# SIERRA RUTILE PROJECT AREA 1 – ENVIRONMENTAL, SOCIAL AND HEALTH IMPACT ASSESSMENT: SPECIALIST TERRESTRIAL, AQUATIC AND WETLAND ECOLOGICAL STUDIES

**Prepared for**

**SRK Consulting (South Africa) (Pty) Ltd**

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# Section A – Summary and Background Information


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# GLOSSARY OF TERMS

**Alien vegetation:** Plants that do not occur naturally within the area but have been introduced either intentionally or unintentionally. Vegetation species that originate from outside of the borders of the biome - usually international in origin.

**Alluvial soil**: A deposit of sand, mud, etc. formed by flowing water, or the sedimentary matter deposited thus within recent times, especially in the valleys of large rivers.

**Base flow:** Long-term flow in a river that continues after storm flow has passed.

**Biodiversity:** The number and variety of living organisms on earth, the millions of plants, animals and micro-organisms, the genes they contain, the evolutionary history and potential they encompass and the Ecosystems, ecological processes and landscape of which they are integral parts.

**Buffer:** A strip of land surrounding a sensitive ecological feature in which activities are controlled or restricted, in order to reduce the impact of adjacent land uses on the floral population.

**Catchment:** The area contributing to runoff at a particular point in a river feature.

**Chroma:** The relative purity of the spectral colour which decreases with increasing greyness.

**Delineation (of a wetland):** To determine the boundary of a wetland based on soil, vegetation and/or hydrological indicators.

**Ecoregion:** An ecoregion is a "recurring pattern of Ecosystems associated with characteristic combinations of soil and landform that characterise that region.

**Ecotone:** An ecotone is a transition area between two biomes, where two communities meet and integrate. It may be narrow or wide, and it may be local (e.g. the zone between a field and forest) or regional (e.g. the transition between forest and grassland ecosystems)

**Ephemeral stream:** A stream that has transitory or short-lived flow.

**Facultative species:** Species usually found in wetlands (76 percent to 99 percent of occurrences), but occasionally found in non-wetland areas.

**Fluvial:** Resulting from water movement (especially rivers and watercourses).

**Gleying:** A soil process resulting from prolonged soil saturation which is manifested by the presence of neutral grey, bluish or greenish colours in the soil matrix.

**Groundwater:** Subsurface water in the saturated zone below the water table.

**Hydric soil:** Soil which is permanently or seasonally saturated by water, resulting in anaerobic conditions.

**Hydrology:** The study of the occurrence, distribution and movement of water over, on and under the land surface.

**Hydromorphic soil:** A soil that in its undrained condition is saturated or flooded long enough to develop anaerobic conditions, favouring the growth and regeneration of hydrophytic vegetation (vegetation adapted to living in anaerobic soils).

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| **Hydromorphy:** | A process of gleying and mottling resulting from the intermittent or permanent presence of excess water in the soil profile. |
| **Hydrophyte:** | Any plant that grows in water or on a substratum that is at least periodically deficient of oxygen as a result of soil saturation or flooding; plants typically found in wet habitats. |
| **Indigenous vegetation:** | Vegetation occurring naturally within a defined area. |
| **Intermittent flow:** | Flows only for short periods. |
| **Mottles:** | Soils with variegated colour patterns are described as being mottled, with the "background colour" referred to as the matrix and the spots or blotches of colour referred to as mottles. |
| **Obligate species:** | Species almost always found in wetlands (>99 percent of occurrences). |
| **Perched water table:** | The upper limit of a zone of saturation that is perched on an unsaturated zone by an impermeable layer, hence separating it from the main body of groundwater. |
| **Perennial:** | Flows all year round. |
| **RAMSAR**: | The Ramsar Convention (The Convention on Wetlands of International Importance, especially as Waterfowl Habitat) is an international treaty for the conservation and sustainable utilisation of wetlands, i.e., to stem the progressive encroachment on and loss of wetlands now and in the future, recognising the fundamental ecological functions of wetlands and their economic, cultural, scientific, and recreational value. It is named after the city of Ramsar in Iran, where the Convention was signed in 1971. |
| **RDL (Red Data listed) species**: | Organisms that fall into the Extinct in the Wild (EW), critically endangered (CR), Endangered (EN), Vulnerable (VU) categories of ecological status. |
| **Riparian**: | Ecosystems defined by the National Water Act (Act 36 of 1998) as: "including the physical structure and associated vegetation of the areas associated with a watercourse which are commonly characterised by alluvial soils, and which are inundated or flooded to an extent and with a frequency sufficient to support vegetation of species with a composition and physical structure distinct from those of adjacent land areas." |
| **Seasonal zone of wetness:** | The zone of a wetland that lies between the Temporary and Permanent zones and is characterised by saturation from three to ten months of the year, within 50cm of the surface. |
| **Species of Conservation Concern** | The term SCC in the context of this report refers to all RDL (Red Data) and IUCN (International Union for the Conservation of Nature) listed species as well as protected species of relevance to the project. |
| **Temporary zone of wetness:** | The outer zone of a wetland characterised by saturation within 50cm of the surface for less than three months of the year. |
| **Wetland:** | Ecosystems defined by the National Water Act (Act 36 of 1998) as: "land which is transitional between terrestrial and aquatic systems where the water table is usually at or near the surface, or the land is periodically covered with shallow water, and which land in normal circumstances supports or would support vegetation typically adapted to life in saturated soil." |

# ACRONYMS

| | |
|---|---|
| **CR** | Critically Endangered |
| **DWAF** | Department of Water Affairs and Forestry |
| **EAP** | Environmental Assessment Practitioner |
| **EC** | Electrical Conductivity |
| **EEZ** | Exclusive Economic Zone |
| **EIS** | Ecological Importance and Sensitivity |
| **EN** | Endangered |
| **EPAA** | Environment Protection Agency Act |
| **ESHIA** | Environmental Social and Health Impact Assessment |
| **ESHMP** | Environmental Social and Health Management Plan |
| **FEOW** | Freshwater Ecoregions of the World |
| **FRAI** | Fish Response Assessment Index |
| **IEZ** | Inshore Exclusive Zone |
| **IFC** | International Finance Corporation |
| **IUCN** | International Union for Conservation of Nature |
| **JORC** | Joint Ore Reserves Committee |
| **LC** | Least Concern |
| **MIRAI** | Macro-invertebrate Response Assessment Index |
| **NT** | Near Threatened |
| **PES** | Present Ecological State |
| **RDL** | Red Data Listed |
| **REC** | Recommended Ecological Category |
| **SASS5** | South African Scoring System version 5 |
| **SCC** | Species of Conservation Concern |
| **SRL** | Sierra Rutile Limited |
| **SRM** | Sierra Rutile Mine |
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| **STS** | Scientific Terrestrial Services |
| **TSMF** | Tropical and Subtropical Moist Forests |
| **VU** | Vulnerable |
| **WWF** | World Wildlife Foundation |

# 1 INTRODUCTION

## 1.1 Background

Scientific Terrestrial Services (STS) was appointed to conduct faunal, floral, wetland and aquatic ecological assessments as part of the process to undertake an Environmental, Social and Health Impact Assessment (ESHIA) and develop an Environmental, Social and Health Management Plan (ESHMP) for the current and proposed dry and wet mining activities for the Sierra Rutile Limited's (SRL) Mine Lease Area 1 (SR Area 1) operations. SR Area 1 is located within the Bonthe and Moyamba Districts of the Southern Province of Sierra Leone. SR Area 1 is situated approximately 30 km inland of the Atlantic Ocean and approximately 135 km southeast of Freetown (geodesic) (Figure 1 and Figure 2).

Sierra Rutile Limited (SRL) is an existing mining operation located in the Bonthe and Moyamba Districts of the Southern Province of Sierra Leone. The mine has been in operation for over 50 years and produces rutile, ilmenite and zircon rich concentrate. The SRL operation has an existing Environmental Licence (reference number EPA-SL030) and has undertaken two previous Environmental and Social Impact Assessment (ESIA) studies for their operations in 2001 and an update in 2012 respectively. When these studies where undertaken, the primary mining process was dredge mining (referred to as wet mining). During 2013 SRL commenced a distinct open cast mining operation (referred to as dry mining) as an auxiliary method of ore extraction in conjunction with wet mining. In 2016 a second dry mining operation was commissioned. It is anticipated that, over time, dredge mining will cease and dry mining would be the primary mining method employed.

In 2015 the Environmental Protection Agency of Sierra Leone (EPA-SL) issued a notification to SRL (reference number EPA-SUHA.96/214/a/HNRM), instructing SRL to undertake an ESHIA and develop an ESHMP for the current and proposed dry and wet mining activities, including the proposed expansion areas within SR Area 1. This included the Gangama and Lanti deposits and other deposits within SRL's current operations in SR Area 1 (i.e. "study area").

These reports aim to map, consider and describe the terrestrial and aquatic ecological resources associated with SR Area 1 from results gathered during the dry and wet season surveys. In addition, their integrity, ecological importance and sensitivity, including the provision of goods and services, is considered and presented. In doing so this report must guide the proponent, Environmental Assessment Practitioner (EAP) and regulating authorities, by means of the presentation of information on the baseline conditions, as to the management of current and future mining operations from an ecological risk management point of view as well as the further studies and assessments required.

Following the wet and dry season assessments the ecological risks were determined, and an analyses of the impacts associated with the project presented in Section E (Impact assessment). Key mitigatory measures were identified in order to minimise the potential impacts on both the local and regional terrestrial and aquatic ecology.

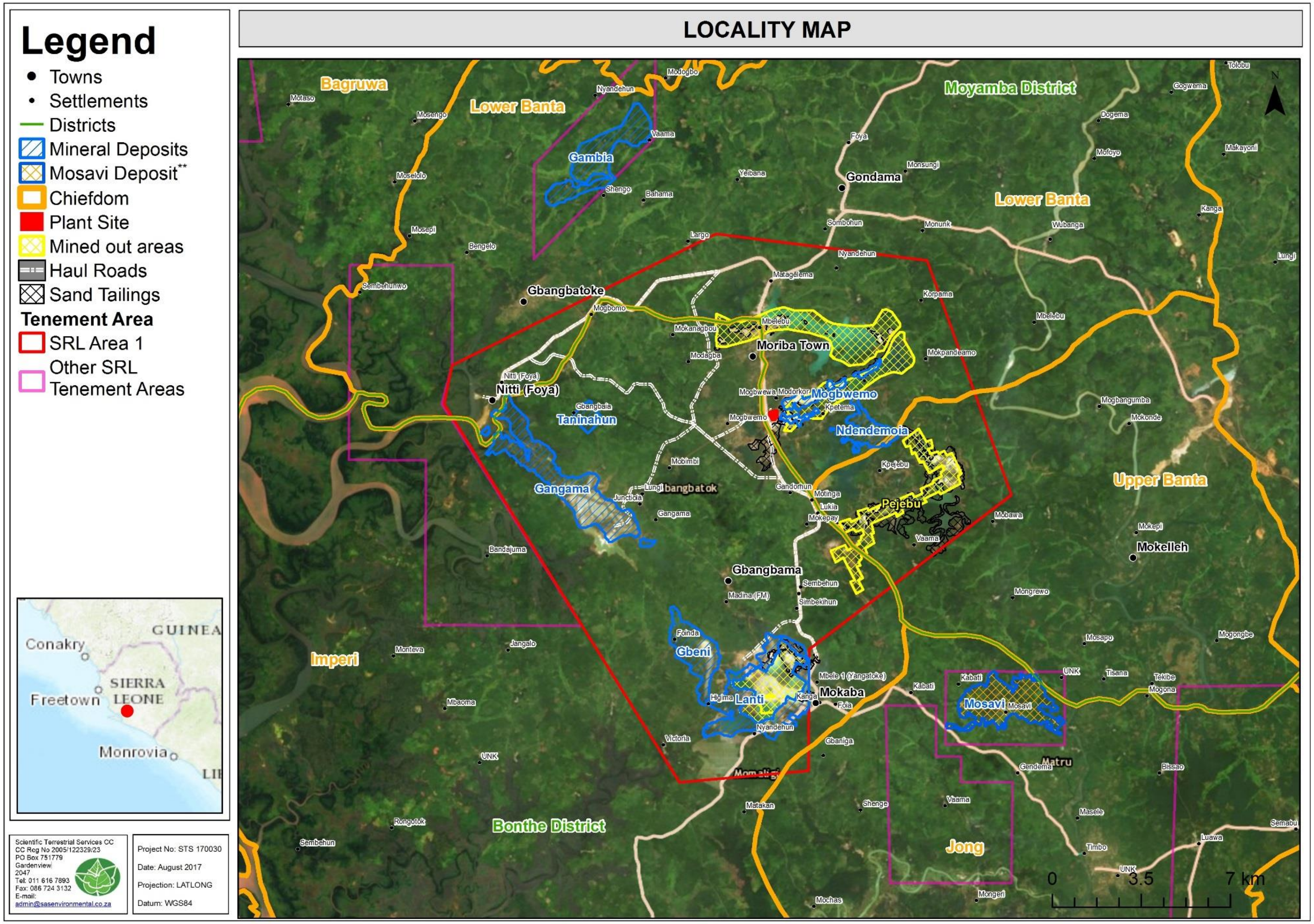


**Figure 1: Digital Satellite image depicting the location of SR Area 1 in relation to surrounding areas.**

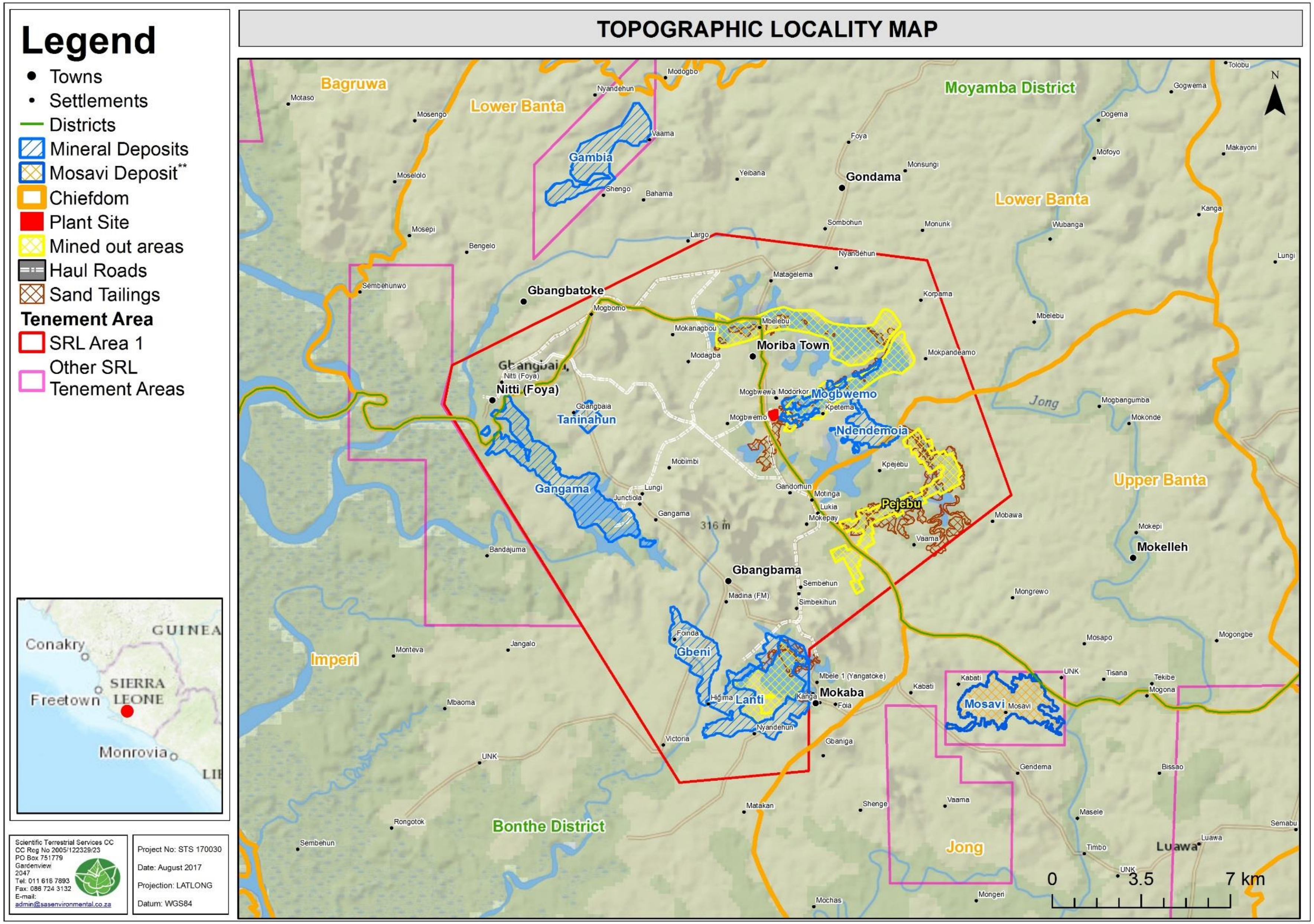


**Figure 2: SR Area 1 depicted on a topographic map in relation to its surrounding area.**

## 1.2 Project Scope

International Best Practice Guidelines and Sierra Leonean Legislation and Regulations were utilised to inform the scope for the assessment of the terrestrial, wetland and aquatic resources associated with SR Area 1. Specific outcomes in terms of these assessments are as follows:

**Terrestrial Ecological Assessment:**

- Desktop assessment to collect all relevant vegetation types, Species of Conservation Concern (SCC) and any other ecological data available for the area;
- To determine and describe primary floral habitat units, communities and general ecological conditions associated with the area;
- To determine the Present Ecological State (PES) of the various habitat units;
- To conduct a floral and faunal SCC assessment, including potential for such species to occur within SR Area 1;
- To provide inventories of floral and faunal species as encountered on site;
- To determine ecological services provided by the resources in and around SR Area 1;
- To describe the spatial significance of the area with regards to surrounding natural areas;
- To identify and consider all sensitive landscapes areas where disturbance should be avoided; and
- To identify opportunities where active management could result in an improvement of ecological resources associated with SR Area 1.

**Wetland Assessment:**

- Points of interest were selected by analysing digital satellite imagery to identify potential freshwater resources. These points of interest were then verified during the field assessment. Where necessary and/or where possible, delineations undertaken on a desktop basis were refined;
- The presence of any wetland characteristics, as defined by the Ramsar Commission, was noted to determine which features can be considered to contain areas displaying wetland or riparian characteristics;
- Characterisation and classification of freshwater resources according to the method of Ollis *et al*; (2013);
- Riparian Vegetation according to the VEGRAI Ecostatus tool;
- The Ecological Importance and Sensitivity (EIS) of the freshwater resources was determined according to the method described by Rountree & Kotze (2013);
- The goods and services provided by the freshwater resources in SR Area 1 were assessed according to the method of Kotze *et al.* (2009). This tool is used to define

the breadth and degree of goods and service provision to the local community as well as to support ecological processes;

- The PES was assessed according to the WetHealth and Wetland IHI methods as described by Macfarlane *et al.* (2008) and DWAF (2007) respectively, depending on which method was most relevant to the various freshwater resources;
- Freshwater resource areas were mapped according to the ecological sensitivity of each freshwater resource hydrogeomorphic unit in relation to SR Area 1. In addition to the freshwater resource boundaries, buffers were generated and were depicted where applicable;
- Advocate a Recommended Ecological Category (REC) for the freshwater resources based on the findings of the EIS assessment;
- The PES, EIS, and wetland ecoservices of the freshwater resources were highlighted, and a preliminary set of risks that the proposed development could pose were developed for further assessment in the future phases of the study; and
- To identify opportunities where active management could result in an improvement of ecological resources associated with SR Area 1.

**Freshwater Resource Assessment:**

The aquatic assessment included a survey of general habitat integrity, habitat conditions for aquatic macro-invertebrates as well as aquatic macro-invertebrate and fish community integrity. In addition, the condition of the riparian vegetation was also considered as it pertains to the overall quality of the aquatic resource.

## *1.3 Assumptions and Limitations*

The following points serve to indicate the assumptions and limitations regarding the aquatic assessment:

- ***Reference conditions are unknown:*** The composition of aquatic biota in aquatic resources associated with SR Area 1 is very limited and very little research is available, even on an aquatic ecoregion level. For this reason, reference conditions are largely hypothetical, and based on professional judgement and/or inferred from previous studies on SR Area 1. Based on the reference data available and based on the observations on site, the information available is, however, deemed adequate to provide the required level of understanding of the systems for the study;
- ***Temporal variability:*** The data presented in this report is based on a single assessment in July 2017 when relatively high flows were being experienced during the wet season. The spatial variation and long-term variation in the ecological conditions

and aquatic biota found in the local river systems are, therefore, largely unknown. Based on the observations made during the single site assessment and in comparison, with the historical studies, the information available is, however, deemed adequate to provide an appropriate level of understanding at this stage, although some aspects of the ecology of the system are likely to have not been observed. These information gaps will however most likely be adequately addressed in the dry season survey;

- ***Ecological assessment timing:*** Aquatic and terrestrial ecosystems are dynamic and complex. It is likely that aspects, some of which may be important, could have been overlooked. A more reliable assessment of the biota would require routine seasonal sampling, with sampling being undertaken on a bi-annual basis to cover seasonal variability. The level of assessment undertaken along with the impending dry season survey is, however, deemed adequate to ensure that an acceptable level of decision making can be afforded;
- ***Access constraints:*** In most areas, the riparian and bankside vegetation was extremely dense and impenetrable. Most points on the river systems that were accessible were located in areas along roads and pathways where increased human disturbance and human use occur, which in turn may have some impact on the results obtained. However, the results obtained at the various assessment points were consistent and hence it is deemed likely that the results obtained are largely representative of the system as a whole, and deemed adequate to provide the required level of understanding of the systems for the study;
- ***Freshwater resource mapping constraints*:** The freshwater resource delineations as presented in this report are regarded as a best estimate of the freshwater resource boundaries based on the site conditions at the time of the assessment. Limitations in the accuracy of the delineation due to limitations in access in the dense vegetation are, however, considered acceptable. Due to the reasonably high quality, high resolution digital aerial imagery of the site, accurate delineation of features using desktop mapping methods was possible in combination with site observations and field mapping exercises;
- ***Variation in freshwater resource mapping**:* Wetland and terrestrial areas form transitional areas where an ecotone is formed as vegetation species change from terrestrial species to facultative and obligate wetland species. Within the transition zone some variation of opinion on the wetland boundary may occur, however, if best practice delineation methods are followed, all assessors should obtain largely similar results; and
- ***Assessment methodologies and indices employed:*** The protocols used in the aquatic and wetland/riparian assessments have been designed in Southern Africa, and

are all considered as tools which should be used when applying best practice protocols or protocols adapted from widely acknowledged and accepted assessment methods for aquatic and wetland assessments. Where needed, assessment methodology (specifically the SASS5 interpretation) were slightly adapted and the fish community assessment was based on broad considerations of inferred biological characteristics of the genus and/or species as available as well as inferred considerations of the sensitivity of the fish species for the purpose of this study. Whilst not developed in the region in which SR Area 1 is located, it is the opinion of the ecologists that these protocols are applicable, relevant and provided an accurate reflection of the current aquatic ecological condition of SR Area 1 and are in support of the International Finance Corporation (IFC) standards for rigorous characterisation of watercourses.

## *1.4 Legislative Requirements*

The following legislative requirements were considered during the assessment:

- The Environment Protection Agency Act (EPAA) 2008;
- The Mines and Minerals Act 2009;
- The Forestry Act 1988;
- The Forestry Regulations 1989;
- The Wildlife Conservation Act 1972;
- The Wildlife Regulation 1997;
- Fisheries Acts 2007;
- The Sierra Rutile Agreement (Ratification) Act 2002;
- The Environmental and Social (Mines and Mining) Regulations 2013;
- Equator Principles (The Equator Principles Association, 2011);
- International Finance Corporation (IFC) Environmental Health and Safety General Guidelines (2007).

The details of each of the above, as they pertain to this study, are provided in Appendix A of this report.

# 2 RESULTS OF THE DESKTOP ANALYSIS

The following section contains data accessed as part of the desktop assessment. It is important to note, that although all data sources used provide useful and often verifiable high-quality data, the various databases do not always provide an entirely accurate indication of SR Area 1's actual biodiversity characteristics.

## 2.1 Sherbro River Estuary Marine Protected Area

Shapefiles for Protected Areas within Sierra Leone was obtained from the National Minerals Agency of Sierra Leone's Geo-Data Information Database[1]. According to the Protected Area 2 shapefile, the Sherbro River Estuary Marine Protected Area (MPA) falls within the north-western corner of SR Area 1. The database further provides a 1-mile buffer shapefile for all protected areas in Sierra Leone (Figure 3). Data pertaining to the Sherbro River Estuary MPA is limited. Investigations have revealed that although this MPA has been gazetted[23], no formal management plan nor official boundary for the site has been established, other than that of the 1-mile buffer as described above.

## 2.2 Terrestrial Ecoregions

According to the World Wildlife Fund (WWF, 2001), the majority of SR Area 1 occurs within the *Guinean Mangroves* (AT1403) terrestrial ecoregion, while the remaining portion of SR Area 1 occurs within the *Western Guinean Lowland Forests* (AT0130) (Figure 4). The sections below briefly describe the characteristics of the terrestrial ecoregions. It must be noted that these ecoregions were delineated on a desktop level and are of low resolution and therefore often not accurate to a site-specific level.

### 2.2.1 Guinean Mangrove

The Guinean Mangrove is a vulnerable terrestrial ecoregion, encompassing approximately 14,000 km$^2$. This ecoregion is influenced by a large tidal range and high inputs of freshwater, containing stands that are more than 25 m in height and extend as far as 160 km inland. As the best developed mangroves in western Africa, this ecoregion provides important habitat for migratory birds and endangered species such as the *Trichechus senegalensis* (West African Manatee) and the *Choeropsis liberiensis* (Pygmy Hippopotamus). However, the mangrove habitat is threatened by agriculture and urban development and has been affected by poor rainfall over the entire region during the past three decades.

The Guinean mangroves stretch from Senegal to west of the Dahomey Gap. This gap is a major ecological barrier separating the rainforest regions of West and Central Africa, which in the marine environment represents the end of the influence of the south-north flowing cold

[1] https://gims.nma.gov.sl/open-data

[2] http://www.rampao.org/Sierra-Leone-Ces-ecosystemes.html?lang=en

[3] http://mpatlas.org/mpa/sites/9663/

waters of the Benguela current. Although more extensive, the West African mangroves are relatively species poor compared to the East African mangroves, containing five compared to nine mangrove tree species. No other data is available for this ecoregion.

### 2.2.2 Western Guinean Lowland Forest (WWF, 2001)

The Western Guinean Lowland Forest is a critically endangered terrestrial ecoregion, encompassing approximately 128,000 $km^2$ (WWF, 2001). The Western Guinean Lowland Forest contains the westernmost rainforest on the African continent. The flora and fauna are distinctive, with larger numbers of narrowly endemic species than in the contiguous Eastern Guinean Lowland Forest ecoregion to the east.

#### 2.2.2.1 Location and General Description

The Western Guinean Lowland forest stretches from eastern Guinea, across Sierra Leone and Liberia, to the Sassandra River in southwestern Côte d'Ivoire. It is the most westerly tropical rainforest block on the African continent. The topography is relatively flat to undulating with altitude ranges between 50 and 500 m, although there are a few isolated mountains rising higher above the landscape. The ancient African shield formation on which the ecoregion sits has eroded over millions of years and is dissected by several major rivers including the Sewa, Mano, St. Paul, Cavally and Sassandra. Some of these might have served as physical barriers to the dispersal or migration of fauna. The soils are generally poor, lateritic and prone to heavy leaching. Some young alluvial deposits are found along river valleys and inland swamps are more fertile and are often converted to agriculture (Gwynne-Jones *et al*. 1977).

#### 2.2.2.2 Climate

The ecoregion is one of the wettest parts of West Africa, with seasonal rains up to 3,300 mm per year soaking the region between Guinea and Liberia. A humid-equatorial climate ensures that certain locations, such as the No.2 River on the Freetown Peninsula in Sierra Leone, receive more than 5,000 mm precipitation annually (Cole, 1968). Weeks of heavy rain are punctuated by short but intense dry seasons (White, 1983; Peters, 1990). The seasonal variation in rainfall has a critical influence on the vegetation (Lawson, 1996). Seasonal temperatures range between 30 and 33 °C during the dry season and 12 and 21 °C during the wet season. The cold, dry Harmattan winds sweep across the Sahara Desert from December to February, lowering temperatures to as cold as 12 and 15 °C (Cole, 1968). The generally warm and humid climate permitted the development of lush forest vegetation along most of this coastal region.

#### 2.2.2.3 Vegetation

The vegetation of the Western Guinean Lowland Forest comprises many different plant associations, several of which are unique to the area. Human impacts on the vegetation have been severe and prolonged (Sowunmi, 1986), and the closed canopy forest is substantially altered from the primary state. Today's forests could be described as late secondary stands (Voorhoeve, 1965; Lebbie, 2001). White (1983) refers to the original forest in this area as 'Upper Guinea', and classifies it as part of the Guineo-Congolian regional center of endemism. There seems to be general agreement that the forest fragments that remain today can be grouped into moist evergreen forest and moist semi-deciduous forests (Cole, 1968; Vooren and Sayer, 1992; Mayers *et al*. 1992). Many canopy trees are at least 30 m tall, with some emergent individuals reaching a height of 50 - 60 m. Tree density and species diversity per hectare are generally low, but stand basal area tends to be high because of the large girth of a small number of trees. Swamp and riparian forests can be found embedded within the moist evergreen and semi-deciduous forests. 'Farmbush', the degraded secondary growth derived from forest that follows slash-and-burn agriculture, is increasingly the most dominant vegetation type in this region.

The tree composition of this ecoregion is quite uniform over long distances, with species such as *Dacroydes klaineana* (Adjouaba), *Strombosia glaucescens* (Kove), *Allanblackia floribunda* (Tallow Tree), *Coula edulis* (African Walnut) and *Diospyros sanza-minika* (African Ebony) being common in many places (Davies, 1987). Local geo - climatic factors, as well as the level of past exploitation, undoubtedly play a large role in the distribution and dominance of different plant associations in a given region and even within the same vegetation type. Typical canopy dominants of the moist evergreen forest of Sierra Leone include *Heritiera utilis* (Red Cedar), *Cryptosepalum tetraphyllum, Erythrophleum ivorense* (Ordeal tree) *and Lophira alata* (Ekki), with small amounts of *Klainedoxa gabonensis, Uapaca guineensis* (False Mahogany), *Oldfieldia africana* (African Oak), *Brachystegia leonensis* (Bush Mahogany) and *Piptadeniastrum africanum* (African Greenheart) (Savill and Fox, 1967; Cole 1968).

In Sierra Leone, common plant associations include species that are also common in the moist evergreen forest: *Anthonotha fragrans, Bridelia grandis* (Bembe), *Daniella thurifera, Parinari excelsa* (Mubura), *Parkia bicolor, Pycnanthus angolensis* (African Nutmeg), *Terminalia superba* (Afara) *and Terminalia ivorensis* (Black Afara) (Fox, 1968; Davies, 1987; Harcourt *et al*. 1992). The swamp and gallery forests of Sierra Leone possess some unique plant associations that include *Pterocarpus santalinoides, Napoleonaea vogelii, Uapaca heudelotii, Newtonia elliotii, Myrianthus arboreus* (Corkwood), *Cynometra vogelii, Mitragyna stipulosa* (African Linden) and *Raphia spp.* (Raphia Palm) (Cole, 1968). 'Farm bush' vegetation is made up of fast growing pioneers, including common species such as *Funtumia Africana* (Silk

Rubber), *Holarrhena floribunda* (False Rubbertree) and *Pycnanthus angolensis* (African Nutmeg).

Recent estimates indicate there are more than 200 plants endemic to this ecoregion, with an endemic liana family *Dioncophyllaceae* containing three monotypic genera (Gillaumet, 1967; Jenkins and Hamilton, 1992; WWF and IUCN, 1994; Bakkar *et al*. 1999). One endemic species, *Didelotia idae* (Near Threatened; NT), is confined to the Gola forest complex between Sierra Leone and Liberia (Fox, 1968).

**2.2.2.4 Fauna**

The current biodiversity patterns of plant and animal endemism in the Western Guinean Lowland Rainforest date from the Pleistocene epoch 15,000-250,000 B.P. (Moreau, 1969). The climatic fluctuations during this period created isolated forest refugia during drier periods, with the forest expanding again in wetter periods, only to contract once more when the conditions became drier. These changes, together with similar phases of tropical forest expansion and contraction over millions of years, have caused species of flora and fauna to become isolated, which has resulted in speciation and relictualisation (Booth, 1958; Moreau, 1969; Grubb, 1978; Grubb *et al*. 1998; Hamilton, 1981; Kingdon, 1990; Happold, 1996). Despite their apparent small size, important refugia during this period included Cape Palmas, Cape Three Point and the Gola Forest region between Sierra Leone and Liberia.

This ecoregion also has a diverse fauna (Martin, 1991; Happold, 1996; Bakkar *et al*. 1999). There are nearly 1,000 vertebrates recorded in Taï National Park, holding viable populations of the near-endemic *Choeropsis liberiensis* (Pygmy Hippopotamus, Vulnerable VU). In the order Artiodactyla, two duikers, *Cephalophus jentinki* (Jentink's Duiker, Endangered EN) and *Cephalophus zebra* (Zebra Duiker, VU) are strictly endemic to this ecoregion. *Hybomys planifrons* (Miller's Striped Mouse, Least Concern LC) is the only other strictly endemic mammal, although more than 15 species of mammal are regarded as near-endemic, with all of these species shared only with the adjacent Eastern Guinea Lowland Forest and/or the Guinea Montane forest ecoregions.

Non-human primates are also diverse and include endemic subspecies of the *Cercopithecus diana* (Diana Monkey, EN), *Procolobus badius* (Red Colobus), *Cercopithecus petaurista* (Lesser Spot-nosed Monkey), and *Cercocebus* torquatus atys (Sooty Mangabey). Other near-endemic primates include *Procolobus verus* (Olive Colobus), and the *Pan troglodytes verus* (Western Chimpanzee, EN). Some of these species are threatened as a result of hunting for bushmeat and habitat loss (Oates, 1986; Lee *et al*. 1988; Bakarr *et al.* 2001). Other important large mammals in the Western Guinean Lowland Forest include the *Panthera pardus*, (Leopard, EN) and *Loxodonta africana cyclotis* (African Forest Elephants, EN). The forest elephants in Taï and Comoé National Parks are considered to be priority baseline populations for West Africa (IUCN, 1990), with the Gola Forest reported to have a potential viable population in Sierra Leone (Roth and Merz 1983). *Cephalophus maxwelli* (Maxwell's Duiker), *Tragelaphus scriptus* (Bushbuck) and the *Potamochoerus porcus* (Red River Hog) are among the wide-ranging mammals that are common in this ecoregion.

Forest birds are diverse and include a number of endemic and rare species. Three bird species are strictly endemic to this ecoregion: the *Phyllastrephus leucolepis* (Liberian Greenbul, CR), *Melaenornis annamarulae* (Liberian Black-flycatcher, VU) and *Malimbus ballmanni* (Ballman's Malimbe, EN). Other species considered endemic include *Glaucidium castaneum* (Chestnut Owlet), *Ceratogymna cylindricus* (brown-cheeked hornbill), *Laniarius turatii* (Turati's bushshrike), *Coccycolius iris* (Iris Glossy-starling), *Illadopsis rufescens* (Rufous-winged Illadopsis), *Agelastes meleagrides* (White-breasted Guineafowl, VU) (Allport *et al*. 1989), *Lobotos lobatus* (Ghana Cuckoo-shrike, VU), and *Schistolais leontica* (Sierra Leone Prinia) (Allport *et al*. 1989; Allport, 1991; Jenkins and Hamilton, 1992; Thompson, 1993; Hilton-Taylor, 2000). While not endemic, there are several other species only shared with the Eastern Guinean Lowland Forest ecoregion or the Guinean Montane Forest Ecoregion (Stattersfield *et al*. 1998). The most important of these include the *Picathartes gymnocephalus* (Yellow-headed Rockfowl, VU), *Scotopelia ussheri* (Rufous Fishing Owl, EN), and *Criniger olivaceus* (Yellow-bearded Greenbul, VU) (Allport *et al*. 1989; Allport, 1991; Jenkins and Hamilton, 1992; Thompson, 1993; Hilton-Taylor, 2000).

The herpetofauna is also diverse (Welch, 1982), and contains a large number of endemic species. In the amphibians, there are 13 strictly endemic species and a number of others shared with the Eastern Guinea Lowland Forest ecoregion. The strict endemics include the rare frog *Pseudhymenochirus merlini* (Merlin's Clawed Frog) known only from Guinea and Sierra Leone (Chabanaud, 1920; Menzies, 1967), and *Arthroleptis aureoli* (Freetown Long-fingered Frog), which is only known from the mountains close to Freetown in Sierra Leone. Other notable endemics include the *Phrynobatrachus taiensis* (Tai River Rrog), *Cardioglossa liberiensis* (Liberian Long-fingered Frog) and *Sclerophrys danielae* (Ivory Coast Toad) (Schiøtz, 1964, 1967; WCMC, 1994; Harcourt *et al*. 1992; Vooren and Sayer, 1992).

The reptile fauna is less rich in endemics, with three strictly endemic species and thirteen shared only with the Upper Guinea forest block. The strict endemics are *Cynisca leonina* (Los Archipelago Worm Lizard), *Trachylepis bensonii* (Benson's Mabuya) and *Letheobia leucostictus* (Liberia Worm Snake).

There are several recent inventories conducted in Sierra Leone which have led to the discovery of several new species, especially among the order Coleoptera (Beetles) such as *Euconnus* spp., and *Termitusodes* spp. (Franciscolo, 1982, 1994; Kistner, 1986; Castellini, 1990). New discoveries in the orders Lepidoptera (Butterflies and Moths) and Diptera (Flies) have also been made (Belcastro, 1986; Munari, 1994), with two endemic species of dragonfly, *Argiagrion leoninum* and *Allorhizucha campioni*, also known from Sierra Leone (Stuart *et al*. 1990).

#### 2.2.2.5 Protection Level

Much of the natural forest in this ecoregion has been lost due to human activities, with almost all remaining forest modified by historic anthropogenic activities. Sierra Leone has experienced severe loss of its natural forest, dating back to the 19th century when timber was exported during British colonial administration. Subsistence agriculture in the wake of commercial logging has reduced the area of primary forest in Sierra Leone from more than 70 percent to just under 6 percent (Davies, 1987). Further losses in forest coverage are projected at 5 percent should the trend in deforestation continue (Barnes, 1990). Both Côte d'Ivoire and Sierra Leone show the greatest level of fragmentation of natural forests, while Liberia still retains large forest blocks. The largest stands of high forest in all of these countries are found within so-called 'protected areas' and 'forest reserves'. Despite these titles, the management of protected areas and reserves is currently poor or non-existent, especially in Guinea, Sierra Leone and Liberia, where civil conflicts drain resources to other areas. The total area of protected forest in this ecoregion is just under 3 percent for all National Parks and other reserves (IUCN levels II-IV) with international designations (based on WCMC Protected Areas Database - March 1999).

#### 2.2.2.6 Threats

Anthropogenic pressures for farmland, timber, bushmeat, fuelwood and mineral deposits are reducing the size and biotic potential of the remaining forests. Most of the high forest areas that remain are late secondary stands, which are isolated from each other within a sea of 'farmbush' vegetation. The Western Area Forest Reserve on the Freetown peninsula of Sierra Leone has experienced intense exploitation for timber because of the inaccessibility of timber resources in historic rebel-held territories (Lebbie, 1998, 2001). Two species, *Heritiera utilis* (Red Cedar) and *Terminalia ivorensis* (Black Afara), are in high demand by furniture makers in Freetown and are experiencing intense exploitation. The global demand for valuable hardwoods continues to spur logging in most of the high forests in this region. The secondary impacts of this activity are perhaps more damaging to the forest than timber harvesting itself, since the roads used to access the timber invite subsistence agriculturists and cash croppers who clear more forest to cultivate (Sayer *et al.* 1992). In this way, timber harvesting has accelerated forest fragmentation.

Hunting for bushmeat now parallels habitat loss as the major threats to the survival of mammals in this ecoregion (Anstey, 1991; Bakarr *et al*. 1999, 2001). Recently, Oates *et al*. (2000) attributed the extinction of *Piliocolobus badius waldroni* (Miss Waldron's Red Colobus) on hunting and the demand for bushmeat in the Eastern Guinean region. Bushmeat is a critical protein source for many people in the region and a large variety of species are hunted. Antelopes, forest pigs and primates dominate the bushmeat trade in urban areas, while *Thryonomys swinderianus* (Grasscutter/Greater Cane Rat) and *Cricetomys gambianus* (Gambian Giant Rat) are widely preferred because they are readily available (Caspary, 1999). The extent of such hunting has prompted governments to enact hunting bans, though the legislation is impractical and cannot be enforced (Sayer *et al.* 1992). It is clear that if action cannot be taken to reduce bushmeat hunting, then it will continue to have a severe impact on the mammal fauna of the ecoregion.

Commercial fuel wood collection is an emerging threat to both protected and already degraded forests. It is exacerbated by reliance of a vast majority of urban dwellers on wood and charcoal for cooking. On the Freetown peninsula of Sierra Leone, charcoal consumption is reported to be higher now than in the last two centuries (Cline-Cole 1987), with charcoal and firewood supplying 80 percent of the total energy demand (Davidson 1985). Fuelwood collection is a major factor in the shortening of in fallow periods because trees are continuously extracted until the land is farmed again.

Though regional instability may have provided respite to some forests and the species that inhabit them, civil war also translates into poor or non-existent management of parks and protected areas. The recent civil conflicts in Sierra Leone and Liberia have resulted in serious damage to forests as a result of mining, logging and bushmeat hunting (Lebbie, 1998; Garnett and Utas, 2000). Logging activities have increased considerably in the Western Area Forest Reserve, with a large number of unemployed refugees providing the man power needs for this illegal trade.

Mining is a locally intense and destructive practice in Sierra Leone and a primary cause of habitat destruction in parts of the country (Bakarr, 1992). Mining has been closely tied to civil conflicts throughout this ecoregion, especially diamond mining (Garnett and Utas, 2000). Mining of bauxite and titanium dioxide (rutile) in the southeast has resulted in forest loss, with the subsequent dredging leaving large bodies of deep water polluted with heavy metals (Bakarr, 1992). These mining activities have also caused displacement of people and have locally increased the pressure on remaining forests. In other regions of the country where mining for diamonds and gold has occurred, siltation is threatening freshwater fish populations, while hunters have increased their assault on the dwindling wildlife populations in nearby forests to supply bushmeat to the mining settlements.

## 2.3 Biomes

The majority of SR Area 1 falls within the Mangroves Biome, while remaining portion is situated within the tropical and subtropical moist broadleaf forests biome (Figure 5). It must be noted that these ecoregions were delineated on a desktop level and are of low resolution and therefore often not accurate to a site-specific level.

### 2.3.1 Mangroves

Mangroves occur in the waterlogged, salty soils of sheltered tropical and subtropical shores. They are subject to the twice-daily ebb and flow of tides, fortnightly spring and neap tides, and seasonal weather fluctuations. They stretch from the intertidal zone up to the high-tide mark. Based on literature review, these forests comprise 12 genera containing about 60 species of salt-tolerant trees (WWF, 2001b). With their distinctive nest of stilt and prop-like roots, mangroves can thrive in areas of soft, waterlogged, and oxygen-poor soil by using aerial and even horizontal roots to gain a foothold. The roots also absorb oxygen from the air, while the tree's leaves can excrete excess salt. Associated with the tree species are a whole host of aquatic and salt-tolerant plants. Together they provide important nursery habitats for a vast array of aquatic animal species.

### 2.3.2 Tropical and Subtropical Moist Broadleaf Forest

Generally found in large, discontinuous patches centred on the equatorial belt and between the Tropics of Cancer and Capricorn, Tropical and Subtropical Moist Forests (TSMF) are characterised by low variability in annual temperature and high levels of rainfall (>2000 mm annually). Forest composition is dominated by semi-evergreen and evergreen deciduous tree species. These trees number in the thousands and contribute to the highest levels of species diversity in any terrestrial major habitat type. In general, biodiversity is highest in the forest canopy which can be divided into five layers: overstory canopy with emergent crowns, a medium layer of canopy, lower canopy, shrub level, and finally understory.

These forests are home to more species than any other terrestrial ecosystem: half of the world's species may live in these forests, where a square kilometre may be home to more than 1,000 tree species. A perpetually warm, wet climate promotes more explosive plant growth than in any other environment on Earth. A tree here may grow over 25 m in height in just 5 years. From above, the forest appears as an unending sea of green, broken only by occasional, taller "emergent" trees.

The canopy is home to many of the forest's animals, including apes and monkeys. Below the canopy, a lower understory hosts to snakes and big cats. The forest floor, relatively clear of undergrowth due to the thick canopy above, is prowled by other animals such as gorillas and deer. All levels of these forests contain an unparalleled diversity of invertebrate species, including New Guinea's unique stick insects and bird wing butterflies that can grow over one foot in length. These forests are under anthropogenic pressure. Many forests are being cleared for farmland, while others are subject to large-scale commercial logging.

## 2.4 Vegetation Types

The vegetation types associated with SR Area 1 are Mangroves (majority of the area) and Forest Transitions and Mosaics (central region of eastern portion) according to Vegetation Map of White, (1983) (Figure 6). The Mangrove vegetation type comprise of edaphic formations of distinct physiognomy (vegetation structure) of open or closed stands of trees (or bushes) occurring on shores between the high- and low-water marks. Forest Transitions and Mosaics comprise of Forests (continuous stands of trees with heights of 10 m or more with interlocking crowns), Scrub forests (a transitional vegetation formation of local extent that is intermediate between forest and bushland or thicket), and Transition woodland (a transitional vegetation formation of local extent that is intermediate between forest and woodland (Kindt, *et al*.,2012).

## 2.5 Aquatic Ecoregion

According to the WWF FEOW (Freshwater Ecoregions of the World, http://www.feow.org/ecoregions/details/511) classification, SR Area 1 is located within the Northern Upper Guinea Aquatic Ecoregion (reference number 511) (Figure 7). The major habitat type is listed as tropical and subtropical coastal rivers, and lies on the western side of the Guinean range, extending from the foothills of the Fouta Djalon in Guinea southeast to Sierra Leone's southern border and encompasses a small portion of Guinea-Bissau and Liberia. This ecoregion is defined by the basins of the Coliba (Tominé and Komba), Kogon, Tinguilinta, Fatala, Konkouré, Kolenté, Kaba and Mongo rivers and is characterized by a rich aquatic fauna with high endemism among fish, molluscs, amphibians, and crabs (Lévêque, 1997).

### 2.5.1 Main rivers or other water bodies

The main rivers are the Coliba (Tominé and Komba), Kogon, Tinguilinta, Fatala, Konkouré, Kolenté, Kaba and Mongo Rivers. The Tominé and Komba Rivers join to form the Coliba River. The Kolente River (basin size: 5,170 km²) flows through the Kindia and Forecariah regions. It has a gentle slope throughout most of its 210 km length and it meets the Atlantic Ocean in Sierra Leone. The Kaba (basin size 5,427 km²) is 91 km long. It is formed by the Kaba and Mongo Rivers coming from the Mamou region. It flows down to the Atlantic Ocean through

Sierra Leone (Samoura *et al.* 1999). The many rivers and streams within this ecoregion form an intricate hydrological network.

### 2.5.2 Topography

The relatively short rivers of the ecoregion descend from the Guinean Dorsale and cross the coastal plain adjacent to the Atlantic Ocean. The rivers begin at elevations of around 500 m above sea level (asl) (and as high as 1,946m asl at Mt. Bintumani in the Loma Mountains) (Hughes & Hughes, 1992). Moving west, the gradient decreases and the landscape changes from undulating foothills to a coastal plain where riverine and floodplain lakes are common. Almost all of the coastal rivers have a torrential flow regime due to their steep downward slopes and rocky bottoms (Dne *et al*. 1999).

### 2.5.3 Freshwater habitats

Floodplain lakes, which support beds of floating and submerged aquatic macrophytes, also occur within the coastal plain, and these lakes are surrounded by extensive tracks of swamp forests (Hughes and Hughes 1992). Mangroves backed by freshwater swamp forests grow along most of the coast, especially along many of the riverine estuaries. Sediments brought downstream by the rivers constitute the soils of these swamps. Species such as *Pterocarpus santalinoides, Napoleonaea vogelii,* and *Mitragyna stipulosa* (African Linden) can be found in the swamp forests behind the mangroves (Sayer *et al.* 1992). Other vegetation includes *Dalbergia, Sesuvium portulacastrum,* and *Paspalum vaginatum* (Salt Paspalum).

### 2.5.4 Fish fauna

The forested coastal streams and rivers of Upper Guinea support a diverse and endemic aquatic fauna. About 28 percent of the 160 fish species are endemic (Lévêque *et al*. 1989).
The endemic fishes are generally small-bodied and adapted to the swift currents and clear waters of the ecoregion. One-quarter of the endemic fish are rivulines, some of which are annuals. During the wet season, these annuals lay their eggs in the soil of temporary floodplain pools that desiccate in the dry season. These eggs hatch with the inundation of floodwaters in the rainy season (Lévêque *et al*. 1992). Species from the Cyprinodontidae (Ray Finned Fish) such as Aphyosemion and Epiplatys and Cyprinidae (Barbus) families dominate the endemics of the coastal streams and rivers. There are also several endemic fish from the Mochokidae (Squeaker Catfish), Mormyridae (Elephantfish), Claroteidae (Claroteid Catfishes), and Cichlidae (Tilapia) families.

### 2.5.5 Other noteworthy aquatic biotic elements

Ten endemic frogs, four endemic freshwater crabs, at least two endemic dragonflies (*Argiagrion leoninum* and *Allorhizucha campioni*), and five endemic molluscs also live in the waters of the Northern Upper Guinea ecoregion. Several nesting and overwintering birds can be found in the coastal floodplain, especially within the mangroves. Mangrove forests provide a variety of food sources for waterbirds such as fish, insects, and shellfish (Hughes and Hughes, 1992). Species such as the *Ardea alba* (Great White Egret), *Bubulcus ibis* (Cattle Egret), *Butorides striata* (Green-Backed Heron), *Ardea purpurea* (Purple Heron), *Nettapus auritus* (African Pygmy Goose), and *Dendrocygna viduata* (White-faced Whistling Duck) nest in the freshwater and brackish swamps near the mouth of the Nunnez and Koumba Rivers (Wetlands International, 2002).

The ecoregion also supports a variety of large aquatic reptiles and mammals. All three species of African crocodiles - *Mecistops cataphractus* (Slender-Snouted, CR), *Crocodylus niloticus* (Nile), and *Osteolaemus tetraspis* (Dwarf, VU) crocodile - have historically inhabited the riverine floodplains and swamps of this ecoregion. The vulnerable *Trichechus senegalensis* (West African Manatee), the *Hippopotamus amphibius* (Common Hippopotamus), and the vulnerable *Choeropsis liberiensis* (Pygmy Hippopotamus, EN [IUCN, 2015]), also live in the ecoregion (IUCN 2002). Important areas for the pygmy hippopotamus include the Moa River around Tiwai Island and the Mahoi River in the Gola Forest (Sayer *et al.* 1992).

### 2.5.6 Justification for delineation

The high level of endemism among fishes in this ecoregion is postulated to be the result of isolation over time (Lévêque, 1997). The Guinean range is an impassable barrier to the dispersal of fish from the Upper Guinean streams to the basins to the northeast, such as the Niger. Rapids and waterfalls within individual basins have likely served as additional barriers. Different habitats potentially contributed to the divergence as well; for example, forested streams characterize the Guinean region, whereas savanna streams predominate in the Nilo-Sudan ichthyofaunal province periods (Hugueny & Lévêque, 1994). Another hypothesis for the high endemism in the bioregion is that the rivers and streams of this forested area acted as a “refuge” during dry climatic periods (Hugueny & Lévêque, 1994).

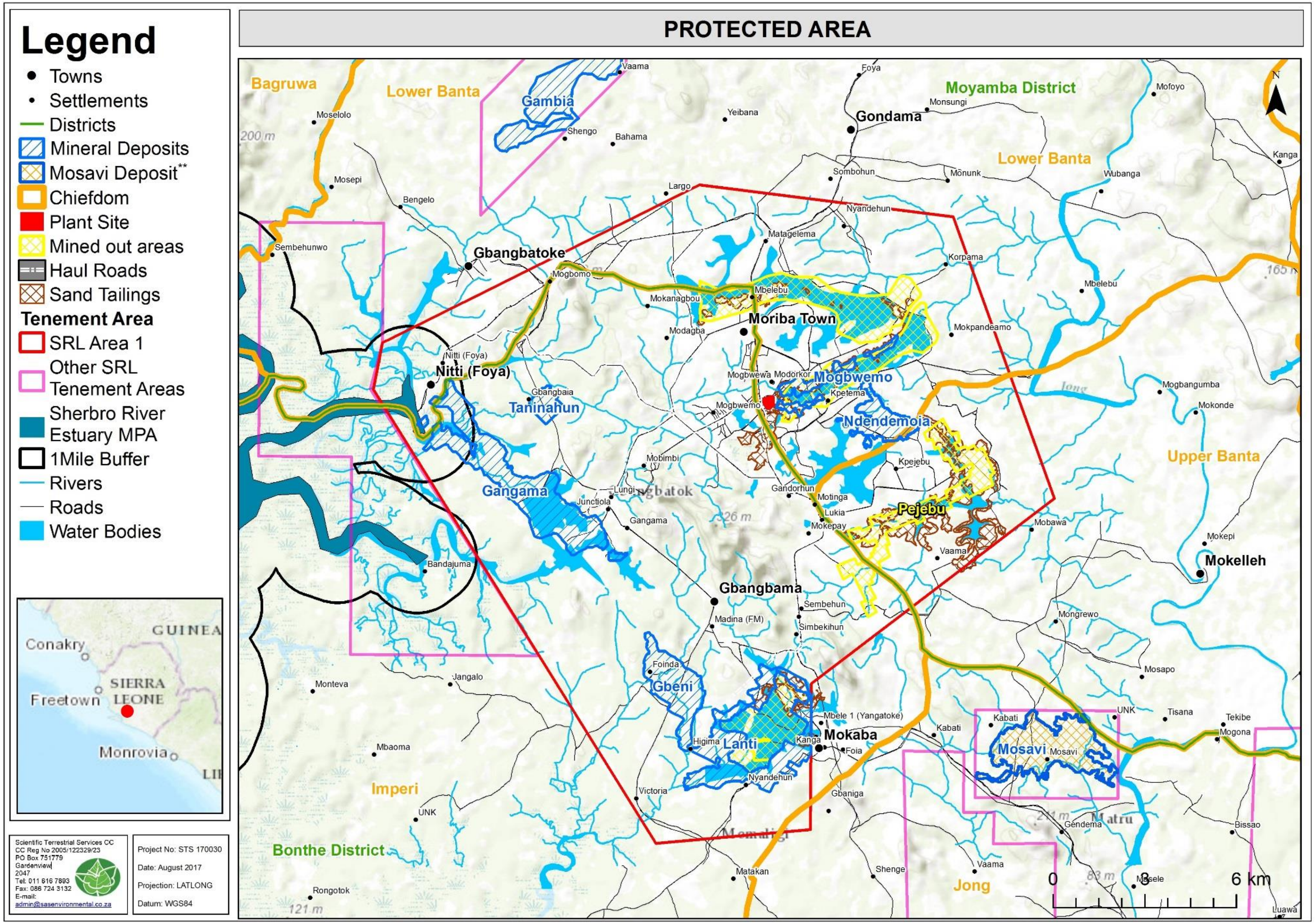


Figure 3: Sherbro River Estuary Marine Protected Area and Protected Area 1 mile (1.6 KM) buffer (NMA, 2016)

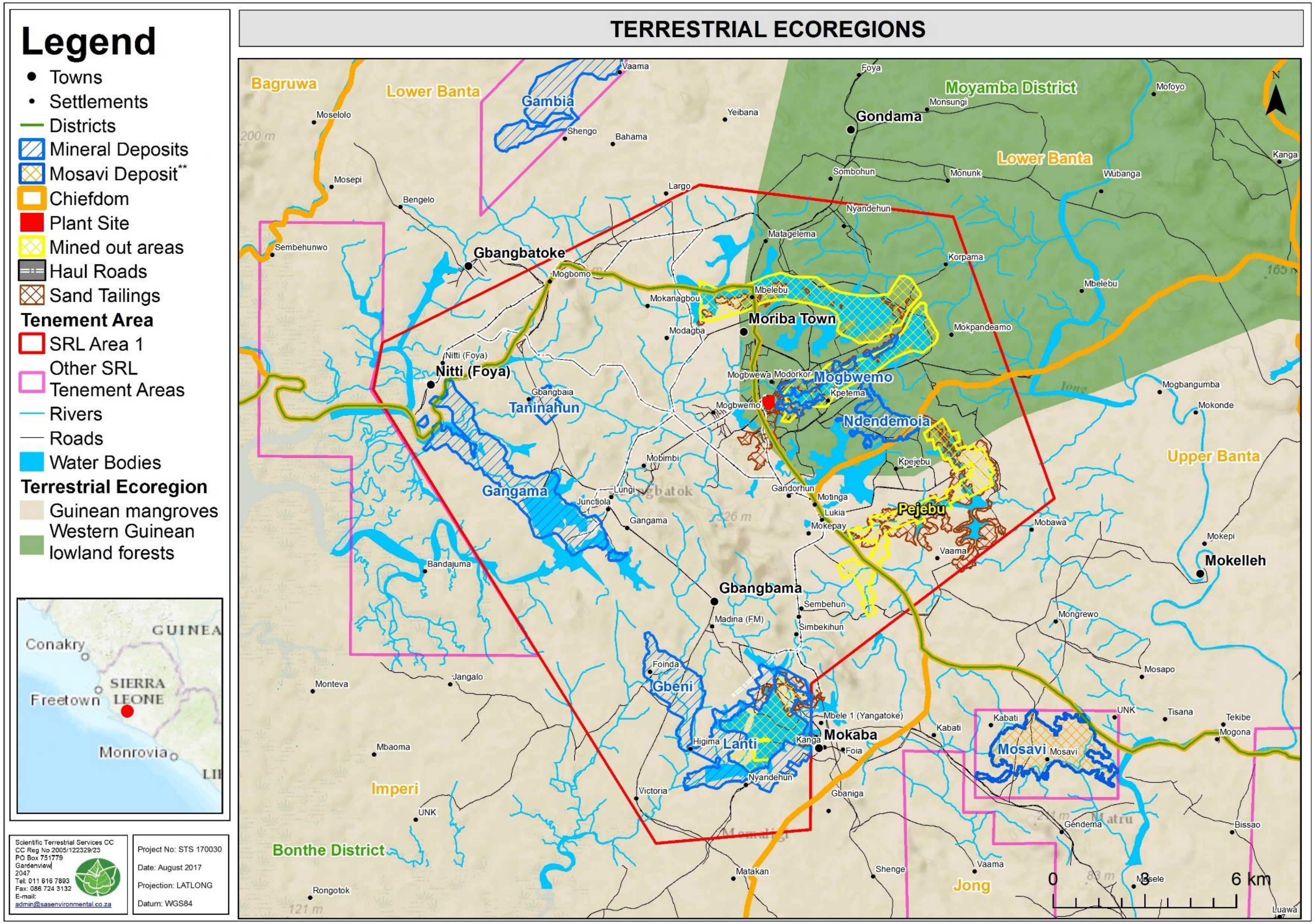


**Figure 4: Terrestrial Ecoregions associated with SR Area 1 (WWF, 2001).**

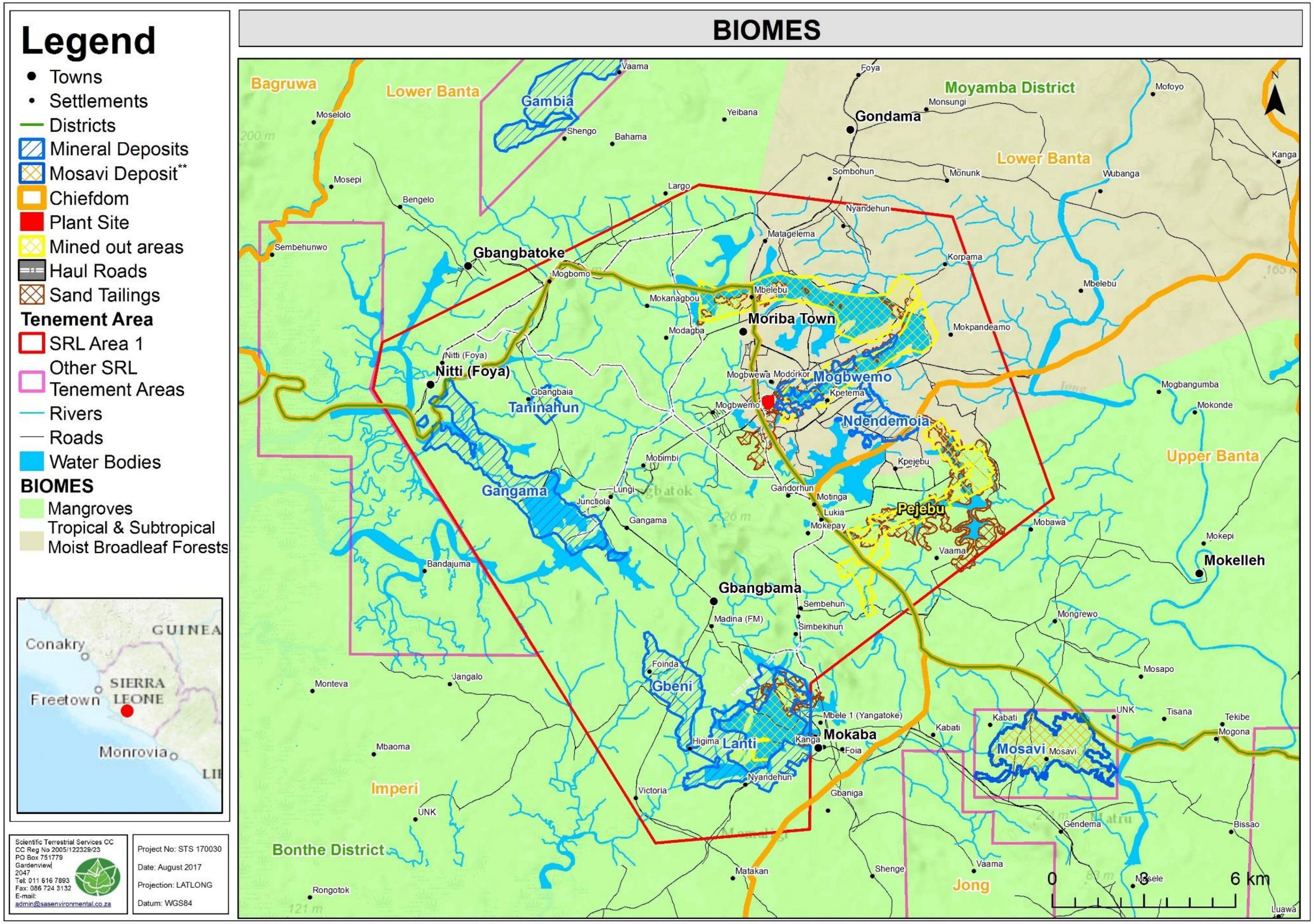


Figure 5: Biome associated with SR Area 1 (WWF, 2001).

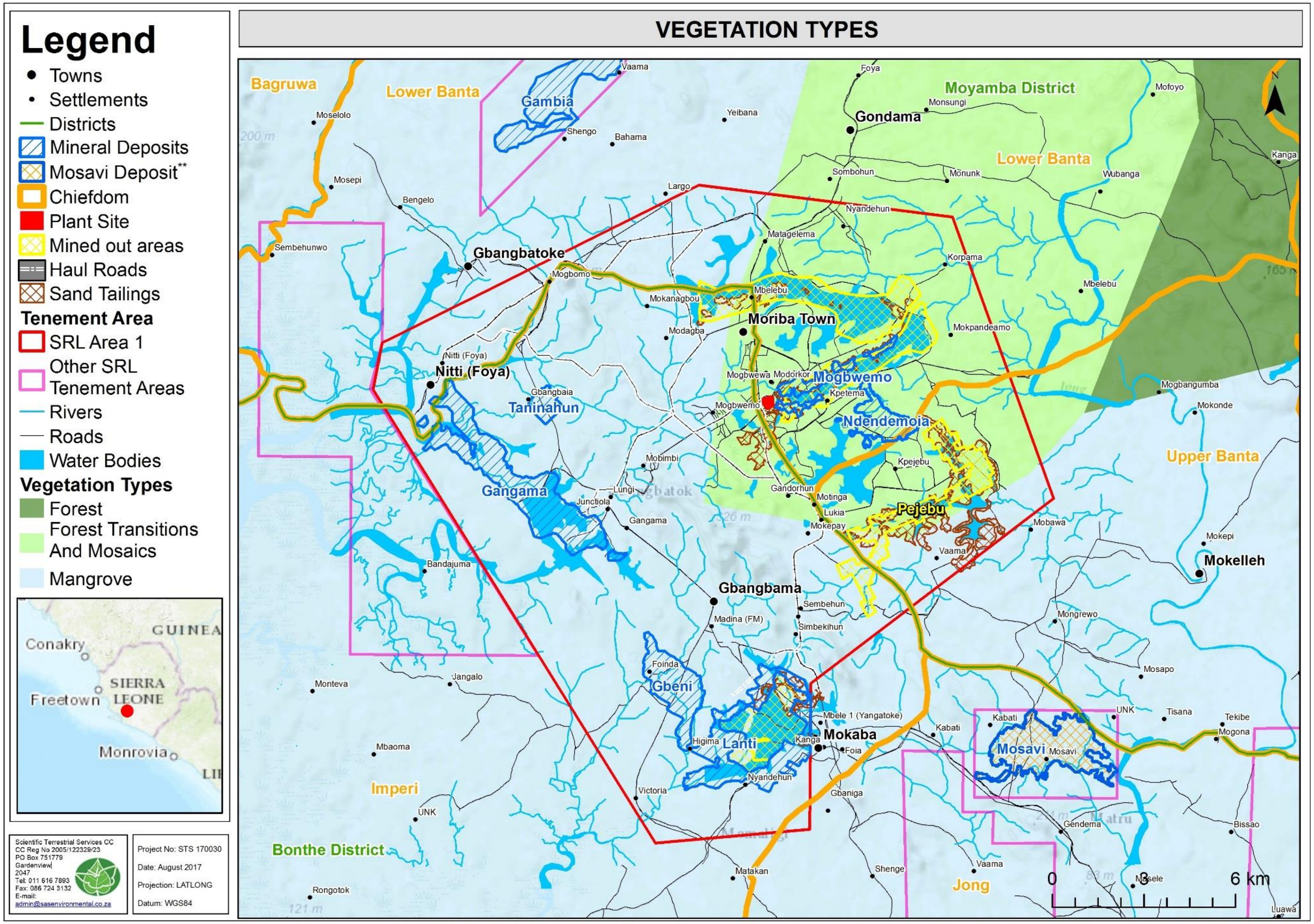


Figure 6: Vegetation type associated with SR Area 1 (WWF, 2001).

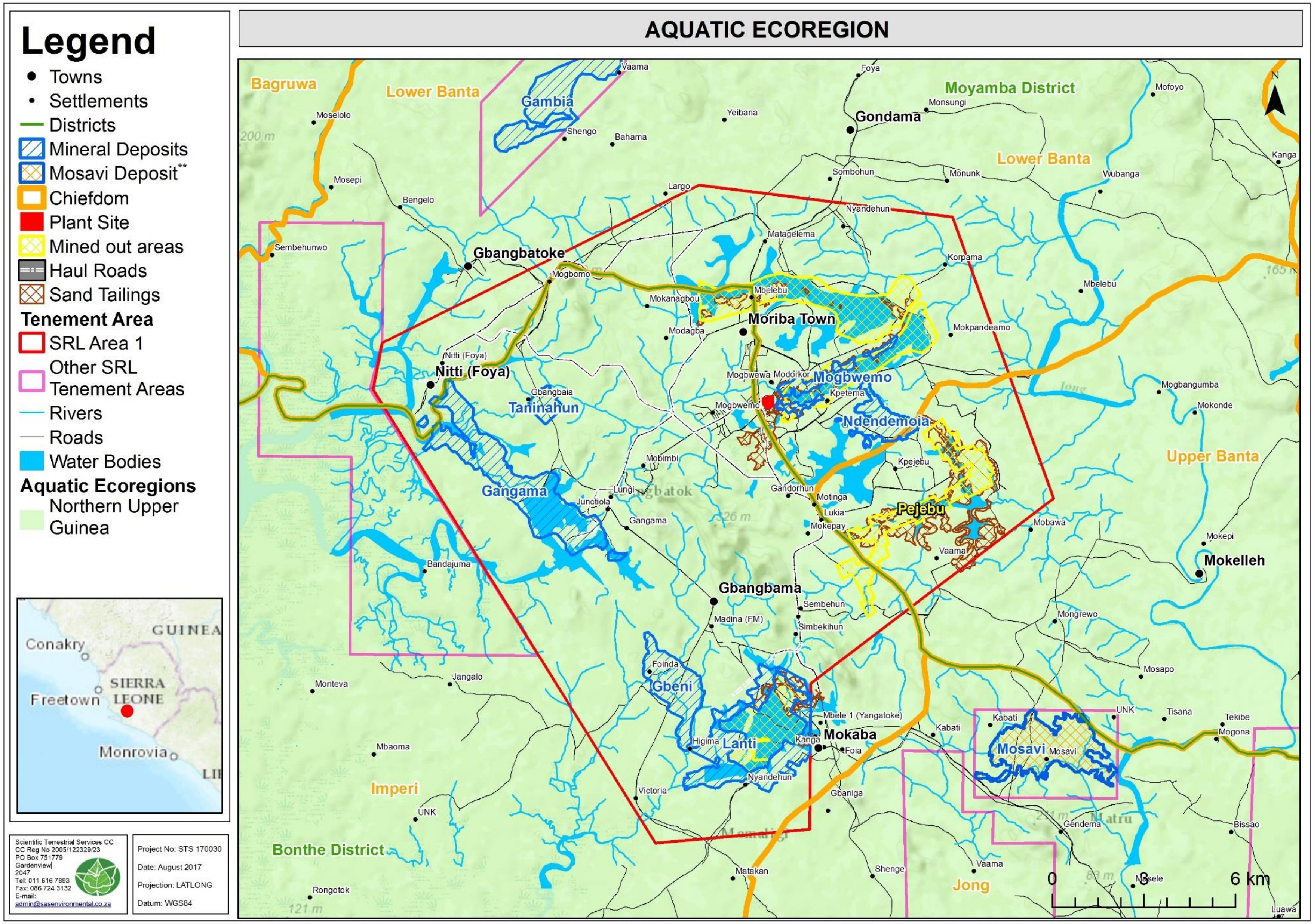


Figure 7: Aquatic Ecoregions associated with SR Area 1 (WWF, 2001).

# 3 STRUCTURE OF THE REPORT

Section A of this report served to provide an introduction to the ecology of SR Area 1 as well as the general approach to the study. Section A also presents the results of general desktop information reviewed as part of the study including the information generated by the relevant authorities as well as the context of the site in relation to the surrounding anthropogenic activities and ecological character.

- Section B addresses all the issues pertaining to the assessment of the floral ecology of SR Area 1.
- Section C addresses all the issues pertaining to the assessment of the faunal ecology of SR Area 1.
- Section D addresses all the issues pertaining to the assessment of the aquatic and wetland ecology of SR Area 1.
- Section E assesses the potential impacts on aquatic and terrestrial ecology of SR Area 1, both before and after mitigation.

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# APPENDIX A: Legislative Requirements

The following section has been compiled from the previous ESIA study conducted by CEMMATS (2012), with only relevant legislation applicable to this study considered.

## The Environment Protection Agency Act 11 of 2008

Subsection 1 of section 24 of the Act submits that an EIA is demanded for certain types of project activities for which, any person who wishes to undertake or cause to be undertaken any of the projects set out in the first schedule shall apply to the Agency for a license. Projects requiring an EIA are those, as given in the first schedule (Section 24) of the Act, whose activities involve or include the following with:

- Exploitation of hydraulic resources (e.g. dams, drainage and irrigation projects, water basin development, water supply);
- Infrastructure (e.g. roads, bridges, airports, harbours, transmission lines, pipes, railways);
- Industrial activities (e.g. metallurgical plants, wood processing plants, chemical plants, power plants, cement plants, refinery and petro-chemical plants, agro-industries);
- Extractive industries (e.g. mining, quarrying, extraction of sand, gravel, salt, peat, oil and gas);
- Waste management and disposal (e.g. sewage systems and treatment plants, landfills, treatment plants for the household and hazardous waste); and
- Housing construction and development schemes.

The introduction of any internationally banned chemicals or substances into Sierra Leone is prohibited, as well as the discharge of any hazardous and toxic substances into the air, land and waters of Sierra Leone. The second schedule (Section 25) of the Environmental Protection Act 2008, gives several factors which determine whether a potential project, necessarily has to prepare an EIA, for approval to implement its activities on the environment. The third schedule (Section 26) of the Act indicates the contents to be considered in preparing the EIA. It is stated in this Act, that an EIA shall contain a true statement and description of:

- The location of the project and its surroundings;
- The principle, concept and purpose of the project;
- The direct or indirect effects that the project is likely to have on the environment;
- The social, economic and cultural effect that the project is likely to have on people and society;
- The communities, interested parties and Government ministries consulted;
- Any actions or measures which may avoid, prevent, change, mitigate or remedy the likely effect on people and society;
- Any alternatives to the proposed project;
- Natural resources in the locality to be used in the project;
- The plans for decommissioning of the project; and
- Such other information as may be necessary for a proper review of the potential environmental impact of the project.

## The Mines and Minerals Act 12 of 2009

The issues and provisions dealing with the protection and management of the environment forms an integral part of the Mines and Minerals Act 2009 and are substantially covered in part XV of the Act. The Act makes it a strict requirement for all small-scale and large-scale mining license holders to acquire environmental impact assessment licenses, in accordance with the Environmental Protection Act 2008. Beyond complying with the EPAA, 2008, and a general duty to protect the environment, it further specifies the following requirements:

- Environmental baseline assessment, including detailed measurements;
- Details on the operations, reclamation and closure; including resource requirements,
- emissions, impacts, immitigable impacts, mitigation measures, timetables, budgets, human resource capacity, monitoring methodology and mechanisms, and an overall environmental management plan;
- Requirement to consult the public and verify possible impacts;
- Annual environmental report, covering progress against the environmental management plan; and
- Requiring any water diversion to be approved within an environmental management plan.

Mineral right holders also require additional approval, by way of a permit to dredge any river, stream, watercourse, pond, lake or continental shelf, especially for minerals. This is done to more clearly

distinguish it from a mineral right license. The objective of this additional permission is to enable Government to better assess the mining method and its potential environmental impact. A dredging permit places more specific conditions on operating than normally provided for within the general provisions associated with the protection of the environment.
By way of strengthening Government's ability to manage environmental issues associated with mining, the Act also empowers the Minister to make specific rehabilitation activities a condition for the acquisition of a mining lease.

## The Environment Protection (Mines and Minerals) Regulations 2013

The Environment Protection (Mines and Minerals) Regulations of 2013 states that every mining operation shall be carried out in a sustainable manner that is reasonably practicable in order to minimise, mitigate or eliminate negative environmental and social adverse impacts, including but not limited to pollution resulting from such operation in accordance with the EPAA of 2008 subsection (1) of section 132 and subparagraphs (xii) and (xiii) of paragraph (b) od subsection (1) of section 133 of the Mines and Minerals act of 2009. The holder of a mineral right shall be responsible for the environmental and social impacts of their activities as well as for managing these impacts.

The holder of, or applicant for an exploration, small or large-scale mining license shall appoint a corporate environmental officer, and may also appoint a deputy corporate environmental officer, who shall be in charge of the environmental control of the mining operation and shall be the primary contact person for the Board, the Executive Chairman, Authorised Officer, and third parties for environmental and social purposes.

No person shall undertake or cause to be undertaken any mining project, specified in the First Schedule of the Act, and for which an EIA license is required, unless that person obtains an EIA licence issued by the Agency in accordance with subsection (1) od section 24 of the Act

## The Forestry Act 1988

In this Act, part VI, section 21 subsection 2 indicates that no protected forest may be cut, burned, uprooted, damaged or destroyed, except with a written permission from the Chief Conservator of the forest. Removal of a national or community forest by whatever means, without legal permission, is an offence punishable with a fine not exceeding ten thousand Leones or a term of two years imprisonment or both.

## The Forestry Regulations 1989

These regulations are deemed to have come into force on the 1st July, 1990. The Chief Conservator holds the same responsibilities as he does for the Act of 1988.
Generally community forests are managed by the Forestry Division or by agreement with the Division; it could be managed by the local government; or Community Forest Association. Based on this responsibility of the Division, no protected forest shall be tampered with in any way as is stated in section 21, subsection (2) of the Forestry Act - 1988, without written permission from the Chief Conservator of the forest. In section 15 of the Forestry Regulations 1989, subsection (1) it is stated that a license may be issued by an inspector of the Forestry Division authorising the holder of the mining lease, to clear land in a classified forest for the purpose of mining. However, having acquired a license, deforestation of, or vegetation removal from the environment, can only be affected by the mining company under certain conditions. These conditions are found under section 15, subsection 3 and are highlighted below:

- Removal of vegetation, can be done for mining operations only within an area licensed for this purpose;
- The specified land area, shall be cleared within a stated time, but trees requested not to be felled, removed or damaged, are to be left standing;
- Trees to be felled shall be identified, except where total felling is authorised;
- A forest severance fee and a minor forest produce fee, shall be paid in respect of all forest produce that is merchantable, which may be removed by clearance of vegetation;

- At the completion of mining, the area shall be replanted with approved crops or trees by the mining company, or provision made for this to be done by payment of the estimated reforestation cost; and
- Required method of cultivation and silviculture specified by the Chief Conservator must be employed.

As a method of environmental protection, it is stated in section 38 of part XI, that no land between the high and low water marks, nor those above the high water mark on both sides of the bank of any waterway, covering a distance of one hundred feet (approx.. 33 m), shall be cleared of any vegetation except permitted by a clearance license.

Sacred bushes are protected by the stipulated regulations of section 40, whereby clearance of vegetation from land designated as sacred bush, is prohibited except by clearance authority from the Chief Conservator.

## The Wildlife Conservation Act 1972

The Wildlife Conservation Act of 1972 gives the Chief Conservation of Forest the authority to execute the directives of the Minister of Agriculture in establishing a Strict Natural Reserve, a National Park and a Game Reserve. It also stipulates that in the process of establishing a reserve or a national park, the Minister should appoint a Reserve Settlement Officer who will investigate claims and rights issues of affected communities. Specific provisions dealing with the protection, management and conservation of these areas and the limitations therein are highlighted in Part II of the Act and include the following:

- Prohibition of all forms of hunting, capture and other activities leading to the injury of wild animals;
- Destruction of any plant form by any means including fire;
- Fishing within these protected areas;
- Erection of structures, construction of dams, forestry, agriculture, mining or prospecting activities; and
- Introduction of species from outside of the boundaries of the reserve.

The Act however gives Chiefdom Councils the authority, albeit with approval from the Minister, to declare an area a Game Sanctuary or reserve. Part III places strict limitations on hunting of species generally (not limited to reserves and parks). The Wildlife Conservation Act of 1972 saw minor amendments in 1990 (known as the Wildlife Conservation Amendment Act), which included redefinition of terms, and other modifications and qualifications. For example, the prohibition of hunting of elephants which was limited to protected areas in the 1972 Act was extended to include all forests. The 1990 Amendment Act provided for change of name from Forestry Department to Forestry Division. The Wildlife Regulations of 1997 makes provision for the acquisition of licenses or permits for hunting in designated areas and for other purpose as may be prescribed. Such licenses and permits can be revoked by the Chief Conservator of Forest if the holder fails to comply with related provisions made in the regulations.

## The Wildlife Regulation 1997

The Wildlife Regulation came in to force in 1997. It describes Wildlife Conservation Estates as areas such as a National Park, Game Reserve, Strict Natural Reserve, Game Sanctuary or Nonhunting Forest Reserve. The regulation prohibits all unlicensed hunting within a Wildlife Conservation Estate to include the removal of honey. It prohibits the hunting of young and immature wild animals or birds; female wild animal accompanied by their young ones; and birds which are apparently breeding. It also prohibits dazzling of birds and animals. The regulations stipulate that a license or permit should be sought before any form of hunting of game and bird can be done as required by Section 33 and 34 of the Act. The regulation also states that such licenses and permits can be revoked by the Chief Conservator of Forest if the holder fails to comply with the provisions of the regulations.

## Fisheries Acts 2007

The major drawback of the 1988 Fisheries Act was that it had very little or no specific conservation provisions. The Fisheries Act of 2007 provides protection for both fresh and marine species as classified by IUCN with the Sierra Leone water. It defines clearly where commercial vessels could harvest-

Exclusive Economic Zone (EEZ) and where artisanal fisheries operations could exploit – Inshore Exclusive Zone (IEZ).

## The Sierra Rutile Agreement (Ratification) Act 2002

As a result of the effect of the ten year rebel war and other factors on the operations of Sierra Rutile Limited the Government of the Republic of Sierra Leone and Sierra Rutile Limited found it necessary to review the Sierra Rutile Act of 1989. A new agreement, the Sierra Rutile Agreement (Ratification) was made and came into effect on 21st March 2002. The Sierra Rutile Act, 1989 guided the development of the SRL mining lease area. This Act established the development, operation, environmental protection, and financial terms related to project development. SRL had agreed to specific environmental and social commitments as part of this agreement. The new agreement of 2002 addresses considerably more issues with greater specificity. Aspects of this Act applicable to the study include the following:

1) It was contemplated that some of the Company's mining operations under the Agreement will consist of mining in the beds and in the environs of rivers, streams and watercourses. To permit and facilitate such mining, the Company was given the right:
   a) Either within or outside the Mining Lease Area to dig, widen or deepen channels in rivers, streams watercourses as may be necessary to permit or facilitate access to the area to be mined and to afford barge access thereto.
   b) Within the mining Lease Area:
      i) To use the water from any natural watercourse and to return the same together with mining spoils to the river, streams or water courses, provided that, in so doing, the Company shall not discharge or permit to be discharged any poisonous or noxious matter not present in the intake water;
      ii) On the lands included within the Mining Lease Area to cut, take and use any tree when necessary in the course of mining operations or when required for mining or domestic purposes, provided that it shall not cut or take any trees in a forest reserve or protected forest except with the consent of a forest officer or before paying the fees and royalties prescribed by the Forestry Act 1988, (Act No. 7 of 1988).
      iii) To divert streams, including the right to secure water from the river stream or watercourse for the purpose of obtaining and maintaining a mining operation, and to build temporary dams and impound water therein as required for such mining operations.

   In doing so the water supply of any lands should not be altered in such a manner as would prejudicially affect the water supply enjoyed by any other person or lands. The Company would be required to obtain the prior consent of the District Officer having jurisdiction over the person or lands that would be prejudicially affected. The Company should also provide an alternative adequate water supply to be determined and approved by the Minister of Health in the event that it pollutes or impairs the supply of potable water to settlements.

2) The Company would prepare at its expense a comprehensive master plan that will address the issues of reclamation and rehabilitation of mined-out areas. The Company shall adopt and implement at its expense programmes and measures approved by Government for the effective reclamation of mined out areas including replanting and dealing with impounded water and mining spoils. In this regard, a detailed programme for the progressive reclamation and rehabilitation of lands disturbed by mining and for the minimization of the effects of such mining on adjoining land/water areas shall be submitted for approval. The Company would, in consultation with appropriate Government Agencies, undertake suitable reforestation, agricultural and other projects within the Mining Lease Area.

## Equator Principles (The Equator Principles Association, 2011)

The Equator Principles aim to ensure that all companies that apply to the Equator Principles Financial Institution (EPFI) for capital are utilising natural resources responsibly and with focus on sustainability of their operations. The Equator Principles further aim to ensure that any development projects in foreign countries are managed to the same level as they would be in a more developed country, or the country of origin in which the development corporation is based.

## International Finance Corporation (IFC) Environmental Health and Safety Guidelines and Performance Standards (2007)

The IFC is a financial services provider which has set out to ensure that their clients act responsibly toward the environment by providing environmental, health and safety guidelines which their clients must follow and apply before lending of finance may take place.

Performance Standard 6 of the IFC reflects the objectives of the Convention on Biological Diversity to conserve biological diversity and promote use of renewable natural resources in a sustainable manner. That protecting and conserving biodiversity, maintaining ecosystem services, and sustainably managing living natural resources are fundamental to sustainable development.
Ecosystem services valued by humans are often underpinned by biodiversity. Impacts on biodiversity can therefore often adversely affect the delivery of ecosystem services. Ecosystem services are the benefits that people, including businesses, derive from ecosystems. Ecosystem services are organised into four types:

- (i) provisioning services, which are the products people obtain from ecosystems;
- (ii) regulating services, which are the benefits people obtain from the regulation of ecosystem processes;
- (iii) cultural services, which are the nonmaterial benefits people obtain from ecosystems; and
- (iv) supporting services, which are the natural processes that maintain the other services.

The objectives as set out in Performance Standard 6 are:

- To protect and conserve biodiversity;
- To promote the sustainable management of living natural resources through the adoption of practices that integrate conservation needs and development priorities; and
- To maintain the benefits from ecosystem services

The requirements of this Performance Standard are applied to projects

- located in modified, natural, and critical habitats;
- that potentially impact on or are dependent on ecosystem services over which the client has direct management control or significant influence; or
- that includes the production of living natural resources (e.g., agriculture, animal husbandry, fisheries and forestry).

IFC performance standard 6 states that as a matter of priority, the client should seek to avoid impacts on biodiversity and ecosystem services. When avoidance of impacts is not possible, measures to minimise impacts and restore biodiversity and ecosystem services should be implemented. Given the complexity in predicting project impacts on biodiversity and ecosystem services over the long term, the client should adopt a practice of adaptive management in which the implementation of mitigation and management measures are responsive to changing conditions and the results of monitoring throughout the project’s lifecycle.
Biodiversity offsets should only be considered once all other avenues of impact avoidance, minimisation and restoration have been thoroughly investigated and where applicable implemented. A biodiversity offset should be designed and implemented to achieve measurable conservation outcomes that can reasonably be expected to result in no net loss and preferably a net gain of biodiversity; however, a net gain is required in critical habitats. The design of a biodiversity offset must adhere to the “like-for-like or better” principle and must be carried out in alignment with best available information and current practices.

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The findings, results, observations, conclusions and recommendations given in this report are based on the author’s best scientific and professional knowledge as well as available information. The report is based on survey and assessment techniques which are limited by time and budgetary constraints relevant to the type and level of investigation undertaken and STS CC and its staff reserve the right to modify aspects of the report including the recommendations if and when new information may become available from ongoing research or further work in this field, or pertaining to this investigation.

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# SIERRA RUTILE PROJECT AREA 1 – ENVIRONMENTAL, SOCIAL AND HEALTH IMPACT ASSESSMENT: SPECIALIST TERRESTRIAL, AQUATIC AND WETLAND ECOLOGICAL STUDIES

**Prepared for**

**SRK Consulting (South Africa) (Pty) Ltd**

**February 2018**

# Section B: Floral Assessment

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# ACRONYMS

| | |
|---|---|
| **CR** | Critically Endangered |
| **EIS** | Ecological Importance and Sensitivity |
| **EN** | Endangered |
| **ESHIA** | Environmental Social and Health Impact Assessment |
| **ESHMP** | Environmental Social and Health Management Plan |
| **EW** | Extinct in the Wild |
| **GIS** | Geographic Information System |
| **GPS** | Global Positioning System |
| **IUCN** | International Union for Conservation of Nature and Natural Resources |
| **NT** | Near Threatened |
| **PES** | Present Ecological State |
| **POC** | Probability of Occurrence |
| **RE** | Regionally Extinct |
| **SCC** | Species of Conservation Concern |
| **SRL** | Sierra Rutile Mine |
| **STS** | Scientific Terrestrial Services |
| **VU** | Vulnerable |

# 1 INTRODUCTION

## 1.1 Background

Scientific Terrestrial Services (STS) was appointed to conduct faunal, floral, wetland and aquatic ecological assessments as part of the process to undertake an Environmental, Social and Health Impact Assessment (ESHIA) and develop an Environmental, Social and Health Management Plan (ESHMP) for the current and proposed dry and wet mining activities for the Sierra Rutile Limited's (SRL) Mine Lease Area 1 (SR Area 1) operations. SR Area 1 is located within the Bonthe and Moyamba Districts of the Southern Province of Sierra Leone. SR Area 1 is situated approximately 30 km inland of the Atlantic Ocean and approximately 135 km southeast of Freetown (geodesic) (Figure 1 and 2 in the Section A report).

This report aims to map, consider and describe the floral ecological resources associated with the SR Area 1 according to data gathered during the dry and wet season surveys. In addition, the integrity, ecological importance and sensitivity, including the provision of goods and services, is considered and presented. In doing so this report must guide the proponent, Environmental Assessment Practitioner (EAP) and regulating authorities, by means of the presentation of information on the baseline conditions, as to the management of current and future mining operations from an ecological risk management point of view as well as provide mitigation and management measures to manage potential and existing impacts.

# 2 ASSESSMENT APPROACH

Initially, a desktop study was undertaken to gather background information regarding the site and its surrounding areas. This involved consulting maps, aerial photographs and digital satellite images in order to determine broad habitats and sensitive sites; a literature review concerning habitats, vegetation types, floral and faunal species distributions and identifying the status of the land as well as conservation requirements and nearby conservation and protected areas. Following this, detailed wet (July 2017) and dry (January 2018) season field assessments were undertaken where the data gathered during the desktop assessment phase was utilised to confirm the presence of potentially sensitive habitat and compile floral and faunal species inventories for each habitat unit. The species lists include potential floral and faunal Species of Conservation Concern (SCC), alien and invasive floral species as well as medicinal species. Detailed explanations of the floral methods of assessment are provided in Appendix A of this report.

## 2.1 Sensitivity Mapping

All the ecological features of SR Area 1 were considered and sensitive areas were delineated with the use of a Global Positioning System (GPS) to augment the mapping of the features undertaken from aerial photography. A Geographic Information System (GIS) was used to project these features onto aerial photographs and topographic maps. The sensitivity map should guide the design and layout of proposed future activities. Due to access constraints and the extent of SR Area 1, extrapolation for the extents of the features was undertaken by comparing “ground-truthed” data to high resolution aerial photography, in order to map features across the study area.

# 3 RESULTS OF WET AND DRY SEASON FLORAL ASSESSMENTS

During the field assessment, a number of habitat units were identified. These habitat units are:

- Degraded Forest, which historically consisted of Moist Semi-Deciduous Forest which has been degraded by extensive, long-term, slash-and-burn subsistence agriculture;
- Ridges which are associated with more intact remnant Moist Semi-Deciduous Forest;
- Watercourses associated with historic dredge ponds where bankside vegetation has re-established as well as systems downstream of the dredge ponds;
- Watercourses not affected by mining or decant, and mangrove areas; and
- Transformed habitat associated with villages, active agricultural fields, borrow pits, active dredge ponds and mining areas and associated infrastructure.

These habitat units are described in the sections below. The methodology for calculating the floral habitat sensitivity of each habitat unit is presented in Appendix A.

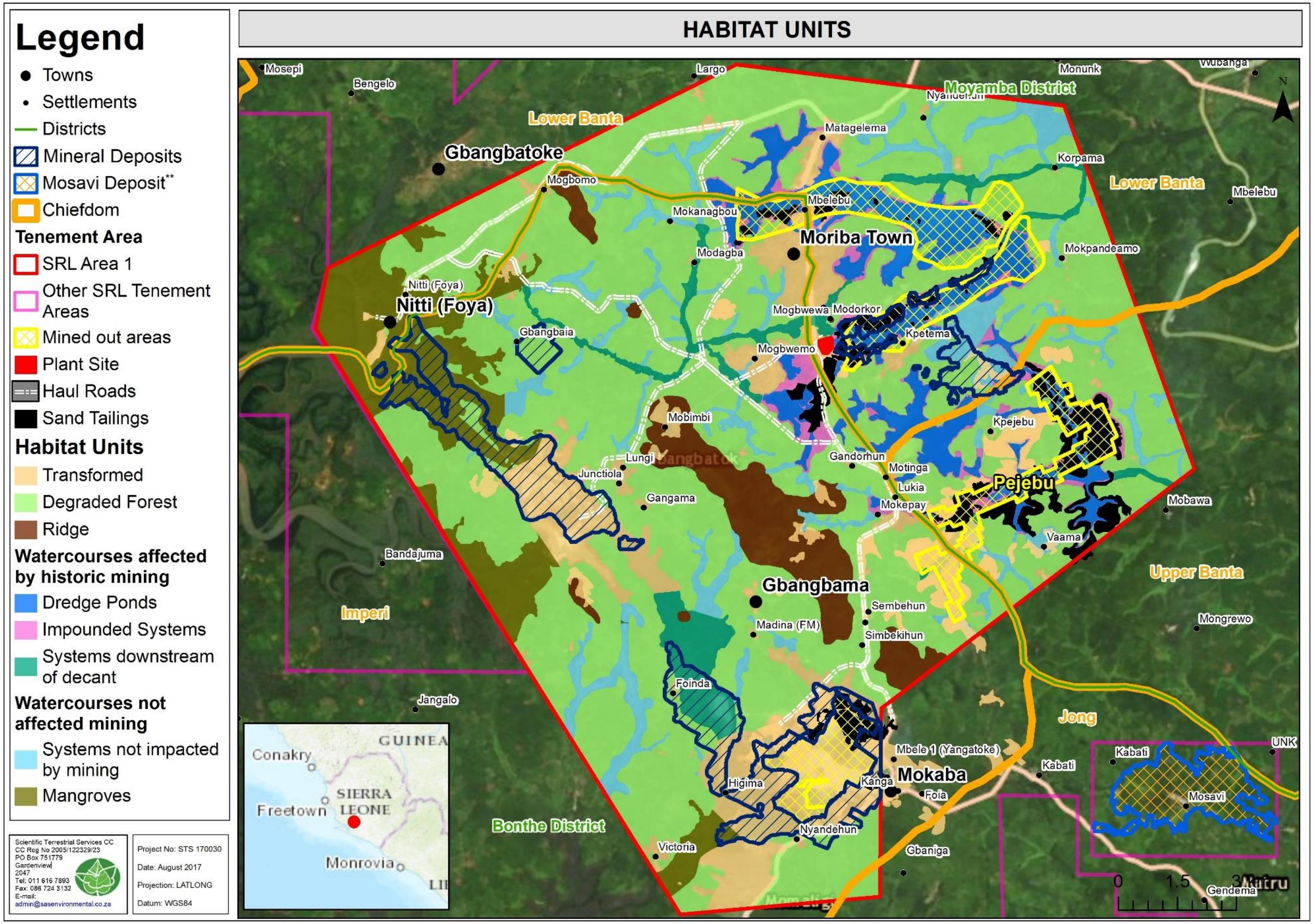



**Figure 1: Conceptual illustration of the habitat units within SR Area 1.**

## 3.1 Habitat Unit 1: Degraded Forest.

**Habitat Unit:**

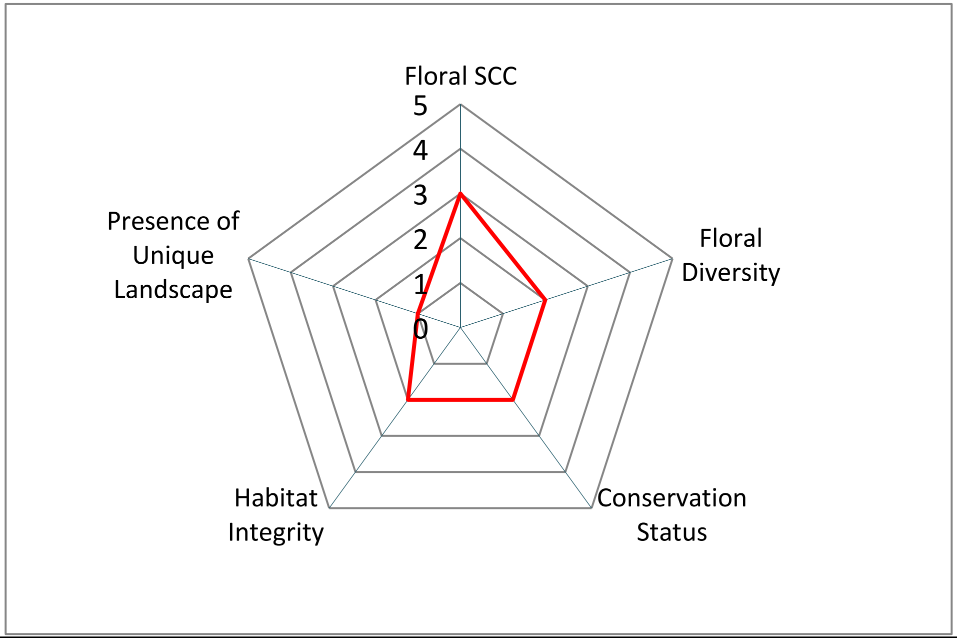
Degraded Forest, which historically consisted of Moist Semi-Deciduous Forest which has been degraded by extensive, long-term, slash-and-burn subsistence agriculture.

| **Floral Habitat Sensitivity** | **Moderately Low** |
|---|---|

**Notes on Photograph:**

Typical view of the degraded forest with the forest edge clearly visible next to a rice paddy (top) and the congested nature of this forest evident in the bottom image.

**Floral Habitat Sensitivity Graph:**



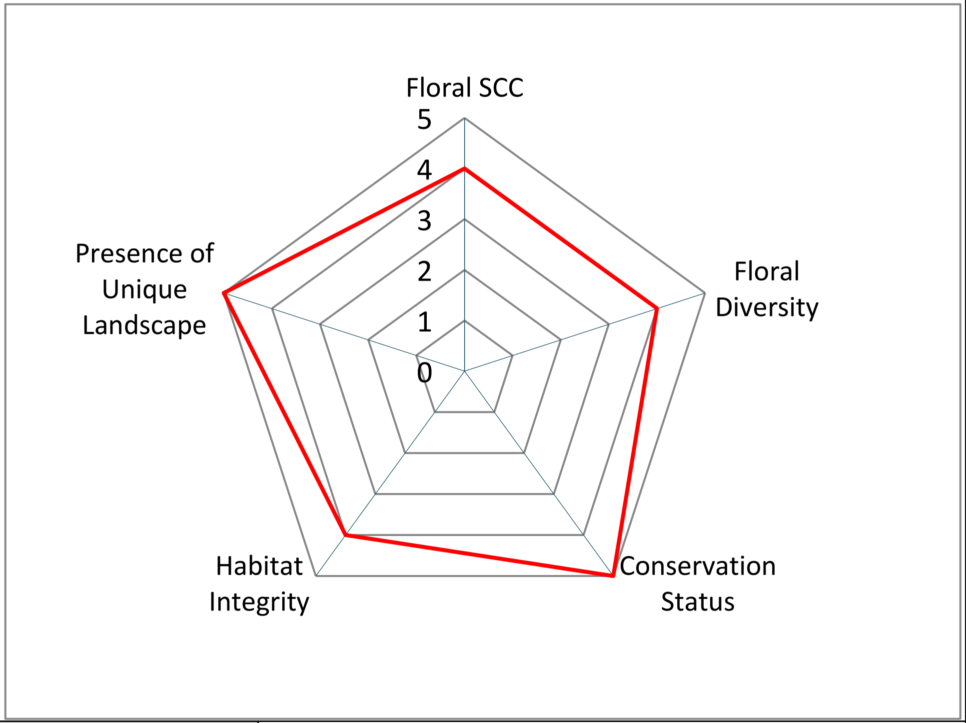

| | |
|---|---|
| **Floral Species of Conservation Concern (SCC)** | As the natural floral community structure has been subjected to long-term impacts associated with subsistence agriculture, floral SCC are no longer abundant within this habitat unit. However, *Terminalia ivorensis* (Bajii/Black Afara) and *Nauclea diderrichii* (Bundui/Opepe), both of which are listed as *Vulnerable* by the IUCN, were encountered sporadically throughout this habitat unit. These trees are under pressure due to over-harvesting for timber purposes. During the field assessment, it was evident that these trees were also actively planted |

<table>
<tr><td></td><td>by local communities, presumably for their useful nature as a timber resource.</td><td colspan="2"></td></tr>
<tr><td>Floral Diversity</td><td>Floral diversity was moderately low as is to be expected in habitat subjected to long-term disturbances. Dominant species included Bombax buonopozense (Titii/West African Bombax), Ceiba pentandra (Nguwei/Ceiba), Musanga cecropioides (Ngovui/Umbrella Tree), Scleria barteri (Razor Grass), Trema orientalis (Ngombei/Pigeonwood), Elaeis guineensis (Oil Palm) and Albizia zygia (Kpakpei/Nongo). All of these species are typical of various stages of forest succession in the region (Savill & Fox, 1967). For dominant species associated with this habitat unit, refer to Appendix B.</td><td rowspan="4">General comments:<br><br>This habitat unit comprises the majority of SR Area 1 and is in various stages of ecological succession. It is characterised by dense, almost impenetrable thicket, with very little to no discernible structure such as a typical understorey or closed canopy. Although there are limited patches of forest which are approaching the secondary stage of ecological succession, the continuation of slash-and-burn agricultural practices makes it unlikely that these patches will have sufficient time to further mature into sub-climax forest communities.</td><td rowspan="4">Business Case, Conclusion and Mitigation Requirements:<br><br>This habitat unit is of moderately low ecological sensitivity and if current land-uses persist, its sensitivity is unlikely to change. However, a case can be made for decreasing impact on this habitat unit through improving the agricultural efficiency by local communities through education and optimisation of technique. This will lessen the pressure on this habitat unit and allow floral communities to progress through the stages of ecological succession to eventually become climax forest communities.<br><br>Another recommended management intervention is alien and invasive species management, especially focussing on C. odorata, A. mangium, A. auriculiformis and E. globulus. These measures will improve the condition of the degraded forest areas and aid in offsetting the impact of future mining activities which may encroach upon this habitat unit through the clearance of vegetation in new mining areas.</td></tr>
<tr><td>Conservation Status of Vegetation Type/Ecosystem</td><td>Very little data is available on the conservation status of this habitat type. According to the WWF, these lowland forests are Critically Endangered. However, due to its degraded nature and the fact that it is well represented regionally, it is considered to be of moderately low importance.</td></tr>
<tr><td>Habitat Integrity/Alien and Invasive species</td><td>Habitat integrity has been compromised by extensive, long-term, slash-and-burn subsistence agriculture. As such, it is natural that a high abundance of alien floral species, mostly associated with agriculture such as Manihot esculenta (Cassava), Psidium guajava (Guava) and Mangifera indica (Mango), have invaded this habitat unit. Furthermore, various exotic timber species, including Acacia mangium (Forest Mangrove), Acacia auriculiformis (Earleaf Acacia) and Eucalyptus globulus (Southern Blue Gum), which have been cultivated as part of rehabilitation efforts, have invaded this habitat unit. Finally, Chromolaena odorata (Famine Weed) is also abundant and seems to pose a significant threat to floral habitat associated with SR Area 1.</td></tr>
<tr><td>Presence of Unique Landscapes</td><td>This habitat type is not considered to be unique and is well represented regionally.</td></tr>
</table>

## *3.2 Habitat Unit 2: Ridges and Remnant Semi-Deciduous Moist Forest.*

| **Habitat Unit:** Ridges associated with remnant Semi-Deciduous Moist Forest. | **Floral Habitat Sensitivity** | **High** |
|---|---|---|
| | **Notes on Photograph:** Landscape view of the ridge at Mobimbi Village (top) and typical forest understorey (bottom). | |

**Floral Habitat Sensitivity Graph:**



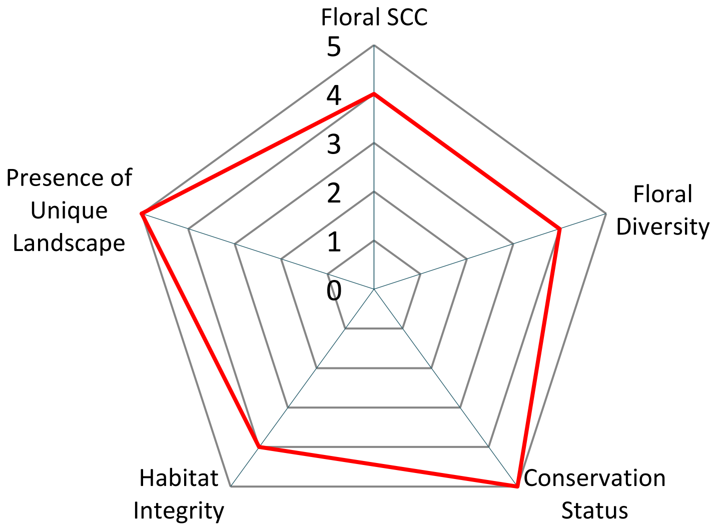

| **Floral Species of Conservation Concern (SCC)** | This habitat unit is associated with various SCC namely *Khaya senegalensis, Afzelia africana* (Kpendei/Afzelia), *Entandrophragma utile* (Jelei/Utile), *Albizia ferruginea* (Kpakpei/West African Albizia), *Nesogordonia papaverifera* (Majaagei/Danta), *Terminalia ivorensis* (Bajii/Black Afara) and *Nauclea diderrichii* (Bundui/Opepe). These trees are listed as *Vulnerable* by the IUCN and are under pressure due to over-harvesting for timber purposes. This elevates the |
|---|---|

| | | | |
|---|---|---|---|
| | sensitivity of this habitat unit as floral SCC were the most abundant and diverse within these remnant forests. | | |
| **Floral Diversity** | Floral diversity was moderately high to high as this habitat unit has been excluded from subsistence agriculture and mining due to the steep terrain and also local taboos where forests known as 'society forests' are left undeveloped for spiritual reasons. Dominant species included *Albizia adianthifolia* (Kpakpei/Nongo), *Nesogordonia papaverifera* (Majaagei/Danta), *Ceiba pentandra* (Nguwei/Ceiba), *Musanga cecropioides* (Ngovui/Umbrella Tree), *Uapaca guineensis* (Kondii), *Brachystegia leonensis* (Bojei), *Celtis zenkeri* (Ohia), *Bridelia grandis* (Kui/Asas), *Cordia platythyrsa* (Pulii), *Piptadeniastrum africanum* (Mbelei), *Terminalia ivorensis* (Bajii/Black Afara) and *Zanthoxylum gilletii* (Sowuli/African Satinwood). All of these species are typical of Semi-Deciduous Moist Forest (Savill & Fox, 1967). For dominant species associated with this habitat unit, refer to Appendix B. | **General comments:**<br><br>In terms of terrestrial floral habitat, this habitat unit is the most ecologically intact within SR Area 1. Furthermore, it contains the highest abundance and diversity of floral SCC, alien floral invasion is limited, and it is considered to be a highly unique landscape within SR Area 1. However, edge effects from agricultural areas and villages, such as alien floral invasion and deforestation for firewood and vegetation clearing are threatening the ecological integrity of this habitat unit. | **Business Case, Conclusion and Mitigation Requirements:**<br><br>This habitat unit is of high ecological sensitivity, however if current land-uses persist, its sensitivity is likely to decrease due to increasing pressure on these forests for firewood and timber as a result of increased population pressure. As such, it is recommended that a biodiversity action plan be developed which will address the threats to this habitat unit and improve its ecological condition through management of edge effects and allowing natural reforestation in cleared areas through ecological succession within SR Area 1 where deemed feasible as per the closure plan. |
| **Conservation Status of Vegetation Type/Ecosystem** | According to the WWF, these lowland forests are *Critically Endangered.* Furthermore, this habitat unit was relatively ecologically intact and is the best representation of Semi-Deciduous Moist Forest within SR Area 1. Thus, it is of high conservation value. | | |
| **Habitat Integrity/Alien and Invasive species** | Habitat integrity has been compromised in isolated areas where forest has been cleared for agricultural purposes. Furthermore, exotic trees such as *Mangifera indica* (Mango) have invaded sections of the forests, especially close to Mobimbi village. However, habitat integrity is considered to be moderately high. | | |
| **Presence of Unique Landscapes** | This habitat type is unique within SR Area 1 and also contained unique species when compared to other habitat types. As such, it is of high sensitivity. | | |

## 3.3 Habitat Unit 3: Watercourses not Affected by Mining or Decant, including Mangroves.

| | | |
|---|---|---|
| **Habitat Unit:** Watercourses not affected by mining or decant, and mangrove areas. | **Floral Habitat Sensitivity** | **High** |
| | **Notes on Photograph:** Typical view of riparian vegetation associated with watercourses (above) and mangrove swamp (below). | |

**Floral Habitat Sensitivity Graph:**




| | |
|---|---|
| **Floral Species of Conservation Concern (SCC)** | The watercourses are associated with two SCC namely *Mitragyna stipulosa* (Mboi/Abura) and *Gilbertiodendron splendidum* (Gogoi). These trees are listed as *Vulnerable* by the IUCN and are under pressure due to habitat loss and as |

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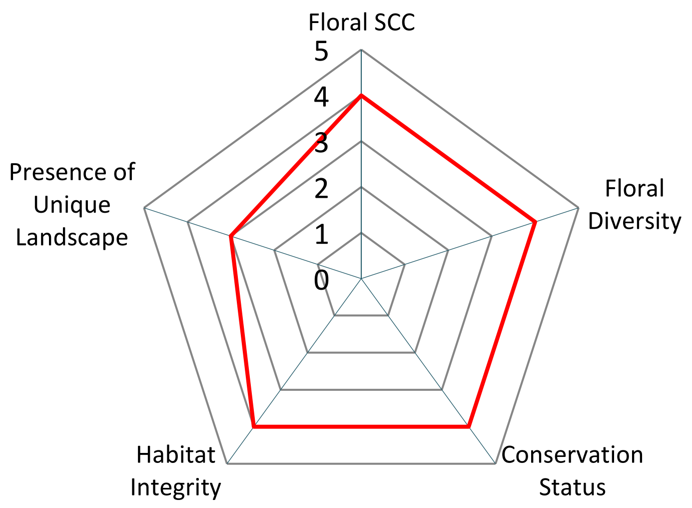
| | such, the watercourses are considered to be of moderately high sensitivity in terms of floral SCC. | | |
| **Floral Diversity** | Floral diversity in the watercourses was moderately high and contained species unique to this habitat unit. Dominant species included *Cleistopholis patens* (Moigbamei), *Anthocleista nobilis* (Pongoi), *Oxytenanthera spp., Raphia vinifera* (Raphia), *Newtonia elliotii* (Hele-lahei), *Imperata cylindrica* (Satintail Grass), *Macaranga heudelotii* (Ndewei), *Gilbertiodendron splendidum* (Gogoi), *Pteridium aquilinum* (Bracken) and *Elaeis guineensis* (Oil Palm). The mangroves were associated with *Avicennia africana* (Gbelettii), *Conocarpus erectus, Laguncularia racemosa* (Lakentmabi) and *Rhizophora* spp. (Dengii). All of these species are typical of mangroves, inland freshwater swamps and watercourses (Savill & Fox, 1967). For dominant species associated with this habitat unit, refer to Appendix B. | **General comments:**<br>Very few watercourses which are unaffected by mining activities or decant are still present within SR Area 1. This increases the conservation importance of this habitat unit significantly. Furthermore, as the mangroves are situated within an MPA, the sensitivity of this habitat unit is further increased, even though mining activities have in the past encroached upon the mangroves. The watercourses also provide habitat for niche floral species and floral SCC. However, the current status of the MPA will be determined during further consultation with authorities. | **Business Case, Conclusion and Mitigation Requirements:**<br>This habitat unit is of high ecological sensitivity, and further impacts must be avoided where possible as the key drivers of modification of these systems are as a result of historical and current mining activities. It is recommended that a biodiversity action plan be developed, which will address the threats to this habitat unit within SR Area 1 and improve its ecological condition through management of impacts including alien and invasive species management, especially focussing on *C. odorata, A. mangium, A. auriculiformis* and *E. globulus.* These measures will improve the condition of the unaffected watercourses and aid in offsetting the impact of future mining activities which may encroach upon this habitat unit through the clearance of new mining areas. |
| **Conservation Status of Vegetation Type/Ecosystem** | Watercourses are inherently sensitive environments, and are generally protected by international best practice guidelines. Furthermore, the mangroves fall within a Marine Protected Area (MPA) according to the National Minerals Agency of Sierra Leone's Geo-Data Information Database (refer to Section A for further detail). As such, this habitat unit is considered to be of high sensitivity. | | |
| **Habitat integrity/Alien and Invasive species** | In general, habitat integrity is moderately high, with isolated areas of disturbance encountered, especially where mining activities have encroached into the mangroves. Of concern is the invasion of exotic trees such as *Acacia mangium* (Forest Mangrove), *Acacia auriculiformis* (Earleaf Acacia) and *Eucalyptus globulus* (Southern Blue Gum) into the watercourses, which will likely result in further proliferation of these species downstream. | | |
| **Presence of Unique Landscapes** | This habitat type is unique as very few watercourses unaffected by mining are left within SR Area 1. As such, it is of high sensitivity. | | |

## 3.4 Habitat Unit 4: Watercourses Associated with Historic Dredge Ponds and Streams Affected by Decant.

| | | |
|---|---|---|
| **Habitat Unit:**<br>Watercourses associated with historic dredge ponds where bankside vegetation has re-established, as well as systems downstream of the dredge ponds. | **Floral Habitat Sensitivity** | **Moderately High** |
| | **Notes on Photograph:**<br>Typical view of re-established bankside vegetation associated with historic dredge ponds (above) and riparian vegetation associated with a watercourse downstream of a decant (below). | |

**Floral Habitat Sensitivity Graph:**




| | |
|---|---|
| **Floral Species of Conservation Concern (SCC)** | Although affected by decant, the watercourses are associated with two SCC namely *Mitragyna stipulosa* (Mboi/Abura) and *Gilbertiodendron splendidum* (Gogoi). These trees are listed as *Vulnerable* by the IUCN and are |

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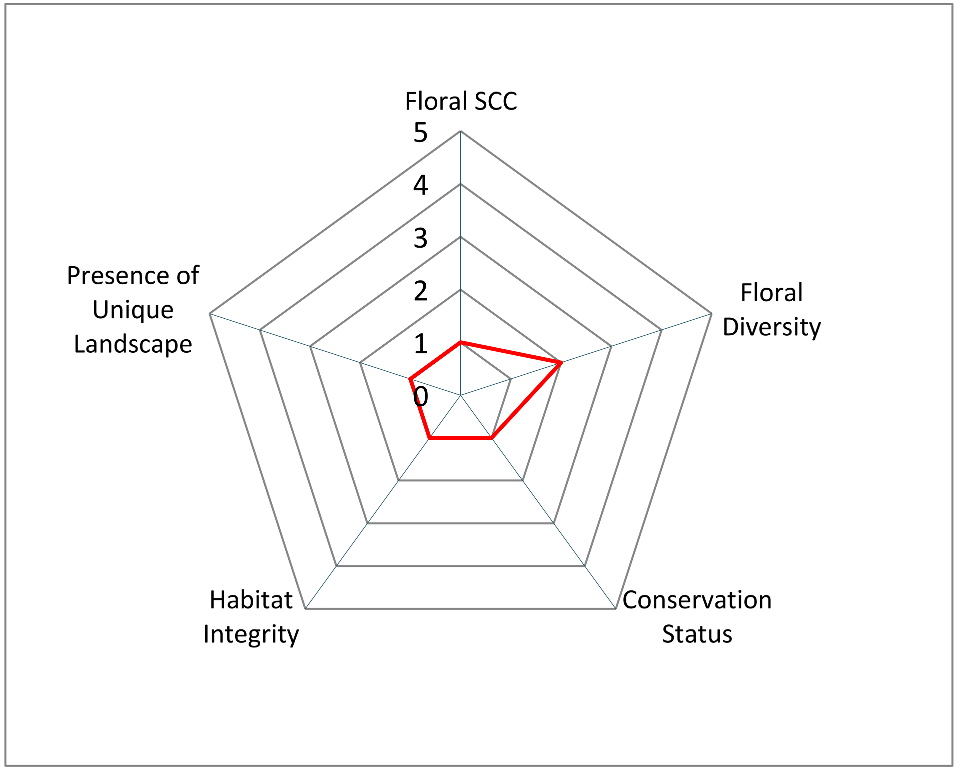
|---|---|---|---|
| | under pressure due to habitat loss. During the dry season assessment, it was confirmed that these species are present within the bankside vegetation communities along the old dredge ponds. |  | |
| **Floral Diversity** | Floral diversity in the watercourses was moderately high and contained species unique to this habitat unit. Dominant species included *Cleistopholis patens* (Moigbamei), *Anthocleista nobilis* (Pongoi), *Oxytenanthera spp., Raphia vinifera* (Raphia), *Newtonia elliotii* (Hele-lahei), *Imperata cylindrica* (Satintail Grass), *Macaranga heudelotii* (Ndewei), *Gilbertiodendron splendidum* (Gogoi), *Pteridium aquilinum* (Bracken) and *Elaeis guineensis* (Oil Palm) All of these species are typical of inland freshwater swamps and watercourses (Savill & Fox, 1967). For dominant species associated with this habitat unit, refer to Appendix B. | **General comments:**<br>Although the old dredge ponds may be considered artificial, mining activities have created habitat for aquatic and riparian floral species. Furthermore, the floral species composition of the watercourses affected by decant does not differ significantly from the unaffected systems. However, alien floral invasion was more prolific in this habitat unit compared to the unaffected watercourses. Thus, it is imperative that effective alien floral control is implemented to prevent further degradation of the floral communities associated with these systems. | **Business Case, Conclusion and Mitigation Requirements:**<br>This habitat unit is of moderately high ecological sensitivity, and an opportunity exists for the condition of the floral communities associated with these systems to be improved. It is recommended that a biodiversity action plan be developed, which will address the threats to this habitat unit within SR Area 1 and improve its ecological condition through management of impacts including alien and invasive species management, especially focussing on *C. odorata, A. mangium, A. auriculiformis* and *Eucalyptus globulus.* Furthermore, rehabilitation measures must be aligned to the final land-use and rehabilitation efforts must be aligned with the closure plan. These measures will improve the condition of this habitat unit and aid in offsetting the impact of historic mining activities. |
| **Conservation Status of Vegetation Type/Ecosystem** | Watercourses are inherently sensitive environments and are generally protected by international best practice guidelines. Even though these systems have been affected by decant, the floral species composition associated with the watercourses is similar to the natural, unaffected watercourses. Furthermore, the bankside vegetation of the old dredge ponds is approaching a secondary to sub-climax state and as such, this habitat unit is considered to be of moderately high sensitivity. | | |

| | | | |
|---|---|---|---|
| **Habitat integrity/Alien and Invasive species** | In general, floral habitat integrity is moderately high, with degradation only encountered where historic mining activities have affected the watercourses. Furthermore, the historic dredge pond bankside vegetation is also considered to be in a secondary to sub-climax state of ecological succession. However, of concern is the invasion of exotic trees such as *Acacia mangium* (Forest Mangrove), *Acacia auriculiformis* (Earleaf Acacia) and *Eucalyptus globulus* (Southern Blue Gum) into the watercourses, which will likely result in further proliferation of these species downstream. | | |
| **Presence of Unique Landscapes** | Although the old dredge ponds can be considered artificial to a degree, they form part of a larger interconnected watercourse network which provides habitat for niche floral species. Furthermore, the riparian vegetation associated with the watercourses downstream of these ponds is unique from surrounding terrestrial areas. Thus, this habitat unit is considered to be of moderately high sensitivity. | | |

## 3.5 Habitat Unit 5: Transformed Areas.

| | | | |
|---|---|---|---|
| **Habitat Unit:**<br>Transformed habitat associated with villages, active agricultural fields, borrow pits, active dredge ponds and mining areas and associated infrastructure. | **Floral Habitat Sensitivity** | Low |  |
| | **Notes on Photograph:**<br>Typical view of transformed habitat with active mining areas (top) and an old borrow pit below. | | |
| **Floral Habitat Sensitivity Graph:** | | | |




**Floral Species of Conservation Concern (SCC)**

As the natural floral community structure has been completely altered by mining activities, slash-and-burn agriculture and the establishment of villages, floral SCC are highly unlikely to occur within this habitat unit. Furthermore, during the field assessment none were encountered. Thus, this habitat unit is of low sensitivity in terms of floral SCC conservation.

**Floral Diversity**

Floral diversity was moderately low as is to be expected in habitat subjected to long term disturbances. Dominant species included pioneer species such as *Cynodon dactylon* (Couch grass) and agricultural species such as *Manihot esculenta* (Cassava), *Psidium guajava* (Guava) and *Mangifera indica* (Mango). Exotic and invasive species dominated this habitat unit. For dominant species associated with this habitat unit, refer to Appendix B.

**General comments:**

This habitat unit is associated with areas such as active mining areas, villages, agricultural fields and other areas where vegetation has been completely cleared. These areas are no longer representative of the vegetation type in which they occur.

**Business Case, Conclusion and Mitigation Requirements:**

This habitat unit is of low ecological sensitivity. The rehabilitation and closure plan has been updated as part of this ESHIA study to utilise indigenous species where possible. In this

| | | | |
|---|---|---|---|
| **Conservation Status of Vegetation Type/Ecosystem** | The floral communities associated with this habitat unit are mostly completely transformed and no longer representative of the historic vegetation type of the region. Thus, this habitat unit is considered to be of low sensitivity in terms of floral habitat conservation. | | regard, it is recommended that the measures as stipulated in the rehabilitation and closure plan are implemented.<br><br>Furthermore, improving the agricultural efficiency of local communities through education and optimisation of technique, may lessen the pressure on the receiving environment. Another recommended management intervention is alien and invasive species management, especially focussing on *C. odorata, A. mangium, A. auriculiformis* and *Eucalyptus globulus* in and around the mining areas |
| **Habitat Integrity/Alien and Invasive species** | Habitat integrity has been compromised by complete alteration of the natural floral communities. As such, it is dominated by exotic and pioneer species, mostly associated with agriculture such as *Manihot esculenta* (Cassava), *Psidium guajava* (Guava) and *Mangifera indica* (Mango). Furthermore, various exotic timber species, including *Acacia mangium, Acacia auriculiformis* and *Eucalyptus globulus,* which have been cultivated as part of rehabilitation efforts, have invaded this habitat unit. Finally, *Chromolaena odorata* is also especially abundant in this habitat unit. | | |
| **Presence of Unique Landscapes** | This habitat type is not considered to be unique as floral habitat has been completed altered and is considered to be of low sensitivity. | | |

## 3.6 Floral Species of Conservation Concern Assessment

An assessment considering the presence of any floral species of conservation concern (SCC), as well as suitable habitat to support any such species was undertaken. Threatened species are species that are facing a high risk of extinction. Any species classified in the IUCN categories as Critically Endangered (CR), Endangered (EN) or Vulnerable (VU) is a threatened species. SCC are species that have a high conservation importance floristic diversity and include not only threatened species, but also those classified in the categories Extinct in the Wild (EW), Regionally Extinct (RE), Near Threatened (NT), Critically Rare, Rare and Declining.

There is no specific list of protected floral species for Sierra Leone, thus the IUCN status for all species identified was determined and listed species are presented in the table below:

**Table 1: Floral SCC identified during the assessment.**

| Latin name | Common Name | Habitat Unit | IUCN Status |
|---|---|---|---|
| *Afzelia africana* | Afzelia | Ridge Forest | Vulnerable |
| *Albizia ferruginea* | West African Albizia. | Ridge Forest | Vulnerable |
| *Entandrophragma utile* | Sipo Mahogany | Ridge Forest | Vulnerable |
| *Gilbertiodendron splendidum* | Gogoi | Watercourses | Vulnerable |
| *Khaya senegalensis* | African Mahogany | Ridge Forest | Vulnerable |
| *Mitragyna stipulosa* | Abura | Watercourses | Vulnerable |
| *Nauclea diderrichii* | Opepe | Degraded Forest; Ridge Forest | Vulnerable |
| *Nesogordonia papaverifera* | Danta | Ridge Forest | Vulnerable |
| *Terminalia ivorensis* | Bajii/Black Afara | Degraded Forest; Ridge Forest | Vulnerable |

In total, nine (9) floral SCC were identified during the wet season assessment, while the dry season assessment yielded the same suite of species. The species listed in the table above are all under pressure due to habitat loss and overutilization for timber purposes.

This places further emphasis on actively protecting those habitat units in which they occur whilst avoiding further impacts on sensitive habitats where possible. Furthermore, as part of the development of a biodiversity action plan, the propagation of species such as *T. ivorensis* and other trees can be investigated through trials. These species can also be used for rehabilitation purposes instead of exotic species currently used. The inclusion of alien and invasive floral control measures into the biodiversity action plan will significantly add to the protection of floral SCC, especially in the more sensitive habitat units. The above measures will contribute to mitigating the current impact by mining on floral SCC and associated habitat and also partly offsetting the historical impact caused by vegetation clearing and flooding of valleys for mining purposes.

## 3.7 Exotic and Invasive Species

Alien floral species in SR Area 1 were mostly associated with villages, agricultural and mining disturbances, where in some instances they were completely dominant. The table below lists the exotic and invader species identified during the assessment along with their basic methods of control. Furthermore, a priority category for control is assigned for each species according to its invasion potential. It is recommended that an alien and invasive plant control plan be developed and incorporated into the biodiversity action plan to control priority species.

**Table 2: Exotic or invasive species identified during the assessment.**

| Scientific name | Common name | Priority for Control | Control |
|---|---|---|---|
| *Acacia auriculiformis* | Earleaf Acacia | High | Mechanical control, herbicide |
| *Acacia mangium* | Forest Mangrove | High | Mechanical control, herbicide |
| *Alpinia speciosa* | Wild Ginger | Low | Mechanical control, herbicide |
| *Bidens pilosa* | Spanish Blackjack | Low | Pre-emergence herbicide |
| *Chromolaena odorata* | Tiffid weed/Siam weed | High | Mechanical control, herbicide |
| *Eucalyptus globulus* | Southern Blue Gum | High | Mechanical control, herbicide |
| *Hibiscus trionium* | Bladder Hibiscus | Medium | Herbicide |
| *Lantana camara* | Lantana | High | Mechanical control, herbicide |
| *Mangifera indica* | Mango | None required (Agricultural Crop) | |
| *Manihot esculenta* | Cassava | None required (Agricultural Crop) | |
| *Psidium guajava* | Guava | None required (Agricultural Crop) | |
| *Sesbania bispinosa* | Spiny Sesbania | Low | Mechanical control |
| *Tithonia diversifolia* | Mexican sunflower | Low | Mechanical control, herbicide |
| *Tithonia rotundifolia* | Mexican sunflower | Low | Mechanical control, herbicide |
| *Zinnia peruviana* | Redstar Zinnia | Low | Herbicide |

## 3.8 Medicinal Plant Species

The table below presents a list of plant species with traditional medicinal value, plant parts traditionally used and their main applications, which were identified during the field assessment. Mr. Moyowo Munda (a registered traditional healer) accompanied the team during the field assessment to identify medicinal species and explain their uses.

The majority of the medicinal species listed below are all considered to be common to the region and were encountered throughout SR Area 1, especially within the degraded forest areas. However, Mr. Munda explained that some species no longer occur within SR Area 1 as a result of habitat degradation. Through managing the floral biodiversity and addressing alien and invasive floral species habitat for medicinal species can be protected and improved. The option of cultivating medicinal species, especially reintroducing medicinal species which no longer occur within SR Area 1, could also be considered and historic impacts associated with mining activities such as vegetation clearance and flooding of valleys can be mitigated. During the dry season survey, no additional medicinal species were identified.

**Table 3: Traditional medicinal plants identified during the field assessment. Medicinal applications and application methods are also presented.**

| Scientific name | Local name | Plant part used | Medicinal use |
|---|---|---|---|
| *Macaranga heudelottii* | Njekoi | Leaves, fruit, bark, roots | An infusion of the leaves in water is prepared and is applied to skin conditions. For coughs, the pith of the wood is chewed. |
| *Cola chlamydantha* | Ndogbojeh | Leaves | Leaves are roasted and mixed with palm oil and taken orally as a general emetic to treat various diseases. |
| *Piptadeniastrum africanum* | Mbelie | Bark, roots | A pulp of the bark and roots is prepared and rubbed onto the head to treat migraines. |
| *Morinda geminata* | Njasui | Roots | A decoction is prepared from the roots and taken orally to treat anaemia in children. |
| *Ficus capensis* | Ndahie | Bark | A decoction is prepared from the bark and taken orally to treat dysentery. |
| *Salacia senegalensis* | Giboi | Leaves | A decoction is prepared from the leaves and taken orally to treat constipation. |
| *Mimosa pudica* | Dbagbomei | Leaves | A paste of the leaves is prepared and mixed with white river clay and applied to the skin to treat inflammation. |
| *Dissotis rotundifolia* | Mbongei | Leaves | A decoction is prepared from the leaves and taken orally 3 times daily to treat gonorrhoea. |
| *Gouania longipetala* | Sawai | Leaves | A decoction is prepared from the leaves and taken orally to treat fever and hallucinations. |
| *Costus afer* | Hoiweh | Roots | A decoction is prepared from the roots and applied into eyes to treat eye infections. Roots are also chewed to induce vomiting to treat snake bite. |
| *Anthocleista procera* | Pongoe | Roots/leaves | A decoction is prepared from the roots and leaves and taken orally to stimulate growth of babies in pregnant women. |
| *Brachiaria serrata* | Kpandai | Leaves | A decoction is prepared from the leaves and applied to the body where affected by polio. |
| *Canna indica* | Jaikie | Root | Root pulp is applied to treat leprosy. |
| *Musanga cecropioides* | Ngovoi | Bark/roots | A decoction is prepared from the bark and roots and taken orally to treat high blood pressure. |
| *Myrianthus serratus* | Foi | Bark | Dried bark is crushed and the powder is mixed with water and taken orally to treat stomach aches and rheumatism. |

# 4 SENSITIVITY MAPPING

The figure and table below illustrate the areas considered to be of increased ecological sensitivity. The areas are depicted according to their sensitivity in terms of the presence or potential for floral SCC, habitat integrity and levels of disturbance, threat status of the habitat type, the presence of unique landscapes and overall levels of diversity (as discussed in Section 3). The table below presents the sensitivity of each identified habitat unit along with an associated conservation objective and implications for development.

**Table 4: A summary of sensitivity of each habitat unit and implications for the proposed development.**

| Habitat Unit | Sensitivity | Conservation Objective | Development Implications |
|---|---|---|---|
| Degraded Forest | Moderately Low | Optimise development potential while improving biodiversity integrity of surrounding natural habitat and managing edge effects. | This habitat unit is of moderately low ecological sensitivity and if current land-uses persist, its sensitivity is unlikely to change. However, a case can be made for decreasing impact on this habitat unit through improving the agricultural efficiency by local communities through education and optimisation of agricultural techniques. This may lessen the pressure on this habitat unit and allow floral communities to progress through the stages of ecological succession to eventually become climax forest communities. |
| Ridge Forest and remnant Semi-Deciduous Moist Forest | High | Preserve and enhance the biodiversity of the habitat unit, no-go alternative must be considered. | This habitat unit is of high ecological sensitivity, however if current land-uses persist, its sensitivity is likely to decrease due to increasing pressure on these forests for firewood and timber. As such, it is recommended that a biodiversity action plan be developed which will address the threats to this habitat unit within SR Area 1 and improve its ecological condition through management of edge effects and allowing natural reforestation in cleared areas through ecological succession as per the closure plan. |
| Watercourses not Affected by Mining or Decant, including Mangroves | High | Preserve and enhance the biodiversity of the habitat unit, no-go alternative must be considered. | This habitat unit is of high ecological sensitivity, and further impacts must be avoided where possible as the key drivers of modification of these systems are as a result of historical and current mining activities. It is recommended that a biodiversity action plan be developed, which will address the threats to this habitat unit within SR Area 1 and improve its ecological condition through management of impacts including alien and invasive species management, especially focussing on *C. odorata, A. mangium, A. auriculiformis* and *E. globulus.* These measures will improve the condition of the unaffected watercourses and aid in offsetting the impact of future mining activities which may encroach upon this habitat unit through the clearance of new mining areas. |
| Watercourses Associated with Historic Dredge Ponds and Streams Affected by Decant. | Moderately High | Preserve and enhance the biodiversity of the habitat unit, limit development and disturbance. | This habitat unit is of moderately high ecological sensitivity, and an opportunity exists for the condition of the floral communities associated with these systems to be improved. It is recommended that a biodiversity action plan be developed, which will address the threats to this habitat unit and improve its ecological condition through management of impacts including alien and invasive species management, especially focussing on *C. odorata, A. mangium, A. auriculiformis* and *Eucalyptus globulus.* These |

| Habitat Unit | Sensitivity | Conservation Objective | Development Implications |
|---|---|---|---|
| | | | measures will improve the condition of this habitat unit and aid in offsetting the impact of historic mining activities. |
| Transformed Areas. | Low | Optimise development potential. | This habitat unit is of low ecological sensitivity. It is recommended that the rehabilitation plan is revisited to improve current rehabilitation efforts. In this regard, it is recommended that the measures as stipulated in the closure plan are implemented.<br><br>Furthermore, improving the agricultural efficiency of local communities through education and optimisation of agricultural techniques may lessen the pressure on the receiving environment. Another recommended management intervention is alien and invasive species management, especially focussing on *C. odorata, A. mangium, A. auriculiformis* and *Eucalyptus globulus* in and around the mining areas. |

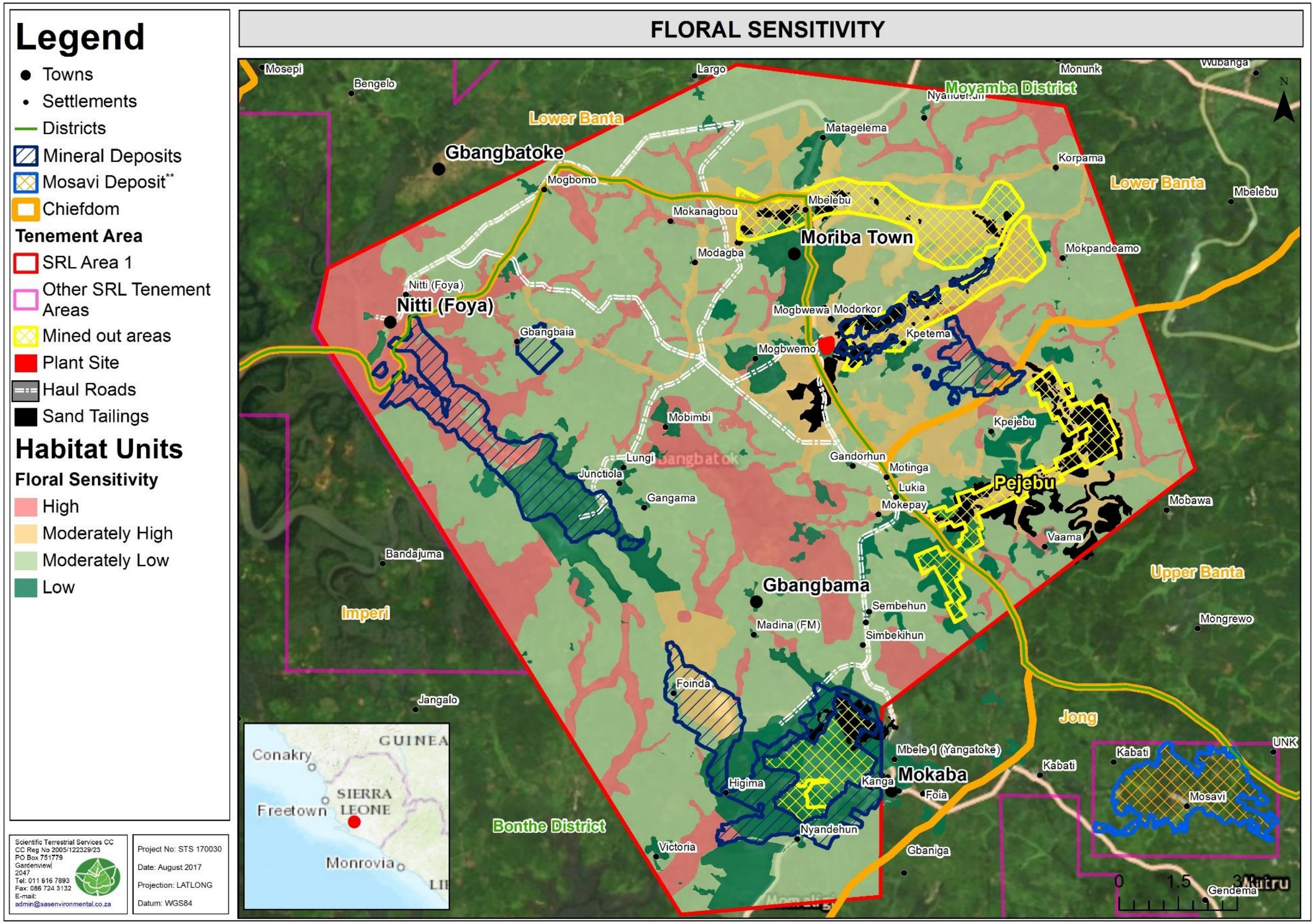



Figure 2: Sensitivity map for SR Area 1.

# 5 CONCLUSION

Scientific Terrestrial Services (STS) was appointed to conduct faunal, floral, wetland and aquatic ecological assessments as part of the process to undertake an Environmental, Social and Health Impact Assessment (ESHIA) and develop an Environmental, Social and Health Management Plan (ESHMP) for the current and proposed dry and wet mining activities including the proposed expansion area and haul road for the Sierra Rutile Limited (SRL) Mine. This section reports on the floral ecology in the vicinity of the SR Area 1 operations.

During the field assessment, a number of habitat units were identified. These habitat units are:

- Degraded Forest, which historically consisted of Moist Semi-Deciduous Forest which has been degraded by extensive, long-term, slash-and-burn subsistence agriculture. This habitat unit is of moderately low ecological sensitivity and if current land-uses persist, its sensitivity is unlikely to change. However, a case can be made for decreasing the impact on this habitat unit through improving the agricultural efficiency by local communities through education and optimisation of agricultural techniques. This may lessen the pressure on this habitat unit and allow floral communities to progress through the stages of ecological succession to eventually become climax forest communities again;
- Ridges which are associated with more intact remnant Moist Semi-Deciduous Forest. This habitat unit is of high ecological sensitivity, however if current land-uses persist, its sensitivity is likely to decrease due to increasing pressure on these forests for firewood and timber. As such, it is recommended that a biodiversity action plan be developed which will address the threats to this habitat unit and improve its ecological condition through management of edge effects and allowing natural reforestation in cleared areas through ecological succession;
- Watercourses associated with historic dredge ponds where bankside vegetation has re-established as well as systems downstream of the dredge ponds. This habitat unit is of high ecological sensitivity, and further impacts must be avoided where possible as the key drivers of modification of these systems are as a result of historical and current mining activities. It is recommended that a biodiversity action plan be developed, which will address the threats to this habitat unit and improve its ecological condition through management of impacts including alien and invasive species management, especially focussing on *C. odorata, A. mangium, A.*

*auriculiformis* and *E. globulus.* These measures will improve the condition of the unaffected watercourses and aid in offsetting the impact of future mining activities which may encroach upon this habitat unit through the clearance of new mining areas;

- Watercourses not affected by mining or decant, and mangrove areas within the SR Area 1. This habitat unit is of moderately high ecological sensitivity, and an opportunity exists for the condition of the floral communities associated with these systems to be improved. It is recommended that a biodiversity action plan be developed, which will address the threats to this habitat unit and improve its ecological condition through management of impacts including alien and invasive species management, especially focussing on *C. odorata, A. mangium, A. auriculiformis* and *Eucalyptus globulus.* These measures will improve the condition of this habitat unit and aid in offsetting the impact of historic mining activities; and
- Transformed habitat associated with villages, active agricultural fields, borrow pits, active dredge ponds and mining areas and associated infrastructure. This habitat unit is of low ecological sensitivity. The rehabilitation and closure plan has been improved as part of this ESHIA for implementation going forward. In this regard, it is recommended that the measures as stipulated in the closure plan are implemented. Furthermore, improving the agricultural efficiency of local communities through education and optimisation of agricultural techniques may lessen the pressure on the receiving environment. Another recommended management intervention is alien and invasive species management, especially focussing on *C. odorata, A. mangium, A. auriculiformis* and *Eucalyptus globulus* in and around the mining areas.

This report aimed to map, consider and describe the floral ecological resources associated with SR Area 1. In addition, the integrity, ecological importance and sensitivity, including the provision of goods and services, was considered and presented. In doing so, this report aimed to guide the proponent, Environmental Assessment Practitioner (EAP) and regulating authorities, by means of the presentation of information on the baseline conditions, as to the management of current and future mining operations from an ecological risk management point of view as well as provide mitigation and management measures to manage potential and existing impacts.

# 6 REFERENCES

**NOTE: Reliable reference material at the required level of detail and accuracy is scant, and thus verified and accurate reference material was utilised. These references are internationally accepted and although many of them do not specifically cover SR Area 1, the species ranges and distributions overlap. Notes on ecological and biological requirements allowed the specialists to reliably extrapolate data.**

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# APPENDIX A: Floral method of Assessment

## Floral Species of Conservational Concern Assessment

Prior to the field visit, a record of floral SCC and their habitat requirements was acquired from SANBI for the Quarter Degree Square in which the study area is situated, as well as relevant regional, provincial and national lists. Throughout the floral assessment, special attention was paid to the identification of any of these SCC as well as the identification of suitable habitat that could potentially support these species.

The Probability of Occurrence (POC) for each floral SCC was determined using the following calculations wherein the distribution range for the species, specific habitat requirements and level of habitat disturbance were considered. The accuracy of the calculation is based on the available knowledge about the species in question, with many of the species lacking in-depth habitat research.

Each factor contributes an equal value to the calculation.

| Distribution | | | | | |
|---|---|---|---|---|---|
| | **Outside of known distribution range** | | | | **Inside known distribution range** |
| **Site score** | | | | | |
| **EVC 1 score** | 0 | 1 | 2 | 3 | 4 | 5 |
| **Habitat availability** | | | | | | |
| | **No habitat available** | | | | | **Habitat available** |
| **Site score** | | | | | | |
| **EVC 1 score** | 0 | 1 | 2 | 3 | 4 | 5 |
| **Habitat disturbance** | | | | | | |
| | **0** | **Very low** | **Low** | **Moderate** | **High** | **Very high** |
| **Site score** | | | | | | |
| **EVC 1 score** | 5 | 4 | 3 | 2 | 1 | 0 |

[Distribution + Habitat availability + Habitat disturbance] / 15 x 100 = POC%

## Vegetation Surveys

Vegetation surveys were undertaken by first identifying different habitat units and then analysing the floral species composition that was recorded during detailed floral assessments using the step point vegetation assessment methodology. Different transect lines were chosen throughout the entire study area within areas that were perceived to best represent the various plant communities. Floral species were recorded and a species list was compiled for each habitat unit. These species lists were also compared with the vegetation expected to be found within the relevant vegetation types as described in Section 4, which serves to provide an accurate indication of the ecological integrity and conservation value of each habitat unit (Evans & Love, 1957; Owensby, 1973).

## Floral Habitat Sensitivity

The floral habitat sensitivity of each habitat unit was determined by calculating the mean of five different parameters which influence floral communities and provide an indication of the overall floristic ecological integrity, importance and sensitivity of the habitat unit. Each of the following parameters are subjectively rated on a scale of 1 to 5 (1 = lowest and 5 = highest):

- **Floral SCC:** The confirmed presence or potential for floral SCC or any other significant species, such as endemics, to occur within the habitat unit;
- **Unique Landscapes:** The presence of unique landscapes or the presence of an ecologically intact habitat unit in a transformed region;
- **Conservation Status:** The conservation status of the ecosystem or vegetation type in which the habitat unit is situated based on local, regional and national databases;
- **Floral Diversity:** The recorded floral diversity compared to a suitable reference condition such as surrounding natural areas or available floristic databases; and
- **Habitat Integrity:** The degree to which the habitat unit is transformed based on observed disturbances which may affect habitat integrity.

Each of these values contribute equally to the mean score, which determines the floral habitat sensitivity class in which each habitat unit falls. A conservation and land-use objective is also assigned to each sensitivity class which aims to guide the responsible and sustainable utilization of the habitat unit in question. In order to present the results use is made of spider diagrams to depict the significance of each aspect of floral ecology for each vegetation type. The different classes and land-use objectives are presented in the table below:

**Table A1: Floral habitat sensitivity rankings and associated land-use objectives.**

| Score | Rating significance | Conservation objective |
|---|---|---|
| 1> and <2 | Low | Optimise development potential. |
| 2> and <3 | Moderately low | Optimise development potential while improving biodiversity integrity of surrounding natural habitat and managing edge effects. |
| 3> and <4 | Intermediate | Preserve and enhance biodiversity of the habitat unit an surrounds while optimising development potential. |
| 4> and <5 | Moderately high | Preserve and enhance the biodiversity of the habitat uni limit development and disturbance. |
| 5 | High | Preserve and enhance the biodiversity of the habitat unit, no-go alternative must be considered. |

# APPENDIX B: Floral Species List

**Table B1: Floral species encountered during the field assessments.**

| Species | Degraded Forest | Ridges and Remnant Semi-Deciduous Moist Forest | Watercourses not Affected by Mining or Decant, including Mangroves. | Watercourses Associated with Historic Dredge Ponds and Streams Affected by Decant. | Transformed Areas |
|---|---|---|---|---|---|
| *Acacia auriculiformis* | X | | X | X | X |
| *Acacia mangium* | X | | X | X | X |
| *Afzelia africana* | | X | | | |
| *Arfzelia bella* | | X | | | |
| *Albizia adianthifolia* | X | X | | | |
| *Albizia ferruginea* | | X | | | |
| *Albizia zygia* | X | | | | |
| *Alpinia speciosa* | X | X | | | X |
| *Anthocleista nobilis* | | | X | X | |
| *Avicennia africana* | | | X | | |
| *Bidens pilosa* | X | | | X | X |
| *Bombax buonopozense* | X | X | | | |
| *Brachystegia leonensis* | | X | | | |
| *Bridelia grandis* | | X | | | |
| *Ceiba pentandra* | X | | | | |
| *Chromolaena odorata* | X | | X | X | X |
| *Cleistopholis patens* | | | X | X | |
| *Conocarpus erectus* | | | X | | |
| *Cynodon dactylon* | X | X | X | X | X |
| *Elaeis guineensis* | X | X | X | X | |
| *Entandrophragma utile* | | X | | | |
| *Eucalyptus globulus* | X | | X | X | X |
| *Gilbertiodendron splendidum* | | | X | X | |
| *Hibiscus trionium* | X | | | | X |
| *Imperata cylindrica* | X | | X | X | |
| *Khaya senegalensis* | | X | | | |
| *Laguncularia racemosa* | | | X | | |
| *Lantana camara* | X | | X | X | X |
| *Macaranga heudelotii* | | | X | X | X |
| *Mangifera indica* | X | | | | X |
| *Manihot esculenta* | X | | | | X |
| *Mitragyna stipulosa* | | | X | X | |
| *Musanga cecropioides* | X | X | | | |
| *Nauclea diderrichii* | X | X | | | |
| *Nesogordonia papaverifera* | | X | | | |
| *Newtonia elliotii* | | | X | X | |
| *Oxytenanthera spp* | | | X | X | |
| *Piptadeniastrum africanum* | X | X | | | |
| *Psidium guajava* | X | | | | X |
| *Pteridium aquilinum* | X | X | X | X | X |
| *Raphia vinifera* | | | X | X | |
| *Rhizophora* spp | | | X | | |

| Species | Degraded Forest | Ridges and Remnant Semi-Deciduous Moist Forest | Watercourses not Affected by Mining or Decant, including Mangroves. | Watercourses Associated with Historic Dredge Ponds and Streams Affected by Decant. | Transformed Areas |
|---|---|---|---|---|---|
| *Scleria barteri* | X | X | | | |
| *Sesbania bispinosa* | | | | | X |
| *Terminalia ivorensis* | X | X | | | X |
| *Tithonia diversifolia* | X | | | | X |
| *Trema orientalis* | X | X | | | |
| *Uapaca guineensis* | X | X | | | |
| *Zanthoxylum gilletii* | | X | | | |
| *Tithonia rotundifolia* | X | | | | X |
| *Zinnia peruviana* | X | | | | X |
| *Cola chlamydantha* | X | | | | X |
| *Piptadeniastrum africanum* | X | | | | X |
| *Morinda geminata* | X | | | | X |
| *Ficus capensis* | X | X | | | X |
| *Salacia senegalensis* | X | X | | | X |
| *Mimosa pudica* | X | X | X | X | X |
| *Dissotis rotundifolia* | X | | | | X |
| *Gouania longipetala* | X | | | | X |
| *Costus afer* | X | | | | X |
| *Anthocleista procera* | X | X | | | X |
| *Brachiaria serrata* | X | X | X | X | X |
| *Canna indica* | X | | | | X |
| *Musanga cecropioides* | X | X | | | X |
| *Myrianthus serratus* | X | | | | X |

# APPENDIX C: SPECIALISTS DETAILS

## Details, Expertise and Curriculum Vitae of Company and Author

## SCIENTIFIC TERRESTRIAL SERVICES (STS) – SPECIALIST CONSULTANT INFORMATION

## CURRICULUM VITAE OF EMILE BASSON VAN DER WESTHUIZEN

### PERSONAL DETAILS

| | |
|---|---|
| Position in Company | Ecologist, Botanist |
| Date of Birth | 30 May 1984 |
| Nationality | South African |
| Languages | English, Afrikaans |
| Joined SAS | 2008 |

### MEMBERSHIP IN PROFESSIONAL SOCIETIES

Member of the South African Council for Natural Scientific Professions (SACNASP) (Reg. Number 100008/15).

### EDUCATION

| | |
|---|---|
| Qualifications | |
| BSc (Hons) Plant Science (University of Pretoria) | 2012 |
| B.Sc. Botany and Environmental Management (University of South Africa) | 2010 |
| Short Courses | |
| Grass Identification – Africa Land Use Training | 2009 |
| Wild Flower Identification – Africa Land Use Training | 2009 |

### COUNTRIES OF WORK EXPERIENCE

South Africa – Gauteng, Mpumalanga, North West, Limpopo, KwaZulu-Natal, Free State, Eastern Cape.

Mozambique (Tete, Sofala and Manica Provinces)

Democratic Republic of the Congo (Katanga and Kivu Provinces)

Angola (Zaire Province)

Cabinda

Ghana (Western and Greater Accra Provinces)

### SELECTED PROJECT EXAMPLES

**Ecological Assessments**

- Floral assessment for the Cacata Phosphate Mining Project, Cabinda, Angola.
- Floral assessment for the Lucunga Phosphate Mining Project, Mucula, Angola.
- Floral assessment for the Auroch Resources Manica Gold Mining Project, Manica, Mozambique.
- Floral assessment for the Namoya Gold Mine project in Namoya, Democratic Republic of Congo.
- Ecological assessment prior to the construction of the proposed 120 km Lepelle Northern Works Ebenezer bulk water pipeline, Haenertsburg, Limpopo Province.

- Ecological assessment for the proposed Qunu City development, Qunu, Eastern Cape.
- Ecological assessment for the proposed Bhisho Legislature Expansion, Bhisho, Eastern Cape.
- Ecological assessment for the proposed new Spar distribution warehouse complex, Port Elizabeth, Eastern Cape.
- High level floral risk assessment and alternatives analysis for the proposed new Tete Airport, Tete, Mozambique.
- Site walkdown and floral ecological input prior to the construction of the proposed 180 km Mfolozi-Mbewu powerline, Richards bay, Kwa-Zulu-Natal Province.
- Floral assessment as part of the EIA process for the proposed King's City Takoradi 3000 hectare development, Takoradi, Ghana
- Floral assessment as part of the EIA process for the proposed Geniland Lubumbashi City 4000 hectare development, Likasi, Katanga Province, Democratic Republic of Congo.
- Floral, faunal, aquatic and wetland assessment as part of the EIA process for the proposed Appollonia City Accra 3000 hectare development, Accra, Ghana.
- Floral assessment as part of the EIA process for the proposed Lubembe Coppermine Project, Lubumbashi, Katanga Province, Democratic Republic of Congo.
- Floral assessment as part of the EIA process for the proposed Kinsenda Coppermine Project, Lubumbashi, Katanga Province, Democratic Republic of Congo.
- Floral assessment as part of the EIA process for the proposed Lonshi Coppermine Project, Lubumbashi, Katanga Province, Democratic Republic of Congo.
- Floral assessment for the proposed Modikwa Platinum Mine South 2 Shaft Project, Burgersfort, Limpopo Province.
- Floral assessment for the proposed New Clydesdale Colliery Stoping Project, Vandyksdrift, Mpumalanga Province.
- Floral assessment as part of the EIA process for the proposed Harriet's Wish PGM Project, Limpopo Province.
- Floral assessment as part of the environmental authorisation process for the proposed Shanduka Coal Argent Colliery in the vicinity of Argent, Mpumalanga.
- Floral assessment for the proposed Richards bay Harbour Compactor Slab development, Richards bay, Kwa-Zulu-Natal Province.
- Floral assessment as part of the EIA process for the proposed Peerboom Colliery, Lephalale, Limpopo Province.
- Floral assessment as part of the EIA process for the proposed Overvaal Underground Coal Mine Project, Ermelo, Mpumalanga Province.
- Floral assessment as part of the EIA process for the proposed Aquarius Platinum Fairway Platinum Mine, Steelpoort, Mpumalanga Province.
- Floral assessment as part of the EIA process for the proposed Leeuw Colliery, Utrecht, Kwa-Zulu Natal Province.
- Floral assessment as part of the EIA process for the proposed Jozini Shopping Mall, Jozini, Kwa-Zulu Natal Province.
- Floral assessment as part of the Biodiversity Action Plan for the Assmang Chrome Dwarsrivier Mine, Steelpoort, Mpumalanga Province.

# SIERRA RUTILE PROJECT AREA 1 - ENVIRONMENTAL, SOCIAL AND HEALTH IMPACT ASSESSMENT: SPECIALIST TERRESTRIAL, AQUATIC AND WETLAND ECOLOGICAL STUDIES

**Prepared for**

**SRK Consulting (South Africa) (Pty) Ltd**

**January 2018**

# Section C: Faunal Assessment

| | |
|---|---|
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| **Report Reference:** | **STS 170030** |
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# ACRONYMS

| | |
|---|---|
| **EAP** | Environmental Assessment Practitioner |
| **EIS** | Ecological Importance and Sensitivity |
| **EN** | Endangered |
| **ESIA** | Environmental and Social Impact |
| **ESMP** | Environmental and Social Management Plan |
| **GIS** | Geographic Information System |
| **GPS** | Global Positioning System |
| **IEM** | Integrated Environmental Management |
| **IUCN** | International Union for Conservation of Nature |
| **LC** | Least Concern |
| **NT** | Near Threatened |
| **NYBA** | Not yet been assessed |
| **PES** | Present Ecological State |
| **POC** | Probability of Occurrence |
| **SCC** | Species of Conservation Concern |
| **SRL** | Sierra Rutile Mine |
| **STS** | Scientific Terrestrial Services |
| **VU** | Vulnerable |

# 1. INTRODUCTION

## 1.1 Background

Scientific Terrestrial Services (STS) was appointed to conduct faunal, floral, wetland and aquatic ecological assessments as part of the process to undertake an Environmental, Social and Health Impact Assessment (ESHIA) and develop an Environmental, Social and Health Management Plan (ESHMP) for the current and proposed dry and wet mining activities for the Sierra Rutile Limited's (SRL) Mine Lease Area 1 (SR Area 1; or the Study area) operations. SR Area 1 is located within the Bonthe and Moyamba Districts of the Southern Province of Sierra Leone. SR Area 1 is situated approximately 30 km inland of the Atlantic Ocean and approximately 135 km southeast of Freetown (geodesic) (Figure 1 and Figure 2 in the Section A report).

This report aims to map, consider and describe the faunal ecological resources associated with SR Area 1 according to the results of the dry and wet season surveys. In addition, the integrity, ecological importance and sensitivity, including the provision of goods and services, is considered and presented. In doing so this report must guide the proponent, Environmental Assessment Practitioner (EAP) and regulating authorities, by means of the presentation of information on the baseline conditions, as to the management of current and future mining operations from an ecological risk management point of view as well as the further studies and assessments required.

Following the wet and dry season assessments the ecological risks were determined, and the analyses of the impacts associated with the project are presented in Section E (Impact assessment). Key mitigatory measures were identified in order to minimise the potential impacts on both the local and regional faunal ecology.

# 2 ASSESSMENT APPROACH

Literature from previous ESIA studies conducted for SRL were assessed, combined with two field assessments. The first field assessment of 14 days was undertaken during July 2017 in order to determine the ecological status of SR Area 1 during the wet season, whilst a second assessment of seven days was undertaken during January 2018 as part of the dry season ecological assessment. A reconnaissance 'walkabout' was initially undertaken to determine the general habitat types found throughout the SR Area 1. Following this, specific study sites were selected that were considered to be representative of the habitats found within the area, with special emphasis being placed on areas that may potentially support faunal Species of Conservation Concern (SCC). Sites were investigated on foot in order to identify the occurrence, and potential occurrence of fauna within the SR Area 1. In order to increase overall observation time, as well as increasing the likelihood of observing shy and hesitant species, motion sensitive camera traps were strategically placed within The SR Area 1. Sherman traps were also used to increase the likelihood of capturing and observing small mammal species, notably small nocturnal mammals. Drift fences and pitfall traps, along with sweep netting were also employed in order to further assess the invertebrate component of the SR Area 1. A detailed explanation of the method of assessment is provided in Appendix A of this report.

The faunal categories covered in this assessment are mammals, avifauna, reptiles, amphibians, general invertebrates and arachnids.

# 3 FAUNAL ASSESSMENT RESULTS

## 3.1 Habitat Description

Habitat integrity combined with the overall availability of resources to faunal species is a large determinant factor in terms of species diversity and abundance, as well as influencing the likelihood of SCC occurrence. The SR Area 1 was assessed in terms of the current levels of habitat integrity and habitat provision for faunal species as is outlined below.

After investigation, it is evident that four faunal habitat units exist within the SR Area 1, namely:

- Ridges associated with more intact Semi-Deciduous Moist Forest;
- Degraded Semi-Deciduous Moist Forest; and
- Transformed Areas;
  - Current mining/dredging areas;
  - Human settlement areas;
  - Croplands;
- Watercourses, comprising of:
  - Watercourses affected by mining;
  - Watercourses not affected by mining including mangroves.

The above-mentioned habitat units are discussed briefly below, for further information please see the floral report (Section B).

**Ridges**

This habitat type was observed in the mountainous areas of the SR Area 1 and has been largely excluded from mining related impacts due to the mountainous conditions and access constraints. Although this habitat unit is excluded from direct mining related impacts, there are still notable impacts to the faunal component of the habitat unit as a result of resource harvesting (wood, food etc) by the local communities. Hunting and the gathering of firewood/building material is resulting in the localised loss of habitat and species diversity. This habitat unit is considered important in terms of habitat provision and as an area of refuge for faunal species.

**Degraded Forest**

This habitat unit encompasses the forest and open areas where the indigenous forest had once been cleared but is now re-establishing, and areas where the harvesting of natural resources (timber) has resulted in the degradation of the forest areas. This habitat unit has been disturbed as a result of edge effects from mining activities, as well as overutilisation by the local communities through subsistence slash and burn agricultural practices. Although this habitat unit has been subject to anthropogenic activities and impacts, it is still considered capable of providing habitat and resources to a number of faunal species.

**Transformed/Mining Areas**

This habitat unit encompasses the areas currently under mining (including current wet and dry mining areas) or agricultural activities that have been largely stripped and cleared of the natural vegetation. This habitat unit has a low habitat provision potential for faunal species as a result of habitat loss and the increased presence of people and on-site machinery. This habitat unit may provide temporary foraging grounds for some faunal species but is unlikely to be utilised on a permanent basis.

**Watercourses**

This habitat unit is split into two sub-habitats, namely watercourses associated with historic dredge ponds where bankside vegetation has re-established and streams downstream thereof; and watercourses not affected by mining or decant and mangroves. The old dredge ponds have at this point in time and to a large extent naturally rehabilitated through the establishment of bankside vegetation. The old ponds were observed to be utilised and favoured by a number of waterfowl in the region, for habitat and foraging purposes. Secondly, the old ponds also provide a more permanent water source for faunal species during the dry season (to be confirmed during dry season survey), when many of the smaller water courses cease to flow. The mangrove habitat is located in the extreme western portion of SR Area 1, and provides habitat to a number of faunal species, notably many of the avifaunal skimmers and other species unique to these vegetation types. Freshwater drainage features dominate much of SR Area 1, providing habitat linkages through the water systems and riparian habitat. These drainage features form an integral part of the ecological functioning of the ecosystems, providing food and water resources to many of the inland faunal species.

## *3.2 Wet and Dry Season Findings per Taxon*

The tables below present the findings of the wet and dry season surveys for mammals, avifauna, reptiles, amphibians, general invertebrates and arachnids in relation to the above habitat types. Data for all classes are presented in a 'dashboard' format discussing all relevant ecological parameters in a concise manner. The method for determining the habitat sensitivity for each taxon is described in Appendix A.

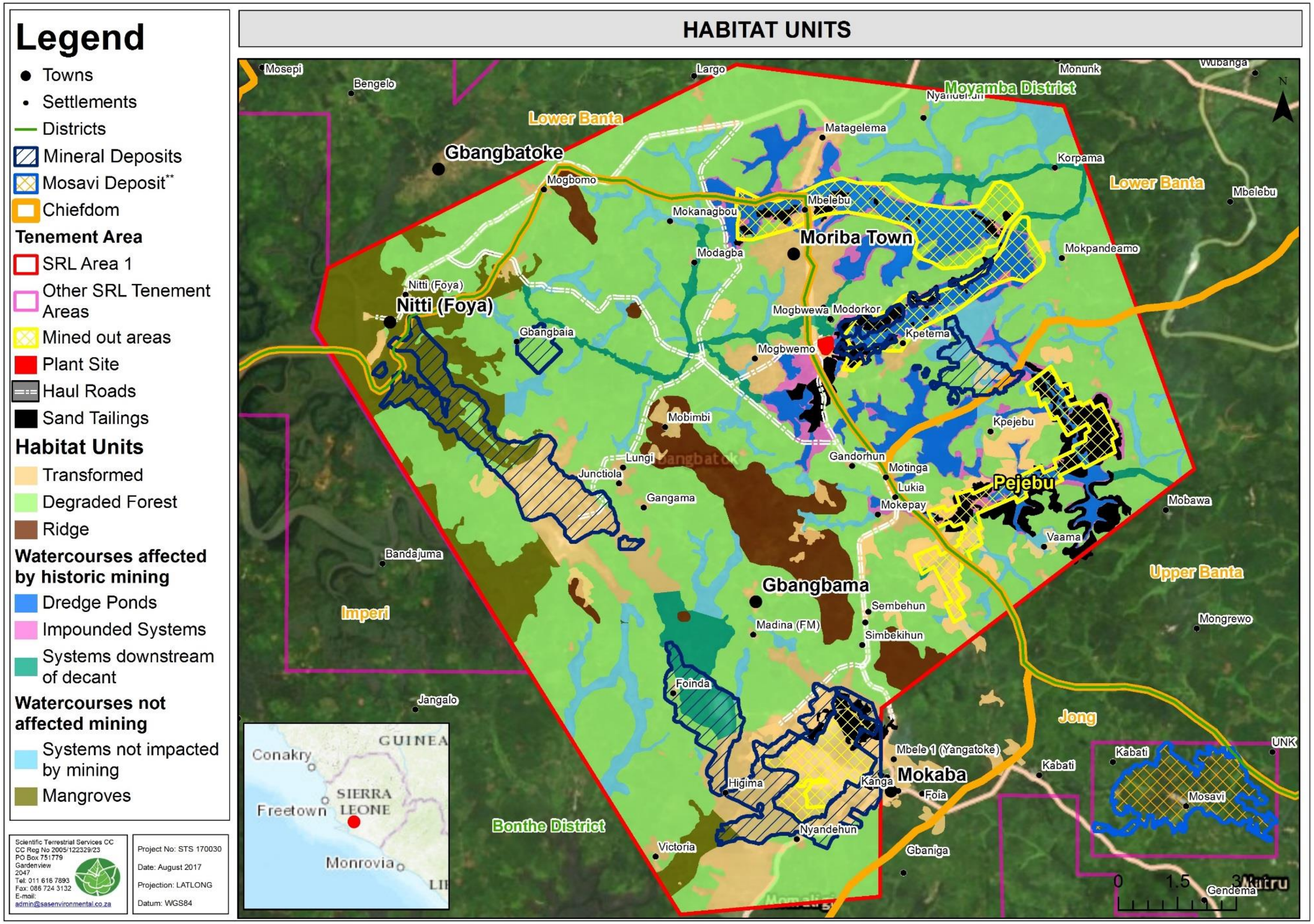
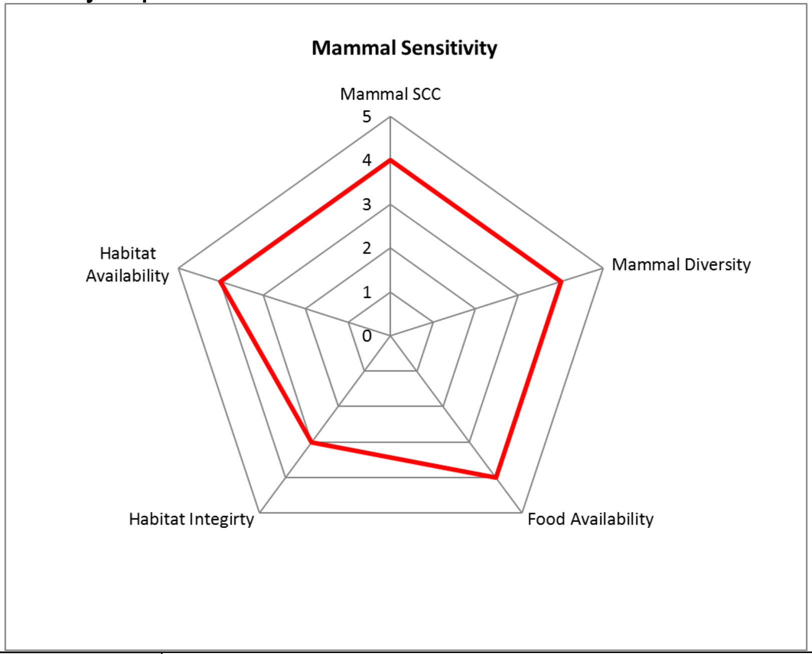



**Figure 1: Map illustrating the various habitat units of the SR Area 1**

## 3.3 Mammals

**Table 1: Mammal assessment for SR Area 1**

| | | | |
|---|---|---|---|
| **Faunal Class: Mammals** | **Faunal Habitat Sensitivity** | **Moderately High** | **Photograph:**  |
| | **Notes on Photograph, top left to bottom right:** *Cercopithecus petaurista* (Lesser Spot-nosed Monkey), *Cercopithecus campbelli* (Campbell's Monkey), *Rattus* (Black Rat), *Philantomba maxwellii* (Maxwell's duiker) caught on the camera trap. Bottom: C. *campbelli* (Campbell's Monkey) killed as part of the local bush meat trade. | | |
| **Faunal Sensitivity Graph:**   | | | |
| **Faunal SCC/Endemics** | Although no SCC were observed during the site assessment, literature reviews indicate that a number of species may occur within SR Area 1. Species expected to occur within the SR Area 1 include *Aonyx capensis* (African clawless Otter); *Hydrictis maculicollis* (Spotted-necked Otter); *Pan troglodytes* (Chimpanzee) and *Miniopterus schreibersii* (Schreibers' Long-fingered Bat). For a full list of SCC please refer to Section 3.9. | | |

<table>
<tr>
<td>Faunal Diversity</td>
<td>Mammal diversity of the SR Area 1 is considered to be moderately high, with mammal species ranging from small rodents to larger antelopes being noted. The forest areas in particular were observed to have the highest diversity, as these habitats provide the necessary food and habitat resources required by mammal species in the region. Species observed include Thryonomys swinderianus (Greater cane rat); Atherurus africanus (African brush-tailed porcupine); Xerus erythropus (Striped ground squirrel); Cercopithecus campbelli (Lesser Spot-nosed Monkey) and Cercopithecus petaurista (Campbell's Monkey).</td>
<td rowspan="4">General comments (dominant faunal species/noteworthy records):<br><br>Mammal species face a number of threats within the SR Area 1, and within the greater region. These threats are due to a combination of habitat loss and increased hunting activities by the local inhabitants for the local bush meat trade. The ever-growing bush meat trade is having significant impacts on the local mammal population, notably the medium to large mammals. Small mammals (rodents) are largely targeted by the local dogs as a source of food, this combined with the predation of small rodents by large raptors and snakes is likely to result in an increased rate of decline of the small mammal population in the years to come.<br><br>It must be taken into consideration, although the locals and mine employees have reportedly heard calls of Pan troglodytes (Chimpanzee), it is unlikely that any family units will utilise the SR Area 1. It is likely that the chimpanzees were moving through the area, probably through the forests and watercourse network, to a preferred locality/ territory away from the SR Area 1.</td>
<td rowspan="4">Conclusion and Way Forward:<br><br>Anthropogenic activities in the SR Area 1, notably the expansion of human settlements and the resultant increase in food requirements, has led to an increased rate of vegetation clearing and bush meat harvesting and trade. These impacts have led to a decreased level of habitat availability and species abundance within the SR Area 1, with most mammals where possible relocating naturally to areas of lower environmental and hunting pressures, notably into the ridge areas. Where feasible, mine employees are to be educated about the surrounding mammal species, their importance and relevance to conservation. Employees and community members are to be educated regarding the unsustainable harvesting rate of bush meat from the ecosystem and encourage bag limits and no go hunting areas. Furthermore, it is recommended that a biodiversity action plan be implemented to encourage the re-establishment of the cleared and degraded forest areas within the SR Area 1.</td>
</tr>
<tr>
<td>Food Availability</td>
<td>The varied habitat within the SR Area 1 provides a diverse range of viable food resources for mammal species, from seasonal fruits and seeds, to generalist plant material for browsing and grazing species. Various invertebrate, reptile, arachnid and smaller mammal species further provide food resources to omnivorous and carnivorous mammal species inhabiting SR Area 1.</td>
</tr>
<tr>
<td>Habitat Integrity</td>
<td>Habitat integrity is considered to be intermediate. This is largely due to the historic and current habitat clearing in the region for both subsistence agriculture and mining activities. These clearing activities have resulted in a noted loss of habitat connectivity within the region, limiting mammal dispersal and habitat usage to a degree.</td>
</tr>
<tr>
<td>Habitat Availability</td>
<td>Habitat availability is considered to be moderately high, although habitat connectivity has been affected as a result of mining activities and agricultural expansion. The remaining forest regions provide suitable habitat for a diverse array of faunal species, both terrestrial and arboreal. Furthermore, the cleared areas that have been left fallow and are not being utilised now provide increased grazing and foraging areas for species that select for open less forested areas. These open areas are noted to have higher abundance of herbaceous plant material, and as such will be utilised to a higher degree by small rodents who feed on the seeds of the grasses, as well as the larger mammals who are predominantly grazers.</td>
</tr>
</table>

**Table 2: Additional dry season notes**

**Notes on Photograph, species left to right:** *Tragelaphus scriptus* (Harnessed bushbuck), *Civettictis civet* (African civet), *Uranomys ruddi* (Rudds mouse), *and Lophuromys sikapusi* (Rusty-bellied brush-furred rat).

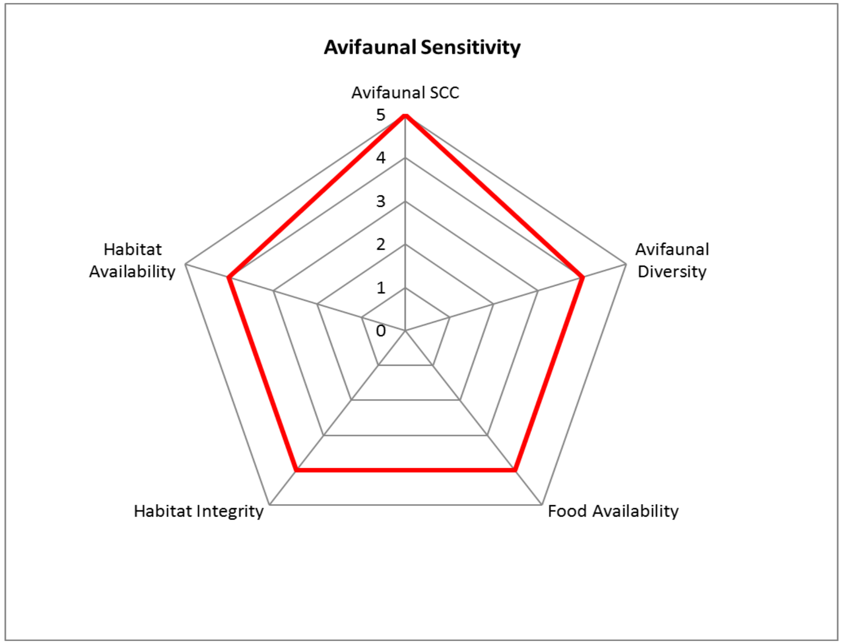
**Additional dry season notes:**

The dry season assessment was conducted during the month of January 2018. The most noticeable seasonal shift is that of the decreased levels of surface water within SR Area 1. As a result of the reduced water levels, area accessibility was notably increased, allowing for mammal species to move between habitats with greater ease. However, the increased area accessibility has also resulted in the increased human presence, notably bush clearing activities (slash and burn, wood for charcoal production). As such, mammal species are likely to be subjected to increased levels of persecution, from a combination of habitat loss as well as increased hunting pressure. Food availability for mammal species was also markedly lower during the dry season, forcing species to travel further in search of food resources, which further increases the risk of being caught by bush meat hunters, either directly or by becoming trapped in snares set out in the forest areas. Faunal diversity, did not appear to have been significantly impacted by the seasonal change, however species abundance is likely to decrease as individuals search further for food resources.

The dry season field assessment further indicated the importance for succinct and well implemented mitigation measures and habitat rehabilitation plans. As mammal species are forced to increase their travel radius in search of food resources during the dry season, it is important to ensure that future mining activities do not result in a further loss of suitable habitat and resources. Where this is not feasible, the rate of forest rehabilitation activities should be equal to or greater than the rate of habitat loss, so as to ensure suitable habitat is always available to mammal species.

## *3.4 Avifauna*

**Table 3: Avifaunal assessment for SR Area 1**

<table>
<tr><td rowspan="2">Faunal Class: Avifauna</td><td>Faunal Habitat Sensitivity</td><td>Moderately High</td><td rowspan="4">Photograph:<br></td></tr>
<tr><td colspan="2">Notes on Photograph: Top left to bottom right: bottom Centropus senegalensis (Senegal coucal); Ispidina picta (African pygmy-kingfisher); Megaceryle maxima (Giant kingfisher); Polyboroides typus (African harrier-hawk); Microcarbo africanus (Long -tailed cormorant); Corythaeola cristata (Great blue turaco).</td></tr>
<tr><td colspan="3">Faunal Sensitivity Graph:<br><br></td></tr>
<tr><td>Faunal SCC/Endemics</td><td colspan="2">No avifaunal SCC were observed at the time of assessment; however, a number have been previously recorded and/or are expected to occur within the SR Area 1, namely Psittacus timneh (Timneh Grey Parrot, EN), Ciconia episcopus (Woolly-necked Stork, VU), Gallinago media (Great Snipe, NT), Numenius arquata (Eurasian Curlew, NT), Limosa lapponica (Bar-tailed Godwit, NT) and Calidris canutus (Red Knot, NT). For a full species list refer to Section 3.9.</td></tr>
</table>

<table>
<tr>
<td>Faunal Diversity</td>
<td>The SR Area 1 presented a moderately high diversity of avifaunal species, from seedeaters and insectivorous birds to larger raptors. Avifaunal diversity appears to be negatively affected by the current anthropogenic activities associated with vegetation clearing and burning. The loss of primary forest areas directly impacts on nesting and breeding sites, notably for the larger raptors which generally nest in the larger established trees. Common avifaunal species observed include Gypohierax angolensis (Palm-nut vulture), Necrosyrtes monachus (Hooded vulture), Scopus umbrette (Hamerkop), Numida meleagris (Helmeted guineafowl) and Vanellus spinosus (Spur-winged lapwing).</td>
<td rowspan="4">General comments (dominant faunal species/noteworthy records):<br><br>Overall, the SR Area 1 is dominated by common avifaunal species that are known to frequent forest areas and watercourses. Water dependant birds are focussed around the water courses, notably in the larger water bodies and mangrove systems, whilst seedeaters, insectivorous birds and raptors were observed throughout the remaining areas of the SR Area 1.<br><br>It must be noted that the some of the SCC that may occur within the SR Area 1 are migratory species, and will not always be observable throughout the year, and as such this needs to be taken into consideration. The current field data was collected during the wet season sampling period and is possible that some of the migratory species may not have been observed during this period. The dry season assessment will address this, increasing the likelihood of observation for migratory avifaunal species. Taking into consideration migratory avifauna, it is still considered that a high number of avifaunal SCC will utilise SR Area 1 throughout the year, for both breeding and foraging purposes.</td>
<td rowspan="4">Conclusion and Way Forward:<br><br>The overall avifaunal sensitivity of the SR Area 1 area is considered to be moderately high. The habitat found within the SR Area 1 area support a diversity of bird species with ample food resources present to sustain these populations. It is likely that many of the avifaunal SCC will be concentrated around the forest areas and less disturbed watercourses, notably the mangroves and old dredge ponds.<br><br>It is recommended that a biodiversity action plan be implemented to encourage the re-establishment of the cleared and degraded forest areas. Where possible, areas of high sensitivity (Ridges, watercourses not affected by mining activities and areas of degraded forest that are in the advanced stages of ecological succession) should be excluded from mining activities. No go hunting/ disturbance areas are to be declared, notably in areas where known breeding avifaunal SCC occur, so as to limit disturbance to these species during the breeding season.</td>
</tr>
<tr>
<td>Food Availability</td>
<td>Varied habitat within the SR Area 1 provides a variety of food resources for avifaunal species. The degraded forest with the patchy open grassland and old agricultural areas are utilised by ground foraging birds, whilst riparian areas are utilised by numerous smaller species who favour densely wooded microhabitats. The degraded and ridge forest areas provide ideal hunting grounds for raptor species within SR Area 1, whilst the mangrove areas and banks of the larger watercourses are ideal foraging grounds for many of the waders and water fowl.</td>
</tr>
<tr>
<td>Habitat Integrity</td>
<td>In terms of avifauna, the habitat integrity for the SR Area 1 is considered to be moderately high. Although vegetation has been cleared for mining and agriculture, there are still sufficient areas of useable habitat remaining, which avifauna are capable of moving between and utilising.</td>
</tr>
<tr>
<td>Habitat Availability</td>
<td>Habitat availability is considered to be moderately high, with the riparian and forested areas still proving to be viable areas for breeding, whilst the cleared areas provide an alternative foraging ground for all species of birds. Furthermore, the old dredge ponds were observed to provide new habitat to water fowl, with the associated riparian habitat being utilised by a number of other avifaunal species.</td>
</tr>
</table>

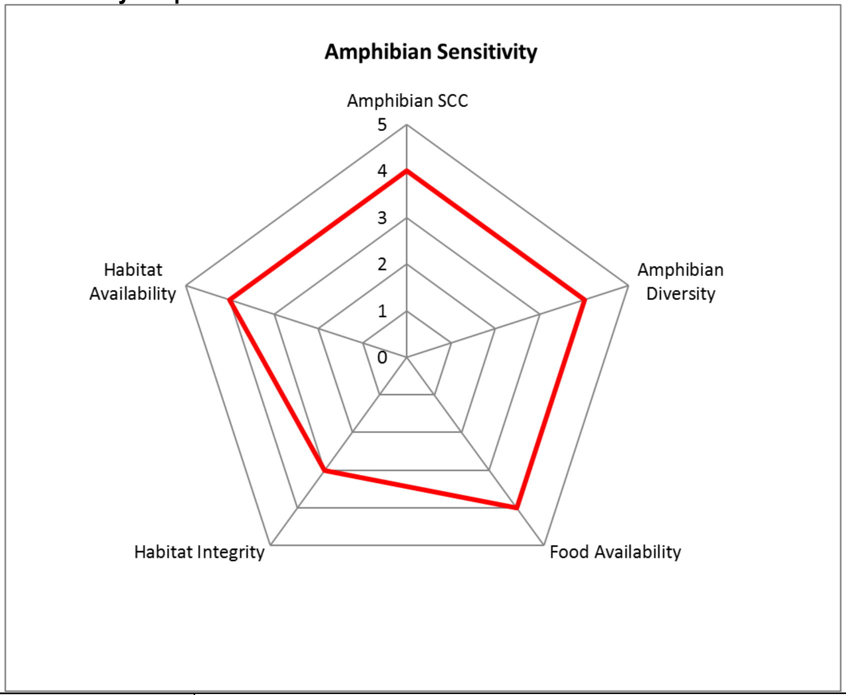
**Table 4: Additional dry season notes**

| |
|---|
| **Notes on Photograph, species left to right:** *Tockus fasciatus* (African pied hornbill), *Accipiter melanoleucus* (Black sparrowhawk), *Caprimulgus climacurus* (Long-tailed nightjar), *and Bubo cinerascens* (Greyish eagle owl). |
|     |
| **Additional dry season notes:**<br>Avifaunal species, due to their increased ease of mobility are often less impacted upon as a result of seasonal shifts, flying greater distances or temporarily relocating to areas of increased resources (food). The overall diversity of avifaunal species did not significantly decrease during the dry season assessment; however, it is likely that individuals will cover larger distances in search for food resources, which does create a fluctuation in abundances in SR Area 1. Avifaunal species were noted to congregate in greater numbers in the intact forest areas as well as along the vegetated stream banks.<br><br>The increased usage and reliance upon intact forest habitat as well as riparian vegetation along the banks of the streams and dams by avifaunal species further illustrates the need to ensure that these habitats are not impacted upon further as a result of current and future mining activities. Rehabilitation/ revegetation of impacted riparian and forest habitat areas is key for the ongoing sustainability of avifaunal abundance and diversity. As far as possible, vegetation clearing should not occur in these areas, in order to ensure that nesting sites and food resources are not impacted upon. |

## 3.5 Amphibians

**Table 5: Amphibian assessment for the SR Area 1**

<table>
<tr><td rowspan="2">Faunal Class: Amphibians</td><td>Faunal Habitat Sensitivity</td><td>Moderately High</td><td rowspan="4">Photograph:

</td></tr>
<tr><td colspan="2">Notes on Photograph: Top left to bottom right: Sclerophrys maculate (Flat-backed toad), Amietophrynus gutturalis (Guttural toad), Ptychadena mascareniensis (Mascarene grass frog), Hyperolius guttulatus (Dotted reed frog)</td></tr>
<tr><td colspan="3">Faunal Sensitivity Graph:


</td></tr>
<tr><td>Faunal SCC/Endemics</td><td colspan="2">No amphibian SCC were observed during the wet season site assessment, however there is the likelihood that a number of SCC may occur in the SR Area 1, namely Kassina cochranae (Cochran's running frog); Phrynobatrachus phyllophilus; Arthroleptis crusculum (Guinea screeching frog) and Ptychadena superciliaris amongst others. For a full list of amphibian SCC refer to Section 3.9.</td></tr>
</table>

<table>
<tr><td>Faunal Diversity</td><td>A relatively high diversity of amphibian species was observed in the SR Area 1, which are considered common and abundant in the region. Amphibian species were observed during both day and night surveys, and as such ensured an accurate representation of amphibian diversity. Due to the large quantity of available surface water and food resources, the SR Area 1 is considered capable of supporting a large diversity of amphibian species. Species observed include Sclerophrys maculate (Flat-backed toad), Amietophrynus gutturalis (Guttural toad), Ptychadena mascareniensis (Mascarene grass frog) and Hyperolius guttulatus (Dotted reed frog).</td><td rowspan="4">General comments (dominant faunal species/noteworthy records):<br><br>Mining methods employed (dry mining, damming and dredging of the land) translates to the removal of vegetation and notably the diversion and damming of waterways. This will have a long term negative impact on amphibian species. Many of the species not only rely on the presence of water for ongoing survival and breeding but rely on specific vegetation cover around the fresh water systems. Furthermore, loss of vegetation cover will impact on the availability of food resources for amphibian in the SR Area 1, further limiting population numbers.</td><td rowspan="4">Conclusion and Way Forward:<br><br>The expansion of human settlements and mining activities has resulted in an increased rate of vegetation clearing. The continued removal of vegetation and altering of water flow regimes for mining activities has impacted upon the distribution and abundance of amphibian species, forcing species to relocate to less disturbed areas for in search of food and breeding areas.<br><br>Where possible, areas of high sensitivity (watercourses not affected by mining activities and areas where streams and degraded forest are in the advanced stages of ecological succession) should be excluded from mining activities. It is recommended that a biodiversity action plan be implemented to encourage the re-establishment of the cleared and degraded forest areas.</td></tr>
<tr><td>Food Availability</td><td>The habitat mosaic, water resources and herbaceous material of the SR Area 1 will inherently allow for high insect abundance. This translates into a stable food supply for many amphibian species throughout the SR Area 1.</td></tr>
<tr><td>Habitat Integrity</td><td>Habitat integrity is considered to moderately high as a result of the numerous fresh water and wetland systems within the SR Area 1. Although the mining and agricultural activities has resulted in the clearing of vegetation, water related habitat connectivity is still considered sufficient, allowing for the movement and breeding of amphibian species within the various habitats.</td></tr>
<tr><td>Habitat Availability</td><td>Clearing of vegetation for mining and agricultural activities has had a noticeable impact on the habitat within the SR Area 1. However, there are still numerous wetlands and river systems within the SR Area 1 that provide sufficient suitable habitat to amphibian species. These habitat conditions persist during the wet season, however, during the dry season the effects of the mining activities on available habitat is expected to be more significant. Due the mining methods, more water is retained in the dredging ponds, thus limiting the recharge of the smaller streams in the vicinity, which will result in a seasonal decrease in habitat availability for amphibian species.</td></tr>
</table>

**Table 6: Additional dry season notes**

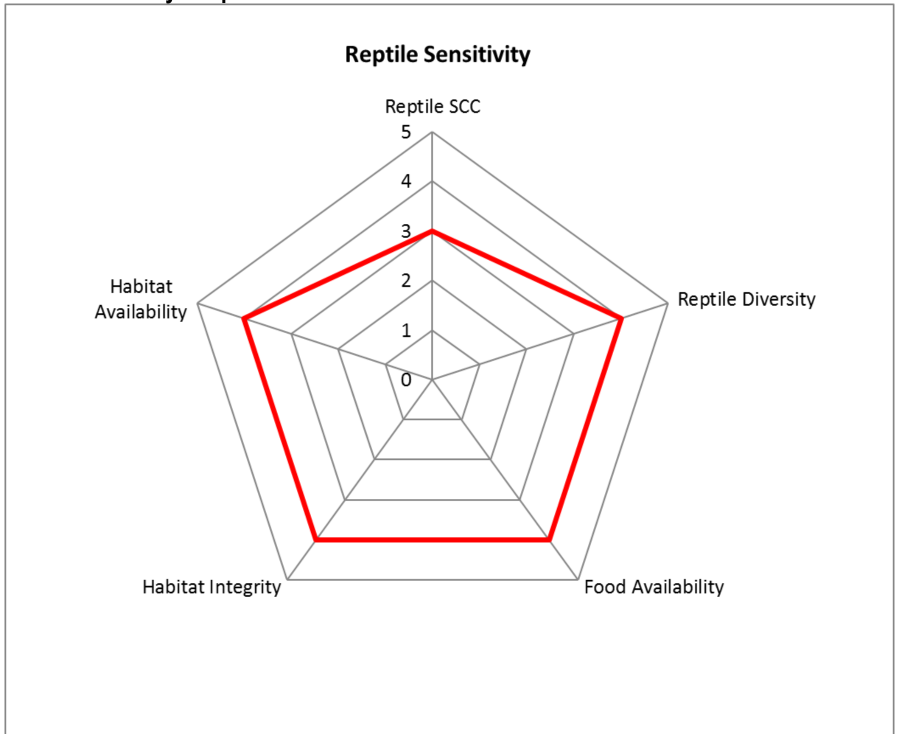
**Notes on Photograph, species left to right:** *Sclerophrys regularis* (Egyptian toad), *Phrynobatrachus sp* (Puddle frogs), *Phrynobatrachus liberiensis* (Liberia River Frog, NT).

**Additional dry season notes:**
Amphibian species where primarily observed along the banks of the streams, and only a small number along the banks of the dredge ponds. The higher amphibian abundance in these areas is likely due to the higher invertebrate abundance (food resources) as well as increased breeding area suitability, further demonstrated by the large number of juvenile amphibians observed along the banks and amongst the leaf litter.

The increased usage and reliance upon these streams and vegetated banks by amphibian species further illustrates the need to ensure that these habitats are not impacted upon further as a result of current and future mining activities. Rehabilitation/ revegetation of impacted streams and associated forest habitat is key for the ongoing sustainability of amphibian abundance and diversity. As far as possible, vegetation clearing should not occur in these areas, in order to ensure that breeding sites and food resources are not impacted upon.

## 3.6 Reptiles

**Table 7: Reptile assessment for the SR Area 1**

<table>
<tr><td rowspan="2">Faunal Class:<br>Reptiles</td><td>Faunal Habitat Sensitivity</td><td>Moderately High</td><td rowspan="4">Photograph:<br></td></tr>
<tr><td colspan="2">Notes on Photograph: Top left to bottom right: Toxicodryas blandingii (Blandings tree snake); Dendroaspis viridis (Western green mamba); Chamaeleo dilepis (Flap necked chameleon); Trachylepis affinis (Senegal mabuya); Agama africana (Western african rainbow lizard); Naja nigricollis (Black-necked spitting cobra).</td></tr>
<tr><td colspan="3">Faunal Sensitivity Graph:<br>
</td></tr>
<tr><td>Faunal SCC/Endemics</td><td colspan="2">No SCC were observed during the site assessment; however, the larger water courses may provide habitat to Osteolaemus tetraspis (Dwarf crocodile) and Crocodylus cataphractus (African slender-snouted crocodile). All observed and identified reptile species are considered to be common and of Least Concern. However, with continued persecution and habitat loss this may change in the future.</td></tr>
</table>

<table>
<tr>
<td>Faunal Diversity</td>
<td>Species observed, available literature and habitat analysis indicates that the SR Area 1 is likely to have a moderately high level of reptile diversity. Species observed within SR Area 1 are considered common species to the region and habitat types, such as species of the genus Trachylepis, Toxicodryas blandingii (Blanding's tree snake); Dendroaspis viridis (Western green mamba); Chamaeleo senegalensis (Senegal chameleon) and species belonging to the genus Agama.</td>
<td rowspan="4">General comments (dominant faunal species/noteworthy records):<br><br>Reptile species within the SR Area 1 are adept to surviving within all of the habitat units. The varying habitats within the SR Area 1 lend themselves to the various foraging techniques of both snakes and lizards, with sheltered forest areas for ambush, and open grassed areas for the active hunting. Reptile density is largely dependent on prey availability, however due to the persecution of snakes especially by local inhabitants, reptile density is expected to be highest in the forested areas, and grass verges along the forests, with reptile density decreasing around local villages and active mining areas.</td>
<td rowspan="4">Conclusion and Way Forward:<br><br>The secretive nature of reptiles makes adequate diversity estimations difficult, and in such instances, inferences have to be made through habitat analysis. In terms of reptiles, the SR Area 1is considered to be of a moderately high sensitivity. The degraded forests, ridge areas and watercourses are important habitat for reptile species, as these provide both food and water resources, as well as ample shelter and breeding areas.<br><br>It is recommended that a biodiversity action plan be implemented to encourage the re-establishment of the cleared and degraded forest areas. Where possible, areas of high sensitivity (Ridges, watercourses not affected by mining activities and areas of degraded forest that are in the advanced stages of ecological succession) should be excluded from mining activities.</td>
</tr>
<tr>
<td>Food Availability</td>
<td>The small-mammal, amphibian and insect abundance of the SR Area 1 indicates that there are suitable food resources for many of the snakes and lizards. The cultivation of crops is likely to further sustain a higher number of rodents, which will invariably result in more predatory snakes in the SR Area 1. However, the mining activities and resultant flooding of areas may negate this to a degree.</td>
</tr>
<tr>
<td>Habitat Integrity</td>
<td>The habitat integrity is considered to be moderately high for reptiles. Although anthropogenic activities are evident throughout, notably slash and burn and mining activities, this has not restricted the movement of reptile species within the SR Area 1.</td>
</tr>
<tr>
<td>Habitat Availability</td>
<td>The hardy nature and adaptability of many reptile species means they can survive in a wide variety of conditions, and flourish in suitable areas. The SR Area 1 provides suitable habitat for both reptiles and their prey items, with suitable areas of refuge and foraging still found throughout the SR Area 1.</td>
</tr>
</table>

**Table 8: Additional dry season notes**

**Notes on Photograph, species left to right:** *Agama africana* (Western African rainbow lizard, male left, female centre), *Lepidothyris fernandi* (Fire skink).

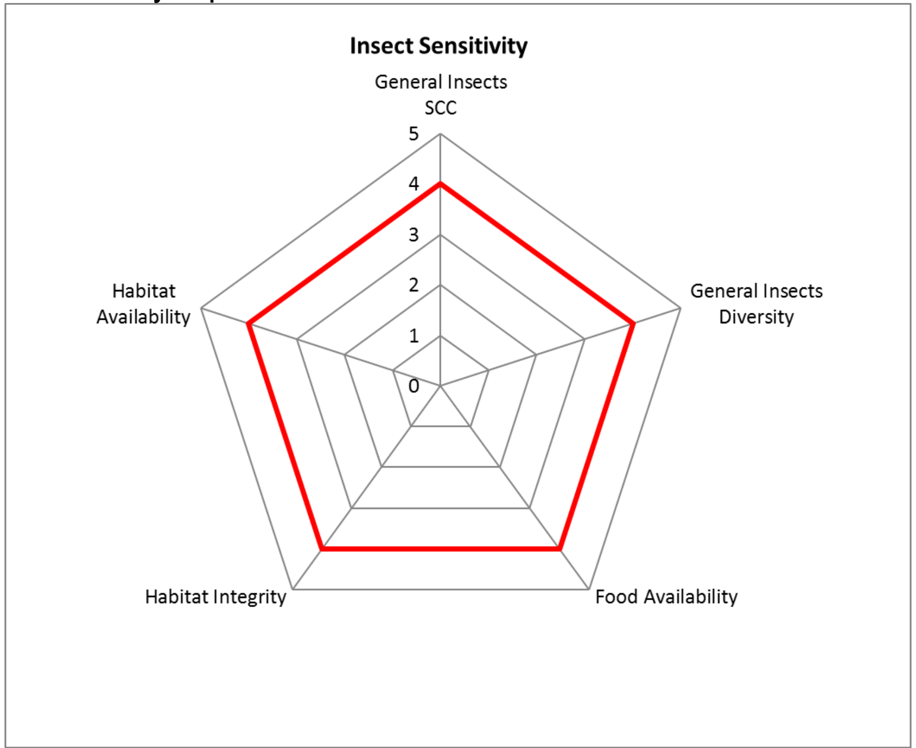
**Additional dry season notes:**

During the dry season assessment, significantly fewer reptiles were observed in comparison to the wet season assessment. Locals further indicated that very few to no snakes had been observed since the onset of the dry season. The decreased abundance and rate of sightings is likely due to reptiles spending a greater amount of time in and around the forested and densely vegetated areas alongside the streams and dams. These areas not only provide sites of refuge, but also represent areas of increased food and water resources, as small mammals and insects are more likely to congregate within these habitats during the dry season and represent the main food sources for the majority of reptile species. Due to the slow metabolic rate of reptiles and restricted/ decreased food resources available, reptiles are likely to adopt a more sedentary lifestyle during the dry season, and as such will not be observed as readily.

The dense vegetation associated with the banks of the streams and dams is considered of high importance for reptile species during the dry season. During the wet season high water levels and increased vegetation growth limits human movement, whilst allows for a higher abundance of food and water resources throughout the SR Area 1. During the dry season, area accessibility increases dramatically and so reptiles along with their food resources retreat to the denser more inaccessible habitat areas along the streams, rivers and dams. As such, it is important that these habitats are retained, and are not subjected to further degradation. Furthermore, rehabilitation/ revegetation of impacted riparian and forest habitat areas is key to increase the available habitat to reptiles in order to ensure the future sustainability of reptile abundance and diversity.

## 3.7 Insects

**Table 9: Insect assessment for SR Area 1**

<table>
<tr><td>Faunal Class:<br>Insects</td><td>Faunal Habitat Sensitivity</td><td>Moderately high</td><td rowspan="4">Photograph:<br></td></tr>
<tr><td></td><td colspan="2">Notes on Photograph: Top left to bottom right: Imbrasia epimethea; Tithoes sp (Giant longhorn beetle); Anachalcos convexus (Plum dung beetle); Junonia Sophia (Little pansy); Papilio Dardanus (Swallowtail).</td></tr>
<tr><td colspan="3">Faunal Sensitivity Graph:<br><br></td></tr>
<tr><td>Faunal SCC/Endemics</td><td colspan="2">No SCC were observed within the SR Area 1; however, the IUCN has listed two species for the region, namely Elattoneura dorsalis (Yellow-fronted threadtail) and Agriocnemis angustirami (Liberian wisp). Both these species are associated with fresh water habitats, the continued loss of which is a major threat to the ongoing survival of these species</td></tr>
</table>

<table>
<tr><td>Faunal Diversity</td><td>Insect diversity within the SR Area 1 is considered to be moderately high. A diversity of species was observed, notably those of the orders Orthoptera (Grasshoppers and Locusts), Hymenoptera (Wasps, bees and ants) and Lepidoptera (Moths and butterflies). This diversity is further enhanced by the variety of habitat units found within the SR Area 1.</td><td rowspan="4">General comments (dominant faunal species/noteworthy records):<br><br>The SR Area 1 was observed to provide habitat to a high diversity of insect species, however the species observed are considered to be largely common and widespread both within the SR Area 1 and the greater region. The mosaic layout of the habitat units within the SR Area 1, combined with the ecotonal zones between the habitat units provide suitable habitat for the support of a large number of insect species of varying diversity. Furthermore, this abundance and diversity of insect species is an integral part of the ecology of the area, with many of the insect forming the primary food supply for many other species within the SR Area 1.</td><td rowspan="4">Conclusion and Way Forward:<br><br>The insect habitat sensitivity is considered to be moderately high. The varying floral characteristics of the SR Area 1 provide a broad range of suitable habitat for a variety of insect species.<br><br>It is recommended that a biodiversity action plan be implemented to encourage the re-establishment of the cleared and degraded forest areas. Where possible, areas of high sensitivity (Ridges, watercourses not affected by mining activities and areas of degraded forest that are in the advanced stages of ecological succession) should be excluded from mining activities.</td></tr>
<tr><td>Food Availability</td><td>Food availability is considered to be moderately high, with the cleared forest areas, broadleaf forests and freshwater systems providing sources of food to a variety of insect species. Orthoptera species within the SR Area 1 will primarily utilise the herbaceous material, as well as leaves of woody plants for food. Hymenoptera species will feed on other insects and plant material found in the SR Area 1, whilst species of the order Lepidoptera will utilise plant material in the larval stage and pollen/nectar once metamorphosis has taken place.</td></tr>
<tr><td>Habitat Integrity</td><td>Although habitat transformation has occurred within the SR Area 1, the reduction of the forest/woody sections has resulted in the expansion of the herbaceous layer. This has resulted in the opening up of new areas of habitat for insect species that previously would have been limited by the lack of grassland, notably for Orthoptera and Lepidoptera which prefer the open less forested areas.</td></tr>
<tr><td>Habitat Availability</td><td>Habitat suitability is considered to be moderately high, as the mosaic vegetation within the SR Area 1 provides habitat for a diversity of species. The open grassland areas provide habitat particular for species of the order Orthoptera, whilst numerous insect species will utilise the forested areas. The watercourses provide ample habitat for dragonflies and other water associated invertebrates, whilst the riparian habitat alongside the watercourses is ideal habitat for a high diversity of insect species.</td></tr>
</table>

**Table 10: Additional dry season notes**

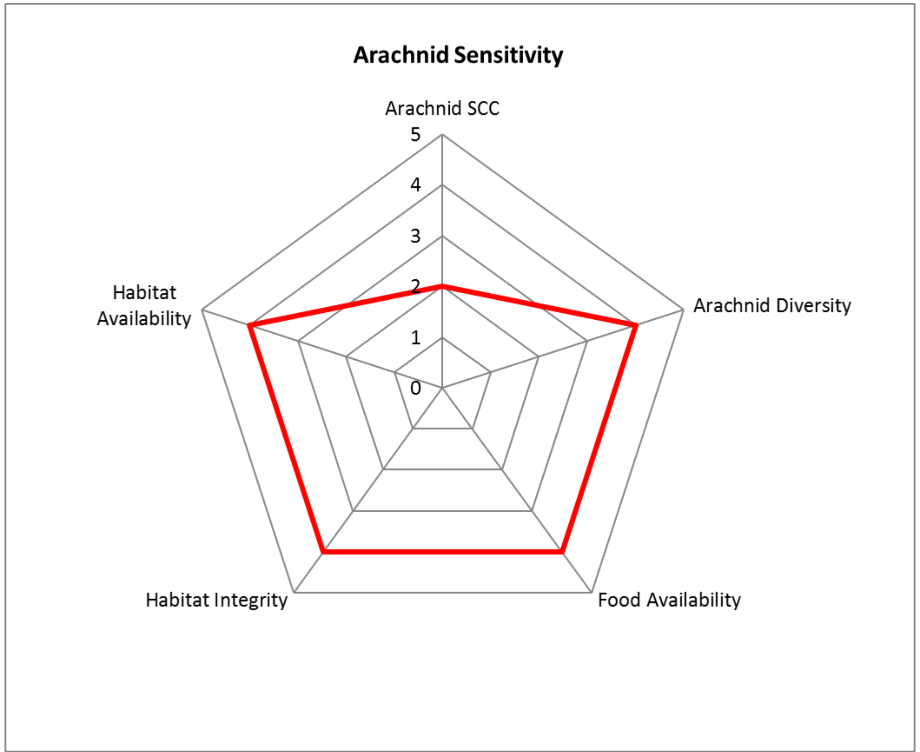
| |
|---|
| **Notes on Photograph, species left to right:** *Polyspilota aeruginosa* (Mantid), *Palpopleura lucia* (Lucia widow), *Pantala flavescens* (Wandering Glider). |
|  |
| **Additional dry season notes:**<br>In contrast to other faunal species, the insect diversity and abundance within the SR Area 1 does not appear to have been significantly reduced during the dry season. Species belonging to the orders Lepidoptera (Butterflies and moths), Odonata (Dragonflies and damselflies) and Orthoptera (Grasshoppers, locusts, crickets etc) were readily observed throughout theSR Area 1. It is likely that the majority of insect species lay their eggs so that they hatch during the dry season, in order to increase survivability rates. Hatching during the wet season would likely result in an increased mortality rate, with many of the newly hatched insect species being drowned. Furthermore, during the dry season many insectivorous species have dispersed over a larger area, and so predatory pressure is likely to be decreased, increased survivability rate and future breeding success of the insect population.<br><br>Habitat utilisation by insect species was predominant along water body edges, as well as vegetation within close proximity of water bodies. The intact and degraded deciduous forest areas were also noted to have a high abundance and diversity of insect species. The open grassland areas resulting from forest clearing activities were noted to have a lower abundance of insect species in comparison to the forested habitats, predominantly being utilised by species of the Orthoptera (Grasshoppers, locusts, crickets etc) order. Rehabilitation/ revegetation of impacted riparian and forest habitat areas is key to increase the available habitat for insects in order to ensure the future sustainability of insect numbers, which is of increased importance as insect species provide a base food resource for many other faunal species. |

## 3.8 Arachnids

**Table 11: Arachnid assessment for the SR Area 1**

| **Faunal Class: Arachnids** | **Faunal Habitat Sensitivity** | **Intermediate** |
|---|---|---|
| | **Notes on Photograph:** Top left: *Neoscona* sp. found in the degraded forest habitat; top right: *Holcolaetis* sp. Bottom left and right differing *Baryphas* species. | |

**Faunal Sensitivity Graph:**




| **Faunal SCC/Endemics** | Very little data and literature could be sourced regarding arachnid SCC within the SR Area 1. However, forest regions with dense plant littered floors are likely to provide habitat for species such as those belonging to the family Theraphosidae (Baboon spiders), amongst other large ground dwelling arachnid species. |
|---|---|

**Photograph:**

<table>
<tr>
<td>Faunal Diversity</td>
<td>Although a number of arachnid species were observed within the SR Area 1, it is likely that the overall arachnid diversity will be higher, as the SR Area 1 comprises of suitable habitat and food resources. The most commonly observed arachnid species within the SR Area 1 were those of the ground dwelling jumping and huntsman spiders, which actively seek (hunt) their prey. These arachnids are highly suited to the varying habitats within the SR Area 1, notably in the disturbed forest and ridge habitat areas. Although no scorpions were observed during the field assessment, it is likely that species such as Pandinus imperator (Emperor scorpion) will occur within here, notably in the forest areas and nearby termite mounds, as termites are their primary food source.</td>
<td rowspan="4">General comments (dominant faunal species/noteworthy records):<br><br>Arachnid species observed are considered to be commonly occurring species. It is likely that both baboon and trap-door spiders will inhabit the SR Area 1, notably in the ridge forest areas where they will hunt amongst the leaf litter. No scorpion species were observed within the SR Area 1, however there is suitable habitat and prey available to support them. Species such as Pandinus imperator (Emperor scorpion), are known to occur in the region, with a feeding primarily on termites, which were readily observed within the SR Area 1.</td>
<td rowspan="4">Conclusion and Way Forward:<br><br>Continued clearing of vegetation through slash and burn activities, as well as for new mining areas will result in the continued loss of niche arachnid habitat associated with the deciduous forests. In order to minimise this loss, it is recommended that the old mining areas as far as possible be rehabilitated, ensuring suitable revegetation of the stripped areas.<br><br>It is recommended that a biodiversity action plan be implemented to encourage the re-establishment of the cleared and degraded forest areas. Where possible, areas of high sensitivity (Ridges, watercourses not affected by mining activities and areas of degraded forest that are in the advanced stages of ecological succession) should be excluded from mining activities.</td>
</tr>
<tr>
<td>Food Availability</td>
<td>Insect species and small reptiles are considered to be the primary food source for many of the arachnids within the SR Area 1. Arachnids that are predominantly ground dwelling will either actively hunt their prey or utilise ambush/trap techniques in order to acquire prey items. Web building species will rely primarily on the numerous airborne insects for food.</td>
</tr>
<tr>
<td>Habitat Integrity</td>
<td>Slash and burn activities by the locals combined with the ongoing mining activities has resulted in a loss of habitat integrity to a degree. However, in terms of arachnids, these disturbances have resulted in the opportunity to flourish, notably in the previously disturbed areas where natural forest recruitment is taking place, and where insect abundance (food resource) is high.</td>
</tr>
<tr>
<td>Habitat Availability</td>
<td>Habitat availability is considered to be moderately high. Although mining activities combined with the expansion of the local communities has resulted in the clearing of forested areas, this has had a limited impact on arachnid species, as they are highly adaptable and are capable of surviving in modified habitats.</td>
</tr>
</table>

**Table 12: Additional dry season notes**

**Notes on Photograph, species left to right:** *Gasteracantha sanguinolenta* (Short-winged kite spider), Genus *Nephila* (Golden orb-web spider), Genus *Neoscona* (Hairy field spider).



**Additional dry season notes:**

Decreased rainfall events during the dry season which are more conducive to web building along with increased insect activities patterns resulted in a higher abundance of spider species being observed during the assessment. Although searches for scorpions were conducted both during daylight hours and at night with UV torches, notably within the intact forest areas, none were located. This however cannot be taken as an indicator of their non-occurrence, as scorpions are notoriously hard to detect during searches, especially in dense forest areas with heavy ground litter. The overall arachnid species abundance and diversity is still considered intermediate.

Although arachnid species do show a higher degree of tolerance to habitat changes, habitat degradation will over time result in a decreased diversity level, as well as abundance of less tolerant species, notably those that are more habitat specific. Furthermore, habitat changes and degradation affect the food resources (insects, small reptiles etc) of arachnids which will further impact on arachnid abundance levels. In order to ensure suitable habitat is available for arachnid species, rehabilitation/ revegetation of cleared and decommissioned areas is key, which will also ensure a continued and suitable food resource supply, thus ensuring the future sustainability of arachnid abundance and diversity within the SR Area 1.

## 3.9 Faunal Species of Conservational Concern Assessment

During field assessments, it is not always feasible to identify or observe all species within SR Area 1, largely due to the secretive nature of many faunal species, possible low population numbers, varying habits of species and dense vegetation cover. As such, and to specifically assess an area for faunal SCC, a Probability of Occurrence (POC) matrix is used, utilising a number of factors as outlined in Appendix A to determine the probability of faunal SCC occurrence within SR Area 1. Species listed below whose known distribution ranges and habitat preferences according to the IUCN include SR Area 1, were taken into consideration. The species listed below are considered to have an increased probability of occurring within SR Area 1.

| ***Scientific Name*** | **Common Name** | **Threat Status** | **POC %** |
|---|---|---|---|
| | **Mammals** | | |
| *Eidolon helvum* | African Straw-coloured Fruit-bat | NT | 70% |
| *Aonyx capensis* | African Clawless Otter | NT | 70% |
| *Hydrictis maculicollis* | Spotted-necked Otter | NT | 70% |
| *Pan troglodytes* | Chimpanzee | EN | 60% |
| *Miniopterus schreibersii* | Schreibers' Long-fingered Bat | NT | 70% |
| *Cercocebus atys* | Sooty Mangabey | VU | 60% |
| *Hipposideros jonesi* | Jones's Roundleaf Bat | NT | 70% |
| *Pipistrellus brunneus* | Dark-brown Serotine | NT | 60% |
| *Caracal aurata* | African Golden Cat | VU | 60% |
| *Smutsia gigantea* | Giant Ground Pangolin | VU | 60% |
| *Cephalophus jentinki* | Jentink's Duiker | EN | 60% |
| *Genetta bourloni* | Bourlon's Genet | VU | 60% |
| *Genetta johnstoni* | Johnston's Genet | VU | 60% |
| *Rhinolophus ziama* | Ziama Horseshoe Bat | EN | 70% |
| *Phataginus tricuspis* | Tree Pangolin | VU | 60% |
| *Colobus polykomos* | King Colobus | VU | 60% |
| *Piliocolobus badius* | Western Red Colobus | EN | 60% |
| *Hipposideros marisae* | Aellen's Roundleaf Bat | VU | 70% |
| *Panthera pardus* | Leopard | NT | 60% |
| *Hipposideros vittatus* | Striped Leaf-nosed Bat | NT | 70% |
| *Rhinolophus guineensis* | Guinean Horseshoe Bat | VU | 70% |
| *Casinycteris ophiodon* | Pohle's Fruit Bat | NT | 60% |
| | Avifauna | | |
| *Ceratogymna elata* | Yellow-casqued Hornbill | NT | 70% |
| *Bycanistes cylindricus* | Brown-cheeked Hornbill | NT | 70% |
| *Scotopelia ussheri* | Rufous Fishing-Owl | NT | 70% |
| *Limosa lapponica* | Bar-tailed Godwit | NT | 70% |
| *Calidris canutus* | Red Knot | NT | 70% |

| *Scientific Name* | Common Name | Threat Status | POC % |
|---|---|---|---|
| *Numenius arquata* | Eurasian Curlew | NT | 70% |
| *Limosa* | Black-tailed Godwit | NT | 70% |
| *Ciconia episcopus* | Woolly-necked Stork | VU | 70% |
| *Calidris ferruginea* | Curlew Sandpiper | NT | 70% |
| *Psittacus timneh* | Timnehs Grey Parrot | NT | 100% |
| *Rynchops flavirostris* | African Skimmer | NT | 100% |
| *Gallinago media* | Great Snipe | NT | 70% |
| *Phoeniconaias minor* | Lesser Flamingo | NT | 70% |
| *Neotis denhami* | Denham's Bustard | NT | 70% |
| *Hylopsar cupreocauda* | Copper-tailed Starling | NT | 70% |
| | Amphibians | | |
| *Kassina cochranae* | Red-legged kassina | NT | 60% |
| *Hyperolius chlorosteus* | NA | NT | 60% |
| *Phrynobatrachus phyllophilus* | NA | NT | 60% |
| *Arthroleptis crusculum* | Guinea Screeching Frog | NT | 60% |
| *Ptychadena superciliaris* | NA | NT | 60% |
| *Hyperolius zonatus* | NA | NT | 60% |
| *Leptopelis macrotis* | Amani Forest Tree Frog | NT | 60% |
| *Phrynobatrachus guineensis* | NA | NT | 60% |
| *Phrynobatrachus liberiensis* | NA | NT | 60% |
| *Phrynobatrachus alleni* | NA | NT | 60% |
| *Phrynobatrachus liberiensis* | Liberia River Frog | NT | 100% |
| *Conraua alleni* | NA | VU | 60% |
| *Odontobatrachus natator* | Sierra Leone Water Frog | NT | 60% |
| *Sclerophrys togoensis* | NA | NT | 60% |
| | Reptiles | | |
| *Osteolaemus tetraspis* | Dwarf Crocodile | VU | 60% |
| *Crocodylus cataphractu* | African Slender-snouted Crocodile | CR | 60% |
| | Insects | | |
| *Elattoneura dorsalis* | Yellow-fronted Threadtail | VU | 60% |
| *Agriocnemis angustirami* | Liberian Wisp | VU | 60% |

The above listed species all have a relatively high probability of occurring within SR Area 1. The above listed species are most likely to occur within and around the forest areas, notably the ridges and within the watercourses and riparian zones, as these habitats provide suitable movement and refuge areas, as well as areas for foraging and nesting (birds). However, if the current land uses of both the local communities and SRL continue unchecked and unmitigated, there is an increased likelihood that the above listed species will no longer be able to utilise SR Area 1 due to the lack of available habitat, and increased persecution by the local communities.

## *3.10 Faunal Sensitivity*

Figure 2 below illustrates the areas considered to be of increased ecological sensitivity. The areas are depicted according to their sensitivity in terms of the presence or potential faunal SCC, habitat integrity and availability, levels of disturbance and overall the levels of faunal diversity. Table 7 below presents the sensitivity of each identified habitat unit along with an associated conservation objective and implications for development.

**Table 13: A summary of sensitivity of each habitat unit and implications for development.**

| Habitat Unit | Sensitivity | Conservation Objective | Development Implications |
|---|---|---|---|
| Transformed Areas | Low | Optimise development potential while improving biodiversity integrity of surrounding natural habitat and managing edge effects. | Development activities in this area are unlikely to have a significant impact on the receiving environment, however edge effects still need to be managed so as to ensure the surrounding environment is not negatively affected. |
| Degraded Forest and Watercourses affected by historic mining | Moderately High | Preserve and enhance the biodiversity of the habitat unit, limit development and disturbance. | Disturbance of this habitat unit is discouraged, as freshwater systems are inherently sensitive to disturbance and edge effects. The freshwater systems and degraded forest provide habitat, movement corridors as well as food and water resources to an abundance of faunal species in the larger area. All edge effects are to be strictly managed, so as to limit further impacts on the surrounding environment, as well as the downstream fresh water systems. |
| Ridges and Watercourses not affected by mining | High | Preserve and enhance the biodiversity of the habitat unit. | The ridge areas, with the intact forest habitat are extensively utilised by faunal species, as these islands of intact habitat provide refuge and shelter. The large trees provide ample roosting and nesting for large raptors, whilst also being utilised by a number of primates in the area. These ridges are to be preserved and managed in order to ensure that further displacement of faunal species does not occur, whilst also providing an additional source for reseeding (through bird and other faunal species droppings) of the degraded areas. Furthermore, the watercourse stipulated here with their associated riparian habitat provide ideal habitat for faunal species, notably for many SCC that are likely to occur in SR Area 1. These species likely already occur in low abundance, and the cumulative loss of habitat and resources will place significant pressure on these already dwindling species populations. |

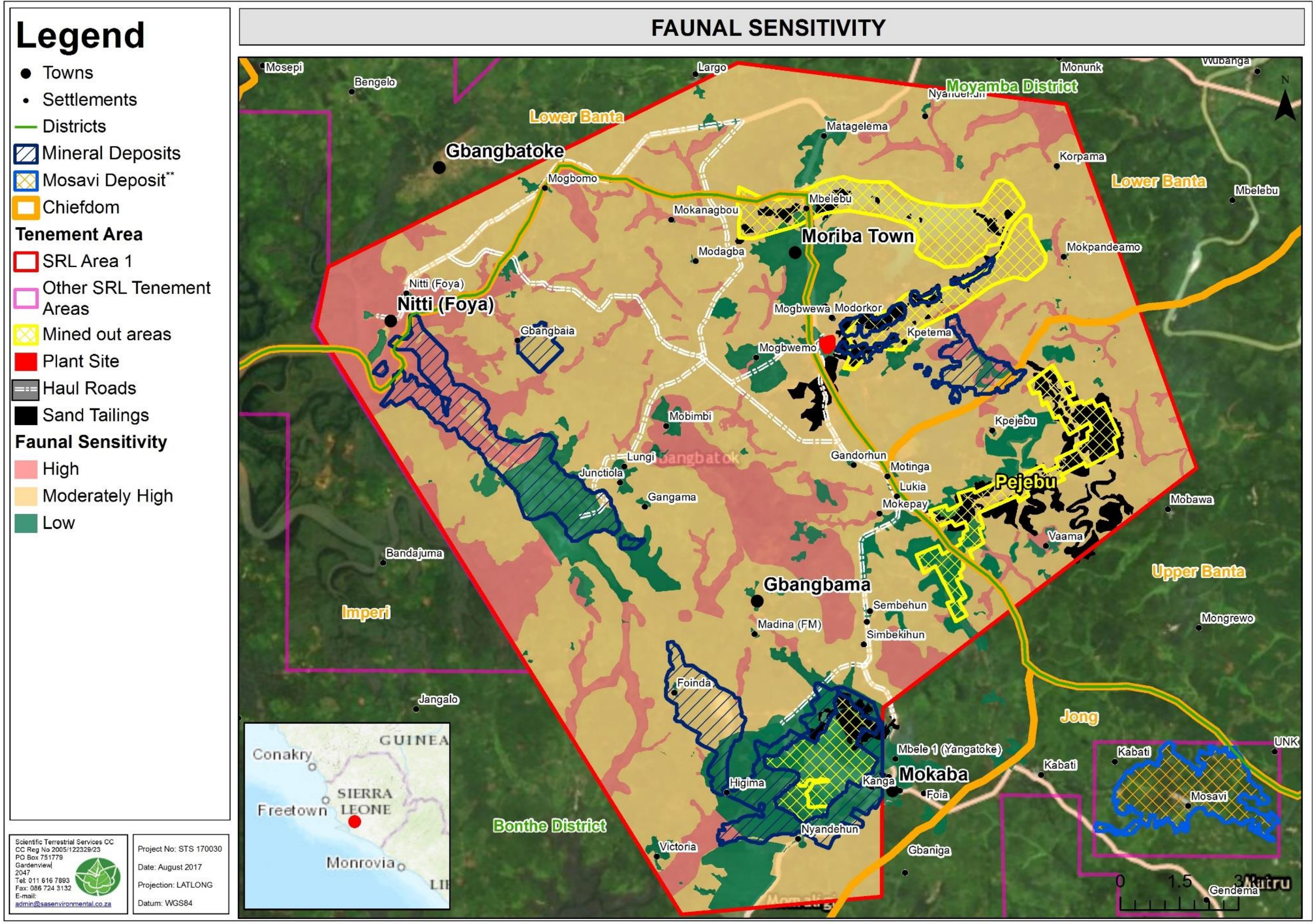



**Figure 2: Map illustrating the faunal habitat sensitivity in relation to SR Area 1**

# 4 IMPACT ASSESSMENT

## *4.1 Impact Assessment*

In order for the Environmental Assessment Practitioner (EAP) to allow for sufficient consideration of all environmental impacts, impacts are assessed using a common, defensible method of assessing significance that will enable comparisons to be made between risks/impacts and will enable authorities, stakeholders and the client to understand the process and rationale upon which risks/impacts have been assessed. The section below briefly highlights some potential impacts that may occur during mining activities. Please refer to Appendix E (Integrated Impact Assessment) for a detailed assessment and discussion of the potential impacts.

## *4.2 Description of Potential Impacts Associated with the Proposed Current and Expanded Mining Operations*

Based on an initial consideration of the current mining project and associated processes, as well as the location of the proposed new mining activities, the following preliminary list of potential impacts have been identified:

- Infrastructure development and encroachment of mining into sensitive habitat areas, may have a significant impact on faunal species found within these habitats;
- Increased ease of access due to new haul roads, influx of human populace seeking jobs as well as general population expansion through child births will result in an increase demand for bush meat, resulting in an increased rate of unsustainable harvesting of faunal species, leading to population decreases and possibly species losses within the surrounding areas;
- Ineffective rehabilitation activities may result in modified faunal habitats that are unable to support the existing faunal species at current population levels;
- Ineffective removal of alien invader species, rehabilitation and monitoring of disturbed areas could lead to re-establishment of invasive species, impacting on the faunal habitat;
- Higher risk of fires as a result of the increased number of personnel on site may lead to the destruction and modification of faunal habitat, as well as contribute to the loss of faunal species within the surrounding areas;
- Placement of infrastructure and mining activities within sensitive habitat will result in the overall loss of faunal habitat as well as a decrease in faunal abundance and diversity; and

- Loss of faunal habitat may impact of faunal SCC within the region.

Significant opportunities for improving the ecological integrity of faunal communities within SR Area 1 exist. These can be achieved through developing a comprehensive biodiversity action plan which includes, *inter alia*, objectives to improve agricultural efficiency by local communities, educating local communities about faunal conservation, improving current rehabilitation strategies and actively managing alien and invasive floral communities within SR Area 1. This will contribute towards offsetting historic, current and future impacts associated with the mine and improving the ecological condition whilst reinstating some of the ecological services provided by faunal ecological resources within SR Area 1.

# 5 CONCLUSION

SR Area 1 comprised of four main faunal habitat units, namely Ridge Forest habitat, Degraded Forest habitat, Watercourses and Transformed areas. Ongoing impacts as a result of human occupation in the area were evident, largely in the form of slash and burn clearing activities in order to make way for agricultural crops. As such, the loss and modification of the faunal habitat as well as increased hunting pressures have had evident impacts on the abundance and diversity of faunal species within SR Area 1. Mining activities within SR Area 1 have been underway for the past 50 years, and as such has had a notable impact on the habitat and ecological drivers within SR Area 1. Loss of forest habitat and the degradation of the watercourses and associated riparian habitat was evident, and has had a notable impact on the faunal abundance and diversity of SR Area 1.

This report aimed to map, consider and describe the faunal ecological resources associated with SR Area 1. In addition, the integrity, ecological importance and sensitivity, including the provision of goods and services, was considered and presented. In doing so, this report aimed to guide the proponent, Environmental Assessment Practitioner (EAP) and regulating authorities, by means of the presentation of information on the baseline conditions, as to the management of current and future mining operations from an ecological risk management point of view as well as provide mitigation and management measures to manage potential and existing impacts.

Following the wet and dry season assessments, the ecological risks were determined, and analyses of the impacts associated with the project presented in Section E (Impact assessment). Key mitigatory measures were identified in order to minimise the potential impacts on both the local and regional faunal ecology.

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# APPENDIX A: Faunal Method of Assessment

## Faunal Assessment Methodology

It is important to note that due to the nature and habits of fauna, varied stages of life cycles, seasonal and temporal fluctuations along with other external factors, it is unlikely that all faunal species will have been recorded during the site assessment. The presence of human habitation nearby the Study area and the associated anthropogenic activities will have an impact on faunal behaviour and in turn the rate of observations. In order to increase overall observation time within the Study area, as well as increasing the likelihood of observing shy and hesitant species, camera traps were strategically placed within the Study area. Sherman traps were also used to increase the likelihood of capturing and observing small mammal species, notably small nocturnal mammals.

### Mammals

Small mammals are unlikely to be directly observed in the field because of their nocturnal/crepuscular and cryptic nature. A simple and effective solution to this problem is to use Sherman traps. A Sherman trap is a small aluminium box with a spring-loaded door (Figure A1). Once the animal is inside the trap, it steps on a small plate that causes the door to snap shut, thereby capturing the individual. In the event of capturing a small mammal during the night, the animal would be photographed and then set free unharmed early the following morning. Traps were baited with a universal mixture of oats, peanut butter, and fish paste.

**Figure A1: Sherman trap (left) and bait used to capture and identify small mammal species and drift fence and pitfall trap (right) used to capture ground invertebrates and small reptiles.**

Motion sensitive infrared camera traps were used to capture medium to large mammal species (Figure A2). These cameras were placed along trails and near suitable habitat areas and left for the full duration of the field site visit.

**Figure A2: Field cameras used to document medium to large mammal species.**

Medium to large mammal species were recorded during the field assessment with the use of visual identification, spoor, call and dung. Specific attention was paid to mammal SCC as listed by the International Union for the Conservation of Nature (IUCN).

### *Avifauna*

Avifaunal species listed for the Cabinda province on AviBase were compared with the recent field survey of avifaunal species identified on the Study area. Field surveys were undertaken utilising a pair of Bushnell 10x50 binoculars and bird call identification techniques were utilised during the assessment in order to accurately identify avifaunal species. Specific attention was given to avifaunal SCC listed on a regional and national level, as well as those identified by the IUCN.

### *Reptiles*

Reptiles were identified during the field survey. Suitable applicable habitat areas (wetland areas and fallen dead trees) were inspected and all reptiles observed were recorded. The data gathered during the assessment along with the habitat analysis provided an accurate indication of which reptile species are likely to occur on the Study area. Specific attention was given to reptile SCC listed by the IUCN.

### *Amphibians*

Identifying amphibian species is done by the use of direct visual identification along with call identification technique. Amphibian species flourish in and around wetland, riparian and moist grassland areas. It is unlikely that all amphibian species will have been recorded during the site assessment, due to their cryptic nature and habits, varied stages of life cycles and seasonal and temporal fluctuations within the environment. The data gathered during the assessment along with the habitat analysis provided an accurate indication of which amphibian species are likely to occur within the Study area as well as the surrounding area.

### *Invertebrates*

Whilst conducting transects through the Study area, all insect species visually observed were identified, and where possible photographs taken. Furthermore, at suitable and open sites within the Study area sweep netting was conducted, and all the insects captured identified.

It must be noted that due to the cryptic nature and habits of insects, varied stages of life cycles and seasonal and temporal fluctuations within the environment, it is unlikely that all insect species will have been recorded during the site assessment period. Nevertheless, the data gathered during the assessment along with the habitat analysis provided an accurate indication of which species are likely to occur in the Study area at the time of survey.

### *Arachnids*

All suitable habitat areas where spiders and scorpions are likely to reside were searched. Specific attention was paid to searching for Mygalomorphae arachnids (Trapdoor and Baboon spiders) as these arachnids are generally considered to have low population numbers and are hard to locate.

## *Faunal Species of Conservational Concern Assessment*

The Probability of Occurrence (POC) for each faunal SCC was determined using the following four parameters:

- Species distribution;
- Habitat availability;
- Food availability; and
- Habitat disturbance.

The accuracy of the calculation is based on the available knowledge about the species in question. Therefore, it is important that the literature available is also considered during the calculation.
Each factor contributes an equal value to the calculation.

| Scoring Guideline | | | | |
|---|---|---|---|---|
| **Habitat availability** | | | | |
| **No Habitat** | **Very low** | **Low** | **Moderate** | **High** |
| 1 | 2 | 3 | 4 | 5 |
| **Food availability** | | | | |
| **No food available** | **Very low** | **Low** | **Moderate** | **High** |
| 1 | 2 | 3 | 4 | 5 |
| **Habitat disturbance** | | | | |
| **Very High** | **High** | **Moderate** | **Low** | **Very Low** |
| 1 | 2 | 3 | 4 | 5 |
| **Distribution/Range** | | | | |
| **Not Recorded** | | **Historically Recorded** | | **Recently Recorded** |
| 1 | | 3 | | 5 |

[Habitat availability + Food availability + Habitat disturbance + Distribution/Range] / 20 x 100 = POC%

## *Faunal Habitat Sensitivity*

The sensitivity of the Study area for each faunal class (i.e. mammals, birds, reptiles, amphibians and invertebrates) was determined by calculating the mean of five different parameters which influence each faunal class and provide an indication of the overall faunal ecological integrity, importance and sensitivity of the Study area for each class. Each of the following parameters are subjectively rated on a scale of 1 to 5 (1 = lowest and 5 = highest):

- **Faunal SCC:** The confirmed presence or potential for faunal SCC or any other significant species, such as endemics, to occur within the habitat unit;
- **Habitat Availability:** The presence of suitable habitat for each class;
- **Food Availability:** The availability of food within the Study area for each faunal class;

- **Faunal Diversity:** The recorded faunal diversity compared to a suitable reference condition such as surrounding natural areas or available faunal databases; and
- **Habitat Integrity:** The degree to which the habitat is transformed based on observed disturbances which may affect habitat integrity.

Each of these values contribute equally to the mean score, which determines the suitability and sensitivity of the Study area for each faunal class. A conservation and land-use objective is also assigned to each sensitivity class which aims to guide the responsible and sustainable utilization of the Study area in relation to each faunal class. The different classes and land-use objectives are presented in the table below:

**Table A1: Faunal habitat sensitivity rankings and associated land-use objectives.**

| Score | Rating significance | Conservation objective |
|---|---|---|
| 1> and <2 | Low | Optimise development potential. |
| 2> and <3 | Moderately low | Optimise development potential while improving biodiversity integrity of surrounding natural habitat and managing edge effects. |
| 3> and <4 | Intermediate | Preserve and enhance biodiversity of the habitat unit and surrounds while optimising development potential. |
| 4> and <5 | Moderately high | Preserve and enhance the biodiversity of the habitat unit limit development and disturbance. |
| 5 | High | Preserve and enhance the biodiversity of the habitat unit, no-go alternative must be considered. |

# APPENDIX B: Faunal Species List

## Mammal species observed

| Scientific name | Common Name | IUCN Status |
|---|---|---|
| *Cercopithecus campbelli* | Lesser Spot-nosed Monkey | LC |
| *Cercopithecus petaurista* | Campbell's Monkey | LC |
| *Rattus* | Black Rat | LC |
| *Philantomba maxwellii* | Maxwell's Duiker | LC |
| *Thryonomys swinderianus* | Greater Can Rat | LC |
| *Xerus erythropus* | Striped Ground Squirrel | LC |
| *Atherurus africanus* | African Brush-tailed Porcupine | LC |

LC = Least Concern

## Avifaunal species observed

| Scientific name | Common Name | IUCN Red List Status |
|---|---|---|
| *Centropus senegalensis* | Senegal Coucal | LC |
| *Ispidina picta* | African Pygmy-kingfisher | LC |
| *Megaceryle maxima* | Giant Kingfisher | LC |
| *Polyboroides typus* | African Harrier-hawk | LC |
| *Microcarbo africanus* | Long -tailed Cormorant | LC |
| *Corythaeola cristata* | Great Blue Turaco | LC |
| *Gypohierax angolensis* | Palm-nut Vulture | LC |
| *Necrosyrtes monachus* | Hooded Vulture | LC |
| *Scopus umbrette* | Hamerkop | LC |
| *Numida meleagris* | Helmeted Guineafowl | LC |
| *Vanellus spinosus* | Spur-winged Lapwing | LC |
| *Egretta garzetta* | Little Egret | LC |
| *Ardea alba* | Great Egret | LC |
| *Streptopelia semitorquata* | Red-eyed Dove | LC |
| *Streptopelia senegalensis* | Laughing Dove | LC |
| *Milvus migrans* | Black Kite | LC |
| *Merops pusillus* | Little Bee-eater | LC |
| *Ceryle rudis* | Pied Kingfisher | LC |
| *Kaupifalco monogrammicus* | Lizard Buzzard | LC |
| *Psittacus timneh* | Timneh Grey Parrot | EN |
| *Ardea purpurea* | Purple Heron | LC |
| *Ciconia episcopus* | Woolly-necked Stork | VU |
| *Vidua macroura* | Pin-tailed Whydah | LC |
| *Pternistis bicalcaratus* | Double-spurred Francolin | LC |
| *Pandion haliaetus* | Osprey | LC |

LC = Least concerned, NYBA = Not yet been assessed by the IUCN.

## Amphibian species

| Scientific name | Common Name | IUCN Status |
| --- | --- | --- |
| *Sclerophrys maculate* | Flat-backed Toad | LC |
| *Amietophrynus gutturalis* | Guttural Toad | LC |
| *Ptychadena mascareniensis* | Mascarene Grass Frog | LC |
| *Hyperolius guttulatus* | Dotted Reed Frog | LC |

LC = Least concerned

## Reptile species observed

| Scientific name | Common Name | IUCN Status |
| --- | --- | --- |
| *Toxicodryas blandingii* | Blandings Tree Snake | LC |
| *Dendroaspis viridis* | Western Green Mamba | LC |
| *Chamaeleo dilepis* | Flap Necked Chameleon | LC |
| *Trachylepis affinis* | Senegal Mabuya | LC |
| *Agama africana* | Western African Rainbow Lizard | LC |
| *Naja nigricollis* | Black-necked Spitting Cobra | LC |
| *Chamaeleo senegalensis* | Senegal Chameleon | LC |

LC = Least Concerned, NYBA = Not yet been assessed by the IUCN.

## Insect species observed

| Scientific Name | Common Name | IUCN Status |
| --- | --- | --- |
| *Imbrasia epimethea* | NA | NYBA |
| *Tithoes* sp | Giant Longhorn Beetle | NYBA |
| *Anachalcos convexus* | Plum Dung Beetle | NYBA |
| *Junonia Sophia* | Little Pansy | NYBA |
| *Papilio Dardanus* | Swallowtail | NYBA |

NYBA = Not Yet Been Assessed

## Arachnid species observed

| Scientific name | Common Name | IUCN Red List Status |
| --- | --- | --- |
| Family Agelenidae | Funnel-web Spider | NYBA |
| *Neoscona* sp | NA | NYBA |
| *Holcolaetis* sp | NA | NYBA |
| *Baryphas* sp | Jumping Spiders | NYBA |

NYBA = Not Yet Been Assessed

# APPENDIX C: SPECIALISTS DETAILS

## Details, Expertise and Curriculum Vitae of Company and Author

# SCIENTIFIC TERRESTRIAL SERVICES (STS) – SPECIALIST CONSULTANT INFORMATION
# CURRICULUM VITAE OF EMILE BASSON VAN DER WESTHUIZEN

## PERSONAL DETAILS

| | |
|---|---|
| Position in Company | Ecologist, Botanist |
| Date of Birth | 30 May 1984 |
| Nationality | South African |
| Languages | English, Afrikaans |
| Joined STS | 2008 |

## MEMBERSHIP IN PROFESSIONAL SOCIETIES

Member of the South African Council for Natural Scientific Professions (SACNASP) (Reg. Number 100008/15).

## EDUCATION

| | |
|---|---|
| **Qualifications** | |
| BSc (Hons) Plant Science (University of Pretoria) | 2012 |
| B.Sc. Botany and Environmental Management (University of South Africa) | 2010 |
| **Short Courses** | |
| Grass Identification – Africa Land Use Training | 2009 |
| Wild Flower Identification – Africa Land Use Training | 2009 |

## COUNTRIES OF WORK EXPERIENCE

South Africa – Gauteng, Mpumalanga, North West, Limpopo, KwaZulu-Natal, Free State, Eastern Cape.
Mozambique (Tete, Sofala and Manica Provinces)
Democratic Republic of the Congo (Katanga and Kivu Provinces)
Ghana (Western and Greater Accra Provinces)
Angola (Cabinda and Zaire Provinces)
Sierra Leone

## SELECTED PROJECT EXAMPLES

**Floral Assessments**

- Floral assessment for the proposed Modikwa Platinum Mine South 2 Shaft Project, Burgersfort, Limpopo Province.
- Floral assessment for the proposed New Clydesdale Colliery Stoping Project, Vandyksdrift, Mpumalanga Province.
- Floral assessment as part of the EIA process for the proposed Harriet's Wish PGM Project, Limpopo Province.
- Floral assessment as part of the environmental authorisation process for the proposed Shanduka Coal Argent Colliery in the vicinity of Argent, Mpumalanga.
- Floral assessment for the Auroch Resources Manica Gold Mining Project, Manica, Mozambique.
- Floral assessment for the Namoya Gold Mine project in Namoya, Democratic Republic of Congo.
- High level floral risk assessment and alternatives analysis for the proposed new Tete Airport, Tete, Mozambique.
- Floral assessment for the proposed Richardsbay Harbour Compactor Slab development, Richardsbay, Kwa-Zulu-Natal Province.
- Site walkdown and floral ecological input prior to the construction of the proposed 180 km Mfolozi-Mbewu powerline, Richardsbay, Kwa-Zulu-Natal Province.
- Floral assessment as part of the EIA process for the proposed Peerboom Colliery, Lephalale, Limpopo Province.
- Floral assessment as part of the EIA process for the proposed Overvaal Underground Coal Mine Project, Ermelo, Mpumalanga Province.
- Floral assessment as part of the EIA process for the proposed King's City Takoradi 3000 hectare development, Takoradi, Ghana
- Floral assessment as part of the EIA process for the proposed Aquarius Platinum Fairway Platinum Mine, Steelpoort, Mpumalanga Province.

- Floral assessment as part of the EIA process for the proposed Geniland Lubumbashi City 4000 hectare development, Likasi, Katanga Province, Democratic Republic of Congo.
- Floral, faunal, aquatic and wetland assessment as part of the EIA process for the proposed Appollonia City Accra 3000 hectare development, Accra, Ghana.
- Floral assessment as part of the EIA process for the proposed Leeuw Colliery, Utrecht, Kwa-Zulu Natal Province.
- Floral assessment as part of the EIA process for the proposed Lubembe Coppermine Project, Lubumbashi, Katanga Province, Democratic Republic of Congo.
- Floral assessment as part of the EIA process for the proposed Kinsenda Coppermine Project, Lubumbashi, Katanga Province, Democratic Republic of Congo.
- Floral assessment as part of the EIA process for the proposed Lonshi Coppermine Project, Lubumbashi, Katanga Province, Democratic Republic of Congo.
- Floral assessment as part of the EIA process for the proposed Jozini Shopping Mall, Jozini, Kwa-Zulu Natal Province.
- Floral assessment as part of the Biodiversity Action Plan for the Assmang Chrome Dwarsrivier Mine, Steelpoort, Mpumalanga Province.

# SCIENTIFIC TERRESTRIAL SERVICES (STS) – SPECIALIST CONSULTANT INFORMATION
# CURRICULUM VITAE OF CHRISTOPHER HOOTON

## PERSONAL DETAILS

| | |
|---|---|
| Position in Company | Ecologist |
| Date of Birth | 24 June 1986 |
| Nationality | South African |
| Languages | English, Afrikaans |
| Joined SAS | 2013 |

## EDUCATION

| Qualifications | |
|---|---|
| BTech Nature Conservation (Tshwane University of Technology) | 2013 |
| National Diploma Nature Conservation (Tshwane University of Technology) | 2008 |

## COUNTRIES OF WORK EXPERIENCE

South Africa – Gauteng, Mpumalanga, North West, Limpopo, KwaZulu-Natal, Eastern Cape, Western Cape, Northern Cape, Freestate
Zimbabwe

## SELECTED PROJECT EXAMPLES

**Faunal Assessments**

- Faunal assessment as part of the environmental assessment and authorisation process for the proposed Mzimvubu Water Project, Eastern Cape.
- Faunal assessment as part of the environmental assessment and authorisation process for the proposed Setlagole Mall Development, North West.
- Faunal assessment as part of the environmental assessment and authorisation process for the proposed Expansion and Upgrade of the Springlake Railway Siding, Hattingspruit, Kwa-Zulu Natal.
- Faunal assessment as part of the environmental assessment and authorisation process for the proposed Styldrift tailings storage facility, return water dams, topsoil stockpile and other associated infrastructure, North West.
- Faunal assessment as part of the environmental assessment and authorisation process for the development of a proposed abalone farm, Brand se Baai, Western Cape.
- Faunal assessment as part of the environmental assessment and authorisation process for the development of a proposed abalone farm, Doringbaai, Western Cape.
- Vegetation composition and subsequent loss of carrying capacity for the Rand Water B19 and VG Residue Pipeline Project, Freestate.
- Faunal assessment as part of the environmental assessment and authorisation process for the Evander Shaft 6 Plant Upgrade, New Tailings Dam Area and Associated Tailings Delivery and Return Water Pipeline, Evander, Mpumalanga.

**Previous Work Experience**

- Spotted Hyaena Research Project, Phinda Private Game Reserve, KwaZulu Natal.
- Camera Trap Survey as part of the Munyawana Leopard Project, Mkuze Game Reserve, KwaZulu Natal.
- Lowveld Wild Dog Project, Savé Valley Conservancy, Zimbabwe.
- Lion collaring and Tracking as part lion management program, Savé Valley Conservancy, Zimbabwe.
- Junior Nature Conservator, Gauteng Department of Rural Development and Land Reform

# SIERRA RUTILE PROJECT AREA 1 - ENVIRONMENTAL, SOCIAL AND HEALTH IMPACT ASSESSMENT: SPECIALIST TERRESTRIAL, AQUATIC AND WETLAND ECOLOGICAL STUDIES

**Prepared for**

**SRK Consulting (South Africa) (Pty) Ltd**

**February 2018**

## Section D: Aquatic, Watercourse Ecology, Goods and Services Assessments


| | |
|---|---|
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# ACRONYMS

| | |
|---|---|
| **CR** | Critically Endangered |
| **EC** | Electric Conductivity or Ecological Category (to be defined in context of the text) |
| **EIS** | Ecological Importance and Sensitivity |
| **EN** | Endangered |
| **ESHIA** | Environmental, Social and Health Impact Assessment |
| **ESHMP** | Environmental, Social and Health Management Plan |
| **EW** | Extinct in the Wild |
| **GIS** | Geographic Information System |
| **GPS** | Global Positioning System |
| **IHI** | Index of Habitat Integrity |
| **IUCN** | International Union for Conservation of Nature and Natural Resources |
| **MIRAI** | Macro-Invertebrate Response Assessment |
| **NT** | Near Threatened |
| **PES** | Present Ecological State |
| **POI** | Points of Interest |
| **POC** | Probability of Occurrence |
| **RE** | Regionally Extinct |
| **SASS5** | South African Scoring System Version 5 |
| **SCC** | Species of Conservation Concern |
| **SRL** | Sierra Rutile Limited Mine |
| **STS** | Scientific Terrestrial Services |
| **VU** | Vulnerable |

# 1 INTRODUCTION

Scientific Terrestrial Services (STS) was appointed to conduct faunal, floral, wetland and aquatic ecological assessments as part of the process to undertake an Environmental, Social and Health Impact Assessment (ESHIA) and develop an Environmental, Social and Health Management Plan (ESHMP) for the current and proposed dry and wet mining activities for the Sierra Rutile Limited's (SRL) Mine Lease Area 1 (SR Area 1; the Study area) operations. SR Area 1 is located within the Bonthe and Moyamba Districts of the Southern Province of Sierra Leone. SR Area 1 is situated approximately 30 km inland of the Atlantic Ocean and approximately 135 km southeast of Freetown (geodesic) (Figure 1 and Figure 2 in the Section A report).

This report aims to map, consider and describe the freshwater resources of SR Area 1. In addition, the integrity, ecological importance and sensitivity, including the provision of goods and services, is considered and presented. In doing so this report must guide the proponent, Environmental Assessment Practitioner (EAP) and regulating authorities, by means of the presentation of information on the baseline conditions, as to the management of current and future mining operations from an ecological risk management point of view as well as the further studies and assessments required.

The results of this study are based on two assessments: a single wet season survey in July 2017 (high flow assessment), and a single survey in January 2018 (start of dry season, low flow assessment). This allowed adequate understanding of the systems to be obtained, resulting in determination of ecological risks and analyses of the impacts associated with the project. A detailed impact assessment was undertaken, according to a predefined impact assessment methodology provided by the lead consultant. Furthermore, key mitigatory measures were identified in order to minimise the potential impacts on both the local and regional ecology of the freshwater resources associated with the SRL operations.

# 2 FRESHWATER RESOURCE ASSESSMENT APPROACH

## *2.1 Instream Ecology*

The key objective of this study was to describe the system and define the Present Ecological State (PES), otherwise referred to as the Ecostatus of the aquatic resource, along with the definition of the Ecological Importance and Sensitivity (EIS) of the system. Once these aspects have been defined, the Recommended Ecological Category (REC) can be established.

As part of the definition of the baseline conditions, the drivers of change in the system were also defined. As noted in Section 3.5 (under "Assumptions and Limitations"), in the absence of protocols and methods of assessment developed specifically for the West African region, protocols developed in Southern Africa as well as methods developed for use in tropical areas on the African continent are utilised, and adapted where necessary, for the purposes of this study. These protocols are considered to be "best practice" tools and are widely used to assist in defining the Ecostatus of aquatic resources across Africa

### 2.1.1 Ecostatus Investigations

The PES or Ecostatus of a watercourse cannot be defined by one measurement, but must be assessed in consideration of the various components of the system. The methods used to assess the aquatic ecological integrity and define the Aquatic Ecostatus of SR Area 1 is described in Appendix A. In defining the Ecostatus of the drainage features in SR Area 1 the following were considered:

1. Instream habitat integrity;
2. Riparian zone habitat integrity;
3. Habitat suitability for aquatic macro-invertebrates;
4. Diatom community analyses and application of the Specific Pollution Index (SPI) Ecostatus tool;
5. Aquatic macro-invertebrate community integrity; and
6. Fish community considerations.

In defining the Ecostatus of the drainage features under each of the methods above, the following general method of classifying the Ecostatus (integrity) of the system was used (Table 1).

**Table 1: Ecological importance and sensitivity categories.**

| Class | Description |
|---|---|
| A | Unimpaired. High diversity of taxa with numerous sensitive taxa. |
| B | Slightly impaired. High diversity of taxa, but with fewer sensitive taxa. |
| C | Moderately impaired. Moderate diversity of taxa. |
| D | Largely impaired. Mostly tolerant taxa present. |
| E | Severely impaired. Only tolerant taxa present |
| F | Critically impaired. Very few tolerant taxa present |

### 2.1.2 Ecological Importance and Sensitivity Assessment

The EIS method considers a number of biotic and habitat determinants surmised to indicate either importance or sensitivity.

The determinants are rated according to a four-point scale specific to each element. The median of the resultant score is calculated to derive the EIS category (Table 2).

**Table 2: Ecological importance and sensitivity categories (DWAF, 1999a).**

| EISC | General Description | Range of median |
|---|---|---|
| Very high | Quaternaries/delineations that are considered to be unique on a national and international level based on unique biodiversity (habitat diversity, species diversity, unique species, rare and endangered species). These rivers (in terms of biota and habitat) are usually very sensitive to flow modifications and have no or only a small capacity for use. | >3-4 |
| High | Quaternaries/delineations that are considered to be unique on a national scale based on their biodiversity (habitat diversity, species diversity, unique species, rare and endangered species). These rivers (in terms of biota and habitat) may be sensitive to flow modifications but in some cases may have substantial capacity for use. | >2-≤3 |
| Moderate | Quaternaries/delineations that are considered to be unique on a provincial or local scale due to biodiversity (habitat diversity, species diversity, unique species, rare and endangered species). These rivers (in terms of biota and habitat) are not usually very sensitive to flow modifications and often have substantial capacity for use. | >1-≤2 |
| Low/ Marginal | Quaternaries/delineations that are not unique on any scale. These rivers (in terms of biota and habitat) are generally not very sensitive to flow modifications and usually have substantial capacity for use. | ≤1 |

### 2.1.3 Ecological Trends Determination

The trend in Ecostatus gives an idea whether the present state is realistic and would stay the same if the management of the catchment were to continue in the same way that gave rise to the present state. Thus, the definition of the trend is *"…viewed as a directional change in the attributes of the drivers and biota (as a response to drivers) at the time of the PES assessment. A trend can be absent (close to natural or in a changed state but stable), negative (moving away from reference conditions) or positive (moving back towards natural - when alien vegetation is cleared, for instance).*

*The ultimate objective is to determine if the biota have adapted to the current habitat template or are still in a state of flux"* (Kleynhans and Louw 2008).

## *2.2 WETLAND ASSESSMENT APPROACH*

### 2.2.1 Definition of Wetlands and Riparian Zones

Wetlands are defined by the Ramsar Commission as "areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres".

As per this definition, a wetland also contains "riparian and coastal zones adjacent to the wetlands, and islands or bodies of marine water deeper than six meters at low tide lying within the wetlands" (Article 2.1, Ramsar Commission). These "riparian zones of habitats" includes vegetation, known as "riparian vegetation", occurring within the area between the water body and the surrounding higher lying areas.

The Australian Government: Department of the Environment and Energy defines wetland similarly: "Wetlands are areas of land where water covers the soil – all year or just at certain times of the year. They include: swamps, marshes billabongs, lakes, lagoons saltmarshes, mudflats mangroves, coral reefs, bogs, fens, and peatlands. Wetlands may be natural or artificial and the water within a wetland may be static or flowing, fresh, brackish or saline."

The Australian River Restoration Centre defines Riparian land as "any land which adjoins, directly influences, or is influenced by a body of water". The body of water could be a creek or stream (even if it flows only occasionally), a river, a lake, or a wetland. There is no rule of nature that defines the 'width' of riparian land, and it is important that riparian land is not thought of as just a narrow strip running alongside a stream.

The Ramsar Commission does not define riparian habitat, nor does the Environmental and Social Regulations for the Minerals Sector of 2011, as they pertain to the Environmental Protection Agency Act of 2008 of Sierra Leone, specify riparian habitat as an "environmentally sensitive locality", although wetlands, fish spawning areas, and important water sources (including watercourses or water bodies providing public water supplies) are considered to be environmentally sensitive localities under this specific legislation. Thus, since riparian habitat is associated with such environmentally sensitive localities and is considered an integral part of the resource, the definition utilised for the purposes of this study is that of DWAF (2008) which is: "an area defined by the physical structure and associated vegetation of the areas associated with a watercourse which are commonly characterized by alluvial soils, and which are inundated or flooded to an extent and with a frequency sufficient to support vegetation of species with a composition and physical structure distinct from those of adjacent areas".

## 2.3 Delineation of Watercourses

Due to the extent and terrain of SR Area 1 which had an influence on accessibility, Laser Imaging, Detection and Ranging (commonly referred to as LIDAR) surveys, aerial photographs and digital satellite imagery were used to identify points of interest (POI) prior to the field survey, in order to ensure that as many areas as possible were assessed and ground-truthed during the initial site visit (refer to Figure 1) were defined taking the following into consideration:

- A geographic spread of points was selected to ensure that conditions in all areas were addressed; and
- Ensuring that features displaying a diversity of digital signatures were identified in order to allow for field verification. In this regard, specific mention is made of the following:
  - Hydrophytic and riparian vegetation: a distinct increase in density, changes in species composition, as well as tree size near drainage lines;
  - Hue: wetlands, riparian areas and drainage lines display varying chroma (colours and colour intensity) created by varying vegetation cover and soil conditions in relation to the adjacent terrestrial areas;
  - Texture: wetland and riparian areas display various textures which are distinct from the adjacent terrestrial areas, created by varying vegetation cover and soil conditions within the watercourse; and
  - POI's were selected on areas where the features of concern were accessible, for example on roads and tracks and along dredge pond walls.

The presence of any wetland characteristics, as defined by the Ramsar Commission, were used to determine if the selected POIs identified from the provided LIDAR imagery could be considered to contain areas displaying wetland or riparian characteristics.

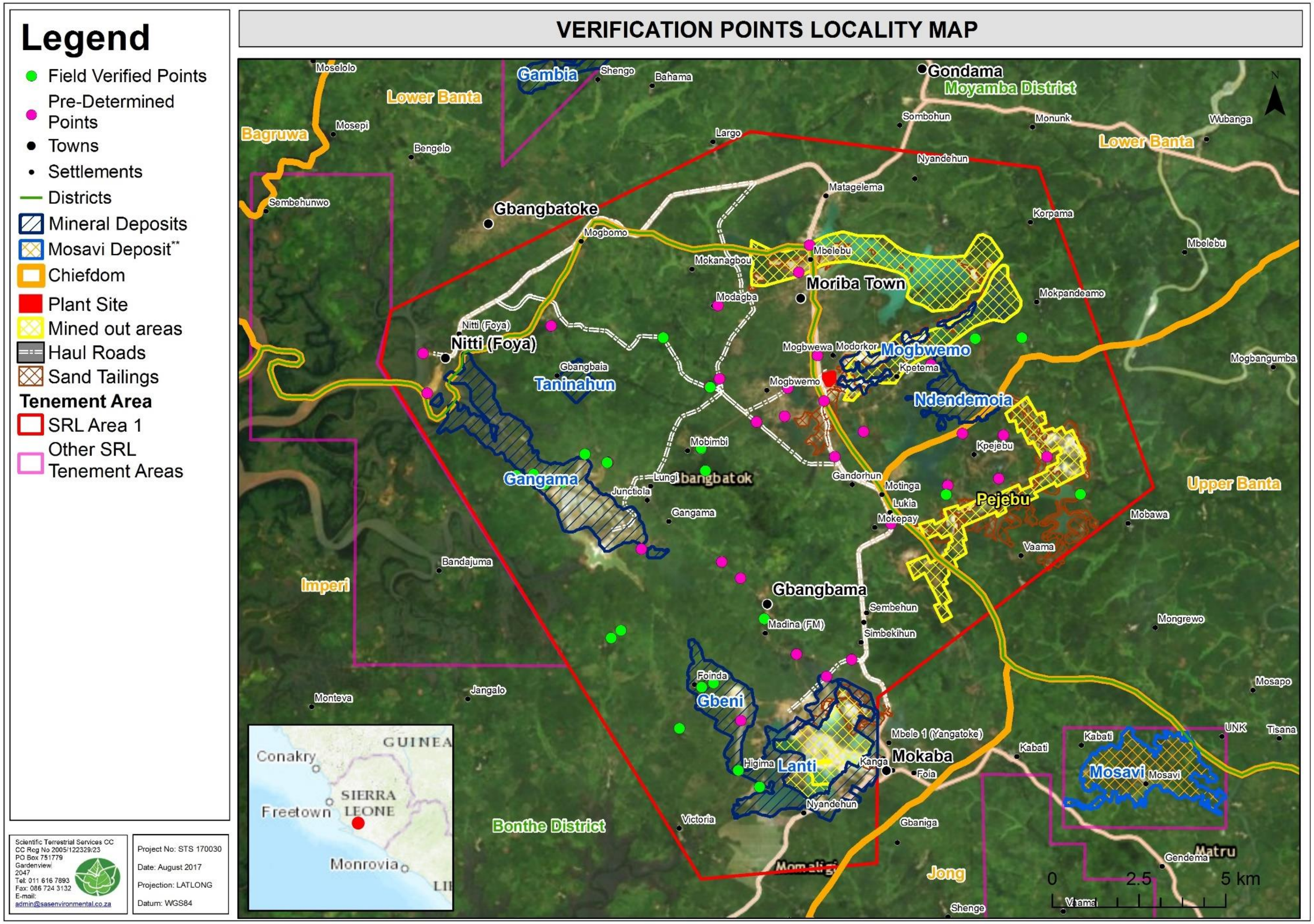



**Figure 1: Conceptual depiction of the locality of pre-determined and field verified watercourse assessment points.**

### 2.3.1 Characterisation of Watercourses

Factors influencing the habitat integrity of each freshwater feature identified during the field surveys were noted, and the functioning, ecological and socio-cultural goods and services (Ecoservices) provided by the various features was determined. As with the aquatic assessment, in the absence of protocols developed specifically for West African wetland systems, "best practice" methods developed for the African continent (such as the various aquatic Ecostatus tools developed in South Africa), were utilised and adapted where necessary in order to ensure the most appropriate and accurate characterisation of the resources.

In addition to the delineation of the freshwater resources, field observation of the systems was undertaken at as many points of interest as possible, in order to define the following important aspects of the wetland ecology:

- Wetland characterisation and classification according to the method of Ollis *et al.* (2013);
- The ecological condition of the riparian vegetation according to the Riparian Vegetation Response Assessment Index (VEGRAI, Kleynhans 2007);
- Wetland (PES) definition according to the WET-Health method as advocated by Macfarlane *et al.* (2008);
- Wetland ecosystem service provision by means of the application of the Wet EcoServices tool according to the method of Kotze *et al.* (2009). This tool is used to define the breadth and degree of goods and service provision to the local community as well as to support ecological processes;
- Wetland Ecological Importance and Sensitivity (EIS) according to the method of Rountree & Kotze (2013); and
- Recommended Ecological Category (REC) based on the determined PES, EIS and in consideration of the ecological and socio-cultural goods and services provided.

A detailed explanation of the method of assessment is provided in Appendix A of this report.

## 2.4 Sensitivity Mapping

All of the ecological features within SR Area 1 were considered, and sensitive areas were delineated with the use of a Global Positioning System (GPS) to augment the mapping of the features undertaken from aerial photography. A Geographic Information System (GIS) was used to project these features onto aerial photographs and topographic maps.

The sensitivity map should guide the design and layout of the proposed mining operation, including aspects such as closure and rehabilitation requirements.

Due to access constraints and the extent of the area, extrapolation of the extent of the features was undertaken by comparing data verified *in situ* to high resolution aerial photography, in order to map features across SR Area 1. As part of the sensitivity mapping the PES, Ecological Importance and Sensitivity (EIS) and wetland Ecoservices are presented.

# 3 RESULTS OF AQUATIC ASSESSMENT

The general area is represented by lush vegetation growth with dense riverside forest and intervening areas of Moist Semi-Deciduous Forest in various stages of succession due to the long term ongoing impact of slash and burn agricultural practices. Terrestrial areas consisted mostly of highly transformed Moist Semi-Deciduous Forest created by extensive and long-term slash and burn / subsistence agriculture. SR Area 1 is located between two main drainage systems which drain into the Atlantic Ocean. The main river to the west is the Sherbro River and its associated tributaries which form an extensive estuary dominated by mangrove habitats. The main river to the east is the Jong River. The drainage density within the Study area is high with numerous first and second order drainage lines. In some areas two drainage systems draining in opposite directions can almost not be differentiated, with the origin of the two systems occurring at almost a singular point. Many of the watercourses within SR Area 1 drain into the two main river systems to the east and west, although some systems in the south confluence and drain directly into the Atlantic Ocean in a number of smaller drainage systems.

The drainage systems, of SR Area 1, have been very significantly altered due to mining activities. Specific mention is made of the following:

1. Upstream impoundment and flooding of the watercourses (historic – no further flooding is planned);
2. Stream diversions and canals (created to relocate the dredge plant) between systems and which create inter-basin transfers in the landscape;
3. Decant from the dredge ponds; and
4. Concentration of flow in systems downstream of the dredge ponds and decant points.

These changes have affected the geomorphological, hydrological and water quality drivers of the system to varying degrees. Some impacts on water quality were also observed with some variance and pH between the sampling sites.

These variances will be discussed further in the results section below. These changes in turn have had impacts on the habitat within the instream environments, as well as the biota associated with these systems.

## 3.1 Sampling Sites

The aquatic assessment serves to document the condition at the time of assessment to indicate the state of the riverine ecological integrity from the following two assessments:

a) July 2017, when relatively high flows were being experienced at the onset of the rainy season;
b) January 2018, when relatively low flows were being experienced at the onset of the dry season.

In selecting the representative sites for the aquatic ecological sampling, consideration was given to several aspects:

- Accessibility and safety;
- The presence of a diversity of habitat, cover and flow;
- The position of the point in relation to important anthropogenic influences including the position in relation to various mining operations such as:
  - Downstream of decant points;
  - Downstream of older mining operations;
  - Downstream of newer mining operations; and
  - Areas not affected by mining, for use as reference sites although impacts from settlements and from slash and burn agriculture occur.

Table 3 below presents the geographic information pertaining to the assessment points used to define the aquatic ecology of SR Area 1. The assessment points are also indicated in relation to SR Area 1 in Figure 2.

**Table 3: Co-ordinates of the aquatic ecological assessment sites.**

| Site | Description | GPS co-ordinates | |
|---|---|---|---|
| | | North | West |
| SR1 | The site is located downstream of the Gangama mining operations on an unnamed tributary of the Sherbro River that is affected by decant from the Gangama pit lake systems. | 7°44'27.52"N | 12°21'46.41"W |
| SR3 | The site is located on the Yumbei River. The site is affected by decant from an old pit lake system which may lead to impacts on the Ecostatus of the system. | 7°45'50.36"N | 12°19'27.54"W |
| SR4 | The site is located downstream of a very large decant from some of the older lakes in the mining study area. The system is known as the Pekote Stream which consists entirely of decant at the sampling point. | 7°44'12.81"N | 12°13'34.82"W |
| SR5 | The site is located in the Rokpoi Stream and serves as a reference site. The site is located to the south-east of the mining study area. This system has not been affected by mining activity. | 7°39'55.46"N | 12°14'32.94"W |

**Note:** SR2 was a wetland site and interpretation of results from this site is thus included in the wetland section (Section 5). The decision was taken not to include SR2 in this report, as it presents a system with no flow, as opposed to the river systems mentioned above. As such aquatic fauna would differ accordingly; which would have made and comparisons with SR2 largely irrelevant. The data from SR2 was, however, considered as part of the assessment of the lentic systems.

The sections that follow present the results obtained for the representative points on the aquatic resources indicated above, by means of application of the various assessment tools.

Figure 2 shows the positions of the four sites assessed within SR Area 1.

Tables 3 to 17 provides photographic documentation and overall description of the sites.

Tables 18 to 26 are in the form of dashboard style reports providing a summary of assessment results per site.

Following that, tables and figures will present specific aspects comparing all four sites together, in order to reach a conclusion of the Ecostatus of the area in general.

## 3.2 Note on Macro-Invertebrate Reference Scores Employed in Determining Ecostatus

Reference scores employed to interpret macro-invertebrate community integrity assessment results, were determined by combining data for all four sites, and then respectively adding up the sensitivity score per taxon observed, as defined by Dickens & Graham (2002), and defining the Average Score Per Taxon (ASPT), scores for the suite of taxa observed. At all sites, low SASS but high ASPT scores were recorded, i.e. large diversity was evident when considering all sites (high SASS reference score), but with less than expected overlap between sites in terms of taxa prevalence, resulting in lower SASS scores per individual site.

Using the defined evaluation criteria (see Appendix A), this results in a very low ecological category classification, despite high ASPT scores.

Due to species composition distribution (spatial variance), described above, the calculated SASS and ASPT scores were reduced by 15% to obtain the following reference scores employed:

a) High flow (wet season) in July 2018: SASS reference score 136 and ASPT reference score 5.9;
b) Low flow (dry season) in January 2018: SASS reference score 82 and ASPT reference score 4.6;

The tool is thus considered to be applicable to the assessment performed, with the reference score relevant to, and based on current macro-invertebrate community characteristics and variation thereof, as well as habitat conditions, within the watercourses located within SR Area 1 and selected surrounding areas.

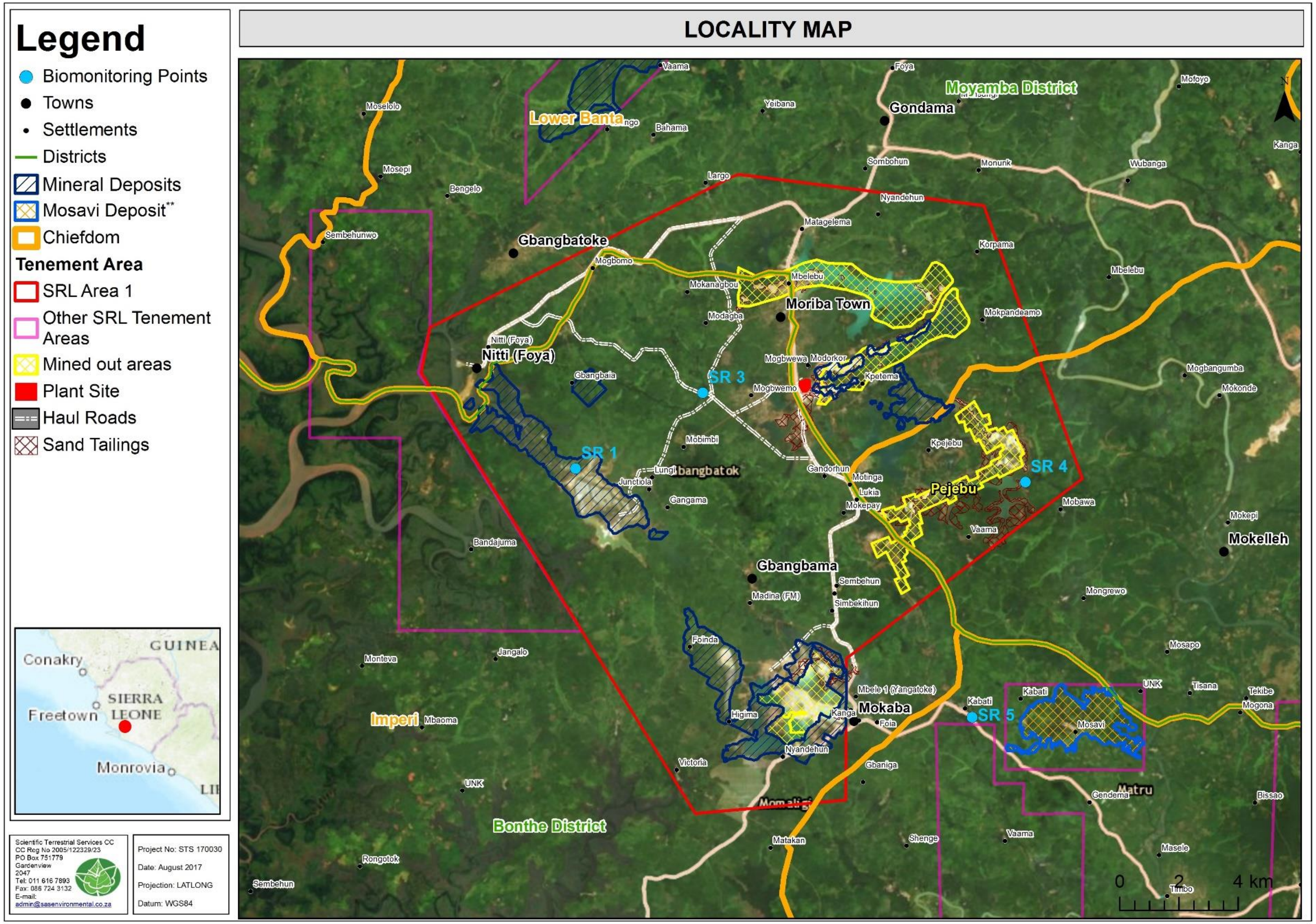



**Figure 2: Aquatic ecological assessment point presented on a digital satellite image.**

**Table 4: Photographic documentation for the unnamed tributary of the Sherbro River (site SR1).**

**Figure 3: Upstream view of the SR1 site on the unnamed tributary of the Sherbro River in the wet season showing the presence of a fish trap of belonging to the local community, not in use at the time of assessment due to high flows (July 2017).**

**Figure 4: Downstream view of the SR1 site on the unnamed tributary of the Sherbro River with mangrove vegetation in the background (high flow, July 2017).**

**Figure 5: Upstream view of the SR1 site on the unnamed tributary of the Sherbro River showing the low flow in the dry season (January 2018).**

**Figure 6: Downstream view of the SR1 site on the unnamed tributary of the Sherbro River showing the lack of flow variation in the system under low flow conditions (January 2018).**

**Table 5: Photographic documentation for the Yumbei River (site SR3).**

| | |
|---|---|
|  |  |
| **Figure 7: Upstream view of the SR3 site on the Yumbei River with excellent substrate (high flow, July 2017).** | **Figure 8: Downstream view of the SR3 site on the Yumbei River showing the relatively intact riparian vegetation and a deep refuge pool (high flow, July 2017).** |

**Figure 9: Upstream view of the SR3 site on the Yumbei River showing clear water and low flow in the dry season survey (January 2018).**

**Figure 10: Downstream view of the SR3 site on the Yumbei River showing a refuge pool during low flow conditions (January 2018)**

**Table 6: Photographic documentation for the Pekote Stream (site SR4).**

**Figure 11: General view of the SR4 site on the Pekote Stream downstream of a major decant point in the wet season showing strong flow (July 2017).**

**Figure 12: Upstream view of the SR4 site on the Pekote Stream showing the low flow and significant algal proliferation (January 2018).**

**Figure 13: Downstream view of the SR4 site on the Pekote Stream showing some diversity in flow but a lack of bankside cover (low flow, January 2018).**

**Table 7: Photographic documentation for Rokpoi Stream (site SR5).**

| | |
|---|---|
|  |  |
| **Figure 14: Upstream view of the SR5 site on the Rokpoi Stream which is unimpacted by mining (high flow, July 2017).** | **Figure 15: Downstream view of the SR5 site on the Rokpoi Stream showing dense riparian vegetation growth (high flow, July 2017).** |

**Figure 16: Upstream view of the SR5 site on the Rokpoi Stream showing dense bankside vegetation (low flow, January 2018).**

**Figure 17: Downstream view of the SR5 site on the Rokpoi Stream showing sluggish flow in the low dry season (low flow, January 2018).**

**Table 8: Photographic documentation synopsis.**

| | |
|---|---|
|   **Figure 18: An example of pit decant in the wet season (Above) and dry season (Below) that affects sites SR1, SR3 and SR4.** | • Sites SR1, SR3 and SR4 are affected by decant from pits, of which an example is provided in Figure 18;<br>• Site SR 1 is located downstream of a breached impoundment in an area where recent and active mining is taking place based on visual observations, the water in this system seems the most disturbed;<br>• Site SR 3 is located downstream of the oldest dredge ponds. In addition, this point is a significant distance downstream of the dredge ponds and the impact on the system seemed, from a visual point of view, to be limited;<br>• The observations suggest that such an "equilibrium" state may also be reached at sites SR1 and SR4 over time and that the extent of impact in the long term from decant is likely limited;<br>• Site SR 4 is located downstream of the largest decant points in the area. The entire system at this point consists of decant water. Based on field estimate calculations, the decant flow rate was determined to be approximately 6 cubic meters per second (6,000 litres per second) in the wet season and visually estimated at 300-400l/s in the dry season survey. These dredge ponds are relatively old but since there is no contribution of water from more natural systems, there is a strong likelihood that the ecology of the natural downstream system would be significantly inhibited at this point from an aquatic ecological integrity point of view, due to changes in water chemistry (low pH and changes in dissolved solid concentrations as well as the natural flow regime of the system;<br>• Site SR5 is unimpacted by mining but is affected by other land uses including subsistence slash and burn agriculture and some impacts, such as use of the area for clothes washing, from small settlements. This was particularly evident in the low flow season when sluggish flow meant that soapy water stagnated in the area;<br>• The sampling area is characterised by slow to very fast-flowing rivers, with the flow rate also influenced by rate of decant from existing pits;<br>• Bank cover at most sites is generally good to excellent, especially at site SR3 and even more so at SR5, where overhanging vegetation is not only a source of shade and cover, but also a potential source of allochthonous (detritus from riparian sources) food input. However, cover at site SR4 was considered limited and the limited supply of allochthonous food input is likely to significantly limit the productivity and hence diversity and community abundance of the system;<br>• Bottom substrate is varied, with good quality rocky substrate in variable currents present at all sites (but very embedded at site SR4). Other substrates include sand, mud and gravel;<br>• Significant algal proliferation was evident at SR4 which is fed by decant from the older dredge ponds;<br>• From visual observation/assessment, as is also evident from photographs presented here, that the general state of the habitat within these systems ranged from slightly modified (SR3) and moderately modified (SR1 and SR4), to largely natural/unmodified (SR5); and<br>• As can be seen from the fish trap fence visible site SR1 (see Figures 4 and 5), the local communities harvest fish from these systems, as well as from the dredge ponds that decant into them (these pits are actively stocked for aquaculture purposes discussed in Section 4). |

**Table 9: Results summary of the assessment at Site SR1 (Unnamed tributary of the Sherbro River downstream of the Gangama mining operations).**

**Site SR1**

**Figure 19: Downstream view of site SR1 at the time of the assessment (dry season, January 2018).**

| *In situ* physico-chemical water quality | | % variation (% Var) compared to site SR5* | | Fish Community Analysis | |
|---|---|---|---|---|---|
| **HIGH FLOW DATA** | | | | | |
| **pH** | 5.67 | **pH** | +3.1 | **Fish Species present** | *Tilapia guineensis; Clarias gariepinus; Hepsetus adoe; Brycinus longipinnis; Hemichromis fasciatus*; *Epiplatys barmoiensis* (not definitive), *Hemichromis bimaculatus, Papyrocranus afer* |
| **EC (mS/m)** | 2.4 | **EC** | +100.0 | | |
| **Temp (°C)** | 29.7 | **Temp** | +10.0 | | |
| **Clarity** | 64 cm | **Clarity** | >36% loss | | |
| **LOW FLOW DATA** | | | | | |
| **pH** | 5.45 | **pH** | +1.1 | **Fish Species present** | *Tilapia guineensis* |
| **EC (mS/m)** | 2.4 | **EC** | +14.3 | | |
| **Temp (°C)** | 31.2 | **Temp** | +20.0 | | |
| **Clarity** | 30 cm | **Clarity** | 45% loss | | |

**Invertebrate community assessment (SASS5 and IHAS, MIRAI)**

| Variables | Scores | % Var from Reference Scores | % of Reference Score | % Var compared to site SR5 |
|---|---|---|---|---|
| **HIGH FLOW DATA** | | | | |
| **SASS5 score** | 23 | -83.1 | 16.9 | -76.0 |
| **Number of taxa** | 4 | NA | NA | -73 |
| **ASPT score** | 5.8 | -1.7 | 98.3 | -9.4 |
| **IHAS** | 62 (Adequate/Fair) | NA | NA | -23.5 |
| **Instream IHI** | 68.1 (Category C) | NA | NA | NA |
| **Riparian IHI** | 47.6 (Category D) | NA | NA | NA |
| **MIRAI** | 38.63 (Category E) | NA | NA | -51.5% |
| **LOW FLOW DATA** | | | | |
| **SASS5 score** | 28 | -65.9 | 34.1 | -61.1 |
| **Number of taxa** | 6 | NA | NA | -53.8 |
| **ASPT score** | 4.7 | 2.2 | 102.2 | -14.5 |
| **IHAS** | 64 (Adequate) | NA | NA | -15.8 |
| **MIRAI** | 39.20 (Category E) | NA | NA | -49.5 |

**NA = Not Applicable, SASS5 reference scores = 136 (high flow July 2017) and 82 (low flow January 2018), ASPT reference scores = 5.9 (high flow July 2017) and 4.6 (low flow January 2018).**

*** Red Text Denotes a change from the spatial reference which is considered unacceptable**

**Site SR1**

| | |
|---|---|
| **Algal Proliferation** | No algal proliferation at this point. |
| **Depth Profiles** | The stream was relatively shallow at this point (generally *<½ m to 1 m).* |
| **Flow Condition** | Mix of flow conditions. |
| **Water Clarity and Odour** | Water was turbid (discoloured) with significant variation from the reference condition. |
| **Riparian Zone Characteristics** | Very good marginal vegetation cover although disturbances form mining have affected cover in areas. |

**NOTE ON ABBREVIATIONS**
In this table and others to follow, the follow abbreviations apply:
**SASS5** = South African Scoring System Version 5;
**MIRAI** = Macro-Invertebrate Response Assessment Index;
**IHI** = Index of Habitat Integrity.

| **SITE ECOSTATUS CATEGORY** | |
|---|---|
| **SASS5** | **High flow: Category F**<br>**Low flow: Category E** |
| **MIRAI** | **High flow: Category E**<br>**Low flow: Category E** |
| **Instream IHI** | **High flow: Category C** |
| **Riparian IHI** | **High flow: Category D** |
| **Diatom assessment (see Tables 15 and 16)** | **High flow: Category A/B**<br>**Low flow: Category A** |

**Comments on Water Quality (trends applicable to both assessments – see Tables 13 and 14 for comparative discussions):**

- The absolute Electrical Conductivity (EC) is considered low/largely natural, but still elevated from that at reference site SR5.
- The absolute pH value can be considered acidic, but largely natural (slightly higher compared to conditions at reference site SR5). pH values do not comply with the IFC guidelines for Mining;
- Temperature appears natural with consideration of seasonal and diurnal fluctuations. Comparing water temperatures to that at reference site SR5, water in the pits may have temperatures elevated by approximately two degrees Celsius, but can only be confirmed through long term monitoring;
- Turbid conditions observed can be attributed to pit decant upstream of this site, and may affect macro-invertebrate taxa diversity negatively. The loss of clarity from the reference site is greater than 45%; and
- According to the surface water assessment by SRK (2018) turbidity, nitrate, aluminium, chromium, iron, manganese and TSS are elevated above background values which may affect aquatic life.

**Comments on the Macro-Invertebrate Community Integrity (trends applicable to both assessments – see Tables 13 and 14 for comparative discussions):**

- IHAS scores indicate habitat conditions are fair and adequate to sustain a diverse macro-invertebrate community;
- However, despite adequate habitat suitability, SASS score (a measure of diversity and overall integrity) at this site is very low compared to both the expected reference score and that obtained at the SR5 reference site;
- Decant from the pit resulting in turbid conditions, impacts on water quality and impacts on instream flow are likely to negatively affect macro-invertebrate diversity. However, despite these factors ASPT score was relatively high, and on par the expected reference values, and less than 15% lower compared to the SR5 site which serves as a reference site;
- These observations indicate that diversity is affected to a greater degree compared to sensitivity, and thus habitat impacts on the system are considered more significant than water quality impacts; and
- This deduction is supported by water quality measurement results, with all parameters measured appearing largely natural (absolute value for EC is still low, even though elevated from that at site SR5). Habitat impacts as indicated by the application of the IHI data (high flow assessment in July 2017 only) are more significant, with instream habitat considered moderately modified and riparian habitat largely modified.

**Comments on the Fish Community Integrity:**

- The fish community is diverse in relation to all other assessed sites although it must be noted that additional fish records were obtained at this point form local fisherman in the wet season survey;
- During the dry season survey no fish were captured and no fishermen were present, which likely indicates a low abundance of fish under low flow conditions; and
- Harvesting by the local community (note fish trap fence in Figure 19) highlights the importance to the local community of the fish in the mangroves and the river systems of the area.

**Current Impacts:**

- The site is located immediately below a disused dredge pond where the wall has been purposefully breached and the pond decants, resulting in turbid conditions and flow variability. Pit decant may contribute to slightly higher EC compared to reference site SR5. Some limited impact on the aquatic community is deemed possible, with specific reference to the macro-invertebrate community based on SASS5 and MIRAI assessment results; and
- Physical impacts from mining related activity are deemed more significant than the impacts on water quality at this point.

**High flow = July 2017 assessment; Low flow = January 2018 assessment**

**Table 10: Results summary of the assessment at Site SR3 (Yumbei River located downstream from decant from the Bamba/Belebu Dredge Pond).**

**Site SR3**

**Figure 20: Upstream view of site SR3 at the time of the assessment (Dry season).**

| ***In situ*** **physico-chemical water quality** | | **% variation (% Var) compared to site SR5*** | | **Fish Community Analysis** | |
|---|---|---|---|---|---|
| **HIGH FLOW ASSESSMENT**<br>**pH**<br>**EC (mS/m)**<br>**Temp (°C)**<br>**Clarity** | <br>4.88<br>2.0<br>30.5<br>>100cm | <br>**pH**<br>**EC**<br>**Temp**<br>**Clarity** | <br>-11.3<br>+66.7<br>+13.0<br>0 | <br>**Species present** | <br>*Pelvicachromis humilis* (not definitive),<br>*Epiplatys barmoiensis* (not definitive),<br>*Brycinus longipinnis* |
| **LOW FLOW ASSESSMENT**<br>**pH**<br>**EC (mS/m)**<br>**Temp (°C)**<br>**Clarity** | <br>4.76<br>5.2<br>24.9<br>>100cm | <br>**pH**<br>**EC**<br>**Temp**<br>**Clarity** | <br>-11.7<br>+147.6<br>-4.2<br>0 | <br>**Species present** | <br>*Pelvicachromis humilis* (not definitive),<br>*Epiplatys barmoiensis* (not definitive),<br>*Brycinus longipinnis* |

**Invertebrate community assessment (SASS5 and IHAS, MIRAI)**

| **Variables** | **Scores** | **% Var from Reference Scores** | **% of Reference Score** | **% Var compared to site SR5** |
|---|---|---|---|---|
| **HIGH FLOW ASSESSMENT** | | | | |
| **SASS5 score** | 89 | -34.6 | 65.4 | -7.3 |
| **Number of taxa** | 15 | NA | NA | 0 |
| **ASPT score** | 5.9 | 0 | 100.0 | -7.8 |
| **IHAS** | 71 (Good) | NA | NA | -12.3 |
| **Instream IHI** | 86.9 (Category B) | NA | NA | NA |
| **Riparian IHI** | 75.4 (Category C) | NA | NA | NA |
| **MIRAI** | 62.41 (Category C) | NA | NA | -21.6 |
| **LOW FLOW ASSESSMENT** | | | | |
| **SASS5 score** | 47 | -42.7 | 57.3 | -34.7 |
| **Number of taxa** | 11 | NA | NA | -15.3 |
| **ASPT score** | 4.3 | -6.5 | 93.5 | -21.8 |
| **IHAS** | 85 (Excellent) | NA | NA | +11.8 |
| **MIRAI** | 51.72 (Category D) | NA | NA | -33.3 |

**NA = Not Applicable, SASS5 reference scores = 136 (high flow July 2017) and 82 (low flow January 2018), ASPT reference scores = 5.9 (high flow July 2017) and 4.6 (low flow January 2018).**

*** Red Text Denotes a change from the spatial reference which is considered unacceptable**

<table>
<tr><th colspan="3">Site SR3</th></tr>
<tr><td>Algal Proliferation</td><td>No algal proliferation at this point.</td><td rowspan="6">Comments on Water Quality (trends applicable to both assessments – see Tables 13 and 14 for comparative discussions):<br>➢ The absolute EC is considered low/largely natural, but still elevated from that at reference site SR5. This was particularly evident during the low flow assessment (January 2018);<br>➢ The absolute pH value can be considered acidic, but largely natural compared to SR5. However, some deviation from the “natural condition” at site SR5 is likely. Furthermore, pH values do not comply with the IFC guidelines for Mining;<br>➢ Temperature appears natural with consideration of seasonal and diurnal fluctuations; and<br>➢ Water is clear and the system seem to have reached an equilibrium with the upstream decant from the pit. However, pit decant may potentially contribute to decreased pH and elevated EC in the system compared to site SR5. These water quality parameters may affect macro-invertebrate community integrity negatively.<br>Comments on the Macro-Invertebrate Community Integrity (trends applicable to both assessments – see Tables 13 and 14 for comparative discussions):<br>➢ Despite an IHAS score that indicates habitat conditions are good to ideal and suitable for sustaining a diverse macro-invertebrate community, SASS score (a measure of diversity) at this site is lower compared to both the expected reference score and SR5 spatial reference site;<br>➢ Water clarity data indicate that decant from the Bamba/Belebu Dredge Pond pond upstream is unlikely to significantly increase turbidity;<br>➢ The generally fast flow during the wet season (as assessed July 2017) may negatively affect macro-invertebrate diversity and abundance. However, despite these factors, ASPT score was high and on par with or slightly below the expected reference values, but lower than the SR5 reference score (particularly with reference to low flow conditions). This indicates that diversity is generally affected to a greater degree compared to sensitivity, but during low flow conditions sensitive species seem to be negatively affected to a greater degree compared to high flow conditions; and<br>➢ Based on the above it is unlikely that water quality parameters are negatively affecting the macro-invertebrate community during high flow conditions, as this would most significantly impact on sensitive species, and hence would have also resulted in a lowered ASPT score. However, decreased pH and slightly elevated EC may in the long term negatively affect macro-invertebrate community integrity. This is evident under low flow conditions, where slightly elevated EC corresponds with both lowered SASS and ASPT scores. See Tables14 and 15 for a detail discussion of temporal trends.<br>Comments on the Fish Community Integrity:<br>➢ Diversity (number) of fish species collected were lower compared to that from reference site SR5. This may be due to the effects of historical mining.<br>Current Impacts<br>➢ The site is located a significant distance downgradient from the decant point from the Bamba/Belebu Dredge Pond which has been disused for a long period of time. The system seems to have reached an equilibrium with the decant, as the water was clear. However, pit decant may still contribute to slightly higher EC and slightly lower pH, when compared to conditions at reference site SR5. This was particularly evident during the low flow assessment (with reference to EC). Limited impact on the aquatic community is deemed possible since the fish and aquatic macro-invertebrate community diversity was reduced in relation to the reference site (high and low flow), with impact on community sensitivity only observed during low flow conditions.</td></tr>
<tr><td>Depth Profiles</td><td>The stream was relatively shallow at this point (generally >½ m to 1 m).</td></tr>
<tr><td>Flow Condition</td><td>Mix of flow conditions.</td></tr>
<tr><td>Water Clarity And Odour</td><td>Water was clear.</td></tr>
<tr><td>Riparian Zone Characteristics</td><td>Very good marginal vegetation cover, including overhanging vegetation.</td></tr>
<tr><td>SITE ECOSTATUS CATEGORY<br><br>SASS5<br><br>MIRAI<br><br>Instream IHI<br><br>Riparian IHI<br><br>Diatom assessment (see Tables 15 and 16)</td><td><br>High flow: Category C<br>Low flow: Category C<br><br>High flow: Category C<br>Low flow: Category D<br><br>High flow: Category B<br><br>High flow: Category C<br><br>High flow: Category A<br>Low flow: Category A</td></tr>
</table>

**High flow = July 2017 assessment; Low flow = January 2018 assessment**

**Table 11: Results summary of the assessment at Site SR4 (Pekote Stream located downstream of a large decant from a pit lake).**

**Site SR4**

**Figure 21: Downstream view of site SR4 at the time of the assessment (high flow, July 2017).**

| ***In situ* physico-chemical water quality** | | **% variation (% Var) compared to site SR5** | | **Fish Community Analysis** | |
|---|---|---|---|---|---|
| **HIGH FLOW**<br>**pH**<br>**EC (mS/m)**<br>**Temp (℃)**<br>**Clartity** | <br>5.06<br>2.7<br>29.8<br>>100cm | <br>**pH**<br>**EC**<br>**Temp**<br>**Clarity** | <br>-8.0<br>+125<br>+10.4<br>0 | **Fish Species present** | *Tilapia guineensis, Epiplatys barmoiensis* |
| **LOW FLOW**<br>**pH**<br>**EC (mS/m)**<br>**Temp (℃)**<br>**Clartity** | <br>4.83<br>3.3<br>31.2<br>>100cm | <br>**pH**<br>**EC**<br>**Temp**<br>**Clarity** | <br>-10.4<br>+57.1<br>+20.0<br>0 | **Fish Species present** | *Tilapia guineensis, Clarias salae* |

**Invertebrate community assessment (SASS5 and IHAS, MIRAI)**

| **Variables** | **Scores** | **% Var from Reference Scores** | **% of Reference Score** | **% Var compared to site SR5** |
|---|---|---|---|---|
| **HIGH FLOW** | | | | |
| **SASS5 score** | 23 | -83.1 | 16.9 | -76.0 |
| **Number of taxa** | 5 | NA | NA | -66 |
| **ASPT score** | 4.6 | -22.0 | 78.0 | -28.1 |
| **IHAS** | 66 (Adequate) | NA | NA | -18.5 |
| **Instream IHI** | 67.7 (Category C) | NA | NA | NA |
| **Riparian IHI** | 43.8 (Category D) | NA | NA | NA |
| **MIRAI** | 39.1 (Category E) | NA | NA | -50.9 |
| **LOW FLOW** | | | | |
| **SASS5 score** | 13 | -84.1 | 15.9 | -81.9 |
| **Number of taxa** | 4 | NA | NA | -69.2 |
| **ASPT score** | 3.3 | -28.3 | 71.7 | -40 |
| **IHAS** | 64 (Adequate) | NA | NA | -15.8 |
| **MIRAI** | 27.45 (Category E) | NA | NA | -64.6 |

**NA = Not Applicable, SASS5 reference scores = 136 (high flow July 2017) and 82 (low flow January 2018), ASPT reference scores = 5.9 (high flow July 2017) and 4.6 (low flow January 2018).**

*** Red Text Denotes a change from the spatial reference which is considered unacceptable**

**Site SR4**

| | |
|---|---|
| **Algal Proliferation** | No algal proliferation at this point. |
| **Depth Profiles** | The stream was relatively shallow at this point (generally ½ m). |
| **Flow Condition** | Mix of flow conditions. |
| **Water Clarity and Odour** | Water was clear. |
| **Riparian Zone Characteristics** | Limited marginal vegetation cover. |
| **SITE ECOSTATUS CATEGORY** | |
| **SASS5** | **High flow: Category F**<br>**Low flow: Category F** |
| **MIRAI** | **High flow: Category E**<br>**Low flow: Category E** |
| **Instream IHI** | **High flow: Category C** |
| **Riparian IHI** | **High flow: Category D** |
| **Diatom assessment (see Tables 15 and 16)** | **High flow: Category A/B**<br>**Low flow: Category A** |

**Comments on Water Quality:**

- The absolute EC is considered low/largely natural, but still elevated from that at reference site SR5;
- The absolute pH value can be considered acidic, but largely natural (lower compared to conditions at reference site SR5). pH values do not comply with the IFC guidelines for Mining;
- Temperature appears largely natural with consideration of seasonal and diurnal fluctuations, but the water in the pits may have temperatures elevated by approximately two (high flow) to five (low flow) degrees Celsius (comparing SR4 site with SR5 site temperatures); and
- No impact on water clarity is evident

**Comments on the Macro-Invertebrate Community Integrity:**

- Despite an IHAS score that indicates habitat conditions are adequate to sustain a diverse macro-invertebrate community, both SASS and ASPT scores (measure of diversity and sensitivity, respectively) at this site is very low compared to both the expected reference score and the spatial reference site SR5. This trend was more pronounced during the low flow assessment (January 2018); and
- Decant from the disused dredge pond significantly affects instream flow which is the most likely driver of change in the system, reducing macro-invertebrate diversity and to a lesser degree affecting the macro-invertebrate community sensitivity of the at this site. However, as was the case at site SR1, diversity is affected to a greater degree compared to sensitivity. Any potential impact from the mine is compounded during the dry season, based on reduction in SASS and ASPT scores in the January 2018 assessment.

**Comments on the Fish Community Integrity:**

- Fish community diversity and abundance was significantly lower than the other sampling sites, especially when compared to site SR1 and SR5.

**Current impacts**

- The site is located immediately below a disused dredge pond that decants, potentially resulting in long term flow variability. Pit decant may contribute to the higher EC and lower pH compared to reference site SR5. However, as these are very poorly buffered systems, significant seasonal variation (high flow versus low flow) confounds any direct comparisons between areas in terms of potential impact. This may have a chronic negative impact on the aquatic community integrity (both macro-invertebrates and fish). These watercourses are very poorly buffered systems, and the fluctuation of salt concentrations between dry and wet seasons is likely to be more significant than spatial variation. This is evident comparing the July 2017 and January 2018 results, and needs to be investigated further as further time series data is developed; and
- Elevated EC and lowered pH may be indicators that water quality is negatively affecting the aquatic community in the long term. However, impacts on instream flow and the limitations in terms of habitat and cover diversity is likely the most important drivers of change in the system. Impact on the macro-invertebrate community is greater during periods of low flow, based on reduction of SASS5 and ASPT scores during January 2018.

**High flow = July 2017 assessment; Low flow = January 2018 assessment**

**Table 12: Results summary of the assessment at Site SR5 (Rokpoi Stream a reference site not affected by mining).**

**Site SR5**

**Figure 22: Upstream view of site SR5 at the time of the assessment (low flow, January 2018).**

| ***In situ* physico-chemical water quality** | | **Fish Community Analysis** | |
|---|---|---|---|
| **HIGH FLOW**<br>**pH**<br>**EC (mS/m)**<br>**Temp (°C)**<br>**Clarity** | <br>5.50<br>1.2<br>27.0<br>>100cm | **Fish Species present** | *Pelvicachromis humilis* (not definitive), *Epiplatys barmoiensis*, *Petrocephalus bovei* (species to be confirmed), *Brycinus longipinnis*<br>Several other species of larger fish observed in the deeper pools but could not be captured for identification. Species of barbs as well as Labeo and larger cichlids were observed in the deep clear water. |
| **LOW FLOW**<br>**pH**<br>**EC (mS/m)**<br>**Temp (°C)**<br>**Clarity** | <br>5.39<br>2.1<br>26.0<br>55cm | **Fish Species present** | *Pelvicachromis humilis* (not definitive), *Epiplatys spp.*, *Brycinus longipinnis,* Species of barbs as well as larger cichlids were observed in the deep clear water |

**Invertebrate community assessment (SASS5 and IHAS, MIRAI)**

| **Variables** | **Scores** | **% Var from Reference Scores** | **% of Reference Score** |
|---|---|---|---|
| **HIGH FLOW** | | | |
| **SASS5 score** | 96 | -29.4 | 70.6 |
| **Number of taxa** | 15 | NA | NA |
| **ASPT score** | 6.4 | +8.5 | 108.5 |
| **IHAS** | 81 (Excellent) | NA | NA |
| **Instream IHI** | 98.8 (Category A) | NA | NA |
| **Riparian IHI** | 82.0 (Category B) | NA | NA |
| **MIRAI** | 79.58 (Category B) | NA | NA |
| **LOW FLOW** | | | |
| **SASS5 score** | 72 | -12.2 | 87.8 |
| **Number of taxa** | 13 | NA | NA |
| **ASPT score** | 5.5 | +19.6 | 119.6 |
| **IHAS** | 76 (Excellent) | NA | NA |
| **MIRAI** | 77.59 (Category C) | NA | NA |

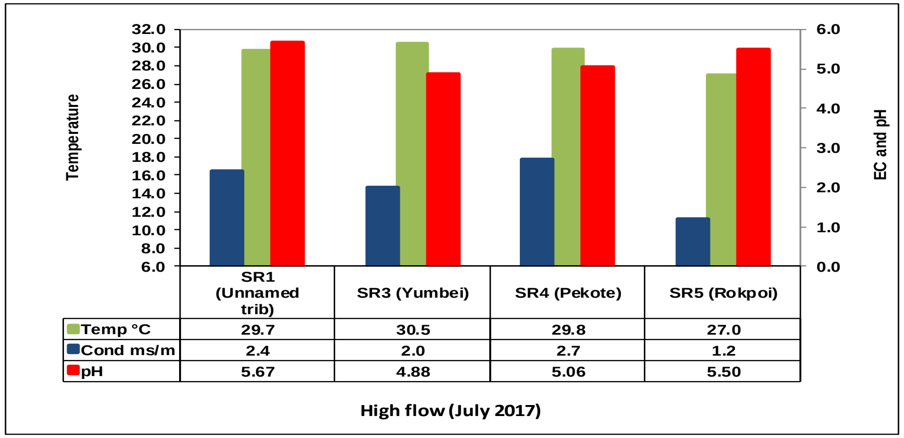
**NA = Not Applicable, SASS5 reference scores = 136 (high flow July 2017) and 82 (low flow January 2018), ASPT reference scores = 5.9 (high flow July 2017) and 4.6 (low flow January 2018).**

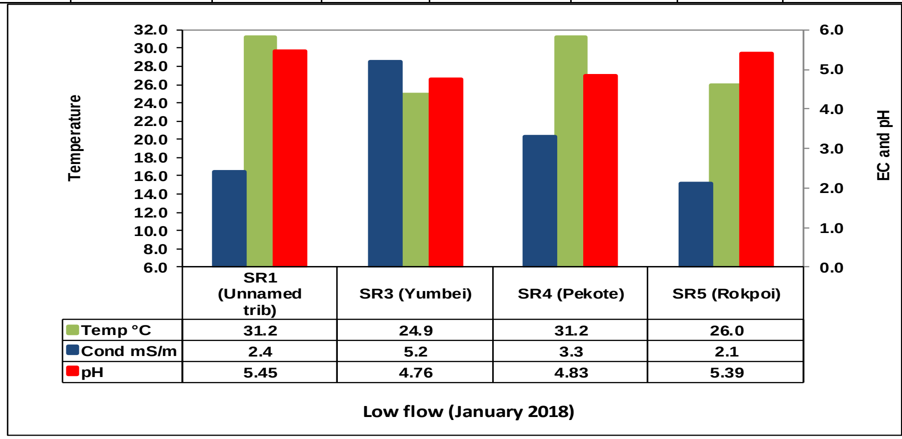
<table>
<tr><th colspan="3">Site SR5</th></tr>
<tr><td>Algal Proliferation</td><td>No algal proliferation at this point.</td><td rowspan="2">Comments on Water Quality:<ul><li>The absolute EC is considered low/natural;</li><li>The absolute pH value can be considered acidic, but natural given the geology and soil conditions of the area. The data indicates that pH values do not comply with the IFC guidelines for Mining; and</li><li>Temperature appears natural with consideration of seasonal and diurnal fluctuations.</li></ul>Comments on the Macro-Invertebrate Community Integrity:<ul><li>IHAS score indicate that habitat conditions are excellent to sustain a diverse macro-invertebrate community. However, SASS score (a measure of diversity) at this site is still lower compared to the theoretical reference score developed. The system can be considered largely natural, despite potential catchment-wide impact due to domestic uses and slash and burn agricultural practices. However, ASPT score (a measure of sensitivity) was higher than the expected reference score, confirming the largely natural macro-invertebrate community integrity classification.</li></ul></td></tr>
<tr><td>Depth Profiles</td><td>The stream was relatively shallow at this point (generally > ½ m to 1 m).</td></tr>
<tr><td>Flow Condition</td><td>Mix of flow conditions.</td><td rowspan="4">Comments on the Fish Community Integrity:<ul><li>An increased variety of fish species were collected and/or observed as presented in the data above, also indicating no significant negative impact on fish community integrity; and</li><li>A diversity of flow and cover provides excellent habitat for a diversity of fish species.</li></ul>Current impacts<ul><li>The site is not subjected to impacts from pit decant, and as such is considered a reference site although some impacts from settlements in the catchment are likely. Examples of impacts related to the settlements include extensive and long term slash and burn agriculture, most likely for a mix of commercial and subsistence purposes as well as crop (rice) cultivation within the floodplains, and use of the system for domestic activities such as bathing and washing of clothes. Other catchment-wide impacts are limited to activities such as clothes washing and some potential fishing activities. Some impact from invasive vegetation as well as the farming of rice in the floodplain may occur.</li></ul></td></tr>
<tr><td>Water Clarity and Odour</td><td>Water was clear.</td></tr>
<tr><td>Riparian Zone Characteristics</td><td>Excellent marginal vegetation cover (>95%).</td></tr>
<tr><td>SITE ECOSTATUS CATEGORY<br><br>SASS5<br><br>MIRAI<br><br>Instream IHI<br><br>Riparian IHI<br><br>Diatom assessment (see Tables 15 and 16)</td><td><br><br>High flow: Category B<br>Low flow: Category A<br><br>High flow: Category B<br>Low flow: Category C<br><br>High flow: Category A<br><br>High flow: Category B<br><br>High flow: Category A<br>Low flow: Category A</td></tr>
</table>

**High flow = July 2017 assessment; Low flow = January 2018 assessment**

**Table 13: Summary results of all aquatic assessment sites in SR Area 1– water quality synopsis.**

| Water Quality Parameter | Site | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SR1 | | | SR3 | | | SR4 | | | SR5 | | |
| Assessment | High (Jul 2017) | Low (Jan 2018) | % temporal variation | High (Jul 2017) | Low (Jan 2018) | % temporal variation | High (Jul 2017) | Low (Jan 2018) | % temporal variation | High (Jul 2017) | Low (Jan 2018) | % temporal variation |
| pH (value) | 5.67 | 5.45 | -3.9 | 4.88 | 4.76 | -2.5 | 5.06 | 4.83 | -4.5 | 5.50 | 5.39 | -2.0 |
| EC (mS/m) | 2.4 | 2.4 | 0 | 2.0 | 5.2 | 160 | 2.7 | 3.3 | 22.2 | 1.2 | 2.1 | 75.0 |
| Temp (°C) | 29.7 | 31.2 | 5.1 | 30.5 | 24.9 | -18.4 | 29.8 | 31.2 | +4.7 | 27.0 | 26.0 | -3.7 |



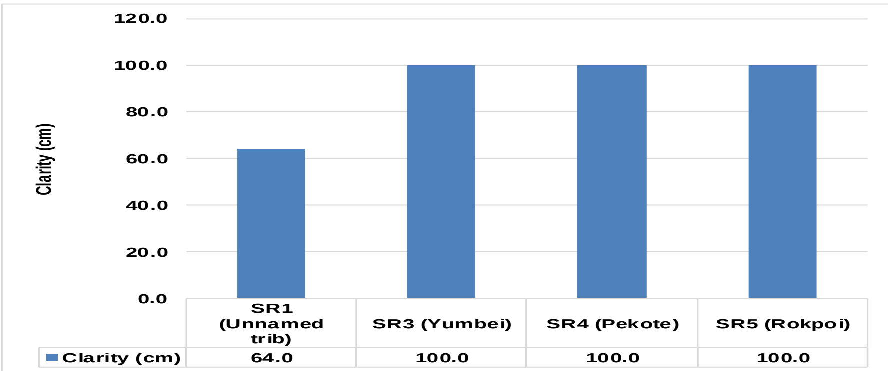




**Figure 23: Water quality parameters measured in SR Area 1 during the high flow (July 2017) assessment.**

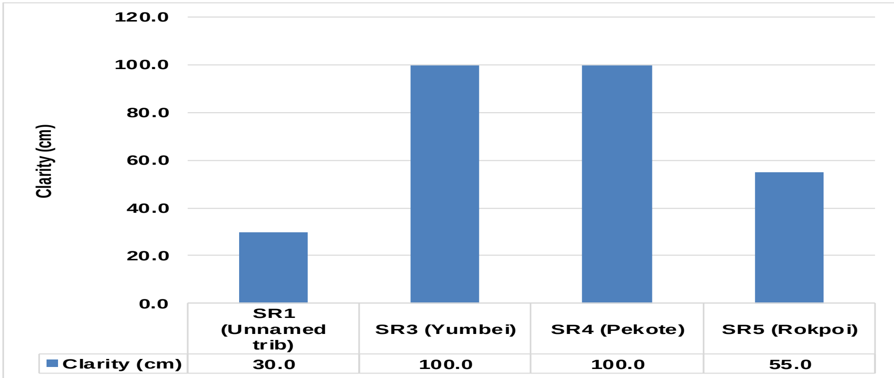



**Figure 24: Water quality parameters measured in SR Area 1 during the low flow (January 2018) assessment.**

**Table 13 (continued): Summary results of all aquatic assessment sites in SR Area 1– water quality synopsis**

**Spatial comparison (to reference site SR5)**

- At these four sites pH values of between 4.76 and 5.67 were recorded and are considered acidic, yet largely natural considering the geochemical processes of the area. Using conditions at site SR5 as a reference, pH values at site SR1 was higher, but lower at sites SR3 and SR4, respectively. The data indicates that pH values do not comply with the IFC guidelines for Mining, even in systems not affected by mining. The low pH in the region may potentially inhibit sensitive macro-invertebrate taxa. However, a high ASPT score and low SASS score at most sites indicate that diversity was potentially affected to a greater degree compared to potential impact on sensitivity. It is possible that decant from pits may contribute to the lower pH observed at some of the sites, but further time series data would be required to quantify and evaluate the impact. The same overall spatial trends were observed during both the high and low flow assessments (Figures 23 and 24), supporting the notion that any significant impact from mining activities on pH value is likely to be very limited;
- Absolute EC values are very low and considered largely natural at all sites. However, compared to conditions at reference site SR5, EC was higher at all sites affected by mining during both assessments. This indicates that pit decant may contribute to salt load in these systems to a small degree. Further time series data would be required to quantify and evaluate the impact
- Temperature appears largely natural with consideration of seasonal and diurnal fluctuations, but the water in the dredge ponds may have temperatures elevated by approximately 2 – 4 °C (comparing temperatures at sites SR1, SR3 and SR4 to that at reference site SR5). Only through further long term and short interval monitoring could this observation be definitively concluded;
- Vegetation clearing may change the micro-climate which in turn increases water temperature, which could affect some more sensitive taxa; and
- High flow data suggest that decant from pits that have been recently mined contain elevated dissolved salt concentrations in relation to the natural environment and may affect the aquatic community to varying degrees based on the distance from decant, as well as the degree to which the decant water is mixed with run-off from the surrounding landscape. However, low flow data indicate temporal increase at site SR3 (oldest pit), also suggesting natural seasonal changes in EC.

**Temporal comparison (high flow versus low flow assessments)**

- At the respective sites pH decreased by between 2.0% and 4.5% between the high (July 2017) and low (January 2018) flow assessments. The Reference site showed the least variation between the two assessments (SR5) while the variation at site SR4 which is most affected by decant showed the greatest variation. This supports the statement that pit decant may contribute lowered pH values in the watercourses downstream of decant points;
- Comparing the high (July 2017) and low (January 2018) flow assessments, EC remained unchanged at site SR1, but increased by between 22.2% (SR4) and 160.0% (SR3). At reference site (SR5) EC increased by 75.0%. Whilst some impact from mining activity is possible, temporal increase at reference site SR5 and significant increase at SR3 (affected by decant from older pit), suggest that EC naturally also varies seasonally, with higher values during low flows (resulting for example from evapoconcentration); and
- Temperature appears largely natural with consideration of seasonal and diurnal fluctuations, but the water in the dredge ponds may have temperatures elevated by approximately 2 – 4 °C (comparing temperatures at sites SR1, SR3 and SR4 to that at reference site SR5) during both the high and low flow assessments (notably for sites SR2 and SR4 in the latter case). Only through further long term and short interval monitoring and the development of detailed time series data could this observation be definitively concluded.

**Conclusion**

- The data indicates that pit decant may contribute a reduction in pH and slightly elevated EC compared to the reference site. Any potential impact in terms of water quality by be compounded during low flow conditions (e.g. as seen for EC at site SR3). Over the long term the naturally low pH values in the area may contribute to the low diversity of macro-invertebrates. Some impacts due to increased turbidity and increased temperature potentially occur.

**Table 14: Summary results of all aquatic assessment sites in SR Area 1 – macro-invertebrate community and macro-invertebrate habitat assessments.**

| Parameter | Site | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SR1 | | | SR3 | | | SR4 | | | SR5 | | |
| Assessment | High (Jul 2017) | Low (Jan 2018) | % temporal variation | High (Jul 2017) | Low (Jan 2018) | % temporal variation | High (Jul 2017) | Low (Jan 2018) | % temporal variation | High (Jul 2017) | Low (Jan 2018) | % temporal variation |
| SASS5 score | 23 | 28 | 21.7 | 89 | 47 | -47.2 | 23 | 13 | -43.5 | 96 | 72 | -25.0 |
| ASPT score | 5.8 | 4.7 | -19.0 | 5.9 | 4.3 | -27.1 | 4.6 | 3.3 | -28.3 | 6.4 | 5.5 | -14.1 |
| IHAS score | 62 | 64 | 3.2 | 71 | 85 | 19.7 | 66 | 64 | -3.0 | 81 | 76 | -6.2 |

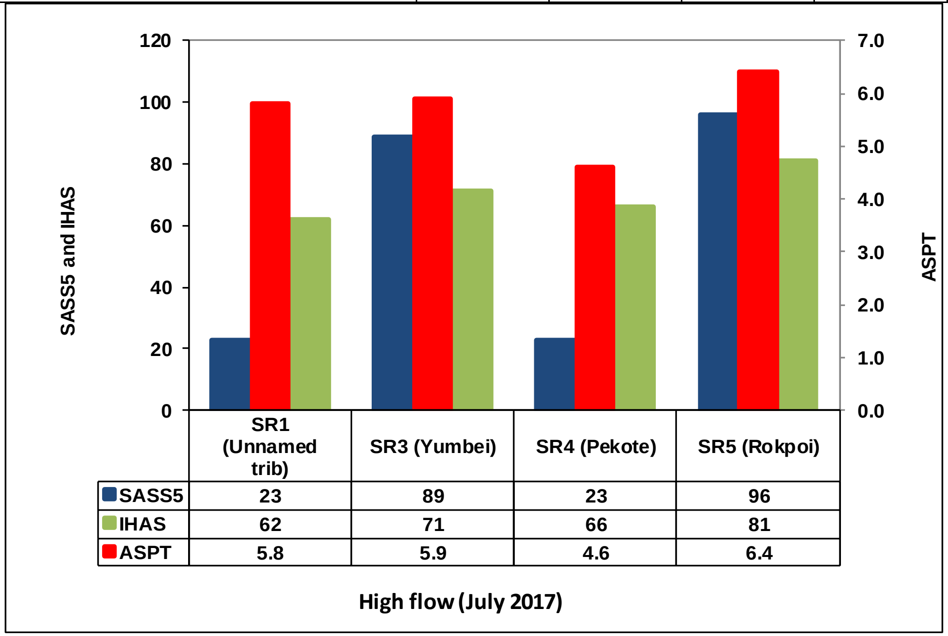



**Figure 25: SASS, ASPT and IHAS scores for assessed sites in SR Area 1during the high flow (July 2017) assessment.**

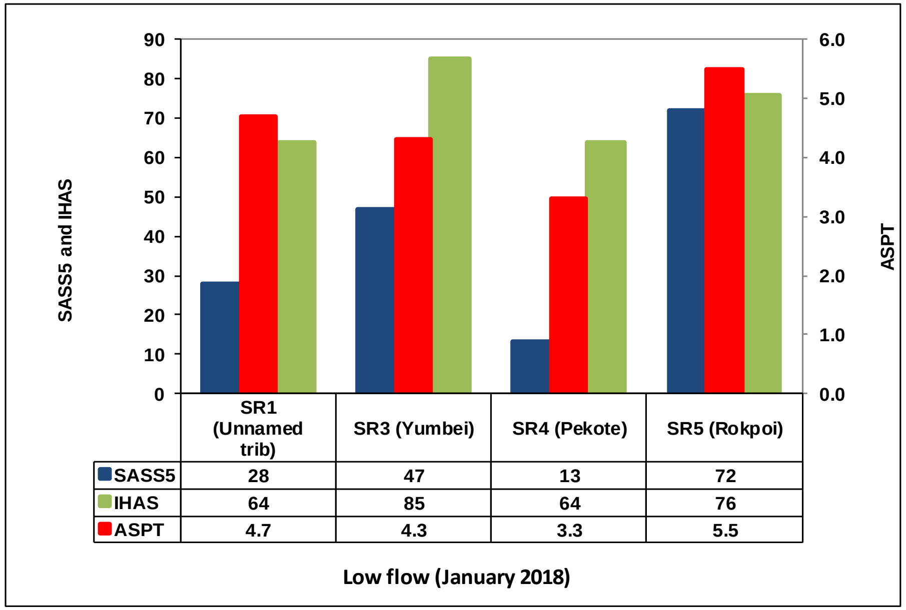



**Figure 26: SASS, ASPT and IHAS scores for assessed sites in SR Area 1 during the low flow (January 2018) assessment.**

**Spatial comparison (compared to reference site SR5)**

- SASS values at all sites were below theoretical reference score (136 during high flow and 82 during low flow) developed based on the collected data;
- When using SR5 as a reference site, SASS5 score at the other sites were also lower during both assessments, but more significantly so during the low flow assessment in January 2018;

- During both assessment the SASS value at site SR3 showed the lowest percentage variation compared to that from SR5. This supports the notion that conditions at site SR3 stabilised (i.e. reached an "equilibrium") with the older pit that discharges into the system. In comparison, the pits that discharge near sites SR1 and SR4 are younger and were closer to the sampling points respectively, and still have a negative impact on the downstream environment;
- During high flow (July 2017) ASPT values at sites SR1 and SR4 were below theoretical reference (1.7% and 22% respectively), whilst this was true for sites SR3 and SR4 (-6.5% and -28.3%, respectively) during the low flow assessment (January 2018). During high flow ASPT score at site SR3 were on par with expected reference. During both assessments the ASPT score at SR5 was higher than the calculated reference value. When using SR5 as a reference site, ASPT scores at the other sites were lower during both assessments. Sensitivity thus largely follows that same trends as diversity, However, low flow assessment data shows that seasonal variability is likely, with lowest variability in in ASPT score evident at site SR1 during January 2018;
- Throughout the area SASS score (indicative of diversity) is more significantly reduced than expected compared to ASPT score (indicative of sensitivity). It is possible that general poor water quality (low pH) may affect diversity, but impact on sensitivity would be expected to be greater if effects on EC and pH were significant; and
- When using SR5 as a reference site, IHAS score at the other sites were lower during the high flow assessment in July 2017, whilst the same was true for sites SR1 and SR4 during the low flow January 2018 assessment. IHAS score increase and decrease generally correlates with that of the SASS score. Habitat suitability is thus considered a significant contributor to trends in diversity, with habitat availability also linked to flow rate, in turn resulting in seasonal fluctuations. However, habitat suitability was generally classified as adequate to excellent, yet SASS scores were much lower than expected. It is likely that other factors such as turbidity (specific reference to site SR1) and impacts on instream flow, resulting from pit decant (or the lack thereof in the dry season), as well as reduced vegetation cover, also have an effect on trends observed;

**Temporal comparison (high flow versus low flow assessments)**

- With the exception of site SR1, SASS score decreased at all sites during the low flow assessment. The smallest percentage variation was observed at reference site SR5. This suggests seasonal impact on macro-invertebrate diversity due to low flow, but also indicated that potential impact from mining may be greater during low flow conditions;
- The same is true for ASPT score, which is a measure of sensitivity. ASPT score decreased at all sites. Once again lowest percentage variation was reported from reference site SR5; and
- IHAS score increased at sites SR1(3.2%) and SR3 (19.7%), but decreased at sites SR4 (3.0%) and SR5 (6.2%). Despite the increase at SR3, SASS score decreased, indicating that habitat suitability is potentially not the most important ecological driver at this site, and that change may be related to water quality impacts and impacts on flow.

**Conclusion**

- Diversity was low (especially during the low flow assessment at sites SR3 and SR4), but the taxa present showed a high average sensitivity. (i.e. lower SASS scores and higher ASPT scores). Factors affecting SASS scores may include low pH, temporal increase in EC (specific reference to site SR3), lower habitat suitability, turbidity (specific reference to site SR1) loss of habitat and cover and changes to instream flow. Pits that decant close to sites SR1 and SR4 are younger than that at SR3. During the high flow assessment higher scores were reported from reference site SR5 (no decant) followed by site SR3. During the low flow assessment higher scores were reported from reference site SR5 (no decant), followed by site SR1, indicating seasonal fluctuations likely related to changes in flow, which may potentially compound and potential mining activity impact during such periods; and
- Trends suggest that the potential impact associated with decant decreases with pit age in the long term (approximately 20 years). The distance from the decant point is also a key factor and impact severity.

**Table 15: Summary results of all aquatic assessment sites in SR Area 1 – MIRAI versus SASS assessment.**

<table>
<tr><th rowspan="3">Site</th><th colspan="4">MIRAI</th><th colspan="4">SASS</th><th rowspan="3">Comments</th></tr>
<tr><th colspan="2">High flow<br>(Jul 2017)</th><th colspan="2">Low flow<br>(Jan 2018)</th><th colspan="2">High flow<br>(Jul 2017)</th><th colspan="2">Low flow<br>(Jan 2018)</th></tr>
<tr><th>Score</th><th>Category</th><th>Score</th><th>Category</th><th>Score</th><th>Category</th><th>Score</th><th>Category</th></tr>
<tr><td>SR1</td><td>38.63</td><td>E</td><td>39.20</td><td>E</td><td>23</td><td>F</td><td>28</td><td>E</td><td rowspan="4">➢ Both MIRAI and SASS category classifications follow the same trend during both assessments. Reference site SR5 has the highest classification, followed by sites SR3, SR4 and SR1;<br>➢ However, it must be noted that the calculated reference SASS and ASPT scores for the low flow assessment were significantly lower than that calculated for the high flow assessment. Results thus indicate that flow is a major ecological driver in this system;<br>➢ Site SR5 is not affected by any dredge pond decant. Site SR3 is affected by decant but from a pit that can be considered old. Both sites SR1 and SR4 are affected by decant from pits that are near to the assessment points; and<br>➢ As was also observed during visual inspection (see photographic record), it would appear that conditions at site SR3 reached an “equilibrium” with decant from the pit (particularly during the high flow assessment). From this it can be deduced that long-term impact from pits on water quality and macro-invertebrate community integrity is likely limited, but can be compounded during low flow conditions.</td></tr>
<tr><td>SR3</td><td>62.41</td><td>C</td><td>51.72</td><td>D</td><td>89</td><td>C</td><td>47</td><td>C</td></tr>
<tr><td>SR4</td><td>39.10</td><td>E</td><td>27.45</td><td>E</td><td>23</td><td>F</td><td>13</td><td>F</td></tr>
<tr><td>SR5</td><td>79.58</td><td>B</td><td>77.59</td><td>C</td><td>96</td><td>B</td><td>72</td><td>A</td></tr>
</table>

**Table 16: Results of all aquatic assessment sites in SR Area 1 – Diatom assessment summary during high flow (July 2017).**

| Abundance of taxa | | | | |
|---|---|---|---|---|
| **Taxa** | **% Relevant abundance** | | | |
| | **SR1** | **SR3** | **SR4** | **SR5** |
| *Achnanthes* J.B.M. Bory de St. Vincent | 0 | 0 | **10** | 0 |
| *Brachysira wygaschii* Lange-Bertalot | **5** | 0 | **5** | 0 |
| *Eunotia bilunaris* (Ehr.) Mills var. bilunaris | 0 | 0 | **8** | 0 |
| *Eunotia flexuosa* (Brebisson) Kützing | 0 | 0 | **25** | 0 |
| *Eunotia minor* (Kützing) Grunow in Van Heurck | 0 | **60** | **5** | **20** |
| *Eunotia pectinalis* (Kütz.) Rabenhorst var.undulata | 0 | 0 | 0 | **5** |
| *Eunotia rhomboidea* Hustedt | 0 | **31** | **6** | **52** |
| *Frustulia crassinervia* (Breb.) Lange-Bertalot et Krammer | **10** | 0 | **10** | 0 |
| *Navicula dutoitana* Cholnoky | **14** | 0 | **6** | 0 |
| *Navicula heimansioides* Lange-Bertalot | **5** | 0 | 0 | 0 |
| *Nitzschia linearis*(Agardh) W.M.Smith var.linearis | 0 | 0 | **6** | 0 |
| *Nitzschia palea* (Kützing) W.Smith | **5** | 0 | 0 | 0 |
| **Specific Pollution Sensitivity Index (SPI) score classification** | | | | |
| Specific Pollution Sensitivity Index score | 16.9 | 18.4 | 16.8 | 17.7 |
| Pollution Tolerant Valves Percentage (% PTV) | 10.5 | 1.0 | 13.8 | 3.8 |
| Class | High quality | High quality | High quality | High quality |
| **Ecological Category** | **A/B** | **A** | **A/B** | **A** |

**Table16 (continued): Results of all aquatic assessment sites in SR Area 1 – Diatom assessment summary during high flow (July 2017).**

- Based on the OMNIDIA results, the water quality at site SR3 and site SR5 are of an Ecological Category A (High quality) and site SR1 and site SR4, an Ecological Category A/B (High quality);
- Site SR3 and site SR5 have a negligible % PTV (1 and 3.8 % PTV, respectively) which suggests there is minor organic content at these sites. Site SR1 and site SR4 have slightly higher organic content (10.5 and 13.8 % PTV, respectively) compared to site SR3 and site SR5;
- At site SR1 and site SR4 is the presence of dominant taxa which occur in oligotrophic waters with low electrolyte content such as *Frustulia crassinervia* and *Brachysira wygaschii*. Taxon *Navicula dutoitana*, also dominant at these sites, has an unknown ecology;
- At site SR1, recorded are sub-dominant taxa of the *Pinnularia* genus as well as sub-dominant taxa *Encyonopsis raytonensis*, *Encyonopsis cesatii* and *Stenopterobia delicatissima*, which are taxa associated with acidic, well-oxygenated, oligotrophic, electrolyte poor conditions;
- Recorded at sites SR3, SR4 and SR5 are dominant taxa of the *Eunotia* genus (significantly more at Site SR3) such as *Eunotia minor*, *Eunotia rhomboidea* and *Eunotia flexuosa*. This genus is found in acidic, oligotrophic, electrolyte-poor waters. At Site SR1, the *Eunotia* genus is sub-dominant;
- Recorded at site SR1 and site SR4 is taxon *Nitzschia palea* (dominant at site SR1 and sub-dominant at site SR4), which suggests that these sites may be more elevated in electrolytes, nutrients and organics compared to site SR3 and site SR5;
- At site SR1 and site SR5, the minor presence of *Hippodonta capitata, Cocconeis placentula* var. *placentula* and *N. amphibia* may point to slight nutrient and electrolyte inputs from anthropogenic activities in the surrounding catchment;
- At site SR4 is the presence of dominant taxon *Nitzschia linearis* var. *linearis* which favour oxygen-rich waters;
- Conclusion**:** All sites presented with a very high Ecological Category classification with consideration of diatom community taxa composition. However, the Category obtained for sites SR1 and SR4 were slightly lower, indicating minor signs of disturbance at these sites. There were, however, no taxa present in SR Area 1 that indicate mining impact, with impact suggested pertaining to input of nutrients, electrolytes and organics. Diatom data thus suggests potential slight impact from anthropogenic sources other than mining; and
- Trends suggest potential impact associated with decant decreases with pit age in the long term (approximately 20 years) impact from pit decant on water quality and the associated impact on the aquatic ecology is not significant. The distance from the decant point is also a key factor.

**Table 17: Results of all aquatic assessment sites in SR Area 1 – Diatom assessment summary during low flow (January 2018).**

| Abundance of taxa | | | | |
|---|---|---|---|---|
| **Taxa** | **% Relevant abundance** | | | |
| | **SR1** | **SR3** | **SR4** | **SR5** |
| *Adlafia bryophila* (Petersen) Moser Lange-Bertalot & Metzeltin | 0 | **8** | 0 | **2** |
| *Achnanthidium eutrophilum* (Lange-Bertalot) | 0 | **2** | 0 | 0 |
| *Achnanthidium macrocephalum* (Hust.) Round & Bukhtiyarova | 0 | **2** | 0 | **1** |
| *Amphora veneta Kützing* | 0 | **2** | 0 | 0 |
| *Brachysira wygaschii* Lange-Bertalot | **6** | 0 | **14** | 0 |
| *Cocconeis placentula* Ehrenberg *var.euglypta* (Ehr.) Grunow | **1** | 0 | 0 | 0 |
| *Ctenophora pulchella (*Ralfs ex Kütz.) Williams et Round | 0 | **2** | 0 | 0 |
| *Eunotia bilunaris* (Ehr.) Mills *var. bilunaris* | **3** | **12** | **11** | **10** |
| *Eunotia flexuosa(*Brebisson)Kützing | 0 | **10** | **37** | **1** |
| *Eunotia formica* Ehrenberg | **1** | **6** | 0 | **3** |
| *Eunotia incisa* Gregory *var.incisa* | 0 | **4** | 0 | **21** |
| *Eunotia pectinalis* (Kütz.)Rabenhorst *var.undulata* (Ralfs) Rabenhorst | 0 | **19** | **2** | **10** |
| *Eunotia rhomboidea* Hustedt | 0 | **15** | **1** | **40** |
| *Frustulia saxonica* Rabenhorst | **47** | **4** | **5** | **5** |
| *Frustulia vulgaris* (Thwaites) De Toni | **7** | **6** | **29** | **3** |
| *Gomphonema parvulum* Kützing | 0 | **2** | 0 | 0 |
| *Navicula heimansioides* Lange-Bertalot | **18** | **2** | 0 | **5** |
| *Nitzschia pura* Hustedt | **5** | **4** | 0 | 0 |
| *Pinnularia divergens* W.M.Smith | **12** | **2** | **3** | 0 |
| *Sellaphora pupula* (Kützing) Mereschkowksy | **1** | 0 | 0 | 0 |

**Table17 (continued): Results of all aquatic assessment sites in SR Area 1 – Diatom assessment summary during low flow (January 2018).**

| **Specific Pollution Sensitivity Index (SPI) score classification** | | | | |
|---|---|---|---|---|
| Specific Pollution Sensitivity Index score | 19.4 | 17.4 | 17.9 | 19.1 |
| Pollution Tolerant Valves Percentage (% PTV) | 4.5 | 5.8 | 0 | 0 |
| Class | High quality | High quality | High quality | High quality |
| **Ecological Category** | **A** | **A** | **A** | **A** |

**SR1**

- The diatom community indicated no pollution impact on water quality in terms the assessed diatom indices.
- The IPS and BDI were very high, indicating good water quality, and very low %PT of 4.5% indicating a negligible number of specifically organic pollution tolerant diatom taxa in the community.
- Considering the ecological indicator values, the community classed as acidobiontic, indicating a preferred continuous pH of <5.5, acidic water.
- The other ecological indicators infer fresh water conditions (<0.2% salinity), low concentrations of organically bound nitrogen (nitrogen autotrophic taxa) and continuously high oxygen concentration (100% saturation).
- According to the ecological indicators, the community is adapted to oligotrophic conditions.

**SR3**

- The diatom community indicated no pollution impact on water quality in terms the assessed diatom indices.
- The IPS and BDI were very high, indicating good water quality, and very low %PT of 5.8% indicating a negligible number of specifically organic pollution tolerant diatom taxa in the community.
- Considering the ecological indicator values, the community classed as acidophilous, indicating a preferred continuous pH of <7, slightly acidic water.
- The other ecological indicators infer fresh water conditions (<0.2% salinity), low concentrations of organically bound nitrogen (nitrogen autotrophic taxa) and continuously high oxygen concentration (100% saturation).
- According to the ecological indicators, the community is adapted to mesotrophic conditions.
- The site showed very little diatom material in the collected sample, although displayed relatively high diversity in comparison to the other sites. Diversity is not, however, necessarily an indicator of good water quality where diatom indices are concerned.

**SR4**

- The diatom community indicated no pollution impact on water quality in terms the assessed diatom indices.
- The IPS and BDI were very high, indicating good water quality, and %PT of 0% indicating a "no specifically organic pollution tolerant diatom taxa" in the community.
- Considering the ecological indicator values, the community classed as acidophilous, indicating a preferred continuous pH of <7, slightly acidic water.
- The other ecological indicators infer fresh water conditions (<0.2% salinity), low concentrations of organically bound nitrogen (nitrogen autotrophic taxa) and continuously high oxygen concentration (100% saturation).
- According to the ecological indicators, the community is adapted to oligotrophic to mesotrophic conditions.
- The sample from the site displayed high concentration of diatom frustule abnormalities (deformations) of 4.5%. This infers impact from metals and / or pesticides and thus further water quality analysis to qualify and quantify this perturbation is advised.

**SR5**

- The diatom community indicated no pollution impact on water quality in terms the assessed diatom indices.
- The IPS and BDI were very high, indicating good water quality, and %PT of 0% indicating a "no specifically organic pollution tolerant diatom taxa" in the community.

- Considering the ecological indicator values, the community classed as acidophilous, indicating a preferred continuous pH of <7, slightly acidic water.
- The other ecological indicators infer fresh water conditions (<0.2% salinity), low concentrations of organically bound nitrogen (nitrogen autotrophic taxa) and continuously high oxygen concentration (100% saturation).
- According to the ecological indicators, the community is adapted to oligotrophic conditions.

**Comparison to the wet season results (high flow in July 2017)**

- Diatom community analysis in July 2017 indicated a “high quality” class for all sites, with ecological category ranging between A/B and A. This is similar to the dry season results (January 2018), where the overall ecological status of the sites was found to be “not polluted”.
- During July 2017 the Category obtained for sites SR1 and SR4 (A/B) were slightly lower than that at SR3 and SR5 (A), indicating minor signs of disturbance at these sites. During the January 2018 assessment, the sample from site S4 displayed high concentration of diatom frustule abnormalities (deformations), again suggesting potential impact at this site.
- Trends suggest potential impact associated with decant decreases with pit age in the long term (approximately 20 years), but impact from pit decant on water quality and the associated impact on the aquatic ecology is not significant. The distance from the decant point is also a key factor and impact severity is considered to be most significant within 3 km of the decant point.

**Table 18: Results of all aquatic assessment sites in SR Area 1 – Ichthyofauna.**

| | |
|---|---|
|  **Figure 27: Adult Guinean tilapia (*Tilapia guineensis*)** |  **Figure 28: Suspected juvenile Guinean tilapia (*Tilapia guineensis*)** |
| **Know to occur at sites:** | **SR1** |
| The IUCN red list for threatened species website (http://www.iucnredlist.org/details/60690/0) provides the following information: *Tilapia guineensis* is known from the coastal waters from the mouth of the Senegal River to mouth of the Cuanza River (Angola). This species has a wide distribution, with no known major widespread threats.<br>According to the IUCN *Tilapia guinensis* is a benthopelagic species that feeds on shrimps, bivalves, plankton and detritus. This species is oviparous. Substrate guarding of eggs as a form of parental care is done by both male and female.<br>**IUCN threat Status: Least Concern**<br>http://www.iucnredlist.org/details/182223/0<br>**Note on aquaculture:** This species was introduced together with *Tilapia niloticus* as part of SRL's aquaculture programme. For more details, please refer to section dealing with *T. niloticus* on next page. | |

<table>
<tr><td colspan="2"><br>**Figure 29:** ***Oreochromis niloticus***<br>Not collected, but local fishermen harvest fish from the old dredge ponds stocked with the fish</td><td colspan="2"><br>**Figure 30:** ***Clarias sp***<br>Not collected/photographed, but local fishermen confirmed presence (photograph from personal collection)</td></tr>
<tr><td>**Known to occur at sites:**</td><td>**SR1 and dredge ponds where introduced**</td><td>**Know to occur at sites:**</td><td>**SR1**</td></tr>
<tr><td colspan="2">The IUCN red list for threatened species website indicate that this taxon has not yet been assessed for the IUCN red list. However, considering how widespread it has been distributed for aquaculture purposes, conservation status can most likely be considered to be of least concern."<br><br>**IUCN threat Status: Not Yet Assessed**<br><br>**Note on aquaculture:** This species was introduced in pits together with *Tilapia guinensis* for the establishment of an aquaculture program. The aquaculture program is managed by SRL Department Community and Rehabilitation, section aquaculture. Based on the records they kept, the program can be considered a success, with 289 582 fish harvested during 2015 and 295 750 fish harvested</td><td colspan="2">The IUCN red list for threatened species website provides the following information: "Due to its wide range and ubiquitous habitat demands, this species does not qualify for Near Threatened or a Threatened category. Therefore, it is assessed as Least Concern."<br><br>**IUCN threat Status: Least Concern**<br><br>http://www.iucnredlist.org/details/166023/0</td></tr>
</table>

| | |
|---|---|
| during 2016. With decant these species also colonised the river systems downgradient of the dredge ponds. | |

**Figure 31: *Brycinus longipinnis* (Robber).**

| | |
|---|---|
| ***Brycinus longipinnis* collected from sites:** | **SR1, SR3 and SR5** |

*Brycinus longipinnis* is distributed along the entire Atlantic coast, from Gambia to Congo. *Brycinus longipinnis* is generally found in the upper and lower reaches of big rivers and also in estuarine zones of mixohaline waters. It is the only *Brycinus* species known to penetrate small rivers and streams (Paugy et al 2003).

**IUCN threat Status: Least Concern**

No known major widespread threats.

http://www.iucnredlist.org/details/182330/0

<table>
<tr><td colspan="2"><br>**Figure 32: African pike (*Hepsetus odoe*) (top).**</td><td colspan="2"><br>**Figure 33: Reticulate knifefish *Papyrocranus afer* (middle)**</td></tr>
<tr><td>***Hepsetus odoe* caught by local fisherman from sites:**</td><td>**SR1**</td><td>***Papyrocranus afer* caught by local fisherman from sites:**</td><td>**SR1**</td></tr>
<tr><td colspan="2">The IUCN red list for threatened species website provides the following information: This species has a wide distribution from Senegal down west and central Africa to Southern Africa, with no known major widespread threats. Although it is now thought to be a species complex, it is likely that all species are widely distributed and not facing any major threats.<br>*Hepsetus odoe* occurs in most coastal rivers, lakes and swamps where it prefers quiet, deep water, like channels and lagoons of large floodplains. Juveniles and fry inhabit well-vegetated marginal habitats. The adults feed on fish, juveniles feed on small invertebrates and fish. Multiple spawner; breeds over the summer months. It is relatively short-lived, only 4-5 years (Skelton 1993). It builds a free-floating bubblenest.<br><br>**IUCN threat Status:** **Least Concern**<br>It has also been assessed regionally as Least Concern for central, southern and western Africa.<br>http://www.iucnredlist.org/details/167942/0</td><td colspan="2">The IUCN red list for threatened species website provides the following information:<br>**Central Africa:** In Lower Guinea, *Papyrocranus afer* is found in the Cross Meme, Wouri and Sanaga River basins in Nigeria and Cameroon.<br>**Western Africa:** It is found in coastal drainages throughout West Africa, from the Niger, Benue, and Niger delta, and in most of the West African coastal rivers in Senegal/Gambia. It is absent from the Volta River basin, and in Togo and from Lake Chad basin.<br>**IUCN threat Status:** **Least Concern**<br>This species has a wide distribution, with no known major widespread threats<br>http://www.iucnredlist.org/details/181889/0<br><br>**Note:** In photograph background, some silver fish are visible. These were *Carlarius parkii*, a marine catfish that can also survive in brackish waters. Because they a marine species, they are not considered in this report but are considered least concern by the IUCN.</td></tr>
</table>

**Figure 34: *Hemichromis fasciatus***

| ***Hemichromis fasciatus* collected from sites:** | **SR1** |
|---|---|

The IUCN red list for threatened species website provides the following information: native to a large portion of north, west, central and Southern Africa.

This species inhabits permanent floodplain lagoons with clear water, occasionally on rocky streams, occasionally in standing deep water, common in shallow swamps. According to contributors to the IUCN database, the species is monogamist keeping and protecting eggs and alevins but not practising oral incubation. According to the IUCN, the eggs are fixed on an immersed support, in a clean place, with the shelter of the current, a depth from 10 to 20 cm. The reproduction of the species seems spread out throughout the year with the proportion of mature individuals constantly remaining relatively low.

**IUCN threat Status: Least Concern** http://www.iucnredlist.org/details/182187/0

**Figure 35: *Pelvicachromis humilis* – Not definitive**

| **Low abundances collected from sites:** | **SR3, SR4 and SR5** |
|---|---|

The IUCN red list for threatened species website provides the following information: *Pelvicachromis humilis* known from most hydrographic basins in western Africa. This species is carnivorous, and very aggressive towards cichlids. It prefers sheltered water and occurs in mud-bottomed and sand-bottomed canals some distance inland from the coast, associated with areas of intact or recently disturbed forest cover.

**Least Concern** http://www.iucnredlist.org/details/182528/0

**Figure 36: Killifish - *Epiplatys sp.***

| | |
|---|---|
| **Collected from sites in high abundances:** | **SR3, SR4 and SR5** |

The IUCN red list for threatened species website provides the following information: It is known from the south of Guinea and Sierra Leone and the south-west of Liberia. The species is found at many locations. This species populates the marshy sectors and the small rivers of the coastal plains generally under the forest cover.

**IUCN threat Status:** **Least Concern**

http://www.iucnredlist.org/details/182633/0

| | | | |
|---|---|---|---|
| <br>**Figure 37: *Petrocephalus bovei*** | | <br>**Figure 38: *Hemichromis bimaculatus* – (Photograph Paugy *et al*, 2003)** | |
| **Collected from sites:** | **SR5 (1 specimen)** | ***Hemichromis guttatus* Observed:** | **SR1** |
| This species has a wide distribution with no known major widespread threats and is therefore listed as Least Concern. No information on the ecology of this fish species is currently available.<br>**IUCN threat Status: Not Yet Assessed**<br>http://www.iucnredlist.org/details/181684/0 | | The IUCN red list for threatened species website provides the following information: *Hemichromis bimaculatus* known from most hydrographic basins in western Africa. This species is carnivorous, and very aggressive towards cichlids. It prefers sheltered water and occurs in mud-bottomed and sand-bottomed canals some distance inland from the coast, associated with areas of intact or recently disturbed forest cover.<br>**IUCN threat Status: Least Concern**<br>http://www.iucnredlist.org/details/182628/0 | |

**Table 19: SR Area 1 ichthyofauna summary.**

| |
|---|
| The following conclusions can be drawn from fish collection efforts:<br>➢ Pits are utilised as an aquaculture resource. In this regard, *Tilapia guineensis* and *Oreochromis niloticus* were introduced to these pits as part of an active aquaculture program. Records supplied indicate that the aquaculture effort can be considered effective (289 582 fish harvested during 2015, and 295 750 fish harvested during 2016);<br>➢ However, the stocking efforts also led to the introduction of these alien species to the aquatic systems in the area, as was evident from collections and communication with subsistence fishermen at site SR1;<br>➢ In total seven fish species were reported from site SR1 and SR5 (excluding the brackish water fish captured at SR1), three species from site SR3 and SR4, two species from site SR4;<br>➢ Overall the aquatic resources in SR Area 1 thus presented with a fair prevalence and diversity of fish species. At site SR5, the spatial reference site, one taxon was collected which was not reported from the other sites (a representative of the family *Petrocephalus bovei*); and<br>➢ Of the taxa identified, the conservation status of all are classified as “Least Concern” or “not yet assessed”. No species of conservation concern were identified. |

**Table 20: SR Area 1 overall aquatic assessment summary.**

| Parameter | Site | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | High flow assessment (July 2017) | | | | Low flow assessment (January 2018) | | | |
| | SR1 | SR3 | SR4 | SR5 | SR1 | SR3 | SR4 | SR5 |
| **Water quality** | | | | | | | | |
| pH (value) | 5.7 | 4.9 | 5.1 | 5.5 | 5.5 | 4.8 | 4.8 | 5.4 |
| EC (mS/m) | 2.4 | 2.0 | 2.7 | 1.2 | 2.4 | 5.2 | 3.3 | 2.1 |
| pH (percentage variation from SR5 reference value) | **+3.1** | **-11.3** | **-8.0** | **NA** | **+1.1** | **-11.7** | **-10.4** | **NA** |
| EC (percentage variation from SR5 reference value) | **+100** | **+66.7** | **+125** | **NA** | **+14.3** | **+147.6** | **+57.1** | **NA** |
| **Habitat assessment** | | | | | | | | |
| Invertebrate Habitat Assessment (IHAS) classification | **Adequate/ Fair** | **Good** | **Good** | **Excellent** | **Adequate/ Fair** | **Excellent** | **Adequate/ Fair** | **Excellent** |
| Instream Index of Habitat Integrity (IHI) | **C** | **B** | **C** | **A** | | | | |
| Riparian Index of Habitat Integrity (IHI) | **D** | **C** | **D** | **B** | | | | |
| **Macro-invertebrate community integrity** | | | | | | | | |
| South African Scoring System version 5 (SASS5) Ecological Category | **F** | **C** | **F** | **B** | **E** | **C** | **F** | **A** |
| Macro-Invertebrate Response Assessment Index (MIRAI) Ecological Category | **E** | **C** | **E** | **B** | | | | |
| **Diatom community integrity** | | | | | | | | |
| Specific Pollution Sensitivity Index (SPI) Ecological Category | **A/B** | **A** | **A/B** | **A** | **A** | **A** | **A** | **A** |
| **Fish community integrity** | | | | | | | | |
| Number of taxa | **7** | **3** | **2** | **5** | **10** | **17** | **8** | **11** |
| **Ecostatus Integration Tool analysis** | | | | | | | | |
| **Integrated Ecostatus Category** | **D** | **C** | **D/E** | **B** | **D** | **C/D** | **D/E** | **C/B** |

**Table 20 (continued): SR Area 1 overall aquatic assessment summary (continued).**

| Synopsis |
|---|
| ➢ The overall Integrated Ecostatus Category aims to define the overall aquatic ecological integrity in a single category. This result is expanded upon below. Please note that for the January 2018 Integrated Ecostatus Category assessment, the riparian zone IHI value were adopted from the July 2017 assessment results, but the MIRAI scores from January 2018 were employed:<br>➢ Water quality is fair throughout SR Area 1, with low EC and also naturally low pH. However, EC at sites SR1, SR3 and SR4 is higher compared to that at reference site SR5 (most notably during low flow in January 2018), with pH at sites SR3 and SR4 lower compared to conditions at SR5 (similar for both assessments). Pit decant may potentially contribute to slightly elevated EC and variability in pH, but absolute values are considered to be largely natural. However, potential mining impact (especially in terms of EC) seems to be compounded during low flow conditions;<br>➢ Habitat suitability in the concession for maintaining a diverse macro-invertebrate community varies from adequate to excellent. However, despite suitable habitat diversity of the aquatic macro-invertebrate community was generally lower than expected, but the community was dominated by sensitive taxa. Indices presented with poor Ecological Category classifications at sites SR1 and SR4, a slightly higher classification at site SR3 and the best classification at reference site SR5. The same trend was evident for both assessments, but with a significant decrease in SASS score and slight decrease in ASPT score evident during the low flow assessment (January 2018). This likely due to reduced flow affecting sensitive taxa and hence also macro-invertebrate diversity;<br>➢ Diatom community results during high flow (July 2017) also present lower classifications at sites SR1 and SR4, indicating potential limited impact. However, species composition does not imply impact from mining, but rather from other anthropogenic activities resulting in nutrient, electrolyte and organic material input. Results from the low flow assessment (January 2018) indicate the overall ecological status of the sites was found to be “not polluted”;<br>➢ Impact on macro-invertebrate diversity at sites SR1, SR4 and to a lesser degree SR3, likely results from a combination of factors, including EC and pH variation, flow variability and turbid conditions (specific reference to site SR1) depending on rate of pit decant as well as age of the pit. Seasonal effects are evident, with greater impact on water quality (notably elevated EC at sites SR3, SR4 and SR5) during low flow conditions;<br>➢ Despite apparent negative impact on macro-invertebrate diversity, the ichthyofauna of SR Area 1 consists of a fair variety of taxa, with taxa occurrence and prevalence dependant on system size, depth and flow parameters. However, possible chronic impacts on fish community integrity at sites SR3 and SR4 is possible, and needs to be investigated further; and<br>➢ In conclusion: The Rokpoi Stream (SR5) can be defined as a largely Natural system although some modifications have occurred. Data suggests that the ecostatus at site SR3 (moderately modified) is improved in relation to that of SR1 and SR4 (Largely modified to seriously modified), with the pit that decants in that system older than the pits impacting sites SR1 and SR4. Trends suggest potential impact associated with decant decreases with pit age in the long term (approximately 20 years) impact from pit decant on water quality and the associated impact on the aquatic ecology is not significant. The distance from the decant point is also a key factor and impact severity is considered to be most significant within 3 km of the decant point. Seasonal effects in terms of elevated EC (potentially evapoconcentration) may further compound any potential mining impacts during the dry season. |

## 3.3 Ecological Importance and Sensitivity Assessment

The EIS method considers a number of biotic and habitat determinants surmised to indicate either importance or sensitivity. The determinants are rated according to a four-point scale, with 1 indicating lowest importance/sensitivity, and 4 highest. The average of the resultant score is calculated to derive the EIS category.

**Table 21: Aquatic EIS determination for SR Area 1.**

| Criteria | Scoring rating for sites: | | | |
|---|---|---|---|---|
| | **SR1** | **SR3** | **SR4** | **SR5** |
| **Biotic Determinants** | | | | |
| Rare and endangered biota | 1 | 1 | 1 | 1 |
| Unique biota | 1 | 2 | 0 | 2 |
| Intolerant biota | 3 | 3 | 2 | 4 |
| Species/taxon richness | 1 | 3 | 1 | 3 |
| **Aquatic Habitat Determinants** | | | | |
| Diversity of aquatic habitat types or features | 1 | 2 | 1 | 4 |
| Refuge value of habitat type | 2 | 2 | 1 | 4 |
| Sensitivity of habitat to flow changes | 1 | 2 | 1 | 2 |
| Sensitivity of flow-related water quality changes | 2 | 2 | 2 | 3 |
| Migration route/corridor for instream and riparian biota | 1 | 2 | 1 | 2 |
| Nature Reserves, Natural Heritage sites, Natural areas, PNEs | 0 | 0 | 0 | 1 |
| **RATING AVERAGE** | **1.3** | **1.9** | **1.0** | **2.6** |
| **EIS CATEGORY** | **Moderate** | **Moderate** | **Moderate** | **High** |

Based on the findings of the assessment it is evident that aquatic features associated with SR Area 1 have an EIS which can be considered either as moderate (sites previously impacted by mining activities) or as high (reference site not impacted by mining activities).

Moderate categories (sites SR1, SR3 and SR4) can generally be described as systems or reaches that are considered to be unique on a provincial or local scale due to biodiversity (habitat diversity, species diversity, unique species, rare and endangered species). These rivers (in terms of biota and habitat) are not usually very sensitive to flow modifications and often have substantial capacity for use.

High categories (site SR5) can generally be described as systems or reaches that are considered to be unique on a national scale based on their biodiversity (habitat diversity, species diversity, unique species, rare and endangered species). These rivers (in terms of biota and habitat) may be sensitive to flow modifications, but in some cases may have substantial capacity for human use.

# 4 RESULTS OF WATERCOURSE ASSESSMENT

## *4.1 System Definition and Characterisation*

The watercourses and associated wetland and riparian features identified within SR Area 1 were classified (according to the Wetland Classification System [Ollis *et al*, 2013] outlined in Appendix B of this report) as Inland Systems falling within the Northern Upper Guinea Aquatic Ecoregion.

Numerous drainage systems were identified throughout the area investigated. The drainage systems were all located in the valley bottom positions. The actual drainage features consisted of both systems with channelled flow, mostly the larger systems, as well as systems with more diffuse flow, mostly smaller systems flowing beneath trees within areas best defined as riparian zones. The drainage systems in the area are characterised by a mosaic of riparian and wetland vegetation. The systems are however dominated by characteristics best defined as riparian forest or secondary riparian forest in various stages of succession. Within these areas as well as the areas with less dense tree growth, the soils often have increased concentrations of organic material. For the purposes of this study, it was decided to assess the watercourses on a system level and group them into similar groups in relation to their position in the landscape and in relation to the mining activities, within SR Area 1. This method was chosen as opposed to assessing each hydrogeomorphic unit individually as there are too many systems to consider on this basis.

Due to the extent and number of these drainage systems, the systems were grouped for the purposes of this assessment. These groupings correspond with the watercourse habitat units as considered in the aquatic ecological assessment and comprise the following:

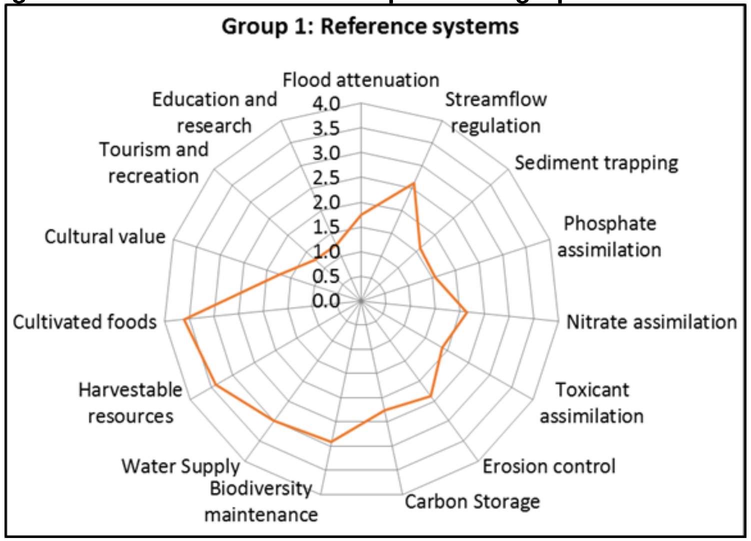
- Group 1: Reference systems, in largely natural condition and as yet unaffected by the existing mining operations although the systems have all been affected by domestic use as well as use in agricultural production;
- Group 2: Impounded systems (due to mining operations);
- Group 3: Systems located downgradient and downstream of impoundments; and
- Group 4: Mangrove forests associated with the Sherbro River.

## 4.2 Freshwater Resource Analyses

The dashboard style reports below summarise the findings of the field verification in terms of relevant aspects (hydrology, geomorphology and vegetation components) of wetland and riparian ecology. The details pertaining to the methodology used to assess the various features is contained in Appendix B of this report. Additionally, the detailed scores that are used to derive the results in the dashboard reports and results for each assessment are presented in Appendix G. These dashboard reports aim to present all the pertinent facts pertaining to each system in as concise and visually appealing a manner as possible and in as limited a space as possible and preferably on one page.

**Table 22: Summary of results pertaining to Group 1 (Reference systems).**

**Ecological & socio-cultural service provision graph:**




**Ecoservice Provision: Moderately High**

This group of watercourses are considered particularly important for the provision of goods and services to the local communities. This includes the provision of harvestable resources such as reeds, water for domestic and farming purposes, and the provision of cultivated foods (rice is grown in many of the wetland areas). However, these watercourses are also deemed important for the provision of various ecological services, including streamflow regulation (i.e. recharge of downstream systems), nutrient and toxicant assimilation, carbon storage and flood attenuation, although the opportunity for the provision of such services is limited due to limited toxicant input and downstream infrastructure risk, for example. Biodiversity maintenance is also considered of importance, as the ecological integrity of this group of wetlands provides ample habitat, refugia and faunal migratory corridors.

**Photograph notes**: Representative photographs of watercourses within Group 1, illustrating the dense vegetation growth in the unaffected wetland and riparian resources.

| | |
|---|---|
| **PES discussion** | **PES Category: A (Natural)**<br>Few modifications to these systems have occurred, and conditions should be considered largely natural, and ecological processes intact. Some minor alterations to the hydraulic processes have occurred, such as the creation of artificial drainage channels and some effects from subsistence agriculture, but the extent and magnitude of these impacts is very low. Similarly, the geomorphology of these systems has been impacted negligibly. Vegetation has been marginally altered due to crop cultivation and the recruitment of alien floral species within abandoned lands, but |

**Watercourse characteristics relating to PES and EIS discussions:**

**a) Hydraulic regime**

Hydrological processes and functions remains largely intact, with few modifications to these systems. Alterations were noted in the form of artificial drainage channels (most likely constructed to either drain water away from cultivated areas or to divert water to crop fields) and some infilling and excavation. Small, informal gravel roads traverse some of these wetlands, but these are not considered to have had a significant impact on the hydraulic regime of the systems.

**b) Geomorphology and sediment balance**

Geomorphology of these systems is considered to be unaltered and in a natural condition, with the exception of a few sites where minor infilling has occurred, and increased run-off is anticipated as a result of vegetation losses associated with subsistence agricultural activities.

**c) Habitat and biota**

Some alterations to the floral community composition and structure have occurred due to disturbances relating to subsistence crop cultivation, and the recruitment (germination of new young plants) of alien floral species in abandoned crop lands due to the historical disturbance. However, the majority of these systems remain relatively intact, providing breeding and foraging habitat, refugia and migratory corridors for an abundant and diverse number of faunal species.

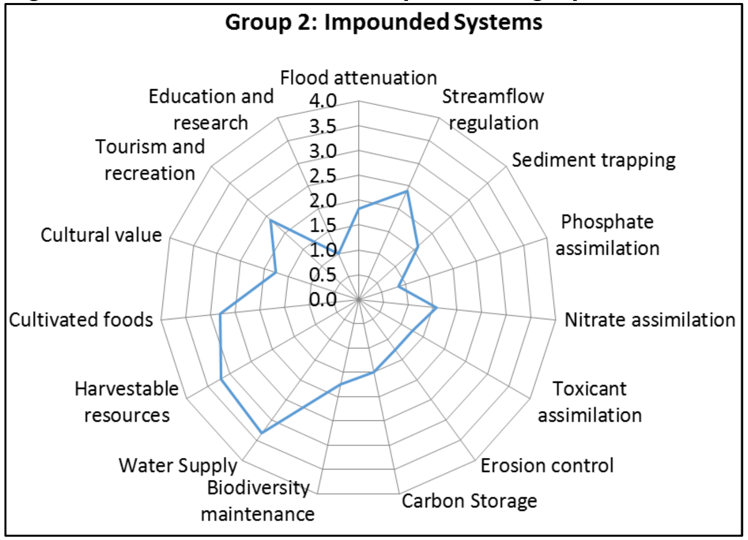
**d) Water quality**

Testing of water quality parameters such as pH, Dissolved Oxygen (DO), EC and turbidity indicated that the water quality within these systems is largely unimpaired with naturally low pH values as well as very

| | | | |
|---|---|---|---|
| | otherwise remains largely natural. The ecology of these systems is considered stable and not currently prone to positive or negative change. | low dissolved salt concentrations. Water in these systems was slightly cooler than the other systems which may be due to the effects of the dense riparian vegetation growth. Please refer to the results in the aquatic assessment for the SR5 point, representative of these systems for more detail. | |
| **EIS discussion** | **EIS Category: High**<br>Considered to be ecologically important from a hydro-functional perspective, and on a local scale, in terms of the contribution it makes to the ecological functions within the landscape. These wetland systems are also deemed important for the provision of goods and services as discussed above, and the ecology is likely to be sensitive to flow, water quality and habitat modifications. | **REC Category** | **REC: A (Natural):**<br>Since these systems are deemed to be in ecologically intact, with few impacts having previously occurred, efforts should be made to retain these conditions in order to ensure the ongoing ecological functioning of the systems.. Should it be impossible to avoid impacting on these systems, then very strict mitigation measures must be implemented throughout all phases of the proposed mining activities in order to minimise the extent and magnitude of such impacts, with the aim of retaining the ecological processes as much as possible. |
| **Preliminary findings and future study requirements:**<br>The systems within Group 1 have been largely unaffected by historical and current mining activities, and as such, contribute to the ecological functioning of SR Area 1 and surrounding areas as a whole. Furthermore, these systems are considered to provide essential goods and services to the local communities which rely very strongly on the systems. | | | |

**Table 23: Summary of results pertaining to Group 2 (Impounded systems).**

**Ecological & socio-cultural service provision graph:**




**Ecoservices Provision:** **Intermediate**

Despite the significantly reduced ecological integrity of this group of watercourses, the provision of goods and services (such as water for domestic use, recreation and fish harvesting) to the community is considered very important. Whilst the provision of ecological functions, such as nutrient and toxicant assimilation and erosion control, are deemed of limited importance. This is due to the reduced ecological integrity of these systems, and in particular, ongoing disturbances in the western and southern systems (in the vicinity of Lanti wet mine and Gangama dry mine). The reduced ecological integrity does not have a significant impact on all aspects of socio-cultural service provision however, the local community has raised concerns through the stakeholder engagement process that impacts on water quality are a concern. The dredge ponds continue to supply sufficiently large areas with appropriate water quality to provide water and support fishing, especially after the introduction of tilapia into the systems as a source of protein to the local community. The local communities have however raised concerns that the dredge ponds affect the quality (taste) of the fish. Furthermore, the communities downstream of the dredge ponds have indicated that the dredge ponds affect fishing activities in the systems below the lakes.

**Photograph notes:** Impoundments have been created from both the development of dredge ponds (left) and through the development of access and haul roads (right). The dredge ponds have been partially infilled by sand and tailings as evident in the background of the photograph on the left. Some of the dredge ponds are of considerable age and the lentic biota have formed a stable community in the low productivity systems. On some systems the adjacent vegetation has become well established and supports increased levels of biodiversity.

<table>
<tr>
<td>**PES discussion**</td>
<td>

**PES Category: D (Largely modified)**

The ecological integrity of these systems has been compromised largely as a result of significant impacts to the hydrological regime and vegetation of the environment though impounding. The hydraulic regime has been considerably altered as a result of the impoundments (i.e. the dredging ponds) within the systems. Additionally, the method of mining requires clearing of extensive areas of vegetation; thus significant losses of riparian and wetland vegetation have occurred in this regard.

Furthermore, the alterations to the hydraulic regime, including decant from the impoundments (one to another) and diversion of water between drainage features, have resulted in some riparian vegetation being affected by the altered hydraulic regimes. A clear example of this is the small stream near the small village of Foinda which is downstream of the Gangama dry mining operations where the riparian vegetation was flooded by the decant from the mine workings. Geomorphology, although modified to a degree by mining activities, is considered in balance, as the impacts are limited in extent (largely to the impounded sections of the affected watercourses) and magnitude. Some impact due to reduced sediment load on the downstream resources may occur in systems that have been disused for a significant period of time. The systems that are currently being mined have increased sediment loads which may affect downstream watercourses negatively. Vegetation integrity is generally stable on a regional scale. Although declining vegetation integrity on a localised scale in some systems is occurring while others are reaching new equilibrium. Impacts on riparian vegetation are predicted to increase due to ongoing impacts from slash and burn / subsistence agriculture.

</td>
<td>

**Watercourse characteristics pertaining to the PES discussion:**

**a) Hydraulic regime**

The hydraulic regimes of these waterbodies have been significantly altered, primarily as a result of historical and current mining activities. The impoundments within these wetlands have resulted in altered flow patterns and displacement of water, causing altered hydroperiods and altering the extent of the seasonal zones of the watercourses. Water volumes, both within the watercourses but more significantly within the impoundments fluctuate seasonally, as decant takes place from the impoundments into the downgradient systems.

**b) Geomorphology and sediment balance**

Geomorphological processes have been modified by anthropogenic influences primarily relating to the mining activities, with specific mention of the creation of various impoundments during the course of dredging activities, which affect sediment movement through the systems. Additionally, increased sediment inputs are anticipated, as a result of disturbances to soils caused by subsistence agriculture and in the mining areas, movement of heavy machinery. Downstream of the decant points of the older dredge ponds, a lack of sedimentation may reduce sediment input and lead to some erosion of the systems. Downstream of the decant points of the actively mined areas, sediment is being deposited which may affect benthic biota as well as habitat for fish and potentially impact on biota that rely on clear water as part of their biology.

**c) Habitat and biota**

These habitats have been transformed largely as a direct consequence of the mining activities within SR Area 1, as extensive areas have been cleared in order for dredging activities to take place. The generally flowing rivers have been transformed into still ponds which will have an effect on biota requiring flowing water as part of their biology and most notably feeding and breeding. Altered hydrological patterns arising from the impoundments have also altered vegetation profiles, both in terms of vegetation loss due to inundation, and the transformation of previously terrestrial areas which have become saturated as a result of altered hydroperiods and decant from impoundments. This has allowed for the recruitment of obligate and facultative vegetation. Additionally, alien vegetation encroachment is apparent in the disturbed areas. Thus, the suitability of the remaining habitat, refugia and faunal migratory corridors has been reduced, and the ability of these wetlands to support biota has subsequently decreased. However, it is deemed likely that sufficient habitat remains to support small populations of commonly occurring, less sensitive faunal species of invertebrates as well as some fish species. The fish in these systems are, in turn, actively harvested as a source of protein both for subsistence and commercial purposes.

**d) Water quality**

Water quality within the upstream, impounded systems is modified from the natural conditions with a slightly reduced pH and dissolved solids concentration. Parameters such as pH, EC and DO are within target ranges. However, turbidity within the impoundments which are currently being mined, specifically at Gangama dry mine and to a lesser extent at Lanti wet mine, is high. This is attributed to the ongoing dredging within the active dredge pond as well as tailings management, causing extensive disturbances to the sediments within these areas. However, turbidity within the northern impoundments, which have not been subjected to mining activities for two to three decades, is within target ranges. Some impact of the large open water bodies on temperature may occur and place additional stress on the aquatic communities both within these systems and potentially the systems downstream of the decant points. For further detail on water quality associated with these systems refer to the data for aquatic assessment points SR1 and SR4.

</td>
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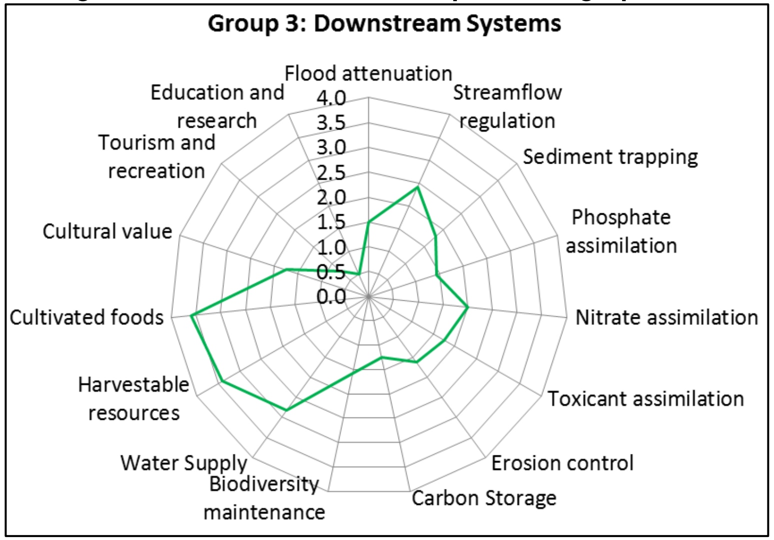
</table>

| | | | |
|---|---|---|---|
| **EIS discussion** | **EIS Category: Moderate (C)**<br>Due to the significantly decreased ecological integrity of the wetlands, ecological sensitivity is considered to be low, although these systems are nevertheless deemed important for hydrological functioning, providing services such as flood attenuation, sediment trapping, nutrient and toxicant assimilation and carbon storage. Additionally, impound systems are considered to have significant socio-cultural value, as discussed above. | **REC Category** | **REC: D (Largely Modified)**<br>At minimum, the ecological integrity of these systems should not be permitted to degrade further, and the present ecological state should be retained. The mine closure plan must aim to, to rehabilitate the dredge ponds once mining is complete to minimise the negative impact on the downstream ecology of the watercourses and in such a way as to enhance the goods and services provided by any latent dredge ponds post mining. Latent negative impacts as a result of the dredge ponds must be minimised, as these features form part of the drainage network which drain into freshwater systems to the east and south-west, and thus affect ecological function and the provision of goods and services to communities downstream since these systems are actively used by the local community. The socio-cultural goods and services provided by these systems should by retained and where possible the extent to which these services are supported should be improved and current levels of ecological functioning supported. |
| **Preliminary findings and future study requirements:**<br>The dredge ponds and areas inundated upstream of road crossings have a very high human use value in terms of essential goods and services provided (such as the provision of water and harvestable resources (fish), in addition to the economic value of the resource which the utilisation of the dredge mining method unlocks. These final findings can be used to guide closure decisions and future management of these water bodies including the design of the ponds for closure purposes in an attempt to improve and manage the productivity of the systems. | | | |

**Table 24: Summary of results pertaining to Group 3 (Downgradient / Downstream systems).**

**Ecological & socio-cultural service provision graph:**




**Ecoservice Provision:** **Intermediate**

As with the other watercourses within SR Area 1, the systems downgradient/downstream of the impacted areas are deemed important for the provision of socio-cultural benefits such as harvestable resources, cultivated foods and water for human consumption (including agricultural purposes). These systems are considered important for hydrological functions such as streamflow regulation as well as nutrient and toxicant assimilation, and as such are considered sensitive to low flows within the systems.

**Photograph notes:** The areas downgradient of the dredge ponds are often used for crop production (especially rice) (left photograph). The decant from mining activities leads to changes in the downstream systems including increased turbidity downstream of areas where current mining activity is occurring, and increased instream flow and potential water quality impacts in areas downstream of older disused dredge ponds.

**PES discussion**

**PES Category: C (Moderately modified)**

The wetland systems downgradient of the impoundments have been indirectly impacted by mining-related impacts, specifically, decant from the dredging ponds, which have resulted in an altered hydraulic regime, inundation of vegetation and the formation of channels (thus affecting geomorphology and flow velocity). Within their existing context, the ecological conditions of these wetland systems is likely to remain largely unchanged in the future, except for systems downstream of the actively mined areas, which are likely to improve in condition over time as water quality improves. Ongoing impacts from subsistence agricultural activities are likely to occur.

**Watercourse characteristics pertaining to the PES and EIS discussions:**

**a) Hydraulic regime**

The hydraulic regimes of these wetland systems have been significantly altered primarily as a result of historical and current mining activities, specifically the impacts relating to the dredge ponds upstream. These dredge ponds overflow into the downstream systems, resulting in the formation of areas displaying riparian characteristics (structure associated with riparian zones) and alterations to existing channels (such as increased channel size and concentration of flow). These changes lead to changes in the vegetation structure and the extent of the drainage lines.

**b) Geomorphology and sediment balance**

Geomorphology has been affected primarily by the upstream impoundment of the systems and subsequent decant as described above. This has resulted in changes to the sediment balance, flow patterns and channel stability as a result of concentrated water flows, and reduced sediment loads due to settlement in the ponds upstream of these watercourse segments.

<table>
<tr><td></td><td></td><td colspan="2">

**c) Habitat and biota**

The floral community structure and composition has been altered by numerous modifiers, including an altered hydroperiod as discussed previously, recruitment of alien vegetation in previously disturbed areas, clearing of natural vegetation in order to allow for commercial and subsistence crop cultivation, erosion and concentration of flow. Therefore, habitat integrity is considered to be impaired, although suitable faunal foraging and breeding habitat remains for less sensitive fauna, and connectivity with less disturbed areas allows for continued migration of fauna.

**d) Water quality**

The tested water quality parameters (i.e. pH, DO, EC and turbidity) indicate that the water quality is slightly changed from natural conditions with reduced clarity, lowered pH and slightly increased dissolved salt concentration and slightly increased temperature. These changes may affect more sensitive aquatic taxa and may affect some goods and service provision such as garment washing and bathing.
</td></tr>
<tr><td>**EIS discussion**</td><td>

**EIS Category: Moderate (C)**

Due to the decreased ecological integrity of these watercourses, ecological sensitivity is considered moderate (as with the impounded systems). Nevertheless, these systems remain important for the provision of goods and services to the surrounding communities, particularly in terms of cultivated foods and domestic water supply. Whilst unlikely to be particularly sensitive to changes in water quality and flood peaks, these systems are nonetheless considered important for hydrological functions such as streamflow regulation and nutrient and toxicant assimilation.
</td><td>**REC Category**</td><td>

**REC: C (Moderately modified)**

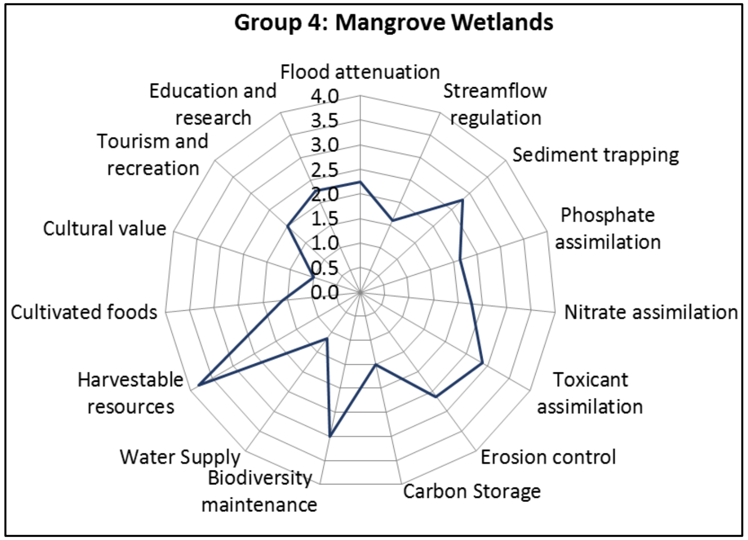
At a minimum, efforts should be made to maintain the present ecological state of these wetland systems, in order to ensure the ongoing functioning and goods and service provision to the communities that rely on these systems. Furthermore, future negative impacts on these systems may impact on the downstream freshwater environments, and therefore as far as possible, additional impacts should be avoided. Where possible, rehabilitation of these wetland systems is recommended, in order to improve ecological integrity and goods and services provision.
</td></tr>
<tr><td colspan="4">

**Preliminary findings and future study requirements:**

Despite the reduced ecological importance and integrity of these systems, they are still considered of significant importance in terms of the provision of goods and services to the local community. Therefore, efforts should, as a minimum, be made to maintain the present ecological state of these systems, in order to ensure the ongoing functioning and goods and service provision to the communities that rely on the goods and services provided by these systems. Systems that have been significantly impacted by mining and decant should be investigated further and measures put in place to reduce impact on these systems and the goods and services they provide. Furthermore, future activities within these systems may impact on the downstream freshwater environments, and therefore as far as possible, further impacts should be avoided or minimised.
</td></tr>
</table>

**Table 25: Summary of results pertaining to Group 4 (Mangrove system).**

**Ecological & socio-cultural service provision graph:**




**Ecoservice provision:** **Very High**

The mangrove system is deemed to be critically important from an ecological as well as socio-cultural perspective. The Sherbro River from just downstream of the Nitti Port forms part of the Sherbro River Marine Protected Area. This area is considered important for the conservation of some species such as manatees. From a cultural point of view the results of the social impact assessment SRK3 (2018) confirmed that there are no significant cultural beliefs and rituals linked to the estuarine system. From a socio-cultural, goods and service provision point of view the mangrove areas are also considered important for harvestable goods, with specific mention of fishing activities which provide local inhabitants with a valuable source of income and sustenance. The system is also used to a small degree for tourism and recreation and has some potential for education and research. The mangrove system is also deemed to be some importance for ecological processes, particularly storm surges (flood attenuation), erosion control (over a long period of time) and carbon storage. Additionally, it is deemed important for biodiversity maintenance, providing important breeding habitat and refugia for a variety of estuarine fauna.

**Photograph notes:** Mangrove areas are associated with the Sherbro River (left). The Nitti Port is also located within the mangrove areas in the main channel of one of the main branches of the Sherbro River. Some mangrove areas are downgradient of mining areas and affected by mining and decant (below). Some other mining operators also have activities in the Sherbro River mangrove system which may impact its ecology, however no detail with regards to their operations or potential impact is available.

<table>
<tr>
<td>PES discussion</td>
<td>PES Category: Class A (Largely natural to natural)<br>The mangrove system is considered in a natural state although in some areas some impacts from historical mining have occurred primarily due to the impoundments and levees which have been constructed which affect the hydrological function of the system and which affect ecological connectivity. In addition, the Nitti Port is also located within the Mangrove system which as the potential to contaminate the receiving environment. These impoundments have impacted upon hydraulic processes and geomorphological characteristics of the affected portions of the system, in turn most likely impacting on the floral community composition and structure. The decant from mining activities ultimately enters the mangrove systems.</td>
<td colspan="2" rowspan="2">Watercourse characteristics:<br>a) Hydraulic regime<br>The hydraulic regime is affected by tidal influences in these lower sections of the Sherbro River. The Sherbro River is a large system and hence the hydrology is largely driven by the rainfall in the very large catchment of this system. The hydraulic regime of the system has not been significantly changed on a system scale however there are local impacts as a result of the impoundments and berms within the system, resulting in significantly altered flow patterns, which may in turn have an effect on the natural hydraulic regime of the watercourse and associated mangrove stands. In addition, these modifications to the geomorphology of the system may have resulted in altered hydroperiods, in turn impacting upon mangrove vegetation.<br><br>b) Geomorphology and sediment balance<br>Geomorphology has, like the hydraulic regime, been impacted by the impoundments, levies and berms created within the system. This has resulted in extensive alterations to any naturally occurring channels and floodplains which are likely to have existed historically. In addition, increased sedimentation of the system is anticipated as a result of ongoing disturbances relating to the mining activities, and the activities associated with the Nitti Port, situated in the west of SR Area 1. Sedimentation of the system inland may have repercussions on the downstream estuarine system, potentially smothering biota and causing transformation of the floral community composition and structure.<br><br>c) Habitat and biota<br>The vegetation community has been altered to some degree by the impoundments, levies and berms created within the system, as these will have caused inundation of floral communities, as well as altered hydroperiods and altered water constituency. Some impact on the faunal species occurring within these brackish waters may also occur with specific mention of fish and especially fish which have larger migratory movements or fish that move with the tides. Some localised physical disturbance of mangroves (Rhizophora racemosa) has occurred in the vicinity of the Nitti Port which is likely related to the handling and shipping of the product from SRL this could lead to die back of mangrove plants and potential erosion (Anchor Environmental 2017).<br><br>d) Water quality<br>According to the findings of the wet season estuarine study, salinity varied between 0.10 and 18.95 Practical Salinity Units (PSU). In the two creeks that drain directly from SR Area 1 (Kangama and Gbangbaia), salinity was very low (<1.0) in both the surface and bottom waters (Anchor Environmental 2017). Water quality may be impacted in some areas by the impoundments, levies and berms created within the system as well as activities at the Nitti port. Particular mention is made of Zinc based on the water quality analyses by (Anchor Environmental 2017). This may in turn affect the biota associated with the brackish water in this system.</td>
</tr>
<tr>
<td rowspan="2">EIS discussion</td>
<td rowspan="2">EIS Category: Very High<br>As mentioned above, the mangrove system is deemed to be of significant importance from a human perspective in-so-far as the provision of livelihoods and sustenance is concerned. Furthermore, the system is considered important both in terms of hydrological functioning on a local scale and also in terms of the contribution of the system to the downstream estuarine system on the west coast and in terms of conservation initiatives. The mangrove system is deemed sensitive to direct disturbances and construction activities within the mangroves, since such impacts will change the hydraulic and geomorphological processes within the system.</td>
</tr>
<tr>
<td>REC Category</td>
<td>REC: Class A (Largely natural to natural)<br>At a minimum, efforts should be made to maintain the present ecological state and functioning of the Sherbro River, in order to ensure the ongoing functioning and service provision to the communities that rely on the goods and services provided by the system. Furthermore, future negative impacts on this system is highly likely to have a negative impact on the estuary system downstream of SR Area 1, and therefore, as far as possible, additional impacts should be avoided. As with the Group 2 and 3 systems, rehabilitation of the mangrove system where possible, is strongly recommended and particular mention is made of removal of the berms and levees to reinstate the natural hydrology and geomorphological processes of the estuary.</td>
</tr>
</table>

**Preliminary findings and future study requirements:**
Mangrove estuaries are generally considered sensitive and are generally known to be important in terms of biological processes they afford and in terms of the goods and services they provide. Therefore, any potential impacts on the mangrove systems should be carefully considered, planned, managed and mitigated. Where appropriate management and mitigation measures are provided in the impact assessment section study. This is considered particularly important in light of the fact that the system is considered in a natural state with some localised impacts. Furthermore, it is considered essential to fully assess risks to this system in light of the fact that the Sherbro River forms part of the Sherbro River Marine Protected Area a short distance downstream. The findings of this freshwater assessment must be considered in conjunction with the estuarine specialist study undertaken to ensure that an integrated understanding of the system is achieved and that the system and the impact of the mine on the system is thus appropriately managed.

## 4.3 Delineation and Sensitivity Mapping

The figures below depict the position of the various wetland systems within SR Area 1 and adjacent areas based on the mix of delineation using desktop methods and field verification methods employed. In delineating watercourse units and in mapping of the sensitivity and functionality of each the following units were defined:

1. Watercourses not affected by mining;
2. Systems impounded and affected by mining;
3. Systems downstream of mining activity; and
4. Mangroves.

Consideration must additionally be given to floodlines associated with these features when considering the planning and placement of infrastructure associated with the proposed mining activities as encroachment into wetland zones and/or floodlines is likely to significantly increase the impact of the proposed mining activity on freshwater resources.

The figures below present the delineation of the various watercourse types (Figure 27), the PES (Figure 28); the EIS, (Figure 29) and ecoservices (Figure 30).

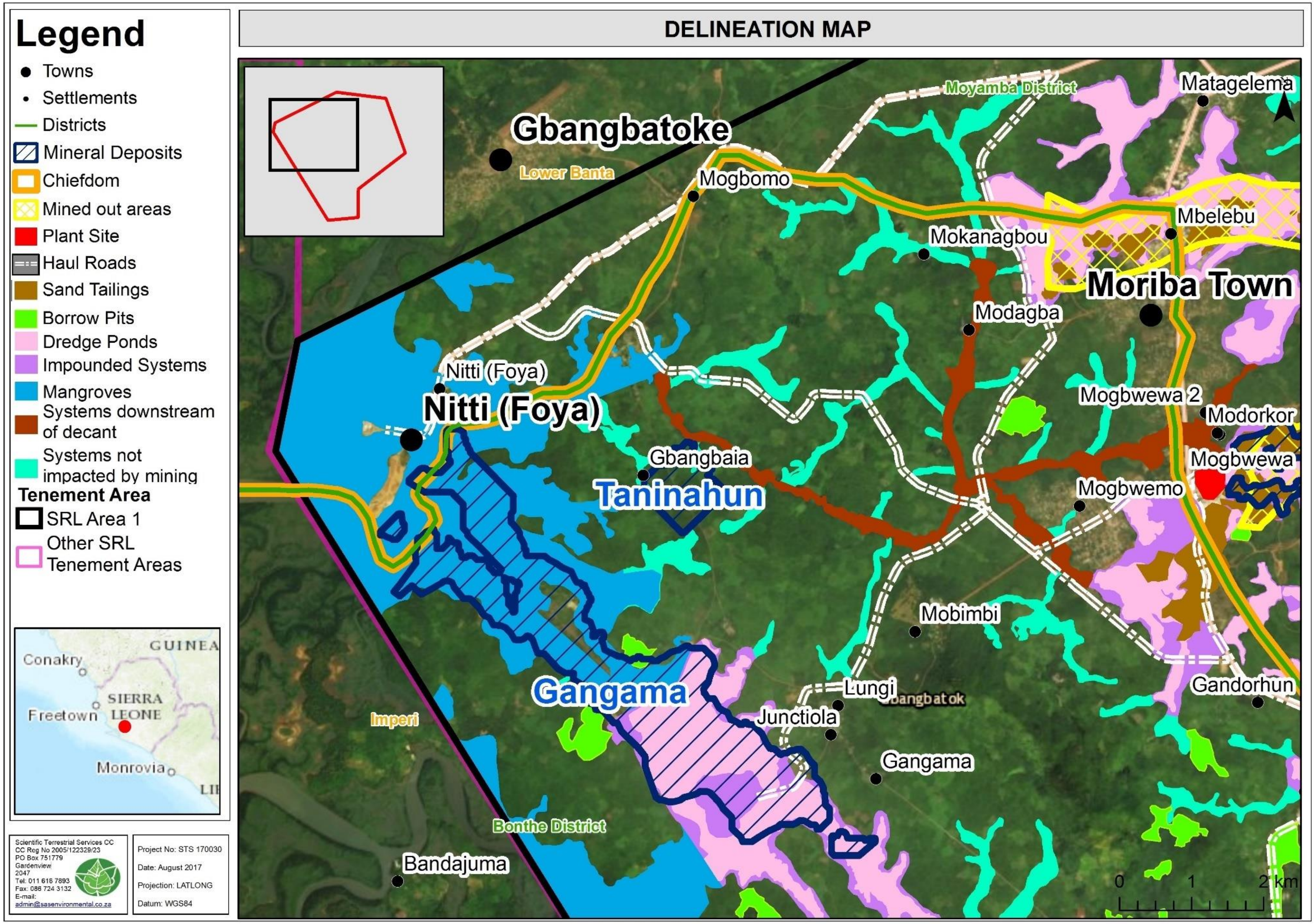



**Figure 39: Conceptual depiction of the freshwater resource delineation.**

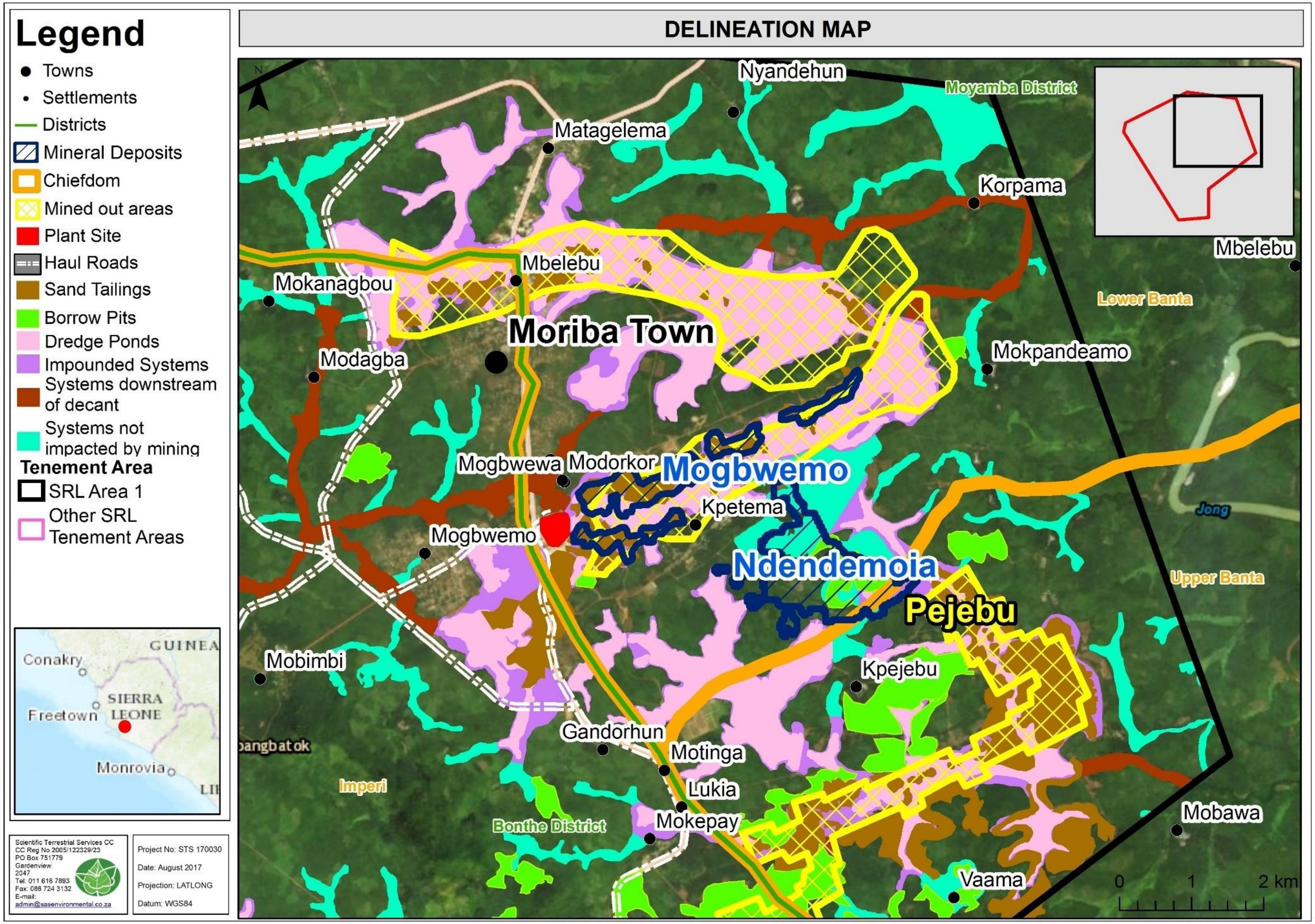



**Figure 40: Conceptual depiction of the freshwater resource delineation.**

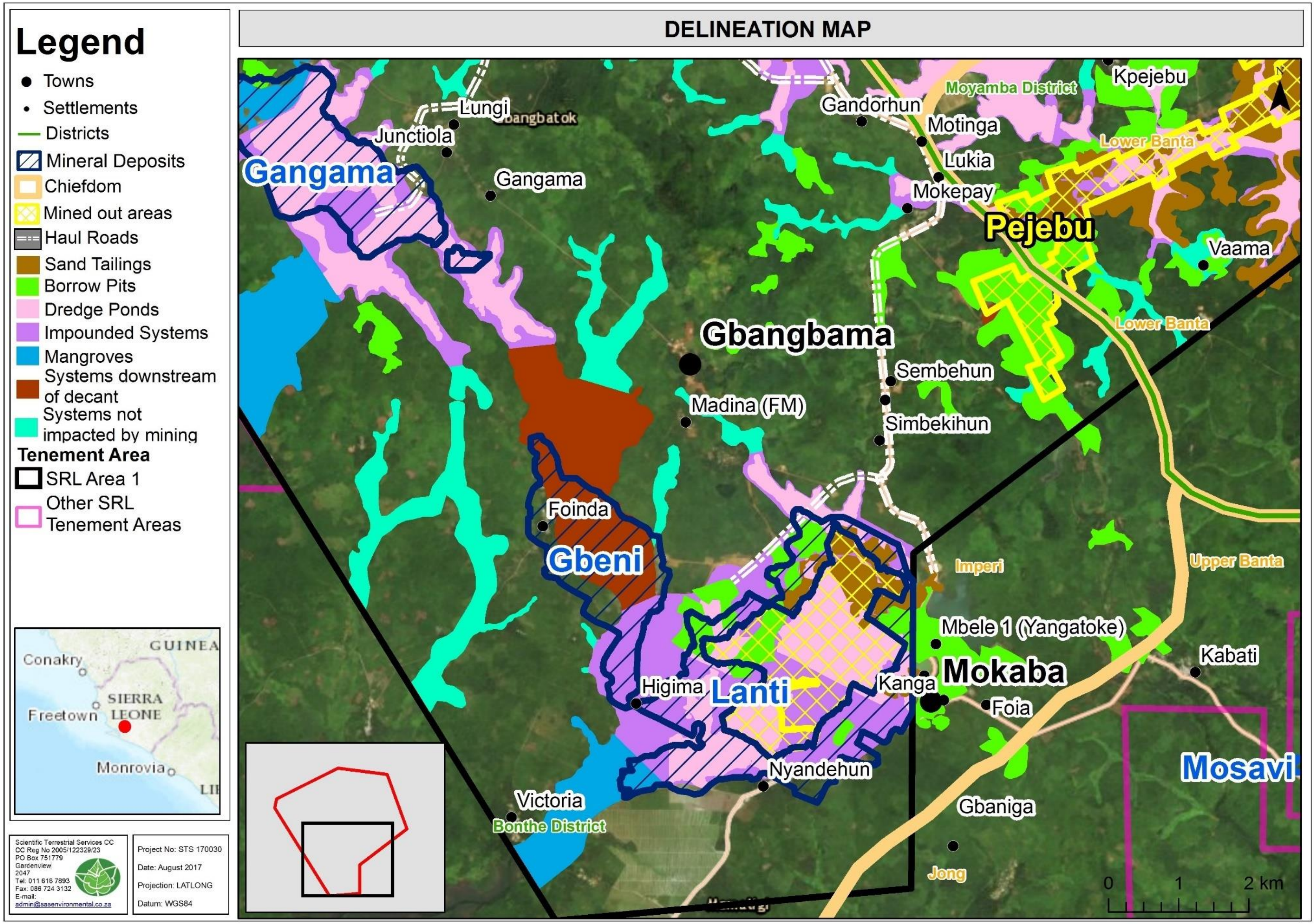



**Figure 41: Conceptual depiction of the freshwater resource delineation.**

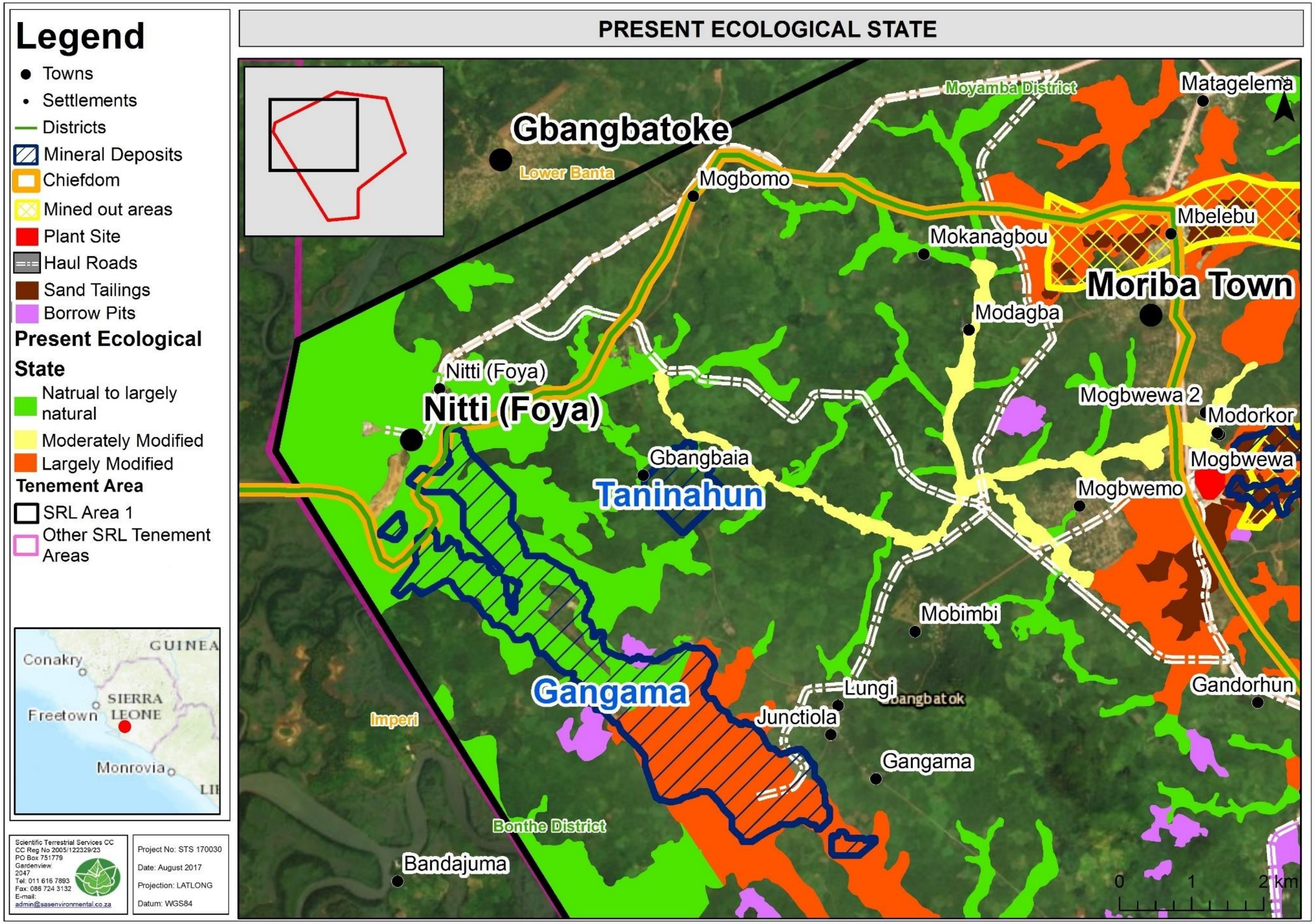



**Figure 42: Conceptual illustration of the freshwater resource Present Ecological State (PES).**

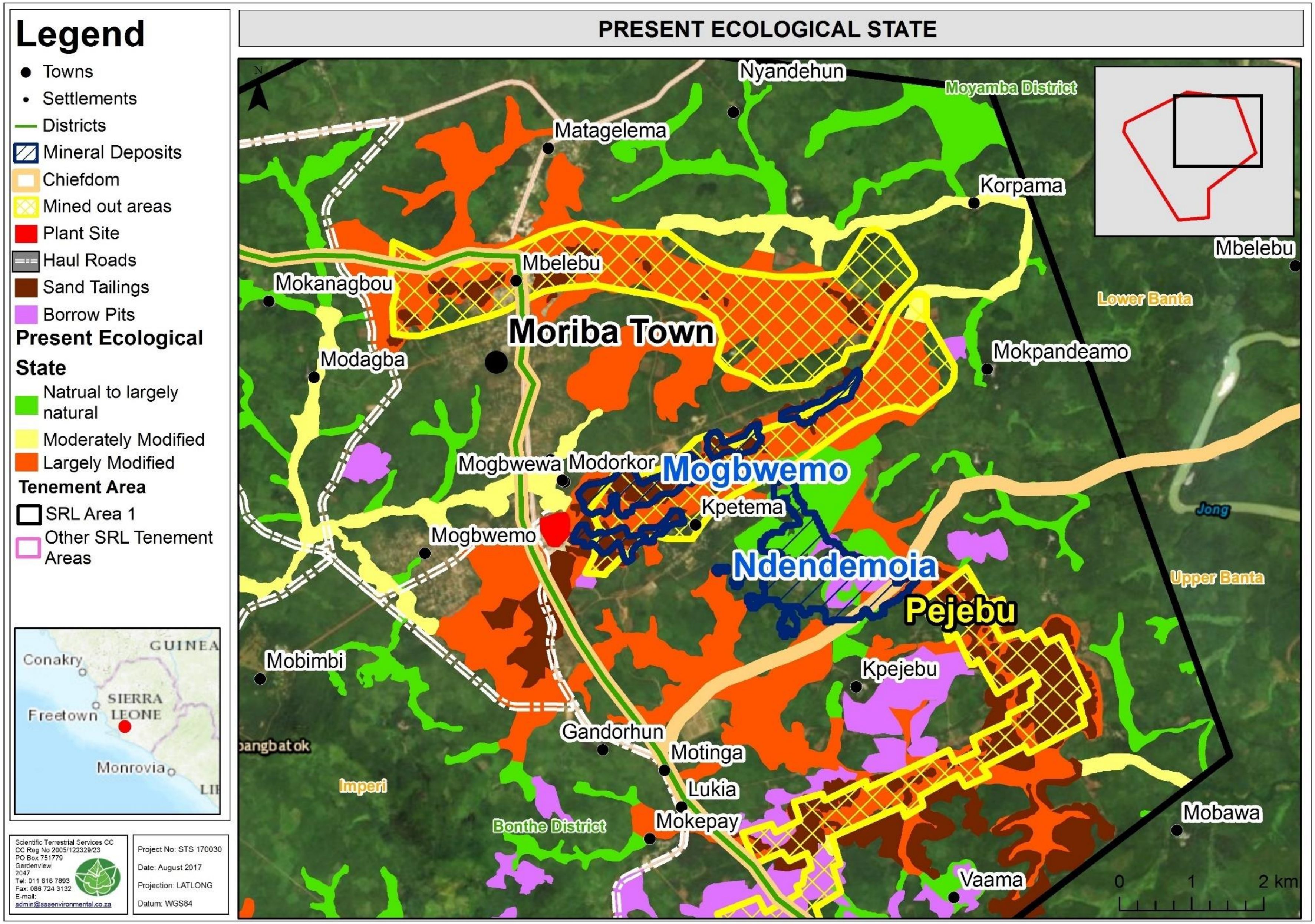



**Figure 43: Conceptual illustration of the freshwater resource Present Ecological State (PES).**

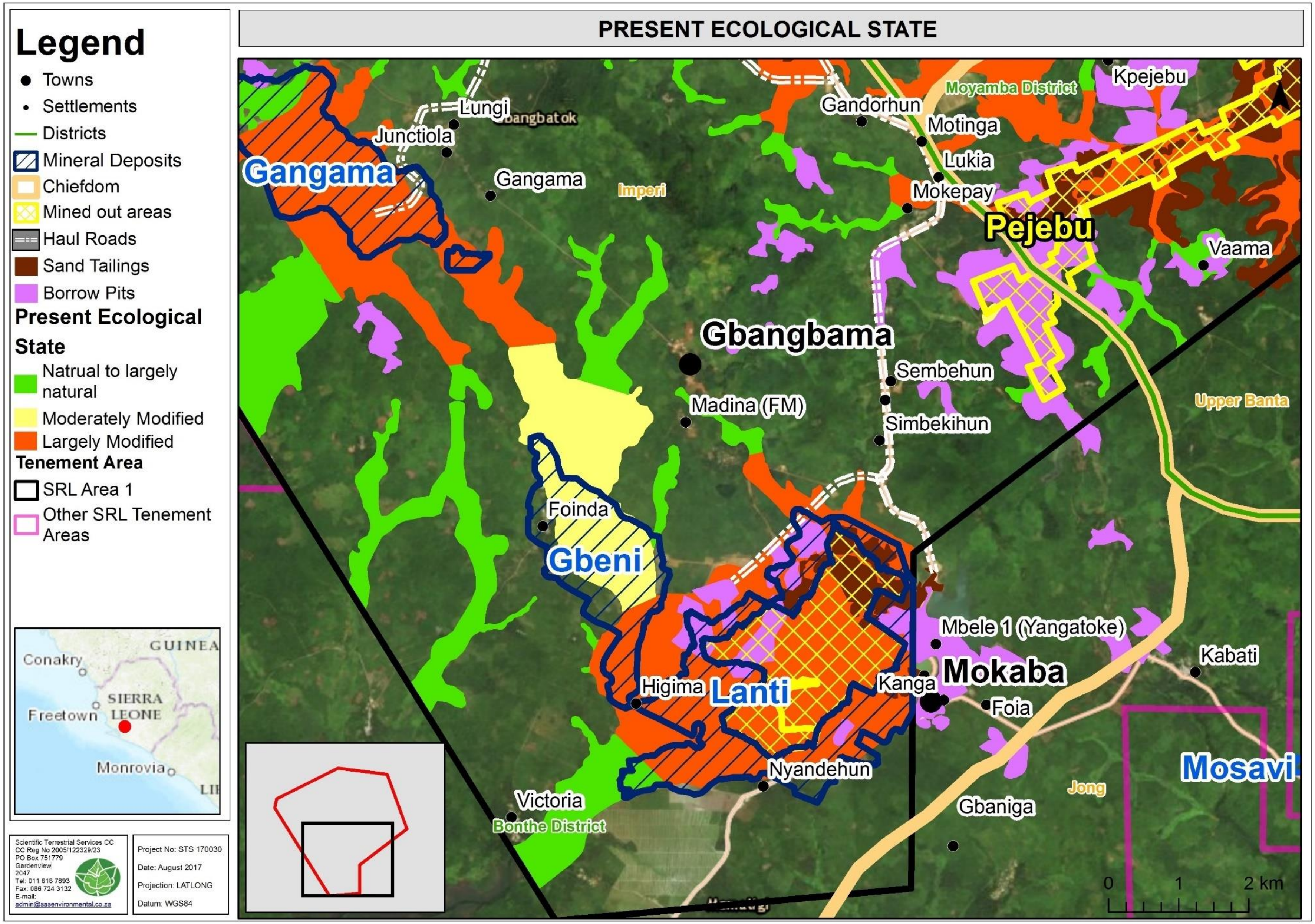



**Figure 44: Conceptual illustration of the freshwater resource Present Ecological State (PES).**

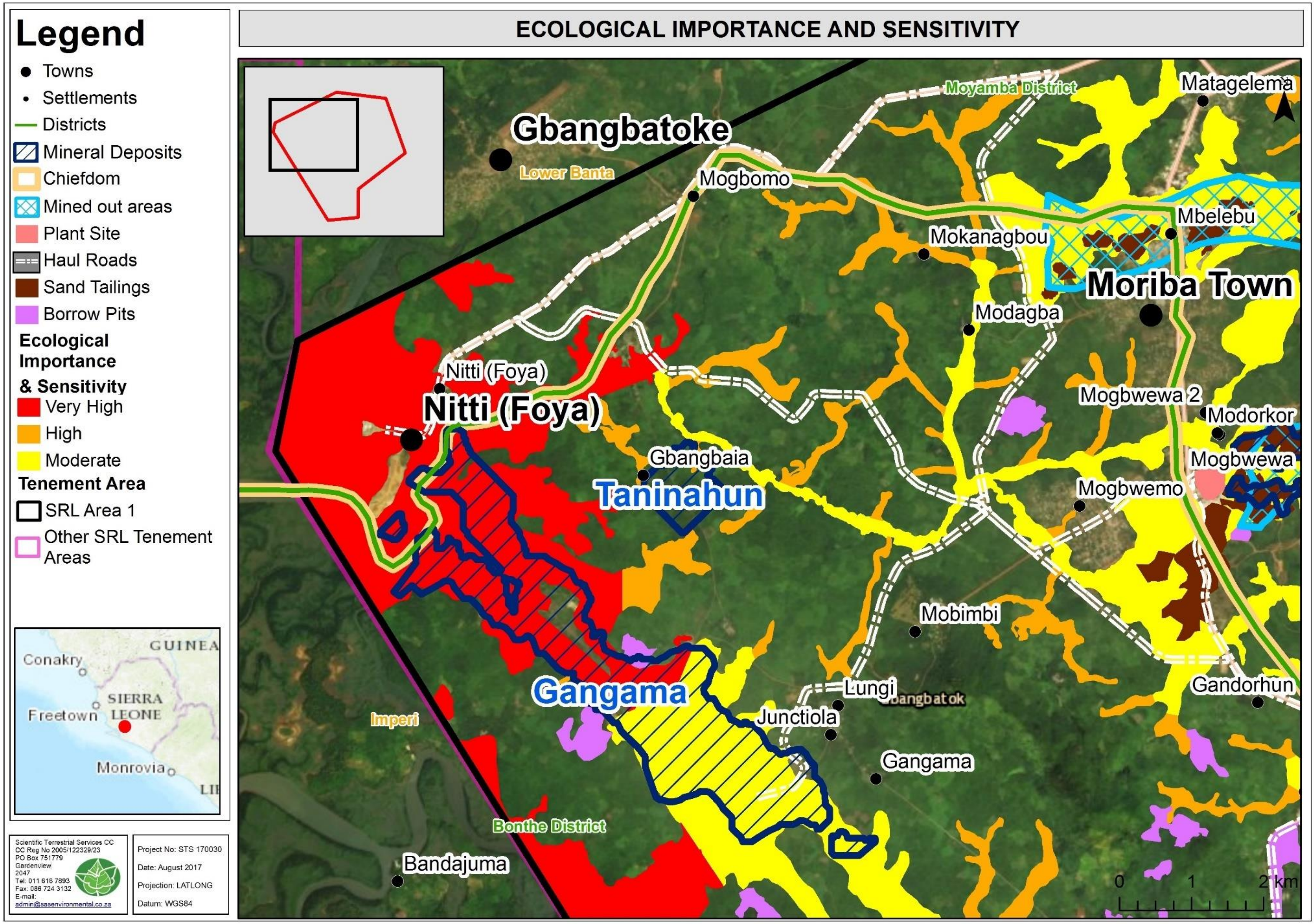



**Figure 45: Conceptual illustration of the freshwater resource Ecological Importance and Sensitivity (EIS).**

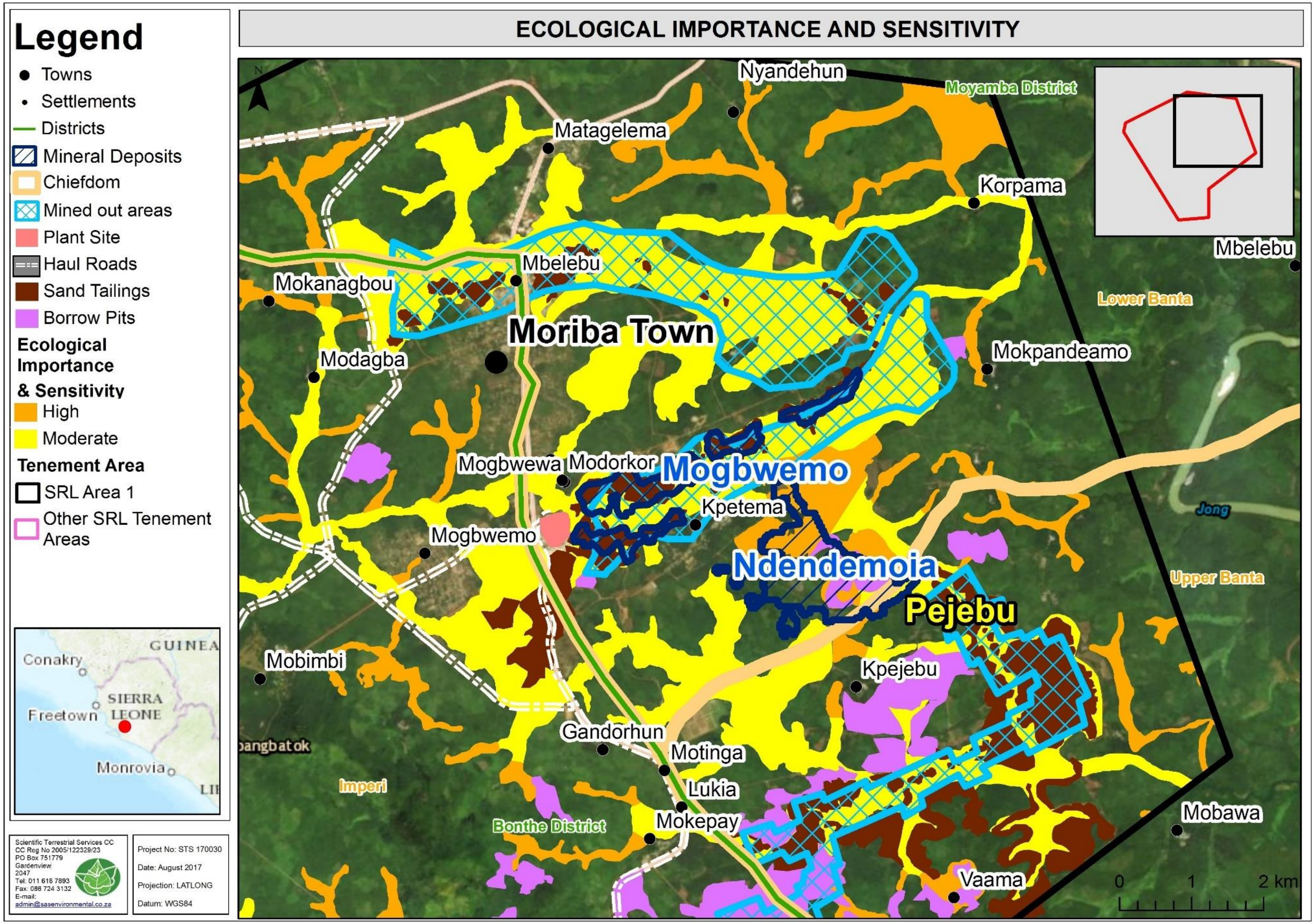



**Figure 46: Conceptual illustration of the freshwater resource Ecological Importance and Sensitivity (EIS).**

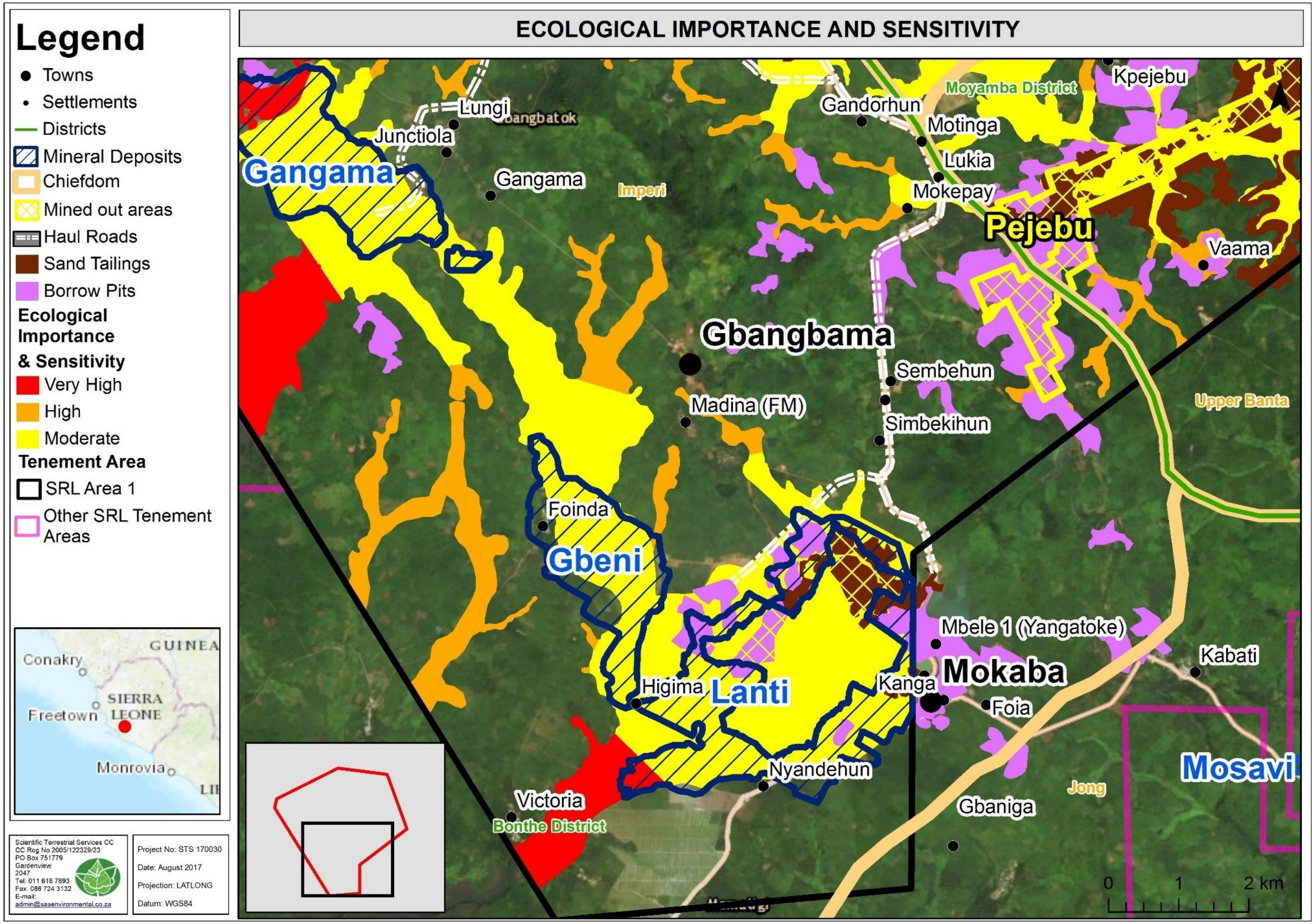



**Figure 47: Conceptual illustration of the freshwater resource Ecological Importance and Sensitivity (EIS).**

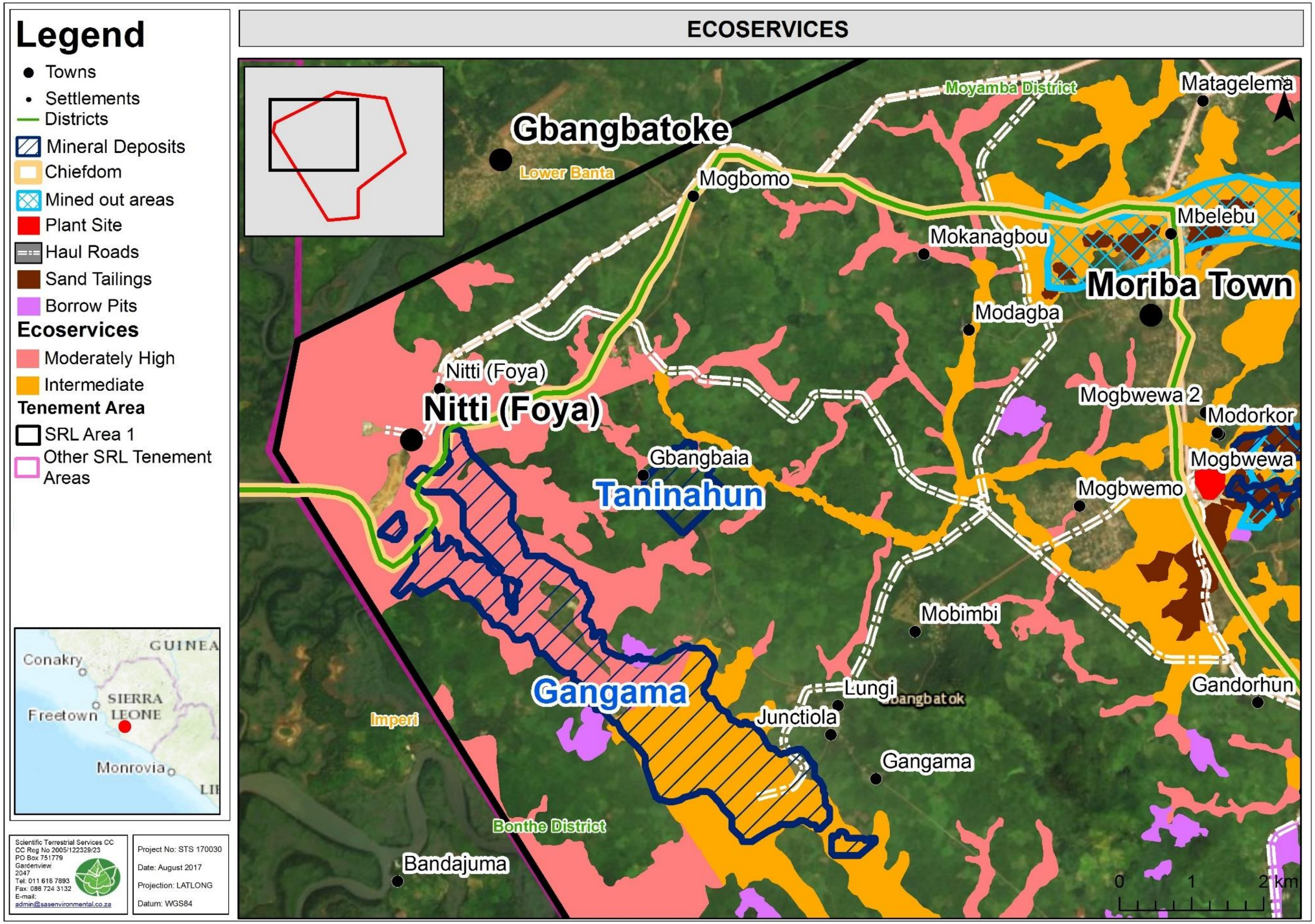



**Figure 48: Conceptual illustration of the freshwater resource Goods and Services provision**

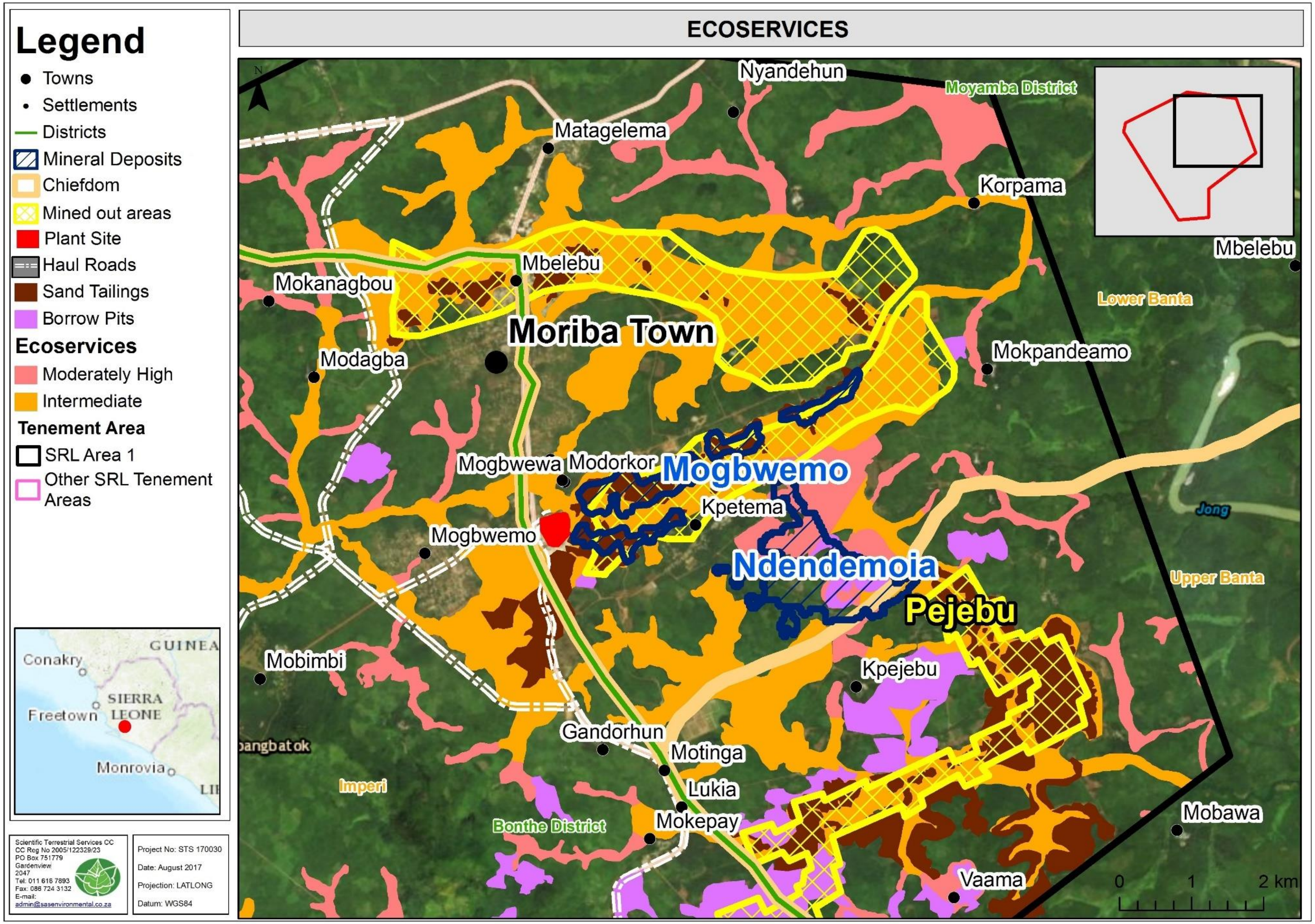



**Figure 49: Conceptual illustration of the freshwater resource Goods and Services provision**

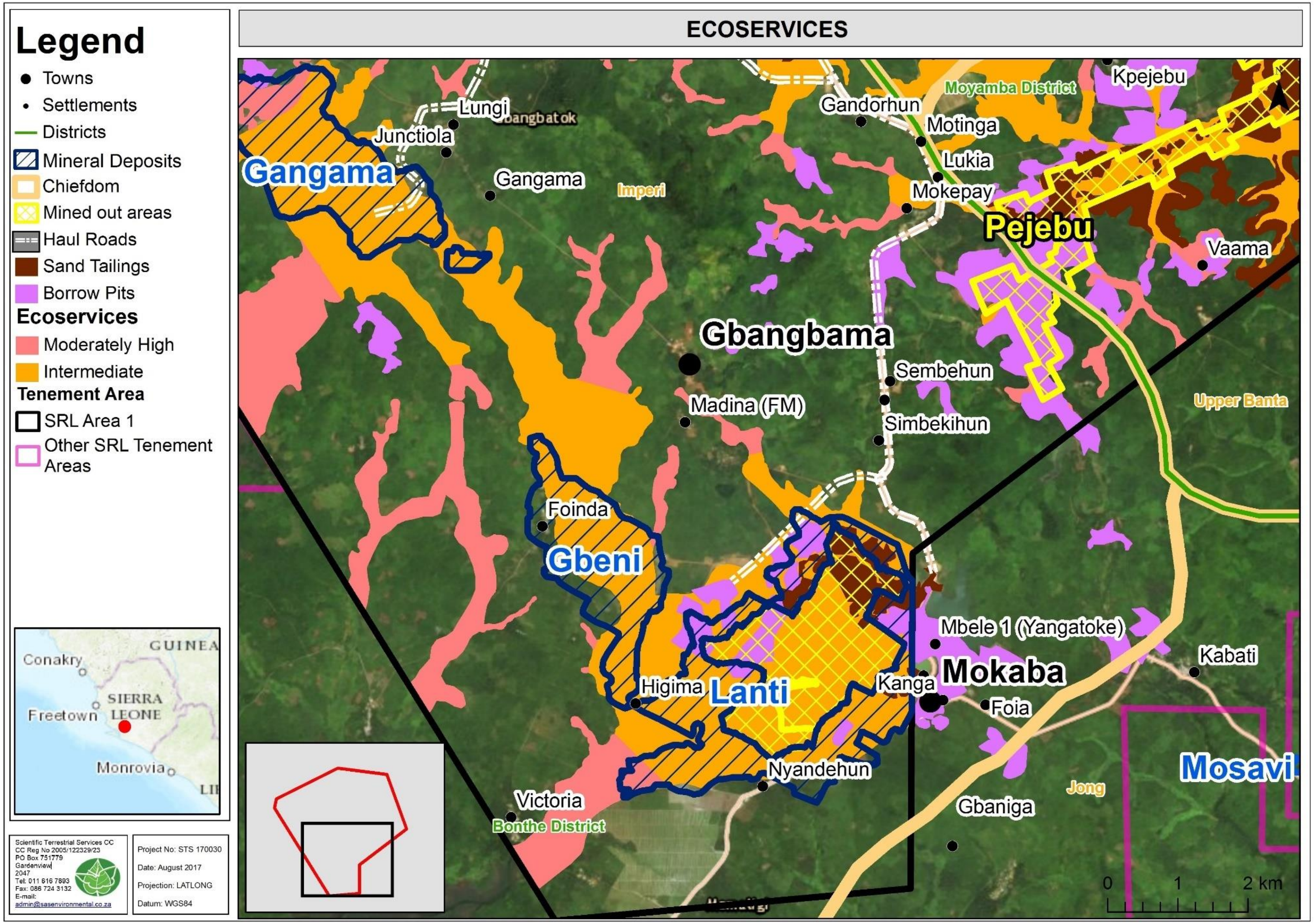



**Figure 50: Conceptual illustration of the freshwater resource Goods and Services provision**

# 5 CONCLUSIONS

Scientific Terrestrial Services (STS) was appointed to conduct faunal, floral, wetland and aquatic ecological assessments as part of the process to undertake an Environmental, Social and Health Impact Assessment (ESHIA) and develop an Environmental, Social and Health Management Plan (ESHMP) for the current and proposed dry and wet mining activities including the proposed expansion within SR Area 1. This section reports on the freshwater ecology of the systems in the vicinity of the SR Area 1 operations.

## *5.1 Aquatic Assessment Conclusion*

Based on the findings of this study, it is evident that the aquatic resources of the area already impacted by mining, are still of moderate yet significant Ecological Importance and Sensitivity (EIS). With the condition of the systems improving over the long term as is evident when results for SR1, SR3 and SR4 are correlated with pit age (SR3 presented with higher assessment scores and receive decant from an "old" pit). Furthermore, it is evident that the impact on the systems is limited in extent downstream of the decant points. The general state for these systems can be described as modified.

Aquatic resources of the area not yet impacted by mining, can be considered ecologically intact and are of high EIS, as is evidenced from conditions at site SR5. The systems are seen to naturally host a relatively diverse aquatic community with both the fish and macro-invertebrate communities hosting taxa known to be sensitive to changes in flow and water quality.

Water quality is good throughout SR Area 1, with low EC and also naturally low pH. However, EC at sites SR1, SR3 and SR4 is higher compared to that at reference site SR5, with pH at sites SR3 and SR4 lower compared to conditions at SR5. Pit decant may potentially contribute to slightly elevated EC and reduced pH, but absolute values are considered largely natural. At site SR1 visual assessment indicated that pit decant may result in increased turbidity, potentially negatively affecting taxa that require clear conditions. However, the high ASPT reported from this site indicate that the potential impact was not significant at the time of assessment. Results from site SR3 indicate that impacts (with specific reference to turbidity) improves over time. However, significant long-term impact from pit decant on water quality is considered limited.

Habitat suitability for maintaining a diverse macro-invertebrate community in SR Area 1, varied from adequate to excellent at the time of assessment.

However, despite suitable available habitat, macro-invertebrate diversity was generally lower than expected, but with a high prevalence of sensitive taxa. SASS5 and MIRAI indices presented with poor Ecological Category classifications at sites SR1 and SR4, a slightly higher classification at site SR3 and the best classification at reference site SR5.

Diatom community results also presented with lower classifications at sites SR1 and SR4, indicating some impact on systems affected by decant. However, diatom species composition in SR Area 1 does not necessarily imply impacts from mining only, but rather from all anthropogenic activities resulting in nutrient, electrolyte and organic material input which includes activities not associated with mining.

Impact on macro-invertebrate diversity at sites SR1, SR4 and to a lesser degree SR3, likely results from a combination of factors. These factors include EC and pH variation, flow variability and turbid conditions (with specific reference to site SR1). The significance of the impact depends on rate of dredge pond decant as well as age of the dredge pond (impact seems to decrease as pit age increases) as well as distance from the dredge pond.

Despite an apparent negative impact on macro-invertebrate diversity, the ichthyofauna of SR Area 1 consists of a fair variety of taxa, with taxa occurrence and prevalence being dependant on system size, depth and flow. However, there is possibly a chronic impact on the fish community at sites SR3 and SR4 as evidenced by the reduced diversity and abundance of the fish community at sites SR1 and SR4 in relation to the SR5 site. Note the use of the term "possibly", as this inference was made based on interviews with local fisherman, as well as simple sample procedures with visual assessment of abundance and diversity based on numbers of fish collected (i.e. no formal population dynamic calculations performed using catch and release techniques). This possibility would need to be confirmed using longer term assessment techniques and trend analyses.

In conclusion, the data suggests that conditions at site SR3 improved in relation to that of SR1 and SR4, with the dredge pond that decants in that system being older than the dredge ponds impacting sites SR1 and SR4. It would thus appear that the long term impact from dredge ponds may be low, with systems reaching a state of equilibrium with established pits, and decant from them, over time. Furthermore, the extent of impact from the dredge pond decant is limited to an extent approximately 3 km in a downstream direction. However, sites affected by mining still show a moderate impact, compared to the reference site which has not been impacted by mining. It must be noted that there is also a direct impact on the instream environments where river systems have been inundated through the flooding of river valleys. No future flooding activities are however planned.

## 5.2 Watercourse Assessment Conclusion

It is apparent that the naturally occurring wetlands and riparian resources and mangrove swamps identified in the vicinity of SR Area 1 are generally deemed in a largely natural to moderately modified condition. The exception is the Group 2 (impounded) systems, which are deemed to have been largely modified, primarily due to the extent and severity of impacts associated with the dredge ponds on these systems. All groups are however considered of moderate to very high ecological importance and sensitivity, and all are deemed to provide essential goods and services to the surrounding communities along with important ecological functions. The results of the various assessments are summarised in the Table 25 below:

**Table 26: Summary of the results of the assessments applied to the wetland systems within the SR Area 1.**

| Wetland system group | Present Ecological State (PES) | Ecological Importance and Sensitivity (EIS) | Eco-services provision (including socio-cultural provisioning) | Recommended Ecological Category (REC) |
|---|---|---|---|---|
| Group 1: Reference | A Largely Natural to Natural) | High | Moderately High | A Largely Natural to Natural) |
| Group 2: Impounded | D (Largely Modified) | Moderate | Intermediate | D (Largely Modified) |
| Group 3: Downstream | C (Moderately Modified) | Moderate | Intermediate | C (Moderately Modified) |
| Group 4: Mangrove | A Largely Natural to Natural) | Very High | Moderately High | A Largely Natural to Natural) |

The watercourses included in Group 1, i.e. systems not affected by mining, are considered to be of high ecological importance, providing both high levels of ecological functioning, but also high levels of socio-cultural services, since the goods and services provided to the surrounding communities are largely not substitutable. Despite the decreased ecological integrity of the systems included in Groups 2 (areas affected by inundation and the dredge ponds themselves) and 3 (systems downstream/downgradient of the dredge ponds), goods and services provision by these wetlands are also deemed to be of high importance, for similar reasons. Additionally, whilst the ecological integrity of these systems is diminished, they are nevertheless still able to provide essential ecological services such as streamflow regulation and recharge of downstream aquatic environments, assimilation of nutrients and toxicants, and biodiversity maintenance. Key concerns for the local residents are impacts on water quality and impacts on drinking water, water for domestic purposes such as clothes washing and fishing activities in systems affected by mining with particular mention of decreased abundance of fish and fish having a different taste.

The mangrove areas are considered to be of high ecological importance and the importance of these systems is further highlighted by the designation of the Sherbro River as part of the Sherbro River Marine Protected Area. Information pertaining to these systems should be integrated with the applicable estuarine study in order to inform future management and decision making regarding this system as well as proposed mining activities .

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**NOTE: Reliable reference material at the required level of detail and accuracy is scant, and thus verified and accurate reference material was utilised. These references are internationally accepted and although many of them do not specifically cover SR Area 1, the species ranges and distributions overlap. Notes on ecological and biological requirements allowed the specialists to reliably extrapolate data.**


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# APPENDIX A: Aquatic Ecological Assessment Approach

## *Visual Assessment*

The assessment site was investigated in order to identify visible impacts, with specific reference to impacts from surrounding activities and any effects resulting from activities occurring upstream in the catchment. Both natural constraints placed on ecosystem structure and functions, as well as anthropogenic alterations to the system, were identified by observing conditions and relating them to professional experience. Photographs of each site were taken to provide visual indications of the conditions at the time of assessment. Factors which were noted in the site specific visual assessments included the following:

- Stream morphology;
- Instream and riparian habitat diversity;
- Stream continuity;
- Erosion potential;
- Depth flow and substrate characteristics;
- Signs of physical disturbance and pollution of the area; and
- Other life forms reliant on aquatic ecosystems.

## *Physico-Chemical Water Quality Data*

On-site testing of biota specific water quality variables took place. Parameters measured included pH, electrical conductivity and temperature. Water quality data were considered to aid in the interpretation of the data obtained in the aquatic ecological assessment.

water qualityimpact considerations were guided by the following guidelines:

- The surface water at SRL is consumed and used by the local communities. However, without identifiable and prescriptive domestic drinking water standards, the water quality is compared with the following sources -
  - World Health Organisation (WHO) Guidelines for Drinking Water 2017;
  - South African Standard for Drinking Water (SANS 241-1:2015) – to assist with a holistic assessment; and
  - Mining (IFC EHS), 2007.

For ease of discussion, percentage variation from the conditions at the reference site (SR5) was calculated and reported for each of the parameters. Percentage variation was employed as it is an easily understandable concept and is considered more appropriate than generic acceptable bands which may not be applicable to a local setting. Also, percentage variation from reference conditions is often employed in guideline recommendations with reference to acceptable temporal variations, as is the case for pH and EC in the Department of Water affairs and Forestry (now Department of Water and Sanitation) guidelines (1996). As a result, this method was also employed for this study. However, it must be noted that pH is based on a logarithmic scale, and thus a small change in pH is considered significant.

## *Riparian Vegetation Response Assessment Index (VEGRAI)*

The Riparian Vegetation Response Assessment Index (VEGRAI) is designed for qualitative assessment of the response of riparian vegetation to impacts, in such a way that qualitative ratings translate into quantitative and defensible results (Kleynhans *et al*, 2007). Results are defensible because their generation can be traced through an outlined process, a suite of rules that convert assessor estimates into ratings and convert multiple ratings into an Ecological Category.

Riparian vegetation is described in the National Water ACT Of South Africa (Act No 36 of 1998) as follows: 'riparian habitat' includes the physical structure and associated vegetation of the areas associated with a watercourse which are commonly characterised by alluvial soils, and which are inundated or flooded to an extent and with a frequency sufficient to support vegetation of species with a composition and physical structure distinct from those of adjacent land areas.

## General Habitat Integrity

The general habitat integrity of each site was discussed based on the application of the Index of Habitat Integrity (Kleynhans *et al.* 2008). It is important to assess the habitat at each site in order to aid in the interpretation of the results of the community integrity assessments, by taking habitat conditions and impacts into consideration. This method describes the Present Ecological State (PES) of both the in-stream and riparian habitat at each site. The method classifies habitat integrity into one of six classes, ranging from unmodified/natural (Class A) to critically modified (Class F), as indicated in Table 1A below.

**Table 1A: Classification of Present State Classes in terms of Habitat Integrity [Kleynhans *et al.* 2008]**

| Class | Description | Score (% of total) |
|---|---|---|
| A | Unmodified, natural. | 90 - 100 |
| B | Largely natural with few modifications. The flow regime has been only slightly modified and pollution is limited to sediment. A small change in natural habitats may have taken place. However, the ecosystem functions are essentially unchanged. | 80 - 89 |
| C | Moderately modified. Loss and change of natural habitat and biota have occurred, but the basic ecosystem functions are still predominantly unchanged. | 60 - 79 |
| D | Largely modified. A large loss of natural habitat, biota and basic ecosystem functions has occurred. | 40 – 59 |
| E | Seriously modified. The loss of natural habitat, biota and basic ecosystem functions is extensive. | 20 – 39 |
| F | Critically / Extremely modified. Modifications have reached a critical level and the system has been modified completely with an almost complete loss of natural habitat and biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible. | 0 - 19 |

## Aquatic Macro-Invertebrates

### South African Scoring System (SASS5)

The SASS5 method has been specifically designed to comply with international accreditation protocols. This method is based on the British Biological Monitoring Working Party (BMWP) method and has been adapted for South African conditions by Dr. F. M. Chutter (1998). The assessment was undertaken according to the protocol as defined by Dickens & Graham (2002). All work was done by an accredited SASS5 practitioner.

The SASS5 method was designed to incorporate all available biotypes at a given site and to provide an indication of the integrity of the of the aquatic macro-invertebrate community through recording the presence of various macro-invertebrate families at each site, as well as consideration of abundance of various populations, community diversity and community sensitivity. Each taxon is allocated a score according to its level of tolerance to river health degradation (Dallas, 1997).

This method relies on churning up the substrate with your feet and sweeping a finely meshed SASS net, with a pore size of 1000 micron mounted on a 300 mm square frame, over the churned up area several times. In stony bottomed flowing water biotopes (rapids, riffles, runs, etc.) the net downstream of the assessor and the area immediately upstream of the net is disturbed by kicking the stones over and against each other to dislodge benthic invertebrates.

The net was also swept under the edge of marginal and aquatic vegetation to cover from 1-2 meters. Identification of the organisms was made to family level (Thirion et al., 1995; Davies & Day, 1998; Dickens & Graham, 2002; Gerber & Gabriel, 2002).

Interpretation of the results of biological monitoring depends, to a certain extent, on interpretation of site-specific conditions (Thirion *et al.*, 1995). In the context of this investigation it would be best not to use SASS5 scores in isolation, but rather in comparison with relevant habitat scores. The reason for this is that some sites have a less desirable habitat or fewer biotopes than others do. In other words, a low SASS5 score is not necessarily regarded as poor in conjunction with a low habitat score. Also, a high SASS5 score, in conjunction with a low habitat score, can be regarded as better than a high SASS5 score in conjunction with a high habitat score. A low SASS5 score, together with a high habitat score, would be indicative of poor conditions. The IHAS Index is valuable in helping to interpret SASS5 scores and the effects of habitat variation on aquatic macro-invertebrate community integrity.

Classification of the system took place by using the following category table (Table 1B):

**Table 1B: Classification used to evaluate SASS5 criteria results for this study**

| Class | Description | SASS Score% | ASPT |
|---|---|---|---|
| A | Unimpaired. High diversity of taxa with numerous sensitive taxa. | 90-100<br>80-89 | Variable<br>>90 |
| B | Slightly impaired. High diversity of taxa, but with fewer sensitive taxa. | 80-89<br>70-79<br>70-89 | <75<br>>90<br>76-90 |
| C | Moderately impaired. Moderate diversity of taxa. | 60-79<br>50-59<br>50-79 | <60<br>>75<br>60-75 |
| D | Largely impaired. Mostly tolerant taxa present. | 50 - 59<br>40-49 | <60<br>Variable |
| E | Severely impaired. Only tolerant taxa present. | 20-39 | Variable |
| F | Critically impaired. Very few tolerant taxa present. | 0-19 | Variable |

## Macro-invertebrate Response Assessment Index (MIRAI)

The four major components of a stream system that determine productivity, with particular reference to aquatic organisms, are flow regime, physical habitat structure, water quality and energy inputs. An interplay between these factors (particularly habitat and availability of food sources) result in the discontinuous, patchy distribution pattern of aquatic macro-invertebrate populations. As such aquatic invertebrates shall respond to habitat changes (i.e. changes in driver conditions).

To relate drivers to such changes in habitat and aquatic invertebrate condition, two key elements are required. Firstly habitat preferences and requirements for each taxa present should be obtained. As such reference conditions can be established against which any response to drivers can be measured. Secondly habitat features should be evaluated in terms of suitability and the requirements mentioned in the first point. As a result expected and actual patterns can be evaluated to achieve an Ecostatus Category (EC) rating.

Based on the three key requirements, the MIRAI provides an approach to deriving and interpreting aquatic invertebrate response to driver changes. The index has been applied following methodology described by Thirion (2007). Aquatic macro-invertebrates expected at each point were derived both from previous studies of rivers near the area (Golder 2012), as well as data obtained during the current assessment.

## Fish biota assessments

Fish were collected employing standard collection techniques which included electrofishing, cast netting, gill netting and catching fish with baited hooks. The fish community integrity assessment undertaken is based on the premise that "drivers" (environmental conditions) may cause fish stress which shall then manifest as changes in fish species assemblage. In the analyses of data preferences and intolerances of the reference fish assemblage, as well as the response of the actual (present) fish assemblage to particular drivers is considered to indicate a change from reference conditions.

The reference or expected fish assemblage must thus be indicated. For this purpose, fish species from the area have been recorded and where possible to date identified.
These records were then used to create a reference list, which also considers aspects such as habitat preference of the various fish species.

Some fish species collected is still to be identified, and thus these results are considered preliminary and must be considered and interpreted with caution.

## Diatom analyses

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 the 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, salinisation and changes in pH. They are therefore useful for providing an overall picture of trends within an aquatic system.

Diatom slides were prepared by acid oxidation using hydrochloric acid and potassium permanganate. Clean diatom frustules were mounted onto a glass slide ready for analysis. Taxa were identified mainly according to standard floras (Krammer & Lange- Bertalot, 2000). The aim of the data analysis was to identify and count diatom valves (400 counts) to produce semi-quantitative data from which ecological conclusions can be drawn.

The diatom index (integrating impacts from organic material, electrolytes, pH and nutrients) used in this assessment was the Specific Pollution sensitivity Index (SPI), one of the most extensively tested indices in Europe. The interpretation of the SPI scores applied in this study is displayed in Table 1

**Table 1C: Class limit boundaries for the Specific Pollution sensitivity Index (SPI) (Koekemoer and Taylor, 2011).**

| SPI Score | Class | Ecological Category |
|---|---|---|
| >17.3 | High quality | A |
| 16.8-17.2 | | A/B |
| 13.3-16.7 | Good quality | B |
| 12.9-13.2 | | B/C |
| 9.2-12.8 | Moderate quality | C |
| 8.9-9.1 | | C/D |
| 5.3-8.8 | Poor quality | D |
| 4.8-5.2 | | D/E |
| <4.8 | Bad quality | E |

## Integrated Ecostatus Determination

The PES or EcoStatus per component (fish, macroinvertebrates, riparian vegetation and habitat integrity) are derived from the various models. These assessments of the biophysical components can be integrated through a rule-based model, with the overall classification given as an EcoStatus score. To determine the EcoStatus, the macroinvertebrates (MIRAI) and fish (FRAI) scores and confidences in the assessments are combined to determine the instream category. The VEGRAI score and confidence in the assessment is then included in the model and the integrated score and EcoStatus category is calculated. If the VEGRAI score is not available, the riparian habitat integrity score is used.

# APPENDIX B: Wetland Method of Assessment

### Wetland Classification System

All areas containing wetland or riparian characteristics that were encountered within the study area were assessed using the Classification System for Wetlands and other Aquatic Ecosystems in South Africa. User Manual: Inland systems, hereafter referred to as the "Classification System" (Ollis *et. al*., 2013). This method encompasses the broad suite of "wetlands" as defined by the Ramsar Convention and includes all ecosystems that the Ramsar Convention is concerned with.

A summary on Levels 1 to 4 of the classification system are presented in the tables below.

**Table B1: Classification System for Inland Systems, up to Level 3.**

| WETLAND / AQUATIC ECOSYSTEM CONTEXT | | |
|---|---|---|
| LEVEL 1:<br>SYSTEM | LEVEL 2:<br>REGIONAL SETTING | LEVEL 3:<br>LANDSCAPE UNIT |
| Inland Systems | DWA Level 1 Ecoregions<br>OR<br>NFEPA WetVeg Groups<br>OR<br>Other special framework | Valley Floor |
| | | Slope |
| | | Plain |
| | | Bench<br>(Hilltop / Saddle / Shelf) |

**Level 1: Inland systems**

From the classification system, Inland Systems (Table B1) are defined as **aquatic ecosystems that have no existing connection to the ocean**[1] (i.e. characterised by the complete absence of marine exchange and/or tidal influence) but **which are inundated or saturated with water, either permanently or periodically.** It is important to bear in mind, however, that certain Inland Systems may have had a historical connection to the ocean, which in some cases may have been relatively recent.

**Level 2: Ecoregions & Wetland Vegetation Groups**

For Inland Systems, the regional spatial framework that has been included in Level 2 of the classification system is that of the aquatic ecoregion (Table B1). Ecoregions have most commonly been used to categorise the regional setting for national and regional water resource management applications, especially in relation to rivers.

[1] Most rivers are indirectly connected to the ocean via an estuary at the downstream end, but where marine exchange (i.e. the presence of seawater) or tidal fluctuations are detectable in a river channel that is permanently or periodically connected to the ocean, it is defined as part of the estuary.

**Table B2: Hydrogeomorphic (HGM) Units for the Inland System, showing the primary HGM Types at Level 4A and the subcategories at Level 4B to 4C.**

| FUNCTIONAL UNIT | | |
|---|---|---|
| LEVEL 4:<br>HYDROGEOMORPHIC (HGM) UNIT | | |
| *HGM type* | Longitudinal zonation/ Landform / Outflow drainage | Landform / Inflow drainage |
| **A** | **B** | **C** |
| River | Mountain headwater stream | Active channel |
| | | Riparian zone |
| | Mountain stream | Active channel |
| | | Riparian zone |
| | Transitional | Active channel |
| | | Riparian zone |
| | Upper foothills | Active channel |
| | | Riparian zone |
| | Lower foothills | Active channel |
| | | Riparian zone |
| | Lowland river | Active channel |
| | | Riparian zone |
| | Rejuvenated bedrock fall | Active channel |
| | | Riparian zone |
| | Rejuvenated foothills | Active channel |
| | | Riparian zone |
| | Upland floodplain | Active channel |
| | | Riparian zone |
| Channelled valley-bottom wetland | (not applicable) | (not applicable) |
| Unchannelled valley-bottom wetland | (not applicable) | (not applicable) |
| Floodplain wetland | Floodplain depression | (not applicable) |
| | Floodplain flat | (not applicable) |
| Depression | Exorheic | With channelled inflow |
| | | Without channelled inflow |
| | Endorheic | With channelled inflow |
| | | Without channelled inflow |
| | Dammed | With channelled inflow |
| | | Without channelled inflow |
| Seep | With channelled outflow | (not applicable) |
| | Without channelled outflow | (not applicable) |
| Wetland flat | (not applicable) | (not applicable) |

**Level 3: Landscape Setting**

At Level 3 of the classification system for Inland Systems, a distinction is made between four Landscape Units (Table B1) on the basis of the landscape setting (i.e. topographical position) within which an HGM Unit is situated, as follows (Ollis *et. al.,* 2013):

- **Slope:** an included stretch of ground that is not part of a valley floor, which is typically located on the side of a mountain, hill or valley;
- **Valley floor:** The base of a valley, situated between two distinct valley side-slopes;
- **Plain:** an extensive area of low relief characterised by relatively level, gently undulating or uniformly sloping land; and
- **Bench (hilltop/saddle/shelf):** an area of mostly level or nearly level high ground (relative to the broad surroundings), including hilltops/crests (areas at the top of a mountain or hill flanked by down-slopes in all directions), saddles (relatively high-lying areas flanked by down-slopes on two sides in one direction and up-slopes on two sides in an approximately perpendicular

direction), and shelves/terraces/ledges (relatively high-lying, localised flat areas along a slope, representing a break in slope with an up-slope one side and a down-slope on the other side in the same direction).

**Level 4: Hydrogeomorphic Units**

Seven primary HGM Types are recognised for Inland Systems at Level 4A of the classification system (Table B2), on the basis of hydrology and geomorphology (Ollis *et. al*., 2013), namely:

- **River:** a linear landform with clearly discernible bed and banks, which permanently or periodically carries a concentrated flow of water;
- **Channelled valley-bottom wetland:** a valley-bottom wetland with a river channel running through it;
- **Unchannelled valley-bottom wetland:** a valley-bottom wetland without a river channel running through it;
- **Floodplain wetland:** the mostly flat or gently sloping land adjacent to and formed by an alluvial river channel, under its present climate and sediment load, which is subject to periodic inundation by over-topping of the channel bank;
- **Depression:** a landform with closed elevation contours that increases in depth from the perimeter to a central area of greatest depth, and within which water typically accumulates;
- **Wetland Flat:** a level or near-level wetland area that is not fed by water from a river channel, and which is typically situated on a plain or a bench. Closed elevation contours are not evident around the edge of a wetland flat; and
- **Seep:** a wetland area located on (gently to steeply) sloping land, which is dominated by the colluvial (i.e. gravity-driven), unidirectional movement of material down-slope. Seeps are often located on the side-slopes of a valley but they do not, typically, extend into a valley floor.

The above terms have been used for the primary HGM Units in the classification system to try and ensure consistency with the wetland classification terms currently in common usage. Similar terminology (but excluding categories for “channel”, “flat” and “valleyhead seep”) is used, for example, in the recently developed tools produced as part of the Wetland Management Series including WET-Health (Macfarlane *et. al*., 2008), WET-IHI (DWAF, 2007) and WET-EcoServices (Kotze *et. al*., 2009).

### *Wetland ecosystem services assessment*

“The importance of a water resource, in ecological social or economic terms, acts as a modifying or motivating determinant in the selection of the management class”.[2] The assessment of the ecosystem services actually supplied by the identified wetlands was conducted according to the guidelines as described by Kotze *et al.* (2009). An assessment was undertaken that examines and rates the following services according to their degree of importance and the degree to which the service is provided:

- Flood attenuation;
- Stream flow regulation;
- Sediment trapping;
- Phosphate trapping;
- Nitrate removal;
- Toxicant removal;
- Erosion control;
- Carbon storage;
- Maintenance of biodiversity;
- Water supply for human use;
- Natural resources;
- Cultivated foods;
- Cultural significance;
- Tourism and recreation;
- Education and research.

The characteristics were used to quantitatively determine the value, and by extension sensitivity, of the wetlands. Each characteristic was scored to give the likelihood that the service is being provided. The scores for each service were then averaged to give an overall score to the wetland.

**Table B3: Classes for determining the likely extent to which a benefit is being supplied.**

| Score | Rating of the likely extent to which the benefit is being supplied |
|---|---|
| <0.5 | Low |
| 0.6-1.2 | Moderately low |
| 1.3-2 | Intermediate |
| 2.1-3 | Moderately high |
| >3 | High |

## *Freshwater Resource PES Assessment (WET-Health Level 1)*

Healthy wetlands are known to provide important habitats for wildlife and to deliver a range of important goods and services to society. Management of these systems is therefore essential if these attributes are to be retained within an ever changing landscape. The primary purpose of this assessment is to evaluate the eco-physical health of wetlands, and in so doing to promote their conservation and wise management.

### Level of Evaluation

Two levels of assessment are provided by WET-Health:

- Level 1: Desktop evaluation, with limited field verification. This is generally applicable to situations where a large number of wetlands need to be assessed at a very low resolution; or
- Level 2: On-site evaluation. This involves structured sampling and data collection in a single wetland and its surrounding catchment.

### Framework for the Assessment

A set of three modules has been synthesised from the set of processes, interactions and interventions that take place in wetland systems and their catchments: hydrology (water inputs, distribution and retention, and outputs), geomorphology (sediment inputs, retention and outputs) and vegetation (transformation and presence of introduced alien species).

### Units of Assessment

Central to WET-Health is the characterisation of HGM Units, which have been defined based on geomorphic setting (e.g. hillslope or valley-bottom; whether drainage is open or closed), water source (surface water dominated or sub-surface water dominated) and pattern of water flow through the wetland unit (diffusely or channelled) as described under the Classification System for Wetlands and other Aquatic Ecosystems above.

### Quantification of Present State of a wetland

The overall approach is to quantify the impacts of human activity or clearly visible impacts on wetland health, and then to convert the impact scores to a Present State score. This takes the form of assessing the spatial extent of the impact of individual activities and then separately assessing the intensity of the impact of each activity in the affected area. The extent and intensity are then combined to determine an overall magnitude of impact. The impact scores, and Present State categories are provided in the table below.

**Table B4: Impact scores and categories of Present State used by WET-Health for describing the integrity of wetlands.**

| Impact category | Description | Impact score range | Present State category |
|---|---|---|---|
| None | Unmodified, natural | 0-0.9 | A |
| Small | Largely natural with few modifications. A slight change in ecosystem processes is discernible and a small loss of natural habitats and biota may have taken place. | 1-1.9 | B |
| Moderate | Moderately modified. A moderate change in ecosystem processes and loss of natural habitats has taken place, but the natural habitat remains predominantly intact. | 2-3.9 | C |
| Large | Largely modified. A large change in ecosystem processes and loss of natural habitat and biota and has occurred. | 4-5.9 | D |
| Serious | The change in ecosystem processes and loss of natural habitat and biota is great, but some remaining natural habitat features are still recognisable. | 6-7.9 | E |
| Critical | Modifications have reached a critical level and the ecosystem processes have been completely modified with an almost complete loss of natural habitat and biota. | 8-10 | F |

### Assessing the Anticipated Trajectory of Change

As is the case with the Present State, future threats to the state of the wetland may arise from activities in the catchment upstream of the unit or within the wetland itself or from processes downstream of the wetland. In each of the individual sections for hydrology, geomorphology and vegetation, five potential situations exist depending upon the direction and likely extent of change (Table B6 below).

**Table B5: Trajectory of Change classes and scores used to evaluate likely future changes to the present state of the wetland.**

| Change Class | Description | HGM change score | Symbol |
|---|---|---|---|
| Substantial improvement | State is likely to improve substantially over the next 5 years | 2 | ↑↑ |
| Slight improvement | State is likely to improve slightly over the next 5 years | 1 | ↑ |
| Remain stable | State is likely to remain stable over the next 5 years | 0 | → |
| Slight deterioration | State is likely to deteriorate slightly over the next 5 years | -1 | ↓ |
| Substantial deterioration | State is expected to deteriorate substantially over the next 5 years | -2 | ↓↓ |

### Overall health of the wetland

Once all HGM Units have been assessed, a summary of health for the wetland as a whole need to be calculated. This is achieved by calculating a combined score for each component by area-weighting the scores calculated for each HGM Unit.

Recording the health assessments for the hydrology, geomorphology and vegetation components provide a summary of impacts, Present State, Trajectory of Change and Health for individual HGM Units and for the entire wetland.

### *Ecological Importance and Sensitivity (EIS) (Rountree & Kotze, 2013)*

The purposed of assessing importance and sensitivity of water resources is to be able to identify those systems that provide higher than average ecosystem services, biodiversity support functions or are especially sensitive to impacts. Water resources with higher ecological importance may require managing such water resources in a better condition than the present to ensure the continued provision of ecosystem benefits in the long term (Rountree & Kotze, 2013).

In order to align the outputs of the Ecoservices assessment (i.e. ecological and socio-cultural service provision) with methods used by the DWAF (now the DWS) used to assess the EIS of other watercourse types, a tool was developed using criteria from both WET-Ecoservices (Kotze, *et, al,* 2009) and earlier DWAF EIA assessment tools. Thus, three proposed suites of important criteria for assessing the Importance and Sensitivity for wetlands were proposed, namely:

- Ecological Importance and Sensitivity, incorporating the traditionally examined criteria used in EIS assessments of other water resources by DWA and thus enabling consistent assessment approaches across water resource types;
- Hydro-functional importance, taking into consideration water quality, flood attenuation and sediment trapping ecosystem services that the wetland may provide; and
- Importance in terms of socio-cultural benefits, including the subsistence and cultural benefits provided by the wetland system.

The highest of these three suites of scores is then used to determine the overall Importance and Sensitivity category (Table B7) of the wetland system being assessed.

**Table A6: Ecological Importance and Sensitivity Categories and the interpretation of median scores for biota and habitat determinants (adapted from Kleynhans, 1999).**

| EIS Category | Range of Mean | Recommended Ecological Management Class |
|---|---|---|
| Very high<br>Wetlands that are considered ecologically important and sensitive on a national or even international level. The biodiversity of these wetlands is usually very sensitive to flow and habitat modifications. | >3 and <=4 | A |
| High<br>Wetlands that are considered to be ecologically important and sensitive. The biodiversity of these wetlands may be sensitive to flow and habitat modifications. | >2 and <=3 | B |
| Moderate<br>Wetlands that are considered to be ecologically important and sensitive on a provincial or local scale. The biodiversity of these wetlands is not usually sensitive to flow and habitat modifications. | >1 and <=2 | C |
| Low/marginal<br>Wetlands that are not ecologically important and sensitive at any scale. The biodiversity of these wetlands is ubiquitous and not sensitive to flow and habitat modifications. | >0 and <=1 | D |

### *Recommended Ecological Category (REC)*

"A high management class relates to the flow that will ensure a high degree of sustainability and a low risk of ecosystem failure. A low management class will ensure marginal maintenance of sustainability, but carries a higher risk of ecosystem failure." [3]

[3] Department of Water Affairs and Forestry, South Africa *Version 1.0 of Resource Directed Measures for Protection of Water Resources 1999*

The Ecological Management Class (EMC) was determined based on the results obtained from the PES, reference conditions and Ecological Importance and Sensitivity of the resource (sections above). Followed by realistic recommendations, mitigation, and rehabilitation measures to achieve the desired EMC.

A wetland may receive the same class for the PES, as the EMC if the wetland is deemed in good condition, and therefore must stay in good condition. Otherwise, an appropriate EMC should be assigned in order to prevent any further degradation as well as to enhance the PES of the wetland feature.

**Table B7: Description of EMC classes.**

| Class | Description |
|---|---|
| A | Unmodified, natural |
| B | Largely natural with few modifications |
| C | Moderately modified |
| D | Largely modified |

### *Wetland delineation*

For the purposes of this investigation, wetland habitat was defined according to the factors associated with the Ramsar Commissions' definition of a wetland. The extent of the wetland was determined by delineating the wetland based upon the Department of Water and Sanitation (DWS) (formerly DWA / DWAF) guidelines 'A practical field procedure for the identification and delineation of wetlands and riparian areas' (DWAF, 2008). This method is regarded as regional best practice adapted from the Ramsar Commissions guidelines and stipulates that consideration be given to four specific wetland indicators to determine the boundary of the wetland. Whilst not developed in the region in which the investigation area is located, this method is regarded as applicable, relevant and provides an accurate rationale in watercourse mapping in support of the International Finance Corporation standards for rigorous characterisation of watercourses.

These indicators are:

- Densification of riparian vegetation;
- Changes in hue of vegetation;
- Linear connectivity of features to drainage systems;
- Position in the landscape, for example valley floors; and
- Presence of surface water showing up either as black areas or white areas reflecting cloud cover.

By observing the evidence of these features, in the form of indicators, wetlands and riparian zones can be delineated and identified. If the use of these indicators and the interpretation of the findings are applied correctly, then the resulting delineation can be considered accurate (DWAF 2005).

The presence of hydric soils as a soil wetness indicator (i.e. examination of redoximorphic features within the soil) are one of the most important factors for identifying wetlands boundaries. The reason being that vegetation (considered to be the primary determining factor) can easily respond to changes in hydrology (e.g. the draining of a wetland), while the soil morphological signatures remain even if the wetland hydrology is altered.

A number of soil forms associated with the permanent zone of the wetland or the seasonal / temporary zones are provided in the guidelines of this method.

One of these are the redoximorphic features, which are the result of the reduction, translocation and oxidation (precipitation) of Fe (iron) and Mn (manganese) oxides that occur when soils are saturated for sufficiently long periods of time to become anaerobic. Only once soils within 500mm of the surface display these redoximorphic features can the soils be considered to be hydric (wetland) soils, and it can then be considered a wetland. Redoximorphic features typically occur in three types:

- A reduced matrix – i.e. an *in situ* low chroma (soil colour), resulting from the absence of $Fe_3^+$ ions which are characterised by "grey" colours of the soil matrix.
- Redox depletions - the "grey" (low chroma) bodies within the soil where Fe-Mn oxides have been stripped out, or where both Fe-Mn oxides and clay have been stripped. Iron depletions and clay depletions can occur; and
- Redox concentrations - Accumulation of iron and manganese oxides (also called mottles).

Once the presence or absence of redoximorphic features within the upper 500mm of the soil profile is identified, that alone is sufficient to identify the soil as being hydric (a wetland soil) or non-hydric (non-wetland soil) (Collins, 2005; DWAF, 2005).

Riparian and wetland zones can be divided into three zones (DWAF 2005). The permanent zone of wetness is nearly always saturated. The seasonal zone is saturated for a significant part of the rainy season and the temporary zone surrounds the seasonal zone and is only saturated for a short period of the year, but is saturated for a sufficient period, under normal circumstances, to allow for the formation of hydromorphic soils and the growth of wetland vegetation.

Since wetlands has a wetness gradient from the middle of the wetland to the adjacent terrestrial area, vegetation in an untransformed state can be used to support the delineation of a wetland, due to plant community adapting to the gradient. Plant communities are assessed, rather than individual indicator species, but the dominant species (hydrophytes or not) in the area are assessed to determine the presence of a wetland.

# APPENDIX C: SASS5 scoresheets

RIVER HEALTH PROGRAMME - SASS 5 SCORE SHEET

| DATE:13-07-2017 | TAXON | | S | VG | GSM | TOT | TAXON | | S | VG | GSM | TOT | TAXON | | S | VG | GSM | TOT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **GRID REFERENCE**: | **PORIFERA** | 5 | | | | | **HEMIPTERA:** | | | | | | **DIPTERA:** | | | | | |
| S:° | **COELENTERATA** | 1 | | | | | Belostomatidae* | 3 | | | | | Athericidae | 10 | | | | |
| E: ° | **TURBELLARIA** | 3 | | | | | Corixidae* | 3 | | | | | Blepharoceridae | 15 | | | | |
| SITE CODE: SR1 | **ANNELIDA:** | | | | | | Gerridae* | 5 | | 1 | | 1 | Ceratopogonidae | 5 | | | | |
| RIVER: UNNAMMED TRIB | Oligochaeta | 1 | | | | | Hydrometridae* | 6 | | | | | Chironomidae | 2 | | | | |
| SITE DESCRIPTION: | Leeches | 3 | | | | | Naucoridae* | 7 | | | | | Culicidae* | 1 | | | | |
| WEATHER CONDITION: WARM & RAINY | **CRUSTACEA:** | | | | | | Nepidae* | 3 | | | | | Dixidae* | 10 | | | | |
| TEMP: 29.7 °C | Amphipoda | 13 | | | | | Notonectidae* | 3 | | | | | Empididae | 6 | | | | |
| Ph: 5.67 | Potamonautidae* | 3 | | | | | Pleidae* | 4 | | | | | Ephydridae | 3 | | | | |
| DO: mg/l | Atyidae | 8 | | A | | A | Veliidae/M..veliidae* | 5 | | | | | Muscidae | 1 | | | | |
| Cond: 2.4 mS/m | Palaemonidae | 10 | | | | | **MEGALOPTERA:** | | | | | | Psychodidae | 1 | | | | |
| **BIOTOPES SAMPLED:** | **HYDRACARINA** | 8 | | | | | Cordalidae | 8 | | | | | Simuliidae | 5 | | | | |
| SIC: 3 TIME: 1 minutes | **PLECOPTERA:** | | | | | | Sialidae | 6 | | | | | Syrphidae* | 1 | | | | |
| SOOC: | Notonemouridae | 14 | | | | | **TRICHOPTERA** | | | | | | Tabanidae | 5 | | | | |
| BEDROCK: | Perlidae | 12 | | | | | Dipseudopsidae | 10 | | | | | Tipulidae | 5 | | | | |
| AQUATIC VEG: DOM SP: | **EPHEMEROPTERA** | | | | | | Ecnomidae | 8 | | | | | **GASTROPODA** | | | | | |
| M VEG IC: 4 DOM SP: GRASSES SEDSES | Baetidae 1sp | 4 | | | | | Hydropsychidae 1sp | 4 | | | | | Ancylidae | 6 | | | | |
| M VEG OOC: 3 DOM SP:GRASSES SEDSES | Baetidae 2 sp | 6 | | | | | Hydropsychidae 2 sp | 6 | | | | | Bulininae* | 3 | | | | |
| GRAVEL: | Baetidae >2 sp | 12 | | | | | Hydropsychidae >2 sp | 12 | | | | | Hydrobiidae* | 3 | | | | |
| SAND: 2 | Caenidae | 6 | | | | | Philopotamidae | 10 | | | | | Lymnaeidae* | 3 | | | | |
| MUD: 2 | Ephemeridae | 15 | | | | | Polycentropodidae | 12 | | | | | Physidae* | 3 | | | | |
| HAND PICKING/VISUAL OBS: | Heptageniidae | 13 | | | | | Psychomyiidae/Xiphocen. | 8 | | | | | Planorbidae* | 3 | | | | |
| **FLOW**: MEDUIM | Leptophlebiidae | 9 | | | | | **CASED CADDIS:** | | | | | | Thiaridae* | 3 | | | | |
| **TURBIDITY**: MEDUIM | Oligoneuridae | 15 | | | | | Barbarochthonidae SWC | 13 | | | | | Viviparidae* ST | 5 | | | | |
| **RIPARIAN LAND USE:** | Polymitarcyidae | 10 | | | | | Calamoceratidae ST | 11 | | | | | **PELECYPODA** | | | | | |
| | Prosopistomatidae | 15 | | | | | Glossosomatidae SWC | 11 | | | | | Corbiculidae | 5 | | | | |
| | Teloganodidae SWC | 12 | | | | | Hydroptilidae | 6 | | | | | Sphaeriidae | 3 | | | | |
| | Tricorythidae | 9 | | | | | Hydrosalpingidae SWC | 15 | | | | | Unionidae | 6 | | | | |
| | **ODONATA:** | | | | | | Lepidostomatidae | 10 | | | | | **SASS SCORE:** | | 0 | 17 | 6 | 23 |
| **DISTURBANCE IN RIVER:** | Calopterygidae ST,T | 10 | | | | | Leptoceridae | 6 | | | 1 | 1 | **NO OF TAXA:** | | 0 | 3 | 1 | 4 |
| | Chlorocyphidae | 10 | | | | | Petrothrincidae SWC | 11 | | | | | **ASPT:** | | 0 | 5.7 | 6 | 5.8 |
| | Chlorolestidae | 8 | | | | | Pisuliidae | 10 | | | | | **IHAS**: | 62% | | | | |
| | Coenagrionidae | 4 | | 1 | | 1 | Sericostomatidae SWC | 13 | | | | | **Other biota:** | | | | | |
| | Lestidae | 8 | | | | | **COLEOPTERA:** | | | | | | T N 11, SPOT MVVTH BROODE | | | | | |
| **SIGNS OF POLLUTION:** | Platycnemidae | 10 | | | | | Dytiscidae* | 5 | | | | | **COMMENTS**: | | | | | |
| | Protoneuridae | 8 | | | | | Elmidae/Dryopidae* | 8 | | | | | AFRICAN PIKE | | | | | |
| | Zygoptera juvs. | 6 | | | | | Gyrinidae* | 5 | | | | | | | | | | |
| | Aeshnidae | 8 | | | | | Halipidae* | 5 | | | | | | | | | | |
| | Corduliidae | 8 | | | | | Helodidae | 12 | | | | | * = airbreathers | | | | | |
| **OTHER OBSERVATIONS:** | Gomphidae | 6 | | | | | Hydraenidae* | 8 | | | | | SWC = South Western Cape T = Tropical | | | | | |
| | Libellulidae | 4 | | | | | Hydrophilidae* | 5 | | | | | VG = all vegetation ST = Sub-tropical | | | | | |
| | **LEPIDOPTERA:** | | | | | | Limnichidae | 10 | | | | | GSM = gravel, sand & mud S = Stone & rock | | | | | |
| | Pyralidae | 12 | | | | | Psephenidae | 10 | | | | | 1=1, A=2-10, B=10-100, C=100-1000, D=>1000 | | | | | |

RIVER HEALTH PROGRAMME - SASS 5 SCORE SHEET

| DATE:16-07-2017 | TAXON | | S | VG | GSM | TOT | TAXON | | S | VG | GSM | TOT | TAXON | | S | VG | GSM | TOT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **GRID REFERENCE**: | **PORIFERA** | 5 | | | | | **HEMIPTERA:** | | | | | | **DIPTERA:** | | | | | |
| S:° | **COELENTERATA** | 1 | | | | | Belostomatidae* | 3 | | | | | Athericidae | 10 | | | | |
| E: ° | **TURBELLARIA** | 3 | 1 | | | 1 | Corixidae* | 3 | | | | | Blepharoceridae | 15 | | | | |
| SITE CODE: SR3 | **ANNELIDA:** | | | | | | Gerridae* | 5 | | | | | Ceratopogonidae | 5 | | | | |
| RIVER: YUMBEI RIVER | Oligochaeta | 1 | 1 | | 1 | 1 | Hydrometridae* | 6 | | | | | Chironomidae | 2 | A | | | A |
| SITE DESCRIPTION: | Leeches | 3 | | | | | Naucoridae* | 7 | | | | | Culicidae* | 1 | 1 | | | 1 |
| WEATHER CONDITION: | **CRUSTACEA:** | | | | | | Nepidae* | 3 | | | | | Dixidae* | 10 | | | | |
| TEMP: 30.5 °C | Amphipoda | 13 | | | | | Notonectidae* | 3 | | | | | Empididae | 6 | | | | |
| Ph: 4.88 | Potamonautidae* | 3 | 1 | | | 1 | Pleidae* | 4 | | | | | Ephydridae | 3 | | | | |
| DO: mg/l | Atyidae | 8 | | | | | Veliidae/M..veliidae* | 5 | A | | | A | Muscidae | 1 | | | | |
| Cond: 2 mS/m | Palaemonidae | 10 | | | | | **MEGALOPTERA:** | | | | | | Psychodidae | 1 | | | | |
| **BIOTOPES SAMPLED: 10** | **HYDRACARINA** | 8 | | | | | Cordalidae | 8 | | | | | Simuliidae | 5 | | | | |
| SIC: 4 TIME: 2 minutes | **PLECOPTERA:** | | | | | | Sialidae | 6 | | | | | Syrphidae* | 1 | | | | |
| SOOC: | Notonemouridae | 14 | | | | | **TRICHOPTERA** | | | | | | Tabanidae | 5 | | | | |
| BEDROCK: | Perlidae | 12 | A | . | A | A | Dipseudopsidae | 10 | | | | | Tipulidae | 5 | | | | |
| AQUATIC VEG: DOM SP: | **EPHEMEROPTERA** | | | | | | Ecnomidae | 8 | | | | | **GASTROPODA** | | | | | |
| MVEG IC: 2 DOM SP: | Baetidae 1sp | 4 | | | | | Hydropsychidae 1sp | 4 | | A | | | Ancylidae | 6 | | | | |
| MVEG OOC: DOM SP: | Baetidae 2 sp | 6 | | | | | Hydropsychidae 2 sp | 6 | A | | | A | Bulininae* | 3 | | | | |
| GRAVEL: 5 | Baetidae >2 sp | 12 | A | | | A | Hydropsychidae >2 sp | 12 | | | | | Hydrobiidae* | 3 | | | | |
| SAND: | Caenidae | 6 | | | | | Philopotamidae | 10 | | | | | Lymnaeidae* | 3 | | | | |
| MUD: | Ephemeridae | 15 | | | | | Polycentropodidae | 12 | | | | | Physidae* | 3 | | | | |
| HAND PICKING/VISUAL OBS: YES | Heptageniidae | 13 | A | A | A | B | Psychomyiidae/Xiphocen. | 8 | | | | | Planorbidae* | 3 | | | | |
| **FLOW**: | Leptophlebiidae | 9 | | | | | **CASED CADDIS:** | | | | | | Thiaridae* | 3 | | | | |
| **TURBIDITY**: | Oligoneuridae | 15 | | | | | Barbarochthonidae SWC | 13 | | | | | Viviparidae* ST | 5 | | | | |
| **RIPARIAN LAND USE:** | Polymitarcyidae | 10 | | | | | Calamoceratidae ST | 11 | | | | | **PELECYPODA** | | | | | |
| | Prosopistomatidae | 15 | | | | | Glossosomatidae SWC | 11 | | | | | Corbiculidae | 5 | | | | |
| | Teloganodidae SWC | 12 | | | | | Hydroptilidae | 6 | | | | | Sphaeriidae | 3 | | | | |
| | Tricorythidae | 9 | | | | | Hydrosalpingidae SWC | 15 | | | | | Unionidae | 6 | | | | |
| | **ODONATA:** | | | | | | Lepidostomatidae | 10 | | | | | **SASS SCORE:** | | 63 | 55 | 26 | 89 |
| **DISTURBANCE IN RIVER:** | Calopterygidae ST,T | 10 | | | | | Leptoceridae | 6 | | 1 | | 1 | **NO OF TAXA:** | | 11 | 7 | 3 | 15 |
| | Chlorocyphidae | 10 | | | | | Petrothrincidae SWC | 11 | | | | | **ASPT:** | | 5.7 | 7.9 | 9 | 5.9 |
| | Chlorolestidae | 8 | | 1 | | 1 | Pisuliidae | 10 | | | | | **IHAS**: | 71% | | | | |
| | Coenagrionidae | 4 | | | | | Sericostomatidae SWC | 13 | | | | | **Other biota:** | | | | | |
| | Lestidae | 8 | | | | | **COLEOPTERA:** | | | | | | KILLRFISH, MOUTHROCDER, IMBRI | | | | | |
| **SIGNS OF POLLUTION:** | Platycnemidae | 10 | | | | | Dytiscidae* | 5 | | | | | **COMMENTS**: | | | | | |
| | Protoneuridae | 8 | | | | | Elmidae/Dryopidae* | 8 | | | | | | | | | | |
| | Zygoptera juvs. | 6 | | | | | Gyrinidae* | 5 | | | | | | | | | | |
| | Aeshnidae | 8 | | | | | Halipidae* | 5 | | | | | | | | | | |
| | Corduliidae | 8 | | 1 | | 1 | Helodidae | 12 | | | | | * = airbreathers | | | | | |
| **OTHER OBSERVATIONS:** | Gomphidae | 6 | | | | | Hydraenidae* | 8 | | | | | SWC = South Western Cape T = Tropical | | | | | |
| | Libellulidae | 4 | | 1 | | 1 | Hydrophilidae* | 5 | 1 | | | 1 | VG = all vegetation ST = Sub-tropical | | | | | |
| | **LEPIDOPTERA:** | | | | | | Limnichidae | 10 | | | | | GSM = gravel, sand & mud S = Stone & rock | | | | | |
| | Pyralidae | 12 | | | | | Psephenidae | 10 | | | | | 1=1, A=2-10, B=10-100, C=100-1000, D=>1000 | | | | | |

RIVER HEALTH PROGRAMME - SASS 5 SCORE SHEET

| **DATE**:16-07-2017 | **TAXON** | | **S** | **VG** | **GSM** | **TOT** | **TAXON** | | **S** | **VG** | **GSM** | **TOT** | **TAXON** | | **S** | **VG** | **GSM** | **TOT** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **GRID REFERENCE**: | **PORIFERA** | 5 | | | | | **HEMIPTERA:** | | | | | | **DIPTERA:** | | | | | |
| S:° | **COELENTERATA** | 1 | | | | | Belostomatidae* | 3 | | | | | Athericidae | 10 | | | | |
| E: ° | **TURBELLARIA** | 3 | | | | | Corixidae* | 3 | 1 | A | | A | Blepharoceridae | 15 | | | | |
| SITE CODE: SR4 | **ANNELIDA:** | | | | | | Gerridae* | 5 | | | | | Ceratopogonidae | 5 | | | | |
| RIVER: PEKOTE STREAM | Oligochaeta | 1 | | 1 | | 1 | Hydrometridae* | 6 | | | | | Chironomidae | 2 | | | | |
| SITE DESCRIPTION: | Leeches | 3 | | | | | Naucoridae* | 7 | | | | | Culicidae* | 1 | | | | |
| WEATHER CONDITION: NOT | **CRUSTACEA:** | | | | | | Nepidae* | 3 | | | | | Dixidae* | 10 | | | | |
| TEMP: 29.8 °C | Amphipoda | 13 | | | | | Notonectidae* | 3 | | | | | Empididae | 6 | | | | |
| Ph: 5.08 | Potamonautidae* | 3 | | | | | Pleidae* | 4 | | | | | Ephydridae | 3 | | | | |
| DO: mg/l | Atyidae | 8 | | | | | Veliidae/M..veliidae* | 5 | | A | | A | Muscidae | 1 | | | | |
| Cond: 2.7 mS/m | Palaemonidae | 10 | | | | | **MEGALOPTERA:** | | | | | | Psychodidae | 1 | | | | |
| **BIOTOPES SAMPLED: PPM 14** | **HYDRACARINA** | 8 | | | | | Cordalidae | 8 | | | | | Simuliidae | 5 | | | | |
| SIC: 4 TIME: minutes | **PLECOPTERA:** | | | | | | Sialidae | 6 | | | | | Syrphidae* | 1 | | | | |
| SOOC: | Notonemouridae | 14 | | | | | **TRICHOPTERA** | | | | | | Tabanidae | 5 | | | | |
| BEDROCK: | Perlidae | 12 | | | | | Dipseudopsidae | 10 | | | | | Tipulidae | 5 | | | | |
| AQUATIC VEG: DOM SP: | **EPHEMEROPTERA** | | | | | | Ecnomidae | 8 | | | | | **GASTROPODA** | | | | | |
| M VEG IC: DOM SP: | Baetidae 1sp | 4 | | | | | Hydropsychidae 1sp | 4 | A | | | A | Ancylidae | 6 | | | | |
| M VEG OOC: DOM SP: | Baetidae 2 sp | 6 | | | | | Hydropsychidae 2 sp | 6 | | | | | Bulininae* | 3 | | | | |
| GRAVEL: | Baetidae >2 sp | 12 | | | | | Hydropsychidae >2 sp | 12 | | | | | Hydrobiidae* | 3 | | | | |
| SAND: | Caenidae | 6 | | | | | Philopotamidae | 10 | | | | | Lymnaeidae* | 3 | | | | |
| MUD: | Ephemeridae | 15 | | | | | Polycentropodidae | 12 | | | | | Physidae* | 3 | | | | |
| HAND PICKING/VISUAL OBS: YES | Heptageniidae | 13 | | | | | Psychomyiidae/Xiphocen. | 8 | | | | | Planorbidae* | 3 | | | | |
| **FLOW**: MEDUIM | Leptophlebiidae | 9 | | | | | **CASED CADDIS:** | | | | | | Thiaridae* | 3 | | | | |
| **TURBIDITY**: LOW | Oligoneuridae | 15 | | | | | Barbarochthonidae SWC | 13 | | | | | Viviparidae* ST | 5 | | | | |
| **RIPARIAN LAND USE:** | Polymitarcyidae | 10 | B | A | | B | Calamoceratidae ST | 11 | | | | | **PELECYPODA** | | | | | |
| | Prosopistomatidae | 15 | | | | | Glossosomatidae SWC | 11 | | | | | Corbiculidae | 5 | | | | |
| | Teloganodidae SWC | 12 | | | | | Hydroptilidae | 6 | | | | | Sphaeriidae | 3 | | | | |
| | Tricorythidae | 9 | | | | | Hydrosalpingidae SWC | 15 | | | | | Unionidae | 6 | | | | |
| | **ODONATA:** | | | | | | Lepidostomatidae | 10 | | | | | **SASS SCORE:** | | 17 | 19 | 0 | 23 |
| **DISTURBANCE IN RIVER:** | Calopterygidae ST,T | 10 | | | | | Leptoceridae | 6 | | | | | **NO OF TAXA:** | | 3 | 4 | 0 | 5 |
| | Chlorocyphidae | 10 | | | | | Petrothrincidae SWC | 11 | | | | | **ASPT:** | | 5.7 | 4.8 | 0 | 4.6 |
| | Chlorolestidae | 8 | | | | | Pisuliidae | 10 | | | | | **IHAS**: | | 66% | | | |
| | Coenagrionidae | 4 | | | | | Sericostomatidae SWC | 13 | | | | | **Other biota:** | | | | | |
| | Lestidae | 8 | | | | | **COLEOPTERA:** | | | | | | NO FISH | | | | | |
| **SIGNS OF POLLUTION:** | Platycnemidae | 10 | | | | | Dytiscidae* | 5 | | | | | **COMMENTS**: | | | | | |
| | Protoneuridae | 8 | | | | | Elmidae/Dryopidae* | 8 | | | | | | | | | | |
| | Zygoptera juvs. | 6 | | | | | Gyrinidae* | 5 | | | | | | | | | | |
| | Aeshnidae | 8 | | | | | Halipidae* | 5 | | | | | | | | | | |
| | Corduliidae | 8 | | | | | Helodidae | 12 | | | | | * = airbreathers | | | | | |
| **OTHER OBSERVATIONS:** | Gomphidae | 6 | | | | | Hydraenidae* | 8 | | | | | SWC = South Western Cape T = Tropical | | | | | |
| | Libellulidae | 4 | | | | | Hydrophilidae* | 5 | | | | | VG = all vegetation ST = Sub-tropical | | | | | |
| | **LEPIDOPTERA:** | | | | | | Limnichidae | 10 | | | | | GSM = gravel, sand & mud S = Stone & rock | | | | | |
| | Pyralidae | 12 | | | | | Psephenidae | 10 | | | | | 1=1, A=2-10, B=10-100, C=100-1000, D=>1000 | | | | | |

RIVER HEALTH PROGRAMME - SASS 5 SCORE SHEET

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **DATE** :18-07-2016 | **TAXON** | | **S** | **VG** | **GSM** | **TOT** | **TAXON** | | **S** | **VG** | **GSM** | **TOT** | **TAXON** | | **S** | **VG** | **GSM** | **TOT** |
| **GRID REFERENCE**: | **PORIFERA** | 5 | | | | | **HEMIPTERA:** | | | | | | **DIPTERA:** | | | | | |
| S:° | **COELENTERATA** | 1 | | | | | Belostomatidae* | 3 | | | | | Athericidae | 10 | | | | |
| E: ° | **TURBELLARIA** | 3 | | | | | Corixidae* | 3 | | | | | Blepharoceridae | 15 | | | | |
| SITE CODE: SR5 | **ANNELIDA:** | | | | | | Gerridae* | 5 | | A | | A | Ceratopogonidae | 5 | | | | |
| RIVER: ROKPOI STREAM | Oligochaeta | 1 | A | | | A | Hydrometridae* | 6 | | | | | Chironomidae | 2 | A | A | | B |
| SITE DESCRIPTION: RETERENCE | Leeches | 3 | | | | | Naucoridae* | 7 | | | | | Culicidae* | 1 | | | | |
| WEATHER CONDITION: WARM NO RAIN | **CRUSTACEA:** | | | | | | Nepidae* | 3 | | 1 | | 1 | Dixidae* | 10 | | | | |
| TEMP: 27.0 °C | Amphipoda | 13 | | | | | Notonectidae* | 3 | | A | | A | Empididae | 6 | | | | |
| Ph: 5.50 | Potamonautidae* | 3 | | | | | Pleidae* | 4 | | A | | A | Ephydridae | 3 | | | | |
| DO: mg/l | Atyidae | 8 | | | | | Veliidae/M..veliidae* | 5 | | | | | Muscidae | 1 | | | | |
| Cond: 12 mS/m | Palaemonidae | 10 | | | | | **MEGALOPTERA:** | | | | | | Psychodidae | 1 | | | | |
| **BIOTOPES SAMPLED: 1 PPM** | **HYDRACARINA** | 8 | | | | | Cordalidae | 8 | | | | | Simuliidae | 5 | A | | A | A |
| SIC: 3 TIME: minutes | **PLECOPTERA:** | | | | | | Sialidae | 6 | | | | | Syrphidae* | 1 | | | | |
| SOOC: | Notonemouridae | 14 | | | | | **TRICHOPTERA** | | | | | | Tabanidae | 5 | | | | |
| BEDROCK: | Perlidae | 12 | A | | 1 | 1 | Dipseudopsidae | 10 | | | | | Tipulidae | 5 | | | | |
| AQUATIC VEG: 4 DOM SP: | **EPHEMEROPTERA** | | | | | | Ecnomidae | 8 | | | | | **GASTROPODA** | | | | | |
| M VEG IC: 2 DOM SP: | Baetidae 1sp | 4 | | | | | Hydropsychidae 1sp | 4 | | | | | Ancylidae | 6 | | | | |
| M VEG OOC: 4 DOM SP: | Baetidae 2 sp | 6 | | | | | Hydropsychidae 2 sp | 6 | | | | | Bulininae* | 3 | | | | |
| GRAVEL: | Baetidae >2 sp | 12 | A | | | A | Hydropsychidae >2 sp | 12 | | | | | Hydrobiidae* | 3 | | | | |
| SAND: | Caenidae | 6 | | | | | Philopotamidae | 10 | | | | | Lymnaeidae* | 3 | | | | |
| MUD: | Ephemeridae | 15 | | | | | Polycentropodidae | 12 | | | | | Physidae* | 3 | | | | |
| HAND PICKING/VISUAL OBS: | Heptageniidae | 13 | | 1 | | 1 | Psychomyiidae/Xiphocen. | 8 | | | | | Planorbidae* | 3 | | | | |
| **FLOW**: MEDUIM | Leptophlebiidae | 9 | | | | | **CASED CADDIS:** | | | | | | Thiaridae* | 3 | | | | |
| **TURBIDITY**: LOW | Oligoneuridae | 15 | A | | A | A | Barbarochthonidae SWC | 13 | | | | | Viviparidae* ST | 5 | | | | |
| **RIPARIAN LAND USE:** | Polymitarcyidae | 10 | | | | | Calamoceratidae ST | 11 | | | | | **PELECYPODA** | | | | | |
| | Prosopistomatidae | 15 | | | | | Glossosomatidae SWC | 11 | | | | | Corbiculidae | 5 | | | | |
| | Teloganodidae SWC | 12 | | | | | Hydroptilidae | 6 | | | | | Sphaeriidae | 3 | | | | |
| | Tricorythidae | 9 | | | | | Hydrosalpingidae SWC | 15 | | | | | Unionidae | 6 | | | | |
| | **ODONATA:** | | | | | | Lepidostomatidae | 10 | | | | | **SASS SCORE:** | | 47 | 42 | 41 | 96 |
| **DISTURBANCE IN RIVER:** | Calopterygidae ST,T | 10 | | | | | Leptoceridae | 6 | | | | | **NO OF TAXA:** | | 6 | 8 | 5 | 15 |
| | Chlorocyphidae | 10 | | | | | Petrothrincidae SWC | 11 | | | | | **ASPT:** | | 7.8 | 5.3 | 8 | 6.4 |
| | Chlorolestidae | 8 | | | | | Pisuliidae | 10 | | | | | **IHAS**: | 81% | | | | |
| | Coenagrionidae | 4 | | A | | A | Sericostomatidae SWC | 13 | | | | | **Other biota:** | | | | | |
| | Lestidae | 8 | | | | | **COLEOPTERA:** | | | | | | Brycinus imberi | | | | | |
| **SIGNS OF POLLUTION:** | Platycnemidae | 10 | | | | | Dytiscidae* | 5 | | | | | **COMMENTS**: | | | | | |
| | Protoneuridae | 8 | | | | | Elmidae/Dryopidae* | 8 | | | | | | | | | | |
| | Zygoptera juvs. | 6 | | | | | Gyrinidae* | 5 | | | | | | | | | | |
| | Aeshnidae | 8 | | | | | Halipidae* | 5 | | | | | | | | | | |
| | Corduliidae | 8 | | 1 | | 1 | Helodidae | 12 | | | | | * = airbreathers | | | | | |
| **OTHER OBSERVATIONS:** | Gomphidae | 6 | | | | | Hydraenidae* | 8 | | | | | SWC = South Western Cape T = Tropical | | | | | |
| | Libellulidae | 4 | | | 1 | 1 | Hydrophilidae* | 5 | | | 1 | 1 | VG = all vegetation ST = Sub-tropical | | | | | |
| | **LEPIDOPTERA:** | | | | | | Limnichidae | 10 | | | | | GSM = gravel, sand & mud S = Stone & rock | | | | | |
| | Pyralidae | 12 | | | | | Psephenidae | 10 | | | | | 1=1, A=2-10, B=10-100, C=100-1000, D=>1000 | | | | | |

# APPENDIX D: IHAS score sheets

| INVERTEBRATE HABITAT ASSESSMENT SYSTEM (IHAS) | | | | | | |
|---|---|---|---|---|---|---|
| **River Name**: UNNAMED TRIB | | | | | | |
| **Site Name**: SR1 | **Date**: 13-07-2017 | | | | | |
| ***SAMPLING HABITAT*** | 0 | 1 | 2 | 3 | 4 | 5 |
| **STONES IN CURRENT (SIC)** | | | | | | |
| Total length of white water rapids (i.e.: bubbling water) (in meters) | none | 0-1 | >1-2 | >2-3 | >3-5 | >5 |
| Total length of submerged stones in current (run) (in meters) | none | 0-2 | >2-5 | >5-10 | >10 | |
| Number of separate SIC area's kicked (not individual stones) | 0 | 1 | 2-3 | 4-5 | 6+ | |
| Average stone size's kicked (cm's) (gravel is <2, bedrock is >20) | none | <2>20 | 2-10 | 11-20 | 2-20 | |
| Amount of stone surface clear (of algae, sediment, etc) (in %)* | n/a | 0-25 | 26-50 | 51-75 | >75 | |
| PROTOCOL: time spent actually kicking stones (in minutes) (gravel/bedrock = 0 min) | 0 | <1 | >1-2 | 2 | >2-3 | >3 |
| (* NOTE: up to 25% of stone is usually embedded in the stream bottom) | | | | | | |
| | **SIC Score (max 20):** | | | 12 | | |
| **VEGETATION** | 0 | 1 | 2 | 3 | 4 | 5 |
| Length of fringing vegetation sampled (river banks) (PROTOCOL - in meters) | none | 0-½ | >½-1 | >1-2 | 2 | >2 |
| Amount of aquatic vegetation sampled (underwater) (in square meters) | none | 0-½ | >½-1 | >1 | | |
| Fringing vegetation sampled in: ('still' = pool/still water only; 'run' = run only) | none | | run | pool | | mix |
| Type of vegetation (% leafy veg. As opposed to stems/shoots) (aq. Veg. Only = 49%) | none | 0 | 1-25 | 26-50 | 51-75 | >75 |
| | **Vegetation Score (max 15):** | | | | 9 | |
| **OTHER HABITAT/GENERAL** | 0 | 1 | 2 | 3 | 4 | 5 |
| Stones out of current (SOOC) sampled: (PROTOCOL - in square meters) | none | 0-½ | >½-1 | 1 | >1 | |
| Sand sampled: (PROTOCOL - in minutes) ('under' = present, but only under stones) | none | under | 0-½ | >½-1 | 1 | >1 |
| Mud sampled: (PROTOCOL - in minutes) ('under' = present, but only under stones) | none | under | 0-½ | ½ | >½ | |
| Gravel sampled: (PROTOCOL - in minutes) (if all gravel, SIC stone size = <2)** | none | 0-½ | ½ | >½** | | |
| Bedrock sampled: ('all' = no SIC, sand, or gravel then SIC stone size = >20)** | none | some | | | all** | |
| Algae present: ('1-2m² = algal bed; 'rocks' = on rocks; 'isol' = isolated clumps)*** | >2m² | rocks | 1-2m² | <1m² | isol | none |
| Tray identification: (PROTOCOL - using time: 'coor' = correct time) | | under | | corr | | over |
| (** NOTE: you must still fill in the SIC section) | | | | | | |
| | **Other Habitat Score (max 20):** | | | | 13 | |
| | **HABITAT TOTAL (MAX 55):** | | | | 34 | |
| ***STREAM CONDITION*** | 0 | 1 | 2 | 3 | 4 | 5 |
| **PHYSICAL** | | | | | | |
| River make up: ('pool' = pool/still/dam only; 'run' only; etc) | pool | | run | rapid | 2mix | 3mix |
| Average width of stream: (in meters) | | >10 | >5-10 | <1 | 1-2 | >2-5 |
| Average depth of stream: (in meters) | >2 | >1-2 | 1 | >½-1 | ½ | <½ |
| Approximate velocity of stream: ('slow' = <½m/s; 'fast' = >1m/s) (use twig to test) | still | slow | fast | med | | mix |
| Water colour: ('disc' = discoloured with visible colour but still transparent) | silty | opaque | | disc | | clear |
| Recent disturbance due to: ('const.' = construction; 'fl/dr' = flood or drought)*** | flood | fire | constr | other | | none |
| Bank/riparian vegetation is: ('grass' = includes reeds; 'shrubs' = include trees) | none | | grass | shrubs | mix | |
| Surrounding impacts: ('erosn' = erosion/shear bank; 'farm' = farmland/settlement)*** | erosn | farm | trees | other | | open |
| Left bank cover: (rocks and vegetation) (in %) | 0-50 | 51-80 | 81-95 | >95 | | |
| Right bank cover: (rocks and vegetation) (in %) | 0-50 | 51-80 | 81-95 | >95 | | |
| (*** NOTE: if more than one option, choose the lowest) | | | | | | |
| | **STREAM CONDITIONS TOTAL (MAX 28** | | | | | 28 |
| | **TOTAL IHAS SCORE (%):** | | | | 62 | |

## INVERTEBRATE HABITAT ASSESSMENT SYSTEM (IHAS)

**River Name**: YUMBEI RIVER
**Site Name**: SR3
**Date**: 16-07-2017

| SAMPLING HABITAT | 0 | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| **STONES IN CURRENT (SIC)** | | | | | | |
| Total length of white water rapids (i.e.: bubbling water) (in meters) | none | 0-1 | >1-2 | >2-3 | >3-5 | >5 |
| Total length of submerged stones in current (run) (in meters) | none | 0-2 | >2-5 | >5-10 | >10 | |
| Number of separate SIC area's kicked (not individual stones) | 0 | 1 | 2-3 | 4-5 | 6+ | |
| Average stone size's kicked (cm's) (gravel is <2, bedrock is >20) | none | <2>20 | 2-10 | 11-20 | 2-20 | |
| Amount of stone surface clear (of algae, sediment, etc) (in %)* | n/a | 0-25 | 26-50 | 51-75 | >75 | |
| PROTOCOL: time spent actually kicking stones (in minutes) (gravel/bedrock = 0 min) | 0 | <1 | >1-2 | 2 | >2-3 | >3 |
| (*NOTE: up to 25% of stone is usually embedded in the stream bottom) | | | | | | |
| | SIC Score (max 20): | | | 15 | | |
| **VEGETATION** | 0 | 1 | 2 | 3 | 4 | 5 |
| Length of fringing vegetation sampled (river banks) (PROTOCOL - in meters) | none | 0-½ | >½-1 | >1-2 | 2 | >2 |
| Amount of aquatic vegetation sampled (underwater) (in square meters) | none | 0-½ | >½-1 | >1 | | |
| Fringing vegetation sampled in: ('still' = pool/still water only; 'run' = run only) | none | | run | pool | | mix |
| Type of vegetation (% leafy veg. As opposed to stems/shoots) (aq. Veg. Only = 49%) | none | 0 | 1-25 | 26-50 | 51-75 | >75 |
| | Vegetation Score (max 15): | | | | 8 | |
| **OTHER HABITAT/GENERAL** | 0 | 1 | 2 | 3 | 4 | 5 |
| Stones out of current (SOOC) sampled: (PROTOCOL - in square meters) | none | 0-½ | >½-1 | 1 | >1 | |
| Sand sampled: (PROTOCOL - in minutes) ('under' = present, but only under stones) | none | under | 0-½ | >½-1 | 1 | >1 |
| Mud sampled: (PROTOCOL - in minutes) ('under' = present, but only under stones) | none | under | 0-½ | ½ | >½ | |
| Gravel sampled: (PROTOCOL - in minutes) (if all gravel, SIC stone size = <2)** | none | 0-½ | ½ | >½** | | |
| Bedrock sampled: ('all' = no SIC, sand, or gravel then SIC stone size = >20)** | none | some | | | all** | |
| Algae present: ('1-2m² = algal bed; 'rocks' = on rocks; 'isol' = isolated clumps)*** | >2m² | rocks | 1-2m² | <1m² | isol | none |
| Tray identification: (PROTOCOL - using time: 'coor' = correct time) | | under | | corr | | over |
| (** NOTE: you must still fill in the SIC section) | | | | | | |
| | Other Habitat Score (max 20): | | | | 11 | |
| | HABITAT TOTAL (MAX 55): | | | | 34 | |

| STREAM CONDITION | 0 | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| **PHYSICAL** | | | | | | |
| River make up: ('pool' = pool/still/dam only; 'run' only; etc) | pool | | run | rapid | 2mix | 3mix |
| Average width of stream: (in meters) | | >10 | >5-10 | <1 | 1-2 | >2-5 |
| Average depth of stream: (in meters) | >2 | >1-2 | 1 | >½-1 | ½ | <½ |
| Approximate velocity of stream: ('slow' = <½m/s; 'fast' = >1m/s) (use twig to test) | still | slow | fast | med | | mix |
| Water colour: ('disc' = discoloured with visible colour but still transparent) | silty | opaque | | disc | | clear |
| Recent disturbance due to: ('const.' = construction; 'fl/dr' = flood or drought)*** | flood | fire | constr | other | | none |
| Bank/riparian vegetation is: ('grass' = includes reeds; 'shrubs' = include trees) | none | | grass | shrubs | mix | |
| Surrounding impacts: ('erosn' = erosion/shear bank; 'farm' = farmland/settlement)*** | erosn | farm | trees | other | | open |
| Left bank cover: (rocks and vegetation) (in %) | 0-50 | 51-80 | 81-95 | >95 | | |
| Right bank cover: (rocks and vegetation) (in %) | 0-50 | 51-80 | 81-95 | >95 | | |
| (*** NOTE: if more than one option, choose the lowest) | | | | | | |
| | STREAM CONDITIONS TOTAL (MAX | | | | | 37 |
| | TOTAL IHAS SCORE (%): | | | | 71 | |

## INVERTEBRATE HABITAT ASSESSMENT SYSTEM (IHAS)

**River Name**: PEKOTE STREAM
**Site Name**: SR4
**Date**: 16-07-2017

| SAMPLING HABITAT | 0 | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| **STONES IN CURRENT (SIC)** | | | | | | |
| Total length of white water rapids (i.e.: bubbling water) (in meters) | none | 0-1 | >1-2 | >2-3 | >3-5 | >5 |
| Total length of submerged stones in current (run) (in meters) | none | 0-2 | >2-5 | >5-10 | >10 | |
| Number of separate SIC area's kicked (not individual stones) | 0 | 1 | 2-3 | 4-5 | 6+ | |
| Average stone size's kicked (cm's) (gravel is <2, bedrock is >20) | none | <2>20 | 2-10 | 11-20 | 2-20 | |
| Amount of stone surface clear (of algae, sediment, etc) (in %)* | n/a | 0-25 | 26-50 | 51-75 | >75 | |
| PROTOCOL: time spent actually kicking stones (in minutes) (gravel/bedrock = 0 min) | 0 | <1 | >1-2 | 2 | >2-3 | >3 |
| (* NOTE: up to 25% of stone is usually embedded in the stream bottom) | | | | | | |
| | SIC Score (max 20): | | | 18 | | |
| **VEGETATION** | 0 | 1 | 2 | 3 | 4 | 5 |
| Length of fringing vegetation sampled (river banks) (PROTOCOL - in meters) | none | 0-½ | >½-1 | >1-2 | 2 | >2 |
| Amount of aquatic vegetation sampled (underwater) (in square meters) | none | 0-½ | >½-1 | >1 | | |
| Fringing vegetation sampled in: ('still' = pool/still water only; 'run' = run only) | none | | run | pool | | mix |
| Type of vegetation (% leafy veg. As opposed to stems/shoots) (aq. Veg. Only = 49%) | none | 0 | 1-25 | 26-50 | 51-75 | >75 |
| | Vegetation Score (max 15): | | | | 8 | |
| **OTHER HABITAT/GENERAL** | 0 | 1 | 2 | 3 | 4 | 5 |
| Stones out of current (SOOC) sampled: (PROTOCOL - in square meters) | none | 0-½ | >½-1 | 1 | >1 | |
| Sand sampled: (PROTOCOL - in minutes) ('under' = present, but only under stones) | none | under | 0-½ | >½-1 | 1 | >1 |
| Mud sampled: (PROTOCOL - in minutes) ('under' = present, but only under stones) | none | under | 0-½ | ½ | >½ | |
| Gravel sampled: (PROTOCOL - in minutes) (if all gravel, SIC stone size = <2)** | none | 0-½ | ½ | >½** | | |
| Bedrock sampled: ('all' = no SIC, sand, or gravel then SIC stone size = >20)** | none | some | | | all** | |
| Algae present: ('1-2m² = algal bed; 'rocks' = on rocks; 'isol' = isolated clumps)*** | >2m² | rocks | 1-2m² | <1m² | isol | none |
| Tray identification: (PROTOCOL - using time: 'coor' = correct time) | | under | | corr | | over |
| (** NOTE: you must still fill in the SIC section) | | | | | | |
| | Other Habitat Score (max 20): | | | | 8 | |
| | HABITAT TOTAL (MAX 55): | | | | 34 | |
| **STREAM CONDITION** | 0 | 1 | 2 | 3 | 4 | 5 |
| **PHYSICAL** | | | | | | |
| River make up: ('pool' = pool/still/dam only; 'run' only; etc) | pool | | run | rapid | 2mix | 3mix |
| Average width of stream: (in meters) | | >10 | >5-10 | <1 | 1-2 | >2-5 |
| Average depth of stream: (in meters) | >2 | >1-2 | 1 | >½-1 | ½ | <½ |
| Approximate velocity of stream: ('slow' = <½m/s; 'fast' = >1m/s) (use twig to test) | still | slow | fast | med | | mix |
| Water colour: ('disc' = discoloured with visible colour but still transparent) | silty | opaque | | disc | | clear |
| Recent disturbance due to: ('const.' = construction; 'fl/dr' = flood or drought)*** | flood | fire | constr | other | | none |
| Bank/riparian vegetation is: ('grass' = includes reeds; 'shrubs' = include trees) | none | | grass | shrubs | mix | |
| Surrounding impacts: ('erosn' = erosion/shear bank; 'farm' = farmland/settlement)*** | erosn | farm | trees | other | | open |
| Left bank cover: (rocks and vegetation) (in %) | 0-50 | 51-80 | 81-95 | >95 | | |
| Right bank cover: (rocks and vegetation) (in %) | 0-50 | 51-80 | 81-95 | >95 | | |
| (*** NOTE: if more than one option, choose the lowest) | | | | | | |
| | STREAM CONDITIONS TOTAL (MAX | | | | | 32 |
| | TOTAL IHAS SCORE (%): | | | | 66 | |

## INVERTEBRATE HABITAT ASSESSMENT SYSTEM (IHAS)

| | | | | | | |
|---|---|---|---|---|---|---|
| **River Name**: | | | | | | |
| **Site Name**: | **Date**: | | | | | |
| ***SAMPLING HABITAT*** | 0 | 1 | 2 | 3 | 4 | 5 |
| **STONES IN CURRENT (SIC)** | | | | | | |
| Total length of white water rapids (i.e.: bubbling water) (in meters) | none | 0-1 | >1-2 | >2-3 | >3-5 | >5 |
| Total length of submerged stones in current (run) (in meters) | none | 0-2 | >2-5 | >5-10 | >10 | |
| Number of separate SIC area's kicked (not individual stones) | 0 | 1 | 2-3 | 4-5 | 6+ | |
| Average stone size's kicked (cm's) (gravel is <2, bedrock is >20) | none | <2>20 | 2-10 | 11-20 | 2-20 | |
| Amount of stone surface clear (of algae, sediment, etc) (in %)* | n/a | 0-25 | 26-50 | 51-75 | >75 | |
| PROTOCOL: time spent actually kicking stones (in minutes) (gravel/bedrock = 0 min) | 0 | <1 | >1-2 | 2 | >2-3 | >3 |
| (*NOTE: up to 25% of stone is usually embedded in the stream bottom) | | | | | | |
| | SIC Score (max 20): | | | 11 | | |
| **VEGETATION** | 0 | 1 | 2 | 3 | 4 | 5 |
| Length of fringing vegetation sampled (river banks) (PROTOCOL - in meters) | none | 0-½ | >½-1 | >1-2 | 2 | >2 |
| Amount of aquatic vegetation sampled (underwater) (in square meters) | none | 0-½ | >½-1 | >1 | | |
| Fringing vegetation sampled in: ('still' = pool/still water only; 'run' = run only) | none | | run | pool | | mix |
| Type of vegetation (% leafy veg. As opposed to stems/shoots) (aq. Veg. Only = 49%) | none | 0 | 1-25 | 26-50 | 51-75 | >75 |
| | Vegetation Score (max 15): | | | | 15 | |
| **OTHER HABITAT/GENERAL** | 0 | 1 | 2 | 3 | 4 | 5 |
| Stones out of current (SOOC) sampled: (PROTOCOL - in square meters) | none | 0-½ | >½-1 | 1 | >1 | |
| Sand sampled: (PROTOCOL - in minutes) ('under' = present, but only under stones) | none | under | 0-½ | >½-1 | 1 | >1 |
| Mud sampled: (PROTOCOL - in minutes) ('under' = present, but only under stones) | none | under | 0-½ | ½ | >½ | |
| Gravel sampled: (PROTOCOL - in minutes) (if all gravel, SIC stone size = <2)** | none | 0-½ | ½ | >½** | | |
| Bedrock sampled: ('all' = no SIC, sand, or gravel then SIC stone size = >20)** | none | some | | | all** | |
| Algae present: ('1-2m²' = algal bed; 'rocks' = on rocks; 'isol' = isolated clumps)*** | >2m² | rocks | 1-2m² | <1m² | isol | none |
| Tray identification: (PROTOCOL - using time: 'coor' = correct time) | | under | | corr | | over |
| (** NOTE: you must still fill in the SIC section) | | | | | | |
| | Other Habitat Score (max 20): | | | | 15 | |
| | HABITAT TOTAL (MAX 55): | | | | 41 | |
| ***STREAM CONDITION*** | 0 | 1 | 2 | 3 | 4 | 5 |
| **PHYSICAL** | | | | | | |
| River make up: ('pool' = pool/still/dam only; 'run' only; etc) | pool | | run | rapid | 2mix | 3mix |
| Average width of stream: (in meters) | | >10 | >5-10 | <1 | 1-2 | >2-5 |
| Average depth of stream: (in meters) | >2 | >1-2 | 1 | >½-1 | ½ | <½ |
| Approximate velocity of stream: ('slow' = <½m/s; 'fast' = >1m/s) (use twig to test) | still | slow | fast | med | | mix |
| Water colour: ('disc' = discoloured with visible colour but still transparent) | silty | opaque | | disc | | clear |
| Recent disturbance due to: ('const.' = construction; 'fl/dr' = flood or drought)*** | flood | fire | constr | other | | none |
| Bank/riparian vegetation is: ('grass' = includes reeds; 'shrubs' = include trees) | none | | grass | shrubs | mix | |
| Surrounding impacts: ('erosn' = erosion/shear bank; 'farm' = farmland/settlement)*** | erosn | farm | trees | other | | open |
| Left bank cover: (rocks and vegetation) (in %) | 0-50 | 51-80 | 81-95 | >95 | | |
| Right bank cover: (rocks and vegetation) (in %) | 0-50 | 51-80 | 81-95 | >95 | | |
| (*** NOTE: if more than one option, choose the lowest) | | | | | | |
| | STREAM CONDITIONS TOTAL (MAX | | | | | 40 |
| | TOTAL IHAS SCORE (%): | | | | 81 | |

# APPENDIX E: IHI score sheets

## SR1

| | MRU |
|---|---|
| **INSTREAM IHI** | |
| Base Flows | 2.0 |
| Zero Flows | 0.0 |
| Floods | 3.5 |
| **HYDROLOGY RATING** | **1.3** |
| pH | 3.5 |
| Salts | 2.5 |
| Nutrients | 1.0 |
| Water Temperature | 1.0 |
| Water clarity | 3.0 |
| Oxygen | 1.5 |
| Toxics | 1.5 |
| **PC RATING** | **1.0** |
| Sediment | 2.5 |
| Benthic Growth | 2.0 |
| **BED RATING** | **2.3** |
| Marginal | 1.5 |
| Non-marginal | 2.0 |
| **BANK RATING** | **1.8** |
| Longitudinal Connectivity | 2.0 |
| Lateral Connectivity | 1.0 |
| **CONNECTIVITY RATING** | **1.9** |
| | |
| **INSTREAM IHI %** | **68.1** |
| **INSTREAM IHI EC** | **C** |
| **INSTREAM CONFIDENCE** | **3.0** |

| | MRU |
|---|---|
| **RIPARIAN IHI** | |
| Base Flows | 0.0 |
| Zero Flows | 0.0 |
| Moderate Floods | 3.5 |
| Large Floods | 2.5 |
| **HYDROLOGY RATING** | **1.2** |
| Substrate Exposure (marginal) | 1.5 |
| Substrate Exposure (non-marginal) | 1.5 |
| Invasive Alien Vegetation (marginal) | 0.5 |
| Invasive Alien Vegetation (non-marginal) | 0.5 |
| Erosion (marginal) | 2.0 |
| Erosion (non-marginal) | 2.0 |
| Physico-Chemical (marginal) | 2.0 |
| Physico-Chemical (non-marginal) | 3.0 |
| **Marginal** | 3.0 |
| **Non-marginal** | 3.0 |
| **BANK STRUCTURE RATING** | **3.0** |
| Longitudinal Connectivity | 4.0 |
| Lateral Connectivity | 4.0 |
| **CONNECTIVITY RATING** | **4.0** |
| | |
| **RIPARIAN IHI %** | **47.6** |
| **RIPARIAN IHI EC** | **D** |
| **RIPARIAN CONFIDENCE** | **3.0** |

# SR3

| INSTREAM IHI | MRU |
|---|---|
| Base Flows | 1.0 |
| Zero Flows | 0.0 |
| Floods | 1.0 |
| **HYDROLOGY RATING** | **0.5** |
| pH | 1.0 |
| Salts | 0.5 |
| Nutrients | 0.5 |
| Water Temperature | 1.0 |
| Water clarity | 0.5 |
| Oxygen | 0.5 |
| Toxics | 1.0 |
| **PC RATING** | **1.0** |
| Sediment | 1.0 |
| Benthic Growth | 0.0 |
| **BED RATING** | **0.6** |
| Marginal | 1.0 |
| Non-marginal | 1.5 |
| **BANK RATING** | **1.3** |
| Longitudinal Connectivity | 0.0 |
| Lateral Connectivity | 1.0 |
| **CONNECTIVITY RATING** | **0.1** |
| | |
| **INSTREAM IHI %** | **86.9** |
| **INSTREAM IHI EC** | **B** |
| **INSTREAM CONFIDENCE** | **2.6** |

| RIPARIAN IHI | MRU |
|---|---|
| Base Flows | 1.0 |
| Zero Flows | 0.0 |
| Moderate Floods | 1.0 |
| Large Floods | 1.0 |
| **HYDROLOGY RATING** | **0.7** |
| Substrate Exposure (marginal) | 1.5 |
| Substrate Exposure (non-marginal) | 1.5 |
| Invasive Alien Vegetation (marginal) | 0.5 |
| Invasive Alien Vegetation (non-marginal) | 0.5 |
| Erosion (marginal) | 2.0 |
| Erosion (non-marginal) | 2.0 |
| Physico-Chemical (marginal) | 0.0 |
| Physico-Chemical (non-marginal) | 0.0 |
| **Marginal** | 2.0 |
| **Non-marginal** | 2.0 |
| **BANK STRUCTURE RATING** | **2.0** |
| Longitudinal Connectivity | 0.5 |
| Lateral Connectivity | 1.0 |
| **CONNECTIVITY RATING** | **0.5** |
| | |
| **RIPARIAN IHI %** | **75.4** |
| **RIPARIAN IHI EC** | **C** |
| **RIPARIAN CONFIDENCE** | **3.0** |

# SR4

| INSTREAM IHI | MRU |
|---|---|
| Base Flows | 2.5 |
| Zero Flows | 0.0 |
| Floods | 3.0 |
| **HYDROLOGY RATING** | **1.3** |
| pH | 3.5 |
| Salts | 2.5 |
| Nutrients | 1.0 |
| Water Temperature | 1.0 |
| Water clarity | 3.0 |
| Oxygen | 1.5 |
| Toxics | 1.5 |
| **PC RATING** | **1.0** |
| Sediment | 2.5 |
| Benthic Growth | 2.0 |
| **BED RATING** | **2.3** |
| Marginal | 1.5 |
| Non-marginal | 2.0 |
| **BANK RATING** | **1.8** |
| Longitudinal Connectivity | 2.0 |
| Lateral Connectivity | 1.0 |
| **CONNECTIVITY RATING** | **1.9** |
| | |
| **INSTREAM IHI %** | **67.7** |
| **INSTREAM IHI EC** | **C** |
| **INSTREAM CONFIDENCE** | **3.0** |

| RIPARIAN IHI | MRU |
|---|---|
| Base Flows | 2.0 |
| Zero Flows | 0.0 |
| Moderate Floods | 3.5 |
| Large Floods | 2.5 |
| **HYDROLOGY RATING** | **1.8** |
| Substrate Exposure (marginal) | 1.5 |
| Substrate Exposure (non-marginal) | 1.5 |
| Invasive Alien Vegetation (marginal) | 0.5 |
| Invasive Alien Vegetation (non-marginal) | 0.5 |
| Erosion (marginal) | 2.0 |
| Erosion (non-marginal) | 2.0 |
| Physico-Chemical (marginal) | 2.0 |
| Physico-Chemical (non-marginal) | 3.0 |
| **Marginal** | 3.0 |
| **Non-marginal** | 3.0 |
| **BANK STRUCTURE RATING** | **3.0** |
| Longitudinal Connectivity | 4.0 |
| Lateral Connectivity | 4.0 |
| **CONNECTIVITY RATING** | **4.0** |
| | |
| **RIPARIAN IHI %** | **43.8** |
| **RIPARIAN IHI EC** | **D** |
| **RIPARIAN CONFIDENCE** | **3.0** |

# SR5

| | MRU |
|---|---|
| **INSTREAM IHI** | |
| Base Flows | 0.0 |
| Zero Flows | 0.0 |
| Floods | 0.0 |
| **HYDROLOGY RATING** | **0.0** |
| pH | 0.0 |
| Salts | 0.0 |
| Nutrients | 0.0 |
| Water Temperature | 0.0 |
| Water clarity | 0.0 |
| Oxygen | 0.0 |
| Toxics | 0.0 |
| **PC RATING** | **0.0** |
| Sediment | 0.0 |
| Benthic Growth | 0.0 |
| **BED RATING** | **0.0** |
| Marginal | 0.0 |
| Non-marginal | 1.0 |
| **BANK RATING** | **0.5** |
| Longitudinal Connectivity | 0.0 |
| Lateral Connectivity | 0.0 |
| **CONNECTIVITY RATING** | **0.0** |
| | |
| **INSTREAM IHI %** | **98.8** |
| **INSTREAM IHI EC** | **A** |
| **INSTREAM CONFIDENCE** | **2.8** |

| | MRU |
|---|---|
| **RIPARIAN IHI** | |
| Base Flows | 0.0 |
| Zero Flows | 0.0 |
| Moderate Floods | 0.0 |
| Large Floods | 0.0 |
| **HYDROLOGY RATING** | **0.0** |
| Substrate Exposure (marginal) | 1.5 |
| Substrate Exposure (non-marginal) | 1.5 |
| Invasive Alien Vegetation (marginal) | 0.5 |
| Invasive Alien Vegetation (non-marginal) | 0.5 |
| Erosion (marginal) | 2.0 |
| Erosion (non-marginal) | 2.0 |
| Physico-Chemical (marginal) | 0.0 |
| Physico-Chemical (non-marginal) | 0.0 |
| **Marginal** | 2.0 |
| **Non-marginal** | 2.0 |
| **BANK STRUCTURE RATING** | **2.0** |
| Longitudinal Connectivity | 0.0 |
| Lateral Connectivity | 0.5 |
| **CONNECTIVITY RATING** | **0.0** |
| | |
| **RIPARIAN IHI %** | **82.0** |
| **RIPARIAN IHI EC** | **B** |
| **RIPARIAN CONFIDENCE** | **3.0** |

# APPENDIX F: DIATOM ANALYSIS REPORT

## WET SEASON ASSESSMENT (HIGH FLOW, JULY 2017):

### APPROACH

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 the 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, salinisation and changes in pH. They are therefore useful for providing an overall picture of trends within an aquatic system.

### ANALYSIS

Diatom slides were prepared by acid oxidation using hydrochloric acid and potassium permanganate. Clean diatom frustules were mounted onto a glass slide ready for analysis. Taxa were identified mainly according to standard floras (Krammer & Lange- Bertalot, 2000). The aim of the data analysis was to identify and count diatom valves (400 counts) to produce semi-quantitative data from which ecological conclusions can be drawn.

### FINDINGS

Sites were sampled within fast flowing waters hence the use of the diatom software package OMNIDIA to infer water quality conditions at each site was applicable. Index values were calculated in OMNIDIA for epilithon data (attached to rocks) (Lecointe *et al.* 1993). In general, each diatom species used in the calculation of the index is assigned two values; the first value reflects the tolerance or affinity of the particular diatom species to a certain water quality (good or bad) while the second value indicates how strong (or weak) the relationship is. These values are then weighted by the abundance of the particular diatom species in the sample. The general water quality indices (integrating impacts from organic material, electrolytes, pH and nutrients), used in the assessment, are:

- the Specific Pollution sensitivity Index (SPI), one of the most extensively tested indices in Europe; and
- the percentage of (organic) pollution tolerant valves (%PTV)

The interpretation of the SPI scores applied in this study is displayed in Table 1.

Appendix A displays a list of species and abundances recorded at each site. A list of the dominant species occurring at the sites, expressed as a percentage of the total sample is displayed in Table 2. The SPI scores and classifications for the sites are shown in Table 3.

**Table F1 Class limit boundaries for the Specific Pollution sensitivity Index (SPI) (Koekemoer and Taylor, 2011).**

| SPI Score | Class | Ecological Category |
|---|---|---|
| >17.3 | High quality | A |
| 16.8-17.2 | | A/B |
| 13.3-16.7 | Good quality | B |
| 12.9-13.2 | | B/C |
| 9.2-12.8 | Moderate quality | C |
| 8.9-9.1 | | C/D |
| 5.3-8.8 | Poor quality | D |
| 4.8-5.2 | | D/E |
| <4.8 | Bad quality | E |

**Table F2 List of dominant diatom species occurring at each site, expressed as a percentage of the total sample.**

| Taxa | % Relative Abundance | | | |
|---|---|---|---|---|
| | SR1 | SR3 | SR4 | SR5 |
| ACHNANTHES J.B.M. Bory de St. Vincent | | | 10 | |
| Brachysira wygaschii Lange-Bertalot | 5 | | 5 | |
| Eunotia bilunaris (Ehr.) Mills var. bilunaris | | | 8 | |
| Eunotia flexuosa(Brebisson)Kützing | | | 25 | |
| Eunotia minor (Kützing) Grunow in Van Heurck | | 60 | 5 | 20 |
| Eunotia pectinalis (Kütz.) Rabenhorst var.undulata | | | | 5 |
| Eunotia rhomboidea Hustedt | | 31 | 6 | 52 |
| Frustulia crassinervia (Breb.) Lange-Bertalot et Krammer | 10 | | 10 | |
| Navicula dutoitana Cholnoky | 14 | | 6 | |
| Navicula heimansioides Lange-Bertalot | 5 | | | |
| Nitzschia linearis(Agardh) W.M.Smith var.linearis | | | 6 | |
| Nitzschia palea (Kützing) W.Smith | 5 | | | |

**Table F3 OMNIDIA Results: Specific Pollution sensitivity Index (SPI) score classification for each site in July 2017.**

| Sites | Specific Pollution Sensitivity Index (SPI) | Pollution Tolerant Valves (% PTV) | Classification | |
|---|---|---|---|---|
| | | | Class | Ecological Category |
| SR1 | 16.9 | 10.5 | High quality | A/B |
| SR3 | 18.4 | 1 | High quality | A |
| SR4 | 16.8 | 13.8 | High quality | A/B |
| SR5 | 17.7 | 3.8 | High quality | A |

- Based on the OMNIDIA results, the water quality at Site SR3 and Site SR5 are of an Ecological Category A (High quality) and Site SR1 and Site SR4, an Ecological Category A/B (High quality).
- Site SR3 and Site SR5 have a negligible % PTV (1 and 3.8 % PTV, respectively) which suggests there is minor organic content at these sites. Site SR1 and Site SR4 have slightly higher organic content (10.5 and 13.8 % PTV, respectively) compared to Site SR3 and Site SR5.
- At Site SR1 and Site SR4 is the presence of dominant taxa which occur in oligotrophic waters with low electrolyte content such as *Frustulia crassinervia* and *Brachysira wygaschii*. Taxon *Navicula dutoitana*, also dominant at these sites, has an unknown ecology.
- At Site SR1, recorded are sub-dominant taxa of the *Pinnularia* genus as well as sub-dominant taxa *Encyonopsis raytonensis*, *Encyonopsis cesatii* and *Stenopterobia delicatissima*, which are taxa associated with acidic, well-oxygenated, oligotrophic, electrolyte poor conditions.
- Recorded at sites SR3, SR4 and SR5 are dominant taxa of the *Eunotia* genus (significantly more at Site SR3) such as *Eunotia minor*, *Eunotia rhomboidea* and *Eunotia flexuosa*. This genus is found in acidic, oligotrophic, electrolyte-poor waters. At Site SR1, the *Eunotia* genus is sub-dominant.
- Recorded at Site SR1 and Site SR4 is taxon *Nitzschia palea* (dominant at Site SR1 and sub-dominant at Site SR4), which suggests that these sites may be more elevated in electrolytes, nutrients and organics compared to Site SR3 and Site SR5.
- At Site SR1 and Site SR5, the minor presence of *Hippodonta capitata, Cocconeis placentula* var. *placentula* and *N. amphibia* may point to slight nutrient and electrolyte inputs from anthropogenic activities in the surrounding catchment.
- At Site SR4 is the presence of dominant taxon *Nitzschia linearis* var. *linearis* which favour oxygen-rich waters.

List of diatom species and associated abundances at each site in July 2017.

| Taxa | Sites | | | |
|---|---|---|---|---|
| | SR1 | SR3 | SR4 | SR5 |
| ACHNANTHES J.B.M. Bory de St. Vincent | 16 | 0 | 41 | 3 |
| Achnanthidium minutissima Kützing | 0 | 0 | 2 | 4 |
| AULACOSEIRA G.H.K. Thwaites | 0 | 0 | 1 | 4 |
| Brachysira brebissonii Ross in Hartley | 11 | 0 | 7 | 0 |
| Brachysira neoexilis Lange-Bertalot | 2 | 0 | 2 | 0 |
| Brachysira wygaschii Lange-Bertalot | 21 | 0 | 21 | 0 |
| Cocconeis pediculus Ehrenberg | 2 | 0 | 4 | 0 |
| Cocconeis placentula Ehrenberg var. placentula | 1 | 0 | 0 | 4 |
| Cocconeis placentula Ehre. var.lineata (Ehr.)Van Heurck | 1 | 0 | 0 | 0 |
| Cymbella turgidula Grunow 1875 in A.Schmidt & al. | 1 | 0 | 4 | 0 |
| CYCLOTELLA F.T. Kützing ex A de Brébisson | 1 | 0 | 0 | 0 |
| Diatoma vulgaris Bory | 0 | 0 | 2 | 0 |
| Eunotia bilunaris (Ehr.) Mills var. bilunaris | 0 | 6 | 32 | 0 |
| Encyonopsis cesatii (Rabenhorst) Krammer | 10 | 0 | 0 | 0 |
| Eunotia flexuosa(Brebisson)Kützing | 14 | 7 | 98 | 0 |
| Eunotia minor (Kützing) Grunow in Van Heurck | 16 | 239 | 21 | 81 |
| Encyonema neogracile Krammer | 2 | 0 | 0 | 0 |
| Eolimna minima(Grunow) Lange-Bertalot | 0 | 0 | 2 | 2 |
| Eunotia pectinalis(Kütz.)Rabenhorst var.undulata | 8 | 0 | 2 | 21 |
| Encyonopsis raytonensis (Cholnoky) Krammer | 17 | 0 | 0 | 0 |
| Eunotia rhomboidea Hustedt | 18 | 122 | 22 | 207 |
| Eunotia serra Ehrenberg var.serra | 9 | 3 | 7 | 13 |

List of diatom species and associated abundances at each site in July 2017 (continued).

| Taxa | Sites | | | |
|---|---|---|---|---|
| | SR1 | SR3 | SR4 | SR5 |
| Encyonopsis subminuta Krammer & Reichardt | 1 | 0 | 0 | 0 |
| Fragilaria biceps (Kützing) Lange-Bertalot | 4 | 0 | 1 | 0 |
| Frustulia crassinervia (Breb.) Lange-Bertalot et Krammer | 38 | 6 | 39 | 6 |
| Fragilaria tenera (W.Smith) Lange-Bertalot | 0 | 0 | 1 | 0 |
| GOMPHONEMA C.G. Ehrenberg | 0 | 0 | 1 | 0 |
| Gomphonema pumilum (Grunow) Reichardt & Lange-Bert. | 0 | 0 | 0 | 1 |
| Gomphonema venusta Passy. Kociolek & Lowe | 0 | 0 | 0 | 4 |
| Hippodonta capitata (Ehr.)Lange-Bert.Metzeltin & Wit. | 1 | 0 | 0 | 1 |
| Melosira varians Agardh | 0 | 0 | 0 | 4 |
| Nitzschia amphibia Grunow f.amphibia | 1 | 0 | 0 | 1 |
| NAVICULA J.B.M. Bory de St. Vincent | 2 | 0 | 0 | 4 |
| Navicula dutoitana Cholnoky | 55 | 9 | 24 | 0 |
| Nitzschia dissipata(Kützing)Grunow var.media | 2 | 0 | 6 | 0 |
| Nitzschia draveillensis Coste & Ricard | 0 | 0 | 7 | 0 |
| Neidium affine(Ehrenberg)Pfitzer | 4 | 0 | 0 | 0 |
| Navicula heimansioides Lange-Bertalot | 20 | 0 | 2 | 12 |
| Nitzschia gracilis Hantzsch | 8 | 0 | 1 | 1 |
| Nitzschia intermedia Hantzsch ex Cleve & Grunow | 0 | 0 | 4 | 0 |
| NITZSCHIA A.H. Hassall | 1 | 0 | 1 | 0 |
| Nitzschia linearis(Agardh) W.M.Smith var.linearis | 11 | 0 | 25 | 7 |
| Nitzschia palea (Kützing) W.Smith var.debilis (Kützing) Grun. | 1 | 0 | 0 | 0 |
| Nitzschia palea (Kützing) W.Smith | 20 | 4 | 16 | 2 |

List of diatom species and associated abundances at each site in July 2017 (continued).

| Taxa | Sites | | | |
|---|---|---|---|---|
| | SR1 | SR3 | SR4 | SR5 |
| Navicula rostellata Kützing | 0 | 0 | 1 | 2 |
| Navicula symmetrica Patrick | 0 | 0 | 1 | 0 |
| Navicula vandamii Schoeman & Archibald | 0 | 0 | 0 | 1 |
| Nitzschia supralitorea Lange-Bertalot | 2 | 0 | 0 | 3 |
| Pinnularia acrospheria W. Smith var. acrospheria | 13 | 0 | 2 | 0 |
| Pinnularia braunii (Grunow) Cleve | 14 | 0 | 0 | 0 |
| PINNULARIA C.G. Ehrenberg | 13 | 0 | 0 | 0 |
| Pinnularia subcapitata Gregory var. subcapitata | 12 | 0 | 0 | 0 |
| Pinnularia viridis (Nitzsch) Ehrenberg | 2 | 0 | 0 | 0 |
| Staurosira elliptica (Schumann) Williams & Round | 0 | 0 | 0 | 10 |
| Sellaphora subhamulata (Grunow) Mann | 0 | 1 | 0 | 0 |
| Sellaphora pupula (Kützing) Mereschkowksy | 12 | 0 | 0 | 2 |
| Stauroneis anceps Ehrenberg | 4 | 0 | 0 | 0 |
| Stenopterobia delicatissima (Lewis) Brebisson ex Van Heu. | 9 | 3 | 0 | 0 |

**DRY SEASON ASSESSMENT (DRY SEASON, JANUARY 2018):**

# Diatom Assessment Report

Ref: SAS-05
Date: 30/01/2018

Prepared for:
Scientific Aquatic Services

Prepared by:
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# List of Abbreviations

| | |
|---|---|
| BDI | Biological Diatom Index |
| %PT | Percentage Pollution Tolerant Valves |
| IPS | Index of Pollution Sensitivity |
| TDI | Trophic Diatom Index |

## Methodology

Diatom samples were prepared to make permanent slides for microscopic analysis according to the methodology outlined by Taylor et al. (2007), specifically the 'hot hydrochloric acid and potassium permanganate method'. A minimum of 300 diatom cells was counted where possible and the different diatom species present were identified to species level. The results were assessed using OMNIDIA Version 5.3 diatom assessment software (Lecointe *et al*., 1993) and dominant species ecology inferred from Taylor *et al*. (2007).

Three diatom indices utilised by OMNIDIA were reported on, these are: the Biological Diatom Index (BDI; Lenoir & Coste, 1996), Index of Pollution Sensitivity (IPS; CEMAGREF, 1982)), and Percentage of Pollution Tolerance Valves (%PT; Kelly & Whitton, 1995)). Where necessary the Trophic Diatom Index (TDI; Kelly & Whitton, 1995) was used for further resolution in consideration of the %PT results. Several Ecological Indicators found in OMNIDIA were also assessed, namely: pH, salinity, nitrogen metabolism, oxygen, and trophic status (Van Dam *et al*., 1994). Diatom frustule abnormalities were also assessed as a means to determine the specific potential impact of pesticides and metals in the aquatic environment following Debenest *et al*. (2008), particularly effective in assessing mining impact.

Values for the BDI and IPS were transformed to a score out of 20 where a score of 0 indicates very heavy pollution and a score of 20 indicates no pollution. The %PT is worked off a maximum score of 100%, where a score of <20% infers that the site is free from significant organic pollution and a score >61% infers that the site is heavily contaminated with organic pollution. For the diatom frustule abnormality assessment, if the percentage of deformed frustules is greater than 2% of the population (Taylor, *pers. comm*., 2012) it is considered that there is significant impact from either pesticides or metals and further assessment is recommended, especially where mining a related concern.

**Key to interpreting BDI & IPS index scores**

| Index Score | Score Interpretation |
|---|---|
| >17 | No pollution |
| 13-17 | Weak pollution or eutrophication |
| 9-13 | Moderate eutrophication |
| 5-9 | Moderate to heavy eutrophication |
| <5 | Very heavy eutrophication |

**Key to interpreting %PT index scores**

| Index Score | Score Interpretation |
|---|---|
| <20% | Free from significant organic pollution |
| >21% - <40% | Some evidence of organic pollution |
| >41% - <60% | Significant organic pollution |
| >61% | Heavy contamination with organic pollution |

**OMNIDIA Ecological Indicators Key for Interpretation**

| Ecological indicator value classification (Van Dam *et al.*, 1994) | | |
|---|---|---|
| **pH Categories** | | |
| **1** | Acidobiontic | Optimal occurrence at pH <5.5 |
| **2** | Acidophilous | Mainly occurring at pH <7 |
| **3** | Circumneutral | Mainly occurring at pH-values about 7 |
| **4** | Alkaliphilous | Mainly occurring at pH >7 |
| **5** | Alkalibiontic | Exclusively occurring at pH >7 |
| **6** | Indifferent | No apparent optimum |
| **Salinity Categories** | | |
| | ***Cl- (mg/l )*** | ***Salinity (%)*** |

| | | | |
|---|---|---|---|
| **1** | Fresh | <100 | <0.2 |
| **2** | Fresh brackish | <500 | <0.9 |
| **3** | Brackish fresh | 500 - 1000 | 0.9 - 1.8 |
| **4** | Brackish | 1000 - 5000 | 1.8 - 9.0 |
| **Nitrogen Metabolism Categories** | | | |
| **1** | Nitrogen-autotrophic taxa. Tolerating very small concentrations of organically bound nitrogen | | |
| **2** | Nitrogen-autotrophic taxa, tolerating elevated concentrations of organically bound nitrogen | | |
| **3** | Facultatively nitrogen-heterotrophic taxa, needing periodically elevated concentrations of organically bound nitrogen | | |
| **4** | Obligately nitrogen-heterotrophic taxa, needing continuously elevated concentrations of organically bound nitrogen | | |
| **Oxygen Requirement Categories** | | | |
| **1** | Continuously high (about 100% saturation) | | |
| **2** | Fairly high (above 75% saturation) | | |
| **3** | Moderate (above 50% saturation) | | |
| **4** | Low (above 30% saturation) | | |
| **5** | Very low (about 10% saturation) | | |
| **Trophic State Categories** | | | |
| **1** | Oligotrophic | **5** | Eutrophic |
| **2** | Oligo-mesotrophic | **6** | Hypereutrophic |
| **3** | Mesotrophic | **7** | Indifferent |
| **4** | Meso-eutrophic | | |
| Note: Ecological Indicator Values inferred from assessment of diatom community as a whole | | | |

# Results

## *Limitations*

The sample collected from site SR 3 had very little by way of diatom material, and thus the desired number of diatom frustules could not be counted. The site did however display high diversity even in spite of this. The results for this site should thus be considered in light of the limitation.

## *Assessment Summary*

**Summary of ecological status inferred from OMNIDIA diatom indices (Lecointe *et al*., 1993)**

| Site | Number of species | TDI | %PT | IPS | BDI | Inferred Ecological Status |
|---|---|---|---|---|---|---|
| SR 1 | 10 | 18.2 | 4.5 | 19.4 | 20 | Not polluted |
| SR 3 | 17 | 18.5 | 5.8 | 17.4 | 20 | Not polluted |
| SR 4 | 8 | 20 | 0 | 17.9 | 20 | Not polluted |
| SR 5 | 11 | 19.6 | 0 | 19.1 | 20 | Not polluted |

TDI-Trophic Diatom Index, %PT-Percentage Pollution Tolerant Valves, IPS-Index of Pollution Sensitivity, BDI-Biological Diatom Index

*'Pollution' refers to both organic pollution input and eutrophication

**Summary of Ecological Indicators (Van Dam *et al*., 1994)**

| | Ecological Indicators | | | | |
|---|---|---|---|---|---|
| **Site** | **pH** | **Salinity** | **Nitrogen** | **Oxygen** | **Trophic state** |
| SR 1 | 1 | 1 | 1 | 1 | 1 – Oligotrophic |
| SR 3 | 2 | 1 | 1 | 1 | 3 – Mesotrophic |
| SR 4 | 2 | 1 | 1 | 1 | 2 - Oligo mesotrophic |
| SR 5 | 2 | 1 | 1 | 1 | 1 - Oligotrophic |

Note: Consult the OMNIDIA Ecological Indicators Key for Interpretation to see ranges for the above indicators for comparisons

Diatom Frustule Abnormalities

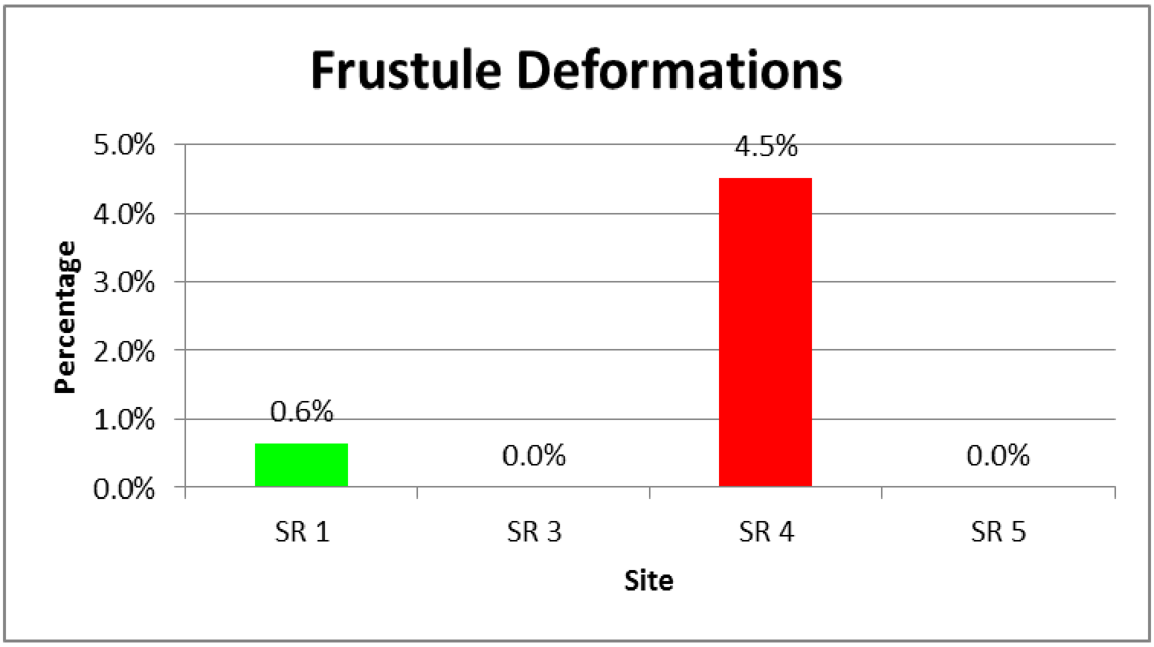



**Figure1: Diatom frustule deformations (abnormalities)**

The sample from site SR 4 showed diatom abnormalities above the threshold of concern of 2% of the assessed population (4.5% deformed), as per figure 1 above. This infers that the water quality at site SR 4 is impacted by metals (often found in mine effluent) pesticides (often found in agricultural runoff), or some other toxicant, to a significant enough extent that there is significant biological response at a primary producer level. Further higher resolution water testing is thus recommended as a means to qualify the cause of the perturbation. The remaining samples were all below the threshold of concern.

## *Site Summaries*

### Site *SR 1* : Summary

**Dominant Species:** *Frustulia saxonica*

| **Number of Species:** | 10 |
|---|---|

**Diatom indices**

| TDI | %PT | IPS | BDI |
|---|---|---|---|
| 18.2 | 4.5 | 19.4 | 20 |

**Ecological Indicators**

| pH | Salinity | Nitrogen | Oxygen | Trophic state |
|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 1 |

| **Frustule Abnormalities:** | 0.6% |
|---|---|

**Dominant species description:**

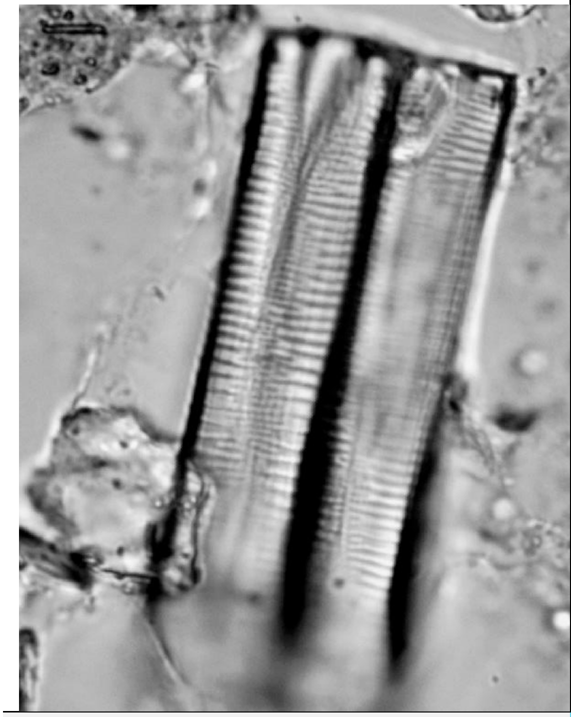
A cosmopolitan species occurring in dystrophic, acidic, electrolyte poor waters.

**Diatom Community Ecology:**

The diatom community indicated no pollution impact on water quality in terms the assessed diatom indices. The IPS and BDI were very high, indicating good water quality, and very low %PT of 4.5% indicating a negligible number of specifically organic pollution tolerant diatom taxa in the community. Considering the ecological indicator values, the community classed as acidobiontic, indicating a preferred continuous pH of <5.5, acidic water. The other ecological indicators infer fresh water conditions (<0.2% salinity), low concentrations of organically bound nitrogen (nitrogen autotrophic taxa) and continuously high oxygen concentration (100% saturation). According to the ecological indicators, the community is adapted to oligotrophic conditions.

## Site *SR 3*: Summary

**Dominant Species:** *Eunotia pectinalis* var. *undulata*



| Number of Species: | 17 |
|---|---|

**Diatom indices**

| TDI | %PT | IPS | BDI |
|---|---|---|---|
| 18.5 | 5.8 | 17.4 | 20 |

**Ecological Indicators**

| pH | Salinity | Nitrogen | Oxygen | Trophic state |
|---|---|---|---|---|
| 2 | 1 | 1 | 1 | 3 |

| Frustule Abnormalities: | 0% |
|---|---|

**Dominant species description:**

Found in circumneutral to weakly acidic, electrolyte poor waters.

**Diatom Community Ecology:**

The diatom community indicated no pollution impact on water quality in terms the assessed diatom indices. The IPS and BDI were very high, indicating good water quality, and very low %PT of 5.8% indicating a negligible number of specifically organic pollution tolerant diatom taxa in the community. Considering the ecological indicator values, the community classed as acidophilous, indicating a preferred continuous pH of <7, slightly acidic water. The other ecological indicators infer fresh water conditions (<0.2% salinity), low concentrations of organically bound nitrogen (nitrogen autotrophic taxa) and continuously high oxygen concentration (100% saturation). According to the ecological indicators, the community is adapted to mesotrophic conditions. The site showed very little diatom material in the collected sample, although displayed relatively high diversity in comparison to the other sites. Diversity is not, however, necessarily an indicator of good water quality where diatom indices are concerned.

## Site *SR 4* : Summary

**Dominant Species:** *Eunotia flexuosa*

| **Number of Species:** | 8 | | |
|---|---|---|---|

**Diatom indices**

| TDI | %PT | IPS | BDI |
|---|---|---|---|
| 20 | 0 | 17.9 | 20 |

**Ecological Indicators**

| pH | Salinity | Nitrogen | Oxygen | Trophic state |
|---|---|---|---|---|
| 2 | 1 | 1 | 1 | 2 |

**Frustule Abnormalities:** 4.5%

**Dominant species description:**

Occur in oligotrophic, standing or slow flowing waters.

**Diatom Community Ecology:**

The diatom community indicated no pollution impact on water quality in terms the assessed diatom indices. The IPS and BDI were very high, indicating good water quality, and %PT of 0% indicating a no specifically organic pollution tolerant diatom taxa in the community. Considering the ecological indicator values, the community classed as acidophilous, indicating a preferred continuous pH of <7, slightly acidic water. The other ecological indicators infer fresh water conditions (<0.2% salinity), low concentrations of organically bound nitrogen (nitrogen autotrophic taxa) and continuously high oxygen concentration (100% saturation). According to the ecological indicators, the community is adapted to oligotrophic to mesotrophic conditions. The sample from the site displayed high concentration of diatom frustule abnormalities (deformations) of 4.5%. This infers impact from metals and / or pesticides and thus further water quality analysis to qualify and quantify this perturbation is advised.

## Site *SR 5*: Summary

**Dominant Species:** *Eunotia rhomboidea*

| **Number of Species:** | 11 |
|---|---|

**Diatom indices**

| TDI | %PT | IPS | BDI |
|---|---|---|---|
| 19.6 | 0 | 19.1 | 20 |

**Ecological Indicators**

| pH | Salinity | Nitrogen | Oxygen | Trophic state |
|---|---|---|---|---|
| 2 | 1 | 1 | 1 | 1 |

| **Frustule Abnormalities:** | 0% |
|---|---|

**Dominant species description:**

Found in oligotrophic, electrolyte-poor waters.

**Diatom Community Ecology:**

The diatom community indicated no pollution impact on water quality in terms the assessed diatom indices. The IPS and BDI were very high, indicating good water quality, and %PT of 0% indicating a no specifically organic pollution tolerant diatom taxa in the community. Considering the ecological indicator values, the community classed as acidophilous, indicating a preferred continuous pH of <7, slightly acidic water. The other ecological indicators infer fresh water conditions (<0.2% salinity), low concentrations of organically bound nitrogen (nitrogen autotrophic taxa) and continuously high oxygen concentration (100% saturation). According to the ecological indicators, the community is adapted to oligotrophic conditions.

## Diatom Species List

| Species Name | BDI | % Abundance in Community | | | |
|---|---|---|---|---|---|
| | | SR1 | SR3 | SR4 | SR5 |
| *Adlafia bryophila* (Petersen) Moser Lange-Bertalot & Metzeltin | * | 0% | 8% | 0% | 2% |
| *Achnanthidium eutrophilum* (Lange-Bertalot) | * | 0% | 2% | 0% | 0% |
| *Achnanthidium macrocephalum* (Hust.) Round & Bukhtiyarova | * | 0% | 2% | 0% | 1% |
| *Amphora veneta Kützing* | * | 0% | 2% | 0% | 0% |
| *Brachysira wygaschii* Lange-Bertalot | | 6% | 0% | 14% | 0% |
| *Cocconeis placentula* Ehrenberg *var.euglypta* (Ehr.) Grunow | * | 1% | 0% | 0% | 0% |
| *Ctenophora pulchella (*Ralfs ex Kütz.) Williams et Round | * | 0% | 2% | 0% | 0% |
| *Eunotia bilunaris* (Ehr.) Mills *var. bilunaris* | * | 3% | 12% | 11% | 10% |
| *Eunotia flexuosa(*Brebisson)Kützing | * | 0% | 10% | 37% | 1% |
| *Eunotia formica* Ehrenberg | * | 1% | 6% | 0% | 3% |
| *Eunotia incisa* Gregory *var.incisa* | * | 0% | 4% | 0% | 21% |
| *Eunotia pectinalis*(Kütz.)Rabenhorst *var.undulata* (Ralfs) Rabenhorst | * | 0% | 19% | 2% | 10% |
| *Eunotia rhomboidea* Hustedt | * | 0% | 15% | 1% | 40% |
| *Frustulia saxonica* Rabenhorst | * | 47% | 4% | 5% | 5% |
| *Frustulia vulgaris* (Thwaites) De Toni | * | 7% | 6% | 29% | 3% |
| *Gomphonema parvulum* Kützing | * | 0% | 2% | 0% | 0% |
| *Navicula heimansioides* Lange-Bertalot | * | 18% | 2% | 0% | 5% |

| | | | | | |
|---|---|---|---|---|---|
| *Nitzschia pura* Hustedt | * | 5% | 4% | 0% | 0% |
| *Pinnularia divergens* W.M.Smith | * | 12% | 2% | 3% | 0% |
| *Sellaphora pupula* (Kützing) Mereschkowksy | * | 1% | 0% | 0% | 0% |

Note: BDI Column with * = this species was used in the BDI calculation

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# APPENDIX G: Wetland Assessment Data Analyses Results

## *PRESENT ECOLOGICAL STATE (PES) SCORE SHEETS*

**Table G1: Presentation of the results of the WET-Health assessment applied to Group 1: Reference systems.**

| Hydrology | | Geomorphology | | Vegetation | | Overall PES Category of the Resource |
|---|---|---|---|---|---|---|
| PES category | Trajectory of change | PES category | Trajectory of change | PES category | Trajectory of change | |
| A | → | A | → | C | → | A (0.74) |

**Table G2: Presentation of the results of the WET-Health assessment applied to Group 2: Impounded systems.**

| Hydrology | | Geomorphology | | Vegetation | | Overall PES Category of the Resource |
|---|---|---|---|---|---|---|
| PES category | Trajectory of change | PES category | Trajectory of change | PES category | Trajectory of change | |
| D | → | B | → | E | ↓ | D (4.47) |

**Table G3: Presentation of the results of the WET-Health assessment applied to Group 3: Downstream systems.**

| Hydrology | | Geomorphology | | Vegetation | | Overall PES Category of the Resource |
|---|---|---|---|---|---|---|
| PES category | Trajectory of change | PES category | Trajectory of change | PES category | Trajectory of change | |
| C | → | C | → | E | → | C (3.73) |

**Table G4: Presentation of the results of the WET-Health assessment applied to the mangrove system.**

| Hydrology | | Geomorphology | | Vegetation | | Overall PES Category of the Resource |
|---|---|---|---|---|---|---|
| PES category | Trajectory of change | PES category | Trajectory of change | PES category | Trajectory of change | |
| A | ↓ | A | → | 1.7 | ↓ | |

## *WETLAND ECOSYSTEM SERVICES ASSESSMENT SCORE SHEETS*

**Table G5: Presentation of the results of the ecoservices assessment applied to all systems.**

| Ecosystem service | Reference systems | Impounded systems | Downstream systems | Mangrove Wetlands |
|---|---|---|---|---|
| Flood attenuation | 1.8 | 1.8 | 1.5 | 2.3 |
| Streamflow regulation | 2.6 | 2.4 | 2.4 | 1.6 |
| Sediment trapping | 2.0 | 2.0 | 2.2 | 2.8 |
| Phosphate assimilation | 1.9 | 1.1 | 1.7 | 2.1 |
| Nitrate assimilation | 2.4 | 1.9 | 2.3 | 2.3 |
| Toxicant assimilation | 2.1 | 1.5 | 2.0 | 2.9 |
| Erosion control | 2.6 | 1.5 | 1.9 | 2.6 |
| Carbon Storage | 2.3 | 1.5 | 1.3 | 1.5 |
| Biodiversity maintenance | 2.9 | 1.8 | 1.6 | 3.0 |
| Water Supply | 3.0 | 3.3 | 2.8 | 1.2 |
| Harvestable resources | 3.4 | 3.2 | 3.4 | 3.8 |
| Cultivated foods | 3.6 | 2.8 | 3.6 | 1.6 |
| Cultural value | 1.8 | 1.8 | 1.8 | 1.0 |
| Tourism and recreation | 1.3 | 2.4 | 0.8 | 2.0 |
| Education and research | 1.3 | 1.0 | 0.5 | 2.3 |
| **SUM** | **34.8** | **29.9** | **29.6** | **32.9** |
| **Average score** | **2.3** | **2.0** | **2.0** | **2.2** |

## *ECOLOGICAL IMPORTANCE AND SENSITIVITY (EIS) ASSESSMENT*

**Table G6: Presentation of the results of the EIS assessment applied to Group 1: Reference systems.**

| Ecological Importance and Sensitivity | Score (0-4) | *Confidence (1-5)* |
|---|---|---|
| **Biodiversity support** | A (average) | (average) |
| | 0.33 | 1.67 |
| ***Presence of Red Data species*** | 0 | 1 |
| ***Populations of unique species*** | 1 | 1 |
| ***Migration/breeding/feeding sites*** | 0 | 3 |
| **Landscape scale** | B (average) | (average) |
| | 1.80 | 2.60 |
| ***Protection status of the wetland*** | 0 | 4 |
| ***Protection status of the vegetation type*** | 1 | 2 |
| ***Regional context of the ecological integrity*** | 4 | 3 |
| ***Size and rarity of the wetland type/s present*** | 2 | 2 |
| ***Diversity of habitat types*** | 2 | 2 |
| **Sensitivity of the wetland** | C (average) | (average) |
| | 2.33 | 2.67 |
| ***Sensitivity to changes in floods*** | 1 | 2 |
| ***Sensitivity to changes in dry season*** | 2 | 3 |
| ***Sensitivity to changes in water quality*** | 4 | 3 |
| **ECOLOGICAL IMPORTANCE & SENSITIVITY** | **(max of A,B or C)** | *(average of A, B or C)* |
| **Fill in highest score:** | **C** | **2.33** |
| High: Wetlands that are considered to be ecologically important and sensitive. The biodiversity of these systems may be sensitive to flow and habitat modifications. They play a role in moderating the quantity and quality of water of major rivers. | | |

| Hydro-Functional Importance | | | Score (0-4) | *Confidence (1-5)* |
|---|---|---|---|---|
| **Regulating & supporting benefits** | **Flood attenuation** | | 2 | 3 |
| | **Streamflow regulation** | | 3 | 3 |
| | **Water Quality Enhancement** | ***Sediment trapping*** | 1 | 2 |
| | | ***Phosphate assimilation*** | 1 | 2 |
| | | ***Nitrate assimilation*** | 2 | 2 |
| | | ***Toxicant assimilation*** | 2 | 2 |
| | | ***Erosion control*** | 2 | 3 |
| | **Carbon storage** | | 2 | 2 |
| **HYDRO-FUNCTIONAL IMPORTANCE** | | | 2 | 2 |

| Direct Human Benefits | | Score (0-4) | *Confidence (1-5)* |
|---|---|---|---|
| **Subsistence benefits** | ***Water for human use*** | 3 | 1 |
| | ***Harvestable resources*** | 3 | 2 |
| | ***Cultivated foods*** | 3 | 1 |
| | | | |
| **Cultural benefits** | ***Cultural heritage*** | 2 | 1 |
| | ***Tourism and recreation*** | 2 | 2 |
| | ***Education and research*** | 1 | 3 |
| **DIRECT HUMAN BENEFITS** | | 2.33 | 2 |

**Table G7: Presentation of the results of the EIS assessment applied to Group 2: Impounded systems.**

| **Ecological Importance and Sensitivity** | Score (0-4) | *Confidence (1-5)* |
|---|---|---|
| **Biodiversity support** | A (average) | (average) |
| | 0.67 | 1.67 |
| ***Presence of Red Data species*** | 0 | 1 |
| ***Populations of unique species*** | 1 | 1 |
| ***Migration/breeding/feeding sites*** | 1 | 3 |
| **Landscape scale** | B (average) | (average) |
| | 1.20 | 2.60 |
| ***Protection status of the wetland*** | 0 | 4 |
| ***Protection status of the vegetation type*** | 1 | 2 |
| ***Regional context of the ecological integrity*** | 2 | 3 |
| ***Size and rarity of the wetland type/s present*** | 2 | 2 |
| ***Diversity of habitat types*** | 1 | 2 |
| **Sensitivity of the wetland** | C (average) | (average) |
| | 0.67 | 2.67 |
| ***Sensitivity to changes in floods*** | 0 | 2 |
| ***Sensitivity to changes in dry season*** | 1 | 3 |
| ***Sensitivity to changes in water quality*** | 1 | 3 |
| **ECOLOGICAL IMPORTANCE & SENSITIVITY** | **(max of A,B or C)** | *(average of A, B or C)* |
| **Fill in highest score:** | **B** | **1.20** |
| Moderate: Wetlands that are considered to be ecologically important and sensitive on a provincial or local scale. The biodiversity of these systems is not usually sensitive to flow and habitat modifications. They play a small role in moderating the quantity and quality of and habitat modifications. They play a small role in moderating the quantity and quality of water of major rivers. | | |

| Hydro-Functional Importance | | | Score (0-4) | *Confidence (1-5)* |
|---|---|---|---|---|
| **Regulating & supporting benefits** | **Flood attenuation** | | 2 | 4 |
| | **Streamflow regulation** | | 2 | 4 |
| | **Water Quality Enhancement** | ***Sediment trapping*** | 2 | 4 |
| | | ***Phosphate assimilation*** | 1 | 4 |
| | | ***Nitrate assimilation*** | 2 | 4 |
| | | ***Toxicant assimilation*** | 1 | 3 |
| | | ***Erosion control*** | 1 | 4 |
| | **Carbon storage** | | 1 | 2 |
| **HYDRO-FUNCTIONAL IMPORTANCE** | | | 2 | 4 |

| Direct Human Benefits | | Score (0-4) | *Confidence (1-5)* |
|---|---|---|---|
| **Subsistence benefits** | ***Water for human use*** | 3 | 2 |
| | ***Harvestable resources*** | 3 | 3 |
| | ***Cultivated foods*** | 3 | 1 |
| **Cultural benefits** | ***Cultural heritage*** | 2 | 1 |
| | ***Tourism and recreation*** | 2 | 3 |
| | ***Education and research*** | 1 | 3 |
| **DIRECT HUMAN BENEFITS** | | 2.33 | 2 |

**Table G8: Presentation of the results of the EIS assessment applied to Group 3: Downstream systems.**

| **Ecological Importance and Sensitivity** | Score (0-4) | *Confidence (1-5)* |
|---|---|---|
| **Biodiversity support** | A (average) | (average) |
| | 1.00 | 1.33 |
| ***Presence of Red Data species*** | 0 | 1 |
| ***Populations of unique species*** | 1 | 1 |
| ***Migration/breeding/feeding sites*** | 2 | 2 |
| **Landscape scale** | B (average) | (average) |
| | 1.20 | 2.80 |
| ***Protection status of the wetland*** | 0 | 4 |
| ***Protection status of the vegetation type*** | 0 | 2 |
| ***Regional context of the ecological integrity*** | 2 | 3 |
| ***Size and rarity of the wetland type/s present*** | 2 | 2 |
| ***Diversity of habitat types*** | 2 | 3 |
| **Sensitivity of the wetland** | C (average) | (average) |
| | 1.67 | 2.67 |
| ***Sensitivity to changes in floods*** | 1 | 3 |
| ***Sensitivity to changes in dry season*** | 3 | 2 |
| ***Sensitivity to changes in water quality*** | 1 | 3 |
| **ECOLOGICAL IMPORTANCE & SENSITIVITY** | **(max of A,B or C)** | *(average of A, B or C)* |
| **Fill in highest score:** | **C** | **1.67** |
| Moderate: Wetlands that are considered to be ecologically important and sensitive on a provincial or local scale. The biodiversity of these systems is not usually sensitive to flow and habitat modifications. They play a small role in moderating the quantity and quality of and habitat modifications. They play a small role in moderating the quantity and quality of water of major rivers. | | |

| **Hydro-Functional Importance** | | | Score (0-4) | *Confidence (1-5)* |
|---|---|---|---|---|
| **Regulating & supporting benefits** | **Flood attenuation** | | 1 | 3 |
| | **Streamflow regulation** | | 2 | 2 |
| | **Water Quality Enhancement** | ***Sediment trapping*** | 2 | 3 |
| | | ***Phosphate assimilation*** | 1 | 2 |
| | | ***Nitrate assimilation*** | 2 | 2 |
| | | ***Toxicant assimilation*** | 2 | 2 |
| | | ***Erosion control*** | 1 | 4 |
| | **Carbon storage** | | 1 | 2 |
| **HYDRO-FUNCTIONAL IMPORTANCE** | | | **2** | **3** |

| Direct Human Benefits | | Score (0-4) | *Confidence (1-5)* |
|---|---|---|---|
| **Subsistence benefits** | ***Water for human use*** | 3 | 2 |
| | ***Harvestable resources*** | 3 | 3 |
| | ***Cultivated foods*** | 3 | 1 |
| | | | |
| **Cultural benefits** | ***Cultural heritage*** | 2 | 1 |
| | ***Tourism and recreation*** | 1 | 1 |
| | ***Education and research*** | 1 | 3 |
| **DIRECT HUMAN BENEFITS** | | 2.17 | 2 |

**Table G9: Presentation of the results of the EIS assessment applied to the mangrove system.**

| Ecological Importance and Sensitivity | Score (0-4) | *Confidence (1-5)* |
|---|---|---|
| **Biodiversity support** | A (average) | (average) |
| | 3.67 | 3.67 |
| ***Presence of Red Data species*** | 4 | 4 |
| ***Populations of unique species*** | 3 | 3 |
| ***Migration/breeding/feeding sites*** | 4 | 4 |
| **Landscape scale** | B (average) | (average) |
| | 2.60 | 2.60 |
| ***Protection status of the wetland*** | 4 | 4 |
| ***Protection status of the vegetation type*** | 1 | 2 |
| ***Regional context of the ecological integrity*** | 4 | 3 |
| ***Size and rarity of the wetland type/s present*** | 2 | 2 |
| ***Diversity of habitat types*** | 2 | 2 |
| **Sensitivity of the wetland** | C (average) | (average) |
| | 2.33 | 2.67 |
| ***Sensitivity to changes in floods*** | 1 | 2 |
| ***Sensitivity to changes in low flows/dry season*** | 2 | 3 |
| ***Sensitivity to changes in water quality*** | 4 | 3 |
| **ECOLOGICAL IMPORTANCE & SENSITIVITY** | **(max of A,B or C)** | *(average of A, B or C)* |
| **Fill in highest score:** | **A** | **3.67** |

| Hydro-Functional Importance | | | Score (0-4) | *Confidence (1-5)* |
|---|---|---|---|---|
| **Regulating & supporting benefits** | **Flood attenuation** | | 2 | 3 |
| | **Streamflow regulation** | | 2 | 3 |
| | **Water Quality Enhancement** | ***Sediment trapping*** | 3 | 2 |
| | | ***Phosphate assimilation*** | 2 | 2 |
| | | ***Nitrate assimilation*** | 2 | 2 |
| | | ***Toxicant assimilation*** | 2 | 2 |
| | | ***Erosion control*** | 3 | 3 |
| | **Carbon storage** | | 1 | 2 |
| **HYDRO-FUNCTIONAL IMPORTANCE** | | | 2 | 2 |

| Direct Human Benefits | | Score (0-4) | *Confidence (1-5)* |
|---|---|---|---|
| **Subsistence benefits** | ***Water for human use*** | 1 | 1 |
| | ***Harvestable resources*** | 4 | 2 |
| | ***Cultivated foods*** | 2 | 1 |
| **Cultural benefits** | ***Cultural heritage*** | 1 | 1 |
| | ***Tourism and recreation*** | 2 | 2 |
| | ***Education and research*** | 2 | 3 |
| **DIRECT HUMAN BENEFITS** | | 2.00 | 2 |

# APPENDIX H: SPECIALISTS DETAILS

## Details, Expertise and Curriculum Vitae of Company and Author

**Declaration that the specialist is independent in a form as may be specified by the competent authority**

I, Stephen van Staden, declare that -

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

**Declaration that the specialist is independent in a form as may be specified by the competent authority**

I, Dionne Crafford, declare that -

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

# SCIENTIFIC TERRESTRIAL SERVICES (STS) – SPECIALIST CONSULTANT INFORMATION

## CURRICULUM VITAE OF STEPHAN VAN STADEN

### PERSONAL DETAILS

| | |
|---|---|
| Position in Company | Managing member, Ecologist, Aquatic Ecologist |
| Date of Birth | 13 July 1979 |
| Nationality | South African |
| Languages | English, Afrikaans |
| Joined SAS | 2003 (year of establishment) |
| Other Business | Trustee of the Serenity Property Trust |

### MEMBERSHIP IN PROFESSIONAL SOCIETIES

Registered Professional Scientist at South African Council for Natural Scientific Professions (SACNASP)
Accredited River Health practitioner by the South African River Health Program (RHP)
Member of the South African Soil Surveyors Association (SASSO) Member of the Gauteng Wetland Forum
Registered Professional Scientist at South African Council for Natural Scientific Professions (SACNASP)

### EDUCATION

| **Qualifications** | |
|---|---|
| MSc (Environmental Management) (University of Johannesburg) | 2002 |
| BSc (Hons) Zoology (Aquatic Ecology) (University of Johannesburg) | 2000 |
| BSc (Zoology, Geography and Environmental Management) (University of Johannesburg) | 1999 |
| Tools for wetland Assessment short course Rhodes University | 2016 |

### COUNTRIES OF WORK EXPERIENCE

South Africa – All Provinces
Southern Africa – Lesotho, Botswana, Mozambique, Zimbabwe
Eastern Africa – Tanzania
West Africa – Ghana, Liberia, Angola, Guinea Bissau
Central Africa – Democratic Republic of the Congo

### SELECTED PROJECT EXAMPLES

**Impoundment studies**

- Lalini Dam specialist aquatic ecological assessment with focus on aquatic macro-invertebrate and fish community analysis and fish migration.
- Ntabalenga Dam specialist aquatic ecological assessment with focus on macro-invertebrate fish community analysis and fish migration.
- Donkerhoek Dam specialist aquatic ecological assessment and consideration of fish migration requirements;
- Groot Phisantekraal dam specialist aquatic ecological assessment and Ecological Water Requirements for the Diep River;
- Musami Dam (Zimbabwe) assessment with focus on the FRAI and MIRAI aquatic community assessment indices and the development of the Ecological Water Requirements;
- Mhlabatsane dam Ecological Water specialist aquatic ecological assessment and consideration of fishway needs and macro-invertebrate community sensitivity.

**Development compliance studies**

- Project co-leader for the development of the EMP for the use of the Wanderers stadium for the Ubuntu village for the World Summit on Sustainable Development (WSSD).
- Environmental Control Officer for Eskom for the construction of an 86 Km 400KV power line in the Rustenburg Region.
- Numerous Environmental Impact Assessment (EIA) and EIA exemption applications for township developments and as part of the Development Facilitation Act requirements.
- EIA for the extension of mining rights for a Platinum mine in the Rustenburg area by Lonmin Platinum.
  - EIA Exemption application for a proposed biodiesel refinery in Chamdor.
- Compilation of an EIA as part of the Bankable Feasibility Study process for proposed mining of a gold deposit in the Lofa province, Liberia.
- EIA for the development of a Chrome Recovery Plant at the Two Rivers Platinum Mine in the Limpopo province, South Africa.
- Compilation of an EIA as part of the Bankable Feasibility Study process for the Mooihoek Chrome Mine in the Limpopo province, South Africa.
- Mine Closure Plan for the Vlakfontein Nickel Mine in the North West Province.

**Specialist studies and project management**

- Development of the Water Resource and biodiversity chapters of the 2015 Limpopo Province Biodiversity outlook.
- Development of a zero discharge strategy and associated risk, gap and cost benefit analyses for the Lonmin Platinum group.
- Development of a computerised water balance monitoring and management tool for the management of Lonmin Platinum process and purchased water.
- The compilation of the annual water monitoring and management program for the Lonmin Platinum group of mines.
- Analyses of ground water for potable use on a small diamond mine in the North West Province.
- Project management and overview of various soil and land capability studies for residential, industrial and mining developments.
- The design of a stream diversion of a tributary of the Olifants River for a proposed opencast coal mine.
- Waste rock dump design for a gold mine in the North West province.
- Numerous wetland delineation and function studies in the North West, Gauteng and Mpumalanga KwaZulu Natal provinces, South Africa.
- Hartebeespoort Dam Littoral and Shoreline PES and rehabilitation plan.
- Development of rehabilitation principles and guidelines for the Crocodile West Marico Catchment, DWAF North West.

**Aquatic and water quality monitoring and compliance reporting**

- Development of the Resource quality Objective framework for Water Use licensing in the Crocodile West Marico Water management Area.
- Development of the Resource Quality Objectives for the Local Authorities in the Upper Crocodile West Marico Water management Area.
- Development of the 2010 State of the Rivers Report for the City of Johannesburg.
- Management of the water quality reporting programs for several mining projects in the Gold, Chrome and Platinum mining industries.
- Initiation and management of a physical, chemical and biological monitoring program, President Steyn Gold Mine Welkom.
- Aquatic biomonitoring programs for several Xstrata Alloys Mines and Smelters.
- Aquatic biomonitoring programs for several Anglo Platinum Mines.
- Aquatic biomonitoring programs for African Rainbow Minerals Mines.
- Aquatic biomonitoring programs for several Assore Operations.
- Aquatic biomonitoring programs for Petra Diamonds.
- Aquatic biomonitoring programs for several Coal mining operations.
- Aquatic biomonitoring programs for several Gold mining operations.
- Aquatic biomonitoring programs for several mining operations for various minerals including iron ore, and small platinum and chrome mining operations.
- Aquatic biomonitoring program for the Valpre bottled water plant (Coca Cola South Africa).
- Aquatic biomonitoring program for industrial clients in the paper production and energy generation industries.
- Aquatic biomonitoring programs for the City of Tshwane for all their Waste Water Treatment Works.
- Baseline aquatic ecological assessments for numerous mining developments.

- Baseline aquatic ecological assessments for numerous residential commercial and industrial developments.
- Baseline aquatic ecological assessments in southern, central and west Africa for gold mining projects, Phosphate mining diamond mining and copper mining.

**Wetland delineation and wetland function assessment**

- Wetland biodiversity studies for three copper mines on the copper belt in the Democratic Republic of the Congo.
- Wetland biodiversity studies for proposed mining projects in Guinea Bissau, Liberia and Angola in West Africa.
- Terrestrial and wetland biodiversity studies for developments in the mining industry.
- Terrestrial and wetland biodiversity studies for developments in the residential commercial and industrial sectors.
- Development of wetland riparian resource protection measures for the Hartbeespoort Dam as part of the Harties Metsi A Me integrated biological remediation program.
- Priority wetland mammal species studies for numerous residential, commercial, industrial and mining developments throughout South Africa.

**Terrestrial ecological studies and biodiversity studies**

- Development of a biodiversity offset plan for Xstrata Alloys Rustenburg Operations.
- Biodiversity Action plans for numerous mining operations of Anglo Platinum throughout South Africa in line with the NEMBA requirements.
- Biodiversity Action plans for numerous mining operations of Assmang Chrome throughout South Africa in line with the NEMBA requirements.
- Biodiversity Action plans for numerous mining operations of Xstrata Alloys and Mining throughout South Africa in line with the NEMBA requirements.
- Biodiversity Action plan for the Nkomati Nickel and Chrome Mine Joint Venture.
- Terrestrial and wetland biodiversity studies for three copper mines on the copperbelt in the Democratic Republic of the Congo.
- Terrestrial and wetland biodiversity studies for proposed mining projects in Guinea Bissau, Liberia and Angola in West Africa.
- Numerous terrestrial ecological assessments for proposed platinum and coal mining projects.
- Numerous terrestrial ecological assessments for proposed residential and commercial property developments throughout most of South Africa.
- Specialist Giant bullfrog (Pyxicephalus adspersus) studies for several proposed residential and commercial development projects in Gauteng, South Africa.
- Specialist Marsh sylph (Metisella meninx) studies for several proposed residential and commercial development projects in Gauteng, South Africa.
- Project management of several Red Data Listed (RDL) bird studies with special mention of African grass owl (Tyto capensis).
- Project management of several studies for RDL Scorpions, spiders and beetles for proposed residential and commercial development projects in Gauteng, South Africa.
- Specialist assessments of terrestrial ecosystems for the potential occurrence of RDL spiders and owls.
- Project management and site specific assessment on numerous terrestrial ecological surveys including numerous studies in the Johannesburg-Pretoria area, Witbank area, and the Vredefort dome complex.
- Biodiversity assessments of estuarine areas in the Kwa-Zulu Natal and Eastern Cape provinces.
- Impact assessment of a spill event on a commercial maize farm including soil impact assessments.

**Fisheries management studies**

- Tamryn Manor (Pty.) Ltd. still water fishery initiation, enhancement and management.
- Verlorenkloof Estate fishery management strategising, fishery enhancement, financial planning and stocking strategy.
- Mooifontein fishery management strategising, fishery enhancement and stocking programs.
- Wickams retreat management strategising.
- Gregg Brackenridge management strategising and stream recalibration design and stocking strategy.
- Eljira Farm baseline fishery study compared against DWAF 1996 aquaculture and aquatic ecosystem guidelines.

# SCIENTIFIC TERRESTRIAL SERVICES (STS) – SPECIALIST CONSULTANT INFORMATION

## CURRICULUM VITAE OF DIONNE CRAFFORD

### PERSONAL DETAILS

| | |
|---|---|
| Position in Company | Managing member, Ecologist, Aquatic Ecologist |
| Date of Birth | 17 October 1975 |
| Nationality | South African |
| Languages | English, Afrikaans |
| Joined SAS | 2003 (year of establishment) |

### MEMBERSHIP IN PROFESSIONAL SOCIETIES

Registered Professional Scientist at South African Council for Natural Scientific Professions (SACNASP)

### EDUCATION

| **Qualifications** | |
|---|---|
| PhD Zoology (University of Johannesburg) | 2013 |
| M.Sc. Zoology Cum Laude (University of Johannesburg) | 2000 |
| B.Sc. (Hons) Zoology Cum Laude (University of Pretoria) | 1997 |
| B.Sc. Ecology (University of Pretoria) | 1996 |

### COUNTRIES OF WORK EXPERIENCE

South Africa – All provinces.
Southern Africa – Caprivi Strip (fish collections)

### SELECTED PROJECT EXAMPLES

**Aquatic and water quality monitoring and compliance reporting**

- Aquatic biomonitoring programs for several Xstrata Alloys Mines and Smelters.
- Aquatic biomonitoring programs for several Anglo Platinum Mines.
- Aquatic biomonitoring programs for African Rainbow Minerals Mines.
- Aquatic biomonitoring programs for several Assmang Chrome Operations.
- Aquatic biomonitoring programs for Petra Diamonds.
- Aquatic biomonitoring programs for several coal mining operations.
- Aquatic biomonitoring programs for several gold mining operations.
- Aquatic biomonitoring programs for several mining operations for various minerals including iron ore, and small platinum and chrome mining operations.
- Aquatic biomonitoring programs for the City of Tshwane for all their Waste Water Treatment Works.
- Baseline aquatic ecological assessments for numerous mining developments.
- Musami Dam assessment with focus on the FRAI and MIRAI aquatic community assessment indices.

## SCIENTIFIC TERRESTRIAL SERVICES (STS) – SPECIALIST CONSULTANT INFORMATION

## CURRICULUM VITAE OF AMANDA MILESON

### PERSONAL DETAILS

| | |
|---|---|
| Position in Company | Ecologist |
| Date of Birth | 15 February 1978 |
| Nationality | Zimbabwean |
| Languages | English |
| Joined SAS | 2013 |

### MEMBERSHIP IN PROFESSIONAL SOCIETIES

Member South African Wetland Society
Member Gauteng Wetland Forum

### EDUCATION

| **Qualifications** | |
|---|---|
| N.Dip Nature Conservation (UNISA) | 2017 |
| Tools for Wetland Assessment (Rhodes University) | 2016 |
| Wetland Rehabilitation short learning programme (UFS) | 2015 |

### COUNTRIES OF WORK EXPERIENCE

South Africa – Gauteng, Mpumalanga, North West, Limpopo, Northern Cape, Eastern Cape
Zimbabwe

### SELECTED PROJECT EXAMPLES

**Wetland Assessments**

- Wetland assessment as part of the environmental authorisation process for the Anglo Platinum Der Brochen Project, Limpopo Province
- Wetland assessment as part of the environmental authorisation process for the proposed Tharisa North eastern waste rock dump, North West Province
- Wetland assessment as part of the environmental authorisation process for the proposed Yzermyn Coal Mining Project near Dirkiesdorp, Mpumalanga
- Wetland assessment as part of the environmental authorisation process for the Mzimvubu Water Project, Eastern Cape
- Wetland assessment as part of the environmental authorisation process for the proposed expansion of mining operations at the Langkloof Colliery, Mpumalanga
- Wetland assessment as part of the proposed water management process at the Assmang Chrome Machadodorp Works, Mpumalanga
- Wetland assessment as part of the water use licencing process for the proposed development in Rooihuiskraal Ext 24, Centurion, Gauteng
- Wetland assessment as part of the environmental authorisation process for the proposed road crossings on The Hills EcoEstate, Midrand, Gauteng
- Wetland ecological assessment as part of the Section 24G application process for the Temba Water Purification Plant
- Wetland assessment and offset studies for the Optimum Colliery Kwagga North Project, Mpumalanga
- Wetland assessment and delineation as part of the environmental authorisation process for the proposed development of a mall adjacent to the M10 Road in Mahube Valley, Mamelodi, Gauteng

| |
|---|
| • Wetland assessment as part of the environmental authorisation process for the proposed construction of a sewer system in Ekangala Township, Gauteng |
| **Terrestrial Assessments**<br>• Investigation of specialist biodiversity aspects required by GDARD in the vicinity of the Apies River, downstream of the proposed construction of new outlet works at the Kudube (Leeuwkraal) Dam in Temba, Gauteng<br>• Terrestrial Ecological Scan as part of the environmental authorisation process for three proposed bridge upgrades near Edenvale, Gauteng<br>• Terrestrial Ecological Scan as part of the environmental authorisation process for the proposed Dalpark Ext 3 filling station development, Gauteng |
| **Rehabilitation Projects**<br>• Wetland rehabilitation and management plan for The Hills EcoEstate, Midrand, Gauteng<br>• Riparian rehabilitation and management plan for The Diepsloot River, Riversands, Gauteng<br>• Riparian rehabilitation and management plan for the Apies River in the vicinity of the proposed construction of new outlet works at the Kudube (Leeuwkraal) Dam in Temba, Gauteng |
| **Environmental Control Officer**<br>• Monthly specialist Environmental Control Officer (ECO) function for the monitoring of riparian crossings at Riversands Country Estate Development, Gauteng |

# SIERRA RUTILE PROJECT AREA 1 – ENVIRONMENTAL, SOCIAL AND HEALTH IMPACT ASSESSMENT: SPECIALIST TERRESTRIAL, AQUATIC AND WETLAND ECOLOGICAL STUDIES

**Prepared for**

**SRK Consulting (South Africa) (Pty) Ltd**

**February 2018**

# Section E – Integrated Impact Assessment


| | |
|---|---|
| **Prepared by:** | **Scientific Terrestrial Services** |
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| **Report Reference:** | **STS 170030** |
| **Date:** | **February 2018** |

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# 1. INTRODUCTION

## *1.1 Background*

Scientific Terrestrial Services (STS) was appointed to conduct faunal, floral, wetland and aquatic ecological assessments as part of the process to undertake an Environmental, Social and Health Impact Assessment (ESHIA) and develop an Environmental, Social and Health Management Plan (ESHMP) for the current and proposed dry and wet mining activities for the Sierra Rutile Limited's (SRL) Mine Lease Area 1 (SR Area 1) operations. The SR Area 1 is located within the Bonthe and Moyamba Districts of the Southern Province of Sierra Leone. The SR Area 1 is situated approximately 30 km inland of the Atlantic Ocean and approximately 135 km southeast of Freetown (geodesic) (Figure 1 and 2 in the Section A report).

This report aims to consider and describe the impact on the terrestrial and aquatic ecological resources associated with the SR Area 1 due to current and future mining operations from results gathered during the wet and wet season surveys. In doing so, this report must guide the proponent, Environmental Assessment Practitioner (EAP) and regulating authorities, by means of the presentation of information on the baseline conditions, as to the management of current and future mining operations from an ecological risk management point of view as well as the further studies and assessments required.

# 2. IMPACT AND RISK ASSESSMENT METHODOLOGY

An impact assessment was performed with reference to the current and planned activities associated with the SRL, with the following life-cycle phases assessed:

- Operational;
- Decommissioning/closure; and
- Post-closure/latent impacts.

Assessments were performed for all the project related activities likely to affect the aquatic resources present, to determine and characterise the potential impact on the receiving environment. The impact assessment was undertaken according to the specifications and methodology provided by SRK, as summarised below.

## *2.1 Impact Assessment Methodology*

The impact assessment was conducted in an integrated manner that links the biophysical components with the socio-economic components of the environment. The impact assessment is divided into issue identification, impact definition and impact evaluation.

All specialists working on the ESHIA used a common, systematic and defensible method of assessing significance that enables comparisons to be made between impacts across different disciplines. It also enables all relevant parties to understand the process and rationale upon which impacts have been assessed.

Generally, the impact assessment is divided into three parts:

- **Issue identification** - each specialist was required to evaluate the 'aspects' arising from the project description and ensure that all issues in their area of expertise have been identified;
- **Impact definition** - positive and negative impacts associated with these issues (and any others not included) were then defined. The definition statement includes the activity (source of impact), aspect and receptor as well as whether the impact is direct, indirect or cumulative. Fatal flaws (if any) will also be identified at this stage; and
- **Impact evaluation –** this is not a purely objective and quantitative exercise. It has a subjective element, often using judgement and values as much as science-based criteria and standards.

The need therefore exists to clearly explain how impacts have been interpreted so that others can see the weight attached to different factors and can understand the rationale of the assessment.

The basic elements used in the evaluation of impact significance are described in Table 1, and the characteristics that are used to describe the consequence of an impact are outlined in Table 2.

**Table 1: Key elements in the evaluation of impact significance**

| Element | Description | Questions applied to the test of significance |
|---|---|---|
| Consequence | An impact or effect is described as the change in an environmental parameter, which results from a particular project activity or intervention. Here, the term "consequence" refers to:<br>(a) The sensitivity of the receiving environment, including its capacity to accommodate the kinds of changes the project may bring about.<br>(b) The type of change and the key characteristics of the change (these are magnitude, extent and duration).<br>(c) The importance of the change (the level of public concern/ value attached to environment by the stakeholders and the change effected by the project).<br>The following should be considered in the determination of impact consequence:<br>(a) Standards and guidelines (thresholds).<br>(b) Scientific evidence and professional judgment.<br>(c) Points of reference from comparable cases.<br>(d) Levels of stakeholder concern. | Will there be a change in the biophysical and/or social environment?<br>Is the change of consequence (of any importance)? |
| Probability | Likelihood/chance of an impact occurring. | What is the likelihood of the change occurring? |
| Effectiveness of the management measures | Significance of the impact needs to be determined both without management measures and with management measures.<br>The significance of the unmanaged impact needs to be determined so there is an appreciation of what could occur in the absence of management measures and of the effectiveness of the proposed management measures. | Will the management measures reduce impact to an acceptable level? |
| Uncertainty/ Confidence | Relating to uncertainty in impact prediction and the effectiveness of the proposed management measures. Sources of uncertainty in impact prediction include:<br>• Scientific uncertainty – limited understanding of an ecosystem (or affected stakeholders) and the processes that govern change.<br>• Data uncertainty – restrictions introduced by incomplete, contradictory or incomparable information, or by insufficient measurement techniques.<br>• Policy uncertainty – unclear or disputed objectives, standards or guidelines.<br>There are a number of approaches that can be used to address uncertainty in impact prediction, including:<br>(a) 'Best' and 'worst' case prediction to illustrate the spread of uncertainty.<br>(b) Attaching confidence limits to impact predictions.<br>(c) Sensitivity analysis to determine the effect of small changes in impact magnitude. | What is the degree of confidence in the significance ascribed to the impact? |

**Table 2: Impact assessment methodology characteristics**

| Characteristics used to describe consequence | Sub-components | Terms used to describe the characteristic |
|---|---|---|
| **Type** | | Biophysical, social or economic |
| **Nature** | | Direct or indirect, cumulative etc. |
| **Status** | | Positive (a benefit), negative (a cost) or neutral |
| **Phase of project** | | During pre-construction (if applicable e.g. resettlement), construction, operation, decommissioning/post closure |
| **Timing** | | Immediate, delayed |
| **Magnitude** | **Sensitivity** of the receiving environment / receptors | High, medium or low sensitivity<br>Low capacity to accommodate the change (impact)/ tolerant of the proposed change |
| | **Severity/ intensity** (degree of change measured against thresholds and/or professional judgment) | Gravity / seriousness of the impact<br>Intensity/ influence / power / strength |
| | **Level of stakeholder concern** | High, medium or low levels of concern<br>All or some stakeholders are concerned about the change |
| **Spatial extent or population affected**<br>The area / population affected by the impact<br>The boundaries at local and regional extents will be different for biophysical and social impacts | | Area / volume covered, distribution, population<br>Site / local (social impacts should distinguish between site and local), regional, national or international |
| **Duration (and reversibility)**<br>Length of time over which an impact occurs and potential for recovery of the endpoint from the impact | | Short term, long term<br>Intermittent, continuous<br>Reversible / irreversibility<br>Temporary, permanent |
| **Confidence**<br>Based on information available and competencies of the assessor | | High, Medium, Low |

The impact significance rating process serves two purposes: firstly, it helps to highlight the critical environmental and social impacts requiring consideration in the management and approval process; secondly, it serves to show the primary impact characteristics, as defined above, used to evaluate impact significance.

The impact significance rating system is presented in Table 3 and involves four parts:

- Part A: Define the impact consequence using the three primary impact characteristics of magnitude, spatial scale/population and duration;
- Part B: Use the matrix to determine a rating for impact consequence based on the definitions identified in Part A;
- Part C: Use the matrix to determine the impact significance rating, which is a function of the impact consequence rating (from Part B) and the probability of occurrence; and
- Part D: Define the Confidence level.

**Table 3: Impact assessment significance rating**

| **PART A: DEFINING CONSEQUENCE IN TERMS OF MAGNITUDE, DURATION AND SPATIAL SCALE** *Use these definitions to define the consequence in Part B* | | |
|---|---|---|
| **Impact characteristics** | **Definition** | **Criteria** |
| **MAGNITUDE** | Major | Substantial deterioration or harm to receptors; receiving environment has an inherent value to stakeholders; receptors of impact are of conservation importance; or identified threshold often exceeded |
| | Moderate | Moderate/measurable deterioration or harm to receptors; receiving environment moderately sensitive; or identified threshold occasionally exceeded |
| | Minor | Minor deterioration (nuisance or minor deterioration) or harm to receptors; change to receiving environment not measurable; or identified threshold never exceeded |
| | Minor+ | Minor improvement; change not measurable; or threshold never exceeded |
| | Moderate+ | Moderate improvement; within or better than the threshold; or no observed reaction |
| | Major+ | Substantial improvement; within or better than the threshold; or favourable publicity |
| **Impact characteristics** | **Definition** | **Criteria** |
| **SPATIAL SCALE OR POPULATION** | Site or local | Site specific or confined to the immediate project area |
| | Regional | May be defined in various ways, e.g. cadastral, catchment, topographic |
| | National/ International | Nationally or beyond |
| **DURATION** | Short term | Up to 12 months. |
| | Medium term | 12 months to 5 years |
| | Long term | Longer than 5 years |

| **PART B: DETERMINING CONSEQUENCE RATING** *Rate consequence based on definition of magnitude, spatial extent and duration* | | | | | |
|---|---|---|---|---|---|
| | | | **SPATIAL SCALE/ POPULATION** | | |
| | | | **Site or Local** | **Regional** | **National/ international** |
| **MAGNITUDE** | | | | | |
| **Minor** | **DURATION** | **Long term** | Medium | Medium | High |
| | | **Medium term** | Low | Low | Medium |
| | | **Short term** | Low | Low | Medium |
| **Moderate** | **DURATION** | **Long term** | Medium | High | High |
| | | **Medium term** | Medium | Medium | High |
| | | **Short term** | Low | Medium | Medium |
| **Major** | **DURATION** | **Long term** | High | High | High |
| | | **Medium term** | Medium | Medium | High |
| | | **Short term** | Medium | Medium | High |

| **PART C: DETERMINING SIGNIFICANCE RATING** *Rate significance based on consequence and probability* | | | | |
|---|---|---|---|---|
| | | **CONSEQUENCE** | | |
| | | **Low** | **Medium** | **High** |
| **PROBABILITY** (of exposure to impacts) | **Definite** | Medium | Medium | High |
| | **Possible** | Low | Medium | High |
| | **Unlikely** | Low | Low | Medium |

| **PART D: CONFIDENCE LEVEL** | | |
|---|---|---|
| High | Medium | Low |

Practical management measures and recommendations and post management significance will be listed, using a good international industry practice (GIIP) management hierarchy in that:

*"Recommendations for management should focus on avoidance, and if avoidance is not possible, then to reduce, restore, compensate/offset negative impacts, enhance positive impacts and assist project design."*

The significance of impacts was re-assessed with assumed management measures in place ("after management"). Specialists also recommended and described appropriate monitoring and review programs to track the efficacy of management measures. These were included as management and / or action plans.

The three parts of the impact assessment (Issue Identification, Impact Definition and Impact Evaluation) are systematically addressed in the sections below. Firstly, the activities deemed to have a potential impact was identified and categorised, to identify the aspects related to both life cycle phases.

Afterwards, the Environmental Impact associated with each aspect was defined and finally, evaluated for each life cycle phase (operational, decommissioning/closure/rehabilitation and post-closure/latent) following the Impact Assessment Methodology described above.

# 3. IMPACT ASSESSMENT AND MITIGATION MEASURES: AQUATIC RESOURCES

Following the assessment of the aquatic resources associated with the SRL, the SRK Impact Assessment Methodology was applied to ascertain the significance of perceived impacts on the aquatic, riparian and wetland components associated with the dredge ponds and river systems.

Firstly, current impacts of the operational phase (dry mining and wet mining) were assessed, including process plant operation and transport of product to the harbour for shipping.

With regard to the decommissioning/closure and rehabilitation, as well as the post-closure/latent phases, there are four key activities that are likely to have ecological impacts on the aquatic resources. These are:

- Lowering of existing dredge pond walls;
- Decommissioning of the mining plant;
- Decommissioning of existing haul roads; and
- Earth moving during rehabilitation efforts.

The activities are expected to have impacts on the following drivers and receptors:

Drivers:

- Hydrology;
- Water quality; and
- Geomorphology.

Receptors:

- Habitat;
- Biota; and
- Goods and services to the local community.

See Table 4 for additional details.

Impacts will be defined as loss of habitat, biota and environmental services (based on responses defined above), linked to mining activities in the respective phases. In sections that follow impacts will be numbered as Aquatic Biodiversity (AB) impacts (e.g. AB1, AB2 etc.)

The results of the impact assessment are presented in the sections below and highlight the various perceived impacts and mitigation measures involved in the Operational, Decommissioning/Closure/Rehabilitation and Post-Closure/Care and Maintenance phases.

**Table 4: Issue Identification (operational, decommissioning/closure/rehabilitation and post-closure/latent phases)**

| Phase | Activities (impact source) | Aspects to be considered |
|---|---|---|
| **Operational Phase** | • Dry Mining and haul road development:<br>- Clearing and mining of dry mining areas; and<br>- Clearance of other areas and development and maintenance of haul roads.<br>• Wet Mining areas:<br>- Ongoing dredge operation within dredge ponds; and<br>- Tailings and sand deposition.<br>• Plant operation:<br>- Processing of mineral sands at the plant.<br>• Transport and shipping of product from the Nitti Port. | **Drivers of freshwater ecosystems:**<br>• Hydrological processes;<br>• Water quality as a driver of ecosystems;<br>• Geomorphological processes.<br><br>**Receptors/responses:**<br>• Habitat (Biophysical);<br>• Biota (Biophysical);<br>• Goods and services to the local community (Social, Cultural and Economic). |
| **Decommissioning/ closure/rehabilitation phase** | **Decommissioning/closure:**<br>• Lowering of dredge pond water levels Demolition of surface infrastructure, including:<br>- Plant and other ancillary infrastructure; and<br>- Haul roads.<br>**Rehabilitation:**<br>• Rehabilitation of specific areas of footprint including:<br>- Earth moving during rehabilitation and reshaping efforts;<br>- Mixing of slime tailings with sand to increase fertility and water holding capacity; and<br>- Revegetation.<br>• Rehabilitation of dredge ponds: | |

| Phase | Activities (impact source) | Aspects to be considered |
| --- | --- | --- |
| | - Earth works and sloping of walls;<br>- Mixing of fine tailings with sand to increase fertility and water holding capacity;<br>- Seeding/planting appropriate wetland and riparian zone plant species as required<br>• Rehabilitation of demolished surfaces:<br>- Remove rubble;<br>- Rip hard surfaces to facilitate revegetation to occur as part of rehabilitation efforts.<br>• Rehabilitation of borrow pits | |
| **Post-closure/latent phase** | • Monitoring of rehabilitation success;<br>• Potential latent impacts (see “impact evaluation” section). | |

## *3.1 Operational Phase Impacts*

The operational activities of the mine development are anticipated to have impacts on the drivers and receptors identified previously. Impacts are largely associated with the wet and dry mining activities as well as the associated support infrastructure including the haul roads, plant and the shipping of the product from the Nitti Port. The significance of these impacts on the aquatic ecology of the receiving environment is summarised in the text and tables below.

### 3.1.1 Impact AB1: Loss of habitat, biota and ecosystem services due to dry mining

Table 5 provides a summary, description and assessment of aquatic impacts pertaining to dry mining during the operational phase. The impact is summarised in terms of drivers and receptors identified previously, followed by a more detailed description. Impacts pertain mainly to changes in water quality, flow paths and flow rates (the latter resulting in sedimentation, siltation, erosion and turbidity, with associated loss of habitat, biota and ecosystem services). The significance of the impact with management measures is considered medium (moderate, short term impact on a regional scale).

**Table 5: Impact AB1 – Loss of habitat, biota and ecoservices resulting from operational phase dry mining activities.**

| Activity | Dry mining and haul road development |
|---|---|
| Project phase | Operational |
| Impact descriptions | **Hydrology**<br>• Diversion of watercourses and concentration of flow in the diversion canal around the dry mining areas;<br>• Clearing, mining and haul road hard surfaces will alter preferential flow paths, decrease surface flow friction and hence increase run-off, and in the process, contribute to variable flow rates in the receiving aquatic environment.<br>Variability in flow rates may in turn affect habitat suitability and availability, and have an impact on biota;<br>• Vegetation on rehabilitated hard surfaces will need to re-establish and reach a new equilibrium (see “decommissioning/closure and rehabilitation” section).<br><br>**Water quality**<br>• Changes in topography, run-off characteristics, and the significant increase in disturbed soils leads to increases in turbidity in downstream areas which has the potential to affect the aquatic biota of the systems. However, historical data shows that the TSS, with the exception of two points, are well within World Bank (WB) and legal limits. Any potential impact is thus anticipated to be limited. This in turn affects suitability for human use and for support of the ecology of these systems;<br>• Potential ongoing impact on water quality within the receiving aquatic environment may occur, relating to turbid conditions (sedimentation/siltation), and addition of hydrocarbons (spillages from vehicles and other mining equipment) and other potential pollutants such as manganese (Mn), nickel (Ni), and zinc (Zn) via run-off. Note that concentrations of Mn and Zn may be elevated from background levels. However, historical data shows heavy metal concentrations comply with South African National Standard (SANS) (Mn with the exception of one site), World Bank (WB) limits (Zn), or both WB and SANS (Ni) This may affect the biological processes and human use value of the aquatic resources;<br>• Currently unidentified potential impacts from mining and other anthropogenic activities (chemical in terms of metals or organic compounds, nutrient, electrolyte and organic material input) are thus also possible.<br>**Geomorphological processes**<br>• Changes in run-off characteristics and the significant increase in disturbed soils lead to increases in turbidity in downstream area which can lead to excessive silt deposition and impacts on instream habitat. This in turn affects suitability for human use and for support of the ecology of these systems;<br>• Erosion and sedimentation/siltation resulting from increased run-off from hard surfaces and surfaces disturbed by dry mining, may result in settlement of suspended solids in the receiving aquatic environment. The settlement of suspended solids may affect sediment balances in these systems (aquatic and wetland), which could in turn affect substrate conditions and thus affect instream and riparian biota;<br>• Dry mining areas and haul roads located near aquatic resources may also contribute to sediment load via settlement of dust particles, or vehicles and associated hydrocarbon spillages may have a direct negative effect on riparian vegetation during clearing procedures.<br>**Habitat**<br>• See hydrology section above considering increased run-off and impact on habitat availability;<br>• Erosion and sedimentation/siltation resulting from increased run-off from hard surfaces and surfaces disturbed by dry mining, may result in smothering of benthic habitats (specifically with shallow riffle areas in mind), and negatively affect biota;<br>• Vehicles and associated hydrocarbon spillages may have a direct negative effect on riparian vegetation during clearing procedures.<br>**Biota**<br>• Changes in run-off characteristics and the significant increase in disturbed soils leads to increases in turbidity in downstream areas which can lead to excessive settling of solids and in turn smothering of benthos and aquatic habitat. Increased turbidity in turn affects suitability for human use and for support of the ecology of these systems;<br>• See hydrology section above considering the diversion of watercourses and concentration of flow. These changes will have an impact on the ecological functioning of the system;<br>• See habitat section above considering sedimentation/siltation and impacts (direct and indirect) on habitat. Impacts on habitat will have a negative impact on biota residing there;<br>• Clearing of areas will have a direct negative impact on vegetation;<br>• See water quality section above considering pollutants. Deterioration in water quality will also negatively affect biota. |

| Activity | Dry mining and haul road development | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Goods and services to the local community**<br>• See sections above. Impacts on flow rate, habitat availability and water quality will potentially also affect the local community in terms of the uses of the aquatic resources, and the areas available to effectively perform these activities (drinking water, bathing, washing clothes, subsistence fishing, and recreational use). | | | | | | | |
| **Potential impact rating: Impact AB1: Loss of habitat, biota and ecosystem services due to dry mining** | | | | | | | | |
| **Status** | **Magnitude** | **Duration** | **Scale** | **Consequence** | **Probability** | **Significance** | **+/-** | **Confidence** |
| **Before management** | Moderate | Short term | Re-gional | Medium | Definite | **Medium** | - | Medium |
| **Management measures** | • Stream diversion structures should be as short as possible. In addition, stream diversion structures should be designed to ensure they are geomorphologically stable and are not prone to excessive erosion;<br>• Clear separation mine impacted and natural run-off water areas, so as to minimise the impact on water quality in the receiving environment;<br>• Erosion management and sediment controls such as the use of rock packing, revegetation of profiled slopes, erosion berms, drift fences with hessian and silt traps must be implemented where relevant from the outset of dry mining activities. This is particularly relevant to areas where topography has changed and created run-off flow paths prone to erosion, with associated sedimentation/siltation risks;<br>• An alien vegetation control programme must be implemented, as encroachment of alien vegetation is expected to increase as a result of the disturbances resulting during the dry mining process, as well as adjacent to disturbed areas such as haul roads. Further detail on this impact and the associated mitigation measures is provided in the botanical impact assessment sections;<br>• Infrastructure should cross wetlands and rivers at right angles, with design of crossings allowing retention of wetland and riparian zone soil conditions;<br>• Engage the community and clearly communicate schedules for the respective phases of the mine with reference to future plans for closure and rehabilitation. | | | | | | | |
| **Status** | **Magnitude** | **Duration** | **Scale** | **Consequence** | **Probability** | **Significance** | **+/-** | **Confidence** |
| **After management** | Moderate | Short term | Re-gional | Medium | Possible | **Medium** (No change in class however, probability is reduced from definite to possible which is significant) | - | Medium |

### 3.1.2 Impact AB2: Loss of habitat, biota and ecosystem services due to wet mining

Table 6 provides a summary, description and assessment of aquatic impacts pertaining to wet mining during the operational phase. Impact is summarised in terms of drivers and receptors identified previously, followed by a more detailed description. Impacts pertain mainly to changes in water quality, flow rates and water levels, with associated loss of habitat, biota and ecosystem services. The significance of the impact with management measures is considered medium (moderate, medium term impact but on a local/site scale).

**Table 6: Impact AB2 – Loss of habitat, biota and ecoservices resulting from operational phase wet mining activities.**

<table>
<tr><th>Activity</th><th>Wet mining areas</th></tr>
<tr><td>Project phase</td><td>Operational</td></tr>
<tr><td>Impact descriptions</td><td>
Hydrology
<ul>
<li>In dredge pond and upstream effects caused by inhibition of run-off from dams and haul roads:
<ul><li>Inundation of valleys to create dredge pond and allow active dredging;</li></ul></li>
<li>Downstream effects:
<ul>
<li>Variable flow rates resulting from dredge pond decant.</li>
<li>Said flow rate variations will also result in water level changes, impacting on other aspects such as suitable habitat availability;</li>
<li>Loss of stream connectivity;</li>
<li>Loss of ecological function due to the above hydrological impacts.</li>
</ul></li>
</ul>
Water quality
<ul>
<li>In dredge pond and upstream effects:
<ul><li>Due to active dredging, potential ongoing impact on water quality within the dredge ponds may occur with specific reference to changes in the pH regime of the system, as well as increased TDS concentrations resulting from mining operations, as well as sand and tailing being deposited. The altered water quality may affect the biological processes and human use value of the dredge pond.</li></ul></li>
<li>Downstream effects:
<ul>
<li>Variation in decant volumes may result in increases in turbidity in downstream areas, as well as the potential addition of pollutants to the receiving aquatic environment;</li>
<li>There is a small risk of hydrocarbon spills during this active dredging period;</li>
<li>Water quality impacts may occur which could affect the productivity and biodiversity of the system, as well as the human use value of the downgradient systems for domestic use and for food production.</li>
</ul></li>
</ul>
Geomorphological processes
<ul>
<li>In dredge pond and upstream effects:
<ul><li>Ongoing settlement of suspended solids in the dredge ponds due to disturbances during active dredging.</li></ul></li>
<li>Downstream effects:
<ul>
<li>The settlement of suspended solids in the dredge ponds will affect sediment balances downstream, which could in turn result in changes in topography and affect substrate conditions, and thus affect instream and riparian biota.;</li>
<li>Changes in topography may also lead to erosion and sedimentation;</li>
<li>Ultimately said changes will result in loss of ecological structure and support.</li>
</ul></li>
</ul>
Habitat
<ul>
<li>In dredge pond and upstream effects:
<ul>
<li>See geomorphological section above. The same risk with reference to sedimentation/siltation, as well as resulting changes in substrate condition applies, which in turn will lead to reduced suitable habitat availability.</li>
<li>See water quality section above. Potential ongoing impact on water quality within the dredge ponds may occur. This may affect the biological processes and human use value of the dredge ponds.</li>
<li>Anthropogenic activities associated with mining, such as vehicle use, may result in destruction of bank cover, and hence loss of suitable habitat.</li>
</ul></li>
<li>Downstream effects:
<ul>
<li>Sediment may smother benthic habitat, specifically with shallow riffle habitat in mind, resulting in loss of suitable habitat;</li>
<li>Inundation will result in variable flow rates, which will in turn affect both availability of and access to suitable habitat (such as shallow, fast flowing sections over rocky substrate);</li>
</ul></li>
</ul>
Biota
<ul>
<li>In dredge pond and upstream effects:
<ul>
<li>See geomorphological section above in terms of sedimentation/siltation risk;</li>
<li>Potential ongoing impact on water quality within the currently disused ponds may occur with specific mention to changes in the pH regime of the system as well as slightly increased TDS concentrations. In turn some increase in concentration of specific metals and metal salts may occur, which may affect the biological processes and human use value of the dredge ponds;</li>
</ul></li>
</ul>
</td></tr>
</table>

| Activity | Wet mining areas |
|---|---|
| | - Potential ongoing impact on water quality within the receiving aquatic environment may occur, relating to turbid conditions (sedimentation/siltation), and addition of hydrocarbons (spillages from vehicles and other mining equipment) and other potential pollutants such as manganese (Mn), nickel (Ni), and zinc (Zn) via run-off. Note that concentrations of Mn and Zn may be elevated from background levels. However, historical data shows heavy metal concentrations comply with South African National Standard (SANS) (Mn with the exception of one site), World Bank (WB) limits (Zn), or both WB and SANS (Ni). This may affect the biological processes and human use value of the aquatic resources<br>• Downstream effects:<br>- See habitat section above, impact on habitat availability and suitability will also affect biota, and may lead to loss of species diversity;<br>- Furthermore, alien vegetation invasion, as well as opportunistic and excessive aquatic growth (as evidenced at the assessment site SR4), may also result from habitat disturbances;<br>- Since the dredge ponds decant to the downstream systems and thus similar impacts on water quality are likely to affect the downstream community similarly;<br>- If in the low flow season decant decreases significantly or ceases, the lack of flow in the downstream systems is likely to significantly impact on the aquatic community of these systems which generally rely on moderate to fast flowing clear water. The overall ecological status of the downstream areas as well as their Ecological Importance and Sensitivity (EIS) may thus be reduced or impaired in perpetuity (see post-closure impact assessment for end final voids);<br>- The above will thus have an impact on instream and flow-sensitive biota and migratory taxa, and will thus have an impact on the overall Present Ecological State (PES) of the system. Also, changes in habitat may also contribute to changes in fish community composition.<br>**Goods and services to the local community**<br>• In dredge pond and upstream effects:<br>- Conflicts with local culture in terms of use of watercourses, traditions and lifestyles, interference with subsistence fisheries and domestic water supply, potential creation of favourable habitat for nuisance insects, risk of accidental drowning, loss of control/income of land inundated by water, reduced water availability downstream of pits, fishery development, recreational use.<br>• Downstream effects:<br>- Downstream effects will be largely linked to impacts on water quality affecting the human use value of the downstream watercourses, and in particular the impact on the ability to use water for domestic purposes, food production as well as the impacts in fish harvesting. |

| Potential impact rating: Impact AB2: Loss of habitat, biota and ecosystem services due to wet mining | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Status** | **Magnitude** | **Duration** | **Scale** | **Consequence** | **Probability** | **Significance** | **+/-** | **Confidence** |
| **Before management** | Major | Medium term | Regional | Medium | Definite | **Medium** | - | Medium |
| **Management measures** | • Active dredging areas must be cordoned off, with specific reference to containing the sand and tailings which are by-products of the active dredging process;<br>• Infrastructure should cross wetlands and rivers at right angles, with design of crossings allowing retention of wetland and riparian zone soil conditions;<br>• Active dredging areas must be cordoned off, with specific reference to containing the sand and tailings which are by-products of the active dredging process<br>• Engage the community and clearly communicate schedules for planned pit wall lowering and changes in decant rates that may occur, so they know when to expect elevated water levels. | | | | | | | |
| **Status** | **Magnitude** | **Duration** | **Scale** | **Consequence** | **Probability** | **Significance** | **+/-** | **Confidence** |
| **After management** | Moderate | Medium term | Site or local | Medium | Definite | **Medium** (No change in class however, magnitude is reduced from major to moderate and | - | Medium |

| Activity | Wet mining areas | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | the extent is reduced from regional to site/local which is significant) | | |

### 3.1.3 Impact AB3: Loss of habitat, biota and ecosystem services due to the processing plant

Table 7 provides a summary, description and assessment of aquatic impacts pertaining to processing plant activities during the operational phase. Impact is summarised in terms of drivers and receptors identified previously, followed by a more detailed description. Impacts pertain mainly to changes in water quality and flow rates, with associated loss of habitat, biota and ecosystem services. The significance of the impact with management measures is considered low (minor, short term impact on a local/site scale).

**Table 7: Impact AB3 – Loss of habitat, biota and ecoservices resulting from operational phase processing plant activities.**

| Activity | Processing plant operation |
|---|---|
| **Project phase** | Operational |
| **Impact descriptions** | **Hydrology**<br>• Hard surfaces associated with the plant and associated roads, will alter preferential run-off flow paths, decrease surface flow friction and hence increase run-off reporting to the receiving aquatic environment. Variability in flow rates may in turn affect habitat suitability and availability and have an impact on biota. However, any such effects are anticipated to be minor.<br>**Water quality**<br>• See hydrology section above considering increased run-off;<br>• Potential ongoing impact on water quality within the receiving aquatic environment may occur, relating to turbid conditions (sedimentation/siltation), as well as addition of hydrocarbons (spillages from vehicles and other mining equipment) and other potential pollutants via run-off;<br>• Other contaminants of concern not tested for during the aquatic assessment may be present and negatively impact aquatic community integrity. Currently unidentified potential impacts from mining and other anthropogenic activities (chemical in terms of metals or organic compounds, nutrient, electrolyte and organic material input) are thus also possible and may negatively affect biota.<br>**Geomorphological processes**<br>• Changes in topography may result in increased run-off and preferential flow paths (also see hydrology section above);<br>• Erosion and sedimentation/siltation resulting from increased run-off from hard surfaces, may result in settlement of suspended solids in the receiving aquatic environment. The settlement of suspended solids may affect sediment balances in these systems (aquatic and wetland), which could in turn affect substrate conditions (habitat availability and suitability), and thus affect instream and riparian biota. However, considering the relative small area involved, and such impacts from the processing plant operations is anticipated to be minor;<br>• Transport roads located near aquatic resources may also contribute to sediment load via settlement of dust particles, or vehicles and associated hydrocarbon spillages. Any such effects are anticipated to be minor.<br>**Habitat and Biota**<br>• See hydrology and geomorphology sections above with reference to increased run-off and impact on habitat availability through smothering of benthic habitats, and subsequent negatively effects on biota. Any such effects are anticipated to be minor, considering the nearby watercourses area is already significantly altered by the presence of old dredge ponds; |

| Activity | Processing plant operation |
|---|---|
| | • See water quality section above for discussion of potential water quality impact on biota;<br>• There is a small risk of slight loss of aquatic species diversity and abundance, an impact on riparian vegetation, and associated risk of alien vegetation invasion.<br>**Goods and services to the local community**<br>• See sections above. Some impact on the nearby watercourse is possible yet unlikely. Specific mention is made of potential impacts on water quality. The significance and risk are, however, considered low. |

| Potential impact rating: Impact AB3: Loss of habitat, biota and ecosystem services due to the processing plant | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Status** | **Magnitude** | **Duration** | **Scale** | **Consequence** | **Probability** | **Significance** | **+/-** | **Confidence** |
| **Before management** | Moderate | Short term | Site or local | Low | Possible | **Low** | - | Medium |
| **Management measures** | • Operational footprints must be minimised, and strict controls of edge effects implemented;<br>• For the duration of the operational phase of the MSP, the controlled release of the water from the MSP ponds into the Mogbwemo Dredge Pond and into the natural water system is to occur;<br>• Erosion management and sediment controls such as the use of rock packing, revegetation of profiled slopes, erosion berms, drift fences with hessian and silt traps must be implemented where relevant. This is particularly relevant to areas where topography has changed, resulting in preferential flow paths prone to erosion, with associated sedimentation/siltation risks;<br>• Support structures for infrastructure such as road crossings, must where possible, be placed outside of watercourses and wetlands;<br>• Infrastructure should cross wetlands and rivers at right angles, with design of crossings allowing retention of wetland and riparian zone soil conditions. | | | | | | | |
| **Status** | **Magnitude** | **Duration** | **Scale** | **Consequence** | **Probability** | **Significance** | **+/-** | **Confidence** |
| **After management** | Minor | Short term | Site or local | Low | Possible | **Low** | - | Medium |

### 3.1.4 Impact AB4: Loss of habitat, biota and ecosystem services due to handling and shipping at Nitti Port

Table 8 provides a summary, description and assessment of aquatic impacts pertaining to handling and shipping at Nitti Port during the operational phase. Impact is summarised in terms of drivers and receptors identified previously, followed by a more detailed description. Impacts pertain mainly to changes in water quality (resulting from spillages) and flow rates (due to run-off from hard surfaces), with associated loss of habitat, biota and ecosystem services. The significance of the impact with management measures is considered low (minor, short term impact on a local/site scale).

**Table 8: Impact AB4 – Loss of habitat, biota and ecoservices resulting from operational phase handling and shipping activities at Nitti Port.**

| Activity | Handling and shipping at Nitti Port | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Project phase | Operational phase | | | | | | | |
| Impact descriptions | • Hard surfaces (transport roads and port infrastructure) resulting in increased run-off, with increased risk of sedimentation, erosion and addition of pollutants to the receiving aquatic environment;<br>• Spilling of product during loading, transport and/or offloading at Nitti Port;<br>• Spilling of hydrocarbons (diesel or fuel oil) from vehicles during loading, transport and/or loading and offloading. | | | | | | | |
| Potential impact rating: Impact AB4: Loss of habitat, biota and ecosystem services due to handling and shipping at Nitti Port | | | | | | | | |
| Status | Magnitude | Duration | Scale | Consequence | Probability | Significance | +/- | Confidence |
| Before management | Moderate | Medium term | Site or local | Medium | Possible | **Medium** | - | Medium |
| Management measures | • Operational footprints must be minimised, and strict controls of edge effects implemented;<br>• Dedicated fuel storage and facilities used to refuel vehicles must be secured, with procedures in place to clean up any fuel spillages;<br>• Storm water and erosion management structures will be upgraded and maintained as per the Stormwater Management Plan, Section 7 of the specialist Surface Water study (SRK 2018 (4))<br>• Procedures must be in place for cleaning up any spillages of product. | | | | | | | |
| Status | Magnitude | Duration | Scale | Consequence | Probability | Significance | +/- | Confidence |
| After management | Minor | Short term | Site or local | Low | Possible | **Low** | - | Medium |

## *3.2 Decommissioning/closure and rehabilitation Phase and Post-Closure Impacts*

The decommissioning/closure and rehabilitation phase of the proposed development is anticipated to have impacts on the drivers and receptors/responses identified previously. The significance of these impacts on the aquatic ecology of the receiving environment is summarised in the tables below.

### 3.2.1 Impact AB5: Loss of habitat, biota and ecosystem services due to lowering of dredge ponds during decommissioning/closure and rehabilitation

Table 9 provides a summary, description and assessment of aquatic impacts pertaining to lowering of dredge ponds during the decommissioning/closure and rehabilitation phase. Impact is summarised in terms of drivers and receptors identified previously, followed by a more detailed description. Impacts pertain mainly to changes in water quality and flow rates (the latter resulting in sedimentation, siltation, erosion and turbidity, with associated loss of habitat, biota and ecosystem services). The significance of the impact with management measures is considered low (minor, short term impact on a local/site scale).

**Table 9: Impact AB5 – Loss of habitat, biota and ecoservices resulting from lowering of dredge ponds during the decommissioning / closure and rehabilitation phase.**

| Activity | Lowering of dredge ponds |
|---|---|
| Project phase | Decommissioning/closure and rehabilitation |
| Impact descriptions | **Hydrology**<br>• In dredge pond and upstream effects:<br>- Water levels will be lowered increasing the euphotic zone of final voids left by the dredge ponds which will potentially increase nutrient levels and biological productivity. In the short term this will be positive as it will increase the potential for supporting sustainable subsistence and potentially small scale commercial fishing practices;<br>• Downstream effects:<br>- Lowering of dredge pond will temporarily result in increased flow rate and increased downstream water levels unless the levels are reduced in a controlled fashion as planned.<br>- Potential resulting impacts include inundation, flow rate and water level changes, loss of connectivity and loss of ecological functions. However, given the gradual release of water, the risk of inundation is considered unlikely.<br>**Water quality**<br>• In dredge pond and upstream effects:<br>- See hydrology section above considering the trophic status of the dredge ponds;<br>• Potential ongoing impact on water quality within the dredge ponds may occur with specific mention to changes in the pH regime of the system as well as slightly increased TDS concentrations. In turn some increase in concentration of specific metals and metal salts, such as Mn, Ni, Se and Zn may occur which may affect the biological processes and human use value of the dredge ponds.<br>- . Refer to the post-closure/latent phase section for additional discussions with reference to water quality impacts post-closure in the end final voids.<br>• Downstream effects:<br>- See hydrology section above considering temporary increase in flow rate;<br>- During the lowering of the final void there may be some short term low magnitude increases in turbidity in downstream areas;<br>- There is a small risk of hydrocarbon spills during this construction period;<br>- Similar impact on water quality as those occurring in the end final voids may occur (see post-closure/latent section discussion) which could affect the productivity and biodiversity of the system as well as the human use value of the downgradient systems for domestic use and for food production.<br>**Geomorphological processes**<br>• In dredge pond and upstream effects:<br>- Release of suspended solids during and immediately after lowering of dredge pond decant.<br>• Downstream effects:<br>- See hydrology section above considering temporary increase in flow rate;<br>- See water quality sections for description turbidity impact;<br>- The settlement of suspended solids released during decant may affect sediment balances downstream which could in turn affect substrate conditions and thus affect instream and riparian biota;<br>- Related potential impacts include changes in topography, sedimentation, erosion and resulting loss of ecological structure and support.<br>**Habitat**<br>• In dredge pond and upstream effects:<br>- See hydrology section above considering the trophic status of the end final voids;<br>- See water quality section for potential impacts similar to that in end final voids (see post-closure section), which may affect the biological processes and human use value of the dredge pond.<br>• Downstream effects:<br>- See geomorphological processes for a description of downstream sediment balance risk. This may affect suitability and availability of habitats (specifically shallow riffle areas due to alteration of the substrate condition);<br>- Other potential impacts include vehicle impacts with associated destruction of bank cover, risk of alien vegetation encroachment and loss of habitat;<br>- Inundation with resulting flow variability will affect availability of suitable habitat.<br>**Biota**<br>• In dredge pond and upstream effects: |

| Activity | Lowering of dredge ponds |
|---|---|
| | - See hydrology section above considering the trophic status of the end final voids;<br>• Downstream effects:<br>- Since the dredge ponds decant to the downstream systems, similar impacts on water quality are likely to affect the downstream community similarly;<br>- If in the low flow season decant decreases significantly or ceases, the lack of flow in the downstream systems is likely to significantly impact on the aquatic community of these systems which generally rely on moderate to fast flowing clear water. The overall ecological status of the downstream areas as well as their Ecological Importance and Sensitivity (EIS) may thus be reduced or impaired in perpetuity;<br>- The impacts above will result in impact on instream and flow-sensitive taxa, impacts on migratory taxa, loss of species diversity, change in fish fauna species composition, and overall impact on the Present Ecological State (PES) of the system;<br>- Alien vegetation encroachment and opportunistic or excessive aquatic growth also present a risk.<br>**Goods and services to the local community**<br>• In dredge pond and upstream effects:<br>- See hydrology section above considering the trophic status of the end final voids;<br>- Conflicts with local culture in terms of use of watercourses, traditions and lifestyles, interference with subsistence fisheries and domestic pit use, creation of favourable habitat for nuisance insects (see post-closure section for a more detailed discussion), risk of accidental drowning, loss of control/income of land inundated by water, reduced water availability downstream of pits, fishery development, recreational use;<br>- During rehabilitation and directly thereafter (with reference to lowering of dredge pond decant and associated temporarily increased flow), there will be temporary interference with subsistence fishery practices. This will include interference with access to suitable fishing areas, as well as physical damage to fish spawning areas which may potentially reduce the productivity of the systems for a period of time;<br>- For the same reason (lowering of dredge pond decant), there will be temporary interference with domestic uses (e.g. bathing and washing clothes).<br>• Downstream effects:<br>- Downstream effects will be largely linked to impacts on water quality and flow rate affecting the human use value of the downstream watercourses, and in particular the impact on the ability to use water for domestic purposes and for food production, as well as the impacts in fish harvesting.<br>- During the rehabilitation phase, conflicts may result from insensitivities of rehabilitation personnel to local culture, traditions and lifestyles. However, as rehabilitation will be performed by local personnel in collaboration with the surrounding communities, said impacts is considered unlikely. |

**Potential impact rating: Impact AB5: Loss of habitat, biota and ecosystem services due to lowering of dredge pond decant during decommissioning/closure and rehabilitation**

| Status | Magnitude | Duration | Scale | Consequence | Probability | Significance | +/- | Confidence |
|---|---|---|---|---|---|---|---|---|
| **Before management** | Moderate | Short term | Regional | Medium | Definite | **Medium** | - | Medium |

| | |
|---|---|
| **Management measures** | • Dredge pond walls must be systematically lowered to allow regulated decant (downstream flow) and reduction of water levels in the dredge pond. Sloping and rehabilitation of dredge pond walls must be performed in such a manner so as not to compromise wall stability;<br>• Rehabilitation footprints must be minimised, and strict controls of edge effects implemented;<br>• Areas where the resource is located near the land surface, allow for shallow strip-mining excavations wide enough to extract most of the mined resource. As a result, such pits tend to be shallower compared to hard rock final voids, with generally large surface areas. Sand pit banks are thus generally also less steep. However, with lowering of dredge pond decants and hence water levels, exposed dredge pond banks may need to be reshaped to avoid slumping. Gradient of exposed dredge pond wall slopes must also be adjusted to ensure safety for recreational use, and sustained wall and bank stability must be ensured with the goal of long term, safe recreational use of the end final void resources. A viable option is using sand removed during previous mining activities for this purpose. Sand should be mixed with tailings material of increased fertility, which will assist with other functions such as revegetation rehabilitation efforts;<br>• An alien vegetation control programme must be implemented, as encroachment of alien vegetation is expected to increase as a result of the disturbances resulting during the decommissioning process (particularly on barren dredge pond sediment/wall areas after lowering of dredge pond decant). Rehabilitation of disturbed areas after lowering dredge pond water levels, utilising indigenous wetland and suitable riparian vegetation species, will assist in retaining essential wetland ecological services, particularly flood attenuation, sediment trapping and erosion control, and assimilation of nutrients and toxicants. |

| Activity | Lowering of dredge ponds | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Fines will be mixed into the sand tails to improve the water holding potential so that the altered substrate has the capacity to provide vegetation with sufficient water in the dry season;<br>• Erosion management and sediment controls such as the use of rock packing, revegetation of profiled slopes, erosion berms, drift fences with hessian and silt traps must be implemented as applicable from the outset of rehabilitation activities. This is particularly relevant to areas below dredge pond decant, where initial increased decant volumes after dredge pond decant lowering poses a significant erosion risk;<br>• Support structures for infrastructure such as road crossings, must where possible, be placed outside of watercourses and wetlands;<br>• Infrastructure should cross wetlands and rivers at right angles, with design of crossings allowing retention of wetland and riparian zone soil conditions;<br>• Engage the community and clearly communicate schedules for planned pit wall lowering and increased decant volume, so they know when to expect elevated water levels. | | | | | | | |
| **Status** | **Magnitude** | **Duration** | **Scale** | **Consequence** | **Probability** | **Significance** | **+/-** | **Confidence** |
| **After management** | Minor | Short term | Site or local | Low | Possible | **Low** | - | Medium |

### 3.2.2 Impact AB6: Loss of habitat, biota and ecosystem services due to decommissioning of plant and unneeded haul roads

Table 10 provides a summary, description and assessment of aquatic impacts pertaining to decommissioning of the plant and unneeded haul roads. Impact is summarised in terms of drivers and receptors identified previously, followed by a more detailed description. Impacts pertain mainly to changes in water quality and flow rates, with associated loss of habitat, biota and ecosystem services. The significance of the impact with management measures is considered low (minor, short term impact on a local/site scale).

**Table 10: Impact AB6 – Loss of habitat, biota and ecoservices resulting from decommissioning of plant and unneeded haul roads**

| Activity | Demolition of surface infrastructure |
|---|---|
| **Project phase** | Decommissioning/closure and rehabilitation |
| **Impact descriptions** | **Hydrology**<br>• Changes in flow rate due to changes in run-off and preferential flow paths.<br>**Water quality**<br>• Turbidity;<br>• Spillages (including hydrocarbons);<br>• Potential for increased contaminated runoff to surrounding watercourses (possibly organic and/or trace metals).<br><br>**Geomorphological processes**<br>• Ineffective removal of waste and demolished construction materials will hamper rehabilitation;<br>• During rehabilitation, there may also be direct vehicle impacts and impacts from supportive structures (such as personnel accommodation, stockpiles and waste areas) on riparian zone and wetland vegetation that may affect aspects such as bankside stability and hardening of surfaces.<br>• Changes in topography and flow paths due to demolition of plant infrastructure, and subsequent sloping and rehabilitation activities.<br>• This may result in changes in topography, increase in hard surface areas, run-off, changes in preferential flow paths and erosion and sedimentation.<br>• Vehicles and related activities will result in increased hard surfaces due to compacting of soils. This will potentially result in increased run-off and creation of preferential flow paths, with potential impact on the hydrology (variability in flow rate and water levels) and sediment balance (erosion and sedimentation) of the nearby watercourses. Vehicles could potentially also contribute to |

<table>
<tr><th>Activity</th><th colspan="8">Demolition of surface infrastructure</th></tr>
<tr><td></td><td colspan="8">spillages of hydrocarbons during rehabilitation. Over the short term this could affect surface water quality;<br>Habitat<br>• Sedimentation/siltation and erosion, leading to slight risk to nearby watercourses. The nearby watercourses area, however, is significantly altered by the presence of old dredge ponds.<br>• Encroachment of alien vegetation is expected to increase as a result of the surface infrastructure demolition disturbances.<br>Biota<br>• Small risk of slight loss of aquatic species diversity and abundance;<br>• Impact on riparian vegetation;<br>• Alien vegetation invasion.<br>Goods and services to the local community<br>• Small risk of impact to the dredge ponds as small areas of surface water accumulation.</td></tr>
<tr><td colspan="9">Potential impact rating: Impact AB6: Loss of habitat, biota and ecosystem services due to decommissioning of plant and unneeded haul roads</td></tr>
<tr><td>Status</td><td>Magnitude</td><td>Duration</td><td>Scale</td><td>Consequence</td><td>Probability</td><td>Significance</td><td>+/-</td><td>Confidence</td></tr>
<tr><td>Before management</td><td>Moderate</td><td>Short term</td><td>Site or local</td><td>Low</td><td>Definite</td><td>Medium</td><td>-</td><td>Medium</td></tr>
<tr><td>Management measures</td><td colspan="8">• Rehabilitation footprints must be minimised, and strict controls of edge effects implemented;<br>• During rehabilitation, there may also be direct vehicle impacts and impacts from supportive structures (such as personnel accommodation, stockpiles and waste areas) on riparian zone and wetland vegetation, that may affect aspects such as bankside stability, and hardening of surfaces;<br>• Demolition of the plant should be performed in a manner to salvage building materials that can be used by the local community;<br>• All waste materials that cannot be recycled must be effectively removed and discarded in a safe and legal manner;<br>• Compacted haul roads must be ripped, treated with available topsoil to allow establishment of natural vegetation and if necessary additional revegetation may need to take place;<br>• An alien vegetation control programme must be implemented, as encroachment of alien vegetation is expected to increase as a result of the disturbances resulting during the decommissioning process;<br>• Erosion management and sediment controls such as rock packing, revegetation of profiled slopes, erosion berms, drift fences with hessian and silt traps must be implemented as applicable from the outset of rehabilitation activities. This is particularly relevant to areas where altered flow paths and increased run-off may pose an erosion risk.</td></tr>
<tr><td>Status</td><td>Magnitude</td><td>Duration</td><td>Scale</td><td>Consequence</td><td>Probability</td><td>Significance</td><td>+/-</td><td>Confidence</td></tr>
<tr><td>After management</td><td>Minor</td><td>Short term</td><td>Site or local</td><td>Low</td><td>Possible</td><td>Low</td><td>-</td><td>Medium</td></tr>
</table>

### 3.2.3 Impact AB7: Loss of habitat, biota and ecosystem services due to earthworks associated with rehabilitation efforts

Table 11 provides a summary, description and assessment of aquatic impacts pertaining to earthworks associated with the rehabilitation efforts. Impact is summarised in terms of drivers and receptors identified previously, followed by a more detailed description. Impacts pertain mainly to changes in water quality and flow rates, with associated loss of habitat, biota and ecosystem services. The significance of the impact with management measures is considered low (minor, short term impact on a local/site scale).

**Table 11: Impact AB7 – Loss of habitat, biota and ecoservices resulting from earthworks associated with rehabilitation during the decommissioning/closure and rehabilitation phase**

| Activity | Rehabilitation efforts |
|---|---|
| **Project phase** | Decommissioning/closure and rehabilitation |
| **Impact descriptions** | **Hydrology**<br>• Changes in flow rate due to changes in run-off and preferential flow paths.<br>**Water quality**<br>• Turbidity;<br>• Spillages (including hydrocarbons), currently unidentified impact affecting aquatic community integrity (possibly organic and/or trace metals).<br>**Geomorphological processes**<br>• Changes in topography and flow paths resulting from sloping and rehabilitation activities in progress, as well as long term run-off related impacts due to ineffective rehabilitation and sloping. This will apply to all rehabilitation efforts, including lowering of dredge pond decants, sloping of dredge pond walls, preparation of exposed dredge pond walls and sediment for rehabilitation (spreading of previously removed sludge and soil material), demolition of surface infrastructure (plant and haul roads), removal of demolished building material, ripping of compacted haul roads, and sloping of demolished and ripped surface areas;<br>• Disturbed loose soils will translate into increased risk for sedimentation/siltation and erosion with reference to altered topography and run-off;<br>• Vehicles and related activities will result in increased hard surfaces due to compacting of soils. This will result in increased run-off and creation of preferential flow paths, with potential impact on both riverine and wetland hydrology (variability in flow rate and water levels) and sediment balance (erosion and sedimentation). Vehicles could potentially also contribute to spillages of hydrocarbons during rehabilitation. Over the short term this could affect surface water quality;<br>**Habitat**<br>• Sedimentation/siltation and erosion;<br>• During rehabilitation, there may also be direct vehicle impacts and impacts from supportive structures (such as personnel accommodation, stockpiles and waste areas) on riparian zone and wetland vegetation;<br>• Destruction of bank cover;<br>• Loss of habitat;<br>• Encroachment of alien vegetation is expected to increase as a result of the earth moving and ground disturbances;<br>**Biota**<br>• Small risk of loss of species diversity;<br>• Impact on riparian vegetation;<br>• Alien vegetation invasion.<br>**Goods and services to the local community**<br>• During the rehabilitation phase, conflicts may result from insensitivities of rehabilitation personnel to local culture, traditions and lifestyles. However, as rehabilitation will be performed by local personnel in collaboration with the surrounding communities, said impacts is considered unlikely. |

| **Potential impact rating: Impact AB7: Loss of habitat, biota and ecosystem services due to earthworks associated with rehabilitation efforts** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Status** | **Magnitude** | **Duration** | **Scale** | **Consequence** | **Probability** | **Significance** | **+/-** | **Confidence** |
| **Before management** | Moderate | Short term | Site or local | Low | Definite | **Medium** | - | Medium |
| **Management measures** | • Rehabilitation footprints must be minimised, and strict controls of edge effects implemented;<br>• Replacement of topsoil and revegetation must be undertaken as guided by the Mine Closure Plan;<br>• An alien vegetation control programme must be implemented, as encroachment of alien vegetation is expected to increase as a result of the disturbances resulting during the decommissioning process;<br>• Erosion management and sediment controls such as the use of gabions or reno mattresses, revegetation of profiled slopes, erosion berms, drift fences with hessian and silt traps must be | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | implemented as applicable from the outset of rehabilitation activities. This is particularly relevant to areas where altered flow paths and increased run-off may pose an erosion risk. | | | | | | | |
| **Status** | **Magnitude** | **Duration** | **Scale** | **Consequence** | **Probability** | **Significance** | **+/-** | **Confidence** |
| **After management** | Minor | Short term | Site or local | Low | Possible | **Low** | - | Medium |

## *3.3 Post-closure/latent Phase Impacts*

The post closure/latent phase of the proposed development is anticipated to have impacts on the same drivers and receptors identified previously.

The significance of these impacts on the aquatic ecology of the receiving environment is summarised in the tables below.

### 3.3.1 Impact AB8: Loss of habitat, biota and ecosystem services due to lowering of dredge pond decant post closure

Table 12 provides a summary, description and assessment of aquatic impacts pertaining to lowering of dredge pond decant during the post-closure/latent phase. Impact is summarised in terms of drivers and receptors identified previously, followed by a more detailed description. Impacts pertain mainly to changes in water quality and flow rates (the latter resulting in sedimentation, siltation, erosion and turbidity, with associated loss of habitat, biota and ecosystem services). The significance of the impact with management measures is considered medium (minor, long term impact on a local/site scale).

**Table 12: Impact AB8 – Loss of habitat, biota and ecoservices resulting from lowering of dredge pond decant during the post-closure/latent phase.**

| Activity | Lowering of dredge pond decant |
|---|---|
| **Project phase** | Post-closure/latent |
| **Impact descriptions** | **Hydrology**<br>• In end final void and upstream effects:<br>- Water levels will be lowered increasing the euphotic zone of the end final void which will potentially increase nutrient levels and biological productivity. In the longer term there is the potential for eutrophication of the system, as well as opportunistic and excessive growth of aquatic macrophytes in the littoral and sub-littoral zone of the dredge ponds. The rate at which this occurs will be driven by adjacent practices such as washing of clothes, and potential sewage ingress into the systems;<br>- After rehabilitation, shallower pits (lower water levels) may have a changed thermodynamic state;<br>- Whilst any management to groundwater flow will most likely not be applicable, said flow compounded by other water inflow such as run-off, will result in decant volume variability;<br>- In-stream end final voids will potentially have an impact on river system connectivity due to inundation, especially during periods of no flow where there is no decant from the pits;<br>- All of the above may result in loss of ecological function.<br>• Downstream effects:<br>- Hydrological connectivity may be improved to some degree by the lowered end final void bank full level. However, during periods where loss of connectivity does occur, this will affect migration, habitat availability and hence also biota;<br>- Warmer water being decanted into the river system. However, given the tropical climate and shallow conditions (stratification unlikely), any such impact is expected to be negligible;<br>- End final void decant volume variability may potentially result in flow variability within the aquatic systems in which the pits decant.<br>**Water quality**<br>• In end final void and upstream effects:<br>- See hydrology section above considering the trophic status of the end final voids;<br>- Water quality in end final voids are strongly influenced by geology and resultant chemistry found within the surface- and groundwater catchments of the lake. Additionally, other contaminants of concern are nutrients (e.g. nitrogen and phosphorous compounds) and road salts resulting from land use practises within the watershed. Contaminant sources generally also include agricultural activities and waste water treatment plants (or sewage ingress). The current end final voids exhibit low pH conditions, and impact on pH is considered a latent impact that will likely continue post-closure;<br>- “Terminal end final voids” (i.e. terminal in that there are no flow-through) can become increasingly saline due to evapo-concentration. However, the pits in question will function as “flow-through end final voids” during the post-closure/latent phase. The end final voids in the current assessment already presented with low EC, and combined with the “flow-through” design any long term negative impact on EC is deemed unlikely. However, “flow-through” pits can in turn discharge other potential contaminants of concern to groundwater and/or surface water which can affect present and future human populations and ecosystems. As mentioned above this potentially includes organic compounds and trace metals (which were not specifically assessed in the aquatic assessment). Concentration of specific metals and metal salts may thus occur and affect the biological processes and human use value of the end final void.<br>• Downstream effects:<br>- Similar impact on water quality as those occurring in the end final voids may occur (including turbidity potential impact on pH), which could affect the productivity and biodiversity of the system as well as the human use value of the downgradient systems for domestic use and for food production.<br>**Geomorphological processes**<br>• In end final void and upstream effects:<br>- Ongoing settlement of suspended solids in the end final void over time will take place, however, this is expected to occur at a slow rate.<br>• Downstream effects: |

| Activity | Lowering of dredge pond decant |
|---|---|
| | - The settlement of suspended solids in the end final void will affect sediment balances downstream which could in turn affect substrate conditions and thus affect instream and riparian biota.<br>  - Other potential impacts include permanent changes in topography, preferential flow paths, erosion and sedimentation, and resulting loss of ecological structure and support.<br>**Habitat**<br>• In end final void and upstream effects:<br>  - See hydrology section above considering the trophic status of the end final voids;<br>  - See water quality above. Potential ongoing impact on water quality within the end final voids may occur. This may affect the biological processes and human use value of the end final void.<br>• Downstream effects:<br>  - The settlement of suspended solids in the end final void will affect sediment balances downstream which could, in turn affect substrate conditions, and hence also habitat suitability and availability (see geomorphological processes);<br>  - Variability in flow rate may also affect habitat availability (see hydrology), and thus also affect habitat availability and suitability, and hence also impact on instream and riparian biota.<br>  - Alien vegetation invasion.<br>**Biota**<br>• In end final void and upstream effects:<br>  - See hydrology section above considering the trophic status of the end final voids;<br>  - Increase of alien invader ichthyofauna (used in the final voids as an aquaculture species) taking over and interbreeding with the indigenous species (also with reference to the receiving riverine environment), is one of the risks of end final void rehabilitation;<br>  - See water quality section above. Potential ongoing impact on water quality within the end final voids may occur with specific mention to changes in the pH regime of the system as well as slightly increased total dissolved solid concentrations. In turn some increase in concentration of specific metals and metal salts may occur which may affect the biological processes and human use value of the end final void. Although water quality parameters indicated favourable conditions (e.g. very low EC) during aquatic assessments, impact on macro-invertebrate communities was evident in river systems affected by dredge pond decant. Similar impact is anticipated in systems subject to end final void decant. This could potentially partially be attributed to low pH, but other contaminants of concern not tested for during the aquatic assessment may be present and negatively impact aquatic community integrity. Currently unidentified potential impacts from mining and other anthropogenic activities (chemical in terms of metals or organic compounds, nutrient, electrolyte and organic material input) are thus also possible.<br>• Downstream effects:<br>  - Shift in fish fauna community composition in the receiving riverine environment (i.e. a shift from typical river species to typical lake species). However, given that aquaculture practises have already been established in the lakes (with species already colonising the receiving riverine environment), and a self-sustainable long-term fishery is one of the desired end points, increase of already established ichthyofauna is considered a positive and desired impact;<br>  - Since the end final voids will continue to decant to the downstream systems and thus similar impacts on water quality are likely to affect the downstream community similarly;<br>  - If in the low flow season decant decreases significantly or ceases, the lack of flow in the downstream systems is likely to significantly impact on the aquatic community of these systems which generally rely on moderate to fast flowing clear water. The overall ecological status (Present Ecological Status) of the downstream areas as well as their Ecological Importance and Sensitivity may thus be reduced or impaired in perpetuity;<br>  - Other potential effects include impact on instream and flow-sensitive and migratory biota and subsequent loss of species diversity, as well as alien vegetation invasion and opportunistic and excessive aquatic growth.<br>**Goods and services to the local community**<br>• In end final void and upstream effects:<br>  - See hydrology section above considering the trophic status of the end final voids;<br>  - Creation of dredge ponds (and subsequently end final voids) generally also create favourable habitats for the growth and proliferation of nuisance insects (some with zoonotic importance e.g. |

<table>
<tr><th>Activity</th><th colspan="8">Lowering of dredge pond decant</th></tr>
<tr><td></td><td colspan="8">mosquitoes posing malaria risk) and disease vectors (such as Bulinus globosus and Biomphalaria pfeifferi snails posing schistosomiasis risk);<br>- Risk of accidental drowning if used for recreational purposes. However, sand final voids normally do not have steep slopes, and the gradient of slopes can be adjusted during rehabilitation efforts for increased safety in areas intended for recreational use; and<br>- Risk of wall slumping failure that can result in flash-flood events or physical harm (pit wall stability also to be addressed during rehabilitation phase).<br>• Downstream effects:<br>- Risk to communities downstream and surrounding the decant pits to contract zoonotic diseases. However, malaria is already a significant risk in Sierra Leone. In 2013 there were more than 1.7 million cases of malaria in Sierra Leone, which indicate a high prevalence of infection, considering a total estimated population size of six million people at the time [http://www.msf.org/en/article/sierra-leone-malaria-other-epidemic]. Furthermore, Schistosoma spp. are already present in the country, and already poses a zoonotic risk. Schistosoma mansoni is endemic throughout the country.<br>- Considering the existing risk in the country, the additional risk posed by the ongoing presence of the end final voids in the region is not considered to be significant;<br>- Downstream effects will be largely linked to impacts on water quality and flow rate affecting the human use value of the downstream watercourses, and in particular the impact on the ability to use water for domestic purposes and for food production as well as the impacts in fish harvesting. This may include reduced availability of river water downstream of pits (especially during the dry season). Flow variability and loss of connectivity has been discussed previously. During the dry season little or no decant from pits can thus affect water availability downstream, both in terms of fisheries activity and recreational and domestic use.<br>• Positive impacts:<br>- One of the desired positive impacts will be establishment of a self-sufficient and productive fishery;<br>- One of the desired positive impacts will be increased opportunity for safe recreational use of pit areas.</td></tr>
<tr><th colspan="9">Potential impact rating: Impact AB8: Loss of habitat, biota and ecosystem services due to lowering of dredge pond decant post closure</th></tr>
<tr><th>Status</th><th>Magnitude</th><th>Duration</th><th>Scale</th><th>Consequence</th><th>Probability</th><th>Significance</th><th>+/-</th><th>Confidence</th></tr>
<tr><td>Before management</td><td>Minor</td><td>Long term</td><td>Site or local</td><td>Medium</td><td>Definite</td><td>Medium</td><td>-</td><td>Medium</td></tr>
<tr><td>Management measures</td><td colspan="8">• Continued rehabilitation of disturbed areas post-closure, clearing alien vegetation and utilising indigenous wetland vegetation species, will assist in retaining essential wetland ecological services, particularly flood attenuation, sediment trapping and erosion control, and assimilation of nutrients and toxicants;<br>• Water resources need to be monitored for potential contaminants of concern as well as Diatom community monitoring during the post-closure/latent phase (see monitoring recommendations to follow in separate section).</td></tr>
<tr><td>After management</td><td>Minor</td><td>Long term</td><td>Site or local</td><td>Medium</td><td>Definite</td><td>Medium</td><td>-</td><td>Medium</td></tr>
</table>

### 3.3.2 Impact AB9: Loss of habitat, biota and ecosystem services due to dry latent impacts of decommissioned plant and haul road

Provided that the plant and haul roads which have no further use are appropriately rehabilitated, with specific mention of ensuring that they are geomorphologically stable and that the vegetation structure is not dominated by undesirable vegetation, no latent impacts from these areas are deemed likely. As such, no assessment table has been presented for this impact.

# 4. AQUATIC MONITORING REQUIREMENTS

## *4.1 Essential Requirements*

### 4.1.1 Water quality

Monitoring of biota specific water quality variables (Electrical Conductivity, Dissolved Oxygen, pH and temperature parameters) is to be performed monthly during the operational and decommissioning/closure and rehabilitation phases, and quarterly during the post-closure phase.

### 4.1.2 Diatom community integrity

Assessment of diatom community integrity in the aquatic systems receiving dredge pond decant, as well as appropriate reference sites, is to be performed on a six-monthly basis to monitor the integrity of the instream community.

## *4.2 Recommended requirements:*

### 4.2.1 Macro-invertebrate community integrity

Assessment of macro-invertebrate community integrity in the aquatic systems receiving dredge pond decant, as well as at least one appropriate reference site, on a six-monthly basis, is strongly recommended.

# 5. AQUATIC IMPACT ASSESSMENT SUMMARY AND CONCLUSION

Impacts on drivers and receptors were evaluated for each life cycle phase, a summary of results are presented below in Table 13.

**Table 13: Summary of impact significance ratings**

<table>
<tr><th rowspan="2">Aspect</th><th colspan="2">Operational phase</th><th colspan="2">Decommissioning/ closure and rehabilitation phase</th><th colspan="2">Post-closure/latent phase</th></tr>
<tr><th>Before management</th><th>After management</th><th>Before management</th><th>After management</th><th>Before management</th><th>After management</th></tr>
<tr><td>Dry mining and haul road development [Impact AB1]</td><td>Medium</td><td>Medium</td><td colspan="4" rowspan="3">Not applicable</td></tr>
<tr><td>Wet mining [Impact AB2]</td><td>Medium</td><td>Medium</td></tr>
<tr><td>Handling and shipping at Nitti Port [Impact AB4]</td><td>Medium</td><td>Low</td></tr>
<tr><td>Processing plant and haul roads [Impact AB3 (operational); Impact AB6 (decommissioning/ closure and rehabilitation)]</td><td>Low</td><td>Low</td><td>Medium</td><td>Low</td><td colspan="2">None</td></tr>
<tr><td>Lowering of dredge pond decant [Impact AB5 (decommissioning/ closure and rehabilitation); Impact AB8 (post-closure)]</td><td colspan="2" rowspan="2">Not applicable</td><td>Medium</td><td>Low</td><td>Medium</td><td>Medium</td></tr>
<tr><td>Earthworks associated with rehabilitation efforts [Impact AB7]</td><td>Medium</td><td>Low</td><td colspan="2">None</td></tr>
<tr><td>Latent impacts of decommissioned plant and haul road [Impact AB9]</td><td colspan="6">Not applicable</td></tr>
</table>

With reference to the operational phase, both dry and wet mining have a medium impact prior to management measures being implemented. For dry mining, management measures are expected to reduce probability of impact from definite to possible, but significance of impact remains as medium. For wet mining, management measures are expected to reduce the magnitude from major to moderate, as well as the scale from regional to local, but significance of impact remains as medium. Impact of handling and shipping of product at the Nitti Port can be reduced from a medium to low significance through management measures, whilst impact from the processing plant is considered low.

With reference to the decommissioning/closure and rehabilitation phase (lowering of dredge pond decants, demolition of processing plant and haul road surface infrastructure, and earthworks associated with demolition and rehabilitation activities), all impact significant ratings during this phase can be reduced from medium to low levels when management measures are implemented.

With reference to the post-closure phase, lowering of dredge pond decants will continue to have a medium impact significance rating, given the long-term duration and definite probability of associated impacts of minor magnitude.

It can be concluded, based on the high flow assessment data, that impacts are moderate to low. However, with mitigation and suitable management measures, impacts can generally be reduced to low significance post-closure, except for end-final void impact significance that will remain as medium.

# 6. IMPACT ASSESSMENT AND MITIGATION MEASURES: TERRESTRIAL RESOURCES

Following the assessment of the terrestrial resources associated with the SRL, the SRK Impact Assessment Methodology was applied to ascertain the significance of perceived impacts on the faunal and floral components associated with SR Area 1.

Three aspects need to be considered:

- Faunal and floral habitat and ecological structure;
- Faunal and floral species diversity; and
- Floral and faunal SCC and habitat.

Impacts on the terrestrial ecological resources within the SRL that are anticipated to occur, pertain to loss of the aspects mentioned above.

Current impacts of the operational phase (dry mining and wet mining) were assessed, including process plant operation, haul road use and construction, current rehabilitation efforts and hunting by the local community and the impact thereof on the faunal component.

With regard to the decommissioning/closure and rehabilitation, as well as the post-closure/latent phases, there are five key activities that are likely to have ecological impacts on the terrestrial component of SR Area 1. These are:

- Lowering of existing dredge pond walls;
- Decommissioning of the mining plant;
- Decommissioning of existing haul roads;
- Continued hunting pressure on faunal component;
- Earth moving during rehabilitation efforts;
- Inefficient rehabilitation; and
- Alien and invasive plant proliferation.

The results of the impact assessment are presented in the sections below, and highlight the various perceived impacts and mitigation measures involved in the Operational, Decommissioning/Closure/Rehabilitation and Post-Closure/Care and Maintenance phases.

**Table 14: Summary of the anticipated activities related to the SRL Mine**

<table>
<tr><th>Phase</th><th>Activities and Aspects (impact source)</th><th>Impacts to be considered</th></tr>
<tr><td>Operational Phase</td><td>• Dry Mining and haul road development:<br>  • Clearing and mining of dry mining areas;<br>  • Clearance of ancillary areas;<br>  • development and maintenance of haul roads;<br>  • Rehabilitation with alien floral species.<br>• Wet Mining areas:<br>  • Ongoing dredge operation within dredge ponds;<br>  • Tailings and sand deposition;<br>  • Rehabilitation with alien floral species.<br>• Ancillary impacts human impacts<br>  • Hunting for bushmeat;<br>  • Slash and burn activities.</td><td rowspan="3">• Loss of faunal and floral habitat and ecological structure;<br>• Loss of faunal and floral species diversity; and<br>• Loss of potential faunal and floral SCC.</td></tr>
<tr><td>Decommissioning/ rehabilitation phase</td><td>Decommissioning:<br>• Lowering of dredge pond water levels through reduction of the dredge pond decant levels in the artificial earth walls;<br>• Decommissioning of surface infrastructure, including:<br>  • Mining Plant;<br>  • Haul roads;<br>  • Open pits/dry mining areas.<br>Rehabilitation:<br>• Rehabilitation of dredge ponds:<br>  • Potential earth works and sloping of walls;<br>  • Seeding/planting appropriate wetland, riparian and terrestrial plant species as required.<br>• Rehabilitation of demolished surfaces:<br>  • Remove rubble;<br>  • Re-shape and reinstate landforms to pre-mining conditions;<br>  • Rip hard surfaces to facilitate revegetation to occur;<br>  • Revegetation of disturbed areas;<br>  • Alien vegetation control.</td></tr>
<tr><td>Post-closure/latent phase</td><td>• Inefficient rehabilitation leading to further faunal and floral impacts.<br>• Alien and invasive species proliferation.</td></tr>
</table>

## *6.1 Operational Phase Impacts*

The operational activities of the mine are anticipated to have impacts on the drivers and receptors identified previously. Impacts are largely associated with the wet and dry mining activities, associated support infrastructure including the haul roads and the human element, both within and outside of the mine. The significance of these impacts on the faunal and floral ecology of the receiving environment is summarised in the tables below.

### 6.1.1 Impact TB1: Loss of faunal and floral habitat, species diversity and SCC due to dry mining

Table 15 provides a summary, description and assessment of faunal and floral impacts pertaining to operational phase dry mining impact. Impacts pertain mainly to loss of faunal and floral habitat, species abundance and diversity, and SCC. The significance of the impact with management measures is considered medium (moderate, medium term impact on a local scale).

**Table 15: Impact TB1 – Loss of faunal and floral habitat, species diversity and SCC due to dry mining (operational phase).**

<table>
<tr><td>Activity</td><td colspan="8">Dry mining and haul road development:<br>• Clearing and mining of dry mining areas;<br>• Clearance of ancillary areas;<br>• Rehabilitation of disturbed areas;<br>• Development and maintenance of haul roads.</td></tr>
<tr><td>Project phase</td><td colspan="8">Operational</td></tr>
<tr><td>Impact summary</td><td colspan="8">• Loss of faunal and floral habitat as forest and riparian areas are cleared;<br>• Loss of faunal and floral species abundance and diversity;<br>• Loss of faunal and floral SCC;<br>• Contamination of surface water resources and subsequent impact on faunal and floral ecology; and<br>• No or limited implementation of mitigation measures.</td></tr>
<tr><td>Impact descriptions</td><td colspan="8">• Vegetation clearing for mining and ancillary purposes will result in the loss of faunal and floral habitat, isolating floral populations and pushing the remaining faunal species into already congested pockets of natural habitat, fuelling intra and inter-specific completion among species for the remaining resources. The result being increased ease of hunting for bushmeat, species displacement and general decrease in abundance and diversity;<br>• SCC are generally listed as such due to their already low numbers, high levels of persecution and/or decreasing favourable habitat. Further habitat loss, clearing of vegetation for charcoal, agriculture, increased competition for resources and the ever-present threat of hunting will further push these species numbers down;<br>• During operational activities, discharge and spillage of untreated substances can be caused by accidental instances or storm events. In return, this will have a negative effect on faunal and floral habitat and diversity. If not attended to immediately the possibility is very high that contamination of soil and water courses will have a detrimental effect on faunal and floral habitat, diversity and faunal and floral SCC;<br>• Rehabilitation efforts utilising alien floral timber species will lead to a further decline in floral SCC, species diversity and habitat availability;<br>• Improper implementation of mitigation measures will see continued loss of habitat, and in turn decreased faunal and floral species.</td></tr>
<tr><td colspan="9">Potential impact rating: Impact TB1: Loss of faunal and floral habitat, species diversity and SCC due to dry mining</td></tr>
<tr><td>Status</td><td>Magnitude</td><td>Duration</td><td>Scale</td><td>Consequence</td><td>Probability</td><td>Significance</td><td>+/-</td><td>Confidence</td></tr>
<tr><td>Before management</td><td>Major-</td><td>Long term</td><td>Regional</td><td>High</td><td>Definite</td><td>High</td><td>-</td><td>Medium</td></tr>
<tr><td>Management measures</td><td colspan="8">• Only clear vegetation in areas where necessary, avoid unnecessary vegetation removal;<br>• As far as possible utilise existing roads, if not feasible, construct roads where possible in areas that have already been disturbed, and not within sensitive habitat;<br>• Throughout the operational phase, management and control of alien plant species is to be exercised;<br>• Investigate the feasibility of developing a nursery utilising indigenous species and implement trials for rehabilitation to determine rehabilitation success;<br>• The species composition can include medicinal and timber species as indicated in the floral ecological assessment, which will lessen the pressure on these species due to habitat destruction and utilisation by local communities;<br>• Develop a biodiversity action plan containing objectives to improve agricultural efficiency by local communities, improving current rehabilitation strategies whilst and actively managing alien and invasive floral communities within SR Area 1;<br>• Educate drivers with regard to species conservation, and encourage them to not unnecessarily drive over faunal species;<br>• Contamination prevention measures should be addressed in the Environmental Management Programme (EMP) for the mining activities;</td></tr>
</table>

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Activity** | **Dry mining and haul road development:**<br>• Clearing and mining of dry mining areas;<br>• Clearance of ancillary areas;<br>• Rehabilitation of disturbed areas;<br>• Development and maintenance of haul roads. | | | | | | | |
| | • All waste, including rubble, domestic waste, empty containers on the site should be disposed of at the dedicated licenced landfill facility;<br>• No uncontrolled fires may be permitted within SR Area 1, unless it as part of the mining management plan and under supervision of mining personnel. Exception is given with regard to fires started by the local community that are out of the control parameters of the SRL mine;<br>• With increased personnel the likelihood of poaching and trapping will also increase, and measures must be implemented to prevent poaching;<br>• In the mining areas, construct berms to help control surface water runoff, minimising erosion activities and excess sedimentation of the surrounding habitat. | | | | | | | |
| **Status** | **Magnitude** | **Duration** | **Scale** | **Consequence** | **Probability** | **Significance** | **+/-** | **Confidence** |
| **After management** | Moderate | Medium term | Local | Medium | Definite | **Medium** | - | Medium |

## 6.1.2 Impact TB2: Loss of faunal and floral habitat, species diversity and SCC due to wet mining

Table 16 provides a summary, description and assessment of faunal and floral impacts pertaining to operational wet mining impact. Impacts pertain mainly to loss of faunal and floral habitat, species abundance and diversity, and SCC. The significance of the impact with management measures is considered medium (moderate, medium term impact on a local scale).

**Table 16: Impact TB2 – Loss of faunal and floral habitat, species diversity and SCC due to wet mining (operational phase).**

| | |
|---|---|
| **Activity** | **Wet mining areas:**<br>• Ongoing dredge operation within dredge ponds;<br>• Tailings and sand deposition;<br>• Rehabilitation of disturbed areas. |
| **Project phase** | Operational |
| **Impact summary** | • Loss of faunal and floral habitat as forest and riparian areas are cleared and flooded;<br>• Loss of faunal and floral species abundance and diversity;<br>• Loss of habitat connectivity;<br>• Loss of faunal and floral SCC;<br>• Contamination of surface water resources and subsequent impact on faunal and floral ecology;<br>• No or limited implementation of mitigation measures. |
| **Impact descriptions** | • Vegetation clearing and flooding for mining purposes will result in the loss of faunal and floral habitat, isolating floral communities and pushing the remaining faunal species into already congested pockets of natural habitat, fuelling intra and inter-specific completion among species for the remaining resources. The result being increased ease of hunting for bushmeat, species displacement and general decrease in abundance and diversity;<br>• SCC are generally listed as such due to their already low numbers, high levels of persecution and/or decreasing favourable habitat. Further habitat loss due to vegetation clearing for timber, fuel and agriculture, increased competition for resources and the ever-present threat of hunting will further push these species numbers down;<br>• Flooding of the dredge ponds creates an impassable barrier to many less mobile species, notably those that are unable to swim, fly or readily move long distances. This may result in an island affect, splitting populations and limiting future breeding potential. The long term effect of such will be an inevitable decrease in population numbers as resources are used up;<br>• Rehabilitation efforts utilising alien floral timber species will lead to a further decline in floral SCC, species diversity and habitat availability;<br>• During operational activities, discharge and spillage of untreated substances can be caused by accidental instances or storm events. In return, this will have a negative effect on faunal and floral habitat and diversity. If not attended to immediately the possibility is very high that contamination of soil and water courses will have a detrimental effect on faunal and floral habitat, diversity and faunal and floral SCC; |

| **Activity** | **Wet mining areas:**<br>• Ongoing dredge operation within dredge ponds;<br>• Tailings and sand deposition;<br>• Rehabilitation of disturbed areas. | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | • Improper implementation of mitigation measures will see continued loss of habitat, and in turn decreased faunal and floral species. | | | | | | | |
| **Potential impact rating: Impact TB2: Loss of faunal and floral habitat, species diversity and SCC due to wet mining** | | | | | | | | |
| **Status** | **Magnitude** | **Duration** | **Scale** | **Consequence** | **Probability** | **Significance** | **+/-** | **Confidence** |
| **Before management** | Major- | Long term | Regional | High | Definite | **High** | - | Medium |
| **Management measures** | • Only clear vegetation and flood areas where necessary, avoid unnecessary vegetation clearing;<br>• As far as possible utilise existing roads, if not feasible, construct roads where possible in areas that have already been disturbed, and not within sensitive habitat;<br>• Throughout the operational phase, management and control of alien plant species is to be exercised;<br>• Educate drivers with regard to species conservation, and encourage them to not unnecessarily drive over faunal species;<br>• Investigate the feasibility of developing a nursery utilising indigenous species and implement trials for rehabilitation to determine rehabilitation success;<br>• The species composition can include medicinal and timber species as indicated in the floral ecological assessment, which will lessen the pressure on these species due to habitat destruction and utilisation by local communities;<br>• Develop a biodiversity action plan containing objectives to improve agricultural efficiency by local communities, improving current rehabilitation strategies and actively managing alien and invasive floral communities within SR Area 1;<br>• Contamination prevention measures should be addressed in the Environmental Management Programme (EMP) for the mining activities;<br>• All waste, including rubble, domestic waste, empty containers on the site should be disposed of at the dedicated licensed landfill facility;<br>• No uncontrolled fires may be permitted within SR Area 1, unless it is part of a management plan;<br>• With increased personnel the likelihood of poaching and trapping will also increase, and measures must be implemented to prevent poaching;<br>• Plan the location of possible future dredge ponds in such a way that no terrestrial islands are formed, so as to ensure habitat connectivity is maintained. | | | | | | | |
| **Status** | **Magnitude** | **Duration** | **Scale** | **Consequence** | **Probability** | **Significance** | **+/-** | **Confidence** |
| **After management** | Moderate | Medium term | Local | Medium | Definite | **Medium** | - | Medium |

### 6.1.3 Impact TB3: Loss of faunal and floral habitat, species diversity and SCC due to ancillary human impacts

Table 17 provides a summary, description and assessment of faunal and floral impacts pertaining to ancillary human impacts. Impacts pertain mainly to slash and burn and hunting activities, as well as loss of faunal and floral species abundance, diversity and SCC. The significance of the impact with management measures is considered medium (moderate, medium term impact on a local scale).

**Table 17: Impact TB3 – Loss of faunal and floral habitat, species diversity and SCC due to ancillary human impacts (operational phase).**

| Activity | Ancillary impacts human impacts | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Project phase | Operational | | | | | | | |
| Impact summary | • Hunting for bushmeat;<br>• Slash and burn activities;<br>• Loss of faunal and floral SCC; and<br>• Loss of faunal and floral species abundance and diversity; | | | | | | | |
| Impact descriptions | • The economic draw of mining, employment and associated business opportunities will always result in an increased human population in the vicinity of mines. Increased human populations will result in an increased need for food resources, with communities often turning to bushmeat to supplement their dietary requirements, notably in the rural areas. As such, this places increased pressure on the faunal and floral component as species are destroyed, actively hunted and snared;<br>• Subsistence farming needs by local communities will result in more forest areas being cleared in order to make way for agricultural lands, in order to increase food production and food security. | | | | | | | |
| **Potential impact rating: Impact TB3: Loss of faunal and floral habitat, species diversity and SCC due to ancillary human impacts** | | | | | | | | |
| **Status** | **Magnitude** | **Duration** | **Scale** | **Consequence** | **Probability** | **Significance** | **+/-** | **Confidence** |
| **Before management** | Major | Medium term | Regional | Medium | Definite | **Medium** | - | Medium |
| **Management measures** | • Within SR Area 1, demarcate no go areas/ areas of refuge for faunal species, where no hunting practices are allowed;<br>• Educate mine workers and local communities about the long-term impacts associated with slash and burn activities, and the inevitable loss of forest and food resources;<br>• Develop a biodiversity action plan containing objectives to improve agricultural efficiency by local communities, improving current rehabilitation strategies and actively managing alien and invasive floral communities within SR Area 1;<br>• Develop ecologically feasible and sustainable crop growing initiatives in areas already cleared/ disturbed so as to negate the need to continue clearing forest areas;<br>• Set aside old mining areas for rehabilitation and include them as no hunting zones where feasible. | | | | | | | |
| **Status** | **Magnitude** | **Duration** | **Scale** | **Consequence** | **Probability** | **Significance** | **+/-** | **Confidence** |
| **After management** | Moderate | Medium term | Site or local | Medium | Definite | **Medium** | - | Medium |

## 6.2 Decommissioning/closure and rehabilitation Phase

The decommissioning/closure and rehabilitation phase of the proposed development is anticipated to have impacts on the drivers and receptors/responses identified previously. The significance of these impacts on the faunal and floral ecology of the receiving environment is summarised in the tables below.

### 6.2.1 Impact TB4: Loss of faunal and floral habitat, species diversity and SCC due to lowering of dredge pond decants

Table 18 provides a summary, description and assessment of faunal and floral impacts pertaining to lowering of dredge pond decants during the decommissioning phase. Impacts pertain mainly to proliferation of alien species, and loss of faunal and floral species abundance, diversity and habitat. The significance of the impact with management measures is considered low (minor, short term impact on a local scale).

**Table 18: Impact TB4 – Loss of faunal and floral habitat, species diversity and SCC due to lowering of dredge pond decants (decommissioning phase).**

| Activity | Lowering of dredge ponds |
|---|---|
| Project phase | Decommissioning/closure and rehabilitation |
| Impact summary | • Proliferation of alien plant species in new terrestrial habitat created by exposed areas;<br>• Flooding of downstream terrestrial habitat as water decants;<br>• Possible impact on faunal and floral species and habitat from dredge pond decant water;<br>• Possible loss of faunal and floral habitat and species therein who have established themselves along the banks of the current dredge ponds; |
| Impact descriptions | • Lowering of the dredge ponds will create new terrestrial habitat as the water levels decrease, creating an ideal environment for the proliferation of alien plant species;<br>• Excess water flowing out of the dredge pond that is not directed to the main water ways may end up temporarily flooding the surrounding terrestrial habitat, resulting in temporary inundation of faunal and floral habitat, and possible increased mortality rates of faunal and floral species unable to adapt to saturated conditions;<br>• Excess sediment from the dredge ponds may end up in the existing water ways, wetlands and terrestrial habitat, smothering vegetation and altering the soil and vegetation component of the faunal and floral habitat. Possible contaminants present in the water will also be leached into the soils, affecting plant growth and faunal species who come into contact with the contaminants; and<br>• During the operation of the dredge ponds, vegetation and species would have begun to re-establish themselves along the banks. Lowering of the ponds may result in the loss of these habitat areas and as such the species therein, however these species are likely to self-relocate to new habitats. |

| Potential impact rating: Impact TB4: Loss of faunal and floral habitat, species diversity and SCC due to lowering of dredge ponds | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Status** | **Magnitude** | **Duration** | **Scale** | **Consequence** | **Probability** | **Significance** | **+/-** | **Confidence** |
| **Before management** | Moderate | Short term | Regional | Medium | Possible | **Medium** | - | Medium |
| **Management measures** | • Footprint areas must be kept as small as possible;<br>• Ensure that rehabilitation of the exposed areas is carried out as per the Mine Closure Plan;<br>• Ensure that decant water is not released into existing terrestrial habitat areas;<br>• Monitoring and control of alien and invasive plants must be performed during the decommissioning and closure phase;<br>• It is recommended that an Alien and Invasive Plant (AIP) Control Plan be implemented and adhered to; and<br>• Care must be taken when rehabilitation activities need to be performed within the watercourses as these areas are sensitive to disturbance. | | | | | | | |
| **Status** | **Magnitude** | **Duration** | **Scale** | **Consequence** | **Probability** | **Significance** | **+/-** | **Confidence** |
| **After management** | Minor | Short term | Site | Low | Possible | **Low** | - | Medium |

### 6.2.2 Impact TB5: Loss of faunal and floral habitat, species diversity and SCC due to decommissioning/rehabilitation of active dry mining areas, plant and haul roads

Table 19 provides a summary, description and assessment of faunal and floral impacts pertaining to decommissioning and rehabilitation of active dry mining areas, plants and haul roads. Impacts pertain mainly to removal of existing infrastructure, vehicle movement through sensitive areas, ripping of compacted soils and roads, landform rehabilitation and proliferation of alien species. The significance of the impact with management measures is considered low (minor, short term impact on a local scale).

**Table 19: Impact TB5 – Loss of faunal and floral habitat, species diversity and SCC due to decommissioning/rehabilitation of active dry mining areas, plant and haul roads (decommissioning phase).**

| Activity | Removal and rehabilitation of surface infrastructure and unneeded haul roads | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Project phase | Decommissioning/Rehabilitation | | | | | | | |
| Impact summary | • Removal of existing mining infrastructure;<br>• Movement of vehicle through sensitive habitat areas;<br>• Ripping of compacted soil surfaces in mining infrastructure areas;<br>• Reshape and reinstate landforms to pre-mining conditions;<br>• Ripping of unneeded haul roads;<br>• Proliferation of alien plant species in new terrestrial habitat areas. | | | | | | | |
| Impact descriptions | • Ineffective removal of waste and demolished construction materials will hamper rehabilitation;<br>• During rehabilitation, there may also be direct vehicle and human impacts as well as impacts from supportive structures, that may affect species composition and faunal and floral habitat;<br>• Ineffective reinstatement of landforms may lead to ineffective reestablishment of vegetation;<br>• Encroachment of alien vegetation is expected to increase as a result of the surface infrastructure demolition disturbances;<br>• Vehicles movement through sensitive areas will result in the hardening of the soil surface, loss of faunal and floral habitat and possible creation of erosion gulleys. | | | | | | | |
| **Potential impact rating: Impact TB5: Loss of faunal and floral habitat, species diversity and SCC due to decommissioning/rehabilitation of active dry mining areas, plant and haul roads** | | | | | | | | |
| **Status** | **Magnitude** | **Duration** | **Scale** | **Consequence** | **Probability** | **Significance** | **+/-** | **Confidence** |
| **Before management** | Moderate | Short term | Local | Low | Definite | **Medium** | - | Medium |
| **Management measures** | • Decommissioning and rehabilitation footprints must be minimised, and strict controls of edge effects implemented;<br>• Demolition of the plant should be performed in a manner to salvage building materials that can be used by the local community;<br>• Replacement of topsoil and revegetation must be undertaken as guided by the mine closure plan;<br>• All waste materials that cannot be recycled must be effectively removed and discarded in a safe and legal manner;<br>• Compacted haul roads must be ripped and treated with available topsoil to allow establishment of natural vegetation. If necessary additional revegetation may need to take place using indigenous species.<br>• Tn AIP control plan must be carried through into this phase, as encroachment of alien vegetation is expected to increase as a result of the disturbances stemming from the decommissioning process;<br>• Erosion management and sediment controls such as rock packing, revegetation of profiled slopes, erosion berms, drift fences with hessian and silt traps must be implemented as applicable from the outset of rehabilitation activities. This is particularly relevant to areas where altered flow paths and increased run-off may pose an erosion risk. | | | | | | | |
| **Status** | **Magnitude** | **Duration** | **Scale** | **Consequence** | **Probability** | **Significance** | **+/-** | **Confidence** |
| **After management** | Minor | Short term | Site | Low | Possible | **Low** | - | Medium |

## 6.3 Post-closure/latent Phase

The post closure/latent phase of the proposed development is anticipated to have impacts on the same drivers and receptors identified previously.

The significance of these impacts on the faunal and floral ecology of the receiving environment is summarised in the tables below.

### 6.3.1 Impact TB6: Loss of faunal and floral habitat, species diversity and SCC due to inefficient rehabilitation and alien and invasive plant proliferation

Table 20 provides a summary, description and assessment of faunal and floral impacts pertaining to decommissioning and rehabilitation of active dry mining areas, plants and haul roads. Impacts pertain mainly to removal of existing infrastructure, vehicle movement through sensitive areas, ripping of compacted soils and roads, landform rehabilitation and proliferation of alien species. The significance of the impact with management measures is considered low (minor, short term impact on a local scale).

**Table 20: Impact TB6 – Loss of faunal and floral habitat, species diversity and SCC due to inefficient rehabilitation and alien and invasive plant proliferation (post-closure)**

| Activity | Rehabilitation | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Project phase | Post-closure | | | | | | | |
| Impact summary | • Inefficient rehabilitation leading to alien and invasive species proliferation. | | | | | | | |
| Impact descriptions | • Areas which are inefficiently rehabilitated are unlikely to recover to a stable ecosystem, contributing to biodiversity loss. | | | | | | | |
| **Potential impact rating: Impact TB6: Loss of faunal and floral habitat, species diversity and SCC due to inefficient rehabilitation and alien and invasive plant proliferation (post-closure/latent phase)** | | | | | | | | |
| **Status** | **Magnitude** | **Duration** | **Scale** | **Consequence** | **Probability** | **Significance** | **+/-** | **Confidence** |
| **Before management** | Minor | Long term | Site | Medium | Definite | **Medium** | - | Medium |
| **Management measures** | • Continued rehabilitation of disturbed areas post-closure, clearing alien vegetation and utilising indigenous floral species, will assist in reinstating essential ecological functioning as part of the faunal and floral habitat;<br>• Monitor the progress of vegetation regrowth, as well as level of faunal and floral abundance and diversity increases within these areas. | | | | | | | |
| **After management** | Minor | Medium term | Site | Low | Possible | **Low** | - | Medium |

### 6.3.2 Impact TB7: Loss of faunal and floral habitat, species diversity and SCC due to latent impacts of decommissioned dredge ponds, mining areas, plant and haul road

Even with extensive mitigation, latent impacts on the receiving faunal and floral ecological environment are likely. The following points highlight the key latent impacts that have been identified:

- Alien and invasive plant proliferation; and

- Disturbed areas are unlikely to be rehabilitated to pre-development conditions of ecological functioning and significant loss of faunal and floral habitat and species diversity can be permanent. However, this will be further investigated during the dry season survey and elaborated upon if deemed significant.

# 7. TERRESTRIAL IMPACT ASSESSMENT SUMMARY AND CONCLUSION

Impacts on drivers and receptors were evaluated for each life cycle phase, a summary of results are presented below in Table 21.

**Table 21: Summary of impact significance ratings**

| Aspect | Operational phase | | Decommissioning/ rehabilitation phase | | Post-closure/latent phase | |
|---|---|---|---|---|---|---|
| | Before management | After management | Before management | After management | Before management | After management |
| Dry mining and haul road development [Impact TB1] | High | Medium | | | | |
| Wet mining [Impact TB2] | High | Medium | | | | |
| Ancillary human impacts [Impact TB3] | Medium | Medium | | | | |
| Lowering of dredge pond decant [Impact TB4] | | | Medium | Low | | |
| Decommissioning/Rehabilitation of dry mining areas, plant and haul roads [Impact TB5] | | | Medium | Low | | |
| Inefficient rehabilitation [Impact TB6] | | | | | Medium | Low |

# 8. TERRESTRIAL MONITORING REQUIREMENTS

Prudent biodiversity monitoring of SR Area 1 is of utmost importance, as this will ensure a continual flow of data, enabling all parties involved to accurately assess and manage biodiversity related progress and issues. To ensure the accurate gathering of data, the following techniques and guidelines should be followed:

- Fixed point monitoring should be applied as the preferred method of monitoring at strategic locations;

- All data gathered should be measurable (qualitative and quantitative);
- Monitoring report should be repeatable and temporally and spatially comparable;
- Data should be auditable;
- Data gathered should be an accurate representation of the PES of SR Area 1, as well as the various faunal and floral communities and habitat units represented by each monitoring site;
- Data, when compared to previous sets, should show spatial and temporal trends;
- Data gathered should represent all aspects of all communities, i.e. mammals, avifaunal, invertebrates, reptiles, amphibians; grasses, forbs, shrubs and trees;
- Recruitment of alien vs. indigenous floral recruitment must be analyzed;
- Success of rehabilitation efforts should be analyzed;
- General habitat unit overviews should also be undertaken; and
- Monitoring of protected species populations must also take place.

## 8.1 Monitoring/sampling Frequency

Biodiversity monitoring should occur on a bi-annual basis during the wet and the dry seasons. In order to ensure that temporal comparisons can be made, assessments should take place at the same time each year.

## 8.2 Monitoring/sampling Technique

Vegetation data must be collected according to the methods below, which are identical to the methods utilised during the baseline ecological assessments:

- Vegetation monitoring should be conducted at pre-determined sites within each habitat unit on an annual basis during the growing season. It is recommended that the Braun-Blanquet method is utilised for vegetation assessment, with a minimum of three quadrats per habitat unit. When considering quadrat sites, it must be ensured that follow up assessments at the same localities will be feasible throughout the operational and closure phases of the mine, so as to ensure repeatability of captured data in order to make year-on comparisons. This method will ensure that both the herbaceous and woody component is accounted for and quantified in a useable and repeatable manner. Through repeated annual assessments, any change in species diversity and composition will be picked up, and can be used to inform the biodiversity action plan where necessary;
- The data gathered using the above method can also be used to monitor changes in basal cover, indigenous species recruitment and species diversity through percentage

analysis. Alien vegetation recruitment and medicinal species recruitment can also be monitored if these species are recorded during the assessment;

- Ad libitum recording of all faunal species observed through direct visual observation or identified by calls, tracks, scats and burrows;
- Bird census involving 15-minute point counts at the monitoring points. Monitoring should take place within each habitat unit in order to ascertain habitat preferences and utilization levels of avifaunal species; and
- Sherman traps and camera traps to gather information on the small mammal community (bi-annually, once per season until 3 years post-closure) These censuses are to be conducted within each habitat unit in order to ascertain habitat utilization, species diversity as well as the overall abundance of mammal species within SR Area 1.

## 8.3 Monitoring/sampling Equipment

- Sampling plot equipment, which includes pegs, string, measuring tape.
- GPS;
- Camera;
- Sweep nets;
- Sherman traps;
- Camera traps;
- Binoculars;
- Sampling bags/buckets; and
- Reference lists and literature.

## 8.4 Reporting Frequency

Reporting should follow after monitoring has taken place, i.e. bi-annually in after each survey (wet and dry season).

## 8.5 Report Content

All aspects pertaining to faunal and floral diversity and sensitive habitats as covered by the Baseline Ecological Assessments STS in 2017 and 2018 should be referred to in the monitoring report. Reporters should ensure that quantitative analyses of data are presented indicating both spatial and temporal variation, in order to ensure that management and mitigation measures are continually improved and to determine the success of rehabilitation efforts.

# 9. CONCLUSION AND WAY FORWARD

STS was appointed to conduct faunal, floral, wetland and aquatic ecological assessments as part of the process to undertake an ESHIA and develop an ESHMP for the current and proposed dry and wet mining activities within SR Area 1. From the impact assessment, it is clear that, prior to mitigation, the majority of the anticipated impacts are of moderate significance. However, with the implementation of mitigation measures as recommended in this section of the report, the vast majority of the anticipated impacts may be reduced to low significance.