Appendix H.3

AQUATIC BIODIVERSITY ASSESSMENT

Public

Igolide Wind (Pty) Ltd

AQUATIC BIODIVERSITY AND IMPACT ASSESSMENT FOR THE PROPOSED IGOLIDE WIND ENERGY FACILITY, GAUTENG

Aquatic Ecology Report

41104282-359413-1
OCTOBER 2023

CONFIDENTIAL

Igolide Wind (Pty) Ltd

AQUATIC BIODIVERSITY AND IMPACT ASSESSMENT FOR THE PROPOSED IGOLIDE WIND ENERGY FACILITY, GAUTENG

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Aquatic Ecology Report

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EXECUTIVE SUMMARY

WSP Group Africa (Pty) Ltd (WSP) was appointed by Igolide Wind (Pty) Ltd.to undertake the necessary ecological baseline studies and impact assessment in support of the scoping, baseline and impact assessment phases of the environmental regulatory process required to authorise their development of the Igolide Wind Energy Facility (WEF; hereafter the Project).

The proposed Project is located within the Gauteng Province under the jurisdiction of the Merafong City Local Municipality, which is in the West Rand District Municipality. The Project development area is approximately 680 hectares (ha) and the proposed footprint covers an area of approximately 50 ha.

This report describes the baseline aquatic biodiversity within areas that will be impacted by the proposed Project. Potential impacts, positive or negative, were assessed and practical mitigation/management measures developed for inclusion in the Environmental Management Programme (EMPr).

The Project is situated within primary drainage region C of the Vaal Water Management Area (WMA) and the C23J and C23D quaternary catchments. Associated watercourses include the Loopspruit Sub-Quaternary Reach (SQR) C23J-01487 and the Kraalkopspruit C23J-01507 SQR. There are no riparian habitat within the C23D quaternary catchment that are associated with the OHL.

The Project area lies on land that is currently untransformed, and used as a game reserve. The surrounding land use activities include farming, (along the immediate Project boundary), mining (with the nearest operations being the Sibanye Driefontein approximately 1.5 km to the north, Kloof Gold Mine approximately 1.2 km to the east); and the Fochville township at the southwest tip of the Project boundary. Several other mines occur within the broader Project area, namely Sibanye Stillwater, Mponeng Gold Plant and the Harmony Kusasalethu Gold Mine.

The following key findings are highlighted as part of the current aquatic biodiversity and impact assessment study:

Findings from the *in situ* water quality within the Loopspruit and Kraalkopspruit indicated modifications based on exceedances in the electrical conductivity and dissolved oxygen content. These were consistent with findings from the diatom community assessment wherein diatom assemblages were generally comprised of species characteristic of fresh brackish (< 500 µS/cm), circumneutral (pH 6.5 to 7.5) water, eutrophic conditions and low to moderate requirements for dissolved oxygen saturation. The upstream mining and agricultural activities were likely the major sources for the water quality deterioration. The riparian and instream habitat integrity was determined to be predominantly *largely modified* (Ecological Category D) with major impacts including modifications to flow and water quality; and the removal of indigenous vegetation and exotic vegetation encroachment. The availability of

macroinvertebrate habitat was determined to range between *poor* where there was a lack of the stones biotope and adequate where the stones was present.

The sampled aquatic macroinvertebrate community assemblages were similar in composition throughout the assessed four sites with a low diversity compared to the expected number of taxa. Pollution-tolerant taxa dominated the assemblages, thus suggesting water quality modifications to be the major driver of the assemblages. The biotic integrity based on the recorded macroinvertebrates was *seriously modified* at each of the sites. Three of the expected five fish species were collected during the survey. A single species was collected at the Loopspruit and Kraalkopspruit downstream sites, and two species were collected at the Kraalkopspruit upstream site. The subsequent biotic integrity ranged between *largely modified* (Ecological Category of D) and *seriously modified* (Ecological Category E). The integrated ecological state (EcoStatus) of the assessed reaches were determined to be *Largely Modified.*

Reasoned opinion whether Project should proceed

Based on the findings of the current study, potential negative impacts upon the main receiving receptor (the Kraalkopspruit) are likely to occur following rainfall events, due to the distance between the river and the proposed activities. Impacts are predicted to range between *very low* to *low*, and significantly reduced upon implementation of mitigation measures. Furthermore, there are no aquatic species of conservation concern expected to occur within the study area. Therefore, no fatal flaws were identified, and thus the proposed Project may proceed with an immediate pre-development implementation of the mitigation measures and the aquatic biomonitoring programme, which must be adhered to throughout the operation phase to ensure that no deterioration of the associated watercourses occurs.

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1 INTRODUCTION

ENERTRAG South Africa (Pty) Ltd is proposing the development of the Igolide Wind Energy Facility (WEF; *hereafter the Project*), which will be operated under the premise of a Special Purpose Vehicle (SPV), namely, Igolide Wind (Pty) Ltd. The proposed Project, aims to bid into renewable Energy Independent Power Producer Procurement Programme (REIPPPP), or a similar procurement program under the Integrated Resource Plan (IRP)

WSP Group Africa (Pty) Ltd (WSP) was appointed by Igolide Wind (Pty) Ltd.to undertake the necessary ecological baseline studies and impact assessment in support of the scoping, baseline, and impact assessment phases of the environmental regulatory process required to authorise development-related activities.

1.1 PURPOSE OF THE REPORT

This report describes the baseline aquatic biodiversity within areas that will be impacted by the proposed Project. Potential impacts, positive or negative, were assessed and practical mitigation/management measures developed for inclusion in the Environmental Management Programme (EMPr).

1.2 PROJECT LOCATION AND EXTENT

The proposed Project is located within the Gauteng Province under the jurisdiction of the Merafong City Local Municipality, which is in the West Rand District Municipality. The current predominant land use activities within the Project area boundary are those associated with a game farm (Figure 1-1). The surrounding land use activities include farming (along the immediate Project boundary); mining (with the nearest operations being the Sibanye Driefontein approximately 1.5 km to the north, Kloof Gold Mine approximately 1.2 km to the east); and the Fochville township at the south west tip of the Project boundary. Several other mines occur within the broader Project area, namely Sibanye Stillwater, Mponeng Gold Plant and the Harmony Kusasalethu Gold Mine.

The proposed Project development area is approximately 680 hectares (ha) and the proposed footprint covers an area of approximately 50 ha (Figure 1-2).

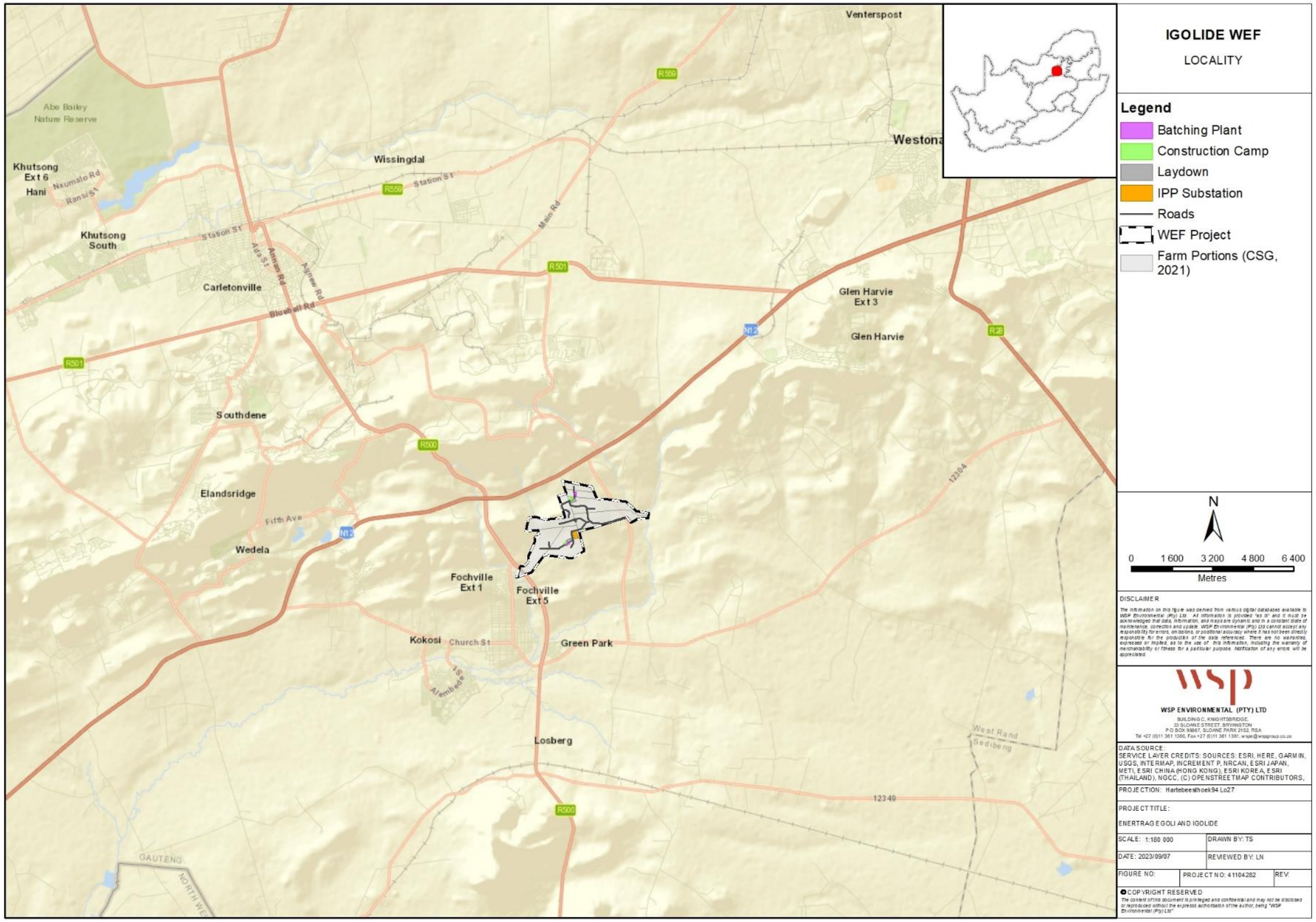

Figure 1-1 - Locality map for the proposed Igolide WEF

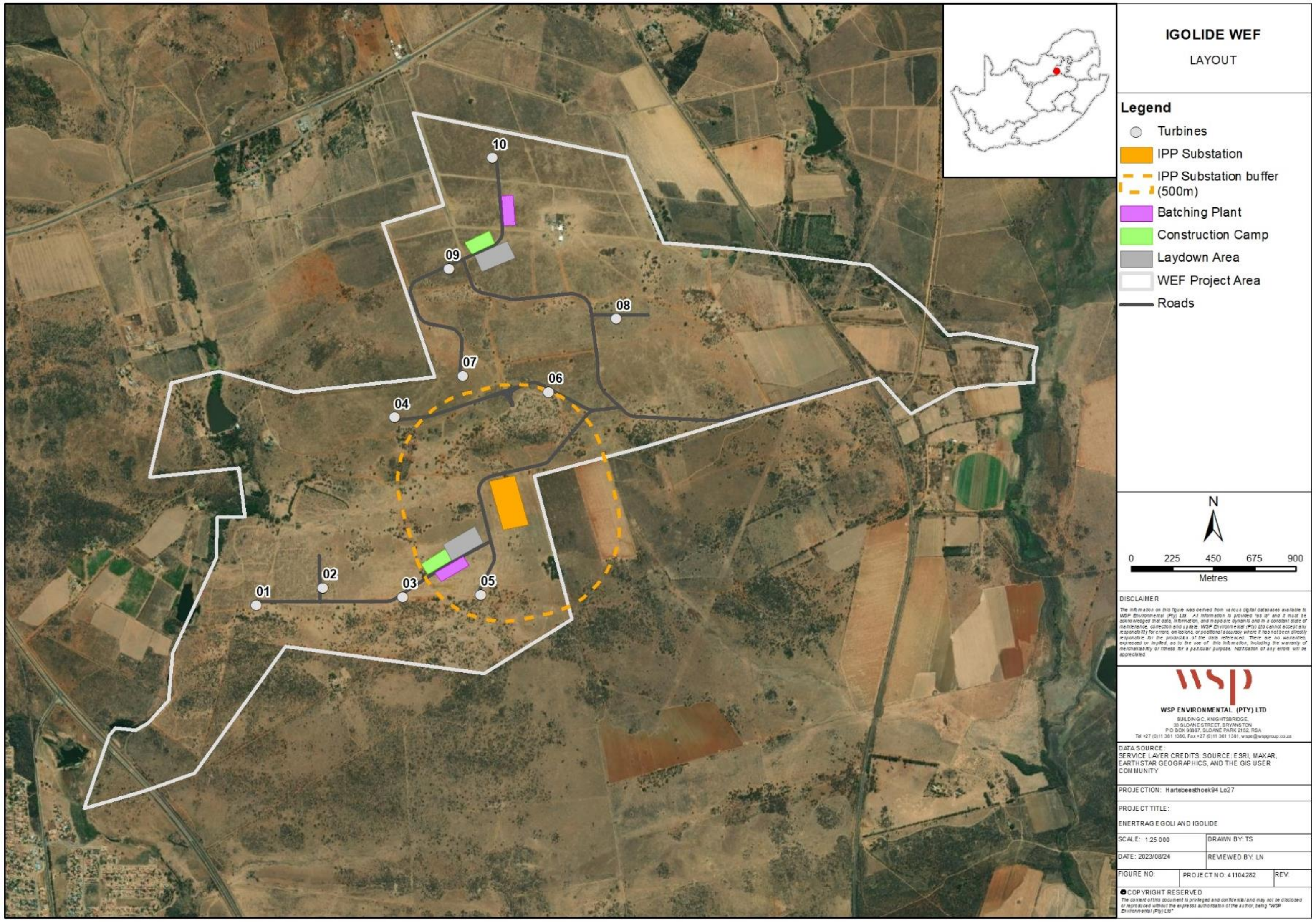

Figure 1-2 - Proposed Project layout plan

1.3 LEGAL REQUIREMENTS, STANDARDS AND GUIDELINES

The legislative context for aquatic ecology studies which applies to the proposed Project are listed and discussed below.

- **National Environmental Management Act, 1998 (Act No. 107 of 1998) (NEMA)** – Section 24 (1)(a) and (b) states that "the potential impact on the environment and socio-economic conditions of activities that require authorisation or permission by law and which may significantly affect the environment must be considered, investigated and assessed before their implementation and reported to the organ of state charged by law with authorizing, permitting, or otherwise allowing the implementation of an activity.
- **National Environmental Management: Biodiversity Act, 2004 (Act No. 10 of 2004) (NEM:BA)** – The NEM:BA regulates the management and conservation of the biodiversity of South Africa within the framework provided under NEMA. This Act regulates the protection of species and ecosystems that require national protection and considers the management of alien and invasive species.
- **National Water Act (Act No. 27 of 2014) (NWA)** – The NWA aims to protect, use, develop, conserve, manage and control water resources including rivers, dams, wetlands, the surrounding land, groundwater, as well as human activities that influence them. The NWA intends to protect these water resources against over exploitation and to ensure that there is water for social and economic development and water for the future.
- **Gauteng Conservation Plan** – this bioregional plan serves as the basis for biodiversity inputs into land use planning processes in the province and the primary informant for the biodiversity component of the Basic Assessment and Environmental Impact Assessment (EIA) processes. The C-Plan provides a map of biodiversity priorities (identified as Critical Biodiversity Areas (CBA) and Ecological Support Areas (ESA)). The CBA's are comprised of key areas that are required to meet national biodiversity pattern and process targets. ESA's are areas required to prevent the degradation of Critical Biodiversity Areas and Protected Areas (GDARD, 2014).

1.4 STUDY LIMITATIONS, ASSUMPTIONS AND EXCLUSIONS

In order to obtain a comprehensive understanding of the dynamics of the biota present within a watercourse (e.g., migratory pathways, seasonal prevalence, etc.), studies should include investigations conducted during different seasons, over a number of years and through extensive sampling efforts. Given the time constraints of the present study, such long-term research could not be conducted. Instead, conclusions provided within this report are based on data collected during a single low flow sampling event, a literature review, and professional experience.

The assessed Loopspruit upstream site is located within a narrow and shallow (approximately 1 m wide and deep) system dominated by reeds and the invasive (category 2 NEMBA) White Poplar trees (Figure 1-3), thus the sampling effort was hindered. Results obtained for this site should be interpreted with caution.

Figure 1-3 - Narrow channel (blue arrow) of the Loopspruit upstream site dominated by reeds and Poplar trees.

2 METHODOLOGY

This aquatic biodiversity and impact assessment took cognisance of Government Notice No. 320, published in 2020 under the National Environmental Management Act (1998) concerning '*Procedures for the Assessment and Minimum Criteria for Reporting on Identified Aquatic Theme in terms of Sections 24(5)(a) and (h) and 44 of the National Environmental Management Act (1998), when applying for Environmental Authorisation*'.

In line with the assessment and reporting requirements set out in the protocol, this report includes two main study components; a desktop literature review, supplemented by a field survey within the proposed development footprint and extended areas of influence. The objectives and tasks associated with these components are described below.

2.1 LITERATURE REVIEW AND GAP ANALYSIS

The aim of the desktop literature review component was to collate and review the extensive available ecological information related to important biodiversity and conservation features in the Project area, key ecological processes and function, and the likely composition and structure of local aquatic fauna communities (specifically macroinvertebrates and fish).

The following sources were consulted for the desktop literature review:

- The Desktop Assessment of the Present Ecological State (PES), Ecological Importance and Ecological Sensitivity per Sub Quaternary Reaches for Secondary Catchments in South Africa. Compiled by RQIS-RDM (DWS, 2014);
- Sibanye Stillwater Biomonitoring of Rivers and Biodiversity – Fact Sheet 2019 ((Sibanye Stillwater, 2019)); and
- National spatial planning datasets, namely the Gauteng Conservation Plan (BSP), the National Freshwater Ecosystem Priority Areas (NFEPA) and National Protected Area Expansion Strategy (NPAES).

2.2 FIELD SURVEY

This section provides a brief description of the aquatic biodiversity study approach and methodologies utilised during the field surveys and the locations that the assessments were undertaken.

STUDY APROACH

To enable an adequate description of the aquatic environment and the determination of the PES, the following stressor, habitat and response indicators were evaluated:

Water Quality

- *In situ* water quality assessment including temperature, pH, electrical conductivity, dissolved oxygen, comparison to applicable guideline values, and identification of variables of potential concern;

Habitat Indicators

- General habitat assessment including site location (GPS coordinates), site photographs and surrounding features such as land uses, potential sources of pollution, erosion etc.

- Aquatic macroinvertebrate biotope evaluation through the Invertebrate Habitat Assessment System (IHAS, Version 2.2).

Response Indicators

- Aquatic macroinvertebrate assessment, including the determination of ecological condition through the South African Scoring System (SASS Version 5) and the Macro-Invertebrate Response Assessment Index (MIRAI);
- Ichthyological assessment, including the evaluation of reference conditions and determination ecological condition through the Fish Response Assessment Index (FRAI); and
- Determination of the integrated EcoStatus (EcoStatus 4, Version 1.02).

A detailed description of the aquatic biomonitoring methodologies used for the survey is provided in Appendix A.

MONITORING SITES

Selection of the monitoring sites was based on the proposed Project footprint relative to the aquatic ecosystems likely to be impacted, i.e. upstream and downstream sites along the Loopspruit and Kraalkopspruit. Furthermore, the sites were strategically selected based on ease of accessibility and availability of suitable habitat.

Site names, GPS coordinates and brief descriptions are provided in Table 2-1 and a map of the study area showing the location of the sampling sites is presented in Figure 2-1. Photographs showing the upstream and downstream views at each monitoring location are provided in Appendix B.

Table 2-1 - Location of the sampling points and brief descriptions

River	Site	Co-ordinates	Site Description
Loopspruit	LO1	26°26'47.63"S 27°32'53.72"E	Located adjacent to the east boundary of the Project area. Site serves as an upstream reference site for the proposed Project area draining the Loopspruit catchment.
	LO2	26°27'28.00"S 27°32'56.50"E	Located approximately 1.2 km downstream of site LO1. Site to serve as a future monitoring point to quantify impacts associated with the Project activities within close proximity to the Loopspruit catchment.
Kraalkopspruit	KR1	26°26'52.11"S 27°30'11.19"E	Located approximately 1 km downstream of the N12 and 100 m upstream of dam. Site serves as an upstream reference site for the proposed Project area draining the Kraalkopspruit catchment.
	KR2	26°27'52.78"S 27°29'59.17"E	Located approximately 300 m upstream of the R500 road. Site to serve as a future monitoring point to quantify impacts associated with the Project activities within close proximity to the Kraalkopspruit catchment.

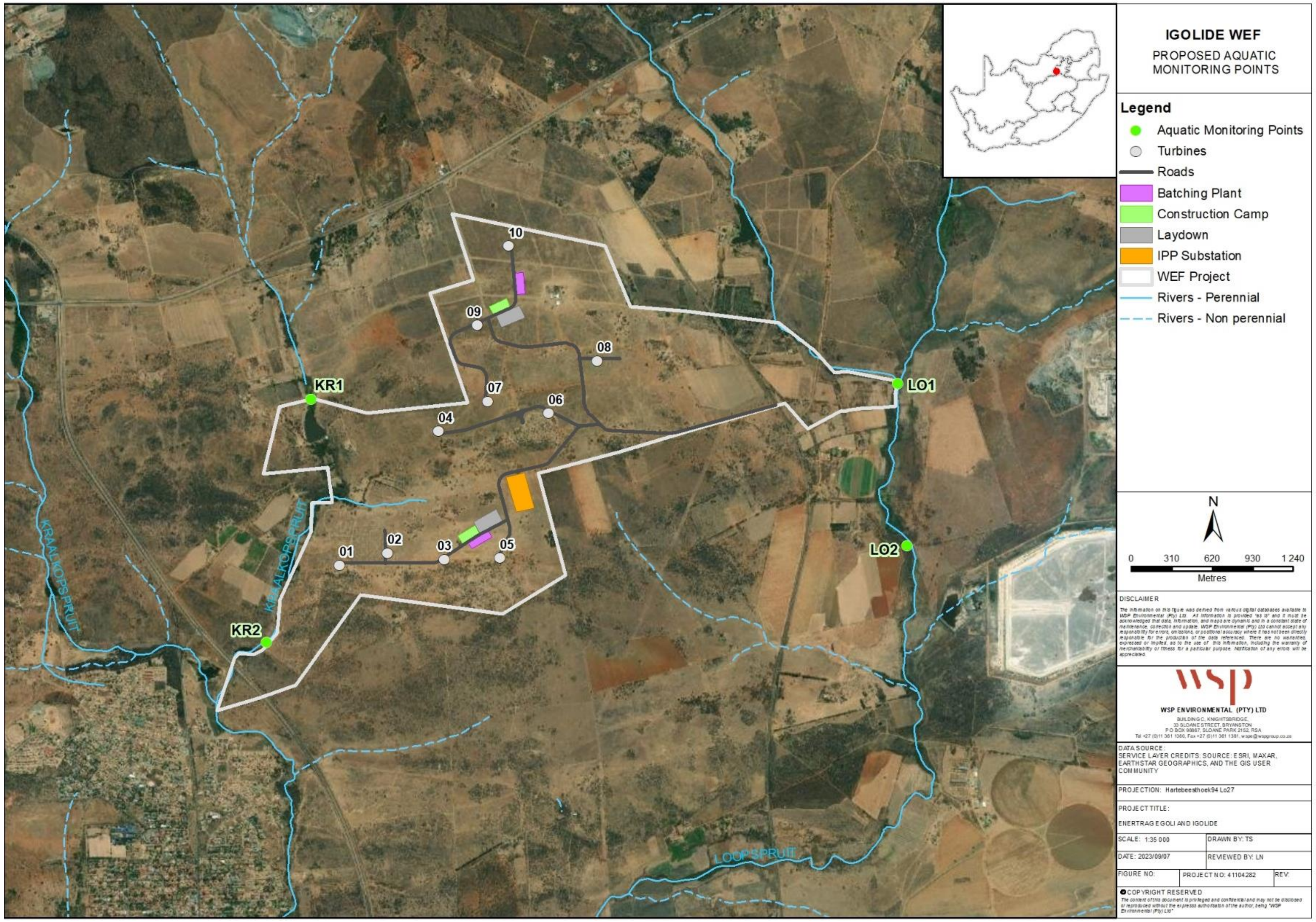

Figure 2-1 - Locations of the Aquatic Ecology sampling points

3 AQUATIC BIODIVERSITY DESKTOP ASSESSMENT

The following sections describe the physical and biological characteristics for the region within which the proposed Project is located.

3.1 FRESHWATER ECOREGIONS

Ecoregions are regions characterised by a relative similarity in the type of ecosystems and ecosystem components, i.e. biotic and abiotic. The proposed Project area is located within the Zambezian Lowveld freshwater ecoregion. This ecoregion is defined by low-lying portions of the coastal rivers south of the Zambezi Delta to Lake St Lucia (Abell *et al*., 2008; Darwall *et al.* 2009).

3.2 ASSOCIATED WATER RESOURCES

The Project lies within the primary drainage region C of the Vaal Water Management Area (WMA) and the C23J and C23D quaternary catchments draining the WEF infrastructure and a portion of the OHL respectively. The WEF infrastructure is drained by the Loopspruit SQR C23J-01487 on the east and by the Kraalkopspruit Sub-Quaternary Reach (SQR) C23J-01507 on the west (Figure 3-1). There is no riparian habitat within the C23D quaternary catchment associated with the OHL.

The Kraalkopspruit SQR is a first order stream which flows for approximately 10 km in a southward direction before joining the Loopspruit. The Loopspruit SQR is also a first order stream which flows for approximately 17 km in the southwest direction.

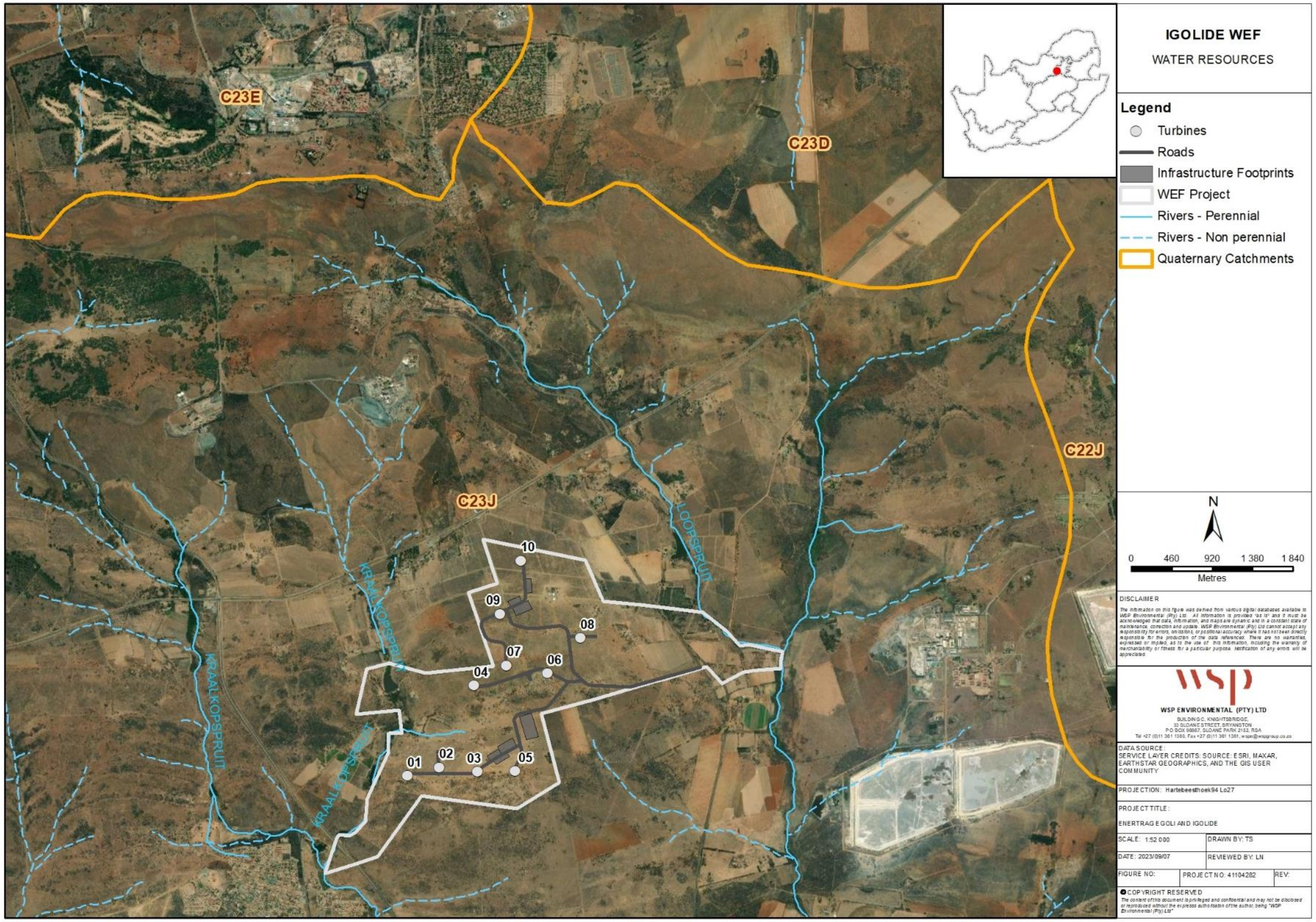

Figure 3-1 - Quaternary Catchments associated with the proposed Project

3.3 REGIONAL BIODIVERSITY CONTEXT

NATIONAL FRESHWATER ECOSYSTEM PRIORITY AREAS

The National Freshwater Ecosystem Priority Areas (NFEPA) project represents a collaboration of multiple organisations including the South African National Biodiversity Institute (SANBI), Council for Scientific and Industrial Research (CSIR), Water Research Commission (WRC), Department of Environmental Affairs (DEA), Department of Water Affairs (DWA), Worldwide Fund for Nature (WWF), South African Institute of Aquatic Biodiversity (SAIAB) and South African National Parks (SANParks). (Water Research Commision, 2011).

The project is aimed to "*provide guidance on how many rivers, wetlands and estuaries, and which ones should remain in a natural or near-natural condition to support the water resource protection goals of the National Water Act (Act 36 of 1998), the National Environmental Management: Biodiversity Act (Act 10 of 2004) and the National Environmental Management: Protected Areas Act (Act 57 of 2003)*" (Water Research Commision, 2011).

The proposed development footprint in relation to FEPA sub-catchments and mapped National Freshwater Ecosystem Priority Areas (NFEPA) rivers and wetlands is illustrated on Figure 3-2.

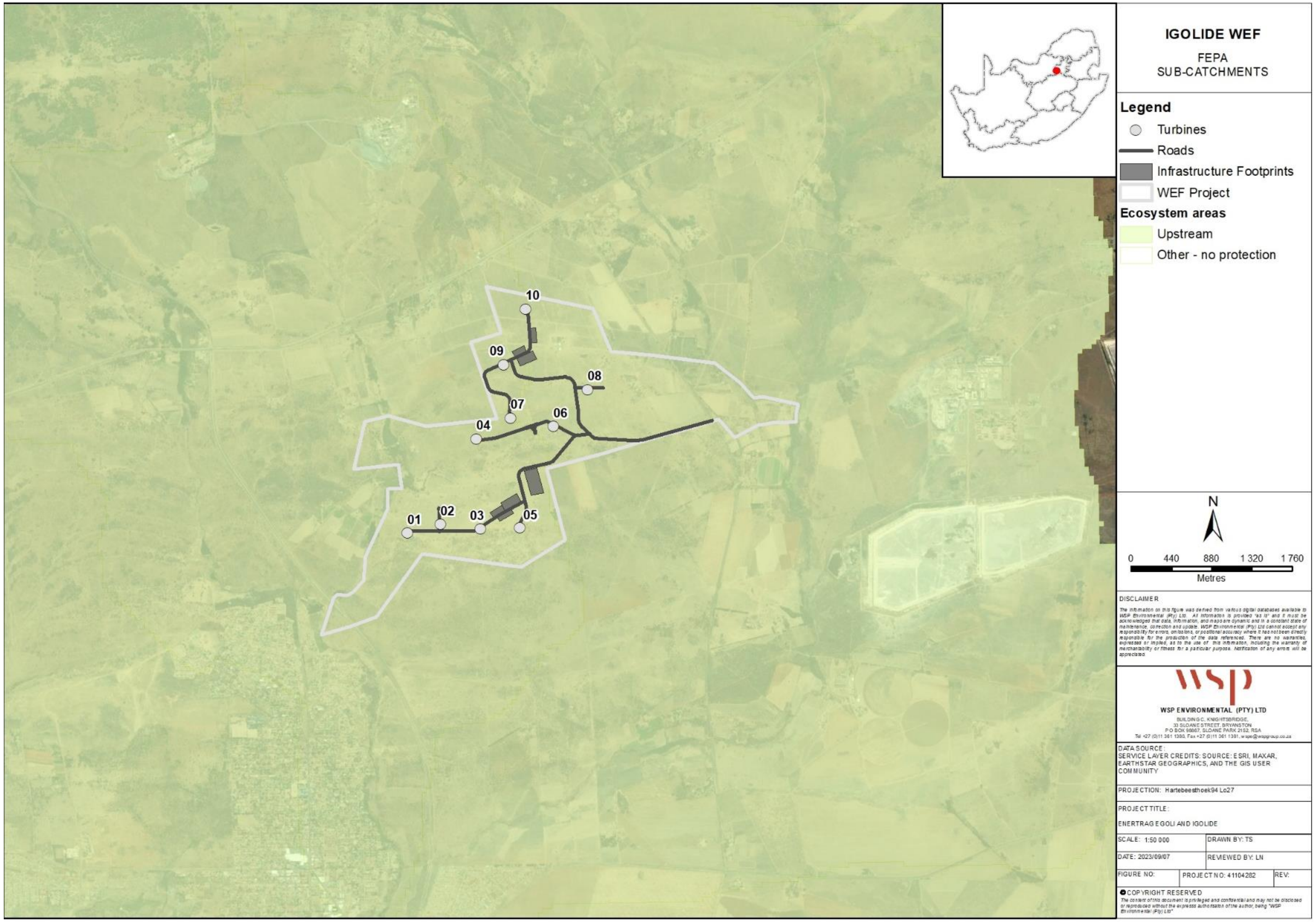

Figure 3-2 - FEPA Sub-Catchments in relation to the Study Area

GAUTENG CONSERVATION PLAN (C-PLAN)

Gauteng Nature Conservation, a component of the Gauteng Department of Agriculture and Rural Development (GDARD), produced the Gauteng Conservation Plan Version 3 (C-Plan v3) in December 2010. The latest version is C-Plan v3.3 which became available in February 2012, with a technical report being released in March 2014 (GDARD, 2014). The Plan is based on the systematic conservation protocol developed by (Margules & Pressey, 2000) of the principles of complementarity, efficiency, defensibility and flexibility, irreplaceability, retention, persistence and accountability. C-Plan 3.3 is a valuable tool in ensuring adequate protection of biodiversity and the environment in the Gauteng Province.

The main purposes of the C-Plan v3.3 are:

- To serve as the primary decision support tool for the biodiversity component of the Environmental Impact Assessment (EIA) process;
- To inform protected area expansion and biodiversity stewardship programmes in the province; and
- To serve as a basis for development of Bioregional Plans in municipalities within the province.

The Gauteng C-Plan v3.3 delineates on a map, terrestrial and freshwater biodiversity areas that are classified as Protected Areas (PAs), Critical Biodiversity Areas (CBAs), Ecological Support Areas (ESAs) or Other Natural Areas (ONAs). The proposed Project lies within isolated patches of CBA-important Areas and CBA-Ecological Support Areas (Figure 3-3).

CBAs are natural or near-natural terrestrial or aquatic areas required to meet targets for biodiversity pattern and/or ecological processes and ESAs are areas that are not essential for meeting biodiversity targets, but that play an important role in supporting the functioning of protected areas or CBAs and for delivering ecosystem services (GDARD, 2014).

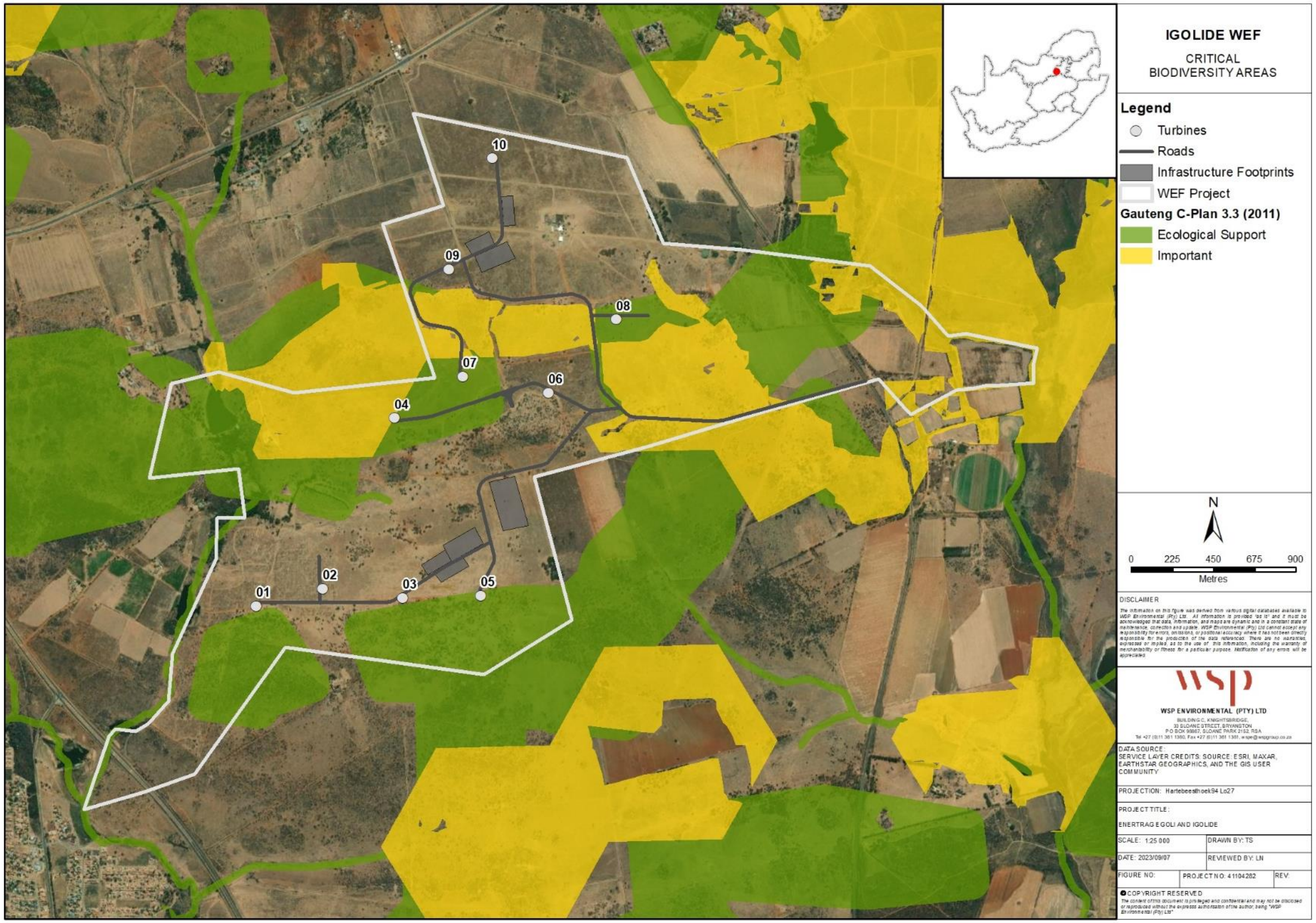

Figure 3-3 – Critical Biodiversity Areas associated with the proposed Project

PRESENT ECOLOGICAL STATE, IMPORTANCE AND SENSITIVITY

According to the DWS (2016) desktop data, the PES for the associated Kraalkopspruit and Loopspruit SQRs are *moderately modified* and *largely modified* respectively. The EIS for the Kraalkopspruit SQR is moderate and high respectively, and both moderate for the moderate for the Loopspruit SQR. The EIS categories are based on the diversity of fish and aquatic macroinvertebrate taxa expected to occur within these systems and their sensitivities to water quality modifications (Table 3-1).

Table 3-1 - Desktop PESEIS for the focus Sub-Quaternary Reaches

River	Kraalkopspruit	Loopspruit
SQR Code	C23J-01507	C23J-01487
Ecological Category	**C**	**D**
Category Description	Moderately Modified	Largely Modified
Ecological Importance (EI)	Moderate	Moderate
Ecological Sensitivity (ES)	High	Moderate
No. of fish species	5	4
No. of aquatic invert taxa	42	41

EXPECTED FISH SPECIES AND AQUATIC MACROINVERTEBRATE TAXA

The expected fish species and aquatic macroinvertebrate taxa for the SQRs associated with the proposed Project are presented in Table 3-2 and Table 3-3 respectively. Five fish species are expected, all of which are categorized as Least Concern (LC) according to the IUCN Red List of Threatened Species. The fish species tolerances to modified water quality and no-flow conditions vary between tolerant to moderately intolerant.

A total of 42 aquatic macroinvertebrate taxa are expected within the study area. The community assemblage is predominantly comprised of taxa with a high preference for slow flows, and with very low sensitivities toward water quality modifications. Few taxa have a high requirement for fast flowing water (i.e., Ceratopogonidae, Chironomidae, Simuliidae, Tipulidae and Ancylidae).

Table 3-2 - Expected fish species, respective tolerance/intolerance to water quality modifications, no-flow conditions, and IUCN conservation status

SQR		Fish Species	Tolerance		Conservation Status
			Modified Water Quality	No-Flow	
C23J-01507	C23J-01487	*Tilapia sparrmanii*	Tolerant	Tolerant	LC
		Enteromius anoplus	Moderately tolerant	Moderately tolerant	LC
		Enteromius paludinosus	Tolerant	Moderately tolerant	LC
		Pseudocrenilabrus philander	Tolerant	Tolerant	LC
		Enteromius pallidus	Moderately Intolerant	Moderately tolerant	LC

Table 3-3 – Expected SASS5 aquatic macroinvertebrates

Taxa/Family names		
Turbellaria	Gerridae	Chironomidae

Taxa/Family names		
Oligochaeta	Hydrometridae	Culicidae
Hirudinea	Naucoridae	Muscidae
Potamonautidae	Nepidae	Psychodidae
Atyidae	Notonectidae	Simuliidae
Hydracarina	Pleidae	Syrphidae
Baetidae > 1 sp	Veliidae/mesoveliidae	Tabanidae
Caenidae	Hydropsychidae 1 sp	Tipulidae
Coenagrionidae	Hydroptilidae	Ancylidae
Aeshnidae	Leptoceridae	Lymnaeidae
Gomphidae	Dytiscidae	Physidae
Libellulidae	Gyrinidae	Planorbinae
Belostomatidae	Hydrophilidae	Corbiculidae
Corixidae	Ceratopogonidae	Sphaeriidae

4 RESULTS AND DISCUSSION

Results for the aquatic biodiversity assessment undertaken on the 21st of June 2023 are discussed in the below sections. The results have been separated per SQR and presented from upstream site to downstream site for ease of interpretation.

4.1 FLOW CONDITIONS AND GENERAL HABITAT OBSERVATIONS

Flow conditions influence the processes that determine the size, shape, structure and dynamics of the aquatic ecosystems, and subsequently linked to habitats and biotic communities (Thoms & Thoms, 2006). Thus, flow conditions and water levels aid in the interpretation of biological results.

The assessed Loopspruit and Kraalkopspruit reaches are predominantly characterised by narrow and shallow streams with the hydrological regime largely influenced by the presence of impoundments along the river systems. Each of the assessed sites were in flow at the time of the survey. The Loopspruit upstream site (LO1) and the Kraalkopspruit downstream site (KR2) were characterised by a gentle slope dominated by a sandy stream bed, thus the flow velocity was slow-to-moderate. The Loopspruit downstream site (LO2) and the Kraalkopspruit upstream site (KR1) were characterised by rocky stream beds with moderate-to-fast flows resulting in riffles (Figure 4-1). These features are characteristic of rivers which lie within the upper foothills longitudinal zone (Class D; Rowntree et al., 2000).

There was no sign of recent disturbances at or near the assessed river reaches at the time of the survey. However, algae was prevalent within the Kraalkopspruit at both sites (Figure 4-2), indicating some nutrient enrichment or mild eutrophication. This was likely attributed to the upstream farming activities i.e. diffuse surface run-off of fertilizers into the river (Hodgkin & Hamilton, 1993).

Figure 4-1 - Photos showing flow conditions at time of the survey. Slow-to-moderate flow velocity (Top) and moderate-to-fast (Bottom)

Figure 4-2 – Algae indicating signs of eutrophication at site KR2

4.2 *IN SITU* WATER QUALITY

In situ water quality parameters were measured on site as a component of the habitat and biotic surveys. The variables in temperature, pH, electrical conductivity and dissolved oxygen were measured by means of portable water meters, which were calibrated prior. Although a snapshot of the water quality at the time of the survey, these data are important to assist in the interpretation of biological results due to the direct influence water quality has on aquatic life forms, while providing an indication of the physico-chemical status of the water at a sampling site at the time of the survey.

Results were referenced against various water quality guidelines shown in Table 4-1.

Table 4-1 - Sources for the recommended water quality guidelines for aquatic ecosystems

Variable	Source	Guideline limit
Temperature	South African Water Quality Guidelines: *Aquatic Ecosystems (Volume 7)* (Department Of Water Affairs And Forestry, 1996)	5 – 30 ˚C
pH		6 – 8
Dissolved Oxygen % Saturation		80 – 120 %
Dissolved Oxygen concentration	Minimum Dissolved Oxygen concentration for aquatic macroinvertebrates (Nebeker et al., 1996)	> 5 mg/ℓ
Electrical Conductivity	Conductivity guideline value of 500 µS/cm stipulated in U.S. U.S. Environmental Protection Agency (2010)	< 500 µS/cm

Table 4-2 – *In situ* water quality data

Sites	Time	T (ºC)	pH	EC (µS/cm)	DO (mg/l)	DO (%)
TWQR	**-**	**5 - 30º**	**6 - 8**	**< 500**	**> 5.0**	**80 - 120**
Loopspruit						
LO1	16h08	10.4	7.26	697	3.97	64.2
LO2	16h45	11.5	7.21	852	5.65	76.1
Kraalkopspruit						
KR1	10h54	12.01	7.50	430	4.81	72.4
KR2	14h02	13.3	7.23	463	4.62	70.7
T = Temperature; EC = Electrical Conductivity; TDS = Total Dissolved Solids; DO = Dissolved Oxygen						
Red highlights represent values which have either exceeded or fallen below the guideline values						

TEMPERATURE

Temperature plays an important role in water by affecting the rates of chemical reactions and consequently the metabolic rates of organisms. Temperature is therefore one of the major factors controlling the distribution of aquatic organisms (DWAF, 1996). In the current study, temperature values ranged between 10.4 ºC (at LO1) and 13.3 ºC (at KR2), thus all the values fell within the range for inland water temperatures in South Africa. The temperature at all sites was not expected to limit the occurrence aquatic biota.

PH

The pH value is a measure of hydrogen (H^+), hydroxyl (OH^-), bicarbonate (HCO_3^-) and carbonate (CO_3^{2-}) ions in water (Dallas & Day, 2004). In natural water, pH is determined by geological influences and biotic activities and may also vary both diurnally and seasonally. Diurnal fluctuations occur in productive systems, where the rates of photosynthesis and respiration vary over a 24-hour period. Most fresh waters in South Africa are relatively well buffered and more or less neutral, with pH ranges between 6 and 8 (DWAF, 1996).

The pH values recorded during the survey were circumneutral (close to neutral pH 7) and ranged between 7.21 and 7.5, thus were within the recommended guideline limits.

ELECTRICAL CONDUCTIVITY

Electrical Conductivity (EC) is a measure of the ability of water to conduct an electrical current. This ability is a result of the presence in water of dissolved ions, which carry an electrical charge. The EC in natural waters varies in part on the characteristics of geological formations which the water has been in contact with and the dissolution of minerals in soils and plant matter. Anthropogenic sources of increased dissolved salts include domestic and industrial effluent discharges and surface runoff from urban, industrial and cultivated areas (DWAF, 1996).

The recorded EC levels ranged between 430 µS/cm (at site KR1) and 852 µS/cm (at site LO2) and exceeded the recommended guideline limit of 500 µS/cm at both Loopspruit sites. EC levels within the Kraalkopspruit were expected to be higher due to the suspected presence of nutrients associated with the farming activities, thus the lower EC levels may have been a result of the algae absorbing the nutrients (Kraan, 2013; Nguyen et al., 2022).

DISSOLVED OXYGEN

The maintenance of adequate Dissolved Oxygen (DO) is critical for the survival of aquatic biota as it is required for the respiration of all aerobic organisms (DWAF, 1996). Therefore, DO concentration provides a useful measure of the health of an ecosystem (DWAF, 1996). The median guideline for DO for the protection of freshwater fish, determined by a variety of fish faunas is > 4 - 5 mg/l (Doudoroff & Shumway, 1970; DWAF, 1996) and that of aquatic macroinvertebrates is ≥ 5 mg/l (Nebeker, Onjukka, Stevens, & Chapman, 1996).

The dissolved oxygen levels were predominantly low and recorded below the recommended guideline limits throughout the sites except at LO2 where the DO concentration recorded within the guideline limit. The DO concentration at this site was attributed to the cascading water within the rocky section which facilitated the entrapment of oxygen from the atmosphere. The low DO saturation levels indicate that the oxygen levels had been depleted from the theoretical equilibrium possibly due to the presence of contaminants.

Overall, the water quality was determined to be modified at each of the assessed sites. These modifications were based on the exceedance of at least one of the measured parameters from the recommended guidelines:

- The Loopspruit sites exceeded the recommended EC guideline, with an increase in deterioration along the longitudinal section of the river.
- The Loopspruit sites exceeded the recommended DO guideline levels, expect the DO concentration at the downstream site. DO levels increased along the longitudinal section of the river.
- Only DO levels exceeded the recommended guideline limits at the Kraalkopspruit, potentially indicating the presence of contaminates influencing the DO saturation.

4.3 DIATOMS ASSESSMENT

Diatoms are unicellular organisms most widely used as indicators of river health. They are cosmopolitan, have a rapid life cycle and can provide a rapid response to specific physico-chemical conditions in water. The presence or absence of indicator taxa can be used to detect specific changes in environmental conditions such as eutrophication, organic enrichment, salinization and changes in pH.

In the current study, diatom samples were collected from each of the assessed sites and submitted to Ecotone Freshwater Consultants CC (independent specialist) for analysis. The index scores and ecological water quality are presented in Table 4-3 and a summary of the results is provided below. Refer to Appendix C which contains the comprehensive Diatom Report for more detail.

A total of 79 diatom species were recorded at the four sites and the diatom assemblages were generally comprised of species characteristic of fresh brackish (< 500 µS/cm), circumneutral (pH 6.5 to 7.5) water, eutrophic conditions and low to moderate requirements for dissolved oxygen saturation. These were consistent with the findings of the *in situ* water quality assessment (section 4.2) – apart from the electrical conductivity values which were above 500 µS/cm at both Loopspruit sites (697 and 852 µS/cm at sites LO1 and LO2 respectively. It is important to note that diatom communities reflect ecological conditions over a period of 2 to 3 weeks whereas the recorded *in situ* water quality parameters represent a snapshot of the water quality at the time of the survey.

The diatom-based ecological water quality reflected *Moderate* conditions with moderate levels of organic pollution at the Loopspruit upstream site LO1 and *Poor* conditions with high levels of organic pollution at the downstream site LO2. The Kraalkopspruit upstream site KR1 reflected *Moderate* conditions with low to moderate organic pollution and the downstream site KR2 reflected *Good* conditions with low organic pollution.

Table 4-3 - Diatom index scores and ecological water quality

River	Site	%PTV	SPI	Ecological Category	Class
Loopspruit	LO1	37.8	9.6	C	Moderate
	LO2	59.8	6	D	Poor
Kraalkopspruit	KR1	21	10.5	C	Moderate
	KR2	5	16.1	B	Good

4.4 HABITAT ASSESSMENT

Habitat quality and availability plays a critical role in the occurrence of aquatic biota. For this reason, habitat evaluation is conducted simultaneously with biological evaluations in order to facilitate the interpretation of results (Ollis et al., 2006). The quality of the instream and riparian habitat influences the structure and function of the aquatic community in a stream; therefore, assessment of the habitat is critical to any assessment of ecological integrity.

The Index for Habitat Integrity (IHI) was applied to determine the instream and riparian habitat integrity and the Integrated Habitat Assessment System (IHAS) was applied to determine the availability and integrity of aquatic macroinvertebrate habitat.

INDEX FOR HABITAT INTEGRITY

The Index for Habitat Integrity (IHI) is a rapid, visual assessment of modifications to a number of pre-selected biophysical drivers and used to determine the PES or Ecological Category of associated instream and riparian habitats (Kleynhans et al., 2008).

The IHI assessment was completed on a desktop-level for each aquatic ecosystem considered in the present study and populated with observations recorded during the field survey. Results are presented in Table 4-4.

Table 4-4: IHI findings for the watercourses associated with the proposed Project

River	Habitat	IHI Score	EC	Major Impacts
Loopspruit	Instream	57.2	D	Flow modification, water abstraction and water quality
	Riparian	57.8	D	Indigenous vegetation removal exotic vegetation encroachment
Kraalkopspruit	Instream	59.0	D	Flow modification, water abstraction and water quality
	Riparian	60.5	C	Indigenous vegetation removal exotic vegetation encroachment

The findings from the IHI assessments conducted during the current survey indicate that the habitat integrity was *largely modified* (Class D) for the instream and riparian habitat components at the Loopspruit; *largely modified* for the instream habitat and *moderately modified* (Class C) for the riparian habitat at the Kraalkopspruit. The observed major impacts of the instream habitat were flow modification, water abstraction and water quality; the removal of indigenous vegetation and exotic vegetation encroachment for the riparian habitat. The mining and farming activities were the likely sources of these impacts i.e. discharge of mine water, use of fertilizers, presence of dams, and clearing of indigenous vegetation.

4.5 AQUATIC MACROINVERTEBRATE ASSESSMENT

The following sections provide insight on the data collected as part of the aquatic macroinvertebrate assessment. The South African Scoring System (SASS, Version 5) and available habitat (Invertebrate Habitat Assessment System) that was sampled at each of the suitable sites, as well as the subsequent determination of the ecological condition of the observed assemblages in relation to reference conditions (Macroinvertebrate Response Assessment Index; MIRAI) are discussed.

INTEGRATED HABITAT ASSESSMENT SYSTEM

The Integrated Habitat Assessment System (IHAS) was developed by McMillan (1998) for use in conjunction with the South African Scoring System (SASS5) bioassessment. Results from the current study are provided in Table 4-5.

The assessed ecosystems lie within the upper foothills geomorphological zone (Class). This geomorphological zone is characteristic of moderately steep, cobble-bed channel, with plain-bed, pool-riffle or pool-rapid reach types. Length of pools and riffles/rapids similar. Narrow flood plain of sand, gravel or cobble often present (Rowntree et al., 2000). As such, sites LO2 and KR1 were dominated by the stones-in-current biotope, whilst the sand biotope dominated sites KR2 and LO1. Marginal vegetation was present in varying extents and all the sites lacked aquatic macrophytes.

Based on the obtained IHAS scores, the Loopspruit downstream site LO2 and the Kraalkopspruit upstream site KR1 presented *adequate* macroinvertebrate habitat availability, whilst the Loopspruit upstream site LO1 and the Kraalkopspruit downstream site KR2 presented *poor* macroinvertebrate habitat availability. Therefore these sites were not expected to host macroinvertebrate assemblages comprising of high diversity of taxa.

Table 4-5 - Integrated Habitat Assessment System scores

River	Site	Sampling Habitat				IHAS	
		Stones-in-Current	Vegetation	Other Habitat	Physical Stream Condition	Score	Description
Loopspruit	LO1	0	9	7	28	44	Poor
	LO2	15	9	11	30	65	Adequate
Kraalkopspruit	KR1	15	7	12	31	65	Adequate
	KR2	0	10	10	28	48	Poor
Maximum possible scores for Stones-in-Current = 20; Vegetation = 15; Other Habitat/General = 20; Physical Stream Condition = 45							

ECOLOGICAL CONDITION OF THE AQUATIC MACROINVERTEBRATE ASSEMBLAGES

The SASS5 protocol provides a general indication of the current state of the macroinvertebrate community and subsequently the 'health' of the river ((Dickens & Graham, 2002). The collected SASS5 data is provided in Table 4-6 and the list of the SASS5 taxa in Appendix D.

A total of 26 aquatic macroinvertebrate taxa were collected from the four sites. The community assemblage was similar in composition throughout the sites with a low diversity compared to the expected number of taxa. Pollution-tolerant taxa dominated the assemblages, thus indicating water quality modifications as seen with the *in situ* water quality and the diatom community assessments (sections 4.2 and 4.3).

The Kraalkopspruit sites hosted the highest number of taxa (16 at site KR1 and 18 at site KR2) compared to the Loopspruit with only 9 taxa at site LO1 and 13 at site LO2. This finding was likely linked to the better water quality based on the recorded *in situ* parameters (section 4.2). Furthermore, sites KR2 recorded the highest diversity of invertebrates despite the *poor* habitat availability (section 4.4). This suggests that habitat availability was not a major driver influencing the invertebrate community assemblages.

The SASS5 data obtained was used in the MIRAI (Thirion, 2008) to determine the Present Ecological State (PES, or Ecological Category) of the associated macroinvertebrate assemblage. The MIRAI provides a habitat-based cause-and-effect basis to interpret the deviation of the aquatic macroinvertebrate community from the reference condition. Results for the site-based MIRAI are shown in Table 4-7.

Based on the MIRAI, the ecological condition of the aquatic macroinvertebrate communities were *Critically Modified* at site LO1, *Seriously Modified* at sites LO2 and KR1 and *Largely Modified* at site KR2. These modifications were as a result of the change from reference conditions, especially within the flow and water quality metrics and the overall low diversity present within the assessed systems. Furthermore, the historic and on-going land use activities (mainly mining and agriculture) within the study area have significantly impacted the receiving environment and subsequently the indigenous fauna and flora including aquatic biota.

Table 4-6 – SASS5 data

River	Site	SASS5 score	Number of Taxa	ASPT
Loopspruit	LO1	36	9	4
	LO2	65	13	5
Kraalkopspruit	KR1	82	16	5,1
	KR2	75	18	4,2
ASPT = Average Score Per Taxon; EC = Ecological Category				

Table 4-7 – MIRAI data for the low flow survey

River	Site	Metric Group % change from Reference		MIRAI Value	EC	Description
Loopspruit	**LO1**	Flow Modification	98	12.5	**F**	Critically Modified
		Habitat	80			
		Water Quality	82			
	LO2	Flow Modification	65	34.4	**E**	Seriously Modified
		Habitat	65			
		Water Quality	68			
Kraalkopspruit	**KR1**	Flow Modification	71	37.3	**E**	Seriously Modified
		Habitat	51			
		Water Quality	64			
	KR2	Flow Modification	68	39.1	**D**	Largely Modified
		Habitat	54			
		Water Quality	60			

4.6 ICTHYOFAUNA

The composition of fish communities is often altered by anthropogenic activities in the catchment. Changes in water quality, flows and habitat can result in the absence or addition of species, ultimately altering the biotic integrity of the system. Thus, fish can effectively give an indication into the degree of modification of the aquatic environment.

Fish sampling was undertaken by means of the electroshocking technique at sites with suitable fish habitat. The collected fish specimens were identified in the field and released back into the river.

A total of 62 specimens comprising of three species out of the expected five species, were recorded in the current study (Table 4-8). A single species was collected at sites LO2 and KR2 (*Enteromius anoplus* and *Tilapia sparrmanii* respectively), and two species at site KR1. None of which are of conservation concern according to the IUCN Red List of Threatened Species (IUCN, 2023).

Table 4-8 - Collected fish species per site

Species	Common Name	LO2	KR1	KR2
Enteromius anoplus	Chubby Head Barb	10	31	-
Pseudocrenilabrus philander	Southern Mouthbrooder	-	15	-
Tilapia sparrmanii	Banded Tilapia	-	-	6

BIOTIC INTEGRITY BASED ON FISH COMMUNITIES

The Fish Response Assessment Index (FRAI) was applied to determine the ecological integrity of the fish community assemblages within the monitoring sites for the current study. FRAI forms part of the River EcoStatus Monitoring Programme (REMP), which replaced the RHP in 2016 and is a component of the National Aquatic Ecosystem Health Monitoring Programme (NAEHMP) (Kleynhans, 2007).

FRAI is based on a combination of fish species habitat preferences, as well as intolerance to habitat changes, and the present frequency of occurrence (FROC) of species compared to the reference FROC (Kleynhans, 2007). This provides a cause-and-effect basis to interpret the deviation of the fish assemblage from the reference condition.

FISH HABITAT POTENTIAL ASSESSMENT

Fish habitat potential refers to the presence and abundance of suitable conditions for fish to inhabit, depending on the expected species' preferences for the particular river reach. The considered habitat metric groups are velocity-depth and cover – with five types of cover within each of the four velocity-depth classes (Table 4-9).

Table 4-9 – Fish habitat potential assessment metric groups.

Slow-Deep	Slow-Shallow	Fast-Deep	Fast-Shallow
Overhanging veg.	Overhanging veg.	Overhanging veg.	Overhanging veg.
Undercut banks	Undercut banks	Undercut banks	Undercut banks
Substrate	Substrate	Substrate	Substrate
Aquatic veg.	Aquatic veg.	Aquatic veg.	Aquatic veg.
Water column	Water column	Water column	Water column

The sampled fish habitat potential was rated between 0 to 5 (1 = rare; 2 = sparse; 3 = common; 4 = abundant; 5 = very abundant) at each of the monitoring sites (Figure 5-9). These ratings were considered in the determination of the expected frequency of occurrence (FROC) for each fish species.

Overall, the fish habitat cover types at the assessed sites were predominantly substrate and overhanging vegetation within the slow-shallow and fast-shallow velocity-depth classes. Therefore, the expected fish species recorded were largely those with a preference for these habitat types.

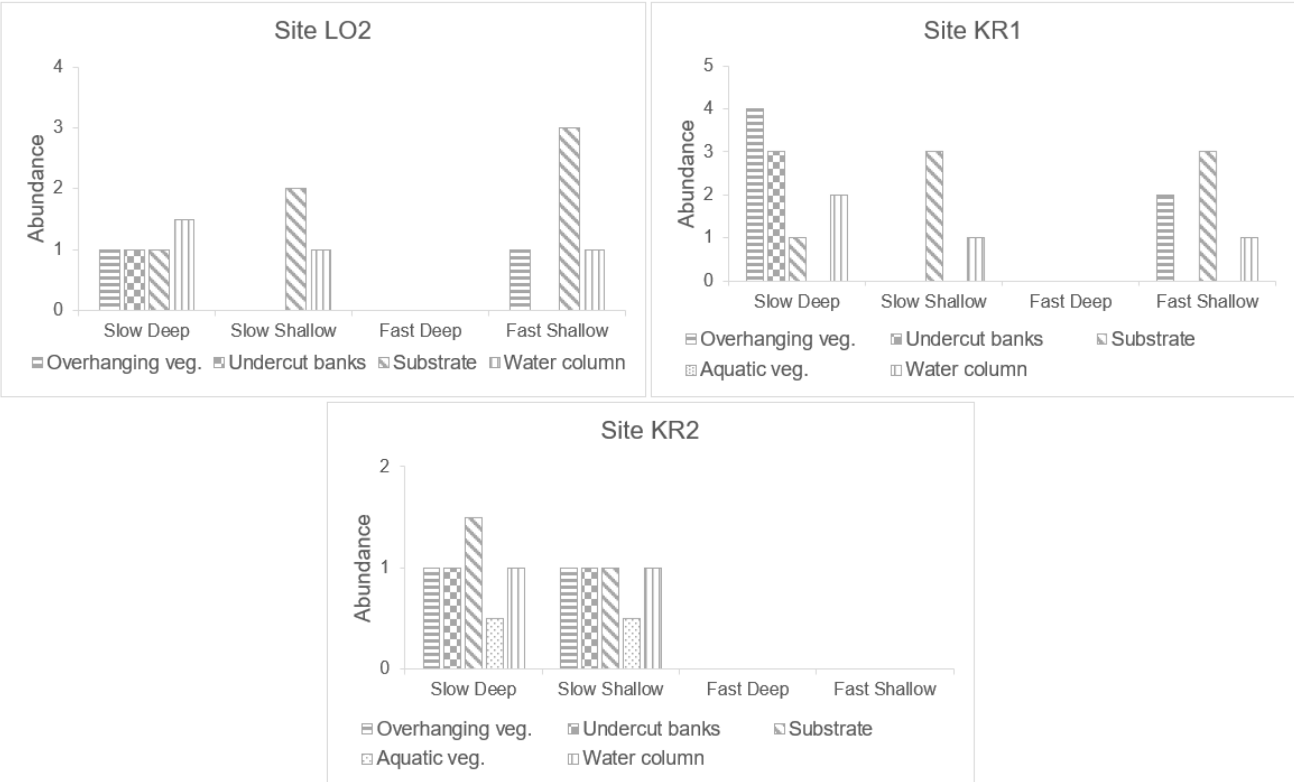

Figure 4-3 – Fish habitat metric group abundances

FISH RESPONSE ASSESSMENT INDEX (FRAI)

Results for the FRAI assessment have been provided for each assessed river reach (Table 4-10) and discussed below. Also provided is the reference and observed FROC per fish species.

All five species were expected to occur within the study area at the time of the survey based on their habitat preferences. The absence of *E. paludinosus and E. pallidus* was concerning as both species prefer habitat that was present at the time of the survey i.e., over-hanging vegetation and substrate within slow-shallow sections, and are tolerant to modified water quality (DWS, 2016). This suggests potential impacts deterring these species. The subsequent biotic integrity was *Largely Modified* (Ecological Category of D) at sites LO2 and KR1 and *Seriously Modified* (Ecological Category E) at site KR2.

Table 4-10: Biotic integrity based on FRAI

Fish Species	Common Name	Frequency of Occurrence	
		Reference	Observed
Site LO2			
Enteromius anoplus	Southern Mouthbrooder	3	3
Enteromius paludinosus	Goldie Barb	4	0
Pseudocrenilabrus philander	Banded Tilapia	4	0
Tilapia sparrmanii	Chubby Head Barb	3	0
Present Ecological State			

Fish Species	Common Name	Frequency of Occurrence	
		Reference	Observed
FRAI (Automated) %			**49 (D)**
Site KR1			
Enteromius anoplus	Southern Mouthbrooder	4	5
Enteromius pallidus	Straightfin Barb	5	0
Enteromius paludinosus	Goldie Barb	4	0
Pseudocrenilabrus philander	Banded Tilapia	5	4
Tilapia sparrmanii	Chubby Head Barb	4	0
Present Ecological State			
FRAI (Automated) %			**54 (D)**
Site KR2			
Enteromius anoplus	Southern Mouthbrooder	5	0
Enteromius pallidus	Straightfin Barb	4	0
Enteromius paludinosus	Goldie Barb	5	0
Pseudocrenilabrus philander	Banded Tilapia	5	0
Tilapia sparrmanii	Chubby Head Barb	5	3
Present Ecological State			
FRAI (Automated) %			**27 (E)**

4.7 INTEGRATED ECOSTATUS DETERMINATION

The EcoStatus is defined as: "*The totality of the features and characteristics of the river and its riparian areas that bear upon its ability to support an appropriate natural flora and fauna and its capacity to provide a variety of goods and services*" (Iversen *et al*., 2000). Thus the EcoStatus represents an integrated ecological state representing the drivers (hydro-morphology and physico-chemical) and responses (riparian vegetation, aquatic invertebrates and fish; Kleynhans & Louw, 2008). The integrated EcoStatus for the sampled river reaches associated with the Project Area are presented in Table 4-11.

Following integration of the defined ecological conditions obtained for the riparian component (i.e. IHI from riparian vegetation assessment) and the instream biological integrity (i.e. MIRAI from aquatic invertebrates and FRAI from fish), it was determined that the sampled reaches represented an integrated EcoStatus of *Largely Modified* conditions (Ecological Category D). The EcoStatus for site LO1 could not be determined because FRAI was not completed.

In relation to the Recommended Ecological Category (REC), the assessed systems were observed to be in line with the stipulated Ecological Category of a D, as gazetted in April 2016 (*Classes and Resource Quality Objectives of Water Resources for Catchments of the Upper Vaal in Terms of Section 13(1)(A) and (B) of the National Water Act, 1998 (Act No.36 of 1998)*, 2016). It should be noted that the Integrated Unit of Analysis (IUA) referred to for the REC was that of the Loopspruit reach within the C23K catchment wherein the streams understudy drain into.

Table 4-11 – Integrated EcoStatus categories for the current study – EcoStatus version 1.02 (Kleynhans and Louw, 2007)

River	System	Response Indices				EcoStatus	
		Riparian Vegetation EC (IHI)	MIRAI EC	FRAI EC	Instream EC	Score	Category
Loopspruit	**LO1**	Not Assessed					
	LO2	57.8	34.4	49	39.1	49.6	D
Kraalkopspruit	**KR1**	60.5	37.3	54	42.7	52.7	D
	KR2	60.5	39.1	27	34.3	48.3	D

5 SCREENING OF POTENTIAL IMPACTS

This section identifies and assesses the significance of the impacts likely to arise during the proposed activities and provide a short description of the mitigation required to limit the magnitude of the potential impact on the aquatic biodiversity receptors.

The proposed Project activities and placement of infrastructure to be considered as part of the impact assessment are listed below.

Foundation:	Approximately 25m diameter x 3m deep – 500 m^3 – 650m^3 concrete. Volume to be excavated will be approximately 2 200m^3, in sandy soils due to access requirements and safe slope stability requirements.
Turbine Hardstand:	Hardstand does not require concrete. Area required will be approximately 1 ha per turbine.
Tower Type	Steel or concrete towers can be utilised at the site. Alternatively, the towers can be of a hybrid nature, comprising concrete towers and top steel sections.
On-site IPP substation and battery energy storage system (BESS):	The total footprint for the on-site substation, including the BESS, will be up to 2.5ha in extent. The on-site IPP portion substation will consist of a high voltage substation yard to allow for multiple up to 132kV feeder bays and transformers, control building, telecommunication infrastructure, and other substation components, as required. A 500m buffer around the on-site IPP substation has been identified to ensure flexibility in routing the powerline. The BESS storage capacity will be up to 100MW/400 megawatt-hour (MWh) with up to four hours of storage. It is proposed that Lithium Battery Technologies, such as Lithium Iron Phosphate, Lithium Nickel Manganese Cobalt oxides or Vanadium Redox flow technologies will be considered as the preferred battery technology; however, the specific technology will only be determined following Engineering, Procurement, and Construction (“EPC”) procurement. The main components of the BESS include the batteries, power conversion system and transformer which will all be stored in various rows of containers. The BESS components will arrive on site pre-assembled.
Cables:	The medium voltage collector system will comprise cables up to and including 33kV that run underground, except where a technical assessment suggests that overhead lines are required, connecting the turbines to the on-site IPP substation.
Operations and Maintenance (O&M) building and storerooms:	The Operations and Maintenance (“O&M”) building footprint will be located near the on-site substation. Typical areas include: - Operations building – 20m x 10m = 200m^2 - Workshop and stores area – of ~300m^2 - Refuse area for temporary waste storage and conservancy tanks to service ablution facility. The total combined area of the buildings will not exceed 5 000m^2.

Construction camps:	The construction camp will house the contractor offices, ablution facilities, mess area, etc., and will have a footprint of 1ha. The construction camp will be demolished after commercial operations date and the area rehabilitated.
Temporary laydown or staging areas:	The laydown area will be used for the storage of equipment or components that will be incorporated into the facility (such as electrical cables) as well as non-facility related equipment and components such as shipping frames, concrete shuttering, etc. The laydown area will also be used for the storage (and filling of vehicles) of diesel fuel. The laydown area will have a footprint of up to 2ha, which could increase to 3ha for concrete towers, should they be required. The laydown area will be demolished after commercial operations date and the area rehabilitated.
Cement Batching Plant (temporary):	The cement batching plant will be used to mix and blend cement, water, sand and aggregates to form quality concrete to be used for foundations. The cement batching plant will have a footprint of 1ha.
Access and Internal Roads:	Access and internal roads will have a width of 8 - 10m, increasing up to 20m for turning circle/bypass areas to allow for larger component transport. The access and internal roads will be placed within a corridor of up to 20m width to accommodate cable trenches, stormwater channels and turning circle/bypass areas of up to 20m. Existing access roads will be used where possible to minimise impact. Where required, the width of the existing roads will be widened to ensure the passage of vehicles.
Supporting Infrastructure:	- Fencing; - Lighting; - Lightning protection; - Telecommunication infrastructure; - Stormwater channels; - Water pipelines; - Offices; - Operational and control centre; - Operations and maintenance area / warehouse / workshop; - Ablution facilities; - Gatehouse; - Security building; - Visitor's centre; and - Substation building.

A map showing the location of the WTGs and the switching station is provided in Figure 1-2.

The proposed activities which could potentially impact on the aquatic biodiversity receptors are indicated in Table 5-1.

Table 5-1 – Project activities per phase

Phase	Activity
Construction	▪ Bush clearing and soil disturbance ▪ Bulk earthworks ▪ Development of required service infrastructure on the site ▪ Development of access roads ▪ Site establishment ▪ Construction of project components (Turbine hardstand; laydown and storage area; BESS; powerline)
Operational	▪ Maintenance of infrastructure (e.g. access roads) ▪ Vegetation management around the turbines ▪ Handling and disposal of general and hazardous waste

5.1 CONSTRUCTION PHASE

The main foreseeable aquatic-related impacts associated with the construction phase are vegetation clearing, soil disturbance and the establishment of infrastructure. Vegetation clearing and soil disturbances result in bare land which increase surface runoff, erosion and subsequently the amount of suspended and dissolved solids and potentially pollutants from the construction site and or areas down gradient of the construction site (hazardous substances from unearthed soil, cement, and concrete composites) entering the associated watercourses. Similarly, the main impact associated with the establishment of infrastructure, is the mobilization of pollutants that reach associated watercourses.

IMPACT DESCRIPTION

Erosion and runoff into the associated aquatic ecosystems can result in increased sedimentation and degradation of habitat. This can directly alter aquatic habitats after deposition (Wood & Armitage, 1997), which in turn will negatively impact biotic community structures by displacing biota that favour the affected habitat. Suspended solids can also directly impact aquatic biota through the accumulation of silt on respiratory organs (i.e. gills) and by decreasing visibility (i.e. increasing turbidity), which will affect feeding habits of specific taxa. Erosion and runoff from cleared land can also alter water quality by increasing turbidity, as aforementioned, and by increasing the number of contaminants entering the watercourses. This is expected to alter the physio-chemistry of water and deter water quality sensitive biota.

Vegetation clearing near watercourses can result in the introduction of alien invasive species (both fauna and flora) which often negatively impact indigenous species. This can lead to the loss of invertebrates such as dragonflies, which in turn, has the potential to alter biological community structure. Most alien invasive trees are taller and characterised by a greater root depth and are responsible for the increased uptake of water thereby decreasing both surface water runoff and groundwater recharge. This can significantly affect hydrological conditions and river flows.

MITIGATION MEASURES

The following impact mitigation and management measures are recommended to avoid/minimise potential impacts on the watercourse arising from the construction activities:

- Limit vegetation removal to the infrastructure footprint area only. Where removed or damaged, vegetation areas (riparian or aquatic related) should be revegetated as soon as possible;
- Bare land surfaces downstream of construction activities must be vegetated to limit erosion from the expected increase in surface runoff from infrastructure;
- Environmentally friendly barrier systems, such as silt nets or, in severe cases, use trenches downstream from construction sites to limit erosion and possibly trap contaminated runoff from construction;
- Storm water must be diverted from the construction site and managed in such a manner to disperse runoff and prevent the concentration of storm water flow;
- Water used at construction sites should be utilised in such a manner that it is kept on site and not allowed to run freely into nearby watercourses;
- Construction chemicals, such as cement and hydrocarbons should be used in an environmentally safe manner with correct storage as per each chemical's specific storage descriptions;
- All vehicles must be frequently inspected for leaks;
- No material may be dumped or stockpiled within any rivers or drainage lines in the vicinity of the proposed Project, and must be removed immediately without destroying habitat;
- All waste must be removed and transported to appropriate waste facilities; and
- High rainfall periods (usually November to March) should be avoided during the construction phase to possibly avoid increased surface runoff in attempt to limit erosion and the entering of external material (i.e. contaminants and/or dissolved solids) into associated aquatic systems.

IMPACT ASSESSMENT

Impact assessment ratings for activities associated with the construction phase the Project are presented in Table 5-2. The proposed placement of infrastructure (WTG's and the substation) is located within the centre of the Project boundary, with the closest WTG (WTG09) to the Loopspruit being over 2 km away. With the presence of barriers such as the Losberg Road and cultivated lands in between the Loopspruit and the infrastructure, it is unlikely that the Loopspruit will be impacted, thus this river was not considered for the impact assessment. The closest WTGs to the Kraalkopspruit are approximately 250 m (WTG01) and 500 m (WTG02) away.

Potential impacts upon the Kraalkopspruit were determined to range between very low and low pre-mitigation and very low post-mitigation. Activities associated with the construction of the turbine hardstands for WTG01 and WTG02, and access roads are likely to impact the Kraalkopspruit, especially due to their proximity to a dirt road leading to a farm dam. Potential impacts include water quality modifications and an increase in sediment load within the Kraalkopspruit. These impacts are, however, expected to be significantly reduced by avoiding construction in the rainy season, and effective implementation of the other recommended sediment and pollutant control mitigation measures.

Table 5-2 – Impact assessment ratings for the construction phase

Description	Character	Ease of Mitigation	Pre-Mitigation						Post-Mitigation					
			Magnitude	Extent	Reversibility	Duration	Probability	Significance	Magnitude	Extent	Reversibility	Duration	Probability	Significance
River water quality modifications	Negative	Moderate	2	2	1	2	2	**14**	1	1	1	1	1	**4**
		Significance	**N1 - Very Low**						**N1 - Very Low**					
Increased sediment load and loss of habitat	Negative	Moderate	2	2	1	2	2	**14**	1	1	1	1	1	**4**
		Significance	**N1 - Very Low**						**N1 - Very Low**					
Increased river flows altering the natural flow regime	Negative	Moderate	3	2	2	2	2	**18**	1	1	1	1	1	**4**
		Significance	**N2 - Low**						**N1 - Very Low**					
Loss of indigenous species and reduced availability of water	Negative	Moderate	1	1	3	4	2	**18**	1	1	3	4	1	**9**
		Significance	**N2 - Low**						**N1 - Very Low**					

5.2 OPERATIONAL PHASE

Operational phase impacts relate to the ongoing risk of erosion, water quality, habitat modifications and the spread of alien invasive species.

IMPACT DESCRIPTION

Bare lands and paved surfaces such as access roads have the potential to increase flow rates, sediment input, erosion, and contaminants in the associated watercourses if allowed to flow freely from the Project area. These influences will directly impact on water quality and aquatic habitat which in turn will negatively affect the aquatic biota.

Increased anthropogenic activities near watercourses increase the risk of introducing alien invasive species. Introduced fish species threaten local fish populations, through habitat destruction and predation for example. The continued spread of alien trees invading riparian zones will decrease river flows through uptake of water, thereby altering the hydrological regime of the watercourses.

MITIGATION MEASURES

The following mitigation measures are recommended to guide the effective management of stormwater and alien invasive species:

- Runoff from the Project area should not be allowed to flow into the nearby watercourses, unless authorised by the DWS (or the competent authority);
- Bare surfaces downstream from the developments, where silt traps are not an option, should be well vegetated in order to attempt to limit erosion and runoff that might be carrying contaminants;
- Careful monitoring of the areas where dust suppression is proposed should be undertaken regularly; and

- Biannual aquatic biomonitoring assessments of the associated water courses should be conducted by an aquatic specialist to determine impacts, whereafter new mitigation actions should be implemented as per the specialist's recommendations.

IMPACT ASSESSMENT

Impact assessment ratings for activities associated with the operational phase are presented in Table 5-3. The management and maintenance of infrastructure (clearing of vegetation around the WTGs and around access roads for example) may result in bare surfaces and thus increased surface runoff and erosion. Potential impacts upon associated watercourses were determined to be low pre-mitigation and very low post-mitigation.

Table 5-3 – Impact assessment ratings for the operational phase

Description	Character	Ease of Mitigation	Pre-Mitigation						Post-Mitigation					
			Magnitude	Extent	Reversibility	Duration	Probability	Significance	Magnitude	Extent	Reversibility	Duration	Probability	Significance
Increased sediment load and loss of habitat	Negative	Moderate	3	2	3	4	2	**24**	1	1	1	4	1	**7**
		Significance	**N2 - Low**						**N1 - Very Low**					
Increased river flows altering the natural flow regime	Negative	Moderate	3	2	3	2	2	**20**	1	1	1	2	1	**5**
		Significance	**N2 - Low**						**N1 - Very Low**					
Loss of indigenous species and reduced availability of water	Negative	Moderate	1	1	3	4	2	**18**	1	1	3	4	1	**9**
		Significance	**N2 - Low**						**N1 - Very Low**					

6 CUMULATIVE IMPACTS

Presently, the primary land-use activities within the Project boundary are those associated with game farming and those of the larger study area include agriculture (along the immediate Project boundary); mining (with the nearest operations being the Sibanye Driefontein approximately 1.5 km to the north, Kloof Gold Mine approximately 1.2 km to the east); and the Fochville township at the south west tip of the Project boundary. Several other mines occur within the broader Project area, namely Sibanye Stillwater, Mponeng Gold Plant and the Harmony Kusasalethu Gold Mine as well as the renewable energy project linked with Sibanye Gold Limited. The cumulative assessment however does not consider the proposed grid infrastructure, as its layout is still to be determined.

Potential impacts associated with the above-mentioned land use activities include water quantity alterations (water abstraction for irrigation, presence of farm dams and the discharge of treated sewage and mine water), water quality deteriorations (contamination due to diffuse surface runoff), vegetation clearing and the introduction of exotic species, and solid waste disposal.

Consequently, major impacts within the assessed Loopspruit reach were increased sedimentation and invasive species encroachment within the riparian zones. Similarly, within the Kraalkopspruit, major impacts were high sediment load and water quality deterioration evidenced by the high abundance of algae at the downstream reaches.

6.1 MONITORING PROGRAMME

An aquatic biomonitoring programme has been developed for the monitoring and preservation of the aquatic ecosystems assessed for the Project. The programme is aimed at better determining the ecological health of the ecosystems, provide long term trends in ecosystem integrity as well as aid in early detection of potential impacts that might severely affect the expected aquatic biota in the associated riverine systems.

Table 6-1 outlines the aquatic monitoring methods to be undertaken at the monitoring points set out above (see section 2.2) on a biannual basis by a suitably qualified aquatic ecologist. The annual programme comprises of a single survey during the dry season (or low flow season) for the Project Area and a single survey during the wet season (or high flow) at the monitoring points indicated. This will determine the PES for the assessed aquatic ecosystems which will further determine whether the proposed Project is impacting the associated aquatic ecology and to what extent.

Table 6-1 – Proposed aquatic biomonitoring programme

Method and Aquatic Component of Focus	Details	Goal/Target	REC
Water Quality: *In situ* water testing focusing on temperature, pH, conductivity and oxygen content.	Water quality should be tested on a biannual basis at each monitoring site to determine the extent of change from baseline results.	No noticeable change from determined baseline (current report) water quality for each respective season.	Salt concentrations must be at levels that do not threaten the ecosystem and are suitable for users. The river water should not be toxic to aquatic organisms or be a threat to human health.

Method and Aquatic Component of Focus	Details	Goal/Target	REC
Habitat Quality: Instream and riparian habitat integrity; and Availability/suitability of macroinvertebrate habitat at each monitoring site.	The application of the IHI should be done for the associated Kraalkopspruit and the Loopspruit reaches; The IHAS must be applied at each monitoring site prior to sampling.	The Ecological Category determined for each assessed site must be improved for the watercourses under study); and The baseline IHAS scores should improve.	Must be in a Moderately Modified or better condition ≥ D (≥ 42)
Aquatic Macroinvertebrates: Aquatic Macroinvertebrate assemblages must be assessed biannually.	This must be done through the application of the latest SASS protocol, incorporated with the application of the MIRAI as outlined in this Aquatic Study.	The baseline SASS5 scores should not noticeably deteriorate; and Baseline Ecological Categories should not be allowed to drop in category for each assessed site.	Must be in a Moderately Modified or better condition ≥ D (≥ 42)
Fish: Fish assemblages must be assessed biannually	Sampling of fish must be undertaken by utilising the electro-narcosis technique at sites presenting suitable fish habitat.	Baseline Ecological Categories should not be allowed to drop in category for each assessed site. The main goal for the Project must be to conserve the expected sensitive species.	Must be in a Moderately Modified or better condition ≥ D (≥ 42)
Diatoms Assemblages: Samples must be collected biannually and sent to the laboratory for analysis	The diatom assessment will improve the understanding of the potential impacts from the surrounding activities on the water quality	The diatom based ecological water quality must not deteriorate from the baseline conditions.	Not available.
REC = Recommended Ecological Category			

7 CONCLUSION AND RECOMMENDATIONS

The following key findings are highlighted as part of the current aquatic biodiversity and impact assessment study:

Findings from the *in situ* water quality assessment indicated modifications based on exceedances in the electrical conductivity and dissolved oxygen content. These were consistent with findings from the diatom community assessment wherein diatom assemblages were generally comprised of species characteristic of fresh brackish water (< 500 µS/cm), circumneutral (pH 6.5 to 7.5), eutrophic conditions and low to moderate requirements for dissolved oxygen saturation. The subsequent ecological water quality reflected *Moderate* conditions at sites LO1 and KR1, *Poor* conditions at site LO2 and *Good* conditions at site KR2. The upstream mining and agricultural activities were likely the major sources for the water quality deterioration. The riparian and instream habitat integrity was determined to be *largely modified* (Ecological Category D) with major impacts including modification to flows and water quality; the removal of indigenous vegetation and exotic vegetation encroachment. The availability of macroinvertebrate habitat was determined to range between poor where there was a lack of stones and adequate where the stones biotope was present.

The sampled aquatic macroinvertebrate community assemblages were similar in composition throughout the four sites with a low diversity compared to the expected number of taxa. Pollution-tolerant taxa dominated the assemblages. Subsequently, the MIRAI-based ecological condition of the aquatic macroinvertebrate communities were *Critically Modified* at site LO1, *Seriously Modified* at sites LO2 and KR1 and *Largely Modified* at site KR2. These modifications were as a result of the change from reference conditions, especially within the flow and water quality metrics and the overall low diversity present within the assessed systems. Three of the expected five fish species were collected during the survey. A single species was collected at sites LO2 and KR2, and two species were collected at site KR1. The FRAI-based ecological condition indicated *Largely Modified* at sites LO2 and KR1 and *Seriously Modified* at site KR2. The integrated ecological state (EcoStatus) of the assessed reaches were determined to be *Largely Modified.*

7.1 REASONED OPINION WHETHER PROJECT SHOULD PROCEED

Based on the findings of the current aquatic biodiversity and impact assessment study, potential negative impacts upon the main receiving receptor (the Kraalkopspruit), are likely to occur following rainfall events due to the distance between the river and the proposed activities. Impacts are predicted to range between very low to low and significantly reduced upon implementation of mitigation measures. Furthermore, there are no aquatic species of conservation concern expected to occur within the study area. Therefore, no fatal flaws were identified during the current study, and thus, the proposed Project may proceed. Immediate implementation of the mitigation measures and the aquatic biomonitoring programme must be adhered to pre-construction, and throughout the operation phase to ensure that no deterioration of the associated watercourses occurs.

7.2 RECOMMENDATIONS

Based on the results of the current study, the following actions have been recommended to allow for commencement of the proposed Project:

- Placement of the WTGs should be outside of the aquatic ecosystem and associated riparian zone.

- The developed Aquatic Biomonitoring Programme must be adopted on a biannual basis. This programme should continue for at least two years following the completion of the Construction Phase.
- The proposed Project should adopt a water and habitat quality preservation mindset throughout the life of the Project to prevent the deterioration of the aquatic ecosystems. At least 100 m buffer zone of regulation must be implemented as a no-go zone between the aquatic systems and construction activities

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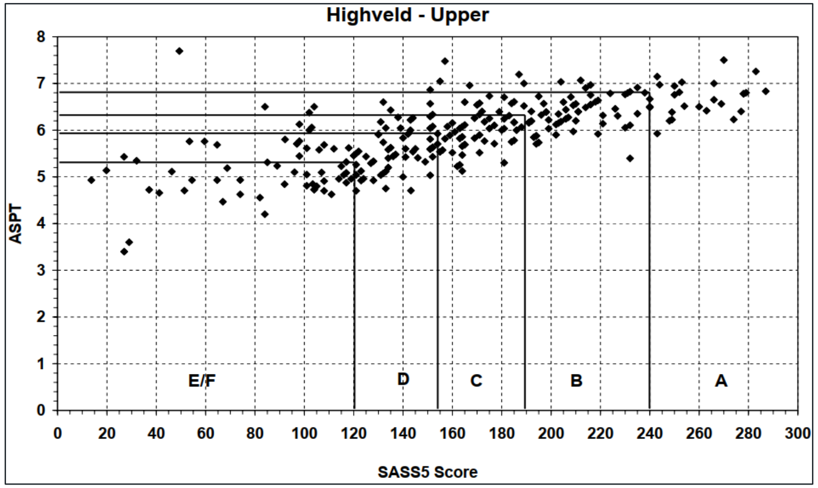
Appendix A

METHODOLOGY

Methodology	Measurement description	Guidelines/Description		
		***In situ* water variable**	**Guideline**	**Guideline referenced**
***In Situ* Water Quality**	Determined using portable field instruments: ▪ pH: Eutech pHTester2; ▪ Electrical Conductivity: Eutech ECTester11 Dual Range; ▪ Dissolved oxygen: Eutech CyberScan DO300; and ▪ Temperature: Eutech CyberScan DO300.	Temperature (ºC)	5 - 30	South African Water Quality Guidelines: *Aquatic Ecosystems (Volume 7)* (Department Of Water Affairs And Forestry, 1996)
		pH	6 - 8	
		Dissolved Oxygen Saturation (%)	80 – 120	
		Dissolved Oxygen concentration (mg/ℓ)	>5	Minimum Dissolved Oxygen concentration for aquatic macroinvertebrates (Nebeker et al., 1996)
		Electrical Conductivity (µS/m)	< 500	Conductivity guideline value of 500 µS/cm stipulated in U.S. U.S. Environmental Protection Agency (2010)
Habitat Assessment	Habitat assessment can be defined as the evaluation of the structure, of the surrounding physical habitat, that influences the quality of the water resource, and the condition of the resident aquatic community (Barbour et al., 1999). Habitat quality and availability plays a critical role in the occurrence of aquatic biota. For this reason, habitat evaluation is conducted simultaneously with biological evaluations in order to facilitate the interpretation of results.			

<table>
<tr><th>Methodology</th><th>Measurement description</th><th colspan="2">Guidelines/Description</th></tr>
<tr><td>Integrated Habitat Assessment System (IHAS)</td><td colspan="2">The quality of the instream and riparian habitat influences the structure and function of the aquatic community in a stream; therefore, assessment of the habitat is critical to any assessment of ecological integrity. The IHAS, Version 2 was developed specifically for use with the SASS5 index and rapid biological assessment protocols in South Africa (McMillan, 1998).</td><td><table><tr><th>IHAS</th><th>Description</th></tr><tr><td>>65%</td><td>Good</td></tr><tr><td>55% – 65%</td><td>Adequate/Fair</td></tr><tr><td><55%</td><td>Poor</td></tr></table></td></tr>
<tr><td rowspan="2">Intermediate Habitat Integrity Assessment</td><td>Habitat integrity refers to the maintenance of a balanced, integrated composition of physico-chemical and habitat characteristics on a temporal and spatial scale that are comparable to the characteristics of natural habitats of the region (Kleynhans, 1996).</td><td colspan="2"><table><tr><th colspan="3">Descriptive classes for the assessment of modifications to habitat integrity (Kleynhans, 1996).</th></tr><tr><th>Score</th><th>Impact Category</th><th>Description</th></tr><tr><td>0</td><td>None</td><td>No discernible impact, or the factor is located in such a way that it has no impact on habitat quality diversity, size and variability.</td></tr><tr><td>1 – 5</td><td>Small</td><td>The modification is limited to a very few localities and the impact on habitat quality, diversity, size and variability is also very small.</td></tr><tr><td>6 – 10</td><td>Moderate</td><td>The modification is present at a small number of localities and the impact on habitat quality, diversity, size and variability is also limited.</td></tr><tr><td>11 – 15</td><td>Large</td><td>The modification is generally present with a clearly detrimental impact on quality habitat quality, diversity, size and variability. Large areas are, however, not influenced.</td></tr><tr><td>16 – 20</td><td>Serious</td><td>The modification is frequently present and the habitat quality, diversity, size and variability almost the whole of the defined section are affected. Only small areas are not influenced.</td></tr><tr><td>21 – 25</td><td>Critical</td><td>The modification is present overall with a high intensity; the habitat quality, diversity, size and variability in almost the whole of the defined section are detrimentally influenced.</td></tr></table></td></tr>
<tr><td colspan="3"><table><tr><th colspan="3">Intermediate habitat integrity assessment classes/categories (Kleynhans, 1996)</th></tr><tr><th>Score</th><th>Class (% of total)</th><th>Description</th></tr><tr><td>90 - 100</td><td>A</td><td>Unmodified, natural.</td></tr><tr><td>80 - 90</td><td>B</td><td>Largely natural with few modifications.</td></tr></table></td></tr>
</table>

<table>
<tr><th>Methodology</th><th colspan="2">Measurement description</th><th colspan="2">Guidelines/Description</th></tr>
<tr><td rowspan="4"></td><td>60 - 79</td><td>C</td><td colspan="2">Moderately modified.</td></tr>
<tr><td>40 - 59</td><td>D</td><td colspan="2">Largely modified.</td></tr>
<tr><td>20 - 39</td><td>E</td><td colspan="2">The loss of natural habitat, biota and basic ecosystem functions is extensive.</td></tr>
<tr><td>0 - 19</td><td>F</td><td colspan="2">Modifications have reached a critical level and the lotic system has been modified completely with an almost complete loss of natural habitat and biota.</td></tr>
<tr><td rowspan="2">Aquatic Macroinvertebrates</td><td colspan="2" rowspan="2">Aquatic macroinvertebrates were sampled using the qualitative kick sampling method called South African Scoring System (SASS, version 5) (Dickens & Graham, 2002)and identified using the hand guide from Gerber & Gabriel (2002).

The biotic integrity rating was based on the ASPT and SASS5 results with reference to the Highveld (Upper) Ecoregion (H. Dallas, 2007)</td><td colspan="2">Biotic Integrity (Highveld (11) Upper Ecoregion)</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td rowspan="7">Diatoms</td><td colspan="2" rowspan="7">Diatoms are a unicellular algal group widely used as indicators of river health as they provide a rapid response to specific physico-chemical conditions in the water and are often the first indication of environmental change. The presence or absence of indicator taxa can be used to detect specific changes in environmental</td><td colspan="2">Interpretation of the Specific pollution index (SPI) scores (CEMAGREF, 1982)</td></tr>
<tr><td>Index score</td><td>Class</td></tr>
<tr><td>>17</td><td>A (high quality)</td></tr>
<tr><td>13 - 17</td><td>B (good quality)</td></tr>
<tr><td>9 - 13</td><td>C (moderate quality)</td></tr>
<tr><td>5 - 9</td><td>D (poor quality)</td></tr>
<tr><td><5</td><td>E (bad quality)</td></tr>
</table>

Methodology	Measurement description	Guidelines/Description	
	conditions namely, eutrophication, organic enrichment, salinization and pH variation (Kelly *et al*. 1998). Diatom laboratory procedures were carried out according to the methodology described by (Taylor et al., 2005). Two indices, namely the Specific Pollution Sensitivity Index (SPI; CEMAGREF, 1982) and the Biological Diatom Index (BDI; (Lenoir, A. & Coste, 1996) were used in the diatom assessment.	**Percentage of Pollution Tolerant Value (%PTV) (Kelly & Whitton, 1995)**	
		<20	Site free from organic pollution.
		21 - 40	There is some evidence of organic pollution.
		41 - 60	Organic pollution likely to contribute significantly to eutrophication.
		>61	Site is heavily contaminated with organic pollution.

Methodology	Measurement description	Guidelines/Description		
		FRAI Score (%)	**Class**	**Description of generally expected conditions for integrity classes**
Ichthyofauna	Fish samples were collected using an electro-fishing device (Smith-Root LR24). Based on a survey of available literature and previous assessments, an expected species list was compiled, utilising the following sources: Skelton (2001), (Kleynhans et al., 2007) and IUCN. The PES or Ecological Category of the fish assemblage of the watercourses associated with the Project Area was conducted by means of the Fish Response Assessment Index (FRAI) (Kleynhans, 2008)	90 – 100	A	Unmodified, or approximate natural conditions closely.
		80 – 89	B	Largely natural with few modifications.
		60 – 79	C	Moderately modified. A lower than expected species richness and presence of most intolerant species.
		40 – 59	D	Largely modified. A clearly lower than expected species richness and presence of most intolerant species.
		21 – 39	E	Seriously modified. A strikingly lower than expected species richness and general absence of intolerant and moderately intolerant species.
		0 – 20	F	Critically modified. Extremely lowered species richness and an absence of intolerant and moderately intolerant species.

Appendix B

SITE PHOTOGRAPHS

Loopspruit	
	
Site LO1 upstream view	**Site LO1 downstream view**
	
Site LO1 upstream view	**Site LO1 downstream view**
Kraalkopspruit	
	
Site KR1 upstream view	**Site KR1 downstream view**

	
Site KR2 upstream view	**Site KR2 downstream view**

Appendix C

LABORATORY ANALYSIS REPORT

WSP

Project no: 41104282_D04

Diatom Analysis Report

ecotone
Freshwater Consultants

Reference:	WSP_41104282_D04_Diatom_Report_July_2023_Draft
Date:	July 2023
No. of samples:	4
Version:	Draft

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Limitations and Disclaimer

The spatial and temporal extents of Ecotone Freshwater Consultants CC (Ecotone) services are described in the proposal and are subject to restrictions and limitations. A total assessment of all probable scenarios or circumstances that may exist on the study site was not undertaken. No assumptions should be made unless opinions are specifically indicated and provided. Data presented in this document may not elucidate all possible conditions that may exist given the limited nature of the enquiry.

Ecotone exercises reasonable skill, care and diligence in the provision of services; however, Ecotone accepts no liability or consequential liability for the use of the supplied project deliverables (in part or whole) and any information or material contained therein. The client, including their agents, by receiving these deliverables, indemnifies Ecotone (including its members, employees, and sub-consultants) against any actions, claims, demands, losses, liabilities, costs, damages and expenses arising directly or indirectly from or in connection with services rendered, directly or indirectly by Ecotone.

The project deliverables, including the reported results, comments, recommendations, and conclusions, are based on the author/s professional knowledge as well as available information. Ecotone, therefore, reserves the right to modify aspects of the project deliverables if and when new/additional information becomes available from research or further work in the applicable field of practice or about this study. Ecotone also reserves the right to authorise peer review of this deliverable by an independent third party.

Declaration of Independence

I, Marco Alexandre, as duly authorised representative of Ecotone Freshwater Consultants CC (Ecotone), hereby confirm my independence (as well as that of Ecotone) as a specialist and declare that neither I nor Ecotone have any interest, be it business, financial, personal or other, in any proposed activity, application or appeal, other than fair remuneration for work performed, specifically in connection with the diatom assessment for the WSP sites.

____

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Table of Contents

List of Tables

List of Abbreviations

%PTV Percentage Pollution Tolerant Valves

SADI South African Diatom Index

SPI Specific Pollution Sensitivity Index

TDI Trophic Diatom Index

Key Terminology Outlined in Taylor *et al.* (2007a)

Trophy	Description
Dystrophic	Rich in organic matter, usually in the form of suspended plant colloids, but of a low nutrient content.
Oligotrophic	Low levels or primary productivity, containing low levels of mineral nutrients required by plants.
Mesotrophic	Intermediate levels of primary productivity, with intermediate levels of mineral nutrients required by plants.
Eutrophic	High primary productivity, rich in mineral nutrients required by plants.
Hypereutrophic	Very high primary productivity, constantly elevated supply of mineral nutrients required by plants.

Mineral Content	Value
Very electrolyte poor	< 50 µS/cm
Electrolyte-poor (low electrolyte content)	50 - 100 µS/cm
Moderate electrolyte content	100 - 500 µS/cm
Electrolyte-rich (high electrolyte content)	> 500 µS/cm
Brackish (very high electrolyte content)	> 1000 µS/cm
Saline	6000 µS/cm

Pollution (Saprobity)	Value
Unpolluted to slightly polluted (oligosaprobic)	BOD <2, O_2 deficit <15%
Moderately polluted (β-mesosaprobic)	BOD <4, O_2 deficit <30%
Critical level of pollution (β-á-mesosaprobic)	BOD <7(10), O_2 deficit <50%
Strongly polluted (á-mesosaprobic)	BOD <13, O_2 deficit <75%
Very heavily polluted (polysaprobic)	BOD <22, O_2 deficit <90%

Executive Summary

Diatom laboratory procedures were carried out according to the methodology described by Taylor *et al.* (2005). The Percentage of Pollution Tolerant Valves (%PTV; Kelly & Whitton, 1995) was included in the analysis to indicate organic pollution. A total of 79 diatom species were recorded at the four sites during this survey and the diatom assemblages were generally comprised of species characteristic of fresh brackish, circumneutral to alkaline waters and eutrophic conditions. The pollution levels indicated that there were moderate to high levels of pollution present at all the sites. The results from the July 2023 assessment support the following conclusions:

- Based on the spatial diatom community analysis the ecological water quality for both sites ranged from *Good* to *Poor* conditions with low (<20%) to high (>40%) levels of organic pollution;
- All the sites reflected moderate to high levels of organic pollution, pointing to the presence of high organic nutrients which is typically associated with eutrophication impacts;
- Site KR2 refelcted better ecological water quality conditions and lower levels of organic pollution compared to the other sites.

1. Introduction and Scope of Work

Diatoms are the unicellular algal group most widely used as indicators of river and wetland health as they provide a rapid response to specific physico-chemical conditions in water and are often the first indication of change. The presence or absence of indicator taxa can be used to detect specific changes in environmental conditions such as eutrophication, organic enrichment, salinization and changes in pH. They are therefore useful for providing an overall picture of trends within an aquatic system as they show an ecological memory of water quality over a period of time.

2. Methodology

2.1. Laboratory Procedures

Diatom laboratory procedures were carried out according to the methodology described by Taylor *et al.* (2005). Diatom samples were prepared for microscopy by using the hot hydrochloric acid and potassium permanganate method. Approximately 300 to 400 diatom valves were identified and counted to produce semi-quantitative data for analysis. Prygiel *et al*. (2002) found that diatom counts of 300 valves and above were necessary to make correct environmental inferences. The taxonomic guide by Taylor *et al.* (2007b) and Cantonati *et al*. (2017) was consulted for identification purposes. Where necessary, Krammer & Lange-Bertalot (1986, 1988, 1991 a, b) were used for identification and confirmation of species identification. Environmental preferences were inferred from Taylor *et al.* (2007b) and Cantonati *et al*. (2017) and various other literature sources as indicated in the discussion section to describe the environmental water quality at each site.

2.2. Diatom-based Water Quality Indices

There are different diatom-based water quality indices that are used globally and are based on the specific water quality tolerances of diatoms. Most of the indices are based on a weighted average equation by Zelinka and Marvan (1961). Two values are assigned to each diatom species used in the calculations of the indices that reflects the tolerance or affinity of the diatom species to a certain water quality (good or bad); and indicates how strong (or weak) the relationship is (Taylor, 2005). These values are then weighted by the abundance of the diatom species in the sample (Lavoie *et al*. 2006;

Taylor *et al.*, 2005; Besse-Lototskaya *et al.*, 2011). The main difference between indices is in the indicator sets (number of indicators and list of taxa) used in calculations (Eloranta & Soininen, 2002). These indices underpin the software packages used to estimate biological water quality. One such software package commonly used and approved by the European Union is OMNIDIA (Lecointe *et al.* 1993). The program is a taxonomic and ecological database of 7500 diatom species, and it contains indicator values and degrees of sensitivity for given species. It allows rapid calculations of indices of general pollution, saprobity and trophic state, indices of species diversity, as well as of ecological systems (Szczepocka, 2007).

2.3. The Specific Pollution Sensitivity Index (SPI)

The SPI was used in this diatom assessment (**Table 2-1**). The SPI is an inclusive index and takes factors such as salinity, eutrophication and organic pollution into account (CEMAGREF, 1982). This index comprises 2035 taxa (Taylor, 2005) which are endemic to and commonly found in South Africa, thus increasing the accuracy of diatom-based water quality assessments (Harding & Taylor, 2011). The limit values and associated ecological water quality classes adapted from Eloranta & Soininen (2002) were used for interpretation of the SPI scores. The SPI index is based on a score between 0 – 20, where a score of 20 indicates no pollution and a score of zero indicates an increasing level of pollution or eutrophication.

Table 2-1: Adjusted class limit boundaries for the Specific Pollution Index in the evaluation of water quality applied in this study (adapted from Eloranta & Soininen, 2002; Harding & Taylor 2011)

Interpretation of Index Scores		
Ecological Category (EC)	**Class**	**Index Score (SPI Score)**
A	High quality	>17.3
A/B		16.8-17.2
B	Good quality	13.3-16.7
B/C		12.9-13.2
C	Moderate quality	9.2-12.8
C/D		8.9-9.1
D	Poor quality	5.3-8.8
D/E		4.8-5.2
E	Bad quality	< 4.8

2.4. The Percentage Pollution Tolerant Valves (%PTV)

The %PTV is part of the UK Trophic Diatom Index (TDI) (Kelly & Whitton, 1995) and was developed for monitoring organic pollution (sewage outfall- orthophosphate-phosphorus concentrations), and not general stream quality (**Table 2-2**). The %PTV has a maximum score of 100, where a score above 0 indicates no organic pollution and a score of 100 indicates definite and severe organic pollution. The presence of more than 20% PTVs shows organic impact. All calculations were computed using OMNIDIA ver. 4.2 programme (Lecointe *et al*., 1993).

Table 2-2: Interpretation of the percentage Pollution Tolerant Valves scores (adapted from Kelly, 1998)

%PTV	Interpretation
<20	Site free from organic pollution.
20 to <40	There is some evidence of organic pollution.
40 to 60	Organic pollution likely to contribute significantly to eutrophication.
>60	Site is heavily contaminated with organic pollution.

3. Results and Discussion

The diatom assessment is divided into two sub-sections: (i) Discusses the ecological classification of water quality for each site according to the diatom assemblage during this assessment. (ii) Provides analyses and discussion of the dominant species and their ecological preference at each site. Thus, allowing spatial variation analyses of ecological water quality between sites.

3.1. Ecological Classification for Water Quality

The ecological classification for water quality according to Van Dam *et al*. (1994) and Taylor *et al*. (2007) are provided in **Table 3-1** for the July 2023 assessment. The overall diatom assemblages comprised of species with a preference for:

- Fresh brackish (<500 µS/cm), circumneutral (pH 6.5 – 7.5) to alkaline (pH > 7.5) waters and eutrophic conditions;
- The nitrogen requirements for all the sites range from N-Autotrophic tolerant, indicating a tolerance for high concentrations of organically bound nitrogen to N-Heterotrophic

obligatory, indicating a requirement for continuously high concentrations of organically bound nitrogen (i.e., indicating the presence of organic nitrogen);

- The dissolved oxygen saturation requirements ranged from low (<10%) to moderate (>50%) for all the sites.

Table 3-1: Ecological descriptors for the sites based on the diatom community (Van Dam *et al.*, 1994 and Taylor *et al*., 2007)

Site	pH	Salinity	Organic Nitrogen uptake	Oxygen Levels	Trophic State
LO1	Alkaline	Fresh brackish	N-Autotrophic tolerant	Low	Eutrophic
LO2	Circumneutral	Fresh brackish	N-Heterotrophic obligatory	Low	Eutrophic
KR1	Alkaline	Fresh brackish	N-Autotrophic tolerant	Moderate	Eutrophic
KR2	Circumneutral	Fresh brackish	N-Autotrophic tolerant	High	Eutrophic

3.2. Diatom Spatial Analysis

A total of 79 diatom species were recorded at the four sites and the dominant species recorded included, *Gomphonema sp., Nitzschia sp., Achnanthidium sp.,* and *Navicula sp.* These taxa are cosmopolitan in nature and have wide ecological amplitudes and thus caution must be taken when analysing the predominance of these species at specific sites. It is important to consider these dominant species in conjunction with the entire diatom assemblage when analysing the results. Diatom communities reflect ecological conditions over a period of 2-3 weeks; thus, the establishment of communities requires a sufficient amount of time in order to reflect current conditions. Ecological information is provided below for the dominant and sub-dominant species in order to make ecological inferences for the sites (**Table 6-1** and **Table 3-2;** Taylor *et al.*, 2007, Cantonati *et al*., 2017):

- **Site LO1:** The ecological water quality at this site reflected *Moderate* conditions with moderate levels of organic pollution (**Table 3-2**):
  - The dominant diatom taxa pointed to eutrophic waters with high electrolyte content, extending into brackish conditions. These taxa are tolerant to strongly polluted conditions (i.e., organic detritus);
  - The %PTV score, indicated that the percentage of diatom taxa that are tolerant to organic pollution was moderate, suggesting that there were moderate levels of organic pollution at this site. However, these levels were not associated with

eutrophication impacts. Overall, the ecological water quality at this site was *Moderate.*

- **Site LO2:** The ecological water quality at this site reflected *Poor* conditions with high levels of organic pollution (**Table 3-2**):
  - The dominant diatom taxa pointed to eutrophic waters with high electrolyte content, extending into brackish conditions. These taxa are tolerant to strongly polluted conditions, including for example high nutrient-rich waters and waters impacted by industrial or other waste water;
  - The %PTV score, indicated that the percentage of diatom taxa that are tolerant to organic pollution was high, suggesting that these levels may be associated with eutrophication impacts. Overall, the ecological water quality at this site was *Poor.*
- **Sites KR1 & KR2:** The ecological water quality at these sites reflected *Moderate* to *Good* conditions with moderate to low levels of organic pollution, respectively (**Table 3-2**):
  - The dominant diatom taxa pointed to eutrophic waters with moderate to high electrolyte content, extending into slightly brackish conditions. These taxa are tolerant to moderately to strongly polluted conditions. The presence of some taxa pointed to slightly acidic conditions at site KR2;
  - The %PTV score indicated that the percentage of diatom taxa that were tolerant to organic pollution was low to moderate for both sites. Site KR2 appeared to reflect better ecological water quality conditions with lower levels of organic pollution compared to site KR1. Overall, the ecological water quality at these sites ranged from *Good* to *Moderate.*

According to the diatom community there appeared to be spatial variation in the ecological water quality between the sites. The ecological water quality for both sites ranged from *Good* to *Poor* conditions with low (<20%) to high (>40%) levels of organic pollution. All the sites, except for site KR2, reflected moderate to high levels of organic pollution, pointing to the presence of high organic nutrients which is typically associated with eutrophication impacts. Overall, site LO1 reflected better ecological water quality conditions compared to site LO2; whereas, site KR2 reflected better conditions compared to site KR1.

Table 3-2: Diatom index scores for the study sites indicating the ecological water quality for the July 2023 assessment

Site	%PTV	SPI	Ecological Category (EC)	Class
LO1	37.8	9.6	C	Moderate
LO2	59.8	6.0	D	Poor
KR1	21	10.5	C	Moderate
KR2	5	16.1	B	Good

4. Summary and Conclusions

The main objective of the aquatic study was to monitor stress responses in the diatom community assemblages that may be attributed to the surrounding land use. The results from the July 2023 assessment support the following conclusions:

- The diatom assemblages were generally comprised of species characteristic of fresh brackish, circumneutral to alkaline waters and eutrophic conditions. The pollution levels indicated that there were moderate to high levels of pollution present at all the sites;
- Based on the spatial diatom community analysis the ecological water quality for both sites ranged from *Good* to *Poor* conditions with low (<20%) to high (>40%) levels of organic pollution;
- All the sites reflected moderate to high levels of organic pollution, pointing to the presence of high organic nutrients which is typically associated with eutrophication impacts;
- Site KR2 refelcted better ecological water quality conditions and lower levels of organic pollution compared to the other sites.

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6. Appendix

Table 6-1: Species and their abundances for sites during the July 2023 assessment

Taxa	LO1	LO2	KR1	KR2
Abnormal diatom valve (unidentified) or sum of deformities abundances	1			1
Achnanthidium biasolettianum (Grunow in Cl. & Grun.) Lange-Bertalot				36
Achnanthidium exiguum (Grunow) Czarnecki			1	1
Achnanthidium minutissimum (Kützing) Czarnecki	5	31	5	168
Amphora pediculus (Kützing) Grunow	5		1	
Amphora veneta Kützing	4		4	
Asterionella formosa Hassall	14			
Aulacoseira ambigua (Grunow) Simonsen	3			
Aulacoseira granulata (Ehr.) Simonsen				2
Caloneis bacillum (Grunow) Cleve				1
Cocconeis pediculus Ehrenberg				19
Cocconeis placentula Ehrenberg var. placentula	50	2	19	21
Craticula buderi (Hustedt) Lange-Bertalot			3	
Craticula halophila (Grunow ex Van Heurck) Mann	1		2	
Craticula molestiformis (Hustedt) Lange-Bertalot	4		6	
Cyclotella meneghiniana Kützing		1	2	
Diatoma vulgaris Bory	8		2	
Diploneis elliptica (Kützing) Cleve		1		
Eolimna minima (Grunow) Lange-Bertalot	66	51	30	
Eolimna subminuscula (Manguin) Moser Lange-Bertalot & Metzeltin	4		1	
EUNOTIA C.G. Ehrenberg		3		
Eunotia minor (Kützing) Grunow in Van Heurck		2		
Frustulia vulgaris (Thwaites) De Toni		2	2	1
GOMPHONEMA C.G. Ehrenberg	1	1		
Gomphonema acuminatum Ehrenberg	2			4
Gomphonema clavatum Ehr.				3
Gomphonema minutum (Ag.)Agardh f. minutum	11	1	5	17
Gomphonema parvulum (Kützing) Kützing var. parvulum f. parvulum	18	17	11	9
Gomphonema parvulum var.parvulum f.saprophilum Lange-Bert.&Reichardt	2			
Gomphonema pumilum var. rigidum Reichardt & Lange-Bertalot			3	
Gyrosigma acuminatum (Kützing)Rabenhorst		1		
Hantzschia amphioxys (Ehr.) Grunow in Cleve et Grunow 1880	1			
Hippodonta capitata (Ehr.) Lange-Bert.Metzeltin & Witkowski	2			3
Lemnicola hungarica (Grunow) Round & Basson			4	
Mayamaea atomus var. permitis (Hustedt) Lange-Bertalot	24		10	
Melosira varians Agardh	18		83	10
NAVICULA J.B.M. Bory de St. Vincent	1			
Navicula cryptocephala Kützing		43	3	17
Navicula cryptotenella Lange-Bertalot	6			6

Taxa	LO1	LO2	KR1	KR2
Navicula erifuga Lange-Bertalot	2			
Navicula gregaria Donkin	5	4	14	1
Navicula heimansioides Lange-Bertalot				3
Navicula longicephala Hustedt var.vilaplanii Sabater & Lange-Bertalot		2		
Navicula radiosa Kützing				1
Navicula reichardtiana Lange-Bertalot var. reichardtiana				3
Navicula rostellata Kützing	2	10		5
Navicula schroeteri Meister var. schroeteri	1			
Navicula schroeteri Meister var. symmetrica (Patrick) Lange-Bertalot	1		3	
Navicula small species	1			
Navicula tripunctata (O.F.Müller) Bory	4	8	9	2
Navicula veneta Kützing	10	5	16	
NITZSCHIA A.H. Hassall	8	19	5	5
Nitzschia acicularis (Kützing) W.M.Smith		5		
Nitzschia amphibia Grunow f.amphibia	4			
Nitzschia archibaldii Lange-Bertalot	5	6	1	
Nitzschia clausii Hantzsch		2		
Nitzschia dissipata (Kützing) Grunow var.dissipata		1		3
Nitzschia frustulum (Kützing) Grunow var.frustulum	5	2	5	
Nitzschia linearis (Agardh) W.M.Smith var.linearis	1	8	2	9
Nitzschia linearis (Agardh) W.M.Smith var.tenuis (W.Smith) Grunow	9		2	
Nitzschia nana Grunow in Van Heurck		2		
Nitzschia palea (Kützing) W.Smith	11	145	9	
Nitzschia paleacea (Grunow) Grunow in van Heurck	6			
Nitzschia recta Hantzsch in Rabenhorst				1
Nitzschia terrestris (Petersen) Hustedt			1	
PINNULARIA C.G. Ehrenberg		4		
Pinnularia gibba Ehrenberg		4	1	
Placoneis elginensis (Greg) Cox		3		
Planothidium engelbrechtii (Choln.) Round & Bukhtiyarova			5	
Planothidium frequentissimum (Lange-Bertalot)Lange-Bertalot	47	2	112	6
Rhoicosphenia curvata (Kützing) Grunow	7		4	10
Sellaphora pupula (Kützing) Mereschkowksy	1	5	1	
Sellaphora radiosa (Hustedt) Kobayasi in Mayama & al.		1		
Sellaphora seminulum (Grunow) D.G. Mann	5	1		
Surirella angusta Kützing	2		9	
Synedra rumpens Kützing	2			1
Tabularia fasciculata (Agardh)Williams et Round	8			2
Tryblionella hungarica (Grunow) D.G. Mann		1		
Tryblionella levidensis Wm. Smith		1		
Ulnaria biceps (Kützing) Compère	2	3	4	29

Taxa	LO1	LO2	KR1	KR2
TOTAL	400	400	400	246
Nutrients				
Organics				
Salinity				
Other dominant				

Appendix D

AQUATIC MACROINVETEBRATES DATA

Taxon	Sensitivity	LO1	LO2	KR1	KR2
ANNELIDA					
Oligochaeta (Earthworms)	1	1	A	A	A
CRUSTACEA					
Potamonautidae* (Crabs)	3	1	A	A	1
EPHEMEROPTERA (Mayflies)					
Baetidae 2sp	6	A			A
Baetidae >2sp	12		B	B	
Caenidae (Squaregills/Cainfles)	6		A	1	A
ODONATA (Dragonflies & Damselflies)					
Coenagrionidae (Sprites and blues)	4	1	A	1	A
Aeshnidae (Hawkers and Emperors)	8		A	A	A
Gomphidae (Clubtails)	6	A		A	A
Libellulidae (Darters/Skimmers)	4			1	1
HEMIPTERA (Bugs)					
Belostomatidae* (Giant water bugs)	3			A	
Corixidae* (Water boatmen)	3			B	A
Gerridae* (Pond skaters/Water striders)	5				A
Hydrometridae* (Water measurers)	6				1
Veliidae/M...veliidae* (Ripple bugs)	5			1	
Pleidae* (Pygmy backswimmers)	4		A		1
TRICHOPTERA (Caddisflies)					
Hydropsychidae 1 sp	4	A			
Hydropsychidae 2 sp	6		A		
Hydropsychidae >2 sp	12			B	
COLEOPTERA (Beetles)					
Dytiscidae* (Diving beetles)	5		1		A
Gyrinidae* (Whirligig beetles)	5	A	1	A	A
Hydrophilidae* (Water scavenger beetles)	5		1		
DIPTERA (Flies)					
Chironomidae (Midges)	2	A		A	A
Culicidae* (Mosquitoes)	1		1		1
Simuliidae (Blackflies)	5	A	1	A	
GASTROPODA (Snails)					
Physidae* (Pouch snails)	3				A
Planorbinae* (Orb snails)	3			A	A
	SASS	36	65	82	75
	Number of Taxa	9	13	16	18

ASPT	4,0	5,0	5,1	4,2

Appendix E

DOCUMENT LIMITATIONS

DOCUMENT LIMITATIONS

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