote this reduction. The pH within the Nyl River is likely to increase (mainly in response to elevated calcium). Therefore, the risk of ammonia toxicity cannot be ignored. | 6                                            | 3        | 3     | 5           | 60    | H  | <ul style="list-style-type: none"> <li>The PCDs for the mine must be appropriately lined and of adequate capacity to cater for a 50-year storm event or more.</li> <li>PCDs must be well maintained, not overfilled (allowing for sufficient freeboard) and should be regularly inspected for structural weaknesses and faults.</li> <li>Changes in flood lines due to climate change should be taken into consideration.</li> <li>An emergency preparedness plan should be prepared to manage large-scale spills of mine water or hazardous substances.</li> <li>Toxicity testing should be conducted quarterly in return water dams and PCDs to determine the risk of toxicity to receiving watercourses. A toxicity hazard of three or higher should prompt management intervention</li> <li>Toxicity testing and biomonitoring in the Nyl River floodplain must take place biannually upstream and downstream of the mine. A class III toxicity hazard or higher should trigger management action.</li> <li>Apply best practice as per Best Practice Guidelines for PCDs and stormwater (DWAf 2006-2008)</li> </ul> | 4                                           | 3        | 3     | 3           | 30    | L  |
| <b>Disturbance from Blasting</b><br>Blasting in close proximity to aquatic ecosystems may also have a direct impact on fish assemblages through disturbance.<br><br>In addition, nitrates from explosives can cause increased nitrate concentrations in groundwater and surface water (through runoff from storage and transport areas. Nitrates promote the growth of algae and cause fluctuations in oxygen concentrations (low at night and elevated during the day). Supersaturated conditions during the day can cause gas bubble disease in fish and promote the growth of blue-green algae, which may be harmful to livestock and humans). Of greater concern, is that inorganic nitrogen (nitrites and nitrates), when reduced, can form ammonia.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 4                                            | 4        | 3     | 3           | 33    | M  | <ul style="list-style-type: none"> <li>Limit blasting in close vicinity to aquatic ecosystems (e.g. where mining takes place within the 1:100 floodline).</li> <li>Use electronic detonation systems to manage vibration output from blasting.</li> <li>Ensure explosives are responsibly stored and transported.</li> <li>Toxicity testing and biomonitoring in the Nyl River floodplain must take place biannually upstream and downstream of the mine. A class III toxicity hazard or higher should trigger management action.</li> <li>Monitor pH, nitrates and ammonia in surface water and groundwater.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 4                                           | 4        | 2     | 2           | 20    | L  |

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| POTENTIAL ENVIRONMENTAL IMPACTS - FAUNA                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION |          |       |             |       |    | RECOMMENDED MITIGATION MEASURES/ REMARKS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION |          |       |             |       |    |
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| Description of Impact                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Magnitude                                    | Duration | Scale | Probability | TOTAL | SP |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Magnitude                                   | Duration | Scale | Probability | TOTAL | SP |
| Ammonia can cause toxicity to aquatic biota. High pH values and temperatures promote this reduction. The pH within the Nyl River is likely to increase (mainly in response to elevated calcium). Therefore, the risk of ammonia toxicity cannot be ignored.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                              |          |       |             |       |    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                             |          |       |             |       |    |
| <b>Sedimentation</b><br>Soil erosion and dust (especially from blasting and ore transportation) may lead to the input of sediment into the wetland system. In addition, dust and eroded sediments from mining activities, stockpiles, waste dumps and roads contain metals and salts that can contaminate surface water and also cause increases in turbidity. Sedimentation within the wetland may lead to changes in wetland vegetation as sediments are colonised by species such as <i>Typha capensis</i> or <i>Phragmites australis</i> , often in monospecific stands. Disturbed areas are also more susceptible to colonisation by alien vegetation within the wetlands. In addition, pool habitats may become shallower and warmer, with lower oxygen concentrations, due to deposition of sediments on pool substrates, thus affecting certain fish species. Sedimentation may cause pool habitats to be silted up, with a consequent displacement of water into a more pronounced channel. Water may also 'back up' behind the deposited sediments, which may obstruct surface flows. These changes are likely to impact on habitat availability for aquatic biota. | 6                                            | 4        | 2     | 4           | 48    | M  | <ul style="list-style-type: none"> <li>• Development and disturbance should be minimised within the 1:100 year flood line and wetland (including its buffer). In particular, infrastructure that may release dust or sediments (e.g. roads, stockpiles, waste dumps, tailings dams) should be located well outside of wetland areas (including wetland buffer zones). Blasting should be kept to a minimum within the 1:100 year floodline.</li> <li>• Mitigation measures should include the construction of a low berm, approximately 1m high by 2-3m wide between the mining activities and the wetlands. These berms would serve to intercept flows containing suspended sediments and create a depositional environment. They should be located outside the wetland boundaries and should be vegetated.</li> <li>• The service road that will run between the wetland and the flood protection berm, in particular, should be protected from erosion as erosion along this road could affect the stability of the berm. It is recommended that the road be gravelled or cemented to prevent erosion.</li> <li>• Install effective flow attenuation, sediment trapping and erosion protection measures along stormwater drains and at stormwater outlets.</li> <li>• Limit surface soil disturbance (including vegetation removal) across the site.</li> <li>• Trucks should use tarpaulins to prevent spillage/dust from loads.</li> <li>• Dust suppression of roads will assist in keeping dust levels down.</li> </ul> | 4                                           | 4        | 2     | 3           | 30    | L  |

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| POTENTIAL ENVIRONMENTAL IMPACTS - FAUNA                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION |          |       |             |       |    | RECOMMENDED MITIGATION MEASURES/ REMARKS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION |          |       |             |       |    |
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| Description of Impact                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Magnitude                                    | Duration | Scale | Probability | TOTAL | SP |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Magnitude                                   | Duration | Scale | Probability | TOTAL | SP |
| <b>Erosion</b><br>Storm water runoff will increase in velocity and volume following rainfall events due to a decrease in infiltration (resulting from vegetation clearance and infrastructure) causing erosion at storm water outlets. Where these occur in wetland areas, vertical incision of the floodplain may alter the flow characteristics, from diffuse, mainly subsurface flows to a more channelised overland flow with decreased lateral connectivity.                                                                                                                                                                                               | 6                                            | 4        | 2     | 4           | 48    | M  | Apply all mitigation measures to ensure effective storm water attenuation as well as sediment-trapping and erosion control measures.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 4                                           | 4        | 2     | 4           | 40    | M  |
| <b>Abstraction and impoundments</b><br>Dams, road crossings and abstraction of water from dams are likely to exacerbate existing impacts to water quality, quantity and flow regimes (e.g. prolonged no-flow periods). Dams and road crossings also impact fish migration patterns.                                                                                                                                                                                                                                                                                                                                                                             | 6                                            | 3        | 3     | 3           | 36    | M  | Ensure compliance to water use licence. Return clean water to natural aquatic ecosystems (without storage) to limit impact on natural hydrological regime of streams. Remove all redundant dams and river crossings.                                                                                                                                                                                                                                                                                                                                                                                                                                       | 4                                           | 3        | 3     | 1           | 10    | L  |
| <b>Increased fishing pressure</b><br>Increased numbers of people in an area often results in increased fishing pressure on the aquatic ecosystems, as it is often a free and readily available source of food. Except for the Sharptooth catfish, indigenous fish species observed in the study area have low importance as angling species. Smaller species are however sometimes netted for subsistence. The abundance of catfish is furthermore as a result of existing alteration (creation of dams) related to agriculture in the area. Ideally these river-crossing and dams should be removed.                                                           | 4                                            | 4        | 3     | 3           | 33    | M  | Prohibit the illegal harvesting of fish with nets, fish traps etc (especially from rivers). Control angling (if allowed). Remove unnatural habitats (created by dams) from the Nyl River wetland ecosystem.                                                                                                                                                                                                                                                                                                                                                                                                                                                | 4                                           | 4        | 3     | 1           | 11    | L  |
| <b>Water quality deterioration related to operational activities</b><br>Water quality deterioration related to hazardous waste, accidental spills and leaks during general operational activities (fuels, cement, PVC, tyres etc). Storm water flushing areas that contain contaminated sediments as well as dust can also carry pollutants into water bodies. Water quality deterioration will especially affect aquatic fauna intolerant to water quality alteration but can have an impact on all aquatic fauna (e.g. fuel and sewage spills).<br><br>In addition, nitrates can cause increased nitrate concentrations which promote the growth of algae and | 8                                            | 2        | 3     | 4           | 52    | M  | <ul style="list-style-type: none"> <li>Identify potential areas where seepage and spills can occur into the natural environment and take necessary precautions to reduce potential spills and seepage.</li> <li>Designated waste handling and storage facilities must be put in place at the start of the construction phase. Hazardous waste and products must be located on bunded areas of sufficient capacity to contain spills and that do not allow seepage of pollutants into the ground or the run-off of polluted water. All waste must be disposed of in registered waste disposal facilities. The waste facilities should be located</li> </ul> | 4                                           | 2        | 3     | 2           | 18    | L  |

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| POTENTIAL ENVIRONMENTAL IMPACTS - FAUNA                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION |          |       |             |       |    | RECOMMENDED MITIGATION MEASURES/ REMARKS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION |          |       |             |       |    |
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| Description of Impact                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Magnitude                                    | Duration | Scale | Probability | TOTAL | SP |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Magnitude                                   | Duration | Scale | Probability | TOTAL | SP |
| <p>cause fluctuations in oxygen concentrations (low at night and elevated during the day). Supersaturated conditions during the day can cause gas bubble disease in fish and promote the growth of blue-green algae, which may be harmful to livestock and humans). The target water quality range specified in the DWAF (1996) guidelines for aquatic ecosystems specifies a maximum increase of inorganic nitrogen by no more than 15% from baseline, unimpacted levels.</p> <p>Of greater concern, is that inorganic nitrogen (nitrites and nitrates), when reduced, can form ammonia. Ammonia can cause toxicity to aquatic biota. High pH values and temperatures promote this reduction. The pH within the Nyl River is likely to increase (mainly in response to elevated calcium). Therefore, the risk of ammonia toxicity cannot be ignored.</p> <p>Chromium can sometimes become problematic in certain mining effluents, particularly when oxidised to form hexavalent chromium which is toxic to aquatic biota. However, this is most likely to occur under acidic conditions which are not expected in the Nyl River.</p> <p>Various surface activities could potentially affect water quality in receiving watercourses. These are summarised below:</p> <ul style="list-style-type: none"> <li>• Leaks/spills from pipelines containing mine water or sewage</li> <li>• Seepage or spills from pollution control dams (including mining contaminants or sewage)</li> <li>• Storm water runoff containing contaminants from workshops (oils, greases) and product storage or transport areas.</li> <li>• Erosion at storm water outlets</li> <li>• Seepage or runoff from waste disposal areas</li> <li>• Leaks or spills from storage areas for hazardous waste and hazardous substances (such as fuel and greases).</li> </ul> <p>These impacts to water quality are likely to impact upon sensitive aquatic species, in particular, Johnston's Topminnow.</p> |                                              |          |       |             |       |    | <p>within the dirty water area of the mine.</p> <ul style="list-style-type: none"> <li>• Compile an emergency preparedness plan in case of spillages, especially in wetland areas. Employees should be made aware of pollution prevention measures as well as procedures to follow in case of emergencies.</li> <li>• Ensure that silt, lime, cement, paint, chemicals, etc. do not wash into drains or nearby watercourses.</li> <li>• Toxicity testing should be conducted in PCDs to determine the risk of toxicity to aquatic ecosystems, in the event of leaks or spills. This applies particularly to return water dams the tailings PCDs.</li> <li>• Regular biomonitoring should be conducted according to recommended target endpoints. Recommendations should be regarded as incidents, with recorded, auditable follow-up actions taken for each recommendation.</li> <li>• Surface water monitoring should include monitoring points within the Nyl River upstream and downstream of the mine.</li> <li>• Nitrates, ammonia, chromium and pH measurements should be included in water quality monitoring programmes.</li> <li>• Apply best practice as per Best Practice Guidelines (DWAF 2006-2008)</li> </ul> |                                             |          |       |             |       |    |

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| POTENTIAL ENVIRONMENTAL IMPACTS - FAUNA                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION |          |       |             |       |    | RECOMMENDED MITIGATION MEASURES/ REMARKS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION |          |       |             |       |    |
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| Description of Impact                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Magnitude                                    | Duration | Scale | Probability | TOTAL | SP |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Magnitude                                   | Duration | Scale | Probability | TOTAL | SP |
| <b>Interception of surface runoff</b><br>Some surface water runoff from upslope areas will be intercepted by the pits and mining infrastructure, resulting in less water reaching the floodplain. This may result in a drop in water levels in the Nyl River (especially during drier months) and longer no-flow periods, ultimately having a negative effect on aquatic biota, particularly sensitive species. A drop in water levels will affect the availability of habitats for aquatic species and will also exacerbate water quality impacts due to conditions being more concentrated (i.e. less dilution). This amount of surface water intercepted is likely to be minimal (based on the surface water report by AEG 2022).                                                                                                                        | 6                                            | 4        | 3     | 4           | 52    | M  | <ul style="list-style-type: none"> <li>Clean stormwater should be diverted around the mine and released into the Nyl River in an attenuated way.</li> <li>Flow attenuation and erosion protection structures must be used within the stormwater drains and at stormwater outlets to prevent sediments from being transported into the river.</li> <li>Apply best practice as per Best Practice Guidelines for stormwater (DWAF 2006-2008)</li> </ul>                                                                                | 4                                           | 4        | 2     | 3           | 30    | L  |
| <b>Loss of Biodiversity and decline in ecological integrity:</b><br>It is likely that there will be a loss of sensitive species from the system due to altered water quality, altered flows and a decline in habitat availability (due to erosion, sedimentation and altered hydrology) as well as colonisation of sediments by monospecific stands of reeds, typically <i>Typha</i> or <i>Phragmites</i> , which then outcompete other species. Pool habitats are also likely to support fewer fish due to sedimentation, while water quality deterioration will affect fish species intolerant to water quality alteration (especially Johnston's topminnow) but will also have an impact on all aquatic fauna. These impacts are likely to be carried downstream and may impact on other animals higher up in the food chain (e.g. frogs, birds, otter). | 8                                            | 5        | 4     | 3           | 51    | M  | <ul style="list-style-type: none"> <li>Implement all mitigation relating to water quality, hydrology, erosion and sedimentation.</li> <li>Regular biomonitoring should be conducted according to recommended target end-points. Recommendations should be regarded as incidents, with recorded, auditable follow-up actions taken for each recommendation.</li> <li>A biodiversity management plan and programme should be compiled and implemented for the floodplain, including a species-level assessment of Odonata.</li> </ul> | 6                                           | 5        | 4     | 3           | 45    | M  |

## 7.7 Closure and Decommissioning

| POTENTIAL ENVIRONMENTAL IMPACTS - FAUNA                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | ENVIRONMENTAL SIGNIFICANCE (Before Mitigation) |          |       |             |       |    | RECOMMENDED MITIGATION MEASURES/ REMARKS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | ENVIRONMENTAL SIGNIFICANCE (After Mitigation) |          |       |             |       |    |
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| <p><b>Reduced flows in the Nyl River</b></p> <p>The Northern pit is located within the 10-, 50- and 100-year flood lines. A flood protection berm will therefore be constructed around the pit to prevent water from entering during flood events.</p> <p>This berm and the associated impacts are discussed in Section 5.1.1. and 5.2.1. There is a risk during this phase – and beyond closure – is that the berm will be damaged, overtopped, or that flood levels will rise due to climate change.</p> <p>There is therefore a risk that water will be lost from the Nyl River post-closure. This could have a severe impact upon flood volumes in the river as well as pool depth during low flow periods. Fish migration and spawning may be affected, while colonisation by alien species will be favoured. There may also be impacts to water quality.</p> <p>It would therefore be critical that the pit is properly rehabilitated to be free draining and that the structural integrity of the berm be maintained well beyond closure. Topsoil should be re-shaped to have a gently sloping, free-draining topography and should be re-vegetated to prevent erosion. A clay layer should be included along the wetland edge of the rehabilitated slope.</p> <p>Please refer to Section 5.1.1 for a more detailed description of this impact.</p> | 10                                             | 5        | 4     | 5           | 95    | H  | <ul style="list-style-type: none"> <li>A maintenance and monitoring plan should ensure regular inspections of the berm and service road to detect possible damage or erosion. Erosion nick points should be stabilized immediately.</li> <li>The berm must remain in place well beyond closure.</li> <li>An emergency preparedness plan should be compiled for possible breaches during storm events post-closure.</li> <li>The backfilled pit must be thoroughly rehabilitated to be free draining. Topsoil should be re-shaped to have a gently sloping, free-draining topography and should be re-vegetated to prevent erosion. A clay layer should be included along the wetland edge of the rehabilitated slope.</li> <li>All clean stormwater runoff should be directed towards the river in a non-erosive and attenuated manner.</li> </ul> | 6                                             | 5        | 3     | 4           | 56    | M  |

| POTENTIAL ENVIRONMENTAL IMPACTS - FAUNA                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | ENVIRONMENTAL SIGNIFICANCE (Before Mitigation) |          |       |             |       |    | RECOMMENDED MITIGATION MEASURES/ REMARKS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | ENVIRONMENTAL SIGNIFICANCE (After Mitigation) |          |       |             |       |    |
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| <p><b>Water quality deterioration related to seepage from the tailings facility</b> will cause increased salts, metals and changes in pH (increased alkalinity) in the groundwater. Should this water emerge at the surface, it may cause a decline in aquatic ecosystem integrity. This impact is also discussed in Section 5.1.3.</p> <p>According to Geo Pollution technologies (2022), mine drainage is likely to be alkaline and saline, although the increase in sulphates is expected to fall within guideline limitless. Calcium is also expected to become elevated and the pH of the leachate is predicted to be slightly alkaline at a value of approximately 8.</p> <p>However, the separation of the surface water from the groundwater by a thick clay layer means that impacts to the Nyl River will primarily be via surface water runoff (e.g. leaks/spills from PCDs and shallow subsurface seepage from the waste rock dump or tailings).</p> <p>An additional scenario is that the ground water will be used for irrigation of crops, thus indirectly reaching surface water in the Nyl River as agricultural return flows. There may therefore be a gradual increase in nitrate and salt concentrations in the receiving Nyl River over time. An increase in nitrate concentrations promotes the growth of algae which causes fluctuations in oxygen concentrations (low at night and elevated during the day). Supersaturated conditions during the day can cause gas bubble disease in fish and promote the growth of blue-green algae, which may be harmful to livestock and humans). Of greater concern, is that inorganic nitrogen (nitrites and nitrates), when reduced, can form ammonia. Ammonia can cause toxicity to aquatic biota. High pH values and high temperatures promote this reduction. The pH of ground water is expected to increase (GPT 2022). Therefore, should this alkaline water reach the river, there will be a risk of ammonia toxicity.</p> | 8                                              | 5        | 3     | 5           | 80    | H  | <ul style="list-style-type: none"> <li>Nitrate and ammonia concentrations must be included in routine surface water and groundwater monitoring programmes.</li> <li>Toxicity testing should be conducted on water sampled from pollution control facilities and boreholes. Toxicity testing should also be performed on water sampled from the Nyl River upstream and downstream of the mine.</li> <li>Irrigation should not be permitted where nitrate and ammonia concentrations in groundwater exceed guideline limits for aquatic ecosystems, or when a toxicity hazard of Class III or higher is recorded for borehole water. Water used for irrigation must comply with Water Use Licence conditions and the ecological water requirements of the Nyl River.</li> <li>Biannual biomonitoring should assess impacts to ecological integrity within the river. This should include an assessment of algal proliferation and oxygen concentrations. Johnston's topminnow may be the most relevant fish to use as indicator of water quality deterioration, although the entire fish assemblage should be monitored to detect changes. Officials from DWS should conduct regular site visits to the mining area.</li> <li>The soils in the Nyl River floodplain and adjoining buffer may not be disturbed so as not to disturb or excavate the clay layer. Disturbance or excavation of the clay layer would need to be prevented well beyond closure, until groundwater quality complies with the RQO for this reach of the Nyl River, as advised by the DWS.</li> <li>Appropriate liners should be used for the tailings dam and WRD, as well as their associated PCDs and RWDS, and must ensure long-term effectiveness.</li> <li>Ensure that rehabilitation and removal of all pollution sources from site (stockpiles, PCDs, waste dumps) is thorough and complete.</li> <li>The risks associated with the tailings facility should continue to be monitored until they are considered to be of negligible risk to surface and groundwater.</li> </ul> | 6                                             | 5        | 3     | 4           | 56    | M  |

| POTENTIAL ENVIRONMENTAL IMPACTS - FAUNA                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | ENVIRONMENTAL SIGNIFICANCE (Before Mitigation) |          |       |             |       |    | RECOMMENDED MITIGATION MEASURES/ REMARKS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | ENVIRONMENTAL SIGNIFICANCE (After Mitigation) |          |       |             |       |    |
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| Water quality deterioration will especially affect fish species intolerant to water quality alteration but will have an impact on all aquatic fauna, causing a decline in diversity.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                |          |       |             |       |    | <ul style="list-style-type: none"> <li>Implement and maintain monitoring programme well beyond closure. Should any signs of pollution be detected, immediate actions should be taken to rectify the problems.</li> <li>Ensure adequate precautions are taken to prevent/limit spills or seepage of polluted water (e.g. lining of dams, trenches, separation of clean and dirty water).</li> <li>Groundwater levels must be regularly monitored to ensure no linkages with surface water. Piezometer borehole transects should be established across the edge of the floodplain downslope of each proposed opencast pit to monitor shallow groundwater levels.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                               |          |       |             |       |    |
| <p><b>Water quality Deterioration (Ingress).</b></p> <p>After closure, the open pits are likely to fill with water (from groundwater recharge, surface runoff or direct inflows from the Nyl River under flood conditions). Water within the pits will become contaminated, notably by salts (especially sulphates, nitrates and chlorides) and metals (especially iron and aluminium) (GeoPollution Technologies, 2022). Contaminated water could potentially migrate from the pit into surrounding groundwater causing a pollution plume.</p> <p>However, according to Geo Pollution Technologies (2022), the clay layer below the Nyl River will prevent groundwater from emerging at the surface and is therefore not likely to affect water quality in the river. In addition, sulphate levels will remain relatively low and the water will be slightly alkaline. Calcium concentrations will become elevated and groundwater pH is predicted to remain slightly elevated to an approximate value of 8 (GPT 2022).</p> <p>An additional scenario is that groundwater will be used for crop irrigation adjacent to the river, thus eventually reaching the Nyl River as agricultural return flows. The quality of the water reaching the Nyl River cannot be determined currently, and ongoing monitoring would be</p> | 8                                              | 5        | 4     | 4           | 68    | H  | <ul style="list-style-type: none"> <li>Nitrate and ammonia concentrations must be included in routine surface water and groundwater monitoring programmes.</li> <li>Toxicity testing should be conducted on water sampled from boreholes. Toxicity testing should also be performed on water sampled from the Nyl River upstream and downstream of the mine.</li> <li>Irrigation should not be permitted where nitrate and ammonia concentrations in groundwater exceed guideline limits for aquatic ecosystems, or when a toxicity hazard of Class III or higher is recorded for borehole water. Water used for irrigation must comply with Water Use Licence conditions and the ecological water requirements of the Nyl River.</li> <li>Biannual biomonitoring should assess impacts to ecological integrity within the river. This should include an assessment of algal proliferation and oxygen concentrations. Johnston's topminnow may be the most relevant fish to use as indicator of water quality deterioration, although the entire fish assemblage should be monitored to detect changes. Officials from DWS should conduct regular site visits to the mining area.</li> <li>The flood berm must remain intact to prevent water from entering the north pit and continually monitored and maintained to prevent damage or erosion.</li> </ul> | 5                                             | 5        | 4     | 4           | 59    | M  |

| POTENTIAL ENVIRONMENTAL IMPACTS - FAUNA                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | ENVIRONMENTAL SIGNIFICANCE (Before Mitigation) |          |       |             |       |    | RECOMMENDED MITIGATION MEASURES/ REMARKS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | ENVIRONMENTAL SIGNIFICANCE (After Mitigation) |          |       |             |       |    |
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| <p>essential. It is likely that there will be some impact to water quality in the Nyl River, albeit indirectly and/or at lower concentrations. With ongoing irrigation over many years, there is likely to be a gradual accumulation of salts and metals at the soil surface, with ongoing evapotranspiration from irrigated fields. These may be washed into the Nyl River in surface runoff. This is likely to be accompanied by a proliferation in algae due to increased salts and nutrients (already evident in sections of the river). Toxic ammonia could potentially become problematic should the pH become too alkaline.</p> <p>Therefore, while there is likely to be some decline in water quality in the Nyl River, this will mainly result in the proliferation in algae, which may affect oxygen concentrations and be harmful to sensitive fish. The formation of toxic ammonia under alkaline conditions cannot be ruled out during dry periods. This is less likely to be problematic during wet periods due to dilution.</p>                                                       |                                                |          |       |             |       |    | <ul style="list-style-type: none"> <li>The pits, in particular the north pit, must be responsibly and completely rehabilitated to prevent surface water from being intercepted. After backfilling, top spoil must be shaped to be gently sloping and free draining towards the wetland. No pooling of water should occur over the rehabilitated pit. The slopes should be grassed to reduce erosion.</li> <li>Existing stormwater structures should remain intact until rehabilitation is complete.</li> <li>Ensure continued water quality and biomonitoring programmes post-closure.</li> </ul>                                                                                                                                                                                                                                                                                                                                                 |                                               |          |       |             |       |    |
| <p><b>Decline in water quality (Decant).</b></p> <p>After closure, the pits are likely to fill with water (from groundwater recharge, surface runoff or direct inflows from the Nyl River under flood conditions). Water within the pits will become contaminated, notably by salts (especially sulphates, nitrates and chlorides) and metals (especially iron and aluminium) (Geo Pollution Technologies, 2022). There is a possibility that the pit will fill with water and eventually start decanting towards the Nyl River.</p> <p>However, according to the groundwater report (GPT 2022), “direct surface decanting of the pits is unlikely”. Should it occur, decant could potentially have a significant negative effect on water quality in the receiving Nyl River, with negative consequences for sensitive species, such as Jonston’s Topminnow.</p> <p>It would be important to prevent ingress into the pit by retaining the berm and ensuring its structural integrity, as well as rehabilitating the pit fully so that it is free draining and does not intercept surface water.</p> | 6                                              | 5        | 4     | 3           | 45    | M  | <ul style="list-style-type: none"> <li>The likelihood of decant should be precisely determined and constantly monitored</li> <li>The flood berm must remain intact to prevent water from entering the north pit and continually monitored and maintained to prevent damage or erosion.</li> <li>The pits, in particular the north pit, must be thoroughly and completely rehabilitated to prevent surface water from being intercepted. After backfilling, top spoil must be shaped to be gently sloping and free draining towards the wetland. No pooling of water should occur over the rehabilitated pit. The slopes should be grassed to reduce erosion.</li> <li>Existing stormwater structures should remain intact until rehabilitation is complete.</li> <li>Groundwater levels must be monitored and managed in the long term to ensure that decant cannot occur. Dewatering must take place when the risk of decant is high.</li> </ul> | 6                                             | 5        | 3     | 2           | 28    | L  |

| POTENTIAL ENVIRONMENTAL IMPACTS - FAUNA                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | ENVIRONMENTAL SIGNIFICANCE (Before Mitigation) |          |       |             |       |    | RECOMMENDED MITIGATION MEASURES/ REMARKS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | ENVIRONMENTAL SIGNIFICANCE (After Mitigation) |          |       |             |       |    |
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|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Magnitude                                      | Duration | Scale | Probability | TOTAL | SP |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Magnitude                                     | Duration | Scale | Probability | TOTAL | SP |
| <b>Erosion and sedimentation</b><br><br>Deconstruction of infrastructure and rehabilitation will cause mobilisation of sediments and erosion. This will result in increased sediment loads being carried downstream. The consequences of this include: <ul style="list-style-type: none"> <li>Increased turbidity;</li> <li>Increased settling out of sediments in downstream reaches, causing changes in benthic habitat suitability and colonisation by monospecific reed beds;</li> <li>Change in instream and marginal habitats from slow-moving dispersive flows to an increasingly incised channel with higher flow velocities and fewer pool habitats</li> </ul> | 6                                              | 2        | 2     | 5           | 50    | M  | <ul style="list-style-type: none"> <li>Demolition activities should be confined to a minimum area, which should be clearly demarcated. Delineated wetlands should be considered no-go areas as far as possible.</li> <li>Sediment trapping mechanisms should prevent soils from being washed into wetlands.</li> <li>Movement of machinery and vehicles during the infrastructure removal process must be strictly controlled to prevent disturbance to wetland areas. Rehabilitated areas should be re-vegetated as soon as possible to minimise erosion.</li> <li>The affected landscape should be rehabilitated in such a way that overland flow is diffuse and free-draining, with no constrictions or risk of preferential flow paths being created. Within rehabilitated areas, steep slopes and concentrated run-off should also be avoided to prevent erosion.</li> <li>The rehabilitated areas should be re-vegetated as soon as possible following completion of the earthworks to minimise erosion. Regular long-term follow up of rehabilitated areas will be required to ensure the successful establishment of vegetation and to survey for any erosion damage on site.</li> <li>Erosion damage should be stabilised immediately.</li> </ul> | 4                                             | 2        | 2     | 3           | 24    | L  |
| <b>Water quality deterioration due to spills/leaks.</b><br><br>It is likely that residual seepage of pollutants will take place from contaminated soils left on site. Dust and sediments may contain contaminants that can pollute surface water. Storm water flushing old stockpile areas, as well as dust, can also carry pollutants into receiving water bodies. Spills or leaks from vehicles and storage areas during decommissioning also pose a risk to water quality.                                                                                                                                                                                           | 6                                              | 2        | 2     | 5           | 50    | M  | <ul style="list-style-type: none"> <li>Ensure separation of clean and dirty water and allow clean water to enter natural water bodies.</li> <li>Ensure adequate rehabilitation and removal of all pollution sources (stockpiles, tailings, waste dumps).</li> <li>To prevent spillages, vehicles should be well maintained</li> <li>Diesel and oil/grease should be stored in bunded areas that will allow any spillages to be easily and quickly isolated and prevent contamination of any soils or water.</li> <li>Spills should be cleaned up with approved absorbent material such as "Drizit" or "Spillsorb". These should be kept in sufficient quantities on site to deal with small spills.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 6                                             | 2        | 2     | 3           | 30    | L  |

| POTENTIAL ENVIRONMENTAL IMPACTS - FAUNA                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | ENVIRONMENTAL SIGNIFICANCE (Before Mitigation) |          |       |             |       |    | RECOMMENDED MITIGATION MEASURES/ REMARKS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | ENVIRONMENTAL SIGNIFICANCE (After Mitigation) |          |       |             |       |    |
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|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Magnitude                                      | Duration | Scale | Probability | TOTAL | SP |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Magnitude                                     | Duration | Scale | Probability | TOTAL | SP |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                |          |       |             |       |    | <p>Absorbent material and contaminated soil should be disposed of at a registered hazardous waste site.</p> <ul style="list-style-type: none"> <li>An emergency preparedness plan should be compiled and all construction staff aware of procedures in event of a spill.</li> <li>Hazardous waste should be stored in banded/impermeable areas and disposed of appropriately at a registered landfill site. Potential spills or seepage of hazardous waste must be anticipated and prevented.</li> <li>Implement an ongoing aquatic biomonitoring and water quality programme. Where target endpoints are not met, recommendations should translate directly into follow-up action that is recorded and auditable</li> </ul> |                                               |          |       |             |       |    |
| <p><b>Decline in ecological integrity and biodiversity</b></p> <p>Where contaminated water reaches the Nyl River, there is likely to be a loss of sensitive species (such as Johnston's Topminnow) and an increase in abundance of more hardy species and exotic fish species (such as predatory mosquito fish). Predators higher up in the food chain (e.g. frogs, birds) may also be affected. Furthermore, the decline in habitats due to ongoing deposition of sediments, may result in continued declines in abundance and species composition. These impacts may be carried downstream, affecting ecosystems downstream of the study site.</p> | 8                                              | 5        | 4     | 3           | 51    | M  | <ul style="list-style-type: none"> <li>Implement all mitigation measures given for erosion, sedimentation and water quality.</li> <li>Implement all mitigation measures regarding effective rehabilitation.</li> <li>Ensure continued water quality and biomonitoring programmes post-closure. Should any monitoring (biomonitoring, groundwater or surface water monitoring or environmental audits) detect any signs of deterioration or pollution, rectifying actions should be taken.</li> <li>A biodiversity management plan and programme should be implemented for the floodplain, including a species-level assessment of Odonata.</li> </ul>                                                                        | 8                                             | 5        | 4     | 3           | 51    | M  |

## **APPENDIX B: CVs.**

## Short Curriculum Vitae

Norma Sharratt

**Profession** : Aquatic Ecologist  
**Contact Details** : norma@cleanstream-bio.co.za;  
**Tel.** : 082 779 0734

### Qualifications:

- BSc [Zoology; Entomology] University of Natal, Pietermaritzburg 1988
- BSc (Hons)[Entomology] *Cum Laude* University of Natal, Pietermaritzburg 1989
- MSc [Entomology] University of KwaZulu-Natal, Pietermaritzburg 1998
- MSc [Ecological Assessment] *Cum Laude* University of Stellenbosch 2005

### Professional Accreditations:

- SACNASP *Pr. Sci. Nat* 400088/15 (Aquatic Science)
- Accredited SASS Practitioner (DWS 2019 -2022)

### Summary of Employment:

|           |                            |                                                                                                                                |
|-----------|----------------------------|--------------------------------------------------------------------------------------------------------------------------------|
| 2006-2021 | Aquatic Ecologist          | Clean Stream Biological Services (Pty) Ltd, Wetland Consulting Services (Pty) Ltd, Nepid Consultants CC. AquaAssess Consulting |
| 2006      | Environmental Co-ordinator | Black Mountain Mine (Anglo Base Metals)                                                                                        |

### Summary of Experience:

- Fourteen years' experience as a specialist aquatic ecologist.
- Specialist aquatic ecosystem assessments, impact assessments and management plans for proposed developments in the Olifants, Steelpoort, Dwars, Wilge, Crocodile (West), Vaal, Luvuvhu, Sabie, Crocodile (East), Komati, Usuthu, Mhlatuzi, Mfolozi, Breede and Berg River catchments.
- Biomonitoring surveys, mainly within the mining sector.
- Application of stressor-response indices (MIRAI, FRAI, IHI); assessment of aquatic macroinvertebrates using SASS5, assessments of instream and riparian habitat integrity, fish and surface water quality.
- Impact assessments and management plans for proposed mining, housing developments, impoundments and golf course developments (amongst others).
- Wetland delineations and assessments for residential developments in Gauteng and Mpumalanga.
- Biodiversity assessments and management plans for aquatic ecosystems.
- Assessment of invertebrate responses to alien tree removal along riparian zones, with implications for stream rehabilitation.
- Assessment of the conservation and ecology of the invertebrate assemblages within the sandstone caves of Table Mountain and the Cape Peninsula.

### Publications:

- SAMWAYS, M. J. and SHARRATT, N. J. (2010), Recovery of Endemic Dragonflies after Removal of Invasive Alien Trees. *Conservation Biology* 24: 267–277.
- SHARRATT, N.J., PICKER, M.D. and SAMWAYS, M.J. (2000). The invertebrate fauna of the sandstone caves of the Cape Peninsula (South Africa): patterns of endemism and conservation. *Biodiversity and Conservation* 9: 107-143.
- SAMWAYS, M.J., SHARRATT, N.J. and SIMAIKA, J.P. (2011). Effect of alien riparian vegetation and its removal on a highly endemic river macroinvertebrate community. *Biological Invasions* 13 (6): 1305-1324.

## Short Curriculum Vitae

Pieter Kotze

Full Names: Petrus Jacobus Kotze  
Address: Clean Stream Biological Services, Lowveld Office.  
110 Selati Crescent, Mhlatikop, Malalane.  
P.O. Box 1358, Malelane, 1320  
082-890-6452

### Academic history

1989: Matriculate (Roodepoort).  
1990 - 1992: B. Sc. (Biological Sciences) Rand Afrikaans University.  
1993: B. Sc. Honors (Zoology) Rand Afrikaans University.  
1994 - 1996: M. Sc. (Zoology) Rand Afrikaans University.  
1997 - 2002: Ph.D. (Aquatic Health) Rand Afrikaans University.

### Specialisation

Aquatic specialist assessments, aquatic biomonitoring, biodiversity management, water quality management and pollution control, design of surface water biomonitoring programs, impact assessments, reserve determinations.

### Total years of environmental experience

20 years

### Positions currently held:

- Director: Clean Stream Biological Services (Ecologist & Projects Manager)
- Director: Biotox Laboratory Services

### Employment History

2005 - Present; Independent Environmental Consultant (Clean Stream Biological Services and Biotox Laboratory Services)

1999 – 2005: Environmental consultant, RauEcon (Rand Afrikaans University / University of Johannesburg)

### Professional Experience

- Application and training in biomonitoring of aquatic ecosystems (fish, macroinvertebrates/SASS5, riverine habitats, water quality).
- Conducting of aquatic specialist assessments (EIA's).
- Experience in and application of DWS reserve determination methodology (fish and aquatic invertebrates)
- Design and execution of detailed environmental monitoring programmes
- Compilation of Biodiversity Management Programmes for the mining industry.
- Compilation of Environmental Impact Assessments.
- Application of human health risk assessment.
- Fish migration and fishway design assessment.

### Professional Appointments

- Environmental consultant to: Anglo Platinum, African Explosives Limited, Kumba Resources, Xstrata Coal South Africa, Xstrata Alloys South Africa, Samancor, Northam Platinum, Ingwe, Amcoal, SACE, Iscor, Ticon SA, Palabora Mining Company, Coal of Africa Limited, SANParks, Tshwane Metro, JHB Metro, Implats, Rand Water, Lepelle Northern Water, Department of Water Affairs and Forestry, BPA International, Nepid Consultants, CT Environmental, Oppenheimer & Son PTY (LTD), Water for Africa, etc.

### General

- Registered as Professional Natural Scientist with the South African Council for Natural Scientific Professions (Registration nr. 400413/04).

Accredited SASS5 practitioner to the South African River Health Programme (DWA).

