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MALINGUNDE GRAPHITE PROJECT

Draft Environmental and Social Impact Assessment
Volume I: Main Report

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ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT REPORT

MALINGUNDE GRAPHITE PROJECT,
LILONGWE DISTRICT, MALAWI

April 2019

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EXECUTIVE SUMMARY

1 Introduction

Sovereign Metals Limited (Sovereign) is proposing the development of an open pit graphite mine and processing plant at Malingunde in Malawi. Sovereign is an Australian publicly listed company that trades on the Australian Securities Exchange (ASX) under the code ASX:SVM. The company is engaged in exploration and appraisal of resource projects, with the main focus being its 100% owned Malingunde Saprolite-hosted Graphite Project (the Project). McCourt Mining Pty Ltd (McCourt Mining) is a wholly owned subsidiary of Sovereign and was acquired by Sovereign in September 2012. McCourt Mining is the licence holder of the exclusive prospecting licence (EPL), EPL0372, an area of 732 km^2 in which the Project is located (Figure E1), and will therefore be the applicant for the relevant environmental authorisation as well as mining licence application.

The Project is located approximately 20 km southwest of Malawi's capital city of Lilongwe and falls within the Lilongwe District of the Central Region (Figure E1). The Project lies directly north of Kamuzu Dam II and is in proximity to the villages of Kumalindi, Ndumila and Kubale in the Masumbankhunda Traditional Authority.

The deposit at Malingunde is a large high-grade saprolite-hosted flake graphite deposit, situated on the Lilongwe plain. Saprolite is very soft, clay-rich oxide material that is formed through intense weathering of the original bedrock. This deposit is the world's largest reported soft saprolite-hosted graphite resource.

It is anticipated that the Project will have an initial life-of-mine of 15 years and will treat approximately 600,000 tonnes (t) of ore to produce approximately 52,000 t per year of graphite concentrate at a targeted purity of 97% total graphitic carbon (TGC).

The total capital cost for the development of the Project is estimated at approximately US$49 million, with the total operating costs averaging approximately US$16 million per annum, equivalent to US$323 per tonne of concentrate. Revenue from product sales is estimated to average US$62 million per annum over the life-of-mine. The Project will generate government revenues during the operational phase in the form of taxation (30%) and royalties (5% of net sales revenue) as well as flow on benefits through indirect taxation of wages and other indirect taxation benefits. Estimated direct tax payable over the life-of-mine is US$150 million, with an additional US$50 million in royalties.

The project has been designed to create maximum economic and social benefits, whilst minimising negative attributes such as relocation and environmental impacts. The mining area has been designed to retain as much of the existing village infrastructure as possible, and to avoid important cultural sites such as graveyards.

Sovereign has commenced a definitive feasibility study (DFS), with an aim to bring the Project into construction in 2020. Development of the project is dependent on the following:

- Approval of the environmental and social impact assessment (ESIA) report.
- Approval of the resettlement action plan (RAP), including consultation with all relevant stakeholders and affected households.
- Completion of Development Agreement with Malawi Government.
- Finalisation of offtake sales agreements with end users.
- Completion and approval of the mining licence application.
- Obtaining financing for the Project.

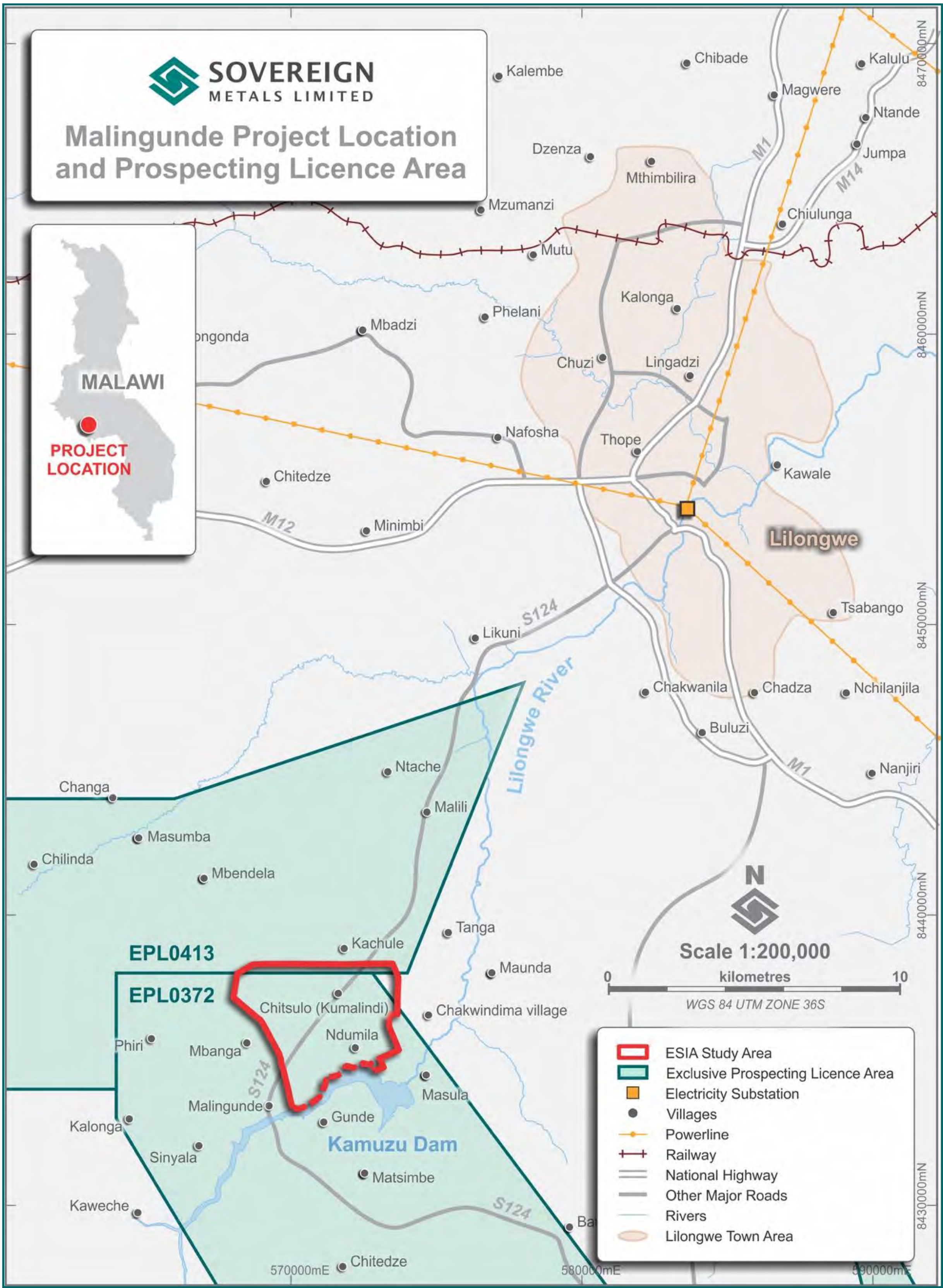

Figure E1: Project Location

2 Project Description

2.1 Project Overview

A very simple mining and processing operation is proposed, producing and selling very high-quality graphite concentrates into existing markets.

It is anticipated that construction will be undertaken over of a period of approximately 14 months. The Project will initially operate using contract mining, with larger numbers of expatriate personnel to support the mine start-up during Year 1 to 3. During this time, power will be generated by on-site diesel fired generators. Operations will convert to grid power, once this becomes available in the area, which is planned from Year 4 to 7. From Year 8 to 15 are planned to change from contract mining to owner operator mining.

The Project is targeting the processing of 9.5 Mt of run-of-mine (ROM) ore over the 15 year life-of-mine to produce 830,000 t of concentrate. The life-of-mine is based on the Proven Ore Reserves of 3.1 Mt (32%) and Probable Ore Reserves of 6.4 Mt (68%) with inferred resources offering an opportunity to increase the life of mine.

Open pit mining will be undertaken with ore being processed on site in a processing plant to produce a graphite concentrate, which will be transported by road from site to Lilongwe and the exported by rail to the Port of Nacala in Mozambique for shipment to overseas markets. Tailings from the processing plant will be disposed of in a dedicated permanent tailings storage facility (TSF). The conceptual mine layout is depicted in Figure E2.

2.2 Access to Project Site

Access to the Project from Lilongwe is via the sealed section of the secondary road, S124, to Likuni and then the unsealed continuation of the S124 to the Kamuzu Dam turn-off. Existing access around the Project site is via a network of unsealed tracks. The S124 passes through the area of the planned northern mining pit and will require modification so that it can continue as a main access route during the operations phase. The Malawi Roads Authority is already planning to upgrade the road from the current unsealed status to a bituminised two-way main road. A separate ESIA has been commissioned by the Roads Authority for the upgrading of the road and this upgrade does not form part of this report. Sovereign will undertake a minor realignment of the section of the S124 which runs through the northern pit areas.

2.3 Exclusion Zone

The Project will require approximately 130 ha of land to develop and operate the mine and associated infrastructure. In addition, a buffer distance of approximately 50 m was placed around all infrastructure to ensure operations are undertaken safely. The buffer zone was kept as small as possible to minimise displacement as a result of the Project. The Project infrastructure and buffer zone are collectively referred to as the exclusion zone and is approximately 260 ha in size. Land within the exclusion zone is currently largely occupied by subsistence agriculture and rural villages, and will require the involuntary resettlement of all households and assets within this zone. It is anticipated that resettlement will be undertaken in two phases as indicated in Figure E2.

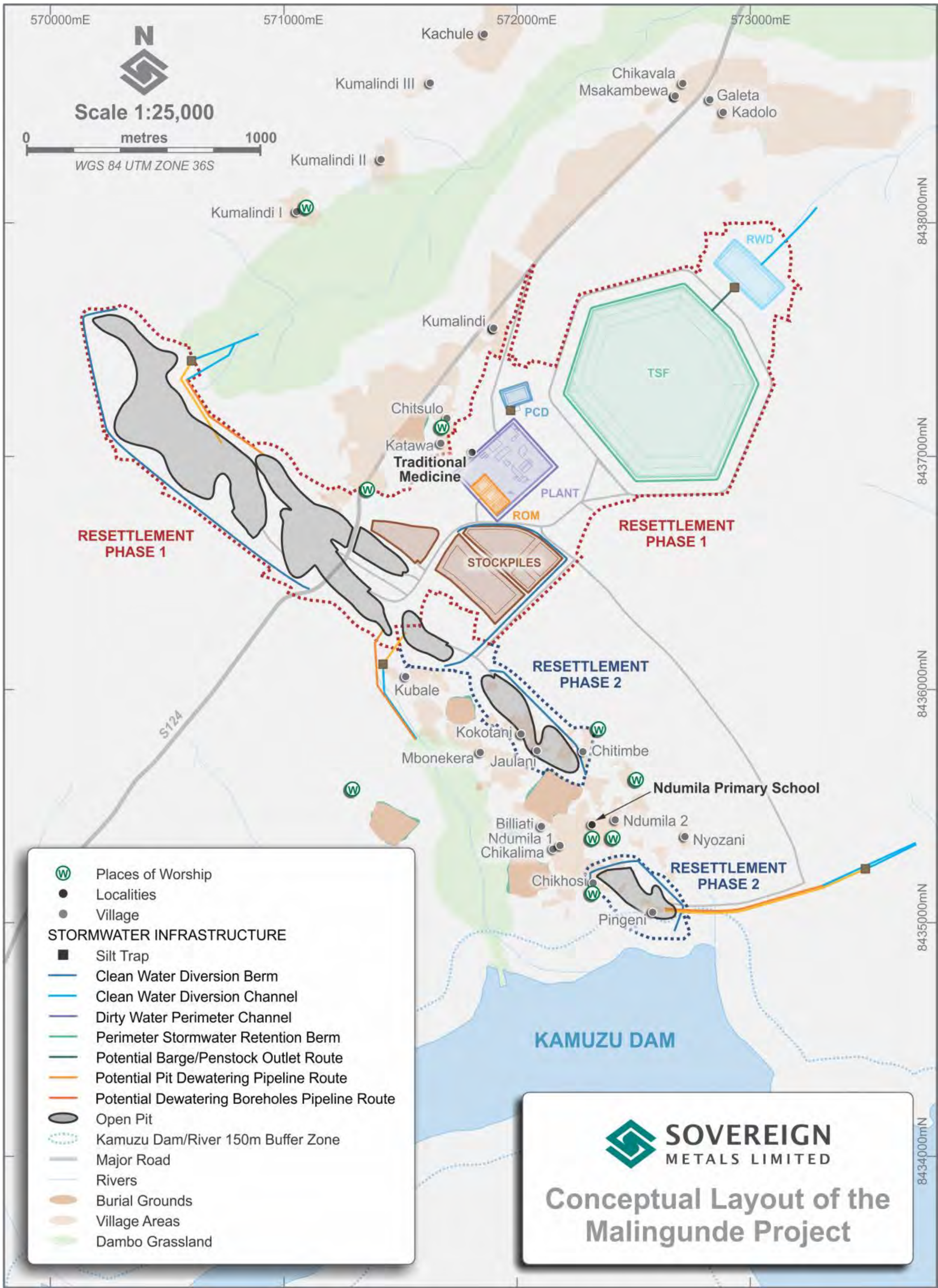

Figure E2: Project Layout

2.4 Open Pit Mining

Mining will be undertaken using traditional excavators and haul trucks, and will target the near surface, relatively soft, weathered material. The ore and waste rock will be free-dig in nature and as a result no drilling or blasting activities will be required for the operation.

Mining will be undertaken in a number of long, shallow open pits over a distance of approximately 3.5 km. Mining depths will vary between 15 and 34 m below surface and open pits will be a maximum of approximately 250 m wide. The open pits will extend below the groundwater table, and therefore inflow of groundwater into the pits is expected during operations and at closure. To enable workable dry conditions for efficient mining, dewatering will be required during the operations phase.

Mining activities will commence in the pits in the north of the Project area, directly south of the S124 secondary road. Generally, mining will begin towards the northern extent of the deposit, after which it will continue directly south of the S124 and move towards the southern extent of the deposit (towards the Kamuzu Dam).

Ore will be loaded on to articulated dump trucks and hauled from the pit directly to the ROM pad or to the stockpiles adjacent to the pits. The small amount of waste rock generated from mining operations will be used in the construction of the TSF and no waste rock dumps will be required.

Mining will be undertaken 5 days a week (Monday to Friday) on a single 12-hour shift basis. No mining will occur at night time.

2.5 Ore Processing

Due to the relatively soft nature of the ore, processing will not require any primary crushing or grinding, and a conventional froth flotation process will be used. Processing will be carried out on a continuous basis with two 12-hour operating shifts and will entail the following stages:

- Plant feed will be delivered from the ROM stockpile by front-end loader to the ROM bin.
- From the ROM bin material will pass through a mineral sizer for primary size reduction and then processed through a wet scrubber charged with steel media.
- Scrubber discharge slurry will pass through a 10 mm screen with a small quantity (0–15%) of oversize directed to a small pebble crusher with the crusher discharge recycled to scrubber feed.
- Scrubber product between 2 mm and 10 mm in size will also be recycled back to the front of the scrubber for reprocessing.
- Scrubber product less than 2 mm in size will be pumped to the rougher flotation section for processing.
- Rougher concentrate will undergo a polishing regrind with the re-ground rougher concentrate feeding to cleaner flotation.
- Cleaner flotation concentrate will be split into coarse and fine fractions at 200 µm and feed to recleaner flotation.
- Three stages of recleaner flotation will be undertaken on the coarse and fine fractions separately with the second two stages operating in close circuit.
- Rougher, cleaner and first stage recleaner tailings will be pumped to the tailings thickener.
- The final concentrate coarse and fine fractions will be combined and thickened in the concentrate thickener.
- Thickened concentrate will be dewatered using a plate and frame filter with air blow and membrane squeeze steps to ensure maximum water removal.
- Filtered concentrate will be dried using a flash dryer.
- Dried product will be screened into various size fractions and bagged for despatch and sale.

2.6 Reagents Used on Site

Approximately 130 g of glycol-based frother, which amounts to 76,000 kg/y, is added per tonne of ore to the flotation cells to promote flotation of the graphite minerals. The majority of the frother will end up with the graphite concentrate and is then evaporated when the concentrate goes through the drying stage. The organic analysis of tailings undertaken indicates that organic analytes from frother are below detection limits, hence there are no anticipated added chemicals that would end up in the TSF or within any other parts of the site.

Approximately 210 g of diesel per tonne of ore is added to the flotation cells (equivalent to approximately 45 g diesel per tonne of ore and process water). This amounts to approximately 130,000 L/y of diesel used in the process. Diesel acts as a collector by adhering to the graphite flakes.

An anionic polyacrylamide ultra-high molecular weight flocculant will be added to the thickener feed to aid in settling prior to pumping the thickened tailings slurry to the TSF. Approximately 100 g of flocculant is added per tonne of concentrate to the concentrate thickener, while 300 g of flocculant per tonne of tailings is added to the tailings thickener. Flocculant use is estimated to be approximately 17,200 kg/y.

2.7 Tailings Management

A total of approximately 8,835,000 t (or approximately 8 Mm^3) of tailings will be produced over the life of the mine and permanently stored in the TSF. Limited waste rock will be produced during mining and no waste rock dump will be constructed on site. All waste material from the pit will be used in the construction of the TSF walls. The TSF site was located outside of the Kamuzu Dam watershed to avoid potential impact on the reservoir. No compacted clay or high-density polyethylene (HDPE) liner has been considered for the TSF, as geochemical modelling show that the only elements in the TSF water (pool and seepage) that are likely to exceed water quality guidelines are aluminium and fluoride.

Decant water from the TSF will flow to a return water dam with an approximate capacity of 80,000 m^3, lined with a 1.5 mm thick HDPE liner to prevent water loss from the dam, from where it will be pumped back to the plant for reuse.

2.8 Water Requirements

The total raw water demand for processing has been estimated at 51.8 m^3 per hour (approximately 38,000 m^3 per month), while water used for dust suppression has been estimated to be approximately of 400 m^3 per day (12,000 m^3 per month). Raw water will mainly be obtained from mine pit dewatering, collection of surface water runoff and/or boreholes.

At the start of mining (Year 1), groundwater inflows into the open pits are relatively low and during the dry season the mine will be reliant on external makeup water (approximately 20,000 m^3 per month or 240,000 m^3 per year) to satisfy the processing plant raw water demands.

Additional water, in this instance, will be obtained from either additional boreholes in the vicinity of the Project or the Kamuzu Dam. Both these options will require abstraction permits.

In the wet season the collected stormwater on site provides a supplementary source of raw water, thereby reducing the use of pit water as a source of raw water for processing and therefore requiring the discharge of water from the site.

From Year 2 onwards the volume of water from pit dewatering more than triples and the mine becomes water positive (i.e. water in excess of what is required for operations will be generated from pit dewatering) for the remainder of the life-of-mine. From this time there will be a need to discharge water to the environment from pit dewatering and no requirement for additional makeup water from boreholes or the Kamuzu Dam.

Pit dewatering will be undertaken mostly through dewatering boreholes with residual and incidental rain water pumped directly from the pit. Water from the dewatering boreholes will be used as raw water for the Project or discharged to the environment directly. Water from dewatering will also be used to supply those communities affected by any temporary groundwater drawdown.

Groundwater and stormwater from the pit are considered free from chemical contamination and require only management of total suspended solids (TSS) prior to use and/or discharge. Water from the pits will therefore be reused or managed through silt traps before discharge.

Water from pit dewatering becomes the predominant source of water for the mine in the dry season, as there is inadequate stormwater collected at the plant and TSF to serve as raw water supply.

Potable water demand has been estimated at 150 L/employee/day, which equates to approximately 456,000 L per month. A 120 m^3 per day potable water treatment plant will be installed within the processing plant area for this purpose.

Waste water (sewage) from the Project will be collected and treated in a modular waste water treatment plant installed to the southeast of the plant area. Treated waste water, which will meet the Malawi water quality guidelines for effluent, will discharge to the TSF. Sludge from the treatment plant will be collected and disposed of off-site in an appropriately licenced facility by a suitably qualified contractor.

2.9 Stormwater Management

A conceptual stormwater management plan has been developed, consistent with the IFC Environmental Health and Safety Guidelines (2007), which comprises clean, silty and dirty water management and includes the following main features:

- Clean water from the catchments upstream of the mining infrastructure (i.e., the pits) will be diverted around the proposed infrastructure and back to the natural drainage.
- Dirty water at the processing plant, ROM pad and the TSF, as well as silty stormwater from the pits, will be collected on site and reused as far as is practicable to minimise effluent discharge and minimise the make-up water requirements.
- Excess silty stormwater from the pits, that is not used as process water at the plant or for onsite dust suppression, will be passed through silt traps to remove suspended solids prior to discharge to the environment. Water from the northern pit (north of the S124) will be released to the Kovuma dambo. Water from the pits directly south of the S124 will be discharged to Dambo 1 (west of the open pits) and water from the most southern pits will discharge to a drainage line located to the east of the pit.
- Sediment control facilities (silt traps) have been designed for a final TSS discharge of 50 mg/L and other applicable parameters and guideline values in the International Finance Corporation EHS Guideline Table 1 (2007).
- Dirty water conveyance infrastructure, silt traps and containment dams have been sized for flows during a 100-year 24-hour event.

2.10 Electricity Supply

Power for initial operations will be generated on site by five 1 megawatt (MW) high-speed generators for a total installed continuous capacity of 3 MW. The generators will be diesel fired and housed in a power station located adjacent the processing plant.

The Malawi Electrical Supply Corporation (ESCOM) plans to construct a 132/11 kV substation near Bunda, 10 km to the east of the Project which will connect to the national grid. Sovereign has received advice from ESCOM that the planned Bunda substation will be operational by 2024. Construction of the transmission line linking the Project to the Bunda sub-station is planned to be complete by the time the Bunda sub-station comes online in 2024. It has therefore been assumed on site diesel power generation will only be required until 2024, with grid power available after this.

A packaged 250 kW diesel standby generator set will provide electrical power in the event of loss of power supply to the administration offices.

2.11 Fencing

Perimeter fencing will be provided to the mine services area and processing plant area only. Fences will be galvanised fence poles concreted into ground, with galvanised chain-wire security type mesh that is 2.1 m high with 3 off strands of barbed wire at top of fence. Open pit areas, the TSF and ore stockpiles will not be fenced off with access restricted by an earthen bund and 24-hour security guards.

2.12 Workforce

Local workers from the surrounding Malingunde area will be given preference for job opportunities, depending on their skills level, as it is anticipated that available jobs will be largely low-skilled or semi-skilled.

A relatively small number of construction workers will be required; approximately 220 workers at peak demand, of which 60 will be expatriate employees.

During operations an estimated 250 to 260 people will be employed of which 17 to 19 will be expatriate employees during Year 1 to Year 3. This will be reduced to 10 to 12 expatriate employees from Year 4 onwards.

Sovereign and McCourt Mining is an equal opportunity employer and endeavour to provide equal opportunities to women in the workforce.

3 Environmental and Social Impact Assessment Process

The Environment Management Act (EMA), No. 19 of 2017 provides the legal framework for protection and management of the environment of Malawi, as well the preparation of an ESIA for prescribed projects. Section 2(f) of the EMA states that an ESIA is a legal requirement for any project that may significantly affect the environment and use of natural resources.

The Guidelines of Environmental Impact Assessment for Malawi (1997) identifies the types of projects in the public and private sectors for which ESIA studies may be required in the lists of prescribed projects (List A and List B) appended to the guidelines. List A identifies projects for which an ESIA is mandatory, and includes mining of minerals, expansions to mines, mining exploration activities, minerals prospecting activities, quarries, gravel pits and removal of sand or gravel from shore lines. The Project falls under this prescribed list of activities, and as such an ESIA process in compliance with the EMA and guidelines was undertaken.

This ESIA process for the Project has also taken cognisance of other relevant Malawian legislation, policies and standards. In the absence of specific guidelines and standards under Malawi legislation, good international industry practice (GIIP) was adhered to, and where relevant, international guidelines and standards applied, such as the International Finance Corporation (IFC) Performance Standards on Environmental and Social Sustainability (IFC, 2012) and the World Bank Group (WBG) Environmental, Health and Safety Guidelines (WBG, 2007). As the Project may require funding from international lenders, the ESIA process and documentation also aimed to comply with the requirements of the Equator Principles (Equator Principles Association, 2013).

A team of international and local environmental specialists was appointed by the proponent to conduct the ESIA process and oversee the various specialist inputs. Dhamana Consulting (an environmental consulting firm based in Australia) was responsible for compilation of the various environmental reports and management of the ESIA process, and was assisted by C12 Consultants (a Malawian environmental consulting firm) and AECOM (South Africa).

3.1 Project Brief

A Project Brief was submitted to the Environmental Affairs Department on 12 June 2017 to initiate the ESIA process for the Project. The Department confirmed in writing on 29 June 2017 that, based on the nature and scale of the activities, an ESIA is required to be undertaken and an ESIA Report submitted, which must be compliant with the Guidelines of Environmental Impact Assessment.

3.2 Environmental Scoping Phase

The main aim of the environmental scoping phase was to identify potential environmental and social issues that require detailed investigation and assessment by the various specialists in the ESIA phase, as well as develop the Terms of Reference for undertaking these investigations.

A draft environmental scoping report (ESR) was made available from 5 March to 13 April 2018 for review and comments by stakeholders. Comments and queries were incorporated in the comments and responses report that forms part of the ESR, and the draft report was amended as needed. The revised ESR was submitted to the Environmental Affairs Department for review and approval of the terms of reference. The Department confirmed in writing on 20 June 2018 that the ESR had identified all the key issues to be addressed in the ESIA report.

3.3 ESIA Phase

The main objectives of the ESIA phase are to identify and assess likely environmental and social impacts; propose appropriate mitigation and management measures, as well as measures to enhance Project benefits; and develop a monitoring plan.

This draft ESIA report is planned to be available from 13 May to 24 June 2019 for review and comments by stakeholders, and the findings will be presented in a series of consultative meetings in early June 2019. Comments and queries will be addressed and the revised report will be submitted to the Environmental Affairs Department for review and approval.

3.4 Specialist Studies

The consultants appointed to undertake the various specialist studies conducted baseline surveys and data collection, with the aim of gaining an understanding of the environmental and social characteristics of the area in which the Project is located. Specialist studies were undertaken in respect of soils, geochemistry, flora, terrestrial fauna, aquatic biology, wetlands, surface and groundwater, noise, air quality, archaeology and cultural heritage, health risk and socio-economic aspects. Specialist studies ensured a thorough understanding of the environmental and social setting within which the Project is located, and enable the specialists to undertake an assessment of the potential impacts associated with the Project.

4 Stakeholder Engagement Process

A comprehensive stakeholder engagement process was implemented as part of the ESIA process, as well as consultation in respect of the RAP. The main aims of stakeholder engagement are to share information and create an understanding of the Project, as well as provide stakeholders with an opportunity to raise issues, concerns and questions. Various stakeholder groups were identified and actively engaged as part of the process. These include government departments and structures; traditional authorities (TAs); affected communities; vulnerable groups of society; civil society organisations (CSOs) and non-government organisations (NGOs); commerce and industry (including the media); and bilateral and multilateral organisations

4.1 Stakeholder Engagement during the Environmental Scoping Phase

A background information document (BID), including a registration and comment form, was compiled in English and translated into Chichewa. The BID contained information on the Project, ESIA process, stakeholder engagement and ESIA team, and invited stakeholders to complete the registration form and submit comments as part of the process.

The Project and ESIA process was announced through a series of stakeholder meetings during the scoping phase from 4 to 7 December 2017. These meetings aimed at engaging stakeholders at national, district and local level. The purpose of these meetings was to provide stakeholders with information about the Project; introduce the ESIA team and proponent; explain the ESIA process that will be undertaken; and give them an opportunity to raise questions and issues. A presentation was given at these meetings, which was based on the information contained in the BID.

A series of meetings were held on completion of the environmental scoping phase from 7 to 9 March 2018 to present and discuss the contents of the draft ESR. The aims of these meetings were to:

- Present a summary of the contents of the draft ESR.
- Identify key issues and concerns that require further assessment during the ESIA phase.
- Present the specialist studies to be undertaken.
- Discuss the extent of, and approach to, the detailed ESIA phase.

4.2 Stakeholder Engagement during the ESIA Phase

As part of its commitment to ongoing consultation with stakeholders affected by the Project, a series of meetings were held between 5 and 10 August 2018. The purpose of these meetings was to provide feedback on the current status of the Project, discuss planned fieldwork activities (particularly exploration drilling) during the second half of 2018, and to serve as a platform to engage with stakeholders on potential resettlement as a result of the Project.

A series of meetings is planned to be held between 10 and 14 June 2019 to present and discuss the contents of the draft ESIA report, as well as the RAP.

5 Key Findings

The key benefits and major negative impacts associated with the Project are discussed below. This discussion does not contain a detailed description of the significance of impacts. For more detail, refer to Chapter 7 of the ESIA report.

5.1 Soils

As dominant soil types in the study area have a moderate to high erodibility, soil will be prone to erosion where vegetation has been removed. Site clearance will increase the risk of erosion, as runoff potential will be increased and exacerbate erosion. Stormwater management measures will be installed to manage surface runoff and remove any suspended solids prior to discharge to the receiving surface water bodies.

Topsoil will be stripped and stockpiled for use during rehabilitation of disturbed areas. Topsoil stockpiles will further be susceptible to erosion due to exposed surfaces.

Stockpiling of topsoil may also further result in changes to the chemical properties, as a result of the anaerobic conditions in these stockpiles. Stockpiles will be revegetated as soon as possible with indigenous grass to reduce the risk of erosion, and to reinstitute the ecological processes within the soil. Changes in soil fertility could result in additional management measures being required, prior to using these soils in rehabilitation activities on site. As phosphorus (P) levels on site are already very low and are expected to decrease as a result of stockpiling, fertilisation will be used as required to establish good crop stand and growth during rehabilitation. In addition, the soil organic carbon content in the Project area is low and an external nutrient input source will be used as required during closure to ensure successful revegetation.

Although the risk of erosion of topsoil will remain over the life-of-mine and post closure, the magnitude of this impact will be reduced significantly through mitigation measures and as vegetation is re-established.

5.2 Land Use

When topsoil is removed from the pit, TSF and infrastructure areas, the land capability will be lost and land use will change from crop production (intensive cultivation) to mining. It is anticipated that an area of approximately 260 ha of agricultural fields and residential housing will be required for the development of infrastructure during the construction and operations phases.

The open pits (an area of approximately 47 ha) will remain as voids upon closure and are anticipated to fill partially with groundwater (approximately to the pre-mining groundwater levels). These areas will, therefore, permanently change from crop production and not return to its original land use. As part of the development of a closure plan for the Project, various options for the sustainable use of the open pits will be investigated, which may include irrigation and aquaculture, depending on the viability of these options. It is the intention that all other areas, including any low grade ore stockpiles and the TSF, will be rehabilitated and returned to the community for use in agricultural activities.

5.3 Terrestrial Biodiversity

Cultivated lands will be the only vegetation community lost as part of development of the Project. Approximately 260 ha of cultivated lands will be cleared, which constitutes 14.8% of this vegetation community within the ESIA study area.

As these cultivated lands continuously change and are not regarded as indigenous vegetation, the environmental significance of this unmitigated impact is considered to be low.

The proposed Project configuration will result in limited disturbance of the dambo grassland (wetlands) vegetation community for the construction of stormwater management infrastructure, while no disturbance of forest fragment or fine-leaf woodland vegetation communities is expected.

An area of approximately 47 ha of cultivated land will be cleared for the open pits. As these pits will not be backfilled and therefore can not be revegetated, this clearance will be permanent. However, as this vegetation community is regarded as highly transformed, this is not regarded as a significant impact.

Biodiversity in the Project area was regarded as low as the area has undergone extensive change through agricultural activities. A general loss of biodiversity can occur directly through vegetation clearing and destruction of habitat, but it is not likely to be significant. The extent to which species will recolonise in the area is dependent on the extent and type of rehabilitation. Areas that will be returned to agricultural use are unlikely to host a wide range of species, and the biodiversity of the Project area is expected to return to similar conditions as prior to Project implementation.

5.4 Wetlands/Dambos

A limited amount (less than 0.5 ha) of vegetation clearing will take place within Kovuma dambo and Dambo 1 for the purpose of constructing clean water diversion drains and stormwater management infrastructure. This clearance, along with changes in the hydrological regime, may cause the loss of wetland biodiversity and habitats, although localised in nature. A reduction of approximately 0.16% in the quantity of catchment runoff is expected (SLR, 2019a). Although the hydraulic conditions may change to some extent, this reduction in volume is regarded as negligible.

Water from the northern pits will be discharged to the Kovuma dambo, north of the Project area. Water from the central pits will be discharged to Dambo 1, which ultimately drains towards the Kamuzu Dam II, while water from the most southern pits will be discharges to a drainage line to the east of the pits. Currently the dambos are seasonal wetlands, which dry out in the dry season and are then inundated again in the wet season. The constant release of water into the wetlands from discharge is likely to result in these wetlands becoming permanent wetlands, although this will only be for the period for which this takes place, i.e. until the end of operations.

In the event that discharge occurs at a higher flow rate compared to baseline rates, turbidity of water in the dambos may increase, which in turn could result in a modification of dambo habitat. These hydrological modifications within the dambo and aquatic habitats due to altered flow velocities and an increase in turbidity levels may impact on the integrity of the habitat and instream biota. To minimise impact, the flow rate will be monitored and discharge will be undertaken to mimic natural conditions as far as possible

Sedimentation from erosion and discharge of pit water containing higher loads of sediment may result in the loss of suitable habitat for certain macro-invertebrate communities, impacting on the integrity of these communities. Silt traps have been designed to discharge water at a rate of between 0.3 and 0.6 m^3/s to ensure adequate time is allowed for sediment to settle out. Measures to reduce erosion and siltation such as erosion control blankets, turf reinforcement matting and riprap have been proposed as part of mitigation considerations. Progressive rehabilitation of these wetland areas (once discharge to a particular wetland area is no longer required) will also ensure no residual erosion impacts remain upon closure.

5.5 Provision of Ecosystem Services

Clearance of vegetation may result in the loss of ecosystem services associated with each habitat and vegetation type. This is especially relevant since the local communities are heavily reliant on these areas as a source of food and traditional medicine, construction materials, fuel wood and as a source of income through activities such as charcoal production. The loss of ecosystem services to communities are addressed through the RAP process, in particular the Livelihood Restoration Plan (LRP).

Increased stormwater runoff and discharge of water to dambos will lead to an increase in water level, flow velocities and sediment loads within dambo habitats, which in turn, may alter the flood attenuation, streamflow regulation, sediment trapping and erosion control service provision of these systems. Implementation and maintenance of the conceptual stormwater management infrastructure will minimise the impact on the ecosystem services provided by the dambos.

As the majority of ecosystem services provided are associated with wetlands in the area, direct and indirect disturbance to these areas are likely to result in the largest impact to these services. Progressive rehabilitation of these wetland areas (once discharge to a particular wetland area is no longer required) will ensure the reestablishment of these services to at least similar conditions as to those prior to implementation of the Project.

5.6 Surface Water Quality

The local surface water resources are considered to be of moderate sensitivity, due to the proximity of the Project site to the various dambos feeding the Lilongwe River (2 km away) and the Kamuzu Dam located 150 m meters from the proposed most southern pit. The Kamuzu Dam is of high importance as it is the main water supply for Lilongwe, the capital city of Malawi. However, baseline water quality measurements indicate existing elevated turbidity and levels of faecal coliform, iron, aluminium, manganese, zinc and antimony.

Unmitigated runoff from the project site could directly affect dambos feeding into the Kamuzu Dam as well as dambos feeding into the Lilongwe River downstream of the dam. Runoff from the tailings and pit waste areas containing elevated aluminium, iron, fluoride and sediment may result in deterioration of water quality in drainage lines and the Lilongwe River. In addition, contamination may occur from runoff from operational areas where accidental spillages of fuels, solvents and chemicals have taken place. Depending on the extent of the spillage or runoff, in the absence of mitigation the project would contribute to the already elevated baseline levels. During operations, discharge of water from the pits that contain levels of suspended solids that are higher compared to existing levels will also occur to the environment.

Sediment control facilities will be operated to ensure water discharged to surface water resources (including the Kamuzu Dam and Lilongwe River) contains a maximum TSS of 50 mg/L. Due to the comparatively small volumes of water that could be discharged (maximum 200 m^3/day or approximately 73,000 m^3 per year) to the Kamuzu Dam II with a storage capacity of approximately 19 Mm^3, it is anticipated that discharge will not significantly contribute to changes in water quality of the Dam or the Lilongwe River.

5.7 Groundwater Availability

Dewatering of the open pits will result in a lowering of the groundwater that will extend beyond the immediate footprint of the open pits. Once mining in a particular pit is complete, dewatering will cease, and the pit left to fill with water to approximately pre-mining groundwater levels.

The cone of drawdown is predicted to reach a maximum depth and extent at the end of the life-of-mine around the central open pits. The cone of drawdown will extend up to 1.2 km from the centre of the open pits. The drawdown will vary between 1 and 27 metres below ground level (mbgl).

A number of community boreholes and hand dug wells are located within the predicted cone of drawdown. Although hand dug wells are not directly connected to the aquifer in which dewatering will take place, vertical flow does occur. It is expected that a partial to complete loss of water would be experienced in boreholes and hand dug wells within the cone of drawdown, impacting on communities who are reliant on groundwater for domestic and subsistence agricultural purposes. Water will be provided by the Project to impacted communities from water earmarked for discharge to the environment.

Upon closure groundwater levels will return to levels similar to what was encountered prior to Project implementation. Drawdown of between 1 and 5 m will remain long-term after closure in the northern extent of the open pits. However, no existing community boreholes were identified in this area that would be adversely affected.

Given that the dambos are fed by rain and surface water runoff, and are not hydraulically linked to any of the aquifers, a drop in groundwater levels is not expected to impact on the availability of water within the dambos.

5.8 Contamination of Aquifers

Contamination of groundwater has the potential to negatively impact groundwater users within the zone of impact and potentially result in health impacts, as groundwater in the area is used for domestic purposes.

Contamination of groundwater may result from ad hoc spills and discharges of substances such as fuel and reagents, as well as more significant long-term pollution associated with permanent structures such as the TSF. The simulated groundwater modelling focussed on potential impacts from the TSF as no other significant sources of contamination will remain on site post-closure.

The seepage quality from the proposed TSF is predicted to be pH neutral, with water quality guideline exceedances for aluminium (Malawian Drinking Water Specification, 2005) and fluoride (Malawian Drinking Water Specification, 2005 and WHO Standard for Drinking Water, 2017). It is worth noting that baseline water quality already exceeds these standards for aluminium in some of the sampled sites.

A seepage plume at concentrations above the Malawian Drinking Water Specification for aluminium and fluoride is predicted to extend off-site, approximately 550 m downgradient of the TSF by Year 100. The extent is understood as the limit where simulated concentrations have a zero value.

No groundwater users are known to occur within this predicted impact zone.

The impact from ad-hoc spillages and discharges will be mitigated by reclamation and remediation of impacted soils prior to the substances entering the groundwater.

5.9 Air Quality - Dust, $PM_{2.5}$ and PM_{10}

Clearing of vegetation, soil stripping, excavation, hauling, stockpiling of material and the use of generators will result in the generation of fugitive dust comprising total suspended particles (TSP), PM_{10} and $PM_{2.5}$, especially from unsealed roads and open surfaces.

Without mitigation, the daily WHO Air Quality Guidelines (2005) for ground level concentrations of $PM_{2.5}$ of 25 µg/m^3 is expected to be exceeded at receptors in close proximity to the Project, including at Kumalindi, Chitsulo and Kubale. The predicted annual ground level concentrations of $PM_{2.5}$ of 8 µg/m^3 are also expected to exceed the WHO Air Quality Guidelines at Chitsulo.

In the absence of mitigation, the daily Malawi Standard for Ambient Air Quality (2005) for ground level concentrations of PM_{10} of 25 µg/m^3 is expected to be exceeded at all nearby communities, as well as the more distant settlement of Malingunde. The predicted annual ground level concentrations are expected to exceed the WHO Air Quality Guidelines (2005) of 20 µg/m^3 at Chitsulo and Kubale.

The predicted dust deposition rates (represented as TSP) were compared to the South African Standard (Dust Control Regulations, 2013) in the absence of Malawi-specific guidelines for dust deposition. The model indicated that the residential limit of 600 mg/m^2/day and the non-residential limit of 1,200 mg/m^2/day are expected to be exceeded up to 2 km from the Project activities without mitigation measures in place (worst case scenario). The modelling results with mitigation measures demonstrate that the distance from the Project where exceedances are expected is reduced to 823 m from the Project infrastructure and would extend as far as the villages of Chitsulo and Kubale.

Implementation of the recommendation mitigation measures, particularly the application of wetting agents and dust suppressants is expected to satisfactorily reduce emissions at nearby sensitive receptors. However, increased emissions are still likely at Project facilities. Ongoing monitoring will be undertaken during construction and operations to determine the level of dust and particulate matter to determine if further mitigation is required.

5.10 Air Quality - SO_2 and NO_2

An increase in sulfur dioxide (SO_2) and nitrogen dioxide (NO_s) is expected as a result of the use of diesel powered generators on site and from fuel consumption in vehicles. Model predictions indicate that the SO_2 ground level concentrations are expected to be below the Malawi Air Quality Guideline (2005) values for the 1-hour, daily and annual averaging periods.

The 1-hour NO_2 ground level concentrations are expected to be higher than the Malawi Air Quality Guideline value of 230 µg/m³ at all communities in the vicinity of the Project, and as far away as the settlement of Malingunde. Emissions of this pollutant will be mitigated by the use of catalytic converters, which has the ability to reduce emissions by up to 80%.

5.11 Greenhouse Gas

The Project is estimated to contribute 13,878 t CO_2-e per annum during construction, 29,504 t CO_2-e per annum during the first 3 years of operations, and 19,410 t CO_2-e per annum from Year 4 of operations onwards. Malawi's total greenhouse gas emissions in 2011 was estimated to be approximately 10.85 million metric tonnes of carbon dioxide equivalent (Mt CO2-e), which is equivalent to 0.02% of global GHG emissions. The Project will contribute approximately 0.18% of Malawi's GHG emissions from Year 4 following connection to the national electricity grid until the end of the life-of-mine. This is not considered a significant contribution compared to other sources of emissions in the country.

5.12 Noise

An increase in noise at nearby receptors is expected as a result of a range activities on site, including vegetation clearing, construction of roads, assembly of the processing plant, establishing of the ROM pad, construction of the TSF, mining activities in the pit, power generations, haul of ore, operation of the processing plant and loading of product onto trucks.

Although the day-time limit value of 55 dBA as per the Malawi Noise Pollution Tolerance Limits (2005) and IFC EHS Guidelines (2007) would not necessarily be exceeded at all receptors, in many instances it would result in an increase of more than 3 dBA over ambient noise levels, which as per the IFC EHS Guidelines (2007), would require appropriate noise mitigation measures to be adopted.

Calculations undertaken using the noise model, indicated that the noise level is generally expected to be approximately 55.2 dBA at a distance of 50 m from the rim of the open pits when open pit mining activities take place. This noise level, in some instances, represents an increase of between 10 dBA and 15 dBA. A 10 dBA change in the sound level is perceived as twice as loud as the original.

The noise exceedance from open pit mining activities is expected to be most significant during the pre-stripping activities at surface, which would be undertaken for a relatively short period of two to three months. Thereafter, in most instances, the mining equipment would be at least 5 m below ground (or deeper) and the noise intrusion would reduce as equipment moves further below the surface.

Noise modelling has indicated that construction of an earth berm between the open pit mining activities and nearby noise receptors will significantly reduce the noise intrusion levels It is anticipated that the noise intrusion level at a distance of 50 m from the rim of the open pits, will not exceed 3 dBA in the event that a noise berm of approximately 4 m high is placed at a distance of 10 m from the rim of the open pit.

5.13 Physical Displacement Caused by Land Acquisition

Land acquisition and land clearance activities will involve the demolition and removal of houses and structures, clearance of vegetation and the establishment of security fencing. It also involves relocation of people who are currently residing within the Project footprint.

Based on the findings of the RAP survey, clearance of the exclusion zone will displace a total of 367 structures, which belongs to 123 households; almost a third of these structures (108) are homestead compounds or residential buildings with supporting structures (toilets, bathrooms, kraal, granary, store rooms) and 5 structures used for economic purposes. Households facing displacement during Phase 1 are mainly from Kumalindi Villages, whereas Phase 2 displacement could potentially affect households from Kubale, Chitimbe, Jaulani, Kokotani, Ndumila II, Pingeni and Chikosi Villages.

It is important to note that the bulk of physical displacement will be as result of acquiring land required for Phase 2 mining activities (99 homesteads), whereas Phase 1 activities will likely only displace 9 homesteads.

5.14 Economic Displacement Caused by Loss of Land, Grazing and Business Assets

A total of 5 small-scale business structures within the exclusion zone are likely to be impacted, all of which are within the phase 2 resettlement zone. These typically take the form of kiosks, road side trading stalls, facilities to brew and sell beer, and sales of agricultural produce from homes or at village markets, etc. Displacement of structures or facilities used for such business activities is regarded as economic displacement, since it would result in a loss of income from those activities until alternative facilities can be established elsewhere.

The loss of agricultural fields will also result in a loss of income and food supply for those affected. Approximately 583 fields belonging to 523 households will be impacted by displacement. Given the low incomes and the high dependency on agriculture as a primary source of livelihood in the Project area, economic displacement will likely result in a reduced standard of living and quality of life, and is likely to impact the food security of households. The most impacted will be receptors solely dependent on agriculture as their source of livelihood, and this will be exacerbated due to the low level of financial and other assets that they have access to and on which they could re-establish livelihoods.

Impacted households/individuals will be provided with the option to receive in-kind or cash compensation for the loss of economic assets and resources. Those households/individuals that opt for cash compensation will be offered training in basic financial literacy and management. This will be provided as part of the livelihood restoration plan.

5.15 Increased Income Leading to Improved Individual and Household Wellbeing

Approximately 220 workers will be employed at peak demand during construction, of which 160 will be filled by local/Malawian employees. During operations an estimated 250 to 260 people will be employed.

Local workers from the surrounding Malingunde area will be given preference for job opportunities, depending on their skills level, as it is anticipated that available jobs will be largely low-skilled or semi-skilled. Project employment during construction and operations will increase the level of income of the employed individual and will likely contribute to improved individual and household wellbeing.

5.16 Local Economy and Economic Opportunities for Small Businesses

Several economic benefits through direct and multiplier effects, stimulated by capital expenditure on construction and operations activities, are expected as a result of the Project. Large scale construction activities will increase the demand for a wide variety of goods and services, and as a result will stimulate and/or sustain growth within the region's manufacturing and service sectors. This economic environment will likely also generate opportunities for micro and small businesses in the immediate area (e.g. shops within Kumalindi and other nearby villages), provided they are formalised and able to meet the procurement requirements of the proposed Project. Regardless of whether these businesses become suppliers to the Project, it is expected that they will experience improved markets and increased numbers of customers for consumable items they sell, and services offered (primarily resulting from the Project-induced influx).

Any local and regional procurement spend will enhance the positive economic impact of the Project, as the revenue accruing to enterprises will produce beneficial downstream impacts on the local and regional economy. Given that a significant proportion of money derived from wages earned would likely be spent within the local and regional area, it is expected to create substantial flows of revenue within surrounding communities, thus acting as a catalyst for growth in the economy.

Apart from employment creation, the Project would be expected to contribute to community development and invest in local social infrastructure and/or services, which will be detailed in a separate Community and Social Development Strategy.

5.17 Increased Government Revenue through Royalties and Taxation

The Project will generate government revenues during the operational phase in the form of taxation (30%) and royalties (5% of net sales revenue). Estimated tax payable over the life-of-mine is US$150 million, with an additional US$50 million in royalties. The overall level of revenue generated by the Project is anticipated to create a noticeable increase to total government revenues. Increased business activity around the Project will also provide increased tax revenue to government. Such an injection into government structures could contribute to the development of the region and district in general, thereby creating conditions conducive to economic growth.

5.18 Loss of Access to Community Assets and Infrastructure

Acquisition of land for the Project will lead to the loss of boreholes and other community assets such as land used for harvesting traditional medicine. Without mitigation it may mean that communities will have to travel greater distances to access similar assets and infrastructure, and it will place increasing pressure on assets and infrastructure in neighbouring villages.

Lost community assets and infrastructure would need to be restored to minimise the detrimental impacts on communities. Consultation with the relevant impacted community will be undertaken to develop the most efficient and tailored approach to asset restoration. The final RAP will include a full inventory of all community assets that will be displaced.

The development of the Project infrastructure will likely lead to the disruption of the existing local network of roads, tracks and paths used by local communities to access agricultural fields, local villages and the Kamuzu Dam, specifically those in and near Kubale and Ndumila in the south, and Chitsulo and Kumalindi towards the north of the Project. New routes will be established for affected communities to bypass the Project site.

5.19 Project-induced Migration (Influx)

The movement of people to an area to take up employment or in anticipation of employment or other economic opportunities is referred to as influx. Project-induced migration or influx to the Project area and surrounding villages may lead to reduced individual and community well-being. Influx generally results in an increased local population, and in some situations can lead to the loss of identity and sense of place in the host communities. It may also result in increased use of land and community resources, and an increase in crime and other social ills, such as alcohol and drug abuse, and prostitution.

Project workers, contractors, their families and others looking to benefit from the Project from outside of the host communities may have different backgrounds and cultural values to those of the host communities. This may result in changes to the sense of place and community identity as the way of life within the impacted local communities change.

Another likely consequence of influx is increased pressure on local housing, social infrastructure and services, including education and healthcare facilities, as well as places of worship. Both education and healthcare facilities within the Project area are currently affected by inadequate infrastructure and resourcing, and the current capacity of the local social infrastructure and services to absorb a higher number of users is extremely limited.

An influx management plan will be developed prior to development of the Project to manage impacts associated with project-induced migration.

5.20 Inflationary Pressures Caused by Project-related Demand

Influx, procurement by the Project from local suppliers, and increased disposable incomes for Project employees have the potential to create inflationary pressures by increasing demand for local goods and services, thereby increasing the cost of living for local communities. Inflation can also be driven by increased expenditure of people who have received payments from land acquisition. Increase in prices without a corresponding increase in incomes can make goods and services unaffordable for some households and lead to increased risk of impoverishment, deteriorating standards of living, and food insecurity. Households that are cash poor and depend mainly on subsistence-based activities are particularly at risk and will be more vulnerable to inflationary pressures.

Procurement by the Project of large quantities of local produce (e.g. vegetables for use in on-site catering) may result in a noticeable increase in prices for local people. Monitoring will be undertaken of costs in local markets during construction and operations, and procurement processes adapted if marked inflation is observed.

5.21 Impact from Increased Traffic on Roads in the Area

Existing vehicle traffic in the Project area is limited and the main forms of traffic include pedestrians, bicycles, animal-drawn carts, and livestock. An increase in large trucks, delivery vehicles, buses and light motor vehicles, particularly along the S124 secondary road is expected to support Project activities. The increase in traffic flow of larger vehicles is likely to result in increased noise and dust; disruption of day-to-day activities such as livestock rearing; accidental damage to assets; and potential injuries to existing road users.

A Traffic Management Plan that includes safety measures such as speed restrictions, a signals network, driving rules and community awareness programs will be developed prior to construction of the Project commencing.

5.22 Unauthorised Access to Project Area

Key Project security provisions will include perimeter fencing installed around the processing plant and mine services area. Fences will be galvanised fence poles concreted into the ground with galvanised chain-wire security type mesh of approximately 2.1 metres high, with three strands of barbed wire at the top of the fence. Open pit areas, the TSF and ore stockpiles will not be fenced off due to their significant spatial extent, with access restricted by an earthen bund.

As the Project area has never been used for industrial or mining activities before, the local population is unlikely to be accustomed to the safety aspects and adjustments required to avoid potential hazards related to alteration of the local terrain through the earthworks/excavations, establishment of industrial facilities, utilities, power transmission lines, the presence of mobile and stationary equipment and machinery. This creates a risk of accidents if there is unauthorised access to the unfenced areas for any kind of purpose (e.g., purely out of curiosity, with intention to find something valuable that might be further practically used or sold, attempting to undertake artisan small-scale mining, etc.). Such cases have a potential to lead to health and safety incidents, i.e. unintentional injuries and fatalities.

5.23 Dependency on the Project to Sustain the Local Economy Post-closure

A considerable number of people and their families will likely become increasingly dependent on the Project for their livelihood. Employment opportunities associated with the proposed Project will be lost at closure, as will be the corresponding project benefits such as community development programmes (if undertaken). Job losses and retrenchment would lead to a loss of income and local expenditure. Unemployed staff may be unable to pay for loans on houses, education, or service their debts on cars and other acquired assets. Taking into consideration the likely dependency on employee income, the loss of income will have considerable negative impact on the wellbeing of households where employees were the sole breadwinners.

Suppliers could also be affected as the opportunity to sell goods and services to the Project will be lost. This could furthermore affect those companies that supply these businesses with goods and services. Alternative livelihood and socio-economic development opportunities for employees will be identified, as well potentially sustainable community-based development projects. Employee training programs will be developed to enable transitioning to alternative employment opportunities.

5.24 Disturbance of Cultural Heritage Sites

Direct impacts are foreseen on four archaeological sites, mainly consisting of Iron Age Sites containing pottery, as well as the grave of Gogo Nkhungulo.

Subsurface probing will be undertaken (test pitting at intervals) of archaeological sites to adequately assess their significance and integrity. Procedures for preservation and protection of sites and artefacts of archaeological significance, specified by the Monuments and Relics Act, 1991, will be followed. Graves that cannot be avoided will be relocated in accordance with the requirements of the Monuments and Relics Act and Public Health Act, 1968.

Heritage resources within 150 metres from the mining infrastructure that could be indirectly impacted during the operations phase include Mbonekera burial ground and forest; Ndumila 1 burial ground; Kubale burial ground and one bwalo. Sites will be clearly demarcated and monitored throughout the life of the Project to ensure no disturbance has occurred.

5.25 Interruption of Access to Cultural Heritage Sites

Indirect impacts may be experienced in the event that the exclusion zone prohibits access to cultural activities such as the sites of churches, burial grounds, ceremonial places (bwalo) and the dambwe (sacred forest areas) of Mbonekera and Ndumila I. However, it is unlikely that such access would be prohibited and activities would be allowed to continue, although access would need to be managed to avoid potential safety incidents at nearby infrastructure and open pits.

6 Conclusion

The significance of the residual impacts varied from very low to moderate (with the implementation of management measures). Mitigation and management measures were proposed that are consistent with good international industry practice and demonstrated that mitigation of impacts is readily achievable.

The Project is committed to implementing all management measures proposed in this report, as well as developing a detailed ESMP. The ESMP will contain a series of sub-plans focussing on aspects that will require management, along with operational procedures to ensure practical mitigation and management measures are implemented throughout the construction, operations, and decommissioning and closure phases.

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Appendices

Units and Symbols

°	degrees
°C	degrees Celsius
%	per cent
% w/w	weight to weight ratio, percentage by weight
Bq	becquerel
g	gram
GJ/h	gigajoules per hour
ha	hectare
kg	kilogram
kg/y	kilogram per year
kL	kilolitre
km	kilometre
km^2	square kilometre
kV	kilovolt
kW	kilowatt
kWh	kilowatt hour
L	litre
L/h	litres per hour
L/y	litres per year
m	metre
mamsl	metres above mean sea level
masl	metres above sea level
mbgl	metres below ground level
µg	microgram
µm	micrometre
mg	milligram
mg/L	milligram per litre
mm	millimetre
m^2	square metre
m^3	cubic metre
m^3/d	cubic meter per day
m^3/h	cubic meter per hour
Mm^3	million cubic metres
mS	millisiemens
mS/m	millisiemens per metre
mSv	millisieverts
Mt	million tonne
MW	megawatt
t	tonne
t/h	tonnes per hour
t/m^3	tonnes per cubic metre
t/y	tonnes per year
y	year

Terms and Abbreviations

ADC	Area development committee
ASPT	Average score per taxon
ASX	Australian Securities Exchange
attritioning	High intensity mechanical agitation of a slurry to clean and prepare mineral surfaces for flotation or other processes.
CBO	Community-based organisation
CEDAW	Convention on the Elimination of all Forms of Discrimination Against Women
dambo	Seasonally waterlogged, predominantly grass covered, shallow depressions (wetlands) bordering headwater drainage lines.
DFS	Definitive feasibility study
DWA or DWAF	South African Department of Water Affairs and Forestry
EAD	Environmental Affairs Department
EC	Electrical conductivity
EIS	Ecological integrity and sensitivity
EMA	Environment Management Act (No. 19 of 2017)
EPFI	Equator Principles Financial Institution
EPL	Exclusive prospecting licence
ESIA	Environmental and social impact assessment
ESMS	Environmental and social management system
ESMP	Environmental and social management plan
ESR	Environmental scoping report
GIIP	Good international industry practice
G.N.	Government notice
HDPE	High-density polyethylene
HIV/AIDS	Human immunodeficiency virus / acquired immune deficiency syndrome
IFC	International Finance Corporation
IHAS	Integrated habitat assessment system
IUCN	International Union for Conservation of Nature
MBS	Malawi Bureau of Standards
MCE	Maximum credible earthquake
MDE	Maximum design earthquake
MRE	Mineral Resource Estimate
MS	Malawi Standard
NEAP	National Environmental Action Plan
NEP	National Environmental Policy
NGO	Non-government organisation
No.	Number
OP	Operational policy

PCD	Pollution control dam
PES	Present ecological state
PFS	Pre-feasibility study
PGA	Peak ground acceleration
refractory	Any material that has an unusually high melting point and that maintains its structural properties at very high temperatures
ROM	Run-of-mine
RWD	Return water dam
SADC	Southern African Development Community
SARCOF	Southern African Regional Climate Outlook Forum
SASS5	South African Scoring System (Version 5)
SAWQG	South African Water Quality Guidelines
TA	Traditional authority
TDS	Total dissolved solids
TGC	Total graphitic carbon
TSF	Tailings storage facility
TSS	Total suspended solids
TWQRs	Target Water Quality Ranges
UNESCO	United Nations Educational, Scientific and Cultural Organisation
US$	United States Dollar
VDC	Village development committee
V:H	Slope gradient - described as vertical rise (V) to horizontal run (H)
VIA	Visual impact assessment
WBG	World Bank Group
WET	Whole effluent toxicity
WHO	World Health Organization

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Chapter 1: Introduction

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1 Introduction

1.1 Project Overview

Sovereign Metals Limited (Sovereign) is proposing the development of an open pit graphite mine and processing plant at Malingunde in Malawi. The Malingunde Graphite Project (the Project) is located approximately 20 kilometres (km) southwest of Malawi's capital city of Lilongwe and falls within the Lilongwe District of the Central Region (Figure 1.1). The Project area is located in the Masumbankhunda Traditional Authority and lies directly north of Kamuzu Dam II, in proximity to the villages of Kumalindi, Ndumila and Kubale.

The deposit at Malingunde is a large high-grade saprolite-hosted flake graphite deposit, situated on the Lilongwe plain. Saprolite is the very soft, clay-rich oxide material that is formed through intense weathering of the original bedrock (Plate 1.1). This deposit is the world's largest reported soft saprolite-hosted graphite resource.

Plate 1.1: Saprolite-hosted Flake Graphite

The Project has the potential to deliver a high quality graphite product with excellent concentrate grades and a very large proportion in the 'super jumbo', 'jumbo' and 'large' flake size categories.

Sovereign is currently still engaged in a number of technical studies, which will culminate in a definitive feasibility study (DFS), to determine the financial viability of developing a mine at Malingunde. An economic scoping study for the Project was completed in mid-2017, while the pre-feasibility study (PFS) was completed in October 2018.

The total capital cost for the development of the Project is estimated at approximately US$49 million, with the total operating costs averaging approximately US$16 million per annum, equivalent to US$323 per tonne of concentrate. Revenue from product sales will average US$62 million per annum over the life-of-mine. The Project will generate government revenues during the operational phase in the form of taxation (30%) and royalties (5% of net sales revenue) as well as flow on benefits through indirect taxation of wages and other indirect taxation benefits. Estimated direct tax payable over the life-of-mine is US$150 million, with an additional US$50 million in royalties.

Sovereign is now moving into the next phase of Project development activities, namely the DFS with an aim to bringing the Project into construction in 2020. The DFS will likely be completed by late 2019. It is anticipated that an application for a mining licence will be submitted to the Department of Mines alongside this ESIA report.

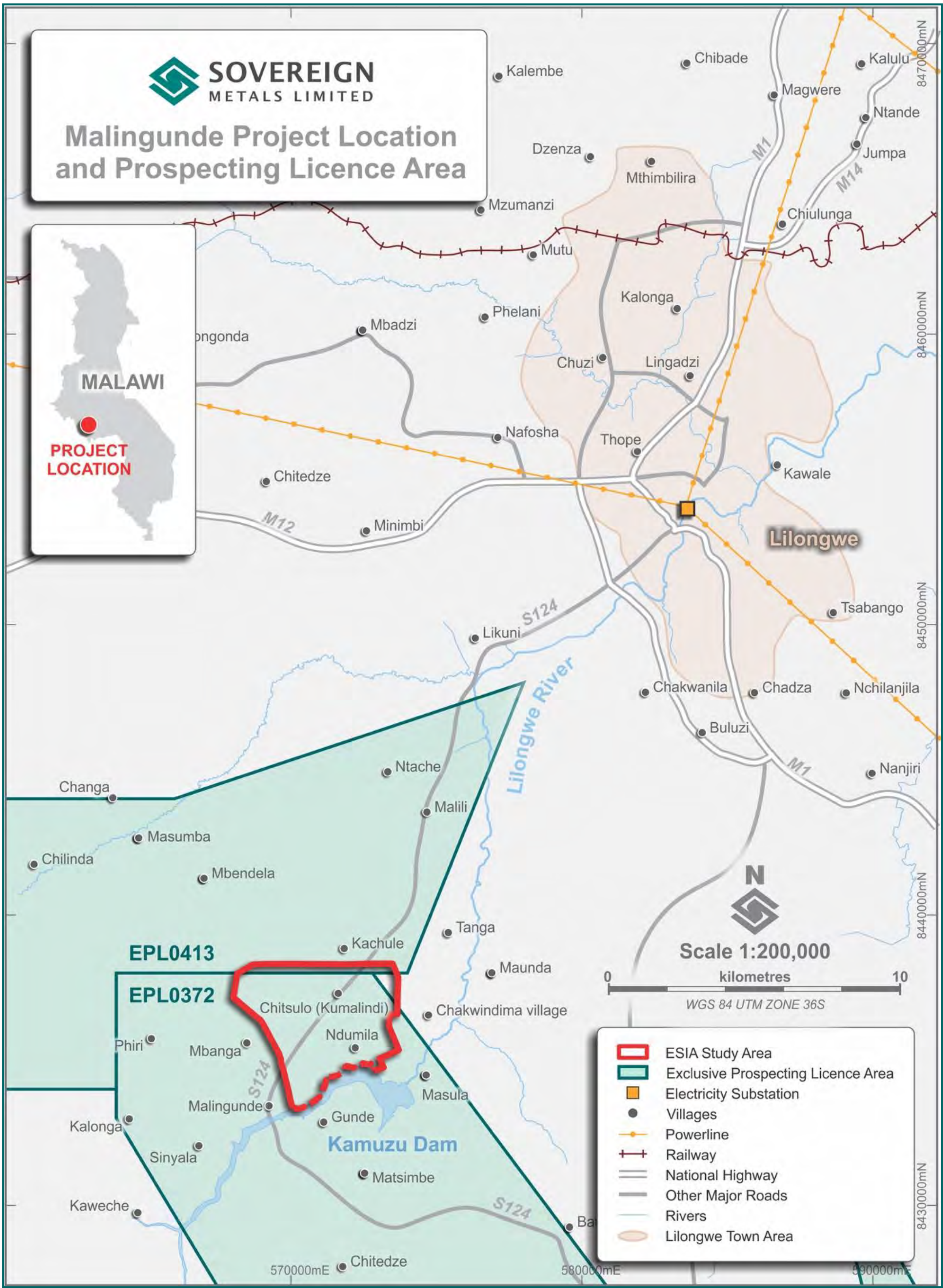

Figure 1.1: Malingunde Project Location

A detailed Project description and conceptual layout of the mining infrastructure is provided in Chapter 2.

1.2 The Proponent

Sovereign is an Australian publicly listed company that trades on the Australian Securities Exchange (ASX) under the code ASX:SVM. Sovereign is engaged in exploration and appraisal of resource projects, with the main focus being its 100% owned Malingunde Saprolite-hosted Graphite Project. Sovereign's other project interests include the Duwi Flake Graphite Project in Malawi, as well as the Carpentaria Joint Venture, a joint venture with Mount Isa Mines in Australia.

Sovereign forms part of the Apollo Group of companies, which have had considerable success in identifying and acquiring world class projects in commodities such as gold, coal, uranium, iron ore, and base metals. Apollo Group has then guided these projects through the exploration, feasibility and development phases by ensuring they have the necessary management and technical skills, investor support and funding from capital markets.

McCourt Mining Pty Ltd (McCourt Mining) is a wholly owned subsidiary of Sovereign and was acquired by Sovereign in September 2012. McCourt Mining is the licence holder of the exclusive prospecting licence (EPL), EPL0372, an area of 732 km^2 in which the Project is located (Figure 1.1). In this report, Sovereign and McCourt Mining is used interchangeably.

1.2.1 Tenure

The Mines and Minerals Act (1981) of Malawi is the governing legislation for the prospecting, exploration and exploitation of minerals in Malawi, administrated by the Ministry of Natural Resources, Energy and Mining. The Mines and Minerals Bill, 2015 was developed to improve on the Act and bring legislation in line with legislation and practice in the region, and was assented to in February 2019, although the new Act has not been gazetted at the time of writing this report.

The Malawi Government is supportive of investors undertaking exploration and eventual exploitation of the country's mineral resources with multiple programs and country wide exploration programs currently underway as a result of foreign investment.

Three classes of licences exist under the Mining Act, namely:

- Reconnaissance licence (RL).
- Exclusive prospecting licence (EPL).
- Mining licence (ML).

An RL is an exclusive licence granted for a maximum of one year over an area no greater than 50,000 square kilometre (km^2) and may be extended on an annual basis for 12 months upon the Minister's approval of an extension application. Ground disturbance activities such as drilling or trenching are not allowed to be carried out under this licence type.

An EPL may be granted for up to three years and extended at most twice for a further two years per extension over an area of no more than 2,500 km^2. A reduction of the spatial extent of a minimum of 50% should occur at each extension, however an increase in the size may be granted upon application to the Minister.

The terms of an ML are significantly more detailed and complex but may not exceed 25 years in period. An ML may be renewed upon application to the Minister.

McCourt Mining has acquired a number of licences for exploration of graphite since 2014, including EPL0355, EPL0372, EPL0413 and EPL0492 (Table 1.1). With the exception of EPL0492, all licences have one more extension period available (EPL0492 has 2 renewable periods).

Table 1.1: Exclusive Prospecting Licence Details

Exploration Licence	Area (km^2)
EPL0355	189
EPL0372	732
EPL0413	1,077
EPL0492	1,895
EPL0528	21
EPL0537	339

1.3 Project Development

1.3.1 Project History

During November and December 2012 a survey program using heli-borne versatile time domain electromagnetic (VTEM) was undertaken to better understand the highly prospective rock packages of the Company's tenement holdings. During late 2014, regional exploration efforts focussed on areas of interest defined by the VTEM program utilising wide spaced ground electromagnetic surveys, resulting in the definition of 43 high priority conductors at Lifidzi and 20 at Malingunde. It was hypothesised that these conductors represented highly graphitic bedrock and that the Lilongwe Plains area had a mostly preserved, deep tropical weathering profile favourable for saprolitic flake graphite deposits.

In 2015, Sovereign's in-country geological team made the significant saprolite-hosted graphite discovery at Malingunde using hand augering.

Following the discovery, extensive drilling was carried out over 3.4 km of strike length which led to the maiden Mineral Resource Estimate (MRE) being released in April 2017.

Subsequently, AMEC Foster Wheeler was engaged to conduct an economic scoping study, which was completed in June 2017.

The PFS for the Project commenced in November 2017, with a number of aspects being considered in more detail to determine the viability of developing the Project. This included:

- Mineral Reserve estimation.
- Mine planning, design and scheduling.
- Process plant design.
- Transport route investigation.
- Project cost estimation and financial modelling.
- Low grade and ore stockpile design.
- Tailings storage facility design.
- Surface water infrastructure design.
- Metallurgical testwork.

The PFS was completed in October 2018 and confirms the financial attractiveness of the Project, and provides the rationale to move the project to a DFS stage.

1.3.2 Project Development Schedule

It is anticipated that this next phase of study will include:

- Completion of a pilot plant program to confirm the flowsheet at a large scale, and to provide significant quantities of material for assessment by potential offtake partners.

- An infrastructure assessment program aimed at identifying opportunities to enhance the Project economics through further capital and operating cost reductions.
- Detailed design and engineering of the process plant and associated infrastructure.
- Ongoing marketing and further discussions with Tier 1 end users and traders of graphite.
- Advancement of product transport and logistics agreements, particularly focused on completing a binding rail transport agreement with the rail concessionaire, Central East African Railways.
- Commencement of meaningful discussions with finance providers with the intent of securing funding for the development and construction of the Project.

The Project development schedule is indicated in Figure 1.2.

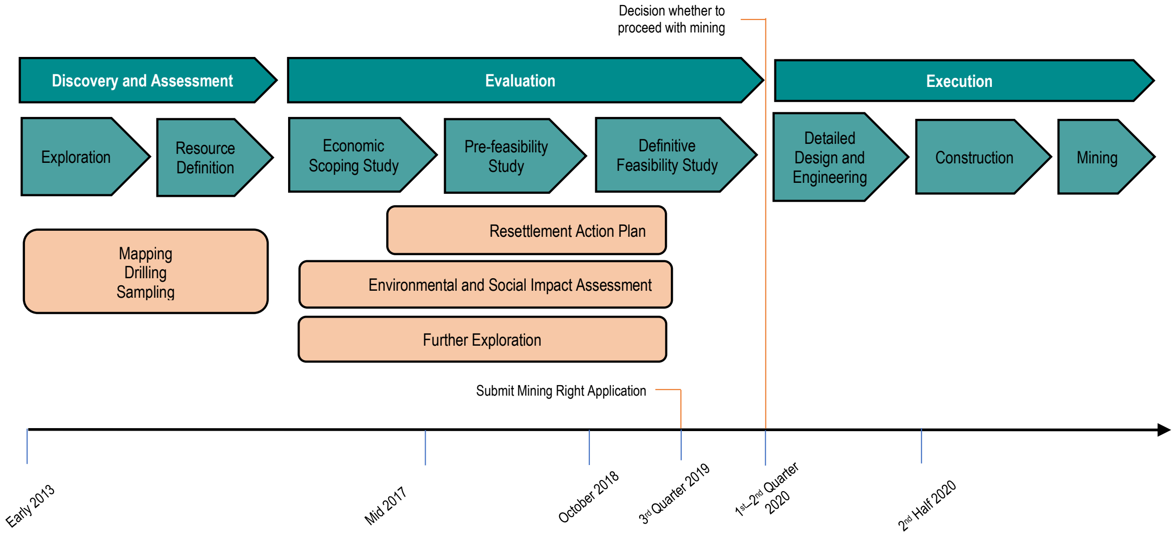

Figure 1.2: Project Development Schedule

Development of the project is dependent on the following:

- Approval of the ESIA Report.
- Approval of the Resettlement Action Plan (RAP), including consultation with all relevant stakeholders and affected households.
- Completion of a Community Development Agreement.
- Completion of Development Agreement with Malawi Government.
- Finalisation of offtake sales agreements with end users.
- Completion and approval of Mining Licence Application
- Obtaining financing for the Project.

1.4 Global Graphite Demand

Flake (or crystalline) graphite is the term for a form of carbon with a layered structure of particles which have a flat and thin morphology and graphitisation of between 95 and 100%.

The primary end-market for flake graphite is the refractory, foundries and crucible sector which consumed approximately 616,000 t of flake graphite production in 2016. The refractory industry is the volume driver for flake graphite, with foundries and crucibles offering smaller markets for higher purity graphite products. The majority of flake graphite production is consumed by magnesia-carbon bricks, a mainstream, global refractory brick used in the steel industry.

The battery sector is the main emerging market for flake graphite. Spherical graphite required in many lithium-ion batteries and the need for greater capacity batteries, such as the ones required for electric vehicles, are expected to drive significant demand from this sector over the coming years.

1.5 Development of the ESIA

The Environment Management Act (EMA), No. 19 of 2017 provides the legal framework for protection and management of the environment of Malawi, as well the preparation of an environmental and social impact assessment (ESIA) for prescribed projects.

Section 2(f) of the EMA states that an ESIA is a legal requirement for any project that may significantly affect the environment and use of natural resources. The general principles also state that precautionary measures must be taken to prevent or mitigate possible detrimental environmental effects of any project, even where scientific evidence is not certain.

In 1997, the Environmental Affairs Department published the Guidelines of Environmental Impact Assessment for Malawi. The purpose of the guidelines is to integrate environmental concerns in national development, and are applicable to all types of projects in the public and private sectors for which ESIA studies may be required, as identified in the lists of prescribed projects (List A and List B) appended to the guidelines. List A identifies projects for which an ESIA is mandatory, and includes mining of minerals, expansions to mines, mining exploration activities, minerals prospecting activities, quarries, gravel pits and removal of sand or gravel from shore lines. The Project falls under this prescribed list of activities, and as such McCourt Mining has commissioned an ESIA process to support an application for environmental authorisation. McCourt Mining will be the applicant for the applicable environmental authorisation as they are the holder of the EPL in which the Project is located.

The ESIA process in Malawi is generally undertaken in three distinct phases, namely the Project Brief, Environmental Scoping and ESIA phases (Figure 1.3). Guidelines for undertaking the process and compilation of the ESIA report have been developed by the Government of Malawi, and were adhered to during the ESIA process for the Project.

This ESIA process for the Project has also taken cognisance of other relevant Malawian legislation, policies and standards. In the absence of specific guidelines and standards under Malawi legislation, good international industry practice (GIIP) was adhered to, and where relevant, international guidelines and standards applied, such as the International Finance Corporation (IFC) Performance Standards on Environmental and Social Sustainability (IFC, 2012) and the World Bank Group (WBG) Environmental, Health and Safety Guidelines (WBG, 2007).

As the Project may require funding from international lenders, the ESIA process and documentation also aimed to comply with the requirements of the Equator Principles (Equator Principles Association, 2013).

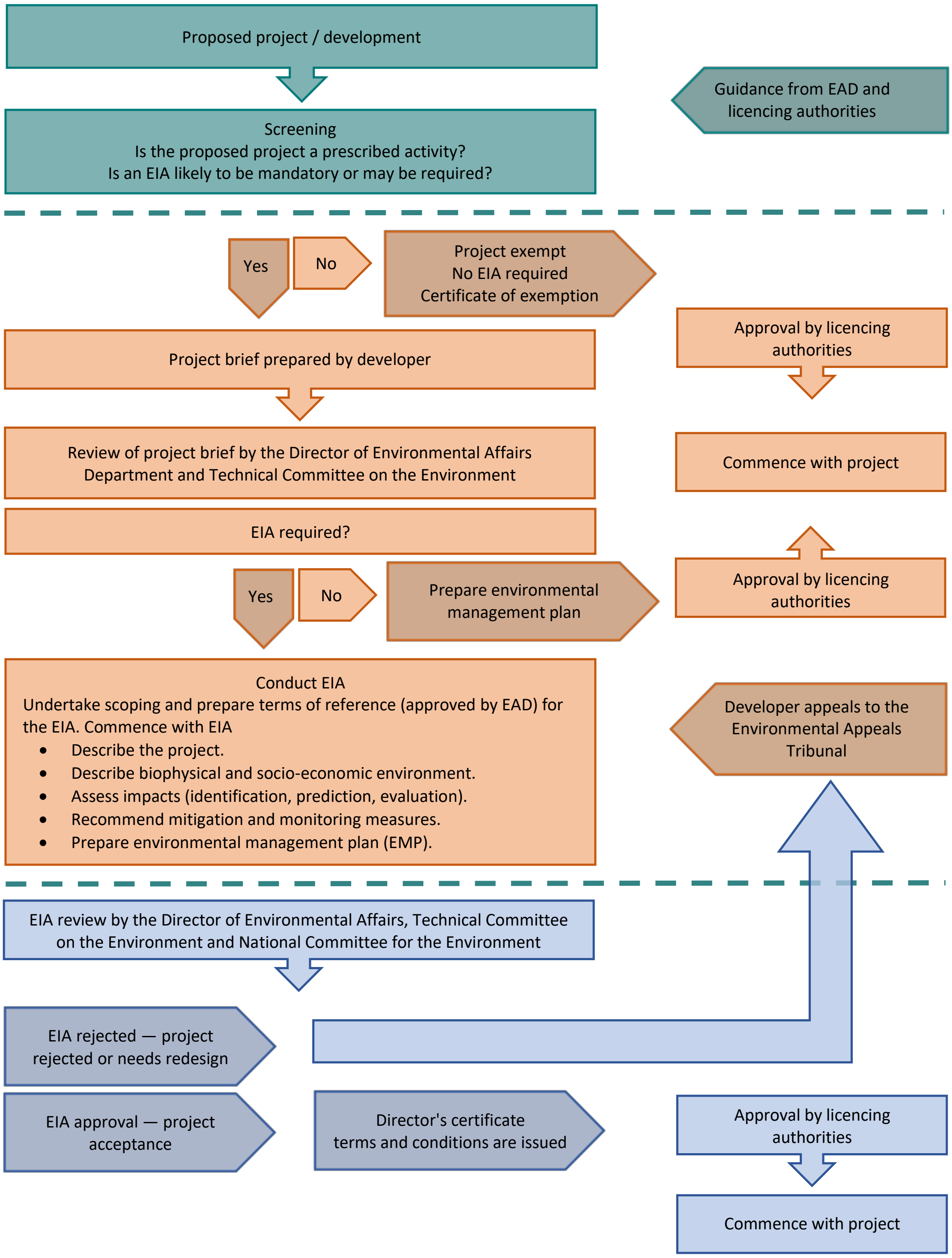

Figure 1.3: Environmental and Social Impact Assessment Process, Malawi

1.5.1.1 Project Brief

A Project Brief was submitted to the Environmental Affairs Department on 12 June 2017 to initiate the ESIA process for the Project. The Department confirmed in writing on 29 June 2017 that, based on the nature and scale of the activities, an ESIA is required to be undertaken and an ESIA Report submitted, which must be compliant with the Guidelines of Environmental Impact Assessment. The Terms of Reference provided by the Environmental Affairs Department are attached in Appendix A.

1.5.1.2 Environmental Scoping Phase

The main aim of the environmental scoping phase was to identify potential environmental and social issues that require detailed investigation and assessment by the various specialists in the ESIA phase, as well as develop the Terms of Reference for undertaking these investigations.

A key component of the scoping phase is the engagement of stakeholders in an attempt to provide them with Project information and identify issues and concerns of importance to them. The process is therefore highly consultative by nature. The stakeholder engagement process is detailed in Chapter 6.

The specific objectives of the scoping phase were to:

- Provide an opportunity for Project stakeholders i.e., the relevant authorities, stakeholder groups and community members in the Project area to exchange information and express their views and concerns regarding the Project.
- Identify key issues and concerns that require further assessment during the ESIA phase.
- Determine the terms of reference for a variety of specialist studies to be undertaken.
- Determine the extent of, and approach to, the ESIA.

A draft environmental scoping report (ESR) was made available from 5 March to 13 April 2018 for review and comments by stakeholders. Comments and queries were incorporated in the comments and responses report that forms part of the ESR, and the draft report was amended as needed. The revised ESR was submitted to the Environmental Affairs Department for review and approval of the terms of reference.

The Department confirmed in writing on 20 June 2018 that the ESR had identified all the key issues to be addressed in the ESIA report. A copy of the letter is attached in Appendix A.

1.5.1.3 ESIA Phase

The main objectives of the ESIA are to identify and assess likely environmental and social impacts; propose appropriate mitigation and management measures, as well as measures to enhance Project benefits; and develop a monitoring plan. Specifically, the ESIA process aimed to:

- Define the existing social, cultural, economic and environmental conditions within the Project area.
- Review feasible Project alternatives.
- Ensure social and environmental considerations and potential impacts are explicitly addressed and incorporated into the Project design and implementation process.
- Assess the potential environmental and social impacts associated with the Project.
- Identify mitigation measures that are both practical and feasible to avoid or minimise the potential impacts of the Project, and to enhance the beneficial outcomes of the Project for the communities within the area.
- Identify relevant monitoring protocols to ensure the mitigation and management measures are implemented effectively.

This draft ESIA report will be available from 13 May to 24 June 2019 for review and comments by stakeholders, and the findings will be presented in a series of consultative meetings in early June 2019. Comments and queries will again be incorporated in the comments and responses report, which will be attached to the final ESIA report. The revised ESIA report will be submitted to the Environmental Affairs Department for review and approval.

1.5.2 Scope of the ESIA

The ESIA for the Project focussed on the infrastructure footprint, as well as surrounding communities and environmental receptors in proximity to the Project infrastructure. The scope of the ESIA did not include an assessment of potential future powerlines to the Project as this will be undertaken by the Electricity Supply Corporation of Malawi Limited (ESCOM), nor did it include the proposed upgrade of the S124 secondary road, as the Malawi Roads Authority has already commenced a separate process for the upgrade of the road.

1.6 ESIA Structure

This ESIA report was generally structured to meet the requirements of the Guidelines of Environmental Impact Assessment for Malawi, 1997. This report consists of 11 chapters, providing details on the following:

- Chapter 1: Introduction – provides background to the project, client details, history, the structure of this ESIA report, and the organisations and the individuals who contributed to its preparation.
- Chapter 2: Project Description – details the mining methods, infrastructure and utilities required, waste and water management measures, and transport and logistics.
- Chapter 3: Alternatives Considered – provides an overview of alternatives considered.
- Chapter 4: Policy and Legal Framework – provides an overview of Malawi legislative requirements, relevant policies, guidelines, international agreements and international standards and best practice applicable to the Project.
- Chapter 5: Environmental and Social Setting – describes the environmental and social baseline conditions within and around the Project area.
- Chapter 6: Stakeholder Engagement – details the stakeholder engagement undertaken in support of the ESIA study program and summarises the issues raised during this process.
- Chapter 7: Impact Prediction and Evaluation – assesses the potential physical and social impacts associated with the Project, their significance before and after implementation of mitigation measures.
- Chapter 8: Management and Monitoring Framework – provides details of the environmental and social management measures to be implemented, as well as the monitoring plan.
- Chapter 9: Rehabilitation and Closure Framework – describes the plans for the closure and decommissioning of the Project.
- Chapter 10: Conclusion – provides a summary of the findings and conclusions of the ESIA report.

1.7 ESIA Team

A team of international and local environmental specialists was appointed to conduct the ESIA process and oversee the various specialist inputs. Dhamana Consulting (an environmental consulting firm based in Australia) was responsible for compilation of the various environmental reports and management of the ESIA process, and was assisted by C12 Consultants (a Malawian environmental consulting firm) and AECOM (South Africa).

The consultants appointed to undertake the various specialist studies conducted baseline surveys and data collection during the scoping phase, with the aim of gaining an understanding of the environmental and social characteristics of the area in which the Project is located. Data collection and field surveys were undertaken relating to flora, terrestrial fauna, aquatic biology, wetlands, surface and groundwater quality, air quality, archaeology and cultural heritage, and socio-economic aspects. Additional surveys and assessments were carried out during the ESIA phase, where deemed necessary, to obtain a thorough understanding of the environmental setting and enable the specialists to undertake an assessment of the potential environmental impacts associated with the Project.

The team of specialists involved in the ESIA is detailed in Table 1.2.

Table 1.2: Environmental and Social Impact Assessment Team

Name	Company	Qualifications	Area of Specialisation
Nanette Hattingh	Dhamana Consulting	BSc (Hons) Geography & Env. Management M Cert. Social Impact Assessment M. Cert. Social Research	ESIA Manager
Akeel Hajat	C12 Consultants	MSc Climate Change and Development	ESIA Report Review and Advisor
Chaitali Mukherjee	C12 Consultants	PhD Geography	ESIA Report Review and Resettlement Action Plan
Boran Altincicek	C12 Consultants	PhD Biology	Data Analysis and Statistics
Katharina Feldman	C12 Consultants	BA Political Science (MSc Pending)	Social Protection
Arthur Kambombe	C12 Consultants	MSc Development Studies	Stakeholder Consultation
Stephen Kuyeli	C12 Consultants	MSc Environmental Sciences	ESIA Report Review
David Mussa	C12 Consultants	Project Management Degree PG Diplomas - HIV/AIDS Management & Social Policy	Stakeholder Consultation
Karien Lötter	AECOM	MA Research Psychology	Social Impact Assessment and Resettlement Action Plan
Jurie Erwee	AECOM	MA Research Psychology	Resettlement Action Plan and Land Access
Allesandra Awolowo	AECOM	MA Globalisation and Corporate Development	Social Impact Assessment
Anelle Lötter	AECOM	National Diploma Journalism	Stakeholder Consultation
Katya Sladkova	AECOM	MA Sociology	Social Impact Assessment
Aleksandra Taskovic	AECOM	MSc International Development and Humanitarian Emergencies	Social Impact Assessment
Mark Westbury	AECOM	BSc Environmental Economics and Environmental Management	Social Impact Assessment
Barend van der Merwe	dB Acoustics	MSc Environmental Management	Noise and Vibration
Matthew Ojelede	Digby Wells Environmental	Ph D Environmental Management	Air Quality and Greenhouse Gas
Siphamandla Madikizela	Digby Wells Environmental	MSc Soil Science	Soils and Land Capability
Nardus Potgieter	EnviroSim Consulting	MSc Chemistry	Health Risk and Radiation
Sandra Carminati	GCS Pty Ltd	MSc Aquatic Health	Aquatic Biology
Erick Dorfling	GCS Pty Ltd	B Tech. Nature Conservation	Surface and Groundwater Quality
Daniel Fundisi	GCS Pty Ltd	MSc Hydrology	Hydrology
Adrian Hudson	Hudson Ecology	MSc Zoology and Ecology	Terrestrial Biodiversity
Chrissy Chiumia	Malawi Department of Antiquities	MSc Rock Art Studies	Archaeology
Oris Chapinga Malijani	Malawi Department of Antiquities	PhD Candidate in Heritage Studies	Cultural Heritage
Shannon Mackenzie	Mine Earth	BAppSc Environmental Management BSc (Hons) Geology	Mine Closure
Ryan Locke	Orelogy	Adv Dip Engineering & Mine Surveying	Mining Engineering
Wouter Fourie	PGS Heritage	BA (Hons) Archaeology and Geography	Archaeology and Cultural Heritage

Name	Company	Qualifications	Area of Specialisation
Marko Hutten	PGS Heritage	BA (Hons) Archaeology	Archaeology
Chenai Makamure	SLR Consulting	MSc Environmental Hydrology	Hydrology and Surface Water
Mihai Muresan	SLR Consulting	MSc Hydrogeology	Hydrogeology and Groundwater
Dawie Janse van Vuuren	SMEC	PhD Development Planning, Environmental Management, Disaster Risk Management	Visual Impact
Julian Stephens	Sovereign Metals	Geology BSc (Hons), PhD, MAIG	Geology

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Chapter 2: Project Description

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2 Project Description

2.1 Introduction

The results of the PFS study completed in October 2018 demonstrated that the Project has the potential to be developed as a low capital and operating cost open pit operation, with an initial life-of-mine of 15 years. It is anticipated that construction will be undertaken over of a period of approximately 14 months. Stage 1 of the operational phase will take place from Year 1 to 3 and will include contract mining with significant expatriate personnel to support the mine start-up. Stage 2 will occur from Year 4 to 7 and will include the conversion of the plant to grid power (from diesel gensets). Stage 3 (from Year 8) will incorporate the change from contract mining to owner operator mining.

A very simple mining and processing operation is being proposed, selling reasonable volumes of very high-quality graphite concentrates into existing markets. The company is not actively considering the construction and operation of highly technically challenging and expensive downstream processing operations, such as a spherical graphite plant.

2.2 Mineral Resource and Ore Reserves

An MRE, compliant with the JORC[1] Code (2012 Edition), was undertaken by CSA Global (CSA) and reported to the ASX on 12 June 2018 with a total tonnage (saprolite + saprock) of 45.7 Mt @ 7.2% TGC, including a higher-grade component of 14.5 Mt @ 9.7% TGC. Results from this MRE confirmed Malingunde as the world's largest reported soft saprolite-hosted graphite resource.

Mineral Reserves were determined based on the results of the PFS with a cut-off grade of 6.75% TGC for saprolite and between 9.5% and 11% TGC for saprock (Table 2.1).

Table 2.1: Malingunde Ore Reserves (November 2018)

Malingunde Ore Reserves						
	Proven		Probable		Total*	
	Tonnes (Mt)	Grade (%C)	Tonnes (Mt)	Grade (%C)	Tonnes (Mt)	Grade (%C)
Saprolite	3.1	9.5%	5.3	8.9%	8.4	9.1%
Saprock	-	-	1.2	12.3%	1.2	12.3%
Total	3.1	9.5%	6.4	9.5%	9.5	9.5%

*Totals may not sum exactly due to rounding.

Using the resource model, pit optimisation, mine design and mine scheduling were completed by Orelogy (Sovereign, 2018), which demonstrated that an average of 52,000 t of concentrate could be produced per annum over 15 years. This equates to an average ore throughput of 600,000 t/y.

The total production target of 9.5 Mt run-of-mine (ROM) ore to produce 830,000 t of concentrate is underpinned by the Proven Ore Reserves of 3.1 Mt (32%) and Probable Ore Reserves of 6.4 Mt (68%).

Additional and substantial exploration potential exists within the EPLs held by McCourt Mining, containing numerous other saprolite prospects discovered, but not yet drilled to resource status.

[1] The Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves ('the JORC Code') is a professional code of practice that sets minimum standards for Public Reporting of minerals Exploration Results, Mineral Resources and Ore Reserves.

2.3 Project Concept

An open pit mining operation is being proposed using traditional excavator and haul trucks for mining, with ore being processed on site in a processing plant to produce a graphite concentrate, which will be exported. Tailings from the processing plant will be disposed of in a dedicated tailings storage facility (TSF). The conceptual mine layout is depicted in Figure 2.1 at a scale of 1:25,000 for ease of readability.

The Project concept was developed as part of the economic scoping study and subsequent PFS, and considered a number of alternatives. These alternatives are described in more detail in Chapter 3 of this report.

2.4 Project Location and Access to the Project Site

Access to the Project from Lilongwe is via the sealed section of the secondary road, S124, to Likuni and then the unsealed continuation of the S124 to the Kamuzu Dam turn-off. Existing access around the Project site is via a network of unsealed tracks.

The S124 passes through the area of the planned northern mining pit and will require modification so that it can continue as a main access route during the operations phase (see Figure 2.1). The Malawi Roads Authority is already planning to upgrade the road from the current unsealed status to a bituminised two-way main road. A separate ESIA has been commissioned by the Roads Authority for the upgrading of the road and does not form part of this report. Sovereign will undertake a minor realignment of the section of the S124 which runs through the northern pit areas.

A haul truck underpass tunnel will be established in the excavated area to avoid heavy vehicles having to traverse the S124.

Sovereign will bituminise the realigned section of the road if the Malawi Roads Authority has already completed the road upgrade prior to commencing of open pit mining.

In addition to the S124 modification, a minor road exists from the S124 through the mine site to the eastern extent of the Ndumila village and the Kamuzu Dam II wall. An alternate route that bypasses the mine site to these areas will need to be established by Sovereign. This route is likely to be to the east of the tailings storage facility but will be finalised during the DFS phase. The road will be a single lane unsealed carriageway provided with suitable drainage to ensure all weather access.

2.5 Exclusion Zone

The Project will require approximately 130 hectares (ha) of land to develop and operate the Project infrastructure. In addition, a buffer distance of approximately 50 m was placed around all infrastructure to ensure operations are undertaken safely. The buffer zone was kept as small as possible to minimise displacement as a result of the Project. The Project infrastructure area and buffer zone are collectively referred to as the exclusion zone and is approximately 260 ha in size. Land within the exclusion zone is currently largely occupied by subsistence agriculture and rural villages, and will require the involuntary resettlement of all households and assets within this zone.

Resettlement impacts will encompass physical displacement (the loss of a home and the necessity of moving elsewhere) and substantial economic displacement (loss of livelihoods associated with subsistence agriculture.

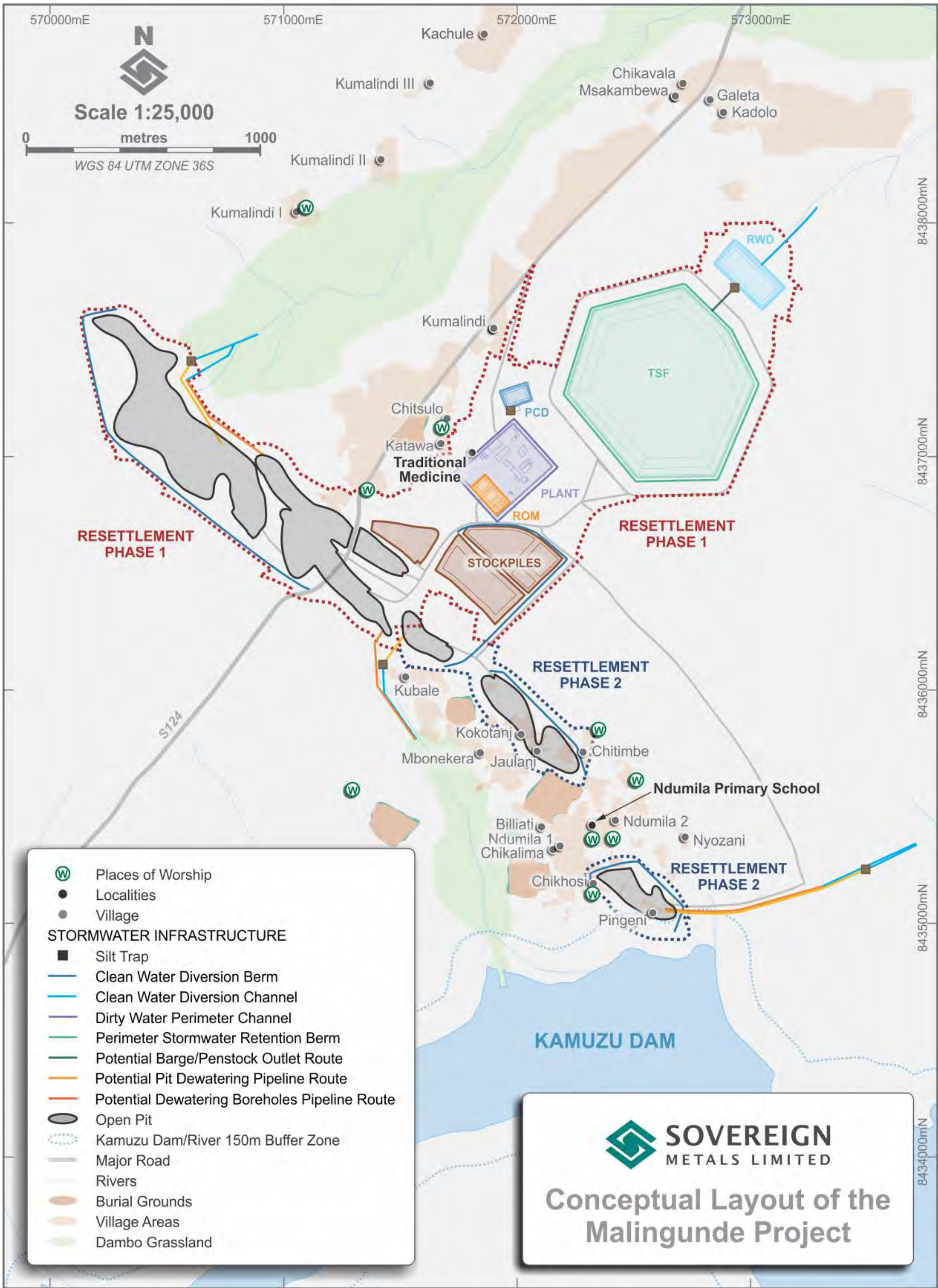

Figure 2.1: Conceptual Mine Layout of the Malingunde Graphite Project (1:25,000)

It is currently anticipated that resettlement will be undertaken in two phases. Phase 1 will entail resettlement for the purposes of construction of Project infrastructure, including the processing plant, TSF, pollution control dam (PCD), temporary ore stockpiles and haul roads, as well as development of the open pits in the northern extent of the Project area (Figure 2.1). Resettlement in Phase 2 is likely to only be undertaken approximately 8 to 10 years after commencement of the Project and will take place to enable mining of the open pits in the southern extent of the Project area.

2.6 Mining

2.6.1 Mining Method

Open pit mining will be undertaken using traditional excavator and haul trucks and focus on the near surface weathered material, with only the high grade, relatively soft saprock considered for initial mining.

The ore and waste rock will be free-dig in nature and as a result no drilling or blasting activities will be required for the operation. Mining will be undertaken in a number of long, shallow open pits over a distance of 3.5 km. Mining depths will vary between 15 metres (m) and 34 m and open pits will be a maximum of approximately 250 m wide. The base of these open pits will be above the level of the Kamuzu Dam. Overall the Project has a very low strip ratio of 1:1 (waste:ore). Open pits will cover an area of approximately 47 ha.

Ore will be loaded on to articulated dump trucks with a payload capacity of ~40 t and hauled from the pit directly to the ROM pad or to the stockpiles adjacent to the pits (Figure 2.1); an area of approximately 15 ha. Ore from the stockpiles will be hauled to the ROM pad as required for blending purposes. At the ROM pad blending of different types of ore will take place to achieve a consistent head grade to the plant which will ensure stable float plant operation.

Mining will be undertaken 5 days a week (Monday to Friday) on a single 12-hour shift basis. No mining will take place during weekends or at night time. Processing/production will operate on a continuous basis with two 12-hour shifts.

2.6.2 Mining Sequence and Schedule

Mining will commence in the northern pits, directly south of the S124 secondary road. Generally, mining will move towards the northern extent of the deposit, after which it will continue directly south of the S124 and move towards the southern extent of the deposit (towards the Kamuzu Dam). The stages of mining of the deposit is indicated in Figure 2.2. However, it should be noted that mining will sometimes take place in various pits at the same time.

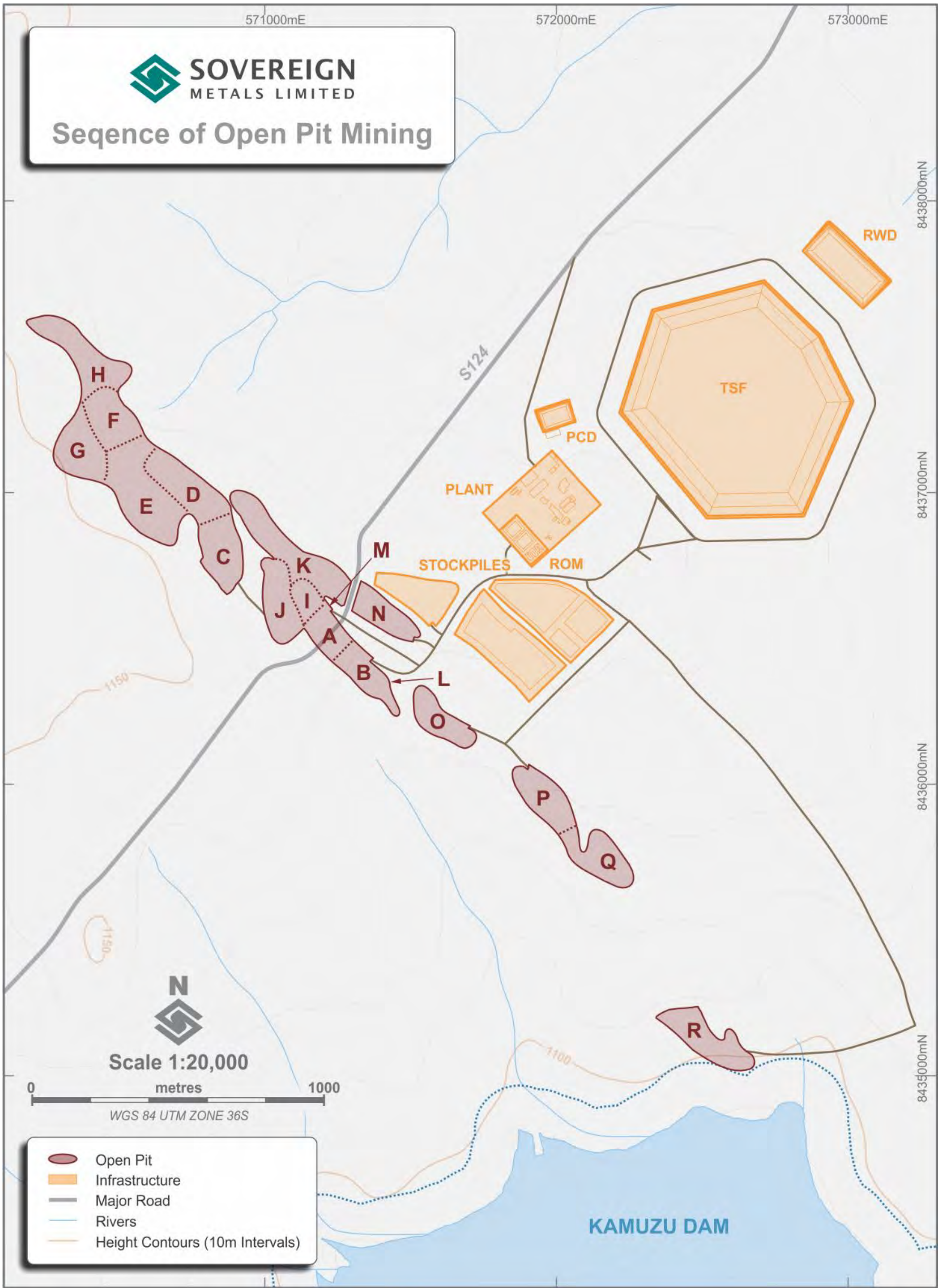

Figure 2.2: Sequence of Open Pit Mining

2.7 Ore Processing

Processing of ore will be undertaken in a processing plant located 500 m to the northeast of the open pits (Figure 2.1). Due to the relatively soft nature of the ore, processing will not require any primary crushing or grinding.

The plant and ROM pad area will be approximately 8 ha in size, with the highest point of the processing plant being approximately 29.5 m above the natural ground surface (dryer stack height) (Figure 2.3). The components of the processing plant and stages of processing are indicated in the process flowsheet in Figure 2.4 and includes the following.

- The plant feed will be delivered from the ROM stockpile by front-end loader to the grizzly and ROM bin.
- Material will pass through a mineral sizer for primary size reduction and then processed through a scrubber charged with steel media.
- Scrubber discharge slurry will pass through a 10 mm screen with a small quantity (0-15%) oversize directed to a small pebble crusher.
- Scrubber product less than 2 mm in size will be pumped to the rougher flotation section for processing. Rougher tailings will be pumped to the tailings thickener.
- Scrubber product between 2 mm and 10 mm in size is recycled back to the front of the scrubber to be reprocessed
- Rougher concentrate will undergo a polishing regrind.
- The ground concentrate will undergo cleaner flotation stages with cleaner concentrate split into coarse and fine fractions at 200 µm.
- Three stages of recleaner flotation will be undertaken on the coarse and fine fractions, with inter-stage attritioning.
- The final concentrate fractions from the coarse and the fine streams will be combined and thickened.
- The thickened concentrate will be dewatered using a plate and frame filter with air blow and membrane squeeze steps to ensure maximum water removal.
- The filtered concentrate will be dried using a flash dryer.
- Dried product will be screened into various size fractions and bagged for despatch and sale.

More details on each of these stages are provided in the sections below.

2.7.1 Feed Preparation and Scrubbing

ROM ore will be stockpiled on the ROM pad. Saprolite (SAPL), saprock (SAPR) and mottled (MOTT) material types will be stockpiled separately to allow blending on the plant feed material.

ROM stockpiles have been designed to support the mining schedule (12-hour shifts, 5 days per week) to ensure that the processing plant can be efficiently operated on a 24 hour/day, 7 days per week basis.

ROM ore will be fed to the ROM bin by a front-end loader. The bin and downstream equipment will be protected by a 700 mm grizzly on the bin opening. ROM ore will be withdrawn from the bin by the primary feeder to feed the mineral sizer. Raw water will be used for dust suppression at the ROM bin.

Ore that has passed through the mineral sizer will be fed to scrubber (3.4 m diameter and 3.7 m long). The scrubber will discharge over a double deck vibrating screen having 10 mm and 20 mm slotted apertures.

Oversize from the top and middle decks of the scrubber discharge screen will be conveyed to the pebble crusher. Pebble crusher discharge will be recycled back to the scrubber.

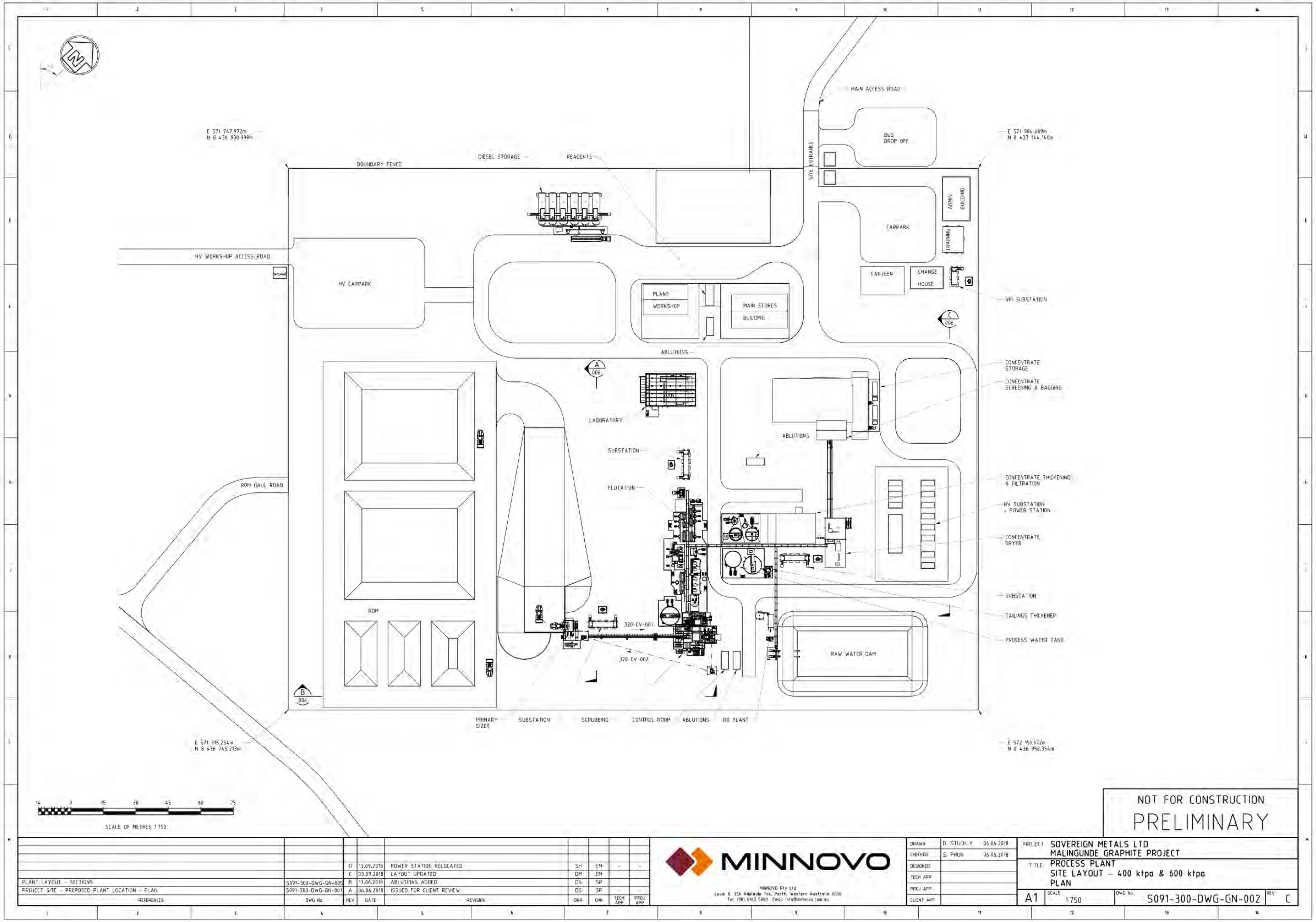

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Figure 2.3: Plant Area Layout

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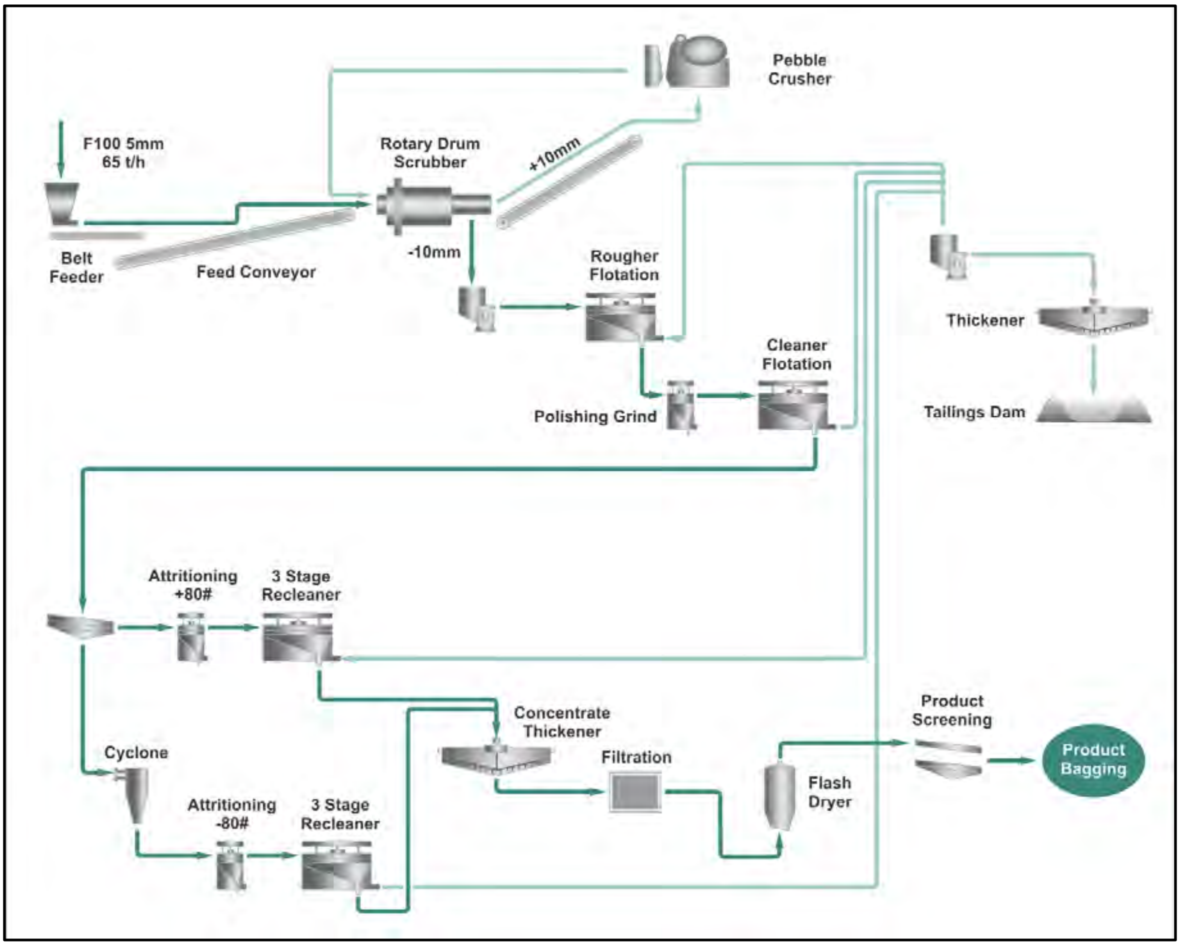


Figure 2.4: Process Flow Sheet

Scrubber discharge screen undersize will be pumped to the scrubber product screen. The scrubber product screen oversize will be fed back into the scrubber for further scrubbing. Scrubber product screen undersize will be fed to the flotation circuit.

Scrubbing media (steel balls) will be added to the scrubber via a dedicated scrubber media loading bin situated above the scrubber feed hopper.

A sump pump in the scrubbing area will discharge spillage to the tailings thickener feed box or to the scrubber discharge screen.

2.7.2 Flotation

Froth flotation is where air is added to an agitated slurry forming bubbles to which the valuable minerals adhere and are carried with the froth off the top of the slurry. Gangue minerals remain in the slurry and are discharged from the bottom of the froth flotation tank.

Frother is a substance that aids in the formation of stable bubbles in the froth flotation cells by increasing the surface tension of the liquid. By encouraging more stable bubbles of air the froth flotation process is enhanced. Collector is a substance added to froth flotation processes to modify the surface chemistry of the valuable minerals, in this case graphite, to make the valuable minerals hydrophobic and cause them to preferentially adhere to the surface of bubbles in the froth flotation cells and be recovered to concentrate (froth).

Slurry from the scrubbing circuit will be pumped to the rougher feed box before gravitating through five 16 m^3 conventional flotation cells. Measured quantities of a glycol-based frother and collector (diesel) will be added to the rougher flotation cells.

Rougher concentrate will feed to the rougher concentrate dewatering cyclone to remove excess water prior to the rougher concentrate regrind. Cyclone underflow will report to the rougher concentrate polishing mill and cyclone overflow bypasses the mill to the cleaner feed. Rougher tailings will be pumped to the tailings thickener.

Rougher concentrate will be lightly reground in a 150 kilowatt (kW) low charge ball mill. Regrind mill product will be fed to the cleaner flotation cell where further quantities of frother and collector will be added.

Cleaner tailings will be pumped to the tailings thickener.

Cleaner concentrate will be pumped to the cleaner concentrate sizing screen which is fitted with a 200 μm aperture deck. Screen oversize will report to the coarse concentrate recleaner circuit whereas screen undersize will report to the fine concentrate recleaner circuit.

Coarse cleaner concentrate will be pumped to a 55 kW vertical stirred mill. Mill product will be pumped to the coarse recleaners, consisting of four 1 m^3 conventional float cells. Quantities of frother, collector and process water will be added for optimum flotation performance. Coarse recleaner tailings will be pumped to the tailings thickener.

Fine cleaner concentrate will be pumped to the dewatering cyclones. Cyclone underflow will be pumped to a 75 kW vertical stirred mill. Mill product will flow to the fine recleaner circuit. The fine recleaner flotation bank consists of four 1 m^3 conventional float cells. Quantities of frother, collector and process water will be added to the recleaner circuit as required for optimum flotation conditions. Fine recleaner tailings will be pumped to the tailings thickener.

2.7.3 Concentrate Handling

Final flotation concentrate from both the coarse and fine recleaner flotation cells will be pumped to the concentrate thickener. Flocculant, that is diluted with process water, will be added to the thickener feed to improve both settling rate and overflow clarity. The flocculant is a long chain organic molecule which acts by adhering to multiple fine solid particles to bind them loosely together to form a larger effective particle increase the settling rate.

Overflow from the thickener will gravitate to the process water tank whereas thickened final flotation concentrate will be pumped to an agitated concentrate storage tank.

A centrifugal pump will be used to feed the thickened slurry to a vertical plate pressure filter. The filter cycle will include air blow and membrane squeeze steps to minimise filter cake moisture. Filter cake will be discharged directly into a covered bunker.

Concentrate filter cake will be reclaimed by a bobcat and fed into the dryer. Material will flow via the dryer feed hoppers to an indirect fired flash dryer. Hot air will be produced in a diesel fired combustion chamber with hot air forced into the dryer by the dryer combustion air fan. Approximately 160,000 L/y of diesel will be used as dryer fuel. The dryer off-gas will report to a dryer dust collector for removal of very fine graphite that is collected and bagged separately with dust free air being discharged to the atmosphere.

Dry concentrate will discharge from the dryer and will be transferred to the product screen surge bin by the dryer discharge conveyor.

The dry concentrate will be delivered via a six-way air slide distributor to the six product screens. Each screen will have three decks with progressively finer aperture. Airborne dust produced by operation of the product screen feeders and product screen will be ducted to a central dust removal system where it is collected.

The three deck apertures will result in four product fractions. The corresponding fractions from each screen will be combined and conveyed to dedicated bagging plants, where concentrate will be bagged in woven fibre bulk bags for transport.

2.7.4 Reagents

2.7.4.1 Frother

A glycol-ether-based frother will be delivered to site in 1,000 L intermediate bulk containers. Two containers will be connected into a common suction for the frother dosing pumps, which will discharge to the following points:

- Rougher flotation cells.
- Cleaner feed hopper.
- Coarse recleaner flotation circuit.
- Fine recleaner flotation circuit.

The frother storage area will be equipped with a dedicated spillage bund and sump pump which discharges to the tailings thickener.

Approximately 130 g of frother is added per tonne of ore, which amounts to 76,000 kg/y. The majority of the frother will end up with the graphite concentrate and is then evaporated when the concentrate goes through the drying stage. The organic analysis of tailings undertaken (SLR,2018a) indicates that organic analytes from frother are below detection limits, hence there are no anticipated added chemicals that would end up in the TSF or within any other parts of the site.

2.7.4.2 Collector

Diesel will be delivered in bulk and stored in the diesel storage facility within the plant area (see Section 2.11). Diesel will be pumped from the storage facility to the plant diesel storage tank. An emulsifying pump will operate in closed circuit with a header tank to provide emulsified diesel for use as the flotation collector. The emulsified collector day tank provides supply to the collector dosing pumps.

The diesel storage tank and the emulsified collector day tank will have a dedicated spillage bund and sump pumps. Each sump pump will discharge spillage to the tailings thickener feed box.

Approximately 210 g of diesel per tonne of ore is added to the flotation cells (equivalent to approximately 45 g diesel per tonne of ore and process water). This amounts to approximately 130,000 L/y of diesel used in the process. Diesel acts as a collector by adhering to the graphite flakes.

The majority of the diesel will also end up with the graphite concentrate and is then evaporated off when the concentrate goes through the drying stage. A portion of the diesel will adhere to the tailings and remain in the TSF.

Organic analysis of tailings samples 42 to 53 mg/kg, which is indicative of the diesel added. The soil screening value for industrial sites given by the Oklahoma Department of Environmental Quality (2012) is 2,500 mg/kg and the Canada-wide standards for petroleum hydrocarbons in soil (Canada Council of Ministers of the Environment, 2001) is 1,700 mg/kg. However, as concentrations are orders of magnitude lower than soil standards, the diesel range organics (DROs) are not likely to be of concern for groundwater contamination.

2.7.4.3 Flocculant

An anionic polyacrylamide ultra-high molecular weight flocculant will be delivered to site in 25 kg bags on a pallet. The day shift operators will take bags from the flocculant store (sea container) and top up the dry flocculant hopper.

The flocculant mixing system will automatically mix dry powder with raw water, agitate the mixed solution, and transfer the hydrated solution to the flocculant storage tank.

The flocculant dosing pumps will be duty only and dedicated to supply to the following areas:

- Concentrate thickener.
- Tailings thickener.

The flocculant mixing and storage area will be provided with a spillage sump and sump pump to capture any spillage. The sump pump will discharge to the tailings thickener.

Approximately 100 g of flocculant is added per tonne of concentrate to the concentrate thickener, while 300 g of flocculant per tonne of tailings is added to the tailings thickener. Flocculant use is estimated to be approximately 17,200 kg/y.

2.7.5 Product Handling and Transport

Bagging of concentrate will be a semi-manual process, initiated and controlled by the operator. At the start of the cycle the operator will place an empty bulk bag below the filling spout. The operator will then open the valve (gate) and allow the bag to fill. The bag will be vibrated during filling to increase the filled bulk density. The full bag will be manually released onto a roller conveyor with a weigh scale at the end of the conveyor. Two bags will be stacked on a pallet and moved using a forklift.

The bagging units will be ducted to the central dust collector. The collected dust will be manually bagged separately.

The graphite concentrate will be trucked to the railhead at Kanengo, a hauling distance of approximately 38 km. At Kanengo the bags will be packed into 20-foot ocean going containers for direct rail (988 km) to the Port of Nacala on the Mozambique coast for export.

The preferred route between the Project and Kanengo is along the S124 towards Lilongwe as indicated in Figure 2.5. Just west of Lilongwe, vehicles will be routed around the Lilongwe city centre along the relatively new Lilongwe Western Bypass Road to avoid congestion in the city centre. The route follows the existing road to the intersection of the S122, and vehicles will then turn in an easterly direction onto the S122 and travel along this road to Kanengo. This is the shortest route, traversing primarily surfaced road and the shortest gravel road section possible.

The Malawi Roads Authority has completed a feasibility study and ESIA on an upgrade to the gravel section of the S124 road, with completion of roadworks anticipated prior to construction of the Malingunde Project.

Tri-axle diesel trucks are being considered for transport of the product from the mine site to Kanengo. This consists of a 6-axle truck-trailer combination (three on the prime mover and three axles on the trailer).

The trucking requirements are shown in Table 2.2. This assumes that transport of product will only be undertaken during daylight hours to reduce the risk of accidents etc.

Table 2.2: Truck Configuration Options

Aspect	Tri-axle Trailer
Payload (t)	30
Concentrate production (t per year)	50,000
Production (t per month)	4,166
Truck working days (per month)	24
Required volume (t per day)	174
Truck trips (per day)	6
Truck trips (per month)	139

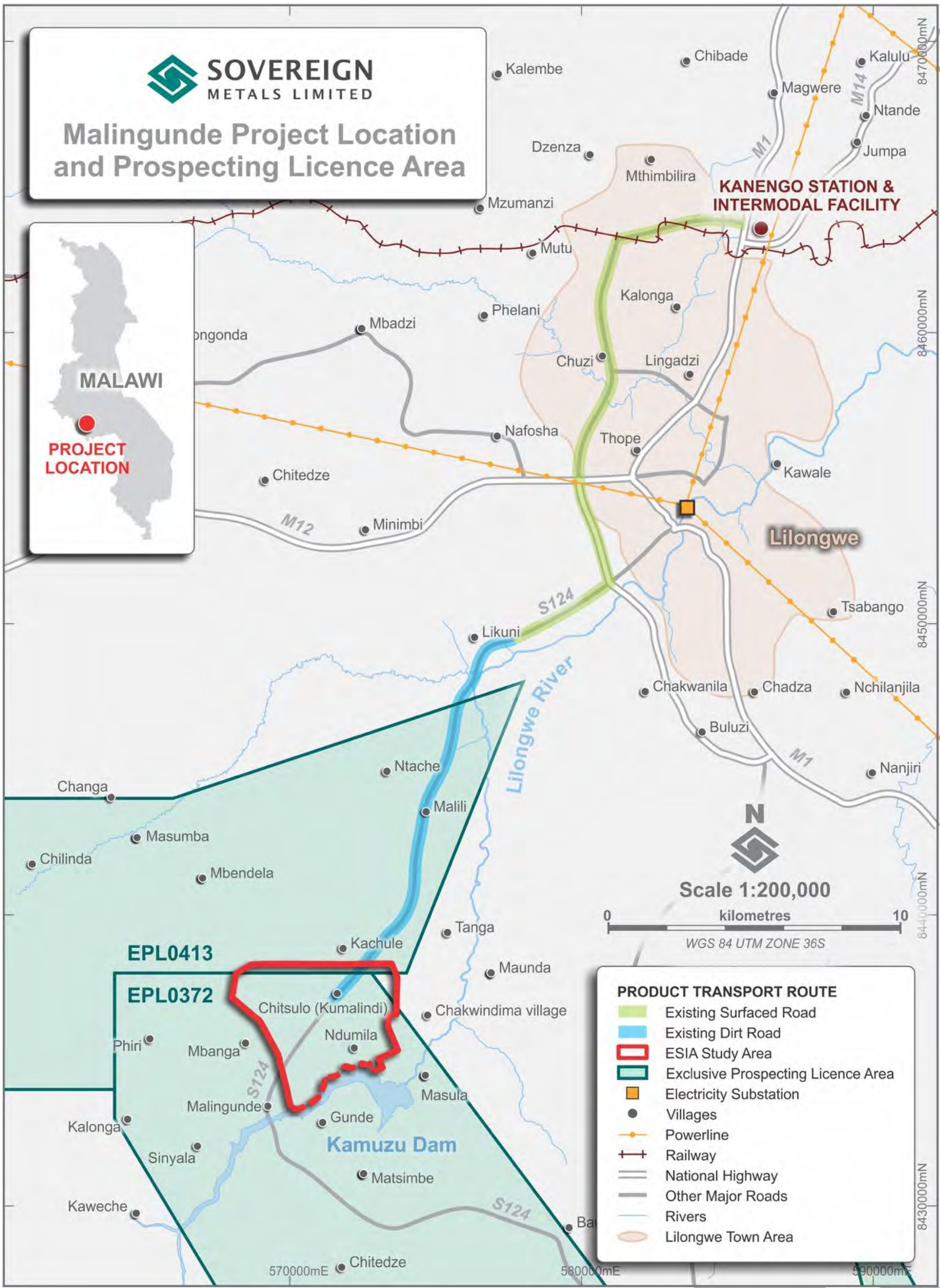


Figure 2.5: Product Transport Route

2.8 Tailings Management

2.8.1 Tailings Storage Facility

A total of approximately 8,835,000 t (or approximately 8 Mm^3) of tailings will be produced over a life-of-mine of 15 years.

Tailings from flotation as well as plant spillages will be pumped to the tailings thickener. Flocculant will be added to improve both the settling characteristics of the solids and the thickener overflow clarity. Tailings thickener overflow will be transferred by gravity to the process water tank.

Thickener underflow will be pumped to the TSF using a single stage centrifugal tailings pump. At the TSF, decant water will be directed to the return water dam before being pumped back to the process water tank.

The initial starter wall for the TSF will be constructed from waste material excavated from the open pits during the establishment stage. Tailings disposal will be undertaken utilising cyclone deposition along the crest of the TSF wall for subsequent wall lifts (Plate 2.1). To accommodate the production rate being sent to the TSF, it is estimated that approximately three 250 mm cyclones will be required at 200 m centres along the TSF wall where the underflow will be directed to the downstream side of the TSF wall to develop the wall and the overflow will be directed into the TSF basin.

Photos: SLR Consulting Africa (Pty) Ltd

Plate 2.1: Example of Cyclone Tailings Deposition

The TSF site was located outside of the Kamuzu Dam watershed to avoid impact on the reservoir.

2.8.2 TSF Construction

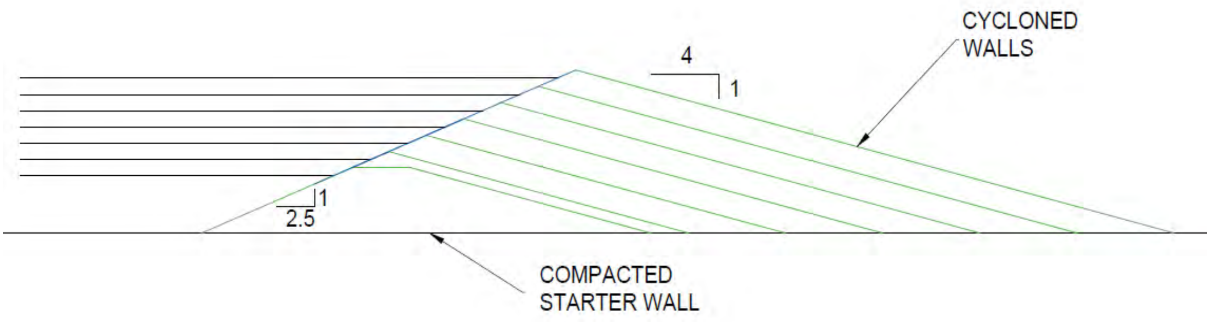
Limited waste material (waste rock) will be produced during mining and no waste rock dump will be constructed on site. All waste material from the pit will be used to batter the TSF walls.

The basin of the TSF will be stripped of topsoil and ripped and re-compacted. No compacted clay or high-density polyethylene (HDPE) liner has been considered for the TSF as the geochemical test results show that the TSF water (pool and seepage) is relatively clean (refer to the PFS Geochemical Investigation attached in Appendix B). Kinetic leach tests undertaken by SGS Canada on the composite tailings sample were used to estimate seepage quality from the proposed TSF (SLR, 2018a), which showed the TSF seepage quality is anticipated to be pH neutral with water quality guideline exceedances expected for aluminium (Al) and fluoride (F). Both Al and F are expected to exceed the Malawian Drinking Water Specification (2005), with F also exceeding the WHO Standard for Drinking Water (2017).

A box cut will be excavated below the 0.5 m topsoil removed under the TSF wall. The material excavated from the box cut will be re-compacted utilising an impact roller and the void filled with pit waste material (under the TSF wall).

The main purpose of the TSF wall is to contain the tailings material produced from the processing plant in the most optimal way taking into consideration safety, water, environmental and social-economic issues. The TSF wall has been designed with the integrity and stability to not only contain tailings during the LOM, but in perpetuity. For this reason, the safest design base being the downstream, sequentially raised tailings dam type has been selected.

A nominal starter wall will be constructed from pit waste material as indicated in Figure 2.6. Pit waste is a highly weathered saprolite (clayey, silty, sand) i.e. there is no waste rock, but it has been determined that this saprolite material can be used for the TSF wall construction. The TSF wall (after development of the starter wall) will be constructed from the coarse underflow tailings material from cycloning. The TSF wall will have an average assumed downstream side slope which varies between 1(V):3(H) and 1(V):4(H).



Source: SLR Consulting Africa (Pty) Ltd

Figure 2.6: TSF Wall Development from Cyclone Tailings

The starter wall height will be 4 m, with the height of the wall at the end of the life-of-mine being 21.4 m. The TSF will cover an area of approximately 46 ha at the end of the life-of-mine.

2.8.3 Tailings Water Management

Two decant systems have been considered to remove TSF pool water off the surface of the tailings. The final selection will be done as part of the final design:

- The traditional penstock decant system with a series of vertical penstock rings which are replaced/removed as the level of the TSF pool water rises/decreases with a horizontal outfall penstock pipe below ground level (Plate 2.2).

Source: SLR Consulting Africa (Pty) Ltd

Plate 2.2: Example of Traditional Penstock Decant System

- A turret system, which floats on top of the TSF pool and decants the TSF pool water (Plate 2.3).

Source: RBH Engineering (Pty) Ltd

Plate 2.3: Example of a Turret Decant System

The water decanted off the TSF will flow to a ±80,000 m^3 return water dam (RWD) lined with a 1.5 mm thick HDPE liner to prevent water loss from the dam, from where it will be pumped back to the plant for reuse. The RWD will not be built during the initial construction phase of the TSF, but will be included as part of the first lift construction activities. To ensure the TSF wall is not overtopped during the first year of operation (in the event that a 1 in 100 year 24-hour storm event is exceeded), a small spillway upstream of the TSF wall will be constructed to divert any potential excess water (over and above the 1:100 year 24-hour storm event) around the TSF wall (Figure 2.7). This water will be discharged to the environment. The TSF pool water quality is anticipated to be relatively clean and further dilution from stormwater is expected (SLR, 2018b).

At the plant area, a stormwater collection trench will be constructed around the outside of the plant and ROM pad draining to a ±10,000 m^3 HDPE lined PCD. This plant run-off water is considered dirty and must be pumped back to the plant for immediate re-use as and when required. Any spillage from the PCD will spill into a rock lined trench and be diverted downstream into the RWD.

Catchment paddocks are constructed downstream of the final TSF wall to allow the silt from the TSF side slope run off to settle out (Figure 2.7).

The TSF walls have a sand toe drain at the inner toe of the wall which drains to an open collection trench outside and downstream of the TSF wall (Figure 2.8).

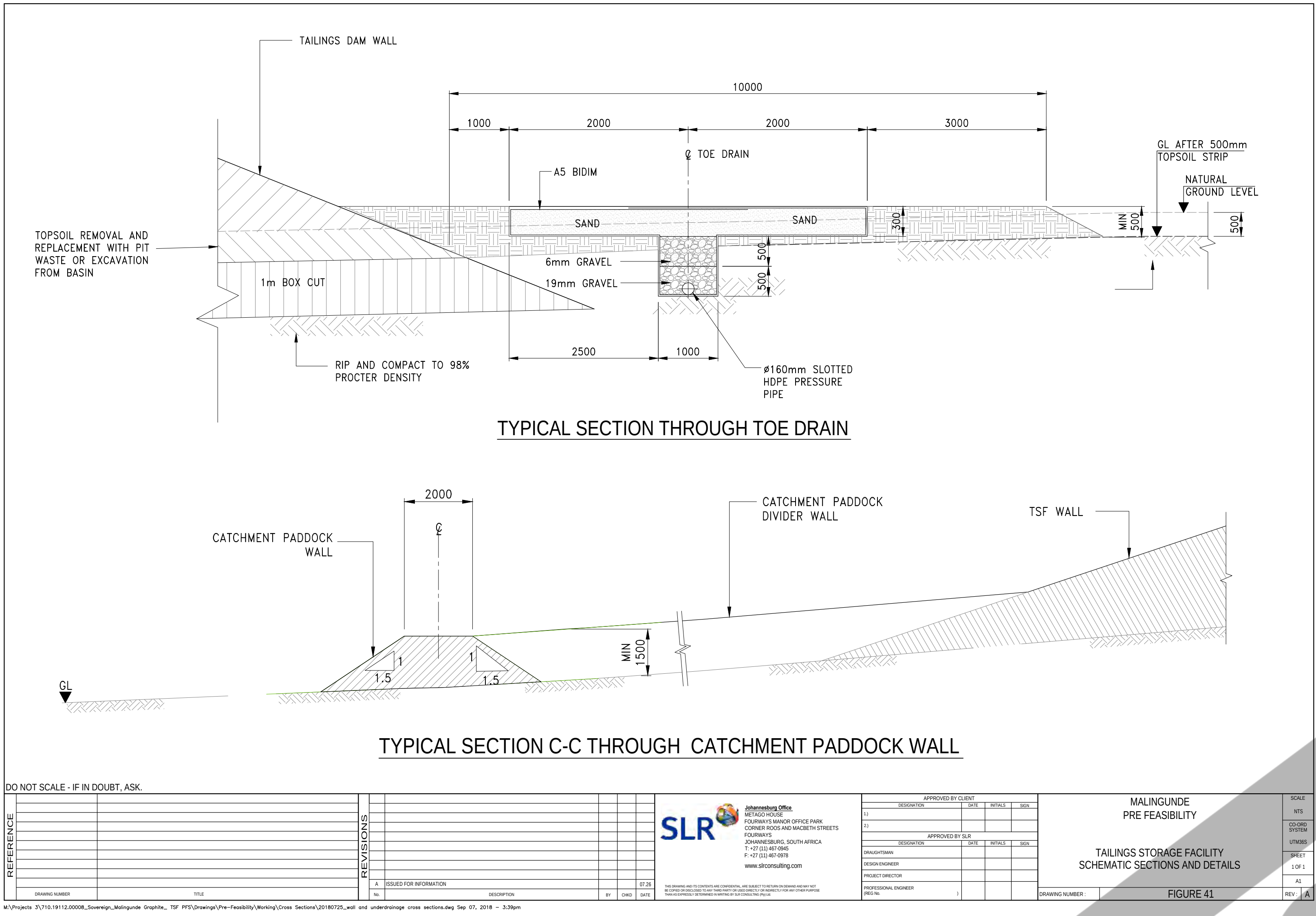


Figure 2.7: TSF Wall and Related Infrastructure

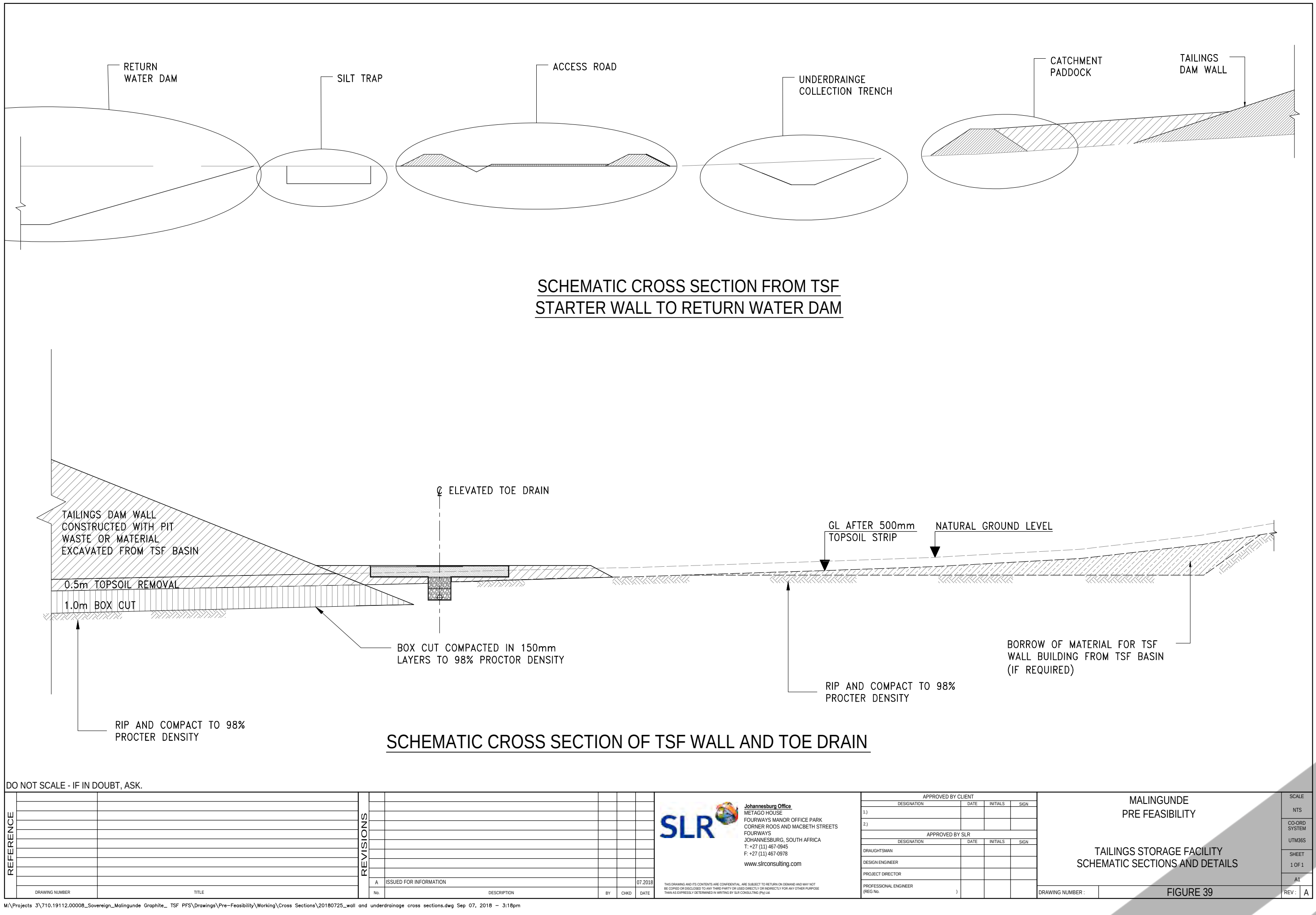


Figure 2.8: Schematic of Toe Drain and Catchment Paddock

2.9 Project Water Management

2.9.1 Raw Water

The total raw water demand for the plant services has been estimated at 51.8 m^3/h (approximately 38,000 m^3/month), while water used for dust suppression has been estimated to be approximately of 400 m^3/d (12,000 m^3/month).

Raw water will largely be obtained from mine pit dewatering and/or boreholes. The raw water will be pumped to the plant raw water dam of approximately 3,000 m^3 in size. From this pond, water will be provided for the various distribution points including the processing plant, potable water treatment plant and mine services area.

The raw water pond will also serve as the fire water storage with adequate secured capacity reserved at all times for fire water requirements.

At the start of mine (Year 1), groundwater inflows into the open pits are relatively low and if this occurs in the dry season the mine will be reliant on external makeup water (approximately 20,000 m^3/month or 240,000 m^3/y) to satisfy the processing plant raw water demands.

The potential sources of water that were identified are:

- Kamuzu Dam.
- Additional boreholes in the vicinity of the Project.

Both these options will require abstraction permits.

In the wet season the collected stormwater on site becomes a supplementary source of process water, thereby reducing the use of pit water and hence a need to discharge water.

From Year 2 onwards the groundwater inflows into the pit more than triples and the mine becomes water positive (i.e. water in excess of what is required for operations will be generated from pit dewatering) for the rest of the life-of-mine, with a need to discharge water to the environment from dewatering of pits and no makeup water is required.

Pit dewatering is envisaged to be undertaken mostly through dewatering boreholes with residual water pumped from the pit and will be undertaken at an average rate of 0.016 m^3/s or 16 L/s.

Water from the dewatering boreholes will be used as raw water or discharged to the dambos directly (see Figure 2.9 for discharge locations) as the water is considered clean and is the same quality as baseline groundwater.

Groundwater and stormwater from the pit are considered free from chemical contamination (as is evidenced by the baseline water quality assessment that has been undertaken; Section 5.10 and Section 5.11) and require only management of total suspended solids (TSS) prior to use and/or discharge and has therefore been classified as silty water. Water from the pits will therefore be reused or managed through silt traps before discharge.

Groundwater inflow into the pit becomes a very significant source of water for the mine in the dry season, as there is inadequate stormwater collected at the plant and TSF to serve as raw water supply.

2.9.2 Potable Water

A 120 m^3/d potable water treatment plant will be installed within the processing plant area adjacent to the raw water pond. Raw water will be pumped to the potable water treatment plant from the raw water reticulation.

The water treatment unit will be supplied in a portable building module containing a reverse osmosis membrane module, a sodium hypochlorite dosing system, water softening system and an ultra violet (UV) disinfection unit fitted with an automatic lens cleaner. The raw water will be treated to ensure potable water quality complies with the Malawi Drinking Water Specification. The plant will be sized for 120% of the total estimated daily usage.

Treated water will discharge to an insulated potable water tank.

Potable water demand has been estimated at 150 L/employee/day. At any one time, it is likely that approximately 115 employees will be present on site. The total potable water demand is therefore approximately 456,000 L per month.

2.9.3 Process Water

The process water tank receives water from potentially dirty sources of tailings thickener overflow, concentrate thickener overflow and TSF decant water. 30% of the tailings water is returned to the process. These water sources will be supplemented with the introduction of raw water as described above.

The process water tank will gradually fill with solids that are entrained within the process water input streams and will require routine cleaning.

Two process water pumps in a duty standby arrangement will distribute the process water to the required areas within the plant.

2.9.4 Fire Water

Fire water will be reticulated from the raw water pond to the processing plant, the buildings within processing plant area and the mine contractor's facilities.

Fire hydrants will be installed to provide full coverage to all buildings and facilities within the process plant area and associated infrastructure. Fire systems generally will be designed to be fully compliant with the requirements of the relevant building codes and standards and in accordance with insurance requirements.

2.9.5 Waste Water

A modular waste water (sewage) treatment plant will be installed to the southeast of the plant area to service the site facilities.

Waste water collected will gravitate via buried PVC piping to strategically located underground pump stations which will in turn feed a central pump station for final delivery to the treatment plant.

At the treatment plant, waste water will be collected in a central holding tank, from where it will be pumped to the waste water treatment plant. The holding tanks will be enclosed to ensure no odour is released to atmosphere.

The treatment plant will be constructed in an earth bunded area, generally located out of sight and downwind of the processing plant and associated facilities with respect to the prevailing wind. The plant will be fenced off and chemical storage provided in a container. There will be an audible and visual alarm which will operate in the event of a malfunction. An unlined overflow pond will be provided inside the fenced area to receive any spillage until it can be pumped back into the plant.

All sanitary fixtures will discharge to the waste water reticulation system. Treated waste water will discharge to the TSF, provided that Malawi water quality guidelines for effluent is not exceeded. Sludge from the treatment plant will be collected and disposed of off-site in an appropriately licenced facility by a suitably qualified contractor.

2.9.6 Stormwater Classification

Based on the conceptual mine layout, clean, silty and dirty water catchments were delineated based on the expected water quality from the different catchments and the associated treatment techniques recommended for each classification as presented in Table 2.3 and Figure 2.9.

Table 2.3: Stormwater Classification and Treatment Methods

Classification	Areas	Treatment Technique
Clean	• Undisturbed areas. • Dewatering boreholes.	• Divert around silty and / or dirty areas. • Discharge to dambo.
Silty	• Pits. • TSF side slope. • Stockpiles.	• Silt traps. • Toe paddocks.
Dirty	• TSF. • Processing plant. • ROM pad.	• Contain in RWD or PCD and re-use.

2.9.7 Stormwater Management Infrastructure

A conceptual stormwater management plan has been developed consistent with the IFC Environmental Health and Safety Guidelines (2007), which comprises clean, silty and dirty water management and includes the following main features:

- Clean water from the catchments upstream of the mining infrastructure (i.e., at the pits) will be diverted around the proposed infrastructure.
- Dirty water at the processing plant, ROM pad and the TSF as well as silty stormwater from the pits will be collected on site and reused as far as is practicable to minimise effluent discharge and minimise the make-up water requirements.
- Several silt traps have been proposed and sized for the management of silty water (i.e., silt traps at the pit discharge points to manage contact water from pit dewatering, inflow into the RWD and at the inflow into the PCD). Sediment control facilities have been designed for a final TSS discharge of 50 mg/L and other applicable parameters and guideline values in the EHS Guideline Table 1 (IFC, 2007).
- On a macro scale, dirty water conveyance infrastructure at the plant have been sized for flows during a 100-year 24-hour event using the United States Department of Agriculture (USDA) Soil Conservation Service (SCS) method.
- The dirty water containment dams (plant PCD and RWD) have been sized to contain stormwater generated during a 100-year 24-hour event:
  - A Plant PCD with a full supply level capacity of approximately 10,000 m^3.
  - A RWD for the TSF of approximately 80,000 m^3 that will contain stormwater generated during a 1 in a 100 year, 24-hour rain event and approximately 15 days of tailings operating water.

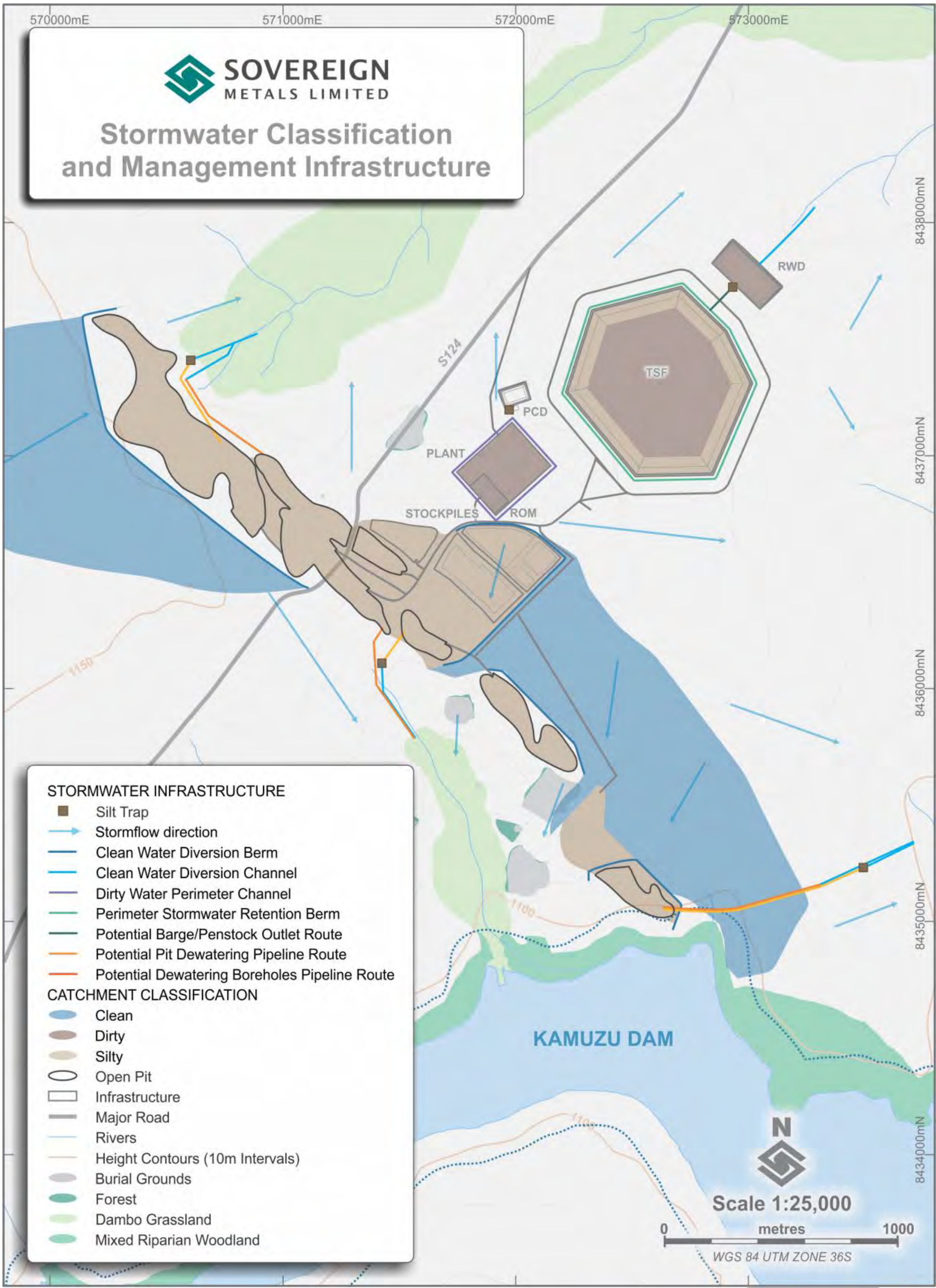


Figure 2.9: Stormwater Classification and Management Infrastructure

2.9.7.1 Processing Plant and ROM Pad

The following stormwater management measures have been incorporated in the conceptual Project layout for the processing plant and ROM pad areas (Figure 2.9):

- There is no clean water catchment upstream of the plant as it is located on a catchment divide, as such no diversion berms are necessary.
- Dirty water from the areas of the plant where diesel will be used in processing will be covered with hard standing and bunded off from the rest of plant catchments and any stormwater will be collected in a sump and reused within the process.
- Dirty stormwater from the rest of the plant and ROM pad will be intercepted at a macro scale by a perimeter drainage channel and conveyed to the plant PCD. The dirty water channel has been designed to accommodate flows of 2.2 m^3/s.
- Dirty stormwater inflow channels from the ROM pad and the plant will pass through a silt trap before flowing into the PCD, although only the ROM pad is envisaged to generate significant loading of silt/sediment. The plant catchment will have some parts which are hard standing, some covered by gravel or erodible stockpile material and natural soils and vegetation. Open channels are preferred for ease of maintenance and can easily be constructed to accommodate design capacity, whilst maintaining suitable drainage gradients.
- Overflow from the PCD will be further passed through a hydrocarbon separator before being routed to the TSF RWD for reuse or spillage to the environment (subject to water quality meeting the relevant standards).

2.9.7.2 Open Pits

The following stormwater management measures have been incorporated in the conceptual Project layout for the pit areas (Figure 2.9):

- Clean stormwater will be prevented from entering into the pit footprint areas through upstream diversion berms for all pits. This will be in addition to the perimeter berms that are normally part of pit designs that prevent runoff ingress of water into the individual pits. The upstream catchments to be diverted are quite small and hence nominal 1 m or 0.5 m berms will be adequate to divert clean water with an inside earth channel. The clean water from the west of the northern pit will be diverted to the north, whilst clean water from the east of the southern pits will be diverted to the south.
- Silty stormwater from the pits will be collected in a pit sump within the lowest point of each pit and will be pumped to provide process water at the plant when there is need for additional water. Any excess water not required for use at the plant or for onsite dust suppression, will be passed through silt traps located upstream of the discharge point flowing towards the dambos where, if any minimal residual silt remains, it can be further settled as water filters through the dambos. As the full footprint of the pits is realised, there is potential that single pit sumps will not have sufficient capacity to store the large volumes of pit water envisaged, and a series of pit sumps or in-pit paddocks will need to be constructed to store sufficient water prior to decanting from the pits.
- The silty stormwater in the northern pit (north of the S124) is pumped north of the pit where it flows by gravity to a silt trap and released to the Kovuma dambo. Water from the pits directly south of the S124 is pumped out of the pit and gravity drained to a silt trap on the south of the pit then to Dambo 1 (refer section 5.7.1 for location of the dambo). Water from the most southern pits is pumped to a silt trap and then to a drainage line located to the east of the pit.
- Clean groundwater inflows will be intercepted by dewatering boreholes and released to the various dambos adjacent to the silt trap release points, avoiding direct discharge into the Kamuzu Dam II. Alternatively, this water may be supplied as potable water to the nearby

community (subject to the water quality meeting the relevant Malawi Drinking Water Specification and the relevant permits are obtained).

- Flow dissipation measures will be installed at clean and silty water release points, where necessary, to help prevent or minimise erosion by dissipating the energy from those flows.

2.9.7.3 Temporary Ore Stockpiles

The following stormwater management measures have been incorporated in the conceptual Project layout for the ore stockpiles (Figure 2.9):

- Considering that some of the stockpiles are located on a gentle catchment divide, a limited section of the upstream catchment will drain towards the stockpiles, and hence nominal 1 m or 0.5 m berms will be adequate to divert clean water towards the south and towards Dambo 1.
- The runoff within the silty stockpile catchments and the pits will be managed at the silt trap to the east of the pits with the excess water pumped from the pit before release to Dambo 1.

2.9.7.4 Tailings Storage Facility

The following stormwater management measures have been incorporated in the conceptual Project layout for the TSF (Figure 2.9):

- Due to the TSF location directly north of the catchment divide, no external clean water catchment will drain towards the TSF and hence there is no requirement to divert clean stormwater away from the TSF.
- Silty stormwater from the TSF sidewalls will be collected in perimeter toe paddocks and allowed to evaporate. The stormwater retention berms will be placed approximately 30 m from the TSF side slope and the paddocks will be approximately 50 m long. The paddocks will contain a volume of approximately 421 m^3 with a maximum water depth of about 28 cm. Considering the high evaporation and a conservative estimate of infiltration, it would take approximately 10 days to empty the toe paddock.
- Dirty stormwater from the TSF will be collected through the supernatant pond and TSF penstock or barge pump system, and conveyed through a silt trap to the RWD for re-use.

2.9.8 Water Balance

The overall site water balance was determined for three different stages of mining over the life-of mine. The average dry and wet season are presented for the Years 0, 8 and 15 in Figure 2.10 through to Figure 2.15 where:

- Year 0 represents the initial years of striping and pit development.
- Year 8 presents the mid-life of mine.
- Year 15 represents the stage in mining where maximum groundwater inflows are expected.

As stated previously, at the start of mine, groundwater inflows are relatively low and in the dry season the mine will be reliant on external makeup water from the Kamuzu Dam or additional boreholes (other than dewatering boreholes).

In the wet season the collected stormwater on site becomes a supplementary source of process water thereby reducing the use of pit water, and hence a need to discharge more pit water.

From Year 2 onwards the mine becomes water positive for the rest of the life-of-mine with a requirement to discharge water from dewatering of pits.

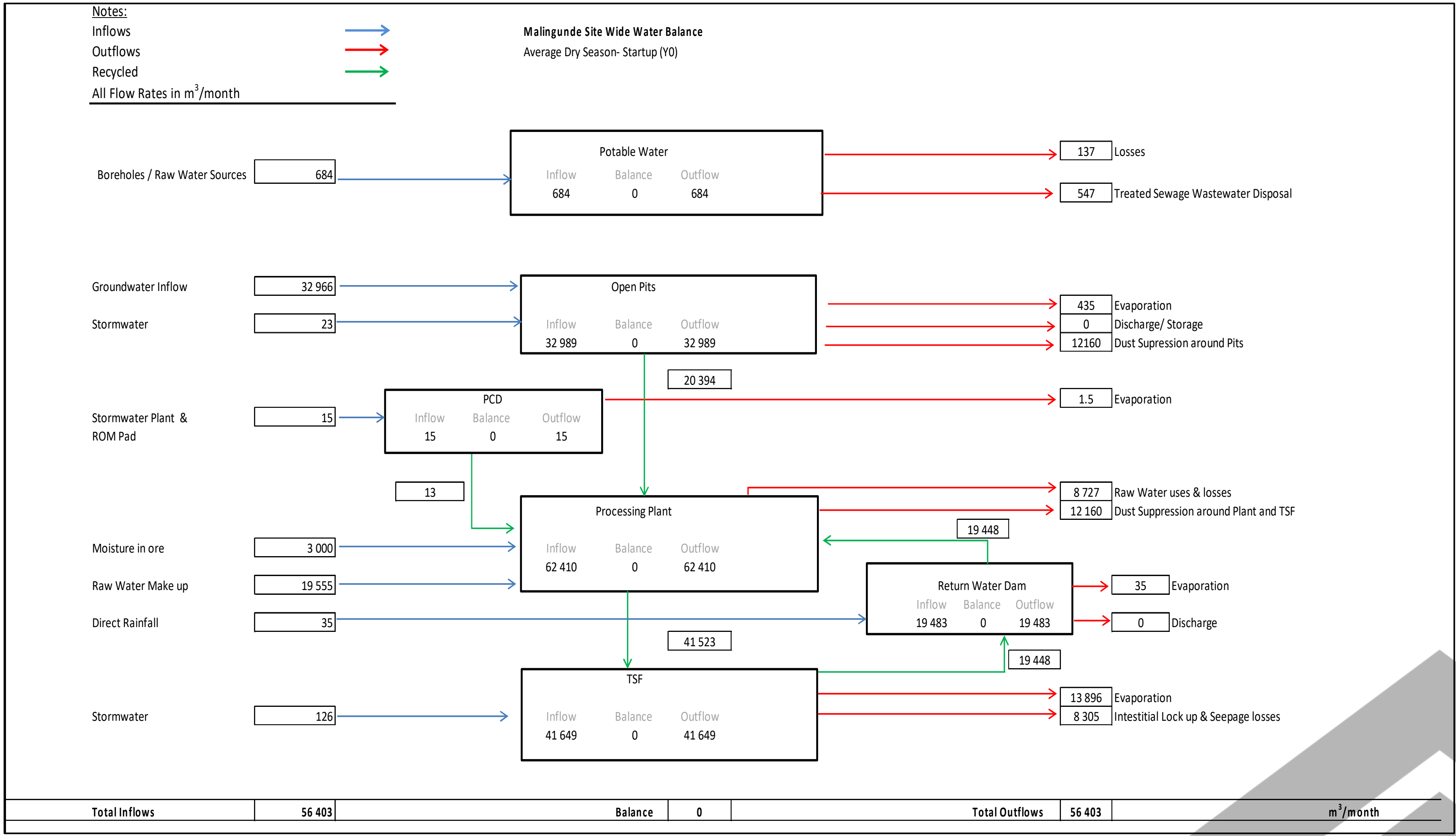


Figure 2.10: Site Water Balance - Average Dry Season in Year 0

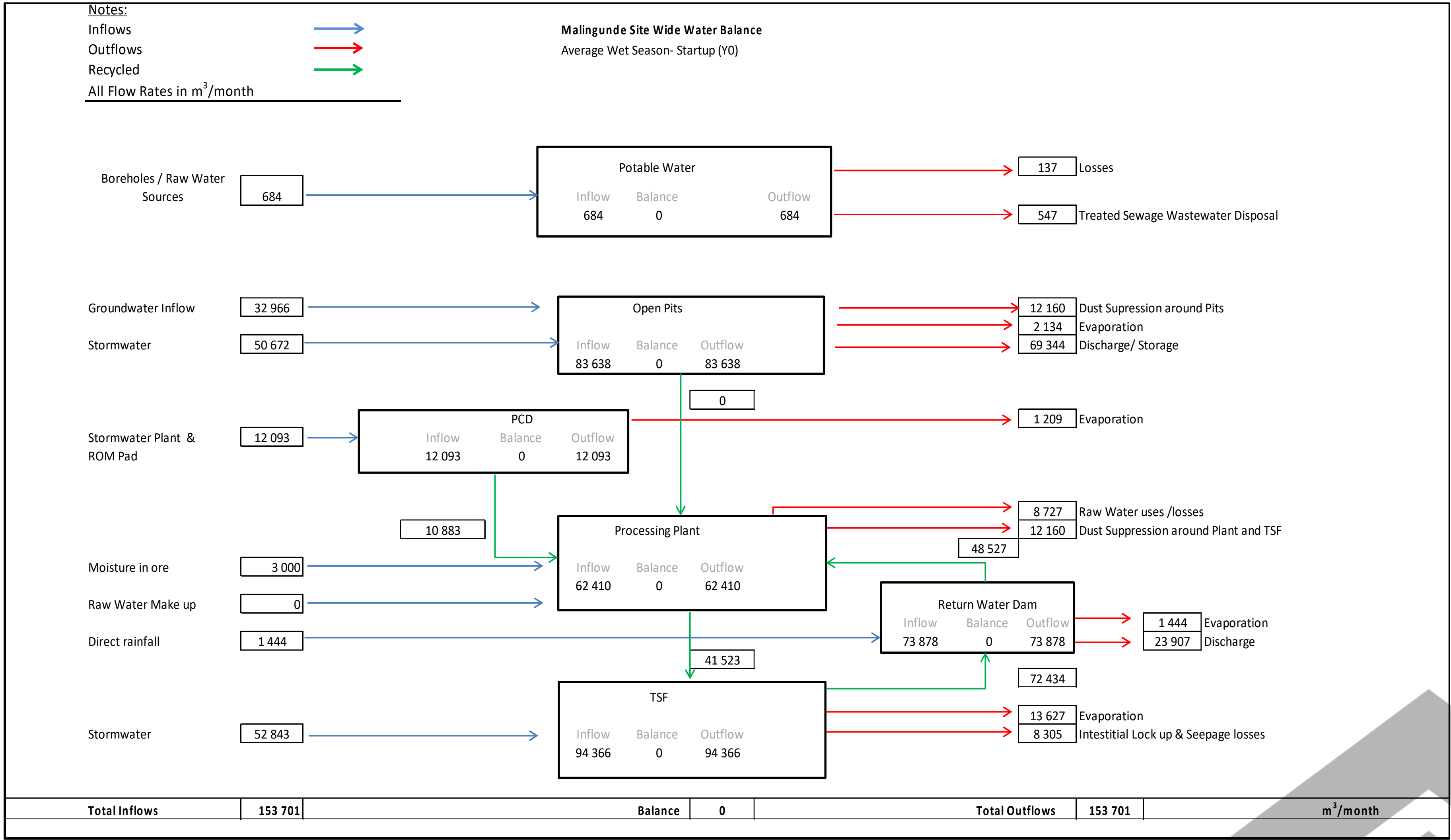


Figure 2.11: Site Water Balance - Average Wet Season in Year 0

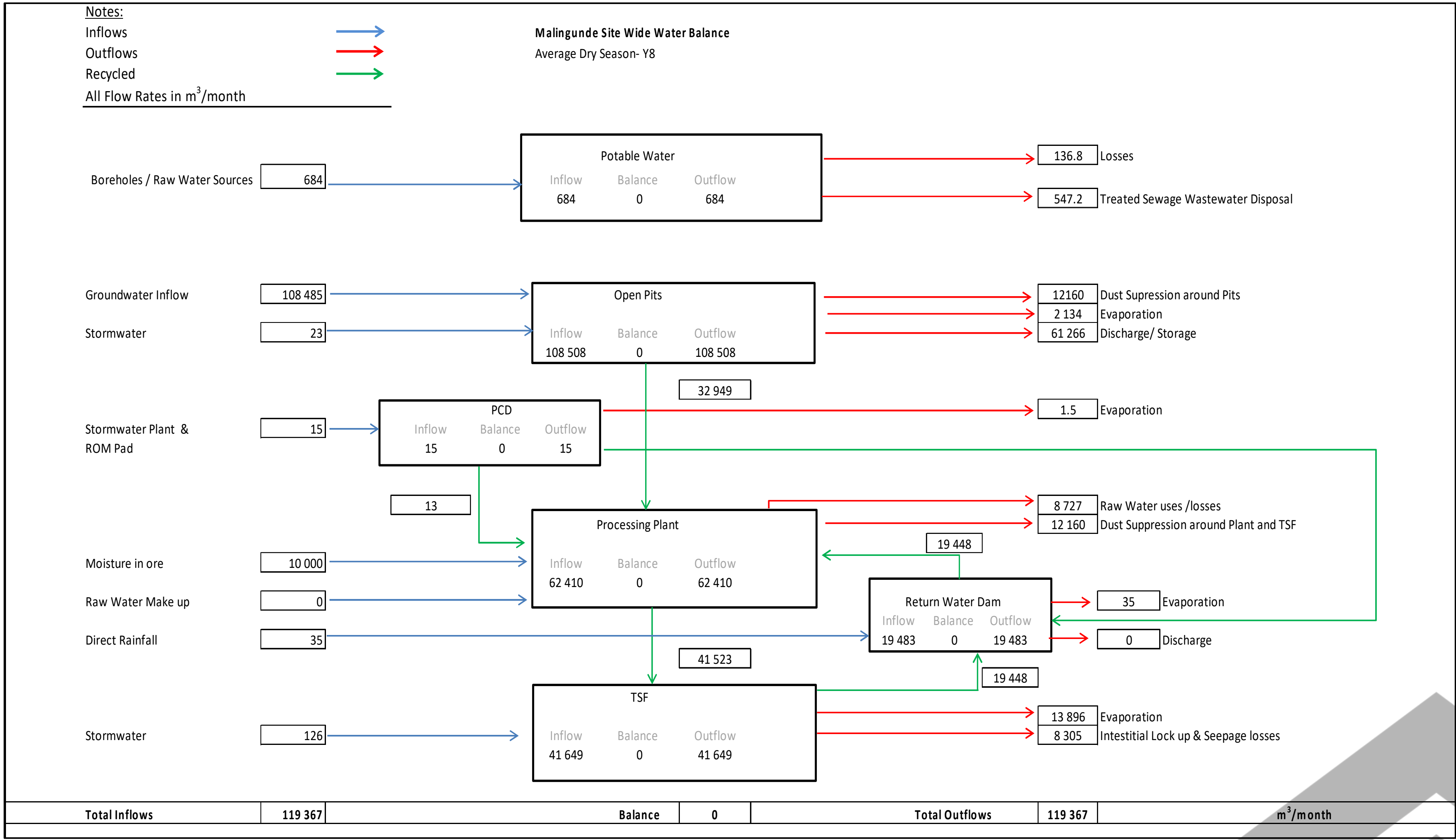


Figure 2.12: Site Water Balance - Average Dry Season in Year 8

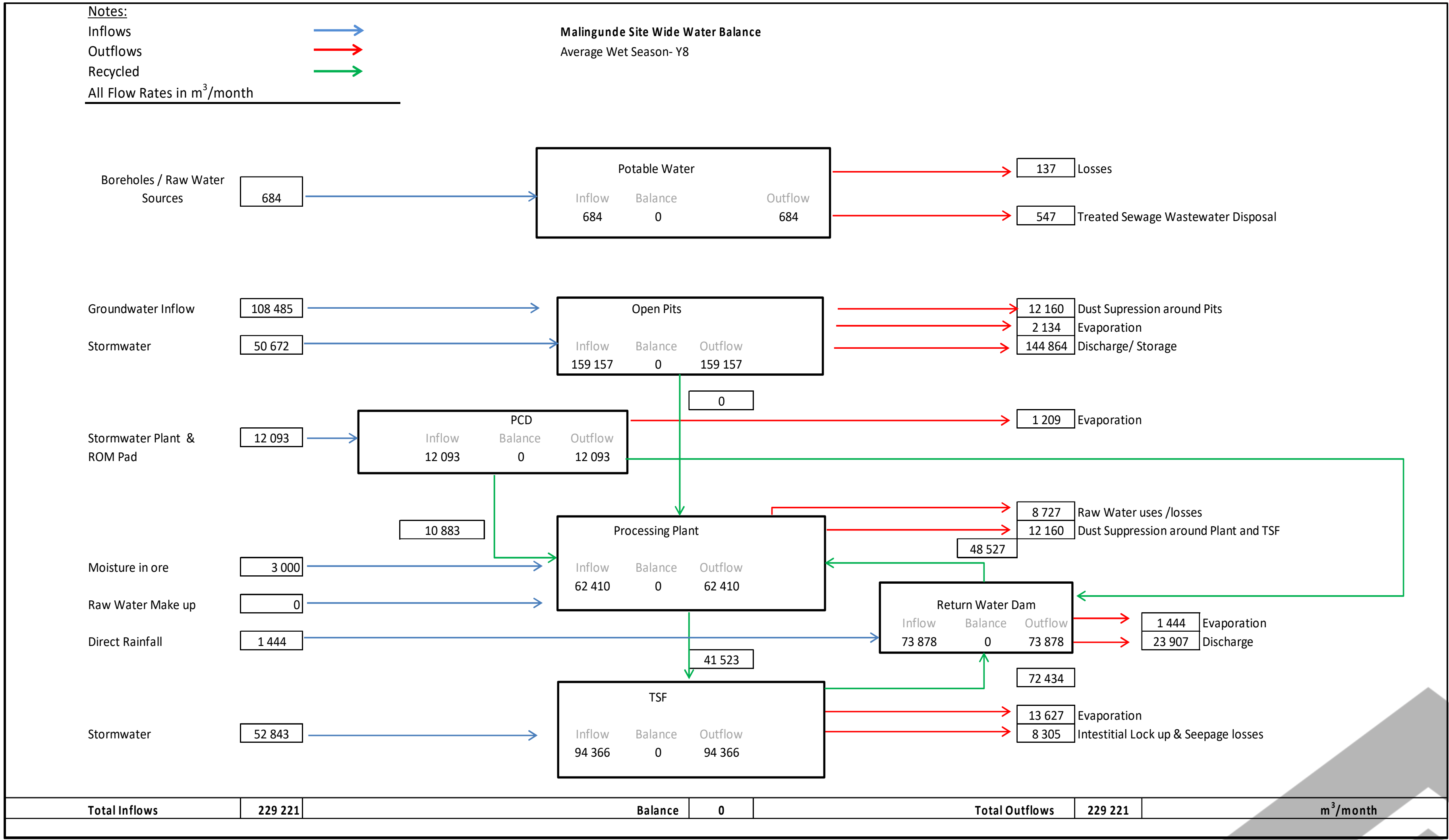


Figure 2.13: Site Water Balance - Average Wet Season in Year 8

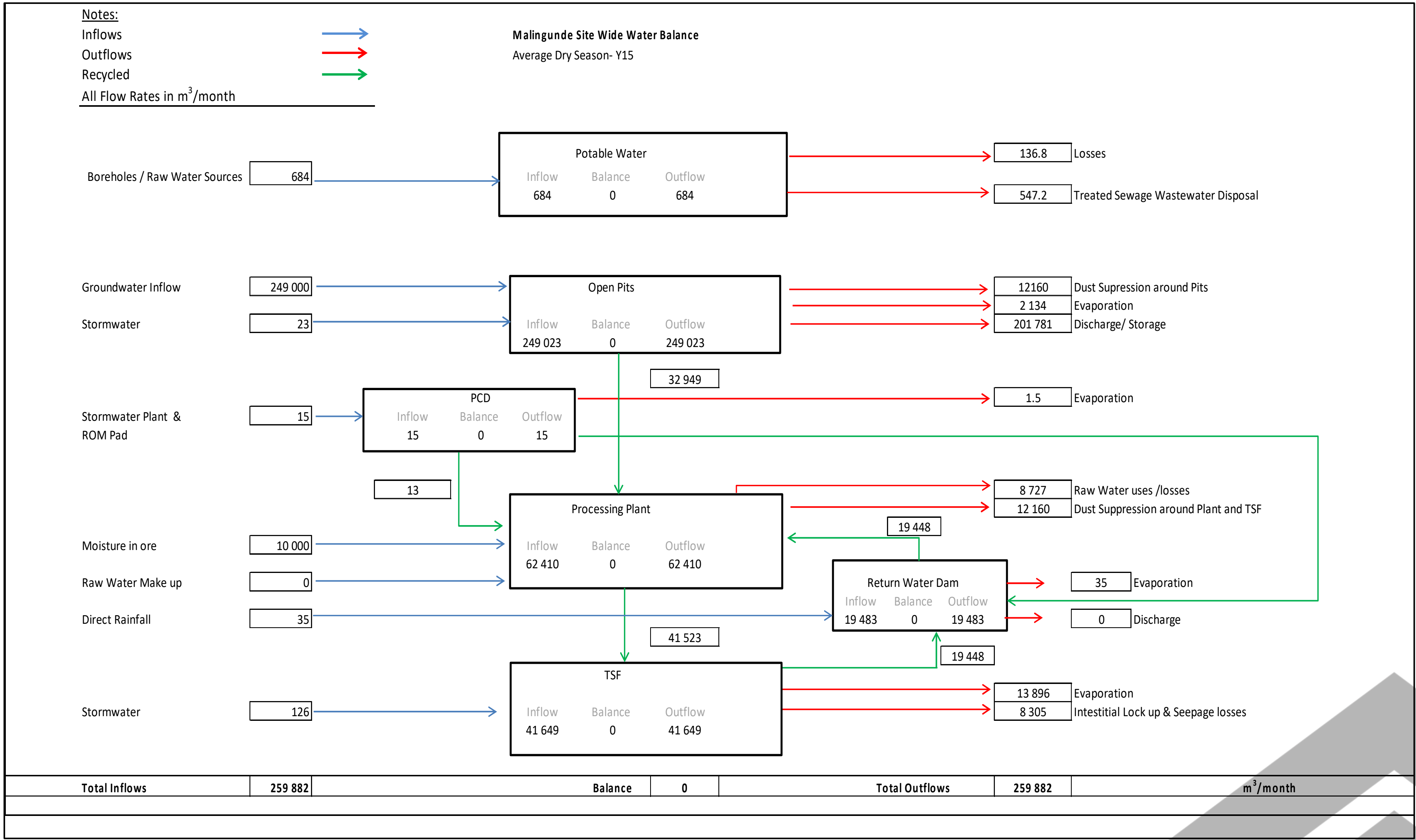


Figure 2.14: Site Water Balance - Average Dry Season in Year 15

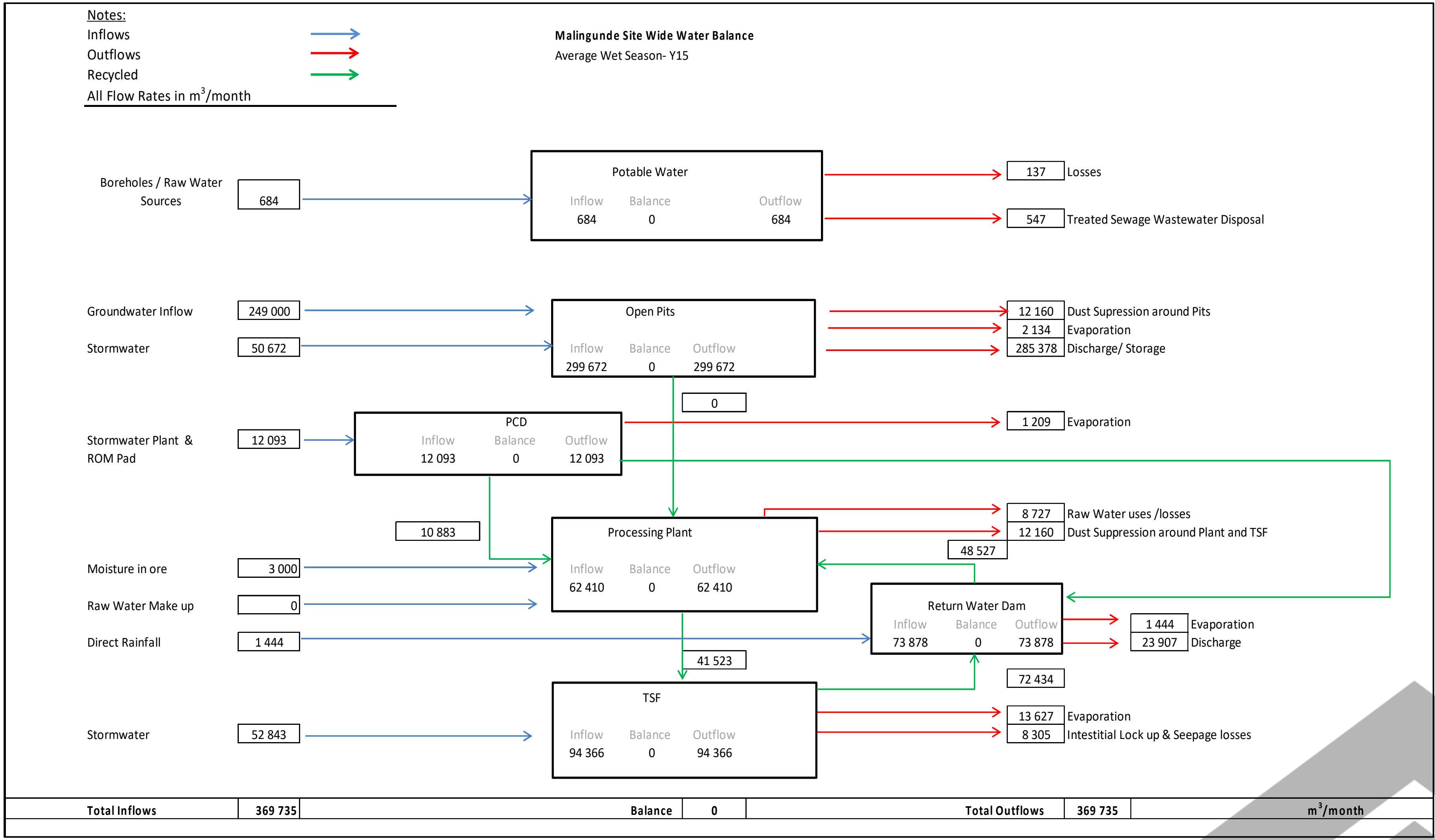


Figure 2.15: Site Water Balance - Average Wet Season in Year 15

2.10 Electricity Supply

2.10.1 Project Power Supply

Power will be generated on site by five 1-megawatt (MW) high-speed generators for a total installed continuous capacity of 3 MW. The generators will be diesel fired and housed in a power station located adjacent the processing plant (Figure 2.3). The electrical output of the power station will be 3 phase, 50 hertz, 11 kilovolt (kV). It is estimated that 1.5 million L/y of diesel will be require during the first four years of operations for power generation.

Power will be supplied from the power station 11 kV switchboard to the processing plant transformers via underground 11 kV cables of approximately 50 to 150 m in length. Power supply to the mine dewatering system shall be by stand-alone diesel generating sets.

In the processing plant area, step-down transformers shall supply 400 volt to the scrubbing, flotation and thickening/services/packing/drying motor control centres and to the non-process infrastructure main switchboard.

The Malawi Electrical Supply Corporation (ESCOM) plans to construct a 132/11 kV substation near Bunda, 10 km to the east of the Project which will connect to the national grid. Sovereign has received advice from ESCOM that the planned Bunda substation will be operational by 2024. Construction of the transmission line linking the Project to the Bunda sub-station is planned to be complete by the time the Bunda sub-station comes online in 2024. It has therefore been assumed on site diesel power generation will only be required until 2024, with grid power available after this.

2.10.2 Essential Power

A packaged 250 kW diesel standby generator set will provide electrical power in the event of loss of power supply to the administration offices. The standby generator will be manually started and will energise the 400 volt office switchboard and thus essential power will be available at all load centres supplied from this switchboard. These offices will be the nominated control centre in case of fire, flood or other emergency.

Refuelling of the generator day tank will be provided by a mine refuelling vehicle.

2.11 Diesel Storage Facility

This facility will be located within the processing plant area as indicate in Figure 2.3.

A bulk fuel storage facility will be provided by the fuel supply contractor consisting of self-contained (bunded) diesel storage tanks. Sufficient storage is included to sustain operations for a period of one week at normal consumption rates (approximately 120,000 L per week).

It is anticipated that 30,000 L tanker loads of fuel will be delivered to site as required to the bulk fuel storage facility. The fuel will be delivered by the fuel supply contractor who will also be responsible to maintain the fuel unloading, storage and delivery systems.

The bulk storage tanks will supply the power station generator day tanks and the processing plant storage tank and allow for refuelling of both heavy and light vehicles.

The facility will include drive over concrete bunded slabs and refuelling arms to for the mining vehicles. The refuelling arms will deliver diesel from the storage tanks at 1,200 L per minute.

The concentrate transport trucks will not be refuelled on site. This will be the responsibility of the transport contractor.

A sludge pit, sump and pump will be provided to recover any minor spillage with contaminated oily water being returned to the processing plant tailings thickener for recycling.

2.12 Non-processing Infrastructure

2.12.1 Administration Building

The administration building will be located near the main entrance to the processing plant area and will have a number of offices and open plan workspaces to accommodate the senior management, accounting, commercial, human resources, environmental, mining, survey and geology personnel at the mine.

The building will have a minimum internal floor area of 250 m^2. The building will be constructed from transportable, modular steel-framed structures with concrete floors and colorbond™ type steel sheet cladding to walls and roofs.

2.12.2 Change House

A combined change house/ locker room will be provided and will be a prefabricated style building nominally 30 m^2 fitted out with lockers, male and female ablutions, showers and laundry.

2.12.3 Canteen

The building will have a minimum internal floor area of about 250 m^2 sufficient to accommodate about 50 personnel at any one time.

The canteen will be of similar construction to the administration building. The crib room will be fitted with cupboards, benches, microwave, hot water dispensers, chilled water dispensers, refrigerators, sinks, dishwashers and external wash troughs.

2.12.4 Sample Preparation and Laboratory Facility

A sample preparation and laboratory facility will be provided inside the plant area to undertake analysis of ore, plant samples and concentrate quality respectively.

It will comprise of a covered steel framed building with open sides housing sample preparation equipment and two closed transportable style buildings fitted out with analytical laboratory equipment, offices, ancillary equipment and laboratory consumable storage.

2.12.5 Workshops

A workshop will be provided for servicing the mining fleet. This workshop will be designed, supplied and installed by the mining contractor and situated on concrete foundations. Wash-down and run-off water from the workshop will be captured and drained into a sludge pit and sump complete with sediment trap.

Mine operations offices will be located adjacent to the workshop and will include amenities.

2.12.6 Heavy Vehicle Wash-down Facility

A wash-down facility will be provided in the hardstand area adjacent to the heavy vehicle workshop. The facility will consist of a single drive through armoured concrete bunded slab, two wash-down platforms with high pressure water cannons. Wash-down water from the facility will be captured and drained into an adjacent sludge pit and sump complete with sediment trap.

2.12.7 Oil-Water Separation Facility

An oil-water separation facility will be installed adjacent to the heavy vehicle workshop. The floor and apron of the workshop will be sloped towards the separator to catch runoff from hosing and rainfall. A similar system will be installed on the vehicle wash-down facility, adjacent to the sump and sediment trap. The waste oil captured by this facility will also be pumped back to the waste oil tank.

2.12.8 Bulk Lubricant and Hydrocarbon Storage Facility

A bulk lubricant and hydrocarbon storage facility will be constructed adjacent to and adjoining the workshop. The facility will comprise three storage tanks for storing the hydraulic, engine and waste oil. The bulk storage tanks will be covered and located within a concrete bunded area. In addition, provision will be made for the storage of intermediate bulk containers and drums of lubricants adjacent to the bulk storage facility.

2.12.9 Waste Management Facility

A clean fill unlined landfill is proposed which will be capable of receiving non-hazardous, non-biodegradable (half-life greater than 2 years) wastes including building and demolition waste (e.g., bricks, concrete and associated glass, metal and timber), unavoidable small quantities of plastics, office and packaging waste (e.g. paper, cardboard, plastics, wood) that is mixed with any other type of waste and, organic waste and non-chemical waste generated from manufacturing and services.

2.12.10 Fencing

Perimeter fencing will be provided to the mine services area and processing plant area only. Fences will be galvanised fence poles concreted into ground with galvanised chain-wire security type mesh that is 2.1 m high with 3 off strands of barbed wire at top of fence.

It is not intended that open pit areas, the TSF and ore stockpiles will be fenced off.

2.13 Workforce

Local workers from the surrounding Malingunde area will be given preference for job opportunities, depending on their skills level, as it is anticipated that available jobs will be largely low-skilled or semi-skilled.

A relatively small number of construction workers will be required; approximately 220 workers at peak demand, of which 60 will be expatriate employees.

During operations an estimated 167 people will be employed by the Project, of which 11 will be expatriate employees during Year 1 to Year 3. The number of expatriate employees will be reduced to four Year 4 onwards.

In addition to this, another 80 to 90 people will be employed by subcontractors during operations (including mining, laboratory, fuel farm, power plant, security, bus services, catering and cleaning), of which 6 to 8 will be expatriate employees.

The Project will endeavour to provide equal opportunities to women in the workforce.

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Chapter 3: Alternatives Considered

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3 Alternatives Considered

3.1 Introduction

Subsequent to completion of the economic scoping study, a number of site layout options were put forward for consideration and further investigation. As indicated in Figure 3.1, four TSF options (i.e., TSF Option 2, TSF Option 3, TSF Option 5 and TSF Option 7), three waste rock dump (WRD) options (i.e., WRD Option A, WRD Option B North and South, and WRD Option C) and three options for the location of the processing plant (i.e., Plant Option A, Plant Option B and Plant Option C) were developed prior to the preferred option (as described in more detail in Chapter 2) being selected.

3.2 TSF Options Assessment

A preliminary study on the proposed TSF options was undertaken by SLR Consulting (Africa) Pty Ltd (SLR, 2017). As part of this study eight TSF sites were sized and located based on the contours, pit location and envisaged plant locations.

During the site selection process numerous criteria were considered to ensure all potential positive and negative impacts are understood. Long and short-term risks associated with a TSF, which have both environmental and economic impacts, were also evaluated.

The key criteria identified were evaluated and a rating given for each of the options according to the following rating scale:

Rating value	1	2	3	4	5	6	7
Description	Worst	Very Poor	Poor	Intermediate	Good	Very Good	Best

A weighting factor was applied to each of the criteria, based on the relative level of importance between the various criteria/impacts/concern. For example, the hazard on public health and safety was considered far more important than the release of silt laden pollutants to a stream, or pumping distance, and therefore given a higher weighting factor.

The multiplication of the site rating value with the weighting factor provided a weighted rating. The weighted ratings were added together to get an overall rating, which determined the ranking of the sites (lowest score is least preferred, while highest score is most preferred). Through this process, the following three sites with the lowest scores were discarded and not further considered:

- TSF Option 1 – total score of 140 (weighted), 31 (unweighted).
- TSF Option 6 – total score of 233 (weighted), 48 (unweighted).
- TSF Option 8 – total score of 195 (weighted), 37 (unweighted).

The weighted and unweighted scores for the remaining five sites are summarised below:

- TSF Option 2 – total score of 345 (weighted), 62 (unweighted).
- TSF Option 3 – total score of 359 (weighted), 66 (unweighted).
- TSF Option 4 – total score of 354 (weighted), 65 (unweighted).
- TSF Option 5 – total score of 272 (weighted), 53 (unweighted).
- TSF Option 7 – total score of 245 (weighted), 45 (unweighted).

Of these, four options (2, 3, 5 and 7) were carried through for conceptual design and costing. Option 4 was very similar to Option 3 and would likely not add any further value to the assessment; as such it was not considered further. The description as well as rating of these four options are summarised in Table 3.1. All eight options were ranked and assessed in a similar manner; however, for the purposes of this report, only the four options carried forward are described here. Based on the risk ranking and the cost estimation, Option 2 was selected as the preferred case for the study.

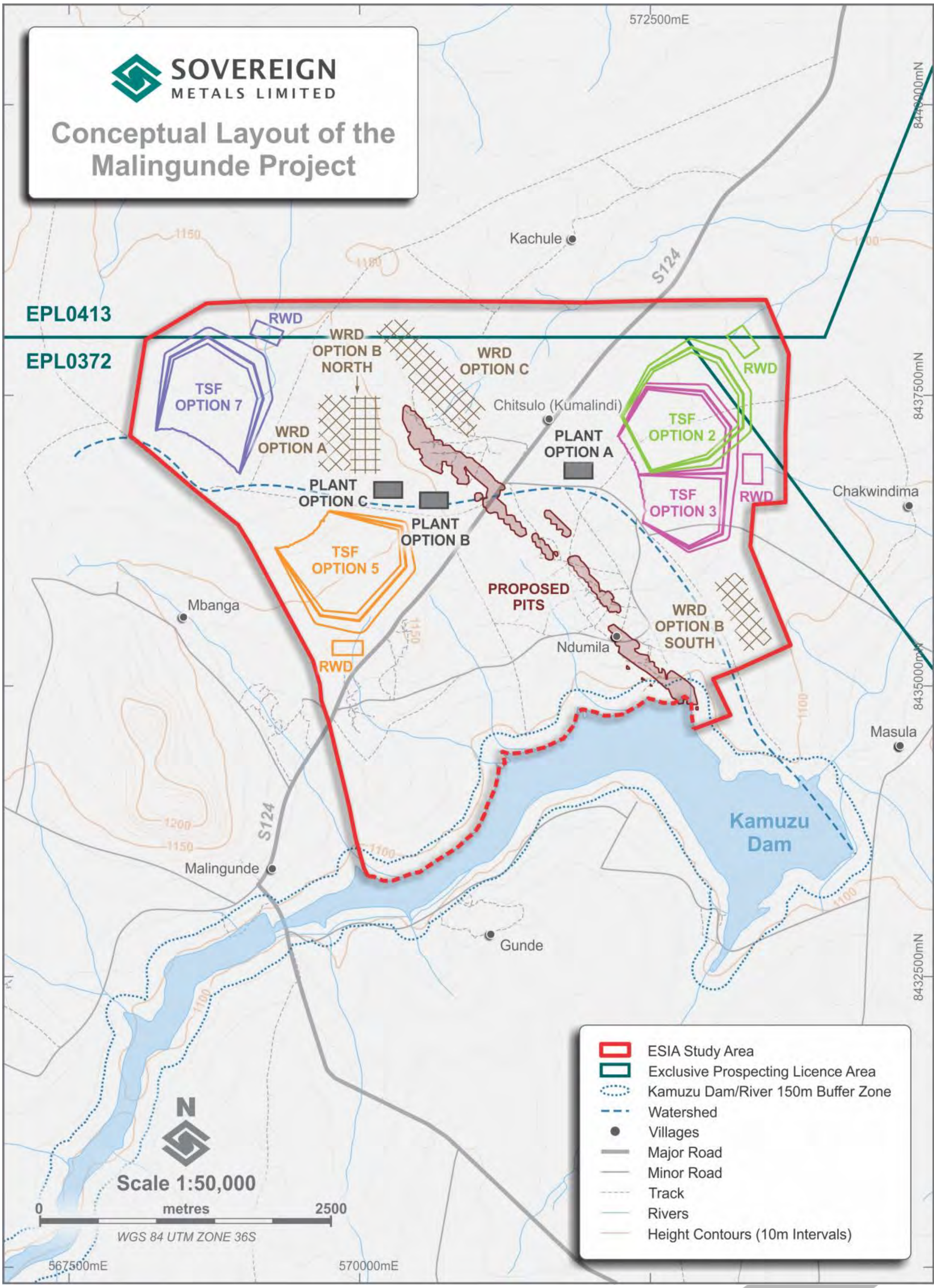

Figure 3.1: Conceptual Layout Options Considered for the Project

Table 3.1: TSF Site Selection Matrix

	Option 2	Option 3	Option 5	Option 7
Key Characteristics	Located east of Chitsulo and Kumalindi Villages and the S124 secondary road from Lilongwe. Located outside of any wetland areas. ±1.5 km from a confluence with a small tributary of the Lilongwe River northeast of the site (total of 3.76 km away from the Lilongwe River). Located a minimum of 100 m from any dwellings or cemeteries. Located outside of the Kamuzu Dam catchment area. Located to the east of the pits within the centre of gravity between the most northern and southern pits. Process Plant Option A is the most feasible option for TSF Option 2 as it is located within 1.4 km from the TSF and there is no requirement to cross any main roads to pump tailings from and water to the plant. Haulage of waste rock from the northern pits to the TSF for TSF wall construction will require a crossing over the S124.	Consists of a double compartment TSF. Located directly south of TSF Option 2, and to the east of Kumalindi Village and the S124 from Lilongwe. Located outside of any wetland areas. ± 2.4 km from the Lilongwe River. Located a minimum of 100 m from any dwellings or cemeteries. Located across the extension of the S124, which will require this road to be diverted. Located outside of the Kamuzu Dam catchment area. Located to the east of the pits close to the centre of gravity between the most northern and most southern pits. Process Plant Option A is the most feasible option for TSF Option 3 as it is located within 1.4 km from the TSF and there is no requirement to cross any main roads to pump tailings from and water to the plant. Haulage of waste rock from the northern pits to the TSF for TSF wall construction will require a crossing over the main S124.	Located west of Kumalindi Village and the S124 from Lilongwe. Located outside of any wetland areas. ±2 km north of the Kamuzu Dam II. Located a minimum of 100 m from any dwellings or cemeteries. Located inside of the Kamuzu Dam catchment area. Located to the west of the pits closer to the most northern pits (1.4 km). Process Plant Option B and Option C are the most feasible options for TSF Option 5 as both process plants are located within 0.9 km from the TSF and there is no requirement to cross any main roads to pump tailings from and water to the plant. Local access road between the TSF and process plant will need to be crossed.	Located northwest of Kumalindi Village and the S124 from Lilongwe. Located at the headwaters of the Kankoma dambo and is ± 10km from the Lilongwe River. Located a minimum of 100 m from any dwellings or cemeteries. Located outside of the Kamuzu Dam catchment area. Located to the northwest of the pits ±1.5 km from the most northern pit and ±4.5km from the most southern pit. Process Plant Option B and Option C are the most feasible options for TSF Option 7 as both Process Plants are located within 1.9 km from the TSF and there is no requirement to cross any main roads to pump to and from the Plant. Haulage of waste rock from the pits to the TSF for TSF wall construction will not require any major road crossings.
TSF Dam Break Hazard - location of dwellings, people, land, streams etc. within failure zone of influence, in the event of a major TSF failure. (NB this is a HAZARD rating and not an assessment of the potential for failure. With appropriate investigations and design, good construction and a well managed operation the risk of a TSF failure would be very small regardless of the option chosen).				
Rating	4	5	4	3
	Intermediate	Good	Intermediate	Poor
Description	a) Upstream dam break will largely affect adjacent agricultural fields. Downstream flow of tailings with the gradient will have a smaller effect on land users compared to a downstream dam break as discussed below. b) Villages and settlements downstream (northeast) will be affected in the event of	a) Upstream dam break will largely affect adjacent agricultural fields. Downstream flow of tailings with the gradient will have a smaller effect on land users compared to a downstream dam break as discussed below. b) Downstream villages in the valley will be affected in the event of a dam break.	a) Upstream dam break will largely affect adjacent agricultural fields. Downstream flow of tailings with the gradient will have a smaller effect on land users compared to a downstream dam break as discussed below. b) Village directly to the southwest and west may be affected in the event of a	a) This option is located in a valley so no upstream dam break is possible as the tailings does not break ground b) Downstream villages in the valley will be affected in the event of a dam break. c) Agricultural land will be impacted. d) Contamination of tributary to Lilongwe River and possibly Lilongwe River

	Option 2	Option 3	Option 5	Option 7
	a dam break. Villages to the northwest should remain unaffected due to the presence of the catchment divide. c) Agricultural land will be impacted. d) Contamination to tributary of the Lilongwe River and possibly the Lilongwe River, 3.7 km away. e) Plant Option A is at a higher elevation than the TSF and therefore no effect on the plant is envisioned. Plant Options B and C are separated from the TSF by the pits and a catchment divide.	c) Agricultural land will be impacted. d) Contamination to tributary of the Lilongwe River and possibly the Lilongwe River, 2.4 km away. d) Plant Option A is at a higher elevation than the TSF and therefore no effect on the plant is envisioned. Plant Options B and C are separated from the TSF by the pits and a catchment divide.	dam break when the TSF is at an elevation, however the TSF is located within a different catchment which could minimise the extent of impact to the village. c) Agricultural land will be impacted. d) Contamination to the Kamuzu Dam II located ±2.4 km away, however there will be a significant amount of dilution within the dam. e) A portion of Plant Option B may be affected. Plant Option C is separated from the TSF by a catchment divide so limited affect will occur on Plant Option C. Plant Option A will not be affected as it is separated from the TSF by a catchment divide and the pits.	±10 km away (however a significant amount of dilution will occur). e) No effect on the process plants
Score = Rating x Weighting (15)	60	75	60	45
Proximity to surface water resources. The Lilongwe River fed by the Kamuzu Dam is a major water supply to Lilongwe.				
Rating	4	4	2	3
	Intermediate	Intermediate	Very Poor	Poor
Description	a) TSF is not located within a dambo. b) TSF is located outside of a valley with the toe of the TSF being located at the top of the valley. c) Downstream toe of the TSF is located ±1.5 km from a confluence of a tributary of the Lilongwe River and ±3.76 km away from the main Lilongwe River. d) Downstream toe of the TSF is ±20.36 km from the outskirts of Lilongwe town. e) Lower dilution potential available in the case of a possible dam break due to 3.7 km distance to Lilongwe River. f) TSF located outside of the Kamuzu Dam catchment.	a) TSF is not located within a dambo. b) TSF is located outside of a valley with the toe of the TSF being located at the top of the valley. c) Downstream toe of the TSF is located ±2.4 km away from the Lilongwe River. d) Downstream toe of the TSF is ±22.9 km from the outskirts of Lilongwe town. e) Lower dilution potential available in the case of a possible dam break due to 2.4 km distance to Lilongwe River. f) TSF located outside of the Kamuzu Dam catchment.	a) TSF is not located within a dambo. b) TSF is located outside of a valley. c) Downstream toe of the TSF is located ±2 km away from the Kamuzu Dam II located on the Lilongwe River. d) Increased dilution potential available in the case of a possible dam break as this would flow into the Kamuzu Dam II. e) TSF is located within the Kamuzu Dam catchment.	a) TSF is located within a dambo and additional geotechnical work may be required under the TSF wall. b) TSF is located within a valley. c) Downstream toe of the TSF is located ±10 km away from the Lilongwe River. d) Downstream toe of the TSF is ±21.2 km from the outskirts of Lilongwe town. e) Increased dilution potential available in the case of a possible dam break due to 10 km distance to Lilongwe River. f) TSF located outside of the Kamuzu Dam catchment.
Score = Rating x Weighting (10)	40	40	20	30

	Option 2	Option 3	Option 5	Option 7
Proximity to dwellings / cultural heritage sites				
Rating	5	6	4	3
	Good	Very Good	Intermediate	Poor
Description	a) TSF is not located over a village. b) Agricultural fields are located ±0.13 km from the downstream toe of the TSF that may require compensation and relocation. c) The toe of the downstream TSF wall is located ±0.6 km away from the edge of Chinole village (within the valley)	a) TSF is not located over a village. b) The toe of the downstream TSF wall is located ±1.5 km from the edge of Chakwindima village	a) TSF is not located over a village. b) The toe of the downstream TSF wall is located ±0.1 km away from the edge of village (across a road). c) Possible resettlement of community members may be required.	a) TSF is not located over a village. b) Agricultural fields are located ±0.5 km from the downstream toe of the TSF. c) The toe of the downstream TSF wall is located ±3.3k m away from edge of a large village (within the valley)
Score = Rating x Weighting (6)	30	36	24	18
Likely impact on groundwater with respect to local water supply from wells, as well as seepage into pits for dewatering/pit slope stability				
Rating	5	5	4	3
	Good	Good	Intermediate	Poor
Description	a) Seepage from the TSF into the pits is not expected to occur. b) Groundwater seepage from the TSF expected to be benign and therefore there will be limited effect on groundwater within the village downstream of the TSF.	a) Seepage from the TSF into the pits is not expected to occur. b) Groundwater seepage from the TSF expected to be benign and therefore there will be limited effect on groundwater within the village downstream of the TSF.	a) Seepage from the TSF into the pits is highly unlikely. b) Groundwater seepage from the TSF expected to be benign and therefore there will be limited effect on groundwater within the village area downstream of the TSF. c) The village downstream of the TSF is located closer to the TSF than other options.	a) Seepage from the TSF into the pits is highly unlikely. b) Groundwater seepage from the TSF expected to be benign and therefore there will be limited effect on groundwater within the village downstream of the TSF.
Score = Rating x Weighting (5)	25	25	20	15
Disturbance of land use and natural habitat				
Rating	4	4	4	3
	Intermediate	Intermediate	Intermediate	Poor
Description	100% agricultural land	100% agricultural land	100% agricultural land	95% agricultural land, 5% dambo vegetation
Score = Rating x Weighting (5)	20	20	20	15

	Option 2	Option 3	Option 5	Option 7
Dust nuisance - predominant wind direction towards the west, northwest and southwest				
Rating	4	4	2	3
	Intermediate	Intermediate	Very Poor	Poor
Description	Dust will blow towards surrounding small-scale farmers, a portion of the village ±0.2 km northwest of the TSF, Plant Option A ±0.78 km to the southwest and possibly the northern and central pits.	Dust will blow towards surrounding small-scale farmers, a portion of the village ±0.4 km northwest of the TSF, Plant Option A ±0.75 km to the southwest and possibly the northern and central pits.	Dust will blow towards the village directly to the west and southwest (±0.1 km) of the TSF and the surrounding small-scale farmers.	Dust will blow towards the village ±0.9 km southwest of the TSF (over a hill) and the surrounding small-scale farmers.
Score = Rating x Weighting (5)	20	20	10	15
Ease of closure and post mining suitability / return of TSF to an appropriate land function				
Rating	4	4	4	4
	Intermediate	Intermediate	Intermediate	Intermediate
Description	a) Located on gently sloping ground with very small upstream catchment. b) Small walls upstream will be present at the LOM with a large wall downstream of the TSF. The TSF wall will require full rehabilitation since downstream construction does not allow for concurrent rehabilitation. c) Surface to be rehabilitated and could possibly be utilised for agricultural activities.	a) Located on gently sloping ground with very small upstream catchment. b) Small walls upstream will be present at the LOM with a large wall downstream of the TSF. The TSF wall will require full rehabilitation since downstream construction does not allow for concurrent rehabilitation. c) Surface to be rehabilitated and could possibly be utilised for agricultural activities.	a) Located on gently sloping ground with very small upstream catchment. b) Small walls upstream will be present at the LOM with a large wall downstream of the TSF. The TSF wall will require full rehabilitation since downstream construction does not allow for concurrent rehabilitation. c) Surface to be rehabilitated and could possibly be utilised for agricultural activities.	a) Located within a valley. Small walls upstream will be present at the LOM with a large wall downstream of the TSF. b) The TSF wall will require full rehabilitation since downstream construction does not allow for concurrent rehabilitation. c) Surface to be rehabilitated and could possibly be utilised for agricultural activities. Has a small upstream catchment for consideration in closure.
Score = Rating x Weighting (6)	24	24	24	24
Technical (engineering) characteristics / challenges of site with respect to design, construction, operation and closure				
Rating	7	6	4	4
	Best	Very Good	Intermediate	Intermediate
Description	A favourable gently sloping for a TSF design and development, and sufficient space for a RWD if required. No problematic foundation conditions are expected (geotechnical investigation still required to confirm).	A favourable gently sloping area for a TSF design and development, and plenty space for a RWD if required. No problematic foundation conditions are expected (geotechnical investigation still required to confirm).	A favourable gently sloping area for a TSF design and development, and plenty space for a RWD if required. Steeper fall of ground and space may increase technical aspects of construction of a silt trap and RWD. No problematic foundation conditions are expected.	Open V-shaped valley with shallow sloping floor considered favourable for TSF construction. Small upstream catchment, with a part of the main wall and ±20% of the TSF basin floor located within a dambo, which tend to exhibit near surface perched water table conditions requiring foundation treatment.
Score = Rating x Weighting (8)	24	24	24	24

	Option 2	Option 3	Option 5	Option 7
Sterilisation of minerals (possible impact on long term mine development)				
Rating	6	5	5	5
	Very Good	Good	Good	Good
Description	Not expected	Not expected	Not expected	Not expected
Score = Rating x Weighting (3)	18	15	15	15
TSF capacity and material required for wall construction				
Rating	5	5	4	4
	Good	Good	Intermediate	Intermediate
Description	a) TSF capacity of 6.58 million m^3 of tailings as per the design criteria, based on production of 7.24 Mt at an assumed deposited dry density of 1.1 t/m^3 b) Estimated maximum TSF wall height will be approximately 19.5 m. c) Estimated volume of the TSF wall approximately 1.71 million m^3.	a) TSF capacity of 6.58 million m^3 of tailings as per the design criteria, based on a production of 7.24 Mt at an assumed deposited dry density of 1.1t/m. b) Estimated maximum TSF wall height will be approximately 20 m. c) Estimated volume of the TSF wall approximately 1.83 million m^3.	a) TSF capacity of 6.58 million m^3 of tailings as per the design criteria, based on a production of 7.24 Mt at an assumed deposited dry density of 1.1t/m. b) Estimated maximum TSF wall height will be approximately 25.1 m. c) Estimated volume of the TSF wall approximately 2.15 million m^3.	a) TSF capacity of 6.58 million m^3 of tailings as per the design criteria, based on a production of 7.24 Mt at an assumed deposited dry density of 1.1t/m. b) Estimated maximum TSF wall height will be approximately 28.5 m. c) Estimated volume of the TSF wall approximately 2.24 million m^3.
Score = Rating x Weighting (4)	20	20	16	16
Location to pits (northern and southern) for possible haulage of pit waste for use in TSF containment walls, and TSF dam break hazard potential				
Rating	5	6	5	3
	Good	Very Good	Good	Poor
Description **Northern pits**	TSF is located at the centre of gravity between most northern and most southern pit. ±2.4 km from most northern pit (average haul distance).	TSF is located at the centre of gravity between most northern and most southern pit. ±2.4 km from most northern pit (average haul distance).	a) TSF is located southwest of the northern pits (±1.4 km from the centre of the TSF to the most northern pit), minimising haulage distance at start up. b) TSF is outside of the pit catchment, therefore any possible dam break will flow into a separate catchment and should have no effect on the pits.	a) TSF is located northwest of the northern pits (±1.5 km from the centre of the TSF to the most northern pit), with a short haulage distance at start up. b) TSF is outside of the pit catchment area, therefore no dam break hazard to pit, but has a possible impact on people and agricultural land downstream of TSF site.
Description **Southern pits**	TSF is located in the centre of gravity between most northern and most southern pit ±2.5 km from most southern pit.	TSF is located in the centre of gravity between most northern and most southern pit ±2.1 km from most southern pit.	Centre of the TSF is located ±3.1 km from the most southern pit.	Centre of the TSF is located ±4.5 km from the most southern pit.
Score = Rating x Weighting (2)	10	12	10	6

	Option 2	Option 3	Option 5	Option 7
Storm water management of TSF				
Rating	6	6	6	4
	Very Good	Very Good	Very Good	Intermediate
Description	a) Storm water management will be required upstream and along the side of the TSF. Storm water management along the sides of the TSF will be simple due to the gradient fall. Upstream of the TSF will need to be managed carefully. b) TSF is located over two catchments.	a) Storm water management will be required upstream and along the side of the TSF. Storm water management along the sides of the TSF will be simple due to the gradient fall. Upstream of the TSF will need to be managed carefully. b) TSF is located over two catchments.	a) Storm water management will be required upstream and along the side of the TSF. Storm water management along the sides of the TSF will be simple due to the gradient fall. Upstream of the TSF will need to be managed carefully. b) TSF is located in one catchment.	a) Storm water management will be required upstream and along the side of the TSF. b) TSF is located in one catchment.
Score = Rating x Weighting (2)	12	12	12	8
Disruption of existing / current transport routes (i.e. existing roads etc.)				
Rating	6	6	4	4
	Very Good	Very Good	Intermediate	Intermediate
Description	a) No relocation of the S124 secondary road required. b) Possible road crossing if Plant Option B is selected.	a) No relocation of the S124 required. b) Minor road diversion of extension of the S124 will be required.	a) No relocation of the S124 required. b) Possible road crossing if Plant Option A is selected.	a) No relocation of S124 required. b) Possible road crossing of S124 required if Plant Option A is selected. c) Possible diversion of local access road, however TSF location can be modified
Score = Rating x Weighting (1)	6	6	4	4
Location to proposed plant (for pumping/conveying/hauling distance)				
Rating	4	6	5	3
	Intermediate	Very Good	Good	Poor
Description **Plant Option A**	a) TSF is located ±1.4 km from Plant Option A. b) No road/pit crossings are required.	a) TSF is located ±1.4 km from Plant Option A. b) No road/pit crossings are required.	a) TSF is located ±1.9 km from Plant Option A. b) The S124 and the northern pits will need to be crossed to access the plant from the TSF.	a) TSF is located ±2.8 km from Plant Option A. b) The S124 and the northern pits will need to be crossed to access the plant from the TSF.
Description **Plant Option B**	a) TSF is located ±2.3 km from Plant Option B. b) Access around/through the northern pits, a local road and the S124 will be required.	a) TSF is located ±2.16 km from Plant Option B. b) Access around/through the northern pits and the S124 will be required.	a) TSF is located ±0.9 km from Plant Option B. b) No road/pit crossings are required.	a) TSF is located ±1.9 km from Plant Option B. b) Local road crossing, but no pit crossing required.
Description **Plant Option C**	a) TSF is located ±2.3 km from Plant Option C. b) Access around/through the northern pits and the S124 will be required.	a) TSF is located ±2.1 km from Plant Option C. b) Access around/through the northern pits and the S124 will be required.	a) TSF is located ±0.92 km from Plant Option C. b) No pit crossing, but one local road crossing is required.	a) TSF is located ±2 km from Plant Option C. b) One local road crossing, but no pit crossing required.

	Option 2	Option 3	Option 5	Option 7
Score = Rating x Weighting (1)	4	6	6	3
Total Score	**345**	**359**	**272**	**246**

3.3 Alternative Methods of Tailings Disposal

Four methods of tailings disposal were considered by SLR (2017) as part of the TSF options assessment. These include:

- Conventional slurry TSF (this includes downstream, centreline or upstream deposition, or a combination thereof using compacted embankments, or a cyclone TSF, or paddock system).
- High density thickened TSF (advancing a multiple cone approach as illustrated in Figure 3.2).

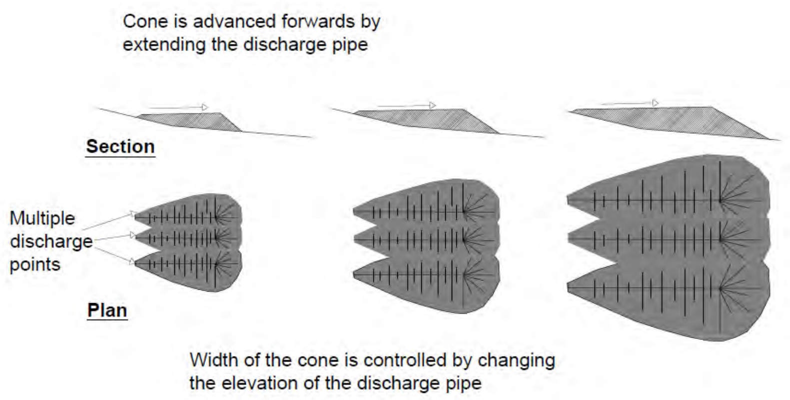

Figure 3.2: Advancing Multiple Cone Discharge of Tailings

- Paste tailings TSF (using either “single” or “multiple vertical cone” paste as indicated in Figure 3.3, or a through advancing cone paste TSF as in Figure 3.2), with the latter being the preferred.

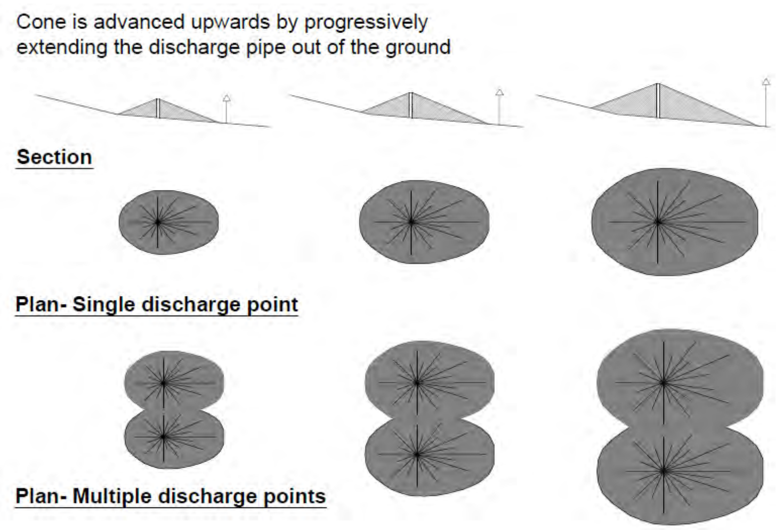

Figure 3.3: Vertical Cone Discharge of Tailings

- Dry tailings disposal (this includes conveying and stacking; or trucking, placing and compacting).

Thirteen comparative criteria (potential impacts or effects) were considered and each of the different disposal methods were assigned a rating value (Table 3.2).

A 5-point rating scale was used ranging from 1 for very high, to 5 for very low:

Rating value	1	2	3	4	5
Description	Very High	High	Medium	Low	Very Low

Each rating value was multiplied by a weighting factor to get a weighted rating score. The weighting factor describes the relative level of importance between the various criteria/impacts/concern.

The cumulative score (weightings times ratings all summed together for each method of disposal) is then totalled. The highest cumulative score indicates the preferred method of disposal while the lowest score the least preferred. The assessment shows paste and dry stack TSF's have similar low scores and hence should be discarded from further consideration.

The assessment indicated that a conventional slurry TSF should be adopted.

Table 3.2: Assessment of Method of Tailings Disposal

	Conventional Slurry Tailings	Thickened Tailings	Paste Tailings	Dry Tailings
Potential increase in the magnitude of water losses in plant-TSF circuit (and associated make up water requirements)				
Weighting = 1	Water supply is not considered an issue at Malingunde due to proximity of the Kamuzu Dam. In addition, the water table in the Project area is high and pit dewatering will be required, hence, excess water may be available. Water scarce areas would typically have a weighting of 10.			
Rating	2	3	4	5
	High	Medium	Low	Very Low
Comments	Assumes highest % solids is achieved for conventional slurry. Largest volume of water loss expected for conventional slurry disposal due to increased evaporative/wetted area, increased seepage to foundations due to saturated phreatic surface within tailings, and maximum interstitial water entrainment	Thickened tailings is likely to result in reduced water losses in the overall circuit due to reduced evaporative surface, less seepage due to lower phreatic surface in facility, and reduced entrapment of interstitial water. Can be used in semi-arid areas but greatest success is in very arid areas.	Paste tailings is likely to result in slight improvement in water losses, compared to thickened tailings, in the overall circuit due to reduced evaporative surface, less seepage due to lower phreatic surface in facility, and reduced entrapment of interstitial water. Greater success in very arid conditions and to a lesser extent in semi-arid conditions.	Smallest water loss possible with dry stacking as most water is physically extracted out of the tailings at the plant i.e. no process water available for return to plant. Most suitable in arid and semi-arid conditions and or where TSF hazard potential is very high (e.g. high seismic area with people downstream)
Score = Rating x Weighting	2	3	4	5
Potential/risk of leachate seepage to foundations				
Weighting = 4	The geological conditions at Malingunde indicate that a thick layer of sandy saprolite exits below the near surface topsoil and transported material. The TSF foundations in the area should exhibit reasonably low seepage rates, except where a TSF overlies a dambo. The rating assumes the TSF will not be lined with an HDPE liner.			
Rating	1	3	4	5
	Very High	Medium	Low	Very Low
Comments	Fully saturated conditions within the body of the TSF result in increased seepage flux to foundations.	Part of the TSF will be saturated but the majority will be partially saturated. Lower phreatic surface within body of the TSF is expected.	A very small section of the TSF is expected to be saturated but the majority will be partially saturated. Very low phreatic surface within body of the TSF is expected.	Partially saturated conditions of low moisture content tailings result in very little seepage loss to foundation (in arid and semi-arid areas). In semi-arid to wet climates stormwater infiltration can lead to some foundation seepage losses during operations, and to a lesser extent during closure once capping has been completed.
Score = Rating x Weighting	4	12	16	20

	Conventional Slurry Tailings	Thickened Tailings	Paste Tailings	Dry Tailings
Risk of acid drainage due to non-segregation and water minimisation during operations and post-closure				
Weighting = 1	In the case of Malingunde, acid drainage issues are not anticipated. The sulfur in the ore is already in the form of sulfates, which reduces the potential for acid drainage.			
Rating	2	3	4	4
	High	Medium	Low	Low
Comments	Particle segregation on edge of TSF leads to increased penetration of oxygen into partially saturated zone promoting acid drainage on the outer faces and perimeter toe area under the TSF.	Non-segregation leads to reduced oxygen infiltration resulting in less acid drainage.	Non-segregation leads to reduced oxygen infiltration resulting in less acid drainage.	Low density high void ratio tailings will allow high infiltration of oxygen and rainfall on initial placement, which reduces substantially if tailings layers are compacted immediately and on-going surface capping and rehabilitation is implemented during operations.
Score = Rating x Weighting	2	3	4	4
Potential for increased power consumption				
Rating (Weighting = 4)	4	3	2	1
	Low	Medium	High	Very High
Comments	Standard and proven thickening and pumping and distribution system required.	Increased process/thickening equipment is likely and higher pumping head losses expected (assumes standard centrifugal pumps still possible).	Increased and more precise process/thickening equipment is highly likely to achieve the pumping and beaching design set point, and high pumping head losses expected (PD pumps required).	Power consumption to drive belt/ disk filters etc. is expected to be high (in comparison to conventional slurry tailings). In the case of stacking and conveying, additional power is required.
Score = Rating x Weighting	16	12	8	4
Potential for TSF footprint to cover a large area (loss of agricultural and residential land)				
Weighting = 5	The general area is predominantly agricultural land made up of summer crops on the higher ground with perennial higher value agricultural land in lower lying dambo areas.			
Rating	3	4	3	2
	Medium	Low	Medium	High
Comments	Standard conventional TSF designed to satisfy rate of rise criteria for density gain, with or without a return water dam, is expected to occupy a sizeable (40 hectares) area	With the ability of thickened tailings to generate a convex surface on the TSF, a smaller area is envisaged compared to a conventional TSF.	Cone type paste systems cover more area than a conventional TSF due to very flat beaching side slopes and "advancing cone" type of deposition is adopted instead of the traditional single or multipole vertical cones approach.	In the case of conveying and stacking, the area is likely to be the same as if not slightly bigger than a conventional TSF. If the material is trucked, placed, compacted and shaped correctly the area is likely to be similar to a conventional TSF, or possibly slightly smaller. Ranking assumes trucking of the "dry" tails
Score = Rating x Weighting	15	20	15	10

	Conventional Slurry Tailings	Thickened Tailings	Paste Tailings	Dry Tailings
Potential for increased structural fill volume and hence large borrow areas				
Weighting = 6	The project site is mostly covered by seasonal agricultural land and transformed dambo areas, along with sporadic dwellings. Minimisation of possible borrow areas (excluding possible use of pit waste) outside of the TSF footprint is favoured. Also, minimisation of TSF wall construction reduces capital and operational expenditure.			
Rating	3	4	4	5
	Medium	Low	Low	Very Low
Comments	Largest volume of fill required for earth fill downstream construction. Possible conversion to centreline and/or upstream construction will reduce LOM fill substantially but risk of wall failure increases.	Volume of earthworks required is less than conventional TSF for the same site. Might increase if pool is retained at the base of the TSF as might be the case for semi-arid to wet climates.	Volume of earthworks required is less than conventional TSF for the same site. Water is never allowed to pond on the paste beach therefore a large runoff collection dam is required in semi-arid to wet climates.	Dry stacking preparatory and ongoing earthworks is considerably less than all the other TSF options considered, although a large runoff collection dam may be required in the case of semi-arid to wet climates.
Score = Rating x Weighting	18	24	24	30
Potential for instability / potential liquefaction issues (deposit strength)				
Weighting = 8	A low strength placed tailings for Malingunde is not expected given a relatively high portion of sand fraction in the tails. Area has a relatively high seismicity due to proximity to the Great Rift Valley.			
Rating	3	4	4	5
	Medium	Low	Low	Very Low
Comments	Assumes a compacted downstream earth wall. If entire face is upstream construction with tailings then the potential for instability is high, given the seismicity in the area.	Provided rate of rise is low and desiccation drying occurs, the stability/liquefaction risk should be low as the natural settled/deposited beach would already be formed at a shallow angle.	Provided rate of rise is low and desiccation drying occurs, the stability/liquefaction risk should be low as the natural settled/deposited beach would already be formed at a shallow angle.	Partially saturated material so no risk of liquefaction, and with trucking and compaction high density will be formed (i.e. high strength and side slopes can be developed to ensure very low risk of failure). With conveying and stacking this may not be the case due to possible wetting up of the loose stacked tails.
Score = Rating x Weighting	24	32	32	40
Potential for not achieving the design pumping (or conveying) density on a consistent basis (thickener and/or dewatering plant issues)				
Weighting = 9	At this stage the tailings is expected to be a clayey silty sand to a sandy silt arising from a washing and screening plant only - no milling and strict particle size distribution (PSD) control is envisaged. The PSD is expected to vary considerably making dewatering (thickening/filtering challenging).			
Rating	4	3	2	1
	Low	Medium	High	Very High
Comments	Achieving a 55% solids or less slurry for conventional slurry tailings is relatively easy to achieve despite the expected variation in PSD over the life of mine. A change in ±4% solids at say 50% solids	Achieving a set design point between typically 55% to 68% solids slurry may be challenging given the expected variation in PSD over the life of mine. A change in ±2% solids at say 63% solids for the	Achieving a set design point typically between 69% to 75% solids slurry may be very challenging given the expected variation in PSD over the life of mine. A change in ±1% solids at say 72% solids for the dewatering plant may be	Achieving a set design point typically above 75% solids may be very challenging given the expected variation in PSD over the life of mine. A change in ±2% solids at say 76% solids for the dewatering plant may prove problematic

	Conventional Slurry Tailings	Thickened Tailings	Paste Tailings	Dry Tailings
	for the dewatering plant can be achieved with no major problems.	dewatering plant can be achieved with no major problems.	problematic (given a wide variation on not more than 1% can typically be entertained for pumping and deposition purposes).	(given a wide variation on not more than 1% can typically be entertained for conveying and stacking, and for trucking placement given it should be close to optimum moisture content (OMC) for compaction).
Score = Rating x Weighting	36	27	18	9
Potential for problematic pumping/conveying of tailings to TSF site, assuming the plant achieves the design set point (% solids and/or rheology)				
Weighting = 4	The site is relatively flat and all TSF sites are within 2 km of the plant, so assuming the percentage solids design set point is achieved (see above) then in general, overland pumping or conveying is not considered to be a major issue.			
Rating	5	4	2	3
	Very Low	Low	High	Medium
Comments	Conventional slurry is easily pumped over the Malingunde terrain and no major issues are envisaged.	High density thickened tailings pumped over the Malingunde terrain is considered to be relatively easy, although the risk of blockages is considered higher than conventional tailings slurry	Paste tailings pumped using positive displacement pumps is considerably more difficult and problematic compared to conventional and thickened tails. Slight variations in PSD, % solids, and paste rheology can affect pumping and hence requires considerable test work, commissioning efforts and intensive process control and management.	Stacking by conveyor or trucking is relatively simple. Stacking does have challenges with relocating overland conveyors and stacker as the TSF develops and hence emergency dump areas and management is required.
Score = Rating x Weighting	20	16	8	12
Potential for problems with TSF operations / flexibility of deposition				
Weighting = 7	All sites are on relatively flat land (1:50 to 1:90 side slopes) or situated in gently falling open V-shaped valleys. Hence there is no major differentiation between sites that makes one site easier to operate compared to any other, when each method of disposal is considered.			
Rating	5	3	2	3
	Very Low	Medium	High	Medium
Comments	Assuming a compacted perimeter earth wall using downstream construction is utilised with standard open end discharge spigot points, minimal problems are expected with operations. The method is more flexible than the other forms of disposal.	Thickened tailings deposition, although relatively easy to operate, needs to be managed carefully. Less flexibility envisaged compared to conventional tailings slurry. Attainment of correct/ design beach slope may require on site changes depending on the potential variation in thickened material arriving at the TSF and therefore less flexible.	Paste deposition is more difficult to operate and must be managed carefully. It is far less flexible than conventional and thickened tails. Attainment of the correct/design beach slope is essential and may require on site changes depending on the potential variation in thickened material arriving at the TSF, and therefore the least flexible system.	Stacking by conveyor or trucking is relatively simple and easy to implement. Stacking does have challenges with relocating overland conveyors and stacker locations to ensure adherence to the dump development design. Stacking / trucking placement becomes a problem if the material arriving at the TSF is too wet (i.e. sloppy and causes "run outs").
Score = Rating x Weighting	35	21	14	21

	Conventional Slurry Tailings	Thickened Tailings	Paste Tailings	Dry Tailings
	Potential for dust emissions			
Weighting = 6	The Malingunde project area is within subsistence farming settlements, with some areas having very sparse settlements while large concentrations of people are found in the vicinity of dambos and next to major roads.			
Rating	4	3	3	2
	Low	Medium	Medium	High
Comments	Assumes surface is kept reasonably wet during dry windy conditions.	A desiccated hard pan surface can be expected which should limit dust emissions. Phased deposition with previously placed and completed faces will require progressive rehabilitation.	A desiccated hard pan surface can be expected which should limit dust emissions. Phased deposition with previously placed and completed faces will require progressive rehabilitation.	During stacking of the advancing face large dust emissions can be expected in the dry windy season. Progressive rehabilitation on back stacked faces required to reduce dust emissions.
Score = Rating x Weighting	24	18	18	12
	Potential for erosion from TSF surface due to large storm events and need for intensive silt control			
Weighting = 3	Intense summer thunder storms are typical in the area and hence substantial rainfall runoff erosion can be anticipated requiring management depending on the method of tailings disposal. As this is largely dependent on the design and management of the facility, it is given a low weighting			
Rating	4	3	3	2
	Low	Medium	Medium	High
Comments	Erosion runoff from the surface of TSF is contained within the surface pool and decant water is generally silt free although some very fine silt can be expected to report to a return water dam, if one needs to be developed.	a) Storm water management will be required upstream and along the side of the TSF. Storm water management along the sides of the TSF will be simple due to the gradient fall. Upstream of the TSF will need to be managed carefully. b) TSF is located over two catchments.	a) Storm water management will be required upstream and along the side of the TSF. Storm water management along the sides of the TSF will be simple due to the gradient fall. Upstream of the TSF will need to be managed carefully. b) TSF is located in one catchment.	a) Storm water management will be required upstream and along the side of the TSF. b) TSF is located in one catchment.
Score = Rating x Weighting	12	12	12	8
	Potential for problematic or more difficult rehabilitation and closure, and/or more rapid rehabilitation and closure of TSF surface back to a suitable land use			
Weighting = 6	Given the dwellings and intensive subsistence agricultural activities in the area, it is considered important that the best possible closure objectives be attained, ideally returning most of the TSF surface back to agricultural fields as far as possible. Hence an above average weighting has been applied.			
Rating	2	3	4	4
	High	Medium	Low	Low
Comments	The expected wet surface of the TSF at closure will take a number of years to a) remove the pool water (assume no treatment required), b) rehabilitate the TSF surface and c) return it to an acceptable land use e.g. agriculture. Long term erosion of side slopes of outer walls will need careful rehabilitation	The surface will be drier than a conventional TSF and hence access can be gained sooner to undertake rehabilitation. Easier rehabilitation of the top flattish surface is envisaged. Lower perimeter walls will be less susceptible to long term erosion. Return water dam could remain in place as part of closure.	The surface will be drier than a conventional TSF and hence access can be gained sooner to undertake rehabilitation. Easier rehabilitation of the top surface is envisaged although a steeper slope is likely compared to thickened TSF. Lower perimeter walls will be less susceptible to long term	The surface will be drier than a conventional, thickened and paste TSF, and hence access can be gained soonest to undertake rehabilitation of the top surface and flattened side slopes. Very low perimeter walls will be the least susceptible to long term erosion. Return water dam could remain in place as part

	Conventional Slurry Tailings	Thickened Tailings	Paste Tailings	Dry Tailings
	measures to minimise long-term erosion of the outer walls		erosion. Return water dam could remain in place as part of closure. Advancing cone method lends itself to progressive rehabilitation.	of closure. Progressive rehabilitation would be essential to return surface to a suitable and appropriate land use.
Score = Rating x Weighting	12	18	24	24
Total Score*	**220**	**215**	**194**	**197**

* Lowest score is least preferred, highest score is most preferred

3.4 Assessment of Preferred Method of TSF Wall Construction

Based on the proposed method of disposal being conventional slurry, along with topography and Project development constraints, the following methods for wall construction were considered:

- Compacted earth fill perimeter walls with spigotted deposition off the downstream wall by either:
  - A downstream compacted earth wall over the life-of-mine.
  - A centreline compacted earth wall over life-of-mine.
  - An upstream earth wall over life-of-mine (could use tailings for upstream construction as opposed to earth fill).
  - A combination of the above with downstream changing to centreline and or eventually to upstream development.
- Cycloned TSF outer wall or “shell” using the coarse underflow for wall development and the finer overflow reporting to the inner basin:
  - A cycloned downstream wall using coarse under flow over life-of-mine (other than some compacted earth starter wall requirements)
  - A cycloned centreline wall using coarse underflow over life-of-mine (other than some compacted earth starter wall requirements)
  - A cycloned upstream wall using coarse underflow over life-of-mine (other than some compacted earth starter wall requirements)
- Paddocked upstream “day wall” construction using the total tailings product for upstream construction. The paddock day walls and the upstream walls are constructed by depositing the full tailings stream within the paddock walls which are either “hand” or “mechanically” packed. The day wall paddocks (as this operation is only done during daylight) are then filled with tailings at night while the finer tailings are deposited within the basin of the TSF (down the beach). Any water flows out of the paddock and into the tailings basin via decant pipes to the inner basin (down the beach slope).
- A hybrid system of spigotted upstream “day wall” construction. The hybrid system is similar to the paddocked upstream day wall; however, the tailings are deposited into the day wall paddock via a spigot system. One spigot pipeline, as opposed to a single discharge pipeline deposits material into the day wall and the second spigot pipeline deposits material into the basin.
- Open end discharge (or limited number of open end discharge points) into the top end of a valley with a compacted earth water dam type wall at the bottom of the valley.

The following methods were screened out early in the process and was not considered further:

- Paddocked upstream day wall construction using the total tailings product. This approach is not suitable as the expected tailings grading (50% to 60% larger than 75 micron) will result in a steep beach profile which is not suitable for day wall construction. The moderate seismicity of the area, and the close proximity of people, dwellings and farm land, is a strong indicator that upstream TSF construction using tailings material should generally be avoided due to the high risk of static / dynamic liquefaction, and side slope instability issues.
- Open end discharge as the relatively flat area results in the valley being insufficiently constrained which makes the containment of the slurry as it “flows” down the valley more difficult. The TSF dam wall at the bottom of the valley may also need to be significantly longer and larger than with the other option due to the flat profile

Table 3.3: Comparison Between Earth and Cycloned TSF Walls

Description of Issue	Compacted Earth Fill Perimeter Walls			Cycloned Walls			Spigotted Day Wall Hybrid
	Downstream Construction over LOM	Centreline Construction over LOM	Upstream Construction over LOM	Downstream Construction over LOM	Centreline Construction over LOM	Upstream Construction over LOM	Upstream Construction
The risk that the tailings material is not amenable to this type of conventional slurry TSF development (spigot deposition from an earth wall, cycloning, paddocking, hybrid, in pit).	Very unlikely	Very unlikely	Very unlikely	Unlikely	Unlikely	Very unlikely	Unlikely
The risk that the climate is not amenable to this type of TSF development.	Very unlikely	Very unlikely	Unlikely	Unlikely	Unlikely	Possible	Unlikely
The risk that a substantial variation in tailings grading, specific gravity, and slurry relative density is likely, will it affect the method of disposal.	Very unlikely	Very unlikely	Very unlikely	Possible	Possible	Unlikely	Unlikely
The risk that the process plant, pumping system, method of deposition (spigot/cycloning) and TSF development need to be designed and operated more strictly to achieve its objectives.	Very unlikely	Very unlikely	Very unlikely	Unlikely	Unlikely	Possible	Possible
The risk of side slope stability issues occurring given the high seismicity of the area and expected behaviour of the placed tailings under drained and undrained conditions.	Very unlikely	Unlikely	Possible	Unlikely	Unlikely	Possible	Possible
The risk of a flow slide failure given the local social, environmental and agricultural conditions.	Very unlikely	Unlikely	Possible	Unlikely	Unlikely	Possible	Possible
The risk of the pond being too close to the crest edge and or overtopping.	Very unlikely	Very unlikely	Unlikely	Possible	Possible	Unlikely	Unlikely
The risk that water losses (evaporation and seepage) will be higher, and whether this a key issue.	Very unlikely	Very unlikely	Very unlikely	Possible	Unlikely	Unlikely	Unlikely
The risk of increased seepage to foundations (important if tailings liquor quality is poor and or there are nearby ground water users).	Unlikely	Unlikely	Unlikely	Possible	Possible	Possible	Unlikely
The risk of runoff erosion from exposed outer side slope faces and need for increased silt control and management.	Unlikely	Unlikely	Very unlikely	Likely	Likely	Unlikely	Unlikely
The risk of excessive dust from the sides, crest and basin of TSF.	Unlikely	Unlikely	Possible	Possible	Possible	Possible	Possible
The probability that there is a need for a RWD (or can return water be pumped from the surface of the TSF via a floating barge decant).	Very unlikely	Very unlikely	Very unlikely	Likely	Likely	Highly likely	Highly likely
Is there a need for increased level of management at the TSF, increased number of highly skilled personnel on site during operations?	Unlikely	Unlikely	Possible	Possible	Likely	Highly likely	Highly likely
The risk that there is limited flexibility in the method of operation and deposition.	Unlikely	Unlikely	Possible	Possible	Likely	Highly likely	Highly likely
The probability that on-going rehabilitation is possible during operations.	Very unlikely	Very unlikely	Possible	Very unlikely	Very unlikely	Possible	Possible
The risk that final closure, and attainment of the final land use, is going to be problematic.	Unlikely	Unlikely	Unlikely	Possible	Possible	Unlikely	Unlikely
Is there likely to be an unusual increase in the TSF footprint? Cycloning with its higher density coarse (fine sand) outer wall and low density overflow clayey fines in the basin is likely to give a lower average overall dry density i.e. a higher TSF and or a larger footprint is required, which together with its steeper outer cycloned side slope is likely to exhibit a larger footprint.	Unlikely	Unlikely	Possible	Unlikely	Possible	Likely	Likely

Based on the information in Table 3.3, the proximity of the TSF site to dwellings and agricultural land, drainage of all water courses in the area towards the Lilongwe River and the moderate seismic potential of the area, it was recommended that all upstream construction methods (be it with earth fill or cycloning or using in-situ tailings material on the beach) should be avoided.

The conservative, least risk, approach of a downstream compacted earth wall over LOM has been adopted for the high-level engineering design and cost comparisons that was undertaken.

3.5 In-Pit Tailings Disposal

A high-level assessment and design was undertaken by SLR on the disposal of tailings into the mined out pits. For the sake of the analysis the 'eastern pit', which is located southwest of ore stockpiles was used to assess the potential (SLR, 2018c). The design considered the construction of pit perimeter earth containment walls to store a tailings volume of double the amount of ore removed from the eastern pit, less the concentrate. The following scenarios and options were considered in more depth:

- **Scenario 1** – assuming a strip ratio of 0.67:1.0 (waste: ore) – based on PFS mining schedule.
  - Option 1 – determine at what distance from the pit perimeter a pit perimeter wall needs to be built (which will not require additional drains) to contain double the ore quantity, less the ore concentrate.
  - Option 2 – assuming only the pit waste excavated from the pit is available to construct the pit perimeter wall, what is the maximum quantity of tailings which can be stored upstream of the wall with the most optimised dimensions and layout of the pit perimeter wall.
- **Scenario 2** – assuming a strip ratio of 1.0:1.0 (waste: ore) – bases on Ore Reserve mining schedule.
  - Option 1 – determine at what distance from the pit perimeter a pit perimeter wall needs to be built (which will not require additional drains) to contain double the ore quantity, less the ore concentrate.
  - Option 2 – assuming only the pit waste excavated from the pit is available to construct the pit perimeter wall, what is the maximum quantity of tailings which can be stored upstream of the wall with the most optimised dimensions and layout of the pit perimeter wall (SLR, 2018c).

These various scenarios were based on the total amount of material excavated from the pit, as per the PFS completed in October 2018, and have been summarised in Table 3.4.

Table 3.4: Comparative Ore and Waste Volumes from the Pit for Scenario 1 and Scenario 2

Description	Value	
Scenario 1 (0.67:1.0 waste to ore ratio)		
Total tonnes ore from eastern pit	336,493	t
Total tonnes waste from eastern pit	225,450	t
Total tonnes of waste and ore from eastern pit	561,943	t
Density pit material (t/m^3) from pit mining schedule	1.912	t/m^3
Total void at eastern pit (for sloping ground)	**293,903**	**m^3**
Scenario 2 (1.0:1.0 waste to ore ratio)		
Total tonnes ore from eastern pit	280,972	t
Total tonnes waste from eastern pit	280,972	t
Total tonnes of waste and ore from eastern pit	561,943	t
Density pit material (t/m^3) from pit mining schedule	1.912	t/m^3
Total void at eastern pit (for sloping ground)	**293,903**	**m^3**

The amount of tailings that will be required to be stored within the eastern pit was determined based on a slurry dry density of 0.95 t/m³, compared to a density of 1.1 t/m³ that was used for the design of the TSF during the pre-feasibility study. The reason for this low density is due to the following:

- Tailings deposited within the pit will not have sufficient drying time before the next layer of tailings being placed on the beach, which reduces the amount of consolidation that can occur within the tailings, hence a reduced density.
- A larger pool area can be expected, therefore less exposed tailings, which in turn results in reduced drying and consolidation.
- In-flow of groundwater into the pit will be managed by pit dewatering boreholes; however, a small amount of ground water may still enter the pits, increasing the pool size (reducing drying area, reducing consolidation and drying, therefore reducing density) (SLR, 2018c).

Allowance was made in the design for pit perimeter walls with the following dimensions:

- Crest: 8 m wide.
- Downstream side slope 1(V):3.5(H).
- Upstream side slope: 1(V):2.5(H).
- Freeboard above tailings to top of the pit perimeter wall crest: 1.5 m.
- Maximum wall height (at the centreline of the crest) of 5 m.

A decant system (possible barge system) will be required within the basin of the pit perimeter wall (above ground) to assist in the drawdown of the operational and stormwater pool.

Based on the above assumptions, the total volume of tailings required to be stored upstream of the pit perimeter wall, as well as the volume of pit waste needed to construct the walls for Scenarios 1 and 2, Option 1 were calculated and summarised in Table 3.5.

Table 3.5: Summary of Tailings Volumes for In-pit Disposal Option 1

Description	Value	
Scenario 1 (Refer to Figure 3.4)		
Total tonnes ore from eastern pit	336,493	t
Total tonnes waste from eastern pit	225,450	t
Total tonnes of waste and ore from eastern pit	561,943	t
Density pit material (t/m³) from pit mining schedule	1.912	t/m³
Volume available in the pit for disposal of tailings	293,903	BCM
Amount of concentrate (from ore only)	10	%
Total concentrate	33,649	t
Total tonnes ore out of eastern pit excluding concentrate (tails to pit)	302,844	t
Tailings required to be stored within pit	605,687	t
Assumed tailings density of placed material in pit	0.95	t/m³
Volume of tailings required to be placed back in the pit and within perimeter wall	637,566	m³
Volume of pit waste needed to construct pit perimeter wall to store required tailings	165,622	m³
Scenario 2 (Refer to Figure 3.5)		
Total tonnes ore from eastern pit	280,972	t
Total tonnes waste from eastern pit	280,972	t
Total tonnes of waste and ore from eastern pit	561,943	t
Density pit material (t/m³) from pit mining schedule	1.912	t/m³
Volume available in the pit for disposal of tailings	293,903	BCM
Amount of concentrate (from ore only)	10	%
Total concentrate	28,097	t

Total tonnes ore out of eastern pit excluding concentrate (tails to pit)	252,874	t
Tailings required to be stored within pit	505,749	t
Assumed tailings density of placed material in pit	0.95	t/m^3
Volume of tailings required to be placed back in the pit and within perimeter wall	532,367	m^3
Volume of pit waste needed to construct pit perimeter wall to store required tailings	132,799	m^3

For Scenario 1 and 2, Option 2, utilising the above assumptions and the total volume of pit waste available from the pit excavation to construct the pit perimeter wall, the total volume of tailings which can be stored upstream of the pit perimeter wall is determined as shown in Table 3.8.

Table 3.6: Summary of Tailings Volumes for In-pit Disposal Option 2

Description	Value	
Scenario 1		
Total tonnes ore from eastern pit	336,493	t
Total tonnes waste from eastern pit	225,450	t
Total tonnes of waste and ore from eastern pit	561,943	t
Density pit material (t/m^3) from pit mining schedule	1.7	t/m^3
Volume of pit waste available to construct pit perimeter wall (Option 2)	132,618	m^3
Volume of tailings which can be stored within a specific pit perimeter wall volume	532,367	m^3
Scenario 2		
Total tonnes ore from eastern pit	280,972	t
Total tonnes waste from eastern pit	280,972	t
Total tonnes of waste and ore from eastern pit	561,943	t
Density pit material (t/m^3) from pit mining schedule	1.7	t/m^3
Volume of pit waste available to construct pit perimeter wall (Option 2)	165,277	m^3
Volume of tailings which can be stored within a specific pit perimeter wall volume	637,566	m^3

A comparison between the in-pit disposal and the PFS TSF tailings volumes, basin areas, wall volumes and wall heights has been undertaken and is shown in Table 3.7.

Table 3.7: Comparison Between In-pit Disposal and PFS TSF Tailings Volumes, Basin Areas and Wall Dimensions

Item	Description	Basin Area	Tailings Volume	Wall Volume	Tailings Volume per Footprint Area	Wall Height	Toe Drains Required	Wall Drains Required
		m^2	m^3	m^3	m^3/m^2	m		
A	Scenario 1 Option 1, Scenario 2 Option 2	354,814	637,566	165,622	1.80	5	No	No
B	Scenario 2 Option 1, Scenario 1 Option 2	290,821	532,367	290,821	1.83	5	No	No
C	TSF Phase 1	233,231	322,696	207,598	1.38	6.9	Yes	Yes
D	TSF Phase 2	332,244	809,481	397,028	2.44	9.3	Yes	Yes

The table shows the ratio of tailings volume able to be stored in the facility versus the basin area. The ratio shows that the TSF phase 2 (item D) is 2.44 compared to the in-pit disposal options (A and B) which is only 1.8 showing that more tailings can be stored within the specified basin for the TSF. This indicates that the PFS TSF is the more preferable solution as it is the more efficient storage facility.

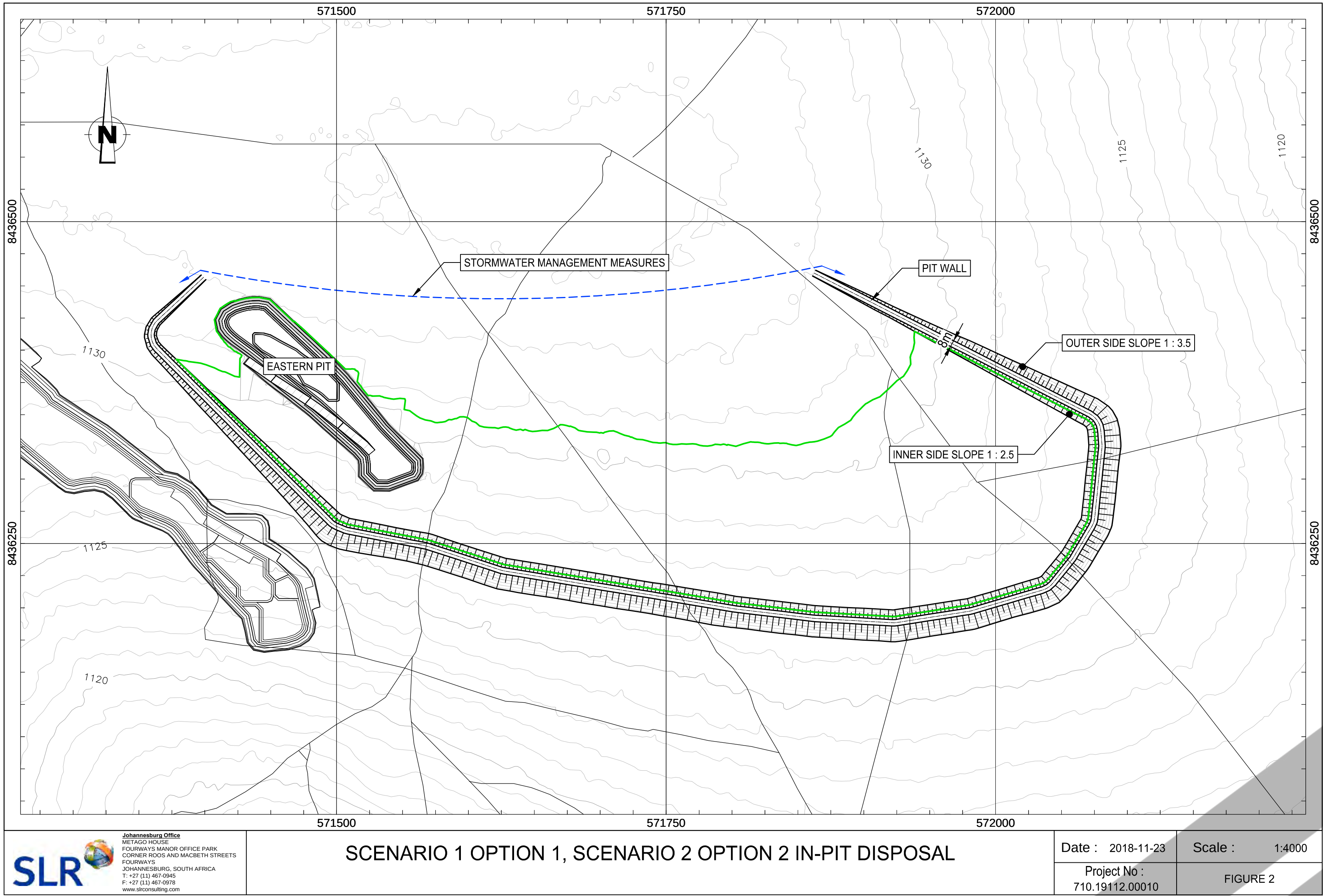

Figure 3.4: Scenario 1 Option 1 and Scenario 2 Option 2 In-pit Disposal

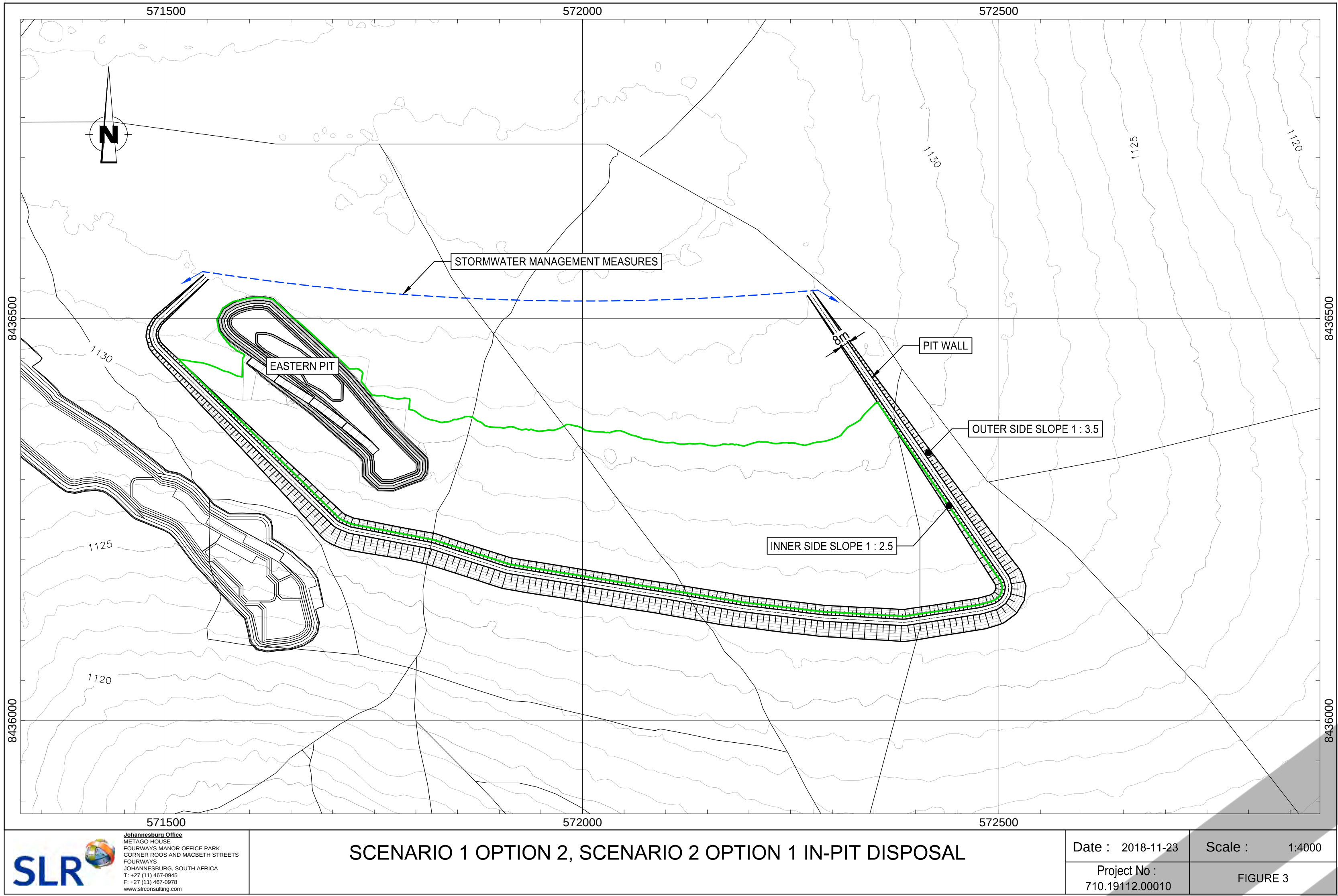

Figure 3.5: Scenario 1 Option 2 and Scenario 2 Option 1 In-pit Disposal

3.6 Dryer Alternatives

An assessment of various drying techniques was undertaken by Minnovo (2018) based on an expected production quantity of 50,000 t/y of graphite flotation concentrate which will be thickened, filtered and dried to remove moisture before being bagged and sold to the market.

Three different drying techniques were investigated to determine their capital costs, operating costs and the risks associated with treating the product at Malingunde. These included; flash drying, rotary drying and fluid bed drying.

3.6.1 Malingunde Dryer Feed

Prior to being fed to the dryer, the product is flocculated and thickened by a high rate thickener before being filtered by a plate and frame filter. Filter cake is expected to have a moisture content of 14%.

The dryer feed will consist of both coarse and fine graphite flotation concentrates and the entrained water in the material is expected not to be chemically bound and therefore assumed it can be readily evaporated.

The Malingunde processing plant is expected to produce 6.3 t/h of graphite concentrate, a significant proportion of which is expected to be coarse flake (+300 µm). Physical handling of the concentrate should be minimised to avoid unintentional size reduction due to graphite's fragility.

3.6.2 Dryer Options

3.6.2.1 Flash Dryers

A flash dryer operates by delivering high temperature gases at high speeds to the solid feed. The solids are contacted with gas travelling at well above the levitation velocity of the particles (typically higher than 20 m/s) which transports the particle up through the dryer to the discharge outlet. It is not uncommon for more air than the heating requirement to be used to meet the particles' transportation requirements which may result in heat wastage.

Because flash dryers accelerate the particles through the hot gas, high levels of gas/particle contact are experienced resulting in high coefficients of heat transfer. Flash dryers utilise high gas velocities, which, when combined with the high heat transfer coefficient, result in very low residence times (often less than 2 seconds). Particles which are impacted by wall effects fall back towards the inlet point, are re-entrained and accelerated upwards.

Flash dryers are particularly efficient at removing surface moisture from drying small nonfriable particles because the particles may be dispersed evenly through the gas stream

High gas velocities have the capability to build up static charges which can result in electric discharge in non-conductive gas. Correct design of the dryer will ensure that the build of static charge during dryer operation does not occur.

3.6.2.2 Fluid Bed Dryers

Fluid bed dryers introduce a stream of heated air to a bed of particles to levitate and distribute the bed. Because the particles do not require transportation, less fan power is needed to operate a fluid bed dryer than a flash dryer. This system provides a relatively low coefficient of heat transfer which in turn results in greater required residence times.

A fluid bed dryer is designed to deliver gas at an optimised velocity to disperse and dry the feed particles. Some material may report to the discharge stream before being completely dry, whilst other smaller material may dry rapidly and report to the discharge stream after being overheated by high temperature gas.

For proper operation, the fluidising air must be introduced uniformly across the cross-sectional area of the bed to avoid dead zones. To achieve this, multiple small diameter gas nozzles are used which results in a high overall pressure drop.

During operation, some particles may collect in the nozzles before being discharged and accelerated at a high rate through the bed to be impacted with another particle. This leads to some size reduction that is like the operation of a jet mill.

Feed material is often found in the plenum chamber after falling through the gas distributor, especially during shutdown. The subsequent start up exposes this material to high temperature gasses which will likely cause the material to combust. The likelihood of this occurring is not insignificant and may result in damages and costs unless mitigating measures are taken.

3.6.2.3 Rotary Dryers

Rotary dryers are widely used in the mining industry and are relatively easy to operate. These pieces of equipment transport the particles along the main axis of the dryer by slowly rotating the cylinder. Heated gas is fed into the unit and contacted with the particles as they tumble through the main chamber. The drying and tumbling action allow the solids to become free flowing within the unit which allows a large range of particle sizes to be processed.

Although like a rotary kiln, a rotary dryer has lifters installed in the main chamber which collect the particles from the bottom of the bed and redistribute them to the top which promotes more even gas contact. A rotary dryer operates at lower temperatures to a rotary kiln and does not boast a high coefficient of heat transfer when compared to either a flash or fluidised bed dryer leading to long residence times. Additionally, because the feed material is tumbled over itself, attritioning of the particles may occur resulting in a finer product size than the feed size. This is more prevalent in fragile, friable materials such as graphite.

Gas may be fed to a rotary dryer either co-current or counter-current to the solid feed. Counter-current operation will typically improve the coefficient of heat transfer and reduce residence times, where co-current operation is often used when the feed material is temperature sensitive.

Because rotary dryers have been used in the mining industry for many years, maintenance and troubleshooting assistance is the most readily available. This, in conjunction with the simple operation and robust design of the units make them a conservative option for drying the Malingunde graphite product, although their low thermal efficiency results in high fuel consumption.

3.6.3 Capital Cost of Dryer Options

The capital costs for the three options were considered and are illustrated in Table 3.8.

Table 3.8: Indicative Capital Costs of Various Drying Options

Description	Vendor	Original Throughput (t/h)	Malingunde Throughput (t/h)	Feed Moisture Content	Cost (USD)
Rotary Dryer A	ThyssenKrupp	12.7	6.3	14	1,325,000
Rotary Dryer B	DryTech	8.5	6.3	14	707,000
Rotary Dryer C	Metso	15.8	6.3	14	731,000
Fluid Bed Dryer A	Allgaier	12.7	6.3	14	1,472,000
Fluid Bed Dryer B	GEA	12.7	6.3	14	736,000
Fluid Bed Dryer C	DryTech	8.5	6.3	14	672,000
Flash Dryer A	DryTech	8.5	6.3	14	778,000

3.6.4 Operating Performance for Dryer Options

Each dryer option has been considered to include an exhaust recycle system for the most thermally efficient operation. Heat losses from the systems will be most prevalent from outside air infiltration and surface heat losses. A rotary dryer's large surface area is expected to experience significantly higher heat losses than the other more compact drying solutions. This, along with the rotary dryer's relatively low gas/particle contact rate and low thermal efficiency suggests that it will have the highest fuel consumption. Diesel consumption for each dryer is calculated for product moisture content of 0.5%.

The power consumption of each dryer option also affects its overall operating cost. A flash dryer requires high pressure gas to accelerate and transport the particles up through the flash vessel. However, this power is expected to be less than the power needed to operate a fluid bed dryer because of how significant the pressure drop experienced by the nozzles in the fluid bed dryer is. A rotary dryer's power consumption is expected to be the lowest of the dryer options considered.

Typical dryer performance parameters are provided in Table 3.9.

Table 3.9: Operating Performance Parameters

Design Variable	Unit	Rotary Dryer	Flash Dryer	Fluid Bed Dryer
Wet feed rate	t/h	7.3	7.3	7.3
Moisture content	% w/w	14	14	14
Discharge rate	t/h	6.3	6.3	6.3
Discharge moisture	% w/w	0.5	0.5	0.5
Thermal energy requirement	GJ/h	3.53	3.53	3.53
Efficiency (incl. heat losses)	%	50	85	80
Diesel consumption	L/h	141	83	89
Overall power consumption	kW	48.3	57.0	70.4

Although the rotary dryer is expected to consume the least power, it is predicted that the lowest operating costs would be achieved in a flash dryer due to its significantly lower diesel consumption.

3.6.5 Operating Costs for Dryer Options

In general, dryers that operate with higher pressure drop consume more power. The fluid bed is expected to have the highest power cost, followed by the flash dryer with the rotary dryer having the lowest power cost.

It is calculated that the most energy efficient operation will be achieved with a flash dryer because it has the highest heat transfer coefficient; low heat losses to air infiltration and surface effects – resulting in low fuel consumption; and low fan pressure drop – resulting in low power consumption.

Table 3.10 provides the calculation of the major operating costs.

Table 3.10: Operating Costs for Dryer Options

Variable	Unit	Rotary Dryer	Flash Dryer	Fluid Bed Dryer
Capital cost	USD	707,000	778,000	672,000
Maintenance factor	%	5	10	12.5
Maintenance cost	USD/y	35,350	77,800	84,000
Diesel unit cost	USD/L	1.00	1.00	1.00
Diesel consumption	L/y	1,111,644	654,372	701,676
Power unit cost	USD/kWh	0.31	0.31	0.31
Power consumption	kW/y	380,797	449,388	555,034
Power cost	USD/y	118,047	139,310	171,751
Overall dryer operating cost	**USD/y**	**1,229,721**	**793,682**	**873,427**

3.6.6 Dryer Option Selection

Rotary dryers are technologically the most basic option, the least complicated to operate and are typically low to the ground providing ease of installation and maintenance. However, these dryers have high residence times which results in larger equipment which in turn requires larger quantities of bulk construction materials which significantly increase the installed cost of the equipment. They have a relatively low thermal efficiency which in turn results in higher fuel consumption. This is an increasingly important consideration as fuel costs are expected to continue to rise during the operating life of the project.

Fluid bed dryers are expected to have the lowest total installed cost of the solutions investigated due to their low fabrication costs and their relatively low height. Operation of a fluid bed dryer is the more technically complicated and the product moisture content is expected to have the greatest variance. A concern is the fire and explosion risk that operation of a fluid bed dryer imparts on the project. It is this factor which dissuaded SVM from considering this solution for Malingunde.

Flash dryers have high thermal efficiency and low residence times which means the equipment is relatively small and occupies a smaller footprint than a rotary or fluid bed dryer of the same duty. The smaller footprint requires less earthworks and concrete, but this saving can be offset by the increased cost of the structural support required by the height of the flash vessel. The increased height can also adversely affect operability and maintenance.

Flash dryers do not promote a high level of particle on particle collisions which reduces the likelihood of unwanted size reduction because of attritioning. There is a low risk of explosion within the flash dryer due to potential build-up of static charge, however this risk is significantly lower than that for the fluid bed dryer and can be eliminated through correct engineering design.

Flash dryer technology is more recent than the other dryer options considered. It is possible vendor technical support may not be as readily available as some of the other options, so it is important that some care is taken during the vendor selection process to ensure that the technical backup is available and is convenient for the operation to access.

The most efficient method for drying the Malingunde product is expected to be flash drying due to its high thermal efficiency, high heat transfer coefficients and moderate mechanical equipment and maintenance costs. Additionally, the operation of the flash dryer boasts a low level of particle attritioning which helps preserve the final product size.

3.7 No-project Scenario

Consideration was given to a case where no mining activities will be undertaken in the Project area. This case will only occur if the significance of negative residual impacts is such that the implementation of the Project cannot be justified and does not receive approval from the EAD, or the Project is not deemed to be financially viable.

Current land use in the vicinity of the proposed Project is largely small-scale agriculture and grazing by local communities. In the event of the no-project alternative, the area will remain undisturbed and displacement of communities will not take place. This will enable the communities to continue with their activities undisturbed; however, no injection of developmental initiatives by Sovereign will be undertaken as would be the case if the Project proceeds. This will also result in no contribution by Sovereign to water supply, improvement of roads, health, and education services, environmental management and other services associated with the Project.

Increases in ambient noise, air quality pollutants and dust are expected as a result of the Project. The nuisance associated with these increases, as well as potential effects on community health will be avoided if the Project does not proceed.

It is anticipated that the Project will contribute to the revenue earnings of the country through payment of royalties and taxes. Procurement of supplies for the Project from the region will also contribute substantially in the economy of region. Therefore, if the Project does not proceed, a direct contribution to the country's revenue-base will not transpire.

In short, the no-project scenario avoids the anticipated negative impacts and prevents the socio-economic benefits as described in Chapter 7.

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Chapter 4: Policy and Legal Framework

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4 Policy and Legal Framework

The construction, operation and closure of the Project will be undertaken in compliance with Malawian legislation, regulations and standards. In addition, the Project will aim to meet the requirements of international guidelines and standards, such as the IFC Performance Standards on Environmental and Social Sustainability (IFC, 2012), the World Bank Group Environmental, Health and Safety Guidelines (WBG, 2007) and the Equator Principles (Equator Principles Association, 2013).

This regulatory and administrative framework is described in the following sections.

4.1 The Constitution of the Republic of Malawi, 1994

The Constitution of the Republic of Malawi, 1994 and as amended, along with national laws and regulations forms the basis of legislative requirements for development of large scale projects such as the Malingunde Graphite Project.

The Constitution contains principles of national policy in section 13, including that of sustainable development of environmental resources. The section sets out a broad framework for sustainable environmental management at various levels in Malawi. Section 13 provides that the State shall actively promote the welfare and development of the people of Malawi by progressively adopting and implementing policies and legislation aimed at managing the environment responsibly in order to, under section 13(d):

a) Prevent the degradation of the environment;
b) Provide a healthy living and working environment for the people of Malawi;
c) Accord full recognition to the rights of future generations by means of environmental protection and the sustainable development of natural resources; and
d) Conserve and enhance the biological diversity of Malawi.

The Constitution provides a framework for the integration of environmental considerations into development programs. The implication of this provision is that development programs and projects are undertaken in an environmentally responsible and sustainable manner.

In line with the principles set out in section 12 of the Constitution, public participation and consultation is encouraged. This principle is based on the presumption that, while organised society delegates its affairs to public institutions, the public retain the right to have an input in decision making and enforcement processes, and to expect, as a minimum, transparency in government decision making.

Further, the Constitution in section 146 establishes local government authorities to represent the people over whom they have authority, and to be responsible for their welfare, and gives them the responsibility of, among other things, promoting infrastructural and economic development, through the formulation and execution of local government plans.

4.2 Republic of Malawi Policies and Frameworks

4.2.1 National Environmental Policy

The National Environmental Policy (NEP), 1996 (amended in 2004) provides a broad policy framework for environmental planning in development programmes and projects, including undertaking environmental impact assessments for prescribed projects. The overall goal of the NEP is the promotion of sustainable social and economic development through the sound management of the environment and natural resources in Malawi. The policy seeks to meet the following goals:

- Ensure environmental security to support the health and well-being for all people in Malawi, now and in the future.
- Promote sustainable utilisation and management of the country's natural resources and

encourage, where appropriate, long-term self-sufficiency in food, fuel wood and other energy requirements.

- Facilitate the restoration, maintenance and enhancement of the ecosystems and ecological processes essential for the functioning of the biosphere and prudent use of renewable resources.
- Integrate sustainable environment and natural resources management into decentralised governance systems.
- Promote participation by local communities, non-government organisations (NGOs) and the private sector in environment and natural resources management.
- Promote the use and application of local knowledge and norms that facilitate sustainable environment and natural resources management.

The policy promotes the rights of every person to a clean environment, and a duty to maintain and enhance the environment.

The NEP contains specific sectoral policies relating to sustainable water use, forestry, fisheries, wildlife and mining. It specifically states that the polluter pays and the precautionary principles must be incorporated in the design, implementation and monitoring of mining projects.

4.2.2 Malawi Mines and Minerals Policy, 2013

The Malawi Mines and Minerals Policy was developed following on from the Malawi Growth and Development Strategy (2006-2011) (MGDS), identified mining as one of the sectors that could potentially generate economic growth for the country. The policy aims to provide guidance to mineral resource development through private sector initiatives, as well focussing on the need to attract modern technology and investment capital to revitalise the sector.

Some of the main objectives of the policy are to contribute to sustainable socio-economic development through development of the mining sector. In addition, this will likely lead to economic diversification, expanded employment opportunities and contribute to the country's foreign exchange base.

The policy recognises that mining impacts on the environment to various degrees and can also seriously impact on the local community. Mining projects must therefore be committed to minimise the disruption of the environment and to maximise the effectiveness of rehabilitation of land and closure measures at the end of the mine’s life.

4.2.3 National Water Policy, 2005

The overall goal of the National Water Policy is to ensure sustainable management and utilisation of water resources, in order to provide water of acceptable quality and of sufficient quantities. It further aims to ensure availability of efficient and effective water and sanitation services that satisfy the basic requirements of every Malawian and for the enhancement of the country’s natural ecosystems. The policy is based on the premise that all people shall have access to potable water and adequate sanitation services to reduce incidences of water related diseases.

Malawi’s policy on water resources management requires that:

- Water should be managed and used efficiently and effectively in order to promote its conservation and future availability in sufficient quantity and acceptable quality.
- All programs related to water should be implemented in a manner that mitigates environmental degradation and at the same time promotes the enjoyment of the asset by all.

The policy further addresses objectives for improving the efficiency and effectiveness of management of the quality of water resources.

4.2.4 National Land Policy, 2002

The goal of the National Land Policy in Malawi is to ensure security of tenure and equitable access to land in accordance with Section 28 of the Constitution, as well as to facilitate the attainment of social harmony and broad-based social and economic development through optimum and ecologically balanced use of land and land based resources.

Section 5 provides for land administration and resettlement. The definition of “land administration” in the policy is broad and includes the delivery of land rights, the planning of land uses, demarcation and survey of land parcels, and the registration and maintenance of land information. It also includes conveyance, policies to facilitate decisions on mortgages and investment, development management, property valuation for assessment purposes, and monitoring the environmental impact of all land-based activities.

Sections 5.19 to 5.22 of the Policy deal with land redistribution and resettlement. It focuses on the acquisition of land for redistribution to the landless, and also for promoting a strategy to encourage the resettlement of landless and land-short households in carefully selected areas throughout the country to relieve land pressure and poverty in some of the most congested agricultural districts.

On relocation of displaced people, the policy advocates adequate consultations between the District Council, Traditional Authority and the affected people so that their interests are adequately considered.

The policy notes that relocation and resettlement would have to take into consideration the following factors:

- The principles of fairness, equity and human rights.
- The fact that people cannot be forced to relocate to any location without their consent and that individuals and households’ readiness to resettle in a different traditional area, district or region is a matter of personal choice.
- The fact that the potential disruption of social, cultural and economic existence may be traumatic enough to make the prospect of relocation untenable to some, and the prospect of leaving valuable immovable property is a cause for resisting relocation.
- How much compensation settlers will demand to be resettled.

4.2.5 National Environmental Action Plan (NEAP), 2004

The NEAP was prepared in 1994 in response to Agenda 21 that required signatories to the 1992 Rio Declaration to prepare an action plan for integrating environmental issues into socio-economic development programs. The NEAP was updated in 2004. The objectives of the NEAP are to:

- Document and analyse all major environmental issues and measures in order to alleviate them.
- Promote sustainable use of natural resources in Malawi.
- Develop an environmental protection and management plan.

4.2.6 National Sanitation Policy, 2006

The aim of this policy, as stated in the foreword, is to enhance the capacity of Malawi to meet its commitments towards the Millennium Development Goals (MDGs) of halving the number of people who do not have access to basic sanitation by 2015, as well as provide universal access to improved sanitation for the people of Malawi by 2020.

The policy provides objectives and strategies around a variety of themes, including:

- Establishing a national sanitation policy for rural areas, cities, towns, schools and health facilities.

- Transformation of hygiene and sanitation in rural areas, including recycling of liquid and solid waste to protect the environment.
- Improvement of hygiene and sanitation and recycling of waste in cities and municipalities through the initiation of a national hygiene and sanitation programme.
- Improvement of health and hygiene education in schools with a clear link to practical improvements in the school and home environment.
- Development of waste management options for the safe disposal for hazardous and non-hazardous liquid and solid waste at health facilities.

The policy also provides guidelines on basic and improved sanitation, and safe hand washing practices.

4.2.7 Malawi Development and Growth Strategy

Several development plans have been created to guide Malawi's growth. In the late 1990s, a long-term strategy, Malawi Vision 2020, was developed to guide socio-economic policy until 2020. Medium term strategies outline objectives for five-year blocks. The Malawi Growth and Development Strategy (MGDS) II covered the period from 2011 to 2016. Infrastructure development and sustainable economic growth were major themes. MGDS III is the latest medium-term plan and covers 2017 to 2022. Building upon lessons learned and international frameworks, MGDS III identifies five key priority areas:

- Agriculture, water development and climate change management.
- Education and skills development.
- Energy, industry and tourism development.
- Transport and Information and Communication Technology (ICT) infrastructure.
- Health and population.

4.3 Republic of Malawi Legislation

4.3.1 Mines and Minerals Act, 1981 and Mines and Minerals Bill, 2015

The Act of 1981 defines the principles under which business in the minerals sector is conducted. The Act outlines the rights, duties and obligations of Government and of the exploration and mining investors as well as the applicable restrictions.

Ownership of mineral rights under the Act is predicated on the principle of social trust whereby the entire property in, and control over minerals in land in Malawi are vested in the President on behalf of the people of Malawi subject to the Act. Section 120 empowers the president to acquire land required to secure the development or utilisation of mineral resources, provided that it is done in accordance with the Land Acquisition Act, 1970.

Section 105 the Act makes provision for the compensation for disturbance of rights of the lawful occupier of any land or damage to any crops, trees, buildings, stock, or works by a holder the authority of mineral rights or carrying on the operations. The compensation is required to be fair and reasonable according to the respective rights or interests of the lawful occupier concerned. However, the amount of compensation is totally left to the agreement of the parties. Only in cases where there is no such agreement may the commissioner make an assessment. Effectively this entails that the commissioner may only get involved if there is a dispute and a claim lodged by one of the parties.

The Mines and Minerals Bill, 2015 was developed to improve on the Act and bring legislation in line with legislation and practice in the region, and was assented to in February 2019, although the new Act has not been gazetted at the time of this report.

The purpose of the proposed new Act is to regulate the development of the mineral resources of Malawi through adherence to sustainable development principles in order to:

a) benefit the economy and promote the economic growth of Malawi;
b) protect and improve the welfare of the present and future citizens of Malawi;
c) provide an attractive and conducive environment for investment in the Mining Sector;
d) minimize or prevent economic declines related to decreased mining activity by creating through training and other means a foundation for the future, social economic empowerment, uplifting and development of local communities and regions affected by mining; and
e) manage environmental impacts for the benefit of all present and future generations of Malawians.

Part VIII describes the conditions under which mining licences are required, as well as the application processes and requirements for companies. In the case of the application for a medium- or large-scale mining licence, the Act requires the following *inter alia* to be submitted as part of the application:

- Documentation proving that the project has received approval, if so required, under the Environment Management Act, and a copy of the environmental impact assessment report that supported such approval.
- A map showing the boundary of the proposed mining licence area.
- A report providing the name of each lawful occupier and landowner of lands located in, or partly in, the licence area applied for and, in the case of more than one such holding, the boundaries of each holding within the area of the proposed mining licence.
- A description of plans and initiatives for planned, sustained economic and social development in the region and local communities affected by the mining operation, and in the case of a large-scale mining licence, any community development agreements that have already been approved.
- A community engagement plan.
- A rehabilitation and closure plan.

The Act further stipulates the information required in the prescribed documents.

> Consistent with the requirements of the Act, McCourt will apply for a mining licence. This ESIA report, and subsequent environmental certificate will be submitted in support of the application.

4.3.2 Environment Management Act (EMA), 2017

The EMA of 2017 repeals the previous Act of 1996 and any subsidiary legislation. It forms the basic legal framework for protection and management of the environment of Malawi, as well the conservation and sustainable utilisation of natural resources.

The general principles detailed in Part II of the Act specifically state that every person shall take all appropriate measures to protect the environment, conserve natural resources, and promote the sustainable utilisation of natural resources. The general principles also state that precautionary measures must be taken to prevent or mitigate possible deleterious environmental effects of any project, even where scientific evidence is not certain.

Section 2(f) of the EMA states that an ESIA is a legal requirement for any project that may significantly affect the environment and use of natural resources.

Section 5 of the Act allows for the effective public participation in environmental management and the right of every person to access environmental information and to participate in environmental decision-making processes (either directly or through a representative body).

The Act establishes the Malawi Environment Protection Authority as the principal agency for the protection and management of the environment. Section 9(f) stipulates that the Authority will be responsible for the review and approval of ESIAs, strategic environmental assessments and other relevant assessment in accordance with the EMA. At the time of compiling this document, the Authority had not yet been established.

Part IX of the EMA makes provision for pollution control of both air and water pollution. With regard to water pollution, the EMA prohibits discharging of any pollutants into the environment. It further makes it a duty of every person to prevent the discharge of any pollutant into the environment other than in accordance with the Act and to comply with such general or specific directions of the Authority for preventing, minimising or cleaning up, removing or disposing of any pollutant discharged into the environment. Although the provision requires that any discharge of pollutants be in accordance with the EMA, the EMA has not made specific provision for that discharge.

Guidelines of Environmental Impact Assessment for Malawi were published in 1997 under the EMA of 1996. Although the Act has been repealed, the guidelines are still used in Malawi. "List A" of prescribed projects attached to the guidelines identifies projects for which an ESIA is mandatory, and includes mining of minerals, expansions to mines, mining exploration activities, minerals prospecting activities, quarries, gravel pits and removal of sand or gravel from shore lines.

The EMA of 2017 and guidelines published under the EMA of 1996 form the principal legislation that guide the compilation of the ESIA and application for all relevant environmental permits and licences required for the Project.

The Project falls under this prescribed list of activities as per List A in the Guidelines of Environmental Impact Assessment, and this ESIA has been compiled in compliance with these guidelines.

4.3.3 Land Act, 2016

The Land Act of 2016 comprehensively deals with tenure of public and private land, and vests all land in the Republic in perpetuity.

The Act vests all land administration responsibilities with a Commissioner of Lands, who may delegate any of his functions to an authorised officer (Sections 3 and 4). In addition, the Minister responsible for lands may delegate any of his powers and duties to the Commissioner.

Two categories of land are recognised in Malawi in terms of the Act, namely private and public land. Private land includes freehold, leasehold and customary estate, while public land includes Government land and unallocated customary land.

Customary land is all land within the boundaries of a Traditional Land Management Area other than Government or reserved land, and land designated as customary land under the Land Act. A Traditional Land Management Area (an area demarcated and registered as falling within the jurisdiction of a Traditional Authority) can be divided into:

- Communal land occupied and used on a communal basis.
- Land occupied by individual or family under customary law.
- Land available for communal or individual occupation through allocation by a land committee.

The Act prescribes procedures of appropriate acquisition of land by the Minister for public purposes. The procedures include the steps to be undertaken for government to acquire land starting from issuance of formal notices to persons with existing land interests to payment of compensations and formal land ownership transfer.

The Act places restrictions on the sale of private land to persons who are not Malawian citizens and provides for conditions under which such transactions may take place.

The Act prescribes the "rules of good husbandry", which stipulates that due regard be given to the maintenance of the land (whether arable, woodland or pasture) free from harmful weeds, clean and in a good state of cultivation and fertility and in good condition. Furthermore, good husbandry must include the maintenance and clearing of drains, earthworks and access roads; as well as proper repair of fences, hedges and field boundaries.

4.3.4 Customary Land Act, 2016

The Act repeals the Customary Land (Development) Act (Act 5 of 1967 and Act 26 of 1988) and provides for the management and administration of customary (traditional) land in Malawi. In terms of the Act, customary land is defined as land within the boundaries of a Traditional Land Management Area other than Government or reserved land; land designated as such under the Land Act, 2016 or any other written law or administrative procedure in force; or land which the boundaries have been agreed upon by a land committee claiming jurisdiction over that land.

The Act bestows the responsibility for management of all customary land in Traditional Land Management Areas onto Land Committees at a group village headman level.

Furthermore the Act makes provision for the transfer of customary land; declaration of customary land as hazardous where it poses a danger to life or lead to environmental degradation; procedures for granting and management of customary estates. Customary land (not communal) may be made the subject of a grant of a customary estate by a land committee through the formal process as described in the Customary Land Act.

4.3.5 Lands Acquisition Act, 1970 and the Lands Acquisition (Amendment) Act, 2017

The Lands Acquisition Act No. 21 of 1970 was enacted to provide for the acquisition of land. The Lands Acquisition (Amendment) Act No. 9 of 2017 has amended some provisions of the Act, the main one pertaining to compensation.

Section 3 of the Act, read with the Amendment Act, empowers the Minister responsible for lands to acquire land for public utility, either compulsorily or by agreement, and pay compensation as determined by the Act.

Section 9 (as amended) provides for the payment of compensation. It stipulates that where any land is acquired by the Minister under this Act, the Minister will pay appropriate compensation agreed to or determined in accordance with the provisions of this Act. The Amendment Act further provides that compensation shall be paid in one lump sum; therefore, the assumption is that compensation shall only be monetary.

Section 10 pertains to the determination of compensation, and states that, unless otherwise agreed, an independent valuer is to calculate compensation based on the following:

- Loss of occupation rights, land, structures and businesses.
- Loss or reduction of tenure.
- Relocation, nuisance and disturbances costs.
- Loss of goodwill.
- Costs of professional advice.

> This Act has particular relevance for the implementation of resettlement associated with the Project, specifically the procedure to be followed to acquire land, and the manner in which compensation is calculated and paid.

4.3.6 Water Resources Act, 2013

The Water Resources Act provides for the control, conservation, apportionment and use of water resources of Malawi. The Act vests ownership of all public water in the President while the control of all public water is vested in the Minister responsible for water affairs.

The objectives of the Act are to:

- Promote the rational use and management of water resources through appropriate standards and techniques for the investigation, use, control, protection, management and administration of water resources; as well as the regulation of all public and private activities which may influence the quality, quantity, distribution, use or management of water resources.
- Allow for the orderly development and use of water resources for all purposes.
- Control pollution and to promote the safe storage, treatment, discharge and disposal of waste and effluents which may pollute water or otherwise harm the environment and human health.

The Act classifies the bed and banks of watercourses and lakes and the adjacent land as public land and no person shall cultivate or carry out any activity within these areas, except as determined by the relevant Authority.

It is an offence for any person to allow effluent to come into contact with any water or cause pollution of a water resource. Persons who own, control, occupy or use land must take measures to prevent pollution from occurring from activities and processes. All effluent discharges must be undertaken in compliance with prescribe standards of effluent quality, as well as an approved discharge permit.

Part X of the Act deals with the impoundment of water, the management of dams with a safety risk and flood management. The Act prohibits the diversion or impoundment of watercourses except in accordance with the provisions of the Act.

> Provisions of the Act will be taken into consideration in the design of water management infrastructure to minimise the impact on watercourses and wetlands in the Project area. In addition, applications for the necessary permits required for water abstraction as well as potential discharge of water to the environment will be submitted subsequent to completion of the ESIA and feasibility studies.

4.3.7 Plant Protection Act, 1969

The Plant Protection Act, 1969 provides for the prevention of introduction and the eradication of pests and diseases destructive to plants and related matters.

In terms of the Act, an owner of land or premises has the duty to take measures prescribed or required by the Act, and reasonable additional measures necessary for the eradication, reduction or prevention of the spread of a pest or disease.

It is also an offence to introduce a pest on to land or premises in Malawi.

The Regulations promulgated under the Act prohibits the import and export of plants from Malawi without having applied for and obtained a phytosanitary certificate first.

4.3.8 Forestry Act, 1997 and the Forestry (Amendment) Act, 2017

The Forestry Act, 1997 (as amended) affirms the role of Department of Forestry on control, protection and management of forest reserves and protected forest areas. Section 86 provides guidelines on values / rates for sale of both indigenous trees and exotic trees. These rates are gazetted, and are reviewed from time to time to reflect current values by authorities. The values are used to calculate compensation to people who may lose timber and fruit trees.

> Provisions under this Act provide for indicative costs for the payment of compensation for timber and fruit trees as a result of Project-induced resettlement.

4.3.9 Monuments and Relics Act, 1991

This Monuments and Relics Act makes provision for the conservation, preservation and study of cultural heritage; the acquisition by Government of rights and trusteeship over monuments and relics and for the preservation thereof by agreement with the owners. The Act further contains provisions on the procedure to be followed in relation to the exportation and importation of monuments, relics and collections of cultural heritage.

The Act provides statutory protection against the threat of development on declared monuments, historical buildings and archaeological, paleontological, geological, anthropological, ethnological and other heritage sites to enable their preservation for posterity and socio economic development.

Section 29 provides statutory and legal mandate of ensuring that a Cultural Heritage Impact Assessment is conducted before embarking on large scale land altering development projects.

Consistent with the provisions of this Act, Cultural Heritage Impact Assessment has been undertaken as part of the ESIA to determine the impact on archaeological, cultural and spiritual sites and graves. The project design has taken into consideration the location of these sites to avoid them where practicable.

4.3.10 Public Health Act, 1984

The Public Health Act regulates the provision of a safe water supply, and the control and amelioration of water pollution in general.

In the event that drinking water has been polluted, the Act imposes a duty on local government to take reasonable and lawful measures to purify polluted water. The Act further provides for local authorities to take necessary measures, including legal proceedings against any person polluting any such supplies or streams, to recover the expenses that may be incurred in the process of preventing or pollution or purifying contamination.

Specifically, section 82 prohibits the passing of matter into public waters, including petroleum spirit and any substance that may cause injury to public health.

The ESIA has taken into consideration the potential impacts on the water quality of the Lilongwe River in an attempt to safeguard the use of this as major water supply to Lilongwe.

4.3.11 Occupational Health, Safety and Welfare Act, 1997

The Occupational Safety, Health and Welfare Act regulates work conditions with respect to safety, health, and welfare of workers. The duty of ensuring safety, health, and welfare of workers rests with the employer. However, every employee is required to take reasonable care for his/her own safety and that of other workers.

Section 13(1) places a duty on every employer to ensure the safety, health and welfare of all his employees at work, including a safe system of work. Training on safe work is also to be provided, as well as adequate supervision.

Section 65 sets out the detailed training requirements, stipulating that every worker must be adequately and suitably informed of potential health hazards to which he may be exposed to at the workplace; and instruction and training must be provided in the measures available for prevention and control and protection against health hazards at the workplace.

All information, instruction and training is to be given in a language understood by the worker, and written, oral, visual and participative approaches used to ensure that the worker assimilates the information, instruction or training.

Specialised training (of which all are relevant to the Project) must be provided in respect of:

(a) drivers and operators of lifting appliances, transport vehicles, earth moving and materials handling equipment and plant, steam boilers and machinery or equipment of specialized or dangerous nature;
(b) workers engaged in the erection and dismantling of scaffolds;
(c) workers engaged in excavations, of shafts, earthworks, underground works or tunnels;
(e) workers in compressed air, coffer dams and caissons;
(f) workers engaged in the erection of prefabricated parts or steel structural frames or tall structures;
(g) workers handling hazardous substances.

Provisions of the Act will be taken into consideration in the development of induction and training programs for the Project, to ensure a safe and healthy working environment.

4.3.12 Gender Equality Act, 2013

The Gender Equality Act reflects Malawi's commitment to gender equality, and makes provisions for the Malawi Human Rights Commission to:

- Monitor and evaluate the state organs, state agencies and public bodies including the private sector to promote gender equality and make recommendations that the Commission deems necessary.
- Carry out investigations and conduct searches in relation to any gender issues on receipt of complaint or on its own accord.
- Make recommendations to the Minister on any gender issues.
- Provide information to any party in a gender dispute on rights, remedies or obligations.
- Perform functions on implementation of the Gender Equality Act.

Provisions of the Act will be taken into consideration in the employment strategy for the Project, to ensure gender equality is promoted.

4.3.13 The Employment Act, 2000

The Employment Act regulates employment matters i.e. minimum wage, fair labour practices, non-discrimination and prohibition (in some cases) of employment of children. When employing people for the implementation of the project activities, the developer should ensure that provisions of this Act are complied with.

The Employment Act further makes provision for anti-discrimination in section 5, and equal pay, as per section 6 of the Act.

4.3.14 Labour Relations Act, 1997

Rights to reach collective agreements are protected under the Labour Relations Act, 1997 and orderly and expeditious dispute settlement is supported. This Act serves to promote sound labour relations through the protection and promotion of freedom of association, the encouragement of effective collective bargaining and the promotion of orderly and expeditious dispute settlement, conducive to social justice and economic development.

4.4 Other Relevant Legislation, Standards and Guidelines

The following legislation, guidelines and standards were also considered during the ESIA process:

- Guidelines of Environmental Impact Assessment for Malawi, 1997.
- Occupational Health and Welfare Act, 1997.
- Water (Water Pollution Control) Regulations (G.N. 31/1978).
- Malawi Standards (MS 539:2013) Industrial effluents – Tolerance limits for discharge into inland surface waters.
- MS 59:2002 Solid waste – Handling, transportation and disposal – Code of practice.
- MS 733 Borehole and shallow well water quality – Specification.
- MS 214:2005 Drinking Water – Specification.
- MS 682-1:2000 Water quality – Sampling Part 1: Guidance on the design of sampling programmes and sampling techniques.
- MS 682-3:2000 Water quality – Sampling Part 3: Guidance on the preservation and handling of water samples.
- MS 682-6:2000 Water quality – Sampling Part 6: Guidance on sampling of rivers and streams.
- MS 173:2005 Acoustics Noise pollution – Tolerance limits.

4.5 Project Permits and Licencing Requirements

In addition to the environmental authorisation for the Project, a number of permits and licences are likely to be required for various activities and infrastructure components. This ESIA report will be submitted in support of the various permit and licence applications, once a decision has been made to proceed with the Project. The permits and licences that are likely to be required are summarised in Table 4.1.

Table 4.1: Licences and Permits Required

Project Activity	Act	Section	Permit Required
Overall Project	Environment Management Act, 2017	Part VI Section 31(2)	ESIA Certificate
Water abstraction	Water Resources Act, 2013	Part V Section 39 A licence shall be required for any of the following purposes- (a) the abstraction, impoundment and use of water from a water resource; and (b) the drainage of any swamp or other land.	Licence to abstract and use water
Borehole Construction	Water Resources Act, 2013	Part VI Section 68 No person shall drill, construct, enlarge or otherwise alter a borehole, or engage in borehole drilling programme, for the purpose of exploring for groundwater, except in accordance with the provisions of a permit	Permit for borehole drilling for groundwater exploration
Borehole Construction	Water Resources Act, 2013	Part VI Section 84 No person shall engage in the trade of drilling or construction of boreholes unless the person is licensed as a borehole driller or a borehole constructor	Licencing of borehole drillers and constructors
Water storage (raw water storage)	Water Resources Act, 2013	Part V Section 39 A licence shall be required for any of the following purposes- (a) the abstraction, impoundment and use of water from a water resource; and (b) the drainage of any swamp or other land.	Licence to abstract and use water
TSF, return water dam, raw water storage dam	Water Resources Act, 2013	Part X Section 114 The owner of a dam with a safety risk shall register that dam with the Authority	Registration of a dam with a safety risk
Discharge of effluent	Water Resources Act, 2013	Part VIII Section 92 A person who wishes to discharge effluent shall apply to the Authority for a discharge permit in the prescribed manner	Effluent discharge permit
Discharge of effluent	Water Resources Controlled Areas Order, 1993	Section 6 No person shall in a controlled water area engage in discharging of effluent, whether industrial or domestic, into a dam, river or body of water or a tributary thereof unless authorised in writing by the Authority.	Effluent discharge permit
Discharge of effluent	Environment Management Act, 2017	Part IX Section 61 A person shall not discharge or emit effluent into the aquatic environment except under a licence issued by the Authority	Effluent discharge licence
Water/effluent discharge into streams and Lilongwe River	Environment Management Act, 2017	Part VII Section 45 A person shall not deposit any substance in a river or lake or in, on or under its bed, if that substance would or is likely to have adverse effects on the environment.	The Authority may, in consultation with a relevant lead agency, in writing waive any of the restrictions in subsection
Construction of bridges over rivers and streams	Environment Management Act, 2017	Part VII Section 45	The Authority may, in consultation with a relevant lead agency, in writing waive any of

Project Activity	Act	Section	Permit Required
		A person shall not use, erect, reconstruct, alter, place, extend, remove or demolish any structure or part of any structure in, on, under, or over the bed	the restrictions in subsection
Generation of Electricity for Own Use	Energy Regulation Act, 2004	Part IV No person may establish, operate, carry on or be involved in any manner in an energy undertaking in Malawi, without a licence issued by the Authority.	Licence
Generation of Electricity for Own Use	Energy Regulation By-Laws, 2008	Part VI Every private owner with generation capacity of above 20kVA shall register with the Authority details of his private generation and associated works	Registration certificate
Bulk Fuel Storage	Liquid Fuels and Gas (Production and Supply) Regulations, 2008	Reg 27 Any person who wishes to store on any premises liquid fuel exceeding four hundred litres in Malawi shall apply to the Authority for a Storage Licence prior to the carrying on of any such business or activity.	Licence and Registration Certificate
Storage of Dangerous Goods	Occupational Safety Health and Welfare Act, 1997	Section 53 Bulk storage of dangerous substances shall only be located at a suitable site approved by the Director	
Waste incinerator	Environment Management Act, 2017	Part VII Section 57(1) A person shall not handle, store, transport, classify or destroy waste other than domestic waste, or operate a waste disposal site or plant, or generate waste except in accordance with a licence	Waste licence
Hazardous / industrial waste transport	Environment Management Act, 2017	Part VII Section 57(1) A person shall not handle, store, transport, classify or destroy waste other than domestic waste, or operate a waste disposal site or plant, or generate waste except in accordance with a licence	Waste licence
Health and Safety	Occupational Health and Safety and Welfare Act, 1997	Section 2 No person shall occupy or use a workplace unless he is a holder of a registration certificate or provisional permit.	Workplace registration certificate
Potential disturbance of graves	Monuments and Relics Act, 1991	Section 13 No person shall without the prior written consent of the Minister (a) make any alteration to, or destroy or damage, any monument or relic or any part thereof; or (b) carry out any cultivation or mining project or other work so as to cause, or likely to	Written consent

4.6 International Agreements

Malawi is party to a number of international conventions, treaties and protocols, which are relevant to the Project. These agreements serve as the framework for international co-operation and collaboration between members of the international community in their efforts to protect the local, regional and global environment. Malawi is bound to the provisions of an international agreement/law only if it signs and submits instruments of ratification in respect of a particular agreement.

The Government of Malawi is a signatory to a number of bilateral and international agreements and conventions, as listed below:

- The Rio Declaration on Environment and Development (1992).
- The United Nations Framework Convention on Climate Change (1992).
- The Montreal Protocol on Substances that Deplete the Ozone Layer (1987).
- The United Nations Convention to Combat Desertification (1994).
- The Convention on Biological Diversity (1992).
- The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (1973).
- The African Convention on the Conservation of Nature and Natural Resources (revised) (2003).
- The SADC Revised Protocol on Shared Watercourses (2000).
- The SADC Protocol on Fisheries (2001).
- The SADC Protocol on Forestry (2003).
- The International Plant Protection Convention (1951).
- The Ramsar Convention on Wetlands of International Importance (1971).
- The Convention Concerning the Protection of World Cultural and Natural Heritage (1972).
- The Convention on the Conservation of Migratory Species of Wild Animals (1979).
- The Revised African Convention on Conservation of Nature and Natural Resources (2017).
- The International Treaty on Plant and Genetic Resources for Food and Agriculture (2001).
- The SADC Protocol on Gender and Development (1997).
- The United Nations Convention on the Elimination of all Forms of Discrimination Against Women (CEDAW) (1979).
- The Vienna Declaration and Programme of Action of the World Conference on Human Rights (1993).
- The International Covenant on Economic, Social and Cultural Rights (1966).
- Vienna Convention for Protection of the Ozone Layer (1985) and the Montréal Protocol on Substances that Deplete the Ozone Layer (1987).
- United Nations Framework Convention on Climate Change (1992).

As a signatory to the 1992 Rio Declaration on Environment and Development, Malawi is required (under principle 17) to undertake environmental impact assessments for all proposed activities likely to have significant adverse impacts on the environment.

4.7 International Standards and Guidelines

The ESIA for the Project was also compiled taking cognisance of generally accepted international good practice and standards, particularly those prescribed by the IFC Performance Standards on Environmental and Social Sustainability (IFC, 2012) and the Equator Principles (2013). In the absence of specific guidelines and standards under Malawian legislation, and where relevant, international guidelines and standards will be applied.

The IFC is a member of the World Bank Group, providing finance and development advice for private sector ventures and projects in developing countries. The Performance Standards developed by the IFC provide benchmarks for identifying and managing environmental and social risks associated with Projects that are to be funded by the IFC. Through the implementation of the Equator Principles, IFC requirements have become the de facto international environmental and social performance benchmark for project financing. Although Sovereign may not necessarily approach the IFC directly for funding, other prospective lenders are likely to prescribe to the Equator Principles (and therefore the IFC Performance Standards) and the ESIA therefore needs to be consistent with these.

The ESIA will take cognisance of the eight IFC Performance Standards and associated Guidance Notes on Environmental and Social Sustainability (IFC, 2012), which together define the optimal environmental, social and health standards to be upheld throughout the life of a project. Also relevant are World Bank Guidelines and Handbooks for specific issues such as cumulative impact assessment and resettlement. Specifically, they provide guidance to:

- Identify environmental and social impacts, risks and opportunities of projects, with effective community engagement and consultation.
- Identify and minimise impacts on workers, affected communities and the environment, and prioritise active management of impacts.
- Identify specific objectives, such as avoidance of damage of areas of cultural significance. A demonstration of an awareness of these standards is expected as part of an environmental and social due diligence process to be undertaken by the financing institution.

4.7.1 IFC Performance Standards

The IFC Performance Standards comprise of a collection of eight quality standards which the project developer is required to meet throughout the life of the investment. The key aspects of these standards are listed in Table 4.2.

Table 4.2: IFC Performance Standards

Performance Standard	Requirements
PS 1: Assessment and Management of Environmental and Social Risks and Impacts	This standard underscores the importance of managing environmental and social performance throughout the life of a project through an effective environmental and social management system (ESMS). Its objectives are: • Identify and evaluate environmental and social risks and impacts of the project. • Adopt a mitigation hierarchy to anticipate, and avoid or manage risks and impacts to workers and communities. • Promote improved environmental and social performance of clients through the effective use of management systems. • Ensure that grievances from communities and external communications from other stakeholders are responded to and managed appropriately. • To promote and provide means for adequate engagement with communities throughout the project cycle on issues that could potentially affect them and to ensure that relevant environmental and social information is disclosed and disseminated.
PS 2: Labour and Working Conditions	This standard recognises that the pursuit of economic growth through employment creation and income generation should be accompanied by protection of the fundamental rights of workers. Its objectives are: • To promote the fair treatment, non-discrimination and equal opportunity of workers. • To establish, maintain and improve the worker-management relationship. • To promote compliance with national employment and labour laws. • To protect workers, including vulnerable categories of workers such as children, migrant workers, workers engaged by third parties, and

Performance Standard	Requirements
	workers in the project proponent's supply chain. • To promote safe and healthy working conditions, and the health of workers. • To avoid the use of forced labour.
PS 3: Pollution Prevention and Abatement	This standard recognises that increased economic activity and urbanisation often generate increased levels of pollution to air, water, and land, and consume finite resources in a manner that may threaten people and the environment at the local, regional, and global levels. Its objectives are: • To avoid or minimise adverse impacts on human health and the environment by avoiding or minimising pollution from project activities. • To promote more sustainable use of resources, including energy and water. • To reduce project-related greenhouse gas emissions.
PS 4: Community Health, Safety and Security	This standard recognises that project activities, equipment, and infrastructure can increase community exposure to risks and impacts. In addition, communities that are already subjected to impacts from climate change may also experience an acceleration and/or intensification of impacts due to project activities. Its objectives are: • To anticipate and avoid adverse impacts on the health and safety of the community during the project life from both routine and non-routine circumstances. • To ensure that the safeguarding of personnel and property is carried out in accordance with relevant human rights principles and in a manner that avoids or minimises risks to the communities.
PS 5: Land Acquisition and Involuntary Resettlement	This standard takes into account that project-related land acquisition and restrictions on land use can have adverse impacts on communities and persons that use this land. Land acquisition may result from involuntary resettlement, that is, physical displacement (relocation or loss of shelter) or economic displacement (loss of assets or access to assets that leads to loss of income sources or other means of livelihood) as a result of project-related land acquisition. The objectives of the standard are: • To avoid, and when avoidance is not possible, minimise displacement by exploring alternative project designs. • To avoid forced eviction. • To anticipate and avoid, or where avoidance is not possible, minimise adverse social and economic impacts from land acquisition or restrictions on land use by (i) providing compensation for loss of assets at replacement cost and (ii) ensuring that resettlement activities are implemented with appropriate disclosure of information, consultation, and the informed participation of those affected. • To improve, or restore, the livelihoods and standards of living of displaced persons. • To improve living conditions among physically displaced persons through the provision of adequate housing with security of tenure at resettlement sites.
PS 6: Biodiversity Conservation and Sustainable Natural Resource Management	The standard follows the principle that protecting and conserving biodiversity, maintaining ecosystem services, and sustainably managing living natural resources are fundamental to sustainable development. Its objectives are: • To protect and conserve biodiversity. • To maintain the benefits from ecosystem services. • To promote the sustainable management of living natural resources through the adoption of practices that integrate conservation needs and development priorities.
PS 7: Indigenous Peoples	This standard recognises that Indigenous Peoples, as social groups with identities that are distinct from mainstream groups in national societies, are often among the most marginalised and vulnerable segments of the population.

Performance Standard	Requirements
PS 8: Cultural Heritage	This standard takes into account the importance of cultural heritage for current and future generations, consistent with the Convention Concerning the Protection of the World Cultural and Natural Heritage. Its objectives are: • To protect cultural heritage from the adverse impacts of project activities and support its preservation. • To promote the equitable sharing of benefits from the use of cultural heritage.

4.7.2 Equator Principles

The Equator Principles are a set of voluntary guidelines which a number of financial institutions have adopted with the intention of creating an industry standard for assessing and managing environmental and social issues in the project finance sector. The Equator Principles are based on the policies and guidelines of the IFC, which is the private sector development arm of the World Bank. The ESIA for the Project identified the requirements listed below as key to the Project and it is the intention that the Project will comply with these principles.

Principle 1: Review and Categorisation

Principle 1 provides that when a project is proposed for financing, the relevant Equator Principles Financial Institution (EPFI) shall, as part of its internal social and environmental review and due diligence, categorise such projects based on the magnitude of their potential impacts and risks in accordance with the environmental and social screening criteria of the IFC.

Proposed projects may be categorised as one of the following:

- Category A: Projects with potential significant adverse social or environmental impacts, those that are diverse, irreversible or unprecedented.
- Category B: Projects with potential limited adverse social or environmental impacts that are few in number, generally site specific, largely reversible and readily addressed through mitigation measures.
- Category C: Projects with minimal or no social or environmental impacts.

In consideration of the above Equator Principle categories, the Project is classified as a Category A project.

Principle 2: Environmental and Social Assessment

Category A projects shall conduct an environmental and social assessment to address, as appropriate and to the EPFI's satisfaction, the relevant social and environmental impacts and risks of the proposed project. The assessment should also propose mitigation and management measures relevant and appropriate to the nature and scale of the proposed project.

Principle 3: Applicable Environmental and Social Standards

Principle 3 requires that the assessment address compliance with local laws, regulations and permits that pertain to environmental and social issues.

Principle 4: Environmental and Social Management System and Equator Principles Action Plan

Under Principle 4, an environmental and social management plan (ESMP) will be prepared to address issues raised during the ESIA process and incorporate actions required to comply with the applicable standards. Where the applicable standards are not met to the EPFI's satisfaction, EPFI will agree an Equator Principles Action Plan. The Action Plan is intended to outline gaps and commitments to meet EPFI requirements in line with the applicable standards.

Principle 5: Stakeholder Engagement

Pursuant to Principle 5, effective stakeholder engagement with interested and affected parties must be undertaken in a structured and culturally appropriate manner. For projects with potentially significant adverse impacts on affected communities, the proponent must conduct an informed consultation and participation process. The consultation process must be tailored to the risks and impacts of the project; the project's phase of development; the language spoken by stakeholders. This process should be free from external manipulation, interference, coercion and intimidation.

Principle 6: Grievance Mechanism

For all Category A projects, a grievance mechanism must be established as part of the ESMS, designed to receive and facilitate resolution of concerns and grievances about the Project's environmental and social performance.

The grievance mechanism will seek to resolve concerns promptly, using an understandable and transparent consultative process that is culturally appropriate, readily accessible, at no cost, and without retribution to the party that originated the issue or concern. The mechanism should not impede access to judicial or administrative remedies.

Principle 7: Independent Review

An independent environmental and social consultant, not directly associated with the client, will carry out an independent review of the assessment documentation, including the ESMP, the ESMS, and the stakeholder engagement process documentation to assist the EPFI's due diligence, and assess Equator Principles compliance.

The independent environmental and social consultant will also propose or comment on a suitable Equator Principles Action Plan capable of bringing the project into compliance with the Equator Principles, or indicate when compliance is not possible.

Principle 8: Covenants

This principle requires the project proponent to include in all financing and related contractual documents, commitments to abide by all of the Principles, all host country laws and regulations and all plans and management systems developed in accordance with the Principles.

Principle 9: Independent Monitoring and Reporting

This requires the proponent where appropriate to retain an independent environmental and/or social consultant to verify its monitoring information, which would be shared with the financing institutions.

Chapter 5: Environmental and Social Setting

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5 Environmental and Social Setting

As indicated in Chapter 1, a number of specialist studies were undertaken as part of the ESIA. These studes included data collection through baseline surveys and review of existing published data and studies. The findings and data from the various specialist reports have largely been included in this chapter, as well as Chapter 7. Only those specialist reports that contain additional information have been attached in the relevant appendices.

5.1 Topography

The Project is located within the Central Region Plateau (also known as the Lilongwe Plain). This is a large, continuous tableland between 900 and 1,400 metres above mean sea level (mamsl) which is located on the western side of the Great Rift Valley.

The gradient of the land varies between 1:50 to 1:90 across the Project site. Although the area is characteristically flat or undulating plains, localised rounded hills (also known as dwalas or inselbergs) of more resistant gneisses rise up above the plain level (Hudson Ecology, 2019a). The most prominent of these are located to the northwest of the Project area.

A slightly elevated catchment divide is located at approximately the centre of the Project area with a general east–west orientation. An existing gravel road through the area is located approximately along the catchment divide. A number of shallow valleys (wetlands or dambos) drain the Project area, flowing into the Lilongwe River. These dambos drain in a southeasterly direction to the south of the catchment divide, while two larger dambo systems drain in a northeasterly direction to the north of the catchment divide.

The topography of the Project area and its surrounds is indicated in Figure 5.1 and Figure 5.2. The 1:50,000 topographic map (toposheet number 1433b1) used in Figure 5.2 was produced by the Malawi Department of Survey.

5.2 Climate

The Project is located in the central area of Malawi that has a typical sub-tropical climate, which is relatively dry and strongly seasonal. The climate is characterised by three distinct seasonal patterns, with a warm, wet season from November to April during which 95% of the annual precipitation takes place, and a cool, dry winter season between May and August with mean temperatures varying between 17 and 27 degrees Celsius (°C). A hot, dry season lasts from September to October with average temperatures varying between 25°C and 37°C.

Meteorological data was obtained from the Food and Agricultural Organisation's (FAO) CLIMWAT 2.0 database[1] for the Kamuzu International Airport outside of Lilongwe (20 km north–northeast of the Project area) and Chitedze (18 km southwest), and an average of these two stations was used to estimate monthly temperature and rainfall averages at the Project site (SLR, 2017).

In addition to the CLIMWAT data, hourly weather data for Kamuzu Dam weather station for the period between 1985 and 2017 was sourced from Meteo Blue (https://www.meteoblue.com; Meteo Blue, 2017). This weather station is located approximately 3 km southwest of the Project.

[1] The FAO CLIMWAT database comprises a dataset of measured climatic parameters taken from over 5 000 weather stations around the world with the records for each weather station comprising at least 15 years, in most cases covers the period 1971 – 2000, and data has been cross checked between stations to ensure for a consistent database suitable for determining regional and temporal variations in average weather conditions.

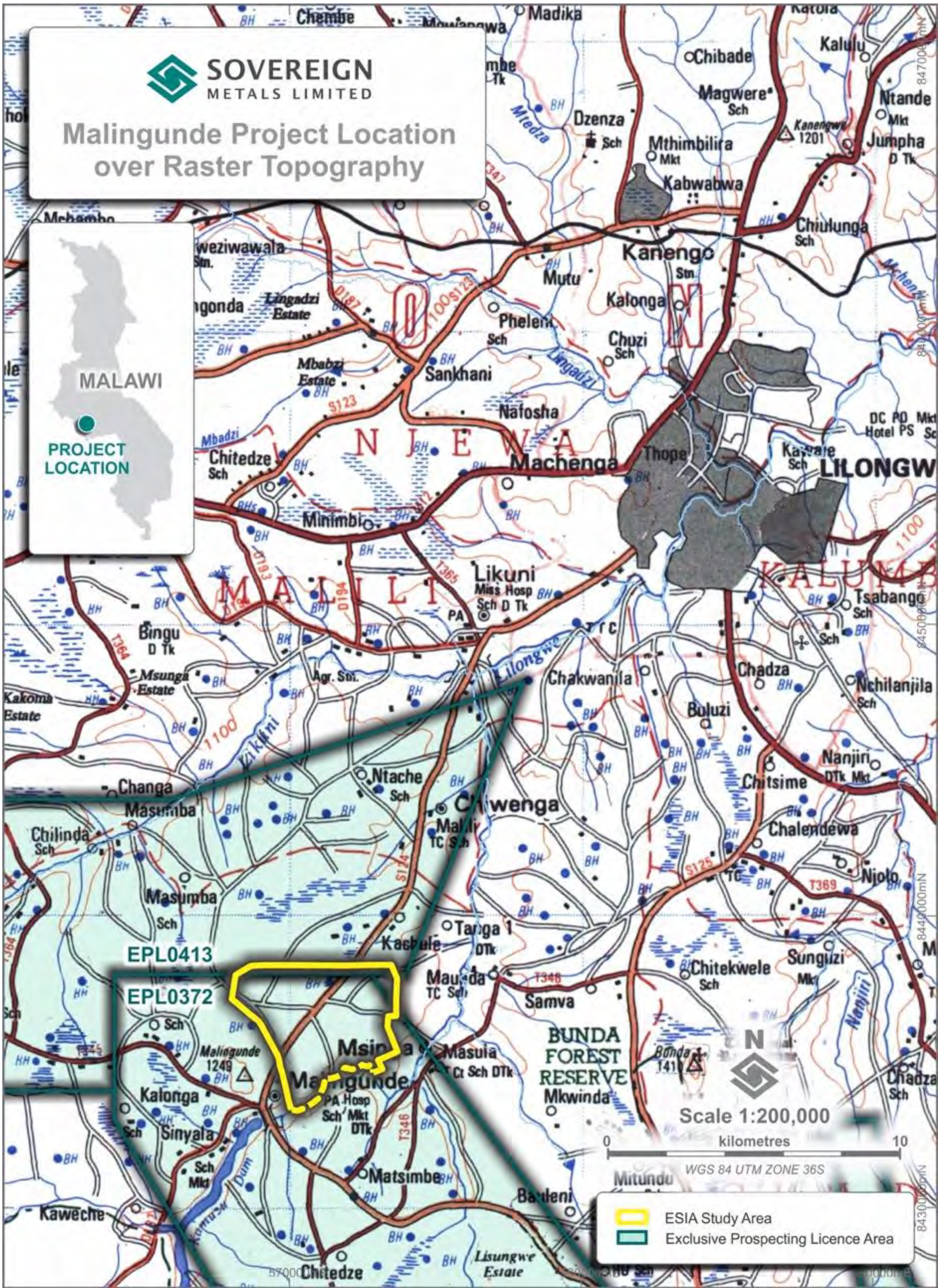


Figure 5.1: Topography of the Malingunde Project Area (1:200,000 scale)

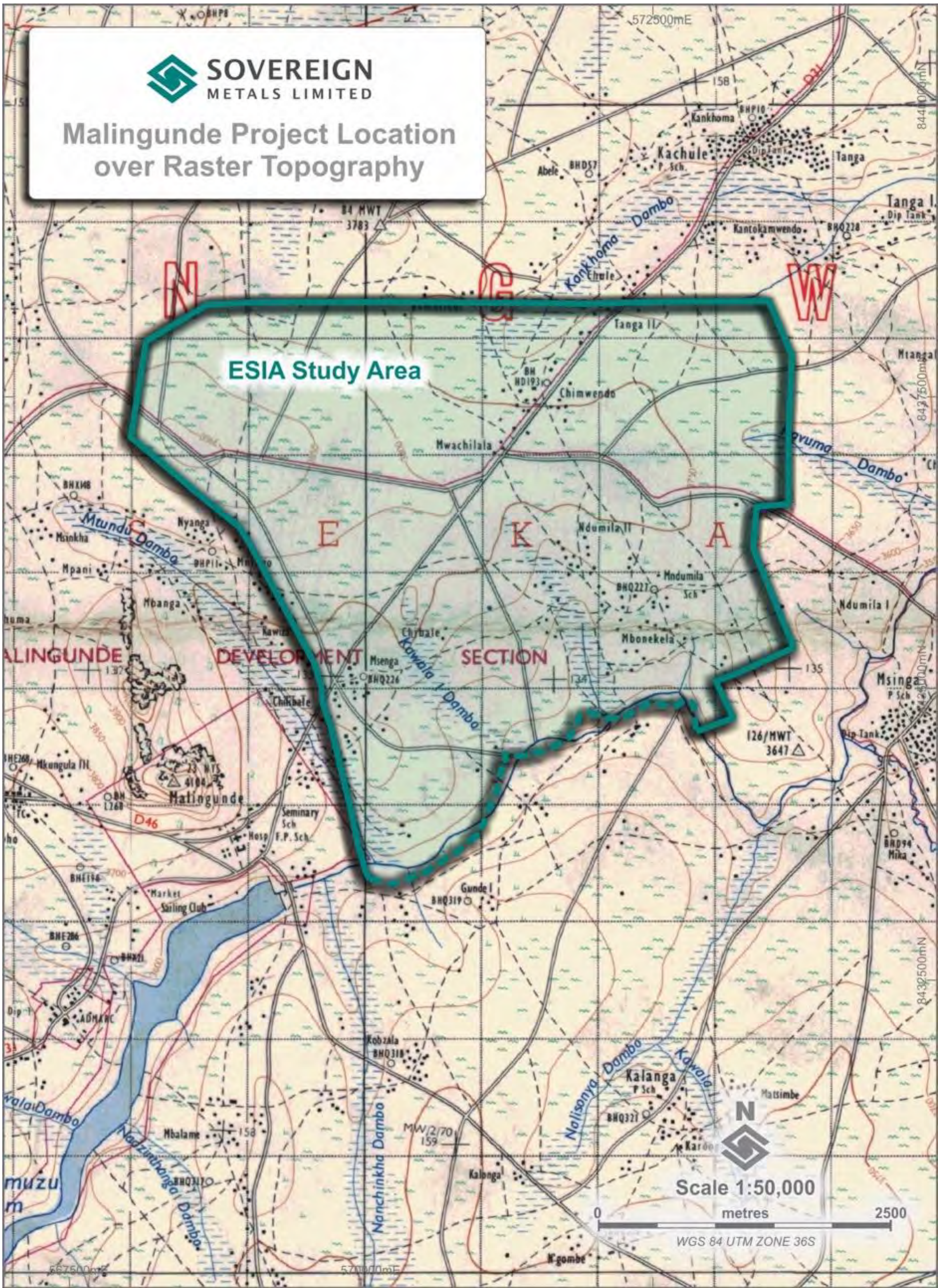


Figure 5.2: Topography of the Malingunde Project Area (1:50,000 toposheet number 1433b1)

5.2.1 Rainfall

Rainfall in Malawi is strongly influenced by the main rain bearing systems including the Inter-Tropical Convergence Zone (ITCZ), Congo air mass, easterly waves and tropical cyclones.

The Malawi Department of Climate Change and Meteorological Services (2018) indicated in their forecast for 2017/2018 that the season will be characterised by neither El Niño nor La Niña neutral conditions, as a result of El Niño Southern Oscillation conditions that have developed over the Eastern Central Equatorial Pacific.

These neutral conditions are analogous to the neutral conditions that were experienced in the 1990/1991, 1993/1994, 2001/2002 and 2012/2013 seasons. During these past neutral years, Malawi experienced late onset of rain and normal to below normal total rainfall amounts over most areas. However, above normal amounts were experienced over highlands and lakeshore areas (Department of Climate Change and Meteorological Services, 2018).

Extreme conditions include the drought that occurred in the 1991/92 season and floods of the 1988/89 season (Department of Climate Change and Meteorological Services, 2017).

The annual average rainfall in the Project area varies between 800 mm and 1,000 mm. In line with weather forecasts, the area experienced normal to above normal rainfall amounts from October 2016 to March 2017. The Southern African Regional Climate Outlook Forum (SARCOF) indicated that normal total rainfall amounts are expected during the period October 2017 to March 2018 (Department of Climate Change and Meteorological Services, 2018).

The average monthly rainfall in the Project area is illustrated in Figure 5.3. The average total annual rainfall measured at the Kamuzu Dam weather station is approximately 950 mm.

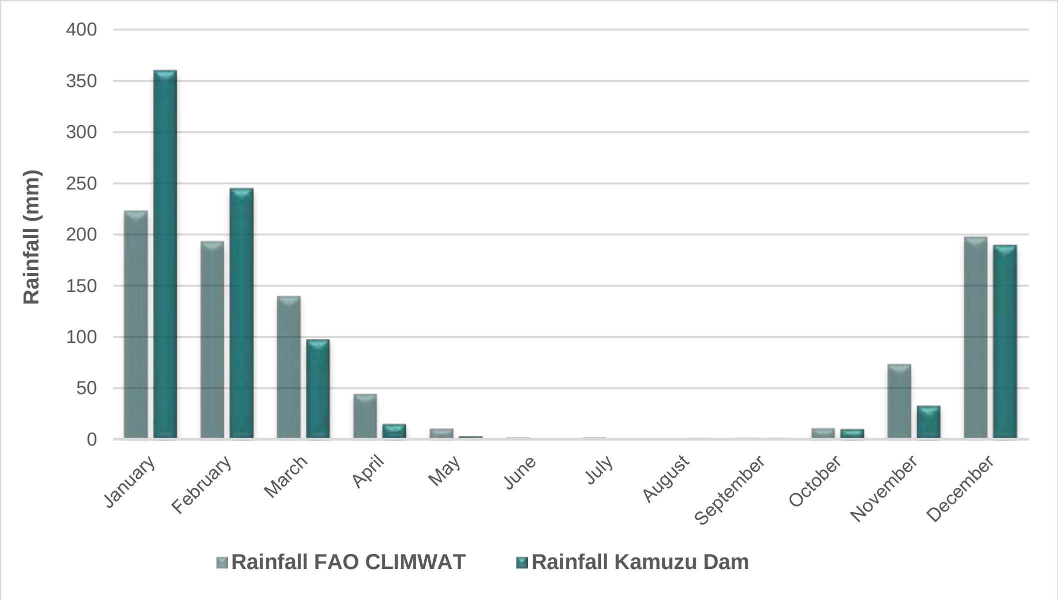


Figure 5.3: Average Monthly Rainfall in the Project Area

5.2.2 Temperature

The average temperatures during the cool, dry winter season (May to August) vary between 8°C (minimum) and 26°C (maximum), while average temperatures during the hot, dry season (September to October) vary between 12°C and 30°C. Figure 5.4 illustrates the average monthly minimum and maximum temperatures.

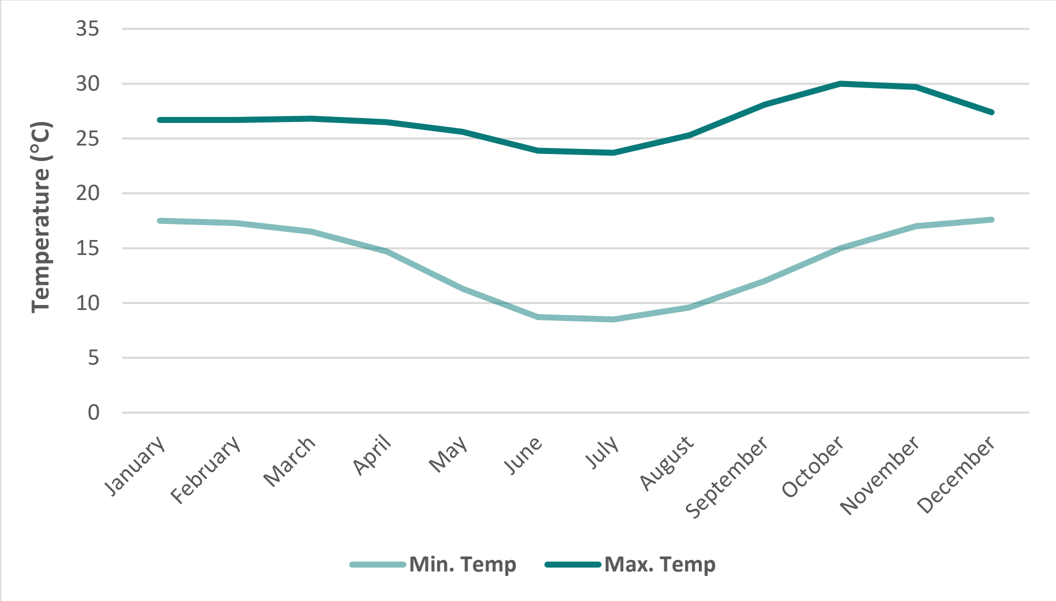


Figure 5.4: Average Monthly Temperatures in the Project Area

5.2.3 Wind Direction and Speed

Data from the Kamuzu Dam weather station for 2015 to 2017 was used to determine the dominant wind direction and speed. The prevailing wind direction is from the southeast (12.2%). and south-southeast (21.3%).

The wind rose in Figure 5.5 indicate the frequencies and directions from which winds blew during the period. The colours reflect the different categories of wind speeds. The dotted circles provide information regarding the frequency of occurrence of wind speed and different categories.

Data modelling undertaken as part of the air quality baseline assessment (Digby Wells, 2018a) (refer Appendix C) indicate the predominant wind direction at night is from the southeast (38.48%) and south-southeast (23.60%). In the morning hours, the dominant winds are from the southeast (19.25%) and northeast (17.96%). In the afternoon, winds from the northeast (17.76%) and north-northeast (12.37%) will dominate, while in the evenings, winds from south-southeast (19.29%) and east-northeast (13.06%) dominates (Digby Wells, 2018a).

The seasonal signature show winds from the southeast and south-southeast dominant during the wet and the dry season.

One of the factors that favour the suspension dispersal of pollutants in the atmosphere is the intensity of the wind speed regime. Wind speed greater than 5.4 m/s leads to erosion of loose dust particulate matter and enhances the degree of dispersion across the landscape. Wind speed data from the Kamuzu Dam weather station indicated high wind speed in the months of August through to November each year, with wind speed greater than 5.4 m/s occuring every month with marked increases observed for October and November (Digby Wells, 2018a). The average wind speed is indicated in Table 5.1.

Table 5.1: Average Monthly Wind Speeds (Kamuzu Dam Weather Station)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Average Wind Speed	5.0	4.7	5.4	5.1	5.4	5.6	6.4	7.7	7.5	7.5	4.9	3.7

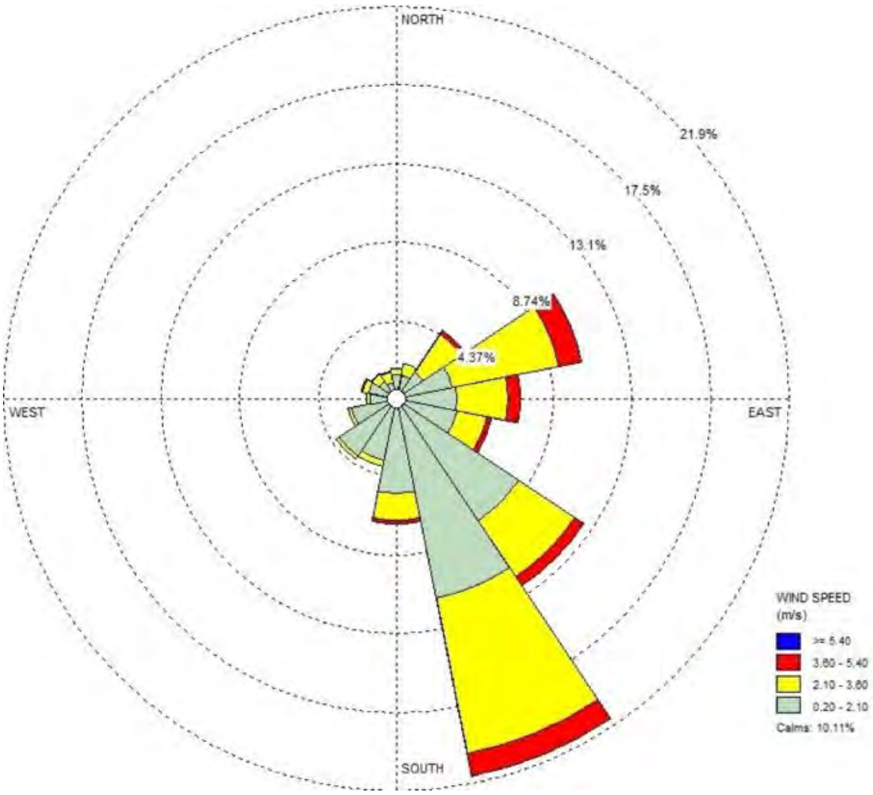


Figure 5.5: Wind Rose for the Project Area

5.3 Seismicity Potential

Malawi is situated in the southern branch of the active East Africa Rift System (Yang and Chen, 2010 as cited in Amec Foster Wheeler, 2017). In the Malawi Rift, several major geological faults (e.g., Livingstone and Bilila-Mtakataka faults) can be identified using seismic stratigraphic analysis.

Geological, geodetic, and geomorphological studies in Malawi indicate the possibility for experiencing infrequent, large earthquakes originated from the well-matured fault systems along Lake Malawi (Amec Foster Wheeler, 2017). Figure 5.6 shows the locations of seven faults in the Malawi Rift region: Livingstone, Usisya, Mbamba, Bandawe, Metangula, Mwanjage, and Bilila-Mtakataka faults.

The seismic hazard for the Project area was evaluated by SLR (2017) as part of TSF Options Study for the Project. To evaluate the seismic hazard the following methodology was adopted:

- Identify all earthquake sources capable of producing damaging ground motions (± 500 km radius from the TSF).
- Characterise the distribution of source-to-site distances associated with potential earthquakes.
- Assess the distribution of ground motion intensity, which is a function of earthquake magnitude and distance.

A review of the United States Geological Survey (USGS) Earthquakes Hazards database was undertaken to identify historical earthquakes centred around the Project area. A total of 189 events have occurred within a radius of ±500 km between 1900 and December 2017. The magnitudes of all of these vary between 0 and 6.7 on the Richter Scale (SLR, 2017).

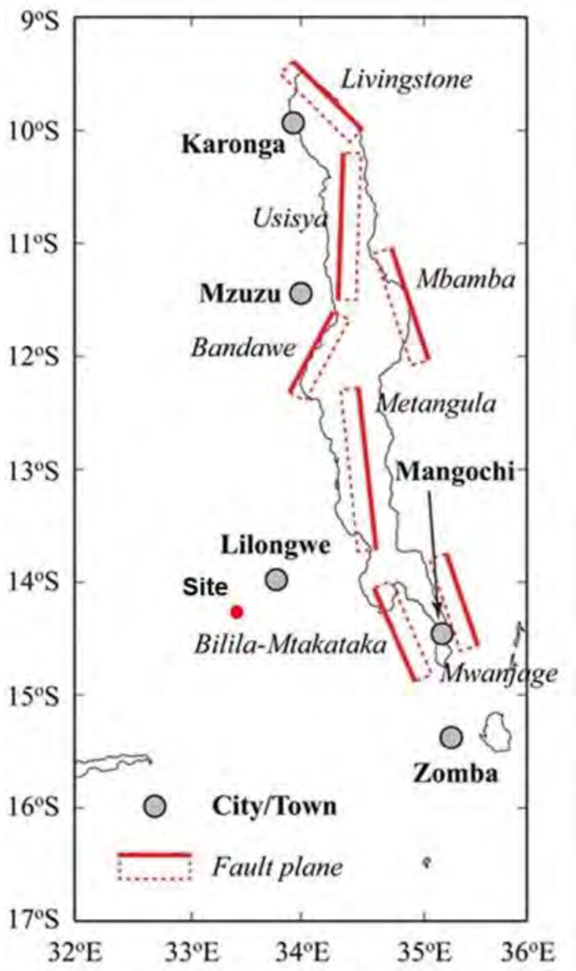


Figure 5.6: Seismicity Inducing Faults Around Lake Malawi (Yang and Chen, 2010 as cited in Amec Foster Wheeler, 2017)

The majority (125) of the earthquakes have a magnitude between 4 and 4.9 (Richter scale). Two earthquakes with a magnitude greater than 6.0 on the Richter scale were recorded within the ±500 km radius of the Project area. There were 24 earthquakes with a magnitude between 5.0 and 5.9 and 34 earthquakes with a magnitude between 3.0 and 3.9 within the ±500 km radius.

The largest magnitude earthquake, with a magnitude of 6.7, was recorded on 1 May 1919 and occurred approximately 303 km northeast of the Project site.

The closest earthquake occurred on 28 February 1990 approximately 50 km from the Project area at a depth of 33 km. This earthquake registered a magnitude of 5.1 on the Richter Scale.

Table 5.2 represents a comparison between the Richter Scale, approximate ground acceleration and Mercalli Equivalent, as well as providing a general description of the observations that are likely for the respective events. Comparison of the earthquakes which have occurred within the 500 km radius to Table 5.2 shows that the earthquakes fall into category I to IX.

Table 5.2: Richter Scale, Approximate Acceleration and Mercalli Equivalent

Richter Scale	Approximate Acceleration (cm/s^2)	Approximate Mercalli Equivalent	
<3.5		I	Felt only by a few persons at rest, especially on upper floors of buildings.
3.5	2.5	II	Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognise it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of truck. Duration estimated.
4.2	2.5	III	
4.5	10	IV	Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motorcars rocked noticeably.
4.8	25	V	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
5.4	50	VI	Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
6.1	100	VII	Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.
6.5	250	VIII	Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.
6.9	250	IX	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
7.3	500	X	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.
8.1	750	XI	Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly.
>8.2	980	XII	Damage total. Lines of sight and level are distorted. Objects thrown into the air.

Source: The Geography Site, 2013 as cited in SLR, 2017

5.3.1 Maximum Credible Earthquake

The maximum design earthquake (MDE) for critical structures (i.e., the TSF) is the maximum level of ground motion for which a structure is designed. The associated performance requirement is that the structure performs without catastrophic failure, although severe damage or economic loss may be tolerated. For critical structures, the MDE is the same as the maximum credible earthquake (MCE) (SLR, 2017).

The MCE is the largest conceivable earthquake that appears possible along a recognised fault or within a geographically defined tectonic province, under the presently known or presumed tectonic framework. For the purposes of the Project, the MCE is defined as the peak ground accelerations (PGA) having a return period of 10,000 years, or equivalently, 0.5% probability of exceedance in 50 years. The selected time period of 10,000 years is standard for critical structures for areas with low to moderate seismicity.

It is standard practice to assume that the maximum credible magnitude is 0.5 units larger (on the Richter scale) than the maximum observed event (Durrheim *et al.*, 2016 as cited in SLR, 2017). The largest earthquake that has occurred within a ±500 km radius had a magnitude of 6.7. The MCE is therefore assumed to have a magnitude of 7.2 on the Richter scale. For conservative purposes, the approximate PGA value for the MCE is approximately 4.8 m/s^2 (0.48 g).

5.4 Geology

5.4.1 Regional Geology

The 'Basement Complex', composed of Precambrian metamorphic and igneous rocks, underlies most of Malawi. The Precambrian of Malawi consists of various Proterozoic lithologies and structures, including paragneisses, quartzites and marbles of the Neoproterozoic Mozambique Belt, rock sequences of the Mesoproterozoic Irumide Belt, including granulite facies rocks in southern Malawi, and northwest-striking rocks of the Paleoproterozoic Ubendian Belt in northern Malawi (CSA Global, 2017).

Sedimentary rocks and basalts of the Permian to Jurassic Karoo System occur in the far north and far south of the country. Several carbonate intrusions are known from southern a south-central Malawi. Quaternary to recent alluvial and lacustrine sediments are found along the shores of Lake Malawi and the Shire Valley.

5.4.2 Project Geology

The Malingunde area is underlain by Neo-Proterozoic to Cambrian semi-pelitic paragneisses of the Mchinji Group (Thatcher and Walter, 1968 as cited in Amec Foster Wheeler, 2017). Lithologies include kyanite, biotite, garnet, pyrrhotite and graphite bearing gneisses and schists. This area has a largely preserved, deep, Tertiary tropical weathering profile containing significant thicknesses of saprolite, which is the soft, clay-rich material hosting the graphite mineralisation.

The host rock at Malingunde is a banded graphitic gneiss which has been subjected to weathering (oxidation and hydration) under tropical climatic conditions. This has resulted in alteration of the primary aluminosilicate minerals (major feldspar, minor kyanite and minor/accessory biotite/muscovite), silicate minerals (major quartz) and sulphide minerals (minor and accessory pyrite and pyrrhotite). The flake graphite remained inert during the weathering process.

Weathering domains identified during drilling undertaken as part of the geological sampling are described in Table 5.3.

Table 5.3: Weathering Domains and Description

Weathering Domain	Description
SOIL	Top of soil. Colluvial soils including cultivated soil. Predominantly sandy clay and may contain grits and angular pebbles.
FERP	Ferruginous pedolith. Ferruginous iron stained clay, with some physical reworking of weathered material resulting in attritioning of graphite flakes.
MOTT	Mottled zone. Ferruginous rich and less ferruginous clay+quartz rich with mottled colouring. Mottles generally range in size 10–20 mm. In-situ chemical weathering of clay gangue minerals with graphite remaining inert. Secondary Goethite and Jarosite present. Base of MOTT is defined as the REDOX boundary
PSAP	Pallid saprolite. Pale saprolite dominated by clay and quartz gangue mineralogy.
SAPL	Saprolite. In-situ, strongly chemically weathered bedrock with a clay quartz gangue mineralogy (same as PSAP). Greater than 20% of weatherable minerals (feldspar, micas, sulfides) are altered. Primary bedrock fabric is retained.
SAPR	Saprock. More compact, slightly weathered rock with a lower porosity and higher density than saprolite. Less than 20% of weatherable minerals (feldspar, micas, sulfides) are altered. Sulfides are oxidized. Weathering predominately occurs along fractures within the groundmass, which remains largely unweathered. The SAPR does not necessarily define the 'top of fresh rock', with a transitional zone sometimes identified extending 10 m into the fresh rock.
FRESH	Fresh rock. Foliated graphitic gneiss. Primary mineralogy of feldspar - quartz - graphite +/- biotite, pyrite and pyrrhotite.

A typical profile from surface is soil (“SOIL”, 0 to 1 m), ferruginous pedolith (“FERP”, 1 to 4 m), mottled zone (“MOTT”, 4 to 7 m), pallid saprolite (“PSAP”, 7 to 9 m), saprolite (“SAPL”, 9 to 25 m), saprock (“SAPR”, 25 to 35 m) and fresh rock (“FRESH” >35 m).

5.4.3 Geochemistry

Geochemical analyses to characterise the geochemistry of the pit waste and low-grade ore was undertaken by SLR in 2018 (refer to Appendix B) to determine the potential for acid and metalliferous drainage (AMD). Analysis was previously performed on two tailings samples (MET ¾ float tails and master composite) by SGS in Canada in 2017.

5.4.3.1 Acid Base Accounting

Acid base accounting (ABA) provides an industry-recognised assessment of the acid generation or acid neutralisation potential of materials. Measurements of total sulfur or sulfide sulfur are used to estimate the amount of acid bearing material. Using this information, the acid producing potential (AP), neutralisation potential (NP) and net neutralisation potential (NNP) are determined.

The AP is due to the oxidation of sulfide minerals in a rock sample and is calculated as the total sulfide sulfur content in percentage multiplied by 31.25. The NP is a measure of the amount of acid a material is capable of neutralising and is predominantly a result of carbonates and exchangeable alkali and alkali earth cations.

The difference between the acid generating mineral phases and acid neutralizing mineral phases is referred to as the NNP and allows for material to be classified as potentially acid consuming or acid producing. The NNP is calculated as follows:

$$NNP = NP - AP$$

Results are reported in kg of calcium carbonate per tonne of rock (or parts per thousand).

The ABA tests assume that all sulfide minerals in a rock sample are acid generating. Some of the sulfur in the rock may be present in non-acid producing sulfates. If a significant part of the total sulfur occurs as sulfate sulfur instead of sulfide sulfur, the overall risk of acid generation is reduced. Samples with sulfide sulfur content below 0.3% are considered only capable of short-term acid generation (SLR, 2018a).

Analysis of the pH is undertaken on paste samples in conjunction with the ABA test, and provides an indication of the presence of readily available NP (generally from carbonate) or stored acidity. A pH value of less than 5 indicate the presence of stored acidity, whereas higher paste pH values suggest the presence of reactive neutralising minerals.

The data is also used to describe the neutralisation potential ratio (NPR) and is calculated as follows:

$$NPR = NP/AP$$

The classification of material in terms of its potential to generate acid was based on the above criteria and shown in Table 5.4.

Table 5.4: Criteria for Acid Mine Drainage Classification

Parameter	Potentially Acid Generating (PAG)	Uncertain/Marginal	Non-potentially Acid Generating (non-PAG)
Paste pH	<3.5	3.5 to 5.5	>5.5
NNP	<-20	-20 to 20	>20
NPR	<1:1	1:1 – 2:1 = Possibly 2:1 – 4:1 = Low	>4:1
Sulfide %	>0.3%	-	<0.3%

5.4.3.2 Results of ABA

Pit waste: The pit waste samples were subjected to ABA tests and selected samples were also subjected to net acid generation (NAG) tests (see section 5.4.3.3). The ABA results indicated that the potential acid generation potential of the pit waste material assessed was uncertain. The 'WRD_Comp' sample had an NPR value above 4 which indicated that it has a high potential to neutralise acid generated. The samples generally had low sulfide sulfur (<0.3%) and low neutralisation potential (<2.25 kg $CaCO_3$/t) resulting in uncertainty in the ABA results.

Low-grade ore: The ABA results for the low-grade ore showed that although the samples had a low potential to generate acid, it had an equally or even lower potential to neutralise any generated acid. Based on the available results the potential acid generation potential of these samples were classified as uncertain.

Tailings: The ABA of the tailings sample indicated that the 'MET ¾ float tails' tailings sample was not potentially acid generating. The 'Master Composite' sample potential acid generating status is uncertain based on the available results. During ten weeks of kinetic leach testing undertaken, the sulfate production rate exceeded the neutralisation rate during all but one of the monitoring weeks. The pH of the material has remained relatively neutral during the assessment period.

5.4.3.3 Net Acid Generation

Static net acid generation (NAG) testwork is carried out in order to determine the maximum potential for acid generation from the samples. The static NAG test differs from the ABA test in that it provides a direct empirical estimate of the overall sample reactivity, including any acid generated by semi-soluble sulfate minerals as well as potentially acid-generating sulfide minerals. As such, the NAG test may provide a better estimate of field acid generation than the more widely-used ABA method, which defines acid potential based solely on sulphide content independent of the site mineralogy and geology (SLR, 2018a).

The guidelines used for assessing the acid generation potential based on NAG results as follows:

- Potentially acid generating – pH <4.5
- Not potentially acid generating – ≥4.5

Net acid generation tests were only performed on selected pit waste material samples and the final pH ranged from 6.1 to 6.7.

The low sulfide sulfur concentration, the low NAG acid concentration, and the NAG near-neutral pH suggests that there is low potential for sustained acid generation.

5.4.3.4 Metal Leaching

A leach test is a laboratory extraction method designed to determine the leachability of elements present in liquids, soils, and wastes under certain conditions. The solid phase is extracted with an extraction fluid, at a liquid-to-solid ratio specified by the selected method. Following extraction, the liquid extract is separated from the solid phase by filtration and analysed.

As a preliminary screening to identify potential constituents of concern, the leachates were compared to the following water quality and effluent standards:

- WHO Guidelines for drinking-water quality (WHO, 2017).
- Malawi Standard (MS214:2005) Drinking Water Specification (MBS, 2005).
- IFC Guidelines for Mining Effluents (IFC, 2007).

The use of drinking water guidelines does not suggest that leachates and drainage from the pit waste will be used for drinking purposes. Use of these guidelines is purely intended as a preliminary indicator of potential water quality risk.

Extractions were carried out using a 2:1 (solid to solution) ratio with distilled water. In the pit waste, aluminium (Al), fluoride (F), iron (Fe), manganese (Mn) and pH were identified as constituents of interest when compared to the WHO and Malawian drinking water guidelines, and the IFC guidelines for effluent standards. No exceedances of the guideline values were observed for the low-grade ore samples. For the tailings samples, Al and Fe exceeded the Malawi Drinking Water Specification (2005). The F and Mn marginally exceeded the screening criteria in one pit waste sample.

5.4.3.5 Contaminant Loads

The risk to groundwater quality from a contaminant source is determined by the rate at which contaminants leaves the source and enters the groundwater system. The product of seepage volume through the source footprint and the concentration of the contaminant being considered determines the contaminant load. These contaminant loads are required as input data into the groundwater contaminant transport model for the prediction of water quality impacts (refer Section 7.9.2).

Potential contaminant loads reporting to the water quality were modelled by SLR (2018b) for the tailings material using the pH, Redox, Equilibrium Code (PHREEQC) for hydrogeochemical modelling, as this is likely to be the main source of contaminants. Leach tests on the Master Composite tailings sample were used to estimate seepage quality from the proposed TSF.

Source terms were developed for the TSF for the constituents of interest that exceeded the water quality guidelines (Al and F) and for sulfate (SO_4). Sulfate occurs in sufficiently high concentration to be used as a conservative tracer to determine the potential groundwater contamination plume development. The source terms for the TSF are summarised as follows:

	Al		**F**		**SO_4**	
Seepage Rate	**Seepage Quality**	**Load**	**Seepage Quality**	**Load**	**Seepage Quality**	**Load**
m^3/year	mg/L	kg/year	mg/L	kg/year	mg/L	kg/year
16,618	1.32	22	3.4	56.5	80	1,330

5.4.4 Radiological Characterisation

Radioactivity is a natural phenomenon and natural sources of radiation are features of the environment. Radiation and radioactive substances can be applied in many beneficial uses, including medicine, industry and agriculture. However, the radiation risks to workers and the public and to the environment that may result from these applications need to be determined and, if necessary, controlled.

Overburden and ore that is handled and processed during mining activities may contain radionuclides that are generally referred to as naturally occurring radioactive material (NORM), as defined in the International Atomic Energy Agency (IAEA) 2018 Safety Glossary. Although the concentration of NORM in most natural substances (such as soil and rocks) is low, activities that extract and process ore can potentially concentrate NORM in product and waste streams (tailings).

The implication is that people involved in the mining and mineral processing operations may be exposed to radioactivity from the radionuclides present in the deposit. Members of the public may also be exposed to radioactivity present in products, by-products, residues and wastes generated by the mining and mineral processing activities (EnviroSim Consulting, 2019a).

Due to uncertainties with regard to the radioactive properties of the Malingunde graphite deposit, concerns were raised as to whether materials associated with the graphite deposit can be classified as NORM, whether a potential radiological impact from the Malingunde graphite deposit on surrounding communities and the environment may exist, and whether this should be considered in the development of the resource. Titanium (Ti) rich minerals in the form of rutile and leucoxene (heavy minerals) have been confirmed to be present in the Malingunde deposit. Titanium rich mineralisation is known to often occur with zircon (zirconium silicate, $ZrSiO4$). Zircon mineralisation may include traces of uranium and thorium (up to 1%) in the crystal structure (World Nuclear Association, 2014). Total concentrations of titanium and zirconium were consequently measured in all samples to determine whether there is a correlation between radioactivity and heavy mineralisation in the Malingunde graphite deposit. The radiological characteristics of the graphite deposit was undertaken by EnviroSim Consulting as part of the ESIA (refer to Appendix D for a copy of the report).

5.4.4.1 Screening Sampling

Two separate rounds of sampling were conducted and used in the radiological characterisation of the Malingunde deposit. As part of the soils investigation in April 2018 (section 5.5), a screening exercise was undertaken with 10 soil samples being collected and submitted to the South African Nuclear Energy Corporation (Necsa) laboratory for gross alpha/beta (or total α/β) radioactivity analysis.

This screening exercise was undertaken to determine whether there were potential issues associaed with NORM that would require specific management protocols.

The results from the Necsa analysis are detailed in Table 5.5.

Table 5.5: Gross Alpha/Beta Radioactivity Analysis of Soil Samples

Sampling Field Code	Alpha Activity			Beta Activity		
	Value	Uncertainty	MDA*	Value	Uncertainty	MDA
	Bq/g					
248 Pit Big	1.42	0.20	0.43	0.338	0.024	0.062
310 WRDA North	1.17	0.19	0.45	0.448	0.025	0.060
147 TSF 2/3	1.02	0.18	0.42	0.291	0.023	0.059
409 Pit	1.48	0.22	0.49	0.746	0.030	0.062
404 Pit School	0.651	0.161	0.44	0.385	0.024	0.057
446 RWD	2.71	0.27	0.43	0.322	0.026	0.071
373 Pit	1.15	0.19	0.45	0.480	0.026	0.060
302 WRD North	1.38	0.20	0.42	0.295	0.023	0.061
TSF 7	1.51	0.21	0.43	0.341	0.024	0.062
380 Pit	0.519	0.157	0.45	0.469	0.025	0.056

Note: * MDA = Minimum detectable availability

As there are no nuclide specific data available for these samples, a simple screening evaluation was performed (EnviroSim, 2019a) to determine whether the measured values could result in an unacceptably high radiological dose. Soil screening levels for gross α and β activity was obtained from the RESRAD computer code, which was designed at Argonne National Laboratory in the United States of America, for estimating radiation doses from radioactively contaminated soils and to derive radionuclide soil guideline levels corresponding to a specific dose criterion. The RESRAD values for gross α/β levels was taken from a thesis manuscript by Brian E. Livingston (2007) as cited in EnviroSim (2019a).

The International Commission on Radiological Protection (ICRP, 1991) recommends that any exposure caused by human activity above natural background radiation should be kept as low as reasonable achievable, but below the following:

- The individual dose limit for public exposure in planned exposure situations is 1 millisieverts per year (mSv/y).

- The current limit of radiation exposure for a worker that will be exposed to radiation because of their employment is 20 mSv/y averaged over 5 years, and not more than 50 mSv received in any one year for effective (whole body) dose.

Assuming that members of the public may be exposed to the materials, the dose limit of 1 mSv/y, which relates to α activity of 1.48 becquerel per gram (Bq/g) and β activity of 2.34 Bq/g, was used.

Based on these very conservative screening values it would seem that the samples from '409 Pit', '446 RWD', 'TSF 7' and potentially '248 Big Pit' may present potential issues for public exposure, as a dose exceeding the dose limit may result.

5.4.4.2 Sampling for Radiological Characterisation

As there were no detailed information available of the materials or locations of the initial soil samples, collection of further samples from the Project area was undertaken in October 2018 (representative of topsoil, subsoil and ore) in order to conclusively determine the radiological characteristics of the deposit. Laboratory analysis of the samples involved both chemical analysis and the determination of radioactivity concentrations.

Table 5.6 and Figure 5.7 present the chemical analysis results for the radiological characterisations samples, listing the total concentrations of uranium (U), thorium (Th), titanium (Ti) and zirconium (Zr) in each sample.

The results indicate that U and Th concentrations are low, with the higher concentrations of U present in the samples of graphite ore, while the highest concentrations of Th are observed in the samples of background soil.

Concentrations of Ti and Zr correlate with U concentrations with the highest values measured in the samples of graphite ore.

Table 5.6: Chemical Analysis Results of the Radiological Characterisation Samples

	Element	Thorium (Th)	Titanium[2] (Ti)	Uranium (U)	Zirconium* (Zr)
Site		mg/kg			
South Pit	Topsoil	3.8	55.8	2.4	10.4
	FERP	1.2	52.4	2.3	28.6
	Ore	2.3	73.9	3.3	28.4
North Pit	Topsoil	4.7	47.6	1.1	4
	FERP	5.4	35.3	2.4	12.6
	Ore	2.5	111.1	4.1	28.3
West Background	Topsoil	7	55.5	1.5	7.7
	Sub-soil	8.8	47.1	1.7	9.3
East Background	Topsoil	7.5	43.8	1.8	6.9
	Sub-soil	11.2	41.9	3.3	13.4

[2] Chemical analysis was undertaken using the aqua regia digestion method. Ti and Zr are highly immobile elements, normally occurring in highly refractory and difficult to dissolve minerals; in this case rutile and zircon present on site. Therefore, the use of a rlatively weak digestion method like aqua regia is unlikely to have been able to solubilise sufficient Ti or Zr, and the levels recorded are significantly lower than those previously recorded through other mothods.

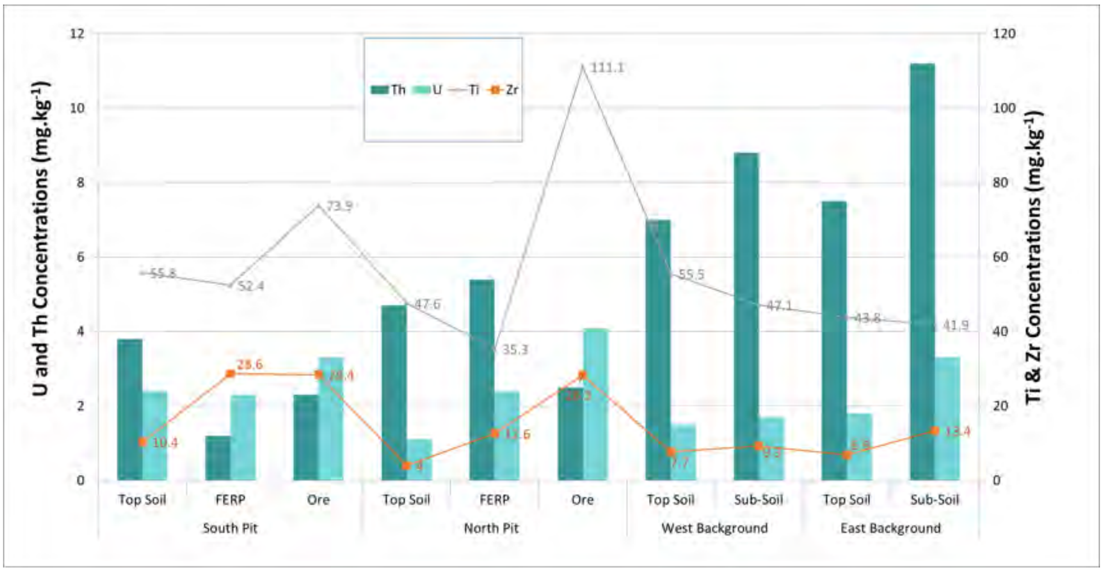


Figure 5.7: Graphical Representation of Chemical Analysis Results

5.4.4.3 Nuclide Specific Properties

The basic compositional data of the radiological characterisations samples was used to extrapolate radiological properties. Although this extrapolation does introduce large uncertainties, the assumptions, ratios and factors used are conservative and internationally accepted standard practice in radiation protection.

The nuclide specific activity concentrations of radionuclides present in the samples were estimated and are presented in Table 5.7.

Table 5.7: Estimated Nuclide Specific Activity Concentrations in Samples from the Project Area

Radionuclide	South Pit			North Pit			West Background		East Background	
	Topsoil	FERP	Ore	Topsoil	FERP	Ore	Topsoil	Sub-soil	Topsoil	Sub-soil
U-238	29.63	28.4	40.75	13.58	29.63	50.63	18.52	20.99	22.23	40.75
U-234	31.63	30.31	43.49	14.5	31.63	54.03	19.77	22.4	23.72	43.49
Th-230	31.63	30.31	43.49	14.5	31.63	54.03	19.77	22.4	23.72	43.49
Ra-226	31.63	30.31	43.49	14.5	31.63	54.03	19.77	22.4	23.72	43.49
Pb-210	31.63	30.31	43.49	14.5	31.63	54.03	19.77	22.4	23.72	43.49
Po-210	31.63	30.31	43.49	14.5	31.63	54.03	19.77	22.4	23.72	43.49
U-235	1.38	1.33	1.9	0.63	1.38	2.36	0.86	0.98	1.04	1.9
Pa-231	1.38	1.33	1.9	0.63	1.38	2.36	0.86	0.98	1.04	1.9
Ac-227	1.38	1.33	1.9	0.63	1.38	2.36	0.86	0.98	1.04	1.9
Th-232	15.42	4.87	9.33	19.07	21.91	10.14	28.41	35.71	30.43	45.45
Ra-228	15.42	4.87	9.33	19.07	21.91	10.14	28.41	35.71	30.43	45.45
Total	**222.76**	**193.66**	**282.55**	**126.11**	**235.74**	**348.15**	**176.76**	**207.36**	**204.81**	**354.78**

To objectively evaluate the radiological characteristics of the different samples, the radionuclide composition of the materials was compared to generally accepted screening criteria. In its Safety Guide on the application of exclusion and exemption the IAEA proposes a 1,000 Bq/kg activity concentration for naturally occurring radionuclides, to be applied to the parent of the decay chain or individually for each decay product in the chains, as appropriate. For all samples the estimated individual nuclide activity values, as well as a total of the long-lived nuclide activities, are well below the 1,000 Bq/kg of 1 Bq/g exclusion level proposed by the IAEA.

5.4.4.4 Gross α/β Radioactivity

The gross α/β levels determined through laboratory analysis on the samples taken in October 2018 are presented in Table 5.8.

Table 5.8: Gross α/β Radioactivity Concentrations in Samples from the Project Area

Sampling Field Code		Alpha Activity			Beta Activity		
		Value	Uncertainty	MDA*	Value	Uncertainty	MDA
		Bq/g					
South Pit Area	Topsoil	1.62	0.23	0.5	0.874	0.032	0.06
	FERP	1.96	0.64	1.5	1.23	0.09	0.14
	Ore	1.61	0.59	1.5	1.1	0.09	0.13
North Pit Area	Topsoil	1	0.45	1.1	0.308	0.053	0.12
	FERP	1.54	0.21	0.46	0.531	0.027	0.059
	Ore	0.932	0.193	0.51	0.903	0.031	0.055
West Background	Topsoil	1.67	0.21	0.43	0.354	0.024	0.06
	Sub-soil	1.1	0.19	0.44	0.405	0.024	0.056
East Background	Topsoil	0.95	0.45	1.2	0.498	0.062	0.12
	Sub-soil	1.2	0.19	0.44	0.41	0.024	0.057

Compared to the gross α/β activities measured in the initial samples in April 2018 (see Table 5.5), the average α-activity measured in the more recent samples is in the same order, while the average β-activity is approximately 50% higher. Most of the higher activity values were measured in samples from the southern pit area, while FERP and ore samples, on average, have the higher associated activity concentrations. However, no activities exceeding 2 Bq/g (2,000 Bq/kg) were measured in any of the in radiological characterisation samples.

If the IAEA criterion of 1 Bq/g is applied to the initial sample results, the α-activities measured in samples of graphite ore, FERP and top soil from the South Pit, as well as FERP from the North Pit indicate potential issues for public exposure. This would also appear to be the case for the sample of background topsoil, implying a naturally elevated level of radioactivity in the area.

As phosphate fertilisers contain trace quantities of naturally occurring radionuclides it has the potential to contribute to radionuclide activity concentrations in soils where it is applied, such as the agricultural areas around Malingunde. In the samples from the proposed pit areas, both measured activity concentrations as well as total U and Th concentrations in topsoil correspond to values measured in ore, at a depth of >6m below surface, indicating that radionuclides present in the topsoil is most likely of natural origin. However, background soil samples collected from areas outside the deposit area indicate concentrations of uranium that are higher than those of topsoil from the deposit area. Should these areas be actively farmed with the regular application of phosphate fertiliser, the observed uranium enrichment could be attributable to the fertiliser. However, given the concentrations of Ti and Zr (which were considered idicative of the presence of heavy minerals) present in the soils outside of the deposit, it is reasonable to assume that a contribution from natural origin is also likely.

Results of both the gross α/β activity and total concentrations of U and Th measurements, indicate that while the samples of graphite ore can include some of the higher activities for individual radionuclides, the background soil samples from areas away from the graphite mineral deposit exhibit similar properties. This implies that the graphite ore most likely does not contain radionuclides at concentrations above that of the surrounding surface environment.

Derived nuclide specific activity concentrations were demonstrated not to exceed generally accepted exclusion levels. Based on this result it can be concluded that the ore and overburden materials samples from the Malingunde mineral deposit can be considered non-radioactive and will most likely not be subject to regulatory control in terms of its radiological properties.

5.5 Soils and Land Capability

5.5.1 Soil Types

A soils investigation was conducted in March 2018 by Digby Wells Environmental using a hand auger to collect representative soil samples for laboratory analysis. The soils were then classified according to the International Soil Classification System for Naming Soils and Creating Legends for Soil Maps (FAO, 2015). Table 5.9 shows the dominant soil types found in the proposed Project area with the distribution of the various soil types across the Project area depicted in Figure 5.8

Table 5.9: Dominant Soil Types

Soil Types	Description
Ferralsols	Strongly leached soils that have lost weatherable minerals. Dominated by stable products such as aluminium oxides, iron oxides and kaolinite. Capacity to supply nutrients to plants and retain nutrients (cation-exchange capacity) are both low (Kihara *et al*., 2012).
Gleysols	Wetland soils that are saturated with water for long periods to develop characteristic gleyic colour patterns. Used often for wetland crop cultivation.
Plinthosols	Soils with a Fe-rich and some cases also Mn-rich with mixture of Kaolinitic sandstone. Poor natural soil fertility and land used for grazing.

Examples of typical soil types indicated in Plate 5.1 (Digby Wells, 2018b).

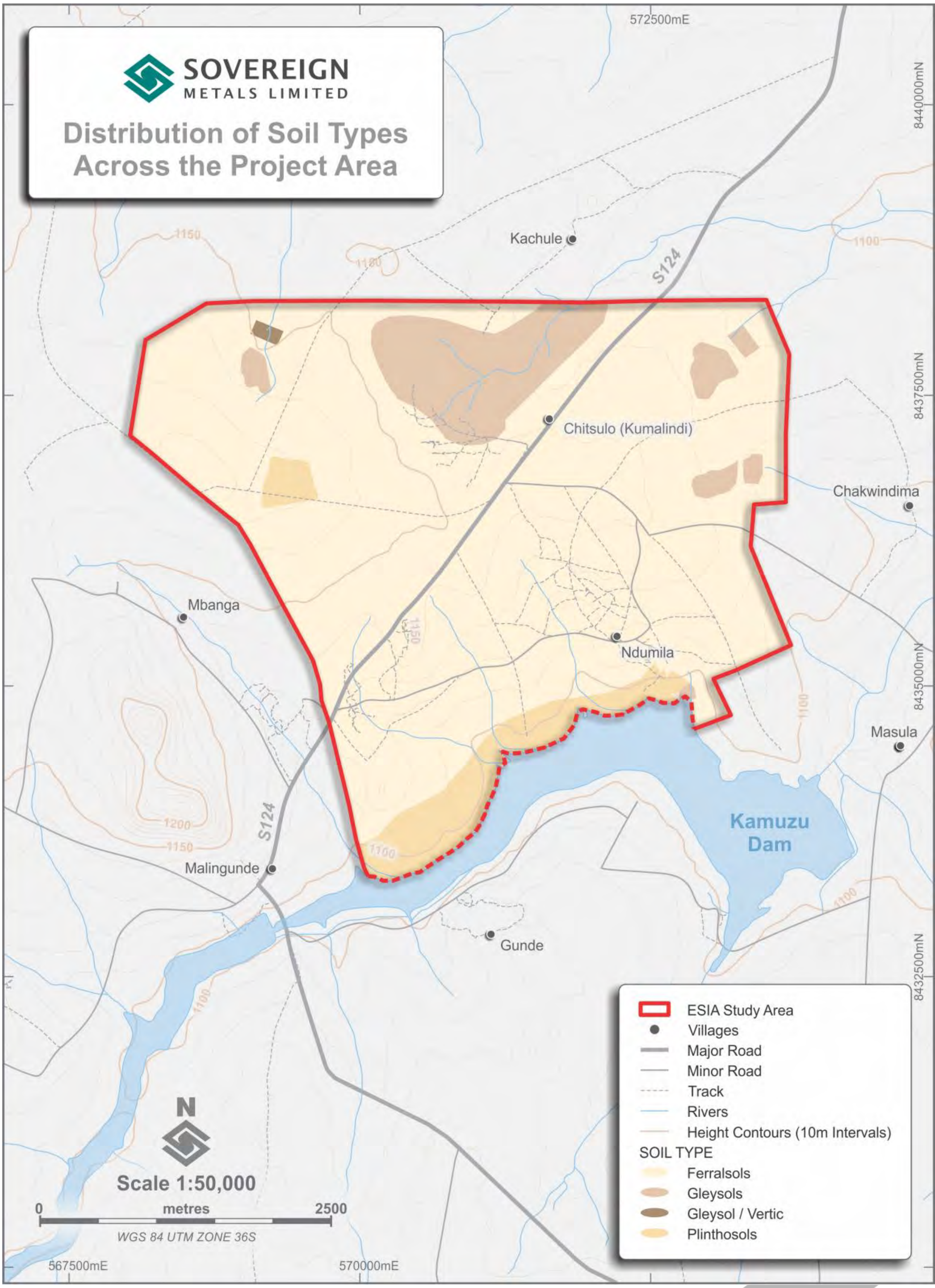
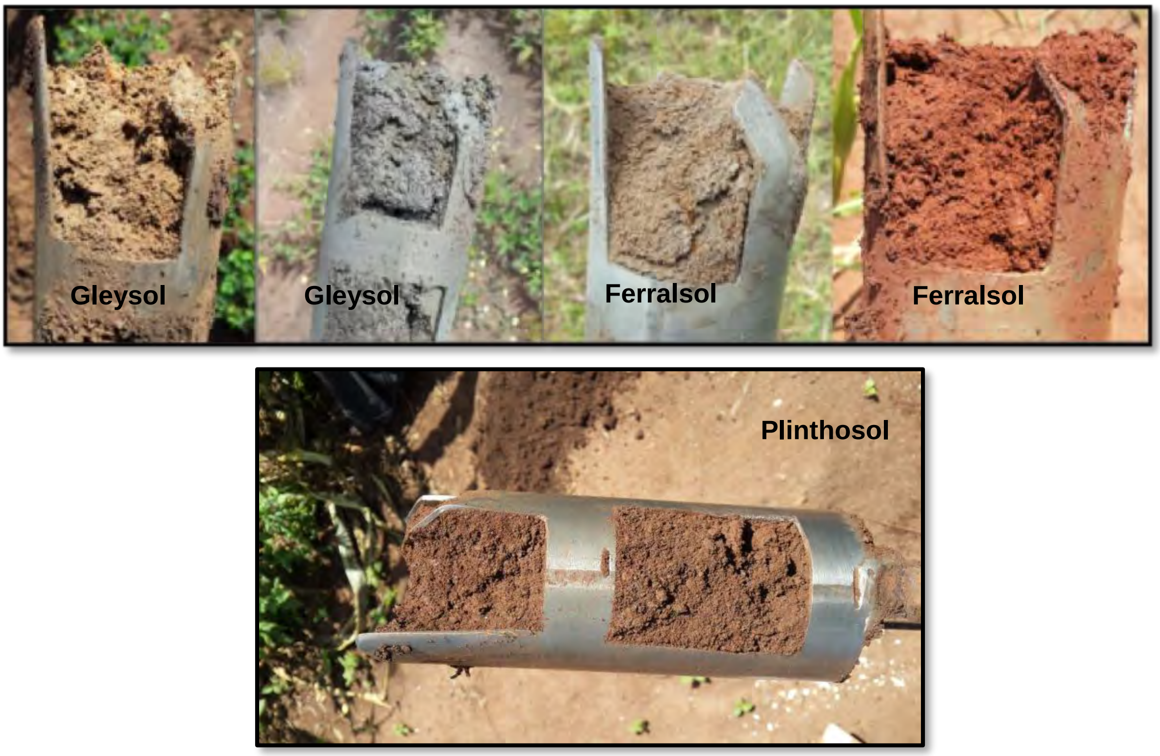


Figure 5.8: Distribution of Soil Types Across the Project Area



Photos: Siphamandla Madikizela

Plate 5.1: Typical Soils from Project Area

5.5.2 Soil Permeability

Geotechnical site assessments (SLR, 2018d) identified the soils as having moderate to slow permeability in the ranges of 2.30 x 10^{-7} and 5.80 x 10^{-8} m/s.

5.5.3 Soil Fertility

A total of twenty soil samples were collected from different sampling points across the ESIA study area, and submitted for analyses to an accredited laboratory in South Africa. In the absence of Malawi-specific guidelines, results were compared against the South African soil fertility guidelines (Fertiliser Association of South Africa, 2016) as indicated in Table 5.10. The results of the laboratory analyses are presented in Table 5.11.

Table 5.10: Soil Fertility Guidelines

<table>
<tr><th colspan="6">Guidelines (mg per kg)</th></tr>
<tr><th colspan="3">Macro Nutrient</th><th colspan="2">Low</th><th>High</th></tr>
<tr><td colspan="3">Phosphorus (P)</td><td colspan="2"><5</td><td>>35</td></tr>
<tr><td colspan="3">Potassium (K)</td><td colspan="2"><40</td><td>>250</td></tr>
<tr><td colspan="3">Sodium (Na)</td><td colspan="2"><50</td><td>>200</td></tr>
<tr><td colspan="3">Calcium (Ca)</td><td colspan="2"><200</td><td>>3000</td></tr>
<tr><td colspan="3">Magnesium (Mg)</td><td colspan="2"><50</td><td>>300</td></tr>
<tr><th colspan="6">pH (KCl)</th></tr>
<tr><th>Very Acid</th><th>Acid</th><th>Slightly Acid</th><th>Neutral</th><th>Slightly Alkaline</th><th>Alkaline</th></tr>
<tr><td><4</td><td>4.1-5.9</td><td>6-6.7</td><td>6.8-7.2</td><td>7.3-8</td><td>>8</td></tr>
</table>

Table 5.11: Results from Soils Analyses

Samples ID	pH	EC (dS/m)	P (mg/kg)	Ca (mg/kg)	Mg (mg/kg)	K (mg/kg)	Na (mg/kg)	C (%)	Clay (%)	Sand (%)	Silt (%)	Texture
410 Pit	5.18	10.5	1	761	259	93	14	0.47	37	49.5	13.5	Sandy clay
310 WRD-B North	4.94	7.8	1	687	134	30	14	0.81	41	47.06	11.94	Sandy clay
373 Pit	4.38	11.2	1	275	59	19	11	0.55	41	50.32	8.68	Sandy clay
563 TSF 7	5.19	9.5	1	549	89	27	10	0.55	33	54.6	12.4	Sandy clay loam
542 TSF 7	4.95	8.6	1	669	110	27	10	0.47	35	49.1	15.9	Sandy clay
462 TSF 5	4.74	7.6	1	563	108	21	8	0.68	37	48.32	14.68	Sandy clay
404 Pit school	5.14	8.9	1	1370	185	106	17	0.16	45	37.6	17.4	Clay
458 TSF 5	4.45	9.2	1	459	124	29	13	0.26	31	63.92	5.08	Sandy clay loam
511 TSF 2/3	4.91	9.5	1	251	53	15	10	0.91	37	48.9	14.1	Sandy clay
147 TSF 2/3	4.99	8.5	2	519	108	102	13	0.52	31	54.6	14.4	Sandy clay loam
241 Plant -B	5.00	7.1	1	566	91	21	11	1.02	41	41.86	17.14	Clay
171 WRD-B	4.76	8.2	1	387	102	107	14	0.75	37	48.3	14.7	Sandy clay
310 WRD-A North	4.76	9.4	2	525	137	46	11	0.49	37	51.9	11.1	Sandy clay
446 RWD	4.62	7.4	1	887	130	45	12	0.70	37	49.2	13.8	Sandy clay
323 RWD North	5.22	9.1	11	395	71	47	8	0.42	5	88.64	6.36	Loamy sand
248 Pit Big	4.31	7.6	3	884	104	22	12	0.62	35	52.28	12.72	Sandy clay loam
284 Pit Big	4.38	6.3	1	277	52	16	10	0.55	15	77.16	7.84	Sandy loam
380 Pit	4.19	13	4	179	41	32	11	0.44	35	50.06	14.94	Sandy clay
220 Pit	4.81	10.5	3	681	95	16	14	0.49	43	39.42	17.58	Clay
409 Pit	6.31	47.8	22	1276	327	766	22	0.36	31	50.2	18.8	Sandy clay loam

5.5.3.1 Soil pH and Electrical Conductivity

Soil pH influences plant growth in the following manner:

- Through the direct effect of the hydrogen ion concentration on nutrient uptake.
- The mobilisation of toxic ions such as aluminium which restrict plant growth.
- Indirect impacts that include the effect on trace nutrient availability.

The soil pH of the samples ranged from 4.1 to 6.3, and these soils are considered to be acidic to slightly acidic. This may be due to the acidic nature of the parent material from which the soils were derived and also high rate of leaching of nutrients down profile. For successful crop production, a pH between 6 and 7.5 is optimum and crops produced in soils with lower pH may suffer aluminium toxicities and phosphorus deficiencies. Lime or gypsum is required to counteract acidity and to increase plant growth performance, as agricultural activities are taking place over the area.

The electric conductivity (EC) is a measure of the amount of soluble salts in the soil solution. Soil samples had an EC between 4 and 8 dS/m. The soil was classified as moderately saline according to the Food and Agriculture Organisation of the United Nations classification of saline-sodic soils (FAO, 2015).

5.5.3.2 Exchangeable Cations

The levels of the basic cations Ca, Mg, K and Na are determined in soil samples for agronomic purposes through extraction with an ammonium acetate solution. For most soils, cations follow the typical trend Ca>Mg>K>Na.

Ca and Mg levels in the soil were generally adequate when compared with fertility guidelines in Table 5.10 for crop production and these nutrients are not limiting any production or considered as toxic. There is unlikely to be a need to add Ca, K and Mg sources during rehabilitation, provided that the current levels do not decrease during stockpiling of soils.

Na levels were low when compared with fertility guidelines in Table 5.10 which may be detrimental to plant growth and development. Dispersion occurs in soils when the repulsive forces between clay particles exceed the attractive forces. Dispersive soils are known to contain a higher content of dissolved Na in their pore water than ordinary soils. Soil dispersion is unlikely to occur and cause dense structure and drainage problems due to low levels of dissolved Na (Digby Wells, 2018b).

5.5.3.3 Phosphorous

The P levels in the samples from the site were all very low, with most values being 1 mg/kg and the maximum 22 mg/kg. Phosphorus will be a limiting factor in terms of ecosystem function as the soil is used for agricultural purposes and at least 15 mg/kg is required for plant production. Phosphorus fertilisation may be required to establish good crop stand and growth where agricultural activities are taking place over the area (Digby Wells, 2018b).

5.5.3.4 Soil Organic Carbon

Soil organic carbon provides an indication of organic matter content in a soil. Levels above 2 to 3% organic carbon are considered moderate to high. The soil organic carbon content of the soils in the Project area ranged from 0.16% to 1.02%, and levels below 2% would require an external nutrient input source, as deficiency of organic matter occurs (Digby Wells, 2018b).

5.5.4 Soil Texture

Soil texture is defined as the relative proportion of sand, silt and clay particles found in the soil. The relative proportions of these 3 fractions (clay, sand and silt) determine 1 of 12 soil texture classes.

The particle size distribution of the soil sampled from the Project area was recorded as percentages of sand, silt and clay present (Table 5.11). The clay fraction ranged from 5 to 45%, sand from 37 to 88% and silt from 5 to 18%. The textural class was obtained by plotting the three fractions on a textural triangle. The soils can be described as texturally variable, containing a mixture of sandy clay loam, sandy clay, clay, sandy loam and loamy sand.

5.5.5 Soil Erosion Potential

The erosion potential of a soil is determined from soil texture, permeability, organic carbon content and soil structure. The erodibility is defined as the vulnerability or susceptibility of a soil to erosion.

The dominant soil types in the study area can be classified as having a moderate to high erodibility index. This is due to low organic carbon content (<2%) and the sensitivity of the soils to solution weathering. The erosion potential of soils is directly related to the disturbance of protective vegetation cover.

5.5.6 Land Capability

Land capability was determined by assessing a combination of soil, terrain and climate features. Land capability is defined by the most sustainable land use under rain-fed conditions. Land capability involves consideration of the risks of land damage from erosion and other causes and the difficulties in land use owing to physical land characteristics, including climate.

The land capability was assessed according to the United States of America (USA) Department of Agriculture's Land Capability Method, which is based on eight classes (I, II, III-VIII), as well as the approach by Schoeman *et al.* (2000) as cited in the report by Digby Wells (2018b). These approaches were used in the absence of specific Malawian guidelines for land capability assessment.

The Project area is dominated by Class II (intensive cultivation), Class III (moderate cultivation), Class IV (light cultivation) and Class V (wetland) type soil/land capability classes (Table 5.12). Soils with arable land capability are well drained, easily managed and has high agricultural potential. Soils classified as wetlands are deeper and have high clay content and shrink/swell properties, making them very difficult to manage from an agricultural perspective. These characteristics restrict the kind of plants that can be grown and prevent normal tillage of cultivated crops.

Table 5.12: Land Capability Classification

Soil Type	Land Capability Class	Description of Class	Agricultural Potential
Ferralsols	Class II	**Land with minor limitations for land use**. Land has some limitations that reduce the choice of plants or require moderate conservation practices. It may be used for cultivated crops with less latitude in the choice of crops or management practices in Class I.	Moderate
	Class III	**Land with slight to moderate limitations for land use**. Land has limitations that reduce the choice of plants or require special conservation practices. It may be used for cultivated crops, but has more restrictions than Class II.	
Gleysols	Class IV	**Land with moderate limitations for land use**. Land has limitations that restrict the choice of plants and require very careful management. It may be used for cultivated crops, but more careful management is required than for Class III. Conservation practices are more difficult to apply and maintain.	Moderate to *Low

	Class V	**Land with moderate to high limitations to land use**. Land has limitations that restrict its use largely to pasture and wildlife. Limitations restrict the choice of plants that can be grown and prevent normal tillage of cultivated crops.	
Plinthosols	Class III	**Land with slight to moderate limitations for land use**. Land has limitations that reduce the choice of plants or require special conservation practices. It may be used for cultivated crops, but has more restrictions than Class II.	Moderate to *Low
	Class IV	**Land with moderate limitations for land use**. Land has limitations that restrict the choice of plants and require very careful management. It may be used for cultivated crops, but more careful management is required than for Class III. Conservation practices are more difficult to apply and maintain.	

*Potential rated low in a wetland context but can be high with suitable management

5.6 Flora

The Project area falls within the Southern Miombo woodlands ecoregion – a discontinuous ecoregion which is located on the Central African Plateau at elevations between 1,000 and 1,500 m. Floristically, the Southern Miombo woodlands ecoregion forms part of a belt of miombo woodland that extends from Angola, in the west, to Tanzania, in the east. This miombo band is synonymous with the Zambezian Phytochorion, the largest of White's (1983) Regional Centres of Endemism within Africa (Hudson Ecology, 2019a). Miombo plant communities are dominated by trees belonging to the family Caesalpiniaceae and characterised by *Brachystegia* and *Julbernardia* species.

Surveys of the terrestrial ecology in the Project area and immediate surrounds were undertaken by Hudson Ecology. Field surveys were conducted during the latter part of the wet season (April 2017), just before the advent of the wet season (October 2017), and in February 2018 during the wet season. The results of these surveys are summarised in Section 5.6 (Flora) and Section 5.7 (Fauna). The detailed report is attached in Appendix E.

5.6.1 Vegetation Communities in the Project Area

Based on physiognomy, moisture regime, rockiness, slope and soil properties, four main vegetation communities were recognised. These vegetation communities and the study area considered are shown in Figure 5.9.

Table 5.13 indicates the relative size of each of the vegetation communities identified in the study area.

Table 5.13: Vegetation Communities Identified in the ESIA Study Area

Vegetation Community	Area in ha	% of Total Study Area
Dambo grassland vegetation community	119.6	6.45
Mixed riparian woodland vegetation community	38.6	2.08
Forest woodland vegetation community	16.2	0.87
Cultivated lands	1,680.2	90.6
Total Study Area	**1,854.6**	**100%**

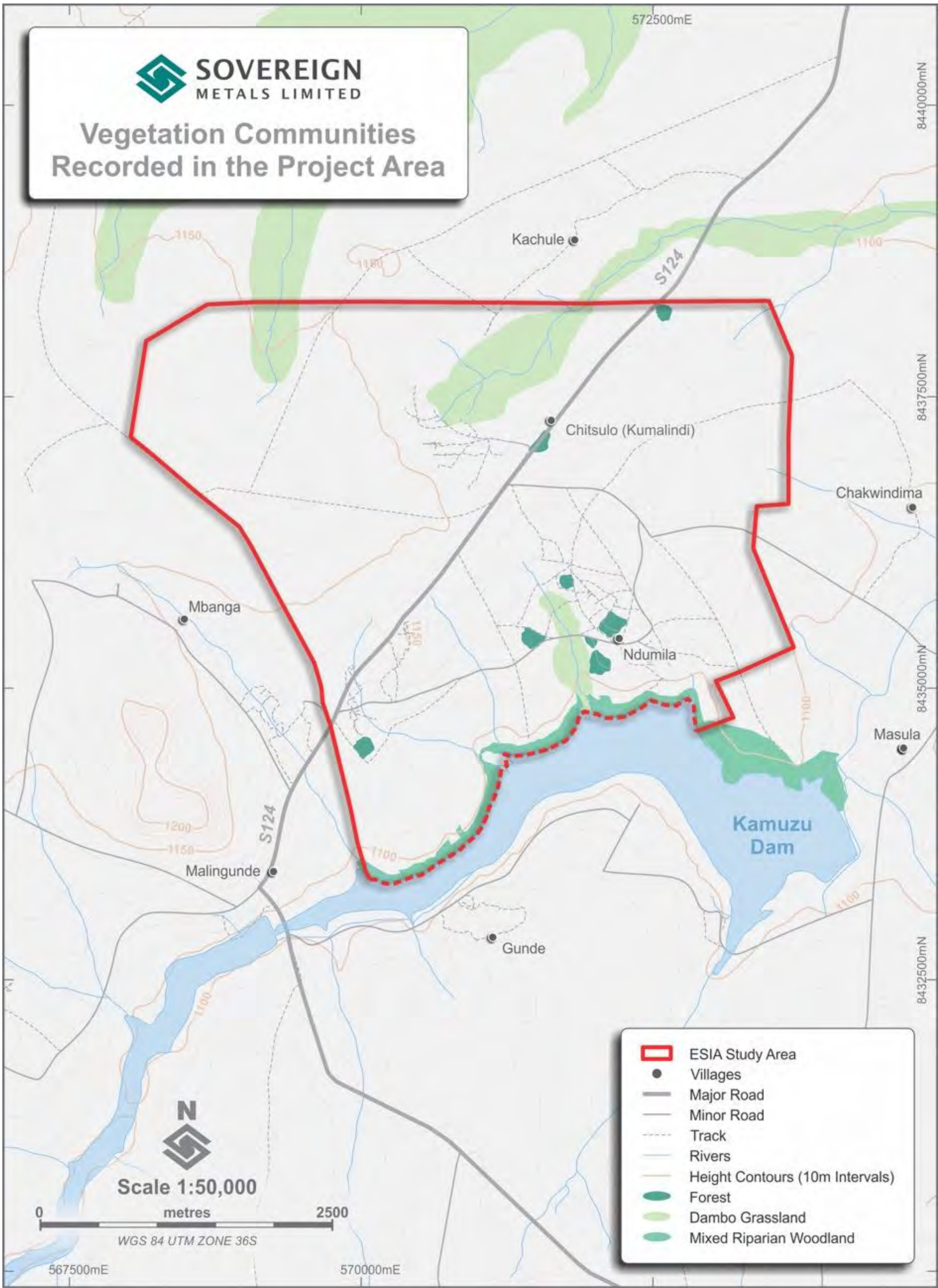


Figure 5.9: Vegetation Communities Identified in the Study Area

5.6.1.1 Dambo Grassland (Wetland) Vegetation Community

The Ramsar Convention (1971) has defined wetlands 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 6 meters"*

Wetlands in Malawi (also called dambos) are seasonally waterlogged, predominantly grass and sedge covered, shallow depressions bordering headwater drainage lines (Plate 5.2).

Topographically, dambos are usually broad, gentle sloping valleys occurring in the catchment area of Malawi's main rivers. These are generally found in higher rainfall flat plateau areas and have river-like branching forms.

Dambo soils are waterlogged at or near the surface for a large part of the year. These hydromorphic soils have a high water table and are poorly drained resulting in poor aeration. They vary from coarse sands to heavy clays with a soil reaction ranging from acid to alkaline. Large variations also occur in the nutrient status and the structural stability of dambo soils. Vegetation, grass and sedge, sometimes shrubs or trees, grow even during the driest months of the year (Mzembe, 1990 as cited in Hudson Ecology, 2019b; see also Appendix F).

Photo: Adrian Hudson

Plate 5.2: Example of a Dambo to the North of the Project Area

This vegetation community varies along a cross-section of the wetlands, based on the soil type and soil moisture composition. Species dominance is not uniform and occurs in mosaics of local dominance of different species.

A total of 64 species of plants (Table 5.14) associated with wetland systems were recorded in the study area during the April 2017 surveys (Hudson Ecology, 2019b).

Table 5.14: Species Recorded in the Dambos in the Regional Study Area

Trees	Forbs[3]	Grasses	Cyperoids[4]
Kigellia africana	*Bidens biternata*	*Hemarthria altissima*	*Cyperus digitatus*
Piliostigma thonningii	*Bidens pilosa*	*Andropogon eucomus*	*Cyperus esculentus*
Senna didymobotrya	*Conyza albida*	*Andropogon gayanus*	*Cyperus tenax*
	Ceratotheca triloba	*Aristida junciformis*	*Kylinga erecta*
	Conyza albida	*Arundinella nepalensis*	*Pycreus aethiops*
	Conyza welwitschii	*Brachiaria deflexa*	*Typha latifolius*
	Euphorbia cyparissoides	*Cynodon dactylon*	*Typha domingensis*
	Haumaniastrum sericeum	*Dactyloctenium aegyptium*	
	Helichrysum species	*Digitaria scalarum*	
	Kniphofia linearifolia	*Eleusine indica*	
	Oldenlandia corymbosa	*Eragrostis capensis*	
	Oldenlandia herbacea	*Eragrostis chapelieri*	
	Polygonum senegalense	*Hyparrhenia filipendula*	
	Ranunculus multifidus	*Melinis repens*	
	Senecio strictifolius	*Monocymbium ceresiiforme*	
	Sesbania microphylla	*Paspalum urvillei*	
	Solanum campylacanthum	*Pogonarthria squarrosa*	
	Tagetes minuta	*Setaria pumila*	
	Verbena bonariensis	*Sporobolus pyramidalis*	
	Azolla nilotica	*Sporobolus subtilis*	
	Pistia stratiotes	*Themeda triandra*	
	Utricularia cf. *intermedia*	*Oryza barthii*	
	Rorippa nasturtium-aquaticum	*Ischaemum afrum*	
	Persicaria lapathifolia	*Brachiaria humidicola*	
	Nymphaea nouchali	*Echinochloa pyramidalis*	
	Nymphaea lotus	*Entolasia imbricata*	
		Hyparrhenia nyassae	

The most common species across all three of the wetlands surveyed are *Cyperus esculentus, Cyperus tenax, Kylinga erecta, Typha domingensis, Aristida junciformis, Andropogon eucomus, Arundinella nepalensis, Cynodon dactylon, Echinochloa pyramidalis, Heteropogon contortus , Hyparrhenia filipendula, Hyparrhenia nyassae, Hyperthelia dissoluta, Melinis repens, Pogonarthria squarrosa, Sporobolus pyramidalis, Bidens biternata, Bidens pilosa, Conyza albida, Euphorbia tirucalli, Oldenlandia corymbosa, Oldenlandia herbacea, Senecio strictifolius, Solanum delagoense,*

[3] An herbaceous flowering plant that is not a graminoid. Graminoid is a grass or grasslike plant species resembling, allied to or belonging to the family Poaceae.

[4] A plant species resembling, allied to, or belonging to the plant-genus *Cyperus* or the family Cyperaceae.

Tagetes minuta, Verbena bonariensis, Dichrostachys cinerea, Gmelina arborea, Senna alata and *Piliostigma thonningii*.

In the outer, drier parts of the dambo the grass community is dominated by *Hyparrhenia filipendula, Setaria incrassata, Sporobolus pyramidalis, Loudetia simplex, Pogonarthria squarrosa, Hyperthelia dissoluta, Cynodon dactylon, Eragrostis chapelieri, Setaria pumila, Stereochlaena cameronii* and *Eragrostis superba.* This area of the dambo is often interspersed by weeds and woody species such as *Kigellia africana, Piliostigma thonningi, Senna siamea, Solanum delagoense, Bidens biternata, B. pilosa, Tagetes minuta, Conyza albida, Sesbania microphylla* and *Oldenlandia corymbosa*.

Closer to the channel of the dambo, vegetation changes so that the grass species are dominated by species such as *Hemarthria altissima, Paspalum urvillei, Arundinella nepalensis, Aristida junciformis,* and sedges such as *Cyperus esculentus, Cyperus tenax, Kylinga erecta, Pycreus aethiops, Typha latifolius and Typha domingensis.* Forb species closer to the channel include *Ranunculus multifidus, Verbena bonariensis, Senecio strictifolius, Helichrysum* species, *Kniphofia linearifolia* and *Polygonum senegalense,* while the channel itself may host aquatic macrophytes such as *Azolla nilotica, Pistia stratiotes, Utricularia cf. intermedia, Persicaria lapathifolia, Nymphaea nouchali* and *N. lotus.*

Although wetlands have intrinsic conservation importance, the degraded (and in some cases transformed) nature of the wetlands in the study area reduces the conservation importance of these areas slightly. Ecological integrity is also compromised in this vegetation community due to anthropogenic impacts of variable nature, extent and intensity. The ecological importance of this vegetation community may be regarded as low to moderate, while the conservation importance is moderate.

5.6.1.2 Mixed Riparian Woodland

Mixed riparian (or riverine) woodland vegetation occurs along the banks of more permanent water bodies such as perennial rivers and dams (Figure 5.9), and is comprised of a mixture of fine- and broad-leaved tree species as well as a well-developed shrub layer and poorly developed grass and forb layers as can be seen in Plate 5.3. This vegetation community demonstrates a far lesser degree of degradation than other vegetation communities in the region and the main form of disturbance occurs in the form of invasive species propagation in the vegetation community.

This vegetation community comprises of a range of tree species including *Vachellia polyacantha, Vachellia sieberiana, Albizia antunesiana, Burkea africana, Combretum molle, Ekebergia benguelensis, Faurea speciose, Piliostigma thonningi, Antidesma venosum, Afzelia quanzensis* and *Trichilia emetic*. Common shrub species in this vegetation community include *Eriosema ellipticum, Eriosema engleranum, Euclea crispa, Gnidia kraussiana, Indigofera arrecta, Lippia javanica, Lopholaena coriifolia, Maytenus senegalensis, Rhynchosia resinosa, Flueggea virosa* and *Diospiros heterophylla*. Due to the increased canopy cover the grass and forb layers are poorly defined and grasses found in this vegetation community include *Aristida junciformis* and *Eragrostis* spp.

Exotic species in this vegetation community include *Bidens biternata, Bidens pilosa, Solanum delagoense, Tagetes minuta, Verbena bonariensis* and *Lantana camara.*

The species recorded in this vegetation community are listed in Table 5.15.

Impacts on this vegetation community are low to moderate and do not reduce the ecological integrity and conservation importance of this vegetation community significantly, although a number of factors will affect the significance of the reduction. The ecological integrity of this vegetation community can be described as high, while the conservation importance of these vegetation communities can also be described as high.

Photo: Adrian Hudson

Plate 5.3: An Example of Mixed Riparian Woodland

Table 5.15: Species Recorded in the Mixed Riparian Woodland in the Regional Study Area

Trees	Shrubs	Forbs	Grasses
Vachellia polyacantha	*Laggera crispata*	*Bidens biternata*	*Aristida junciformis*
Vachellia sieberiana	*Eriosema ellipticum*	*Bidens pilosa*	*Cynodon dactylon*
Albizia antunesiana	*Eriosema engleranum*	*Conyza albida*	*Eragrostis spp.*
Burkea africana	*Euclea crispa*	*Ceratotheca triloba*	*Heteropogon contortus*
Combretum molle	*Gnidia kraussiana*	*Conyza welwitschii*	*Hyparrhenia filipendula*
Cussonia arborea	*Helichrysum kraussii*	*Euphorbia cyparissoides*	*Hyperthelia dissoluta*
Ekebergia benguelensis	*Indigofera arrecta*	*Haumaniastrum sericeum*	*Perotis patens*
Faurea speciosa	*Lippia javanica*	*Helichrysum species*	*Pogonarthria squarrosa*
Ozoroa insignis	*Lopholaena coriifolia*	*Oldenlandia corymbosa*	*Sporobolus pyramidalis*
Strychnos spinosa	*Maytenus heterophylla*	*Polygonum senegalense*	
Vangueria infausta	*Maytenus senegalensis*	*Ranunculus multifidus*	
Piliostigma thonningii	*Pavetta schumanniana*	*Senecio strictifolius*	
Dichrostachys cinerea	*Rhynchosia resinosa*	*Sesbania microphylla*	
Antidesma venosum	*Flueggea virosa*	*Solanum delagoense*	
Afzelia quanzensis	*Diospiros heterophylla*	*Tagetes minuta*	
Trichilia emetica	*Asparagus terrisfolias*	*Verbena bonariensis*	
Psidium guajava		*Euphorbia tirucalli*	
Bauhinia thonningii			
Gmelina arborea			
Eucalyptus saligna			
Senna siamea			

5.6.1.3 Forest Vegetation Community

Forest vegetation communities are found mostly surrounding ancestral graveyards (*dambwes*), which represent forest islands (Figure 5.9) of relatively unspoiled vegetation, with smaller patches in cultivated dambo grassland. This habitat has a good representation of older and larger trees, typically with dense canopy cover, and includes indigenous trees such as *Rauvolfia caffra, Julbemardia globiflora, Kigellia africana, Parinari curatellifolia, Ochna puhra, Pericopsis angolensis, Toonia ciliata, Vangueriopsis lanciflora, Piliostigma thonningii* and *Cussonia arborea*.

Due to the disturbance by livestock and the high density of the crown cover (60%) the shrub, grass and forb layers are poorly defined, with the shrub layer being particularly poorly defined. Shrub species recorded in this vegetation community include *Euclea crispa, Gnidia kraussiana, Helichrysum kraussii, Indigofera arrecta, Lantana camara* and *Leptactina benguelensis*.

The grass layer is sparse and characterised by *Eragrostis* spp., *Heteropogon contortus, Hyperthelia dissoluta, Melinis repens, Pogonarthria squarrosa* and *Sporobolus pyramidalis*, while the forb layer is dominated by exotic species such as *Achyranthes aspera* and *Bidens pilosa*, in high densities, as well as species such as *Polygonum senegalense, Ranunculus multifidus, Senecio strictifolius, Sesbania microphylla* and *Solanum* spp. Forest woodlands in the Project area are restricted to isolated stands of vegetation with minimal connection, with more expansive regional forests found within forest reserves in the region (Plate 5.4).

The list of species recorded in the forest vegetation community is given in Table 5.16.

Although these forests are significant from a cultural point of view and may hold some intrinsic importance to biodiversity in the region, there are a number of factors which reduce the ecological integrity of these forest woodlands. These factors are:

- The lack of connectivity of these forests, to one another and to more expansive forests in the region, thus movement between these resource patches is impeded to a very high degree.
- Edge effects on these forest patches, these habitat fragments exhibit especially pronounced edge effects that may extend throughout the habitat. As the edge effects increase, the impacts from surrounding areas increase, such as the infestation by invasive species.

Due to their proximity to settlements grazing pressure, on the grass, forb and even shrub layers of these habitat patches, is high.

Furthermore, these impacts also reduce the ecological integrity and conservation importance of this vegetation community, although many factors will affect the significance of the reduction. The ecological integrity of this vegetation community can be described as moderate, while the conservation importance of these vegetation communities can also be described as moderate. These forests are, however, very significant from a social perspective due to the graveyards in these areas.

Photo: Adrian Hudson

Plate 5.4: An Example of the Forest Fragments in the Project Area

Table 5.16: Species Recorded in the Forest Vegetation Community

Trees	Shrubs	Forbs	Grasses
Brachystegia spiciformis	*Blumea alata*	*Achyranthes aspera*	*Cynodon dactylon*
Burkea africana	*Eriosema engleranum*	*Amaranthus hybridus*	*Eragrostis spp.*
Cussonia arborea	*Euclea crispa*	*Bidens biternata*	*Heteropogon contortus*
Julbemardia globiflora	*Gnidia kraussiana*	*Bidens pilosa*	*Hyparrhenia filipendula*
Kigellia africana	*Helichrysum kraussii*	*Ceratotheca triloba*	*Hyperthelia dissoluta*
Ochna puhra	*Indigofera arrecta*	*Conyza albida*	*Melinis repens*
Parinari curatellifolia	*Lantana camara*	*Conyza welwitschii*	*Perotis patens*
*Toonia ciliata**	*Leptactina benguelensis*	*Datura stramonium*	*Pogonarthria squarrosa*
Piliostigma thonningii	*Lopholaena coriifolia*	*Euphorbia cyparissoides*	*Sporobolus pyramidalis*
Dichrostachys cinerea	*Maytenus senegalensis*	*Haumaniastrum sericeum*	
Pericopsis angolensis	*Pavetta schumanniana*	*Helichrysum species*	
Terminalia sericea		*Kniphofia linearifolia*	
Vangueriopsis lanciflora		*Oldenlandia corymbosa*	
Pterocarpus angolensis		*Oldenlandia herbacea*	
Trichilia emetica		*Polygonum senegalense*	
Bauhinia thonningii		*Ranunculus multifidus*	
Rauvolfia caffra		*Senecio strictifolius*	
Senna didymobotrya		*Sesbania microphylla*	
Agave (cf) sisalana		*Solanum delagoense*	
		Tagetes minuta	
		Verbena bonariensis	
		Euphorbia tirucalli	

5.6.1.4 Cultivated Lands

Cultivated land within the local study area consists of cultivated dambo and cropland, and covers approximately 89% of the local study area.

Cultivated lands in the dambo areas are used to grow vegetable crops, such as tomatoes (*Solanum lycopersicum*), Irish potatoes (*Solanum tuberosum*), maize (*Zea mays*), sugarcane (*Saccharum officinarum*) and a variety of squashes (*Cucurbita* sp.). During the dry season, some of these areas are irrigated from shallow groundwater wells or the river. The remainder of the cultivated land area is used for the cultivation of maize and groundnuts (*Arachis villosulicarpa*).

These areas are often devoid of trees, or very sparsely populated by scattered trees. Tree species found in this vegetation community include exotic species of economic importance, such as *Eucalyptus saligna* and *Gmelina arborea* for wood, and *Mangifera indica* (mango) and *Psidium guajava* (guava) for fruit. Indigenous trees that occur in this vegetation community include *Kigellia africana, Piliostigma thonningi, Senna siamea* and *Dichrostachys cinerea* (Plate 5.5).

The shrub layer in this vegetation is virtually non-existent although coppiced trees do occur in areas, while forb species in these areas are dominated by weed species such as *Bidens biternata, Bidens pilosa, Oldenlandia herbacea, Sesbania microphylla, Solanum delagoense*, *Tagetes minuta* and *Verbena bonariensis*. Due to the fact that these areas are heavily grazed when not cultivated, the grass layer is relatively sparse and dominated by unpalatable and sub-climax species such as *Aristida junciformis, Cynodon dactylon, Eragrostis* spp. *Heteropogon contortus* and *Hyparrhenia filipendula*.

The list of species recorded in the Cultivated lands vegetation community is given in Table 5.17.

Due to the significant and widespread anthropogenic impacts already existent in this vegetation community, it can be described as transformed with a low ecological integrity and low conservation importance.

Photo: Adrian Hudson

Plate 5.5: *Kigelia africana* Located in Cultivated Lands

Table 5.17: Species Recorded in the Cultivated Lands Vegetation Community

Trees	Shrubs	Forbs	Grasses	Cyperoids
Kigellia africana	*Gnidia kraussiana*	*Bidens biternata*	*Aristida junciformis*	*Cyperus esculentus*
Piliostigma thonningii	*Blumea alata*	*Bidens pilosa*	*Arundinella nepalensis*	*Cyperus tenax*
Dichrostachys cinerea	*Eriosema ellipticum*	*Ceratotheca triloba*	*Brachiaria deflexa*	*Kylinga erecta*
Faldebia albida	*Eriosema engleranum*	*Oldenlandia herbacea*	*Cynodon dactylon*	
Bauhinia thonningii	*Euclea crispa*	*Conyza welwitschii*	*Dactyloctenium aegyptium*	
Senna didymobotrya	*Helichrysum kraussii*	*Euphorbia cyparissoides*	*Eragrostis capensis*	
	Indigofera arrecta	*Sesbania microphylla*	*Eragrostis spp.*	
	Lippia javanica	*Helichrysum species*	*Heteropogon contortus*	
	Lopholaena coriifolia	*Kniphofia linearifolia*	*Hyparrhenia filipendula*	
	Maytenus heterophylla	*Solanum delagoense*	*Melinis repens*	
	Maytenus senegalensis	*Senecio strictifolius*	*Paspalum urvillei*	
	Pavetta schumanniana	*Polygonum senegalense*	*Pogonarthria squarrosa*	
	Rhynchosia resinosa	*Ranunculus multifidus*	*Sporobolus pyramidalis*	
		Tagetes minuta	*Themeda triandra*	
		Verbena bonariensis		

5.6.2 Species Richness and Abundance of Vegetation Communities

Six monitoring sites were established in the Project area (refer Figure 5.12 in section 5.7.1) to determine species richness and abundance; three riparian sites were located across the Lilongwe River (upstream and downstream of the Kamuzu Dam), with another three in each of the three identified dambos. Species diversity in the regional and local study areas can be considered as moderate.

One hundred and fourteen (114) terrestrial plant species were recorded in the Project area representing 29 families. Tree species accounted for 31 species (27%) and shrub species 18 species (16%), while forbs accounted for 27 species (24%) of the total number of species recorded. Grass species accounted for 27% of the total number of species recorded with 31 species. With only 7 species (6%) being cyperoid plants.

A detailed list of flora species identified is attached in the Terrestrial Ecology Baseline Assessment in Appendix E, while the number of species recorded in each of the vegetation communities is given in Table 5.18.

Table 5.18: Number of Species Recorded per Vegetation Community

Vegetation Community	Number of Species Recorded	% of Total Number of Species
Dambo grassland vegetation community	63	55%
Mixed riparian vegetation community	63	55%
Forest woodland vegetation community	61	54%
Cultivated lands	51	45%
Total Study Area	**114**	**100%**

Both species richness and abundance were considerably lower during the October 2017 and February 2018 surveys when compared with the April 2017 surveys, and species recorded was a subset of those recorded in the April 2017 surveys.

One hundred and fourteen (114) species were recorded during the April 2017 survey, 81 during the October 2017 survey and 98 during the February 2018 survey. These differences can be attributed to the fact that the October 2017 surveys were conducted before the advent of the annual rains and the February 2017 many of the annual species were as yet unidentifiable.

Species diversity varies considerably across the six monitoring sites with the Kankoma dambo and the riparian monitoring site upstream of the Kamuzu Dam (riparian monitoring site 1) showing the highest species diversity with 58 and 70 species respectively, while the sites with the lowest species diversity being Kovuma dambo and Dambo 1, with 45 and 37 species respectively (Figure 5.10).

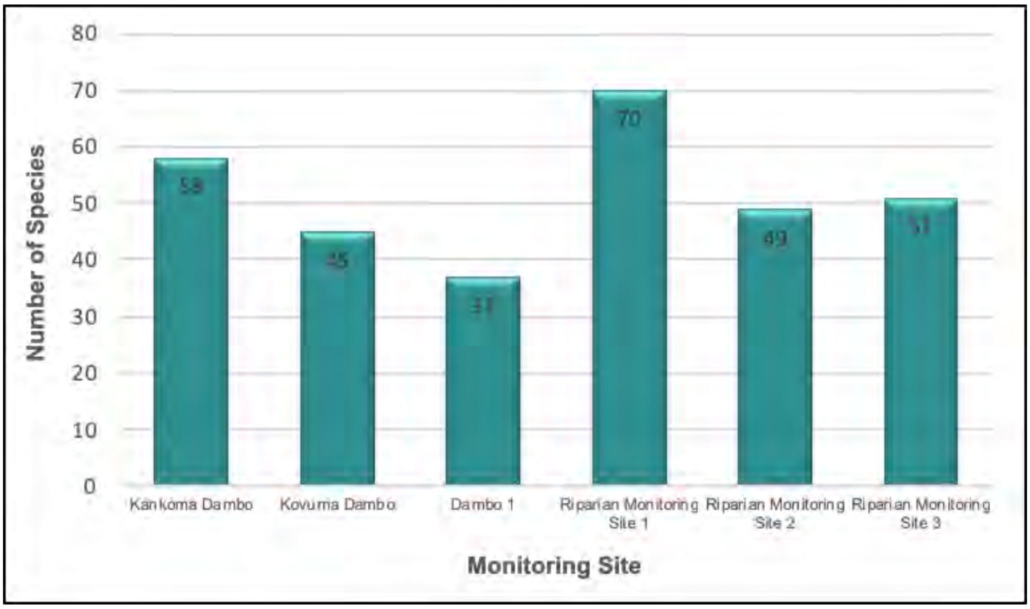


Figure 5.10: Plant Species Richness Across Wetland and Riparian Monitoring Sites

5.6.3 Species of Conservation Importance

Malawi has about 5,500 to 6,000 flowering plants, and 250 species of bryophytes, 200 of which are mosses. Out of the documented more than 6,000 plant species, 253 are considered threatened, vulnerable, rare or endangered (Hudson Ecology, 2019a).

Of the species of conservation importance that may occur in the Project area (Table 5.19), one species is currently listed as *Least Concern*, two species are listed as *Near Threatened*, two species are listed as *Vulnerable,* while one species is listed as *Critically Endangered* under the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (Red List). Two species have a moderate and five species have a high probability of occurrence.

Four species of conservation importance, namely *Burkea africana*, *Afzelia quanzensis, Pterocarpus angolensis* and *Terminalia sericea* were recorded in the riparian forest and the forest fragments. These species are classified as protected under the Malawi National Parks and Wildlife (Protected, Engangered and Listed Species) (Declaration) Order, 2017.

Table 5.19: Species of Conservation Importance that May Occur in the Project Area

Biological Name	Common Name	Growth Form	IUCN Status	Malawi National Status	Probability of Occurrence
Adina microcephala (Breonadia microcephala)	Redwood	Tree	Not Listed	Protected	High
Aerangis distincta	Distinct aerangis	Arboreal orchid	Not Listed	Protected	Low
Afzelia quanzensis	Mahogany bean	Tree	Not Listed	Protected	Recorded
Aloe bulbicaulis		Succulent	Not Listed	Protected	Low
Aloe cannellii		Succulent	Not Listed	Protected	Low
Aloe chabaudii var. chabaudii	Grey aloe	Succulent	Not Listed	Protected	Low
Aloe cryptopoda		Succulent	Not Listed	Protected	Low
Aloe myriacantha		Succulent	Not Listed	Protected	Low
Aloe swynnertonii		Succulent	Not Listed	Protected	Low
Borassus aethiopum	Deleb palm	Palm	Least Concern	Protected	Low
Bridelia micrantha	Coast gold leaf	Tree	Not Listed	Protected	High
Burkea africana	Ash	Tree	Not Listed	Protected	Recorded
Colophospermum mopane	Mopane	Tree	Not Listed	Protected	Low
Cordyla africana	Wild mango	Tree	Not Listed	Protected	High
Dalbergia melanoxylon	African blackwood	Tree	Near Threatened	Protected	High
Humularia descampsii		Tree	Not Listed	Protected	Low
Hyphaene crinata	Doum palm	Palm	Not Listed	Protected	Low
Khaya anthotheca	Mahogany	Tree	Vulnerable	Protected	High
Milicia excels	Iroko	Tree	Not Listed	Protected	Moderate
Morinda asteroscepa		Forb	Vulnerable	Protected	Low
Morus mesozygia	African mulberry	Tree	Critically Endangered	Protected	Low
Prunus africana	African cherry	Tree	Vulnerable	Protected	Moderate
Pterocarpus angolensis	African teak	Tree	Near Threatened	Protected	Recorded
Rytigynia adenodonta		Forb	Not Listed	Protected	Low
Terminalia sericea	Silver cluster leaf	Tree	Not Listed	Protected	Recorded

5.6.4 Ecological Integrity of Vegetation Communities

Ecological integrity describes the level to which ecological patterns and processes are still present and functional in an ecosystem, and can also be referred to as ecological function of a system. Factors which influence the ecological integrity of a system include (Hudson Ecology, 2019a):

- Patterns (observable factors):
  - Vegetation zonation.
  - Connectivity.
  - Area to edge ratio (edge effects).
  - Species present.
  - Association of species.
  - Population densities.
  - Animal behaviour.
- Processes (underlying factors):
  - Nutrient cycling.
  - Herbivory.
  - Competition.
  - Predation risk.
  - Nutrient availability.
  - Rainfall.
  - Fire regime.
  - Hydrological regime.
  - Patterns of disturbance.
  - Energy flow.
  - History.

The presence or absence of these factors, as well as the functional level of the present factors were assessed in order to determine the ecological integrity of vegetation communities in teh Project area.

Due to the spatial displacement of the vegetation communities in the survey area it is possible for the same vegetation community, in different areas, to have varying levels of ecological integrity. The ecological integrity of the vegetation communities is as follows:

- Dambo Grassland Vegetation Community – Low to moderate.
- Mixed Riparian Vegetation Community – High.
- Forest Vegetation Community – Moderate.
- Cultivated Lands – Low.

5.6.5 Conservation Importance

Conservation importance is the degree of importance, which can be assigned to an ecological system, for the careful preservation and protection of something; particularly the planned management of a system to prevent exploitation, destruction, or neglect (Hudson Ecology, 2019a).

Factors which influence conservation importance are, *inter alia*:

- Species richness.
- Suitable habitat for a number of threatened species.
- Inherent importance to biodiversity.
- Importance of a system to maintain hydrological regimes.
- Importance of a system for CO_2 scrubbing or removal of toxins.

The conservation importance of the vegetation communities in the ESIA study area is as follows:

- Dambo Grassland Vegetation Community – Low to moderate.
- Mixed Riparian Vegetation Community – High.
- Forest Vegetation Community – Moderate.
- Cultivated Lands – Low.

5.7 Wetlands

5.7.1 Wetland Delineation

A delineation of wetlands in and around the Project area was undertaken by Hudson Ecology (2019b) according to the South African Department of Water Affairs Guidelines for Delineating the Boundaries of a Wetland (DWAF, 2008), in the absence of Malawi guidelines on this aspect. The detailed Wetland Baseline Assessment Report is attached as Appendix F.

Three wetlands (dambos) were delineated as part of the study; 'Dambo 1' is located to the west and close to Project infrastructure, while Kankoma dambo and Kovuma dambo occur to the north of the Project (Figure 5.11).

The Kankoma and Kovuma dambos (Plate 5.6 and Plate 5.7) generally flow in a southwest–northeast direction. As with the majority of the dambos in the area, these two dambos have been impacted to a significant degree by anthropogenic impacts such as impoundments, cropping, grazing and extensive utilisation of natural resources. These dambos have, unlike other dambos in the area, not been completely transformed.

Photo: Adrian Hudson

Plate 5.6: Kankoma Dambo Viewed from North to South

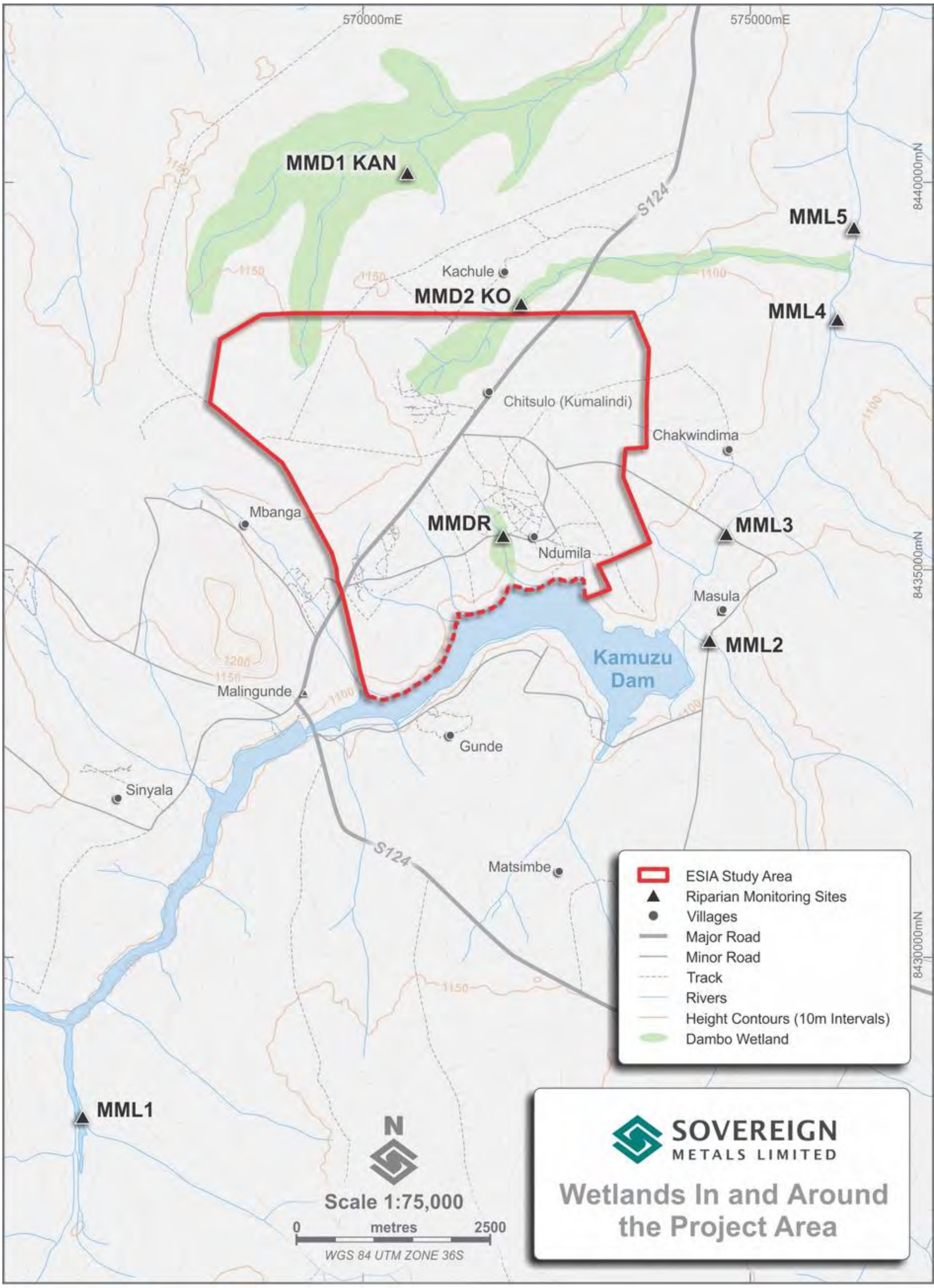


Figure 5.11: Wetlands Delineated Around the Project Area and Riparian Monitoring Locations

Photo: Adrian Hudson

Plate 5.7: Kovuma Dambo Cross-section from Southeast to Northwest

Dambo 1 occurs in the southern part of the ESIA study area draining southwards into the Kamuzu Dam II. This dambo has been completely transformed and has very little, to no, functionality usually associated with wetlands. Almost all aspects of this dambo have been severely impacted or transformed through anthropogenic impacts. Transformation has occurred through the natural vegetation being removed throughout the wetland and replaced by agriculture, mainly in the form of maize (*Zea mays*) and groundnuts (*Arachis villosulicarpa*).

5.7.2 Wetland Classification

Due to the lack of a classification system for wetlands in Malawi and the similarity in the Malawian and South African definitions of wetlands, the classification developed by the South African National Biodiversity Institute (SANBI) *"Further Development of a Proposed National Classification System for South Africa"* (SANBI, 2009) was used to classify the wetlands within the study area (Hudson Ecology, 2019b). The wetlands were classified up to level four, which includes the system, regional setting, landscape unit and hydrogeomorphic unit. A summary of the classification system for inland wetlands is provided in Table 5.20.

All three dambos were classified as valley bottom wetlands with a channel. These types of wetlands occur in valley bottom areas with a well-defined stream channel but lack characteristic floodplain features. The wetland area may be gently sloped and characterised by the net accumulation of alluvial deposits, or may have steeper slopes and be characterised by the net loss of sediment. Water inputs are from the main channel (when channel banks overspill) and from adjacent slopes.

Table 5.20: SANBI Wetland Classification System

Level 3: Landscape unit	Level 4: Hydrogeomorphic (HGM) unit			
Landscape setting	Hydrogeomorphic Unit	Longitudinal zonation / landform	Drainage - outflow	Drainage - inflow
	A	B	C	D
SLOPE	Channel (river)	Mountain headwater stream	Not applicable	Not applicable
		Mountain stream	Not applicable	Not applicable
		Transitional river	Not applicable	Not applicable
		Rejuvenated bedrock fall	Not applicable	Not applicable
	Hillslope seep	Not applicable	With channel inflow	Not applicable
			Without channel inflow	Not applicable
	Depression	Not applicable	Exorheic	With channel inflow
				Without channel inflow
			Endorheic	With channel inflow
				Without channel inflow
			Dammed	With channel inflow
				Without channel inflow
VALLEY FLOOR	Channel (river)	Mountain stream	Not applicable	Not applicable
		Transitional river	Not applicable	Not applicable
		Rejuvenated bedrock fall	Not applicable	Not applicable
		Upper foothill river	Not applicable	Not applicable
		Lower foothill river	Not applicable	Not applicable
		Lowland river	Not applicable	Not applicable
		Rejuvenated foothill river	Not applicable	Not applicable
		Upland floodplain river	Not applicable	Not applicable
	Channelled valley-bottom wetland	Valley-bottom depression	Not applicable	Not applicable
		Valley-bottom flat	Not applicable	Not applicable
	Unchannelled valley-bottom wetland	Valley-bottom depression	Not applicable	Not applicable
		Valley-bottom flat	Not applicable	Not applicable
	Floodplain wetland	Floodplain depression	Not applicable	Not applicable
		Floodplain flat	Not applicable	Not applicable
	Depression	Not applicable	Exorheic	With channel inflow
				Without channel inflow
			Endorheic	With channel inflow
				Without channel inflow
			Dammed	With channel inflow
				Without channel inflow
	Valleyhead seep	Not applicable	Not applicable	Not applicable
PLAIN	Channel (river)	Lowland river	Not applicable	Not applicable
		Upland floodplain river	Not applicable	Not applicable
	Floodplain wetland	Floodplain depression	Not applicable	Not applicable
		Floodplain flat	Not applicable	Not applicable
	Unchannelled valley-bottom wetland	Valley-bottom depression	Not applicable	Not applicable
		Valley-bottom flat	Not applicable	Not applicable
	Depression	Not applicable	Exorheic	With channel inflow
				Without channel inflow
			Endorheic	With channel inflow
				Without channel inflow
	Flat	Not applicable	Not applicable	Not applicable
BENCH (Hilltop/saddle/shelf)	Depression	Not applicable	Exorheic	With channel inflow
				Without channel inflow
			Endorheic	With channel inflow
				Without channel inflow
	Flat	Not applicable	Not applicable	Not applicable

A further assessment and classification of the three dambos was undertaken in terms of:

- Present ecological status (PES).
- Ecological importance and sensitivity (EIS).
- Wetland function assessment (wetland ecosystems services assessment).

Although wetlands have intrinsic conservation importance, the degraded (and in some cases transformed) nature of the dambos in the study area do reduce the conservation importance of these areas. The ecological integrity is also compromised in this vegetation community due to anthropogenic impacts of variable nature, extent and intensity. The ecological importance of this vegetation community may be regarded as low to moderate, while the conservation importance is moderate.

5.7.3 Present Ecological Status

The PES of the three identified dambos were assessed using the WET-health Tool, a tool developed by the South African Water Research Commission for rapidly assessing the health or integrity of a wetland (Macfarlane *et al*., 2007). Wetland health is defined as a measure of the deviation of wetland structure and function from the wetland's natural reference condition.

As part of the assessment wetlands were divided into hydrogeomorphic (HGM) units, which were then assessed separately in terms of hydrological, geomorphological and vegetation health, based on the extent, intensity and magnitude of impact. Once the HGM units were identified, the results for each assessment unit were then combined to obtain an indication of the health of the wetland as a whole (Table 5.21).

Table 5.21: Health Categories Used in Determining the Present Ecological Status of Welands (WET-health Tool)

Hydrologic Integrity	Present Geomorphic State	Present Vegetation State	Impact Score Range per Category	Health Category
No discernible modifications or the modifications are of such a nature that they have no impact on the hydrological integrity.	Unmodified, natural.	Vegetation composition appears natural.	0 - 0.9	A
Although identifiable the impact of the modifications on the hydrological integrity are small.	Largely natural with few modifications. A slight change in geomorphic processes is discernable but the system remains largely intact.	A very minor change to vegetation composition is evident at the site.	1 - 1.9	B
The impact of the modifications on the hydrological integrity is clearly identifiable, but limited.	Moderately modified. A moderate change in geomorphic processes has taken place but the system remains predominantly intact.	Vegetation composition has been moderately altered but introduced; alien and/or increased ruderal species are still clearly less abundant than characteristic indigenous wetland species.	2 - 3.9	C
The impact of the modifications is clearly detrimental to the hydrological integrity. Approximately 50% of the hydrological integrity has been lost.	Largely modified. A large change in geomorphic processes has occurred and the system is appreciably altered.	Vegetation composition has been largely altered and introduced; alien and/or increased ruderal species occur in approximately equal abundance to the characteristic indigenous wetland species.	4 - 5.9	D

Hydrologic Integrity	Present Geomorphic State	Present Vegetation State	Impact Score Range per Category	Health Category
Modifications clearly have an adverse effect on the hydrological integrity. 51% to 79% of the hydrological integrity has been lost.	Greatly modified. The change in geomorphic processes is great but some features are still recognisable.	Vegetation composition has been substantially altered but some characteristic species remain, although the vegetation consists mainly of introduced, alien and/or ruderal species.	6 - 7.9	E
Modifications are so great that the hydrological functioning has been drastically altered. 80% or more of the hydrological integrity has been lost.	Modifications have reached a critical level as geomorphic processes have been modified completely.	Vegetation composition has been totally or almost totally altered, and if any characteristic species still remain, their extent is very low.	8 - 10	F

5.7.3.1 Present Ecological Status of the Kankoma Dambo

This wetland has been canalised to a lesser extent than the other wetlands in the area, but has been impounded to allow for vehicle and pedestrian traffic.

Although many of the graminoid and cyperoid species expected still occur in the area, some woody species such as *Senna alata* have encroached upon the canal. Cyperoid species include *Cyperus digitatus, Cyperus esculentus, Cyperus tenax, Kylinga erecta* and *Pycreus aethiops.* While *Typha latifolius* and *Typha domingensis* are also present in areas where water persists. The majority of wetlands in the area are severely degraded and grass species occurring in these wetlands include *Andropogon gayanus, Aristida junciformis, Arundinella nepalensis, Brachiaria deflexa, Cynodon dactylon, Eragrostis capensis, Eragrostis chapelieri, Hyparrhenia filipendula, Melinis repens, Pogonarthria squarrosa, Setaria pumila, Sporobolus pyramidalis, Sporobolus subtilis* and *Themeda triandra*. Many exotic species are present at this site.

This wetland is severely overgrazed and canalisation and erosion both occur frequently in this wetland. The state of this wetland is expected to deteriorate slightly over the next 5 years, if existing conditions prevail.

The PES of Kankoma dambo was determined to be Category C.

5.7.3.2 Present Ecological Status of Kovuma Dambo

This wetland has been canalised considerably, causing the desiccation of the outer edges of the wetland resulting in the encroachment of terrestrial grass species, such as *Themeda triandra*, and woody species. Although many of the graminoid and cyperoid species expected still occur in the area, the number of these species has been greatly reduced from the number of species expected. There is encroachment of some woody species, such as *Senna alata,* in the channel, and the dambo is also being impacted on by the cultivation of water intensive species such as *Eucalyptus* spp. in the adjacent areas. Many exotic species such as *Bidens pilosa, Blumea alata, Conyza albida, Eucalyptus saligna, Psidium guajava, Sesbania microphylla, Solanum delagoense, Tagetes minuta, Verbena bonariensis* and *Lantana camara* are present at this site. Cyperoid species include *Cyperus digitatus, Cyperus esculentus* and *Cyperus tenax.* While *Typha domingensis* is present and in certain areas dominates where water persists. The majority of wetlands in the area are severely degraded and grass species occurring in these wetlands include *Andropogon gayanus, Aristida junciformis, Brachiaria deflexa, Cynodon dactylon, Eragrostis capensis, Eragrostis chapelieri, Melinis repens, Pogonarthria squarrosa, Sporobolus pyramidalis* and *Themeda triandra* where the dambo has been desiccated through the canalisation of the valley.

The PES at the Kovuma dambo monitoring site was determined to be Category D.

5.7.3.3 Present Ecological Status of Dambo 1

Dambo 1 can only be described as completely transformed. From an ecological point of view this means that very little, if any, of the ecological function of the wetland still remains. This area is also colonised by exotic species in many areas, with the infestation by exotic species ranging from mild to severe in various areas of the dambo. Small areas (<1ha) of natural vegetation occur very sparsely within this dambo. Tree species recorded in this dambo area include mainly *Senna alata*, with a few *Kigellia africana* and *Piliostigma thonningii* individuals being recorded on the edge of cultivated lands. The grass and sedge layers of this dambo have been virtually eradicated and are limited to regrowth in fallow lands where species such as *Aristida junciformis*, *Arundinella nepalensis*, *Cynodon dactylon*, *Hyparrhenia filipendula*, *Pogonarthria squarrosa* and *Sporobolus pyramidalis* are emergent. Forb species are dominated by alien invasive species such as *Bidens biternata*, *Bidens pilosa*, *Solanum delagoense*, *Tagetes minuta*, *Agave* sp., *Opuntia* sp. and *Verbena bonariensis*.

The PES of Dambo 1 was determined to be Category F.

5.7.4 Ecological Importance and Sensitivity

The EIS assessment by Hudson Ecology (2019b) was conducted according to the guidelines developed by the South African Department of Water Affairs (DWA, 1999) – *Resource Directed Measures for Protection of Water Resources: Wetland Ecosystems*. The ecological importance of a water resource or wetland is defined as its importance to maintain ecological diversity and function on local and wider scales. Ecological sensitivity refers to the system's ability to resist disturbance and its capability to recover from disturbance once it has occurred. The EIS assessment provides a guideline for the determination of the ecological management class.

In the method outlined by DWA (1999) a series of determinants for EIS are assessed for the wetlands and scored on a scale of 0 to 4; where 0 indicates no importance and 4 indicates very high importance. The median of the scores for the determinants was used to determine the EIS and ecological management class of the wetland units (Table 5.22).

Table 5.22: Ecological Importance and Sensitivity Categories and the Interpretation of Median Scores for Biotic and Habitat Determinants (DWA, 1999)

Range of Median	EIS Category	Category Description	Recommended Ecological Management Class
>3 and <=4	Very High	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. They play a major role in moderating the quantity and quality of water of major rivers.	A
>2 and <=3	High	Wetlands that are considered to be ecologically important and sensitive. The biodiversity of these wetlands is usually very sensitive to flow and habitat modifications. They play a role in moderating the quantity and quality of water in major rivers.	B
>1 and <=2	Moderate	Wetlands that are to be considered ecologically important and sensitive on a provincial or local scale. The biodiversity of these floodplains is not usually sensitive to flow and habitat modifications. They play a small role in moderating the quantity and quality of water of major rivers.	C
>0 and <=1	Low/ Marginal	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. They play an insignificant role in moderating the quantity and quality of water of major rivers.	D

The EIS for the three dambos, determined during the April 2017 assessment, is given in Table 5.23. The October 2017 assessment showed similar results, however the scores were lower due to the very dry conditions prevailing at the time of the October surveys.

Table 5.23: Ecological Importance and Sensitivity of Kankoma Dambo, Kovuma Dambo and Dambo 1

Determinant	Kankoma Dambo		Kovuma Dambo		Dambo 1	
	Score	Confidence	Score	Confidence	Score	Confidence
Primary Determinants						
1. Rare and Endangered Species	1	3	1	3	1	4
2. Populations of Unique Species	1	3	1	3	1	4
3. Species/taxon Richness	2	3	1	3	2	4
4. Diversity of Habitat Types or Features	2	4	2	3	1	4
5. Migration Route/Breeding and Feeding Site for Wetland Species	3	4	2	2	1	3
6. PES as Determined by Wet-Health Assessment	3	5	1	4	1	4
7. Importance in Terms of Function and Service Provision	1	3	1	4	1	4
Modifying Determinants						
1. Protected Status	4	5	1	4	1	4
2. Ecological Integrity	2	5	1	3	1	3
TOTAL	**18**		**13**		**10**	
MEAN	**2.0**		**1.0**		**1.0**	
OVERALL EIS (Recommended Ecological Management Class)	**C**		**D**		**D**	

5.7.5 Ecosystem Services Supplied by Wetlands

The assessment of the ecosystem services supplied by the identified wetland units was conducted according to the guidelines as described by Kotze, *et al*. (2007) in the WET-EcoServices Tool developed by the South African Water Research Commission (Hudson Ecology, 2019b). A 'Level 2' assessment was undertaken which examines and rates natural and human services.

This tool is used to assess the goods and services that individual wetlands provide by scoring the importance of a wetland in delivering each of 15 different ecosystem services (including e.g., flood attenuation, sediment trapping and provision of livestock grazing). The various services are summarised in Table 5.24.

The tool does not provide a single overall measure (in monetary or other terms) of the value or importance of a wetland, nor does it quantify the benefits supplied by a wetland. It rather assigns indices to these benefits of relative level of function for comparative purposes.

The assessment was undertaken on the same HGM units identified as part of the PES assessment and the ecosystem services for each HGM determined separately.

Table 5.24: Ecosystem Services Assessed as Part of WET-EcoServices Tool (Kotze, 2007)

Ecosystem Services Supplied by Wetlands	Indirect Benefits	Regulating and Supporting Benefits	Flood attenuation		The spreading out and slowing down of floodwaters in the wetland, thereby reducing the severity of floods downstream
			Streamflow regulation		Sustaining streamflow during low flow periods
			Water quality enhancement benefits	Sediment trapping	The trapping and retention in the wetland of sediment carried by runoff waters
				Phosphate assimilation	Removal by the wetland of phosphates carried by runoff waters
				Nitrate assimilation	Removal by the wetland of nitrates carried by runoff waters
				Toxicant assimilation	Removal by the wetland of toxicants (e.g. metals, biocides and salts) carried by runoff waters
				Erosion control	Controlling of erosion at the wetland site, principally through the protection provided by vegetation
			Carbon storage		The trapping of carbon by the wetland, principally as soil organic matter
	Direct Benefits	Biodiversity maintenance			Through the provision of habitat and maintenance of natural process by the wetland, a contribution is made to maintaining biodiversity
		Provisioning benefits	Provision of water for human use		The provision of water extracted directly
			Provision of harvestable resources		The provision of natural resources from the wetland, including livestock grazing, craft plants, fish etc.
			Provision of cultivated foods		The provision of areas in the wetland favourable for the cultivation of foods
		Cultural benefits	Cultural heritage		Places of special cultural significance in the wetland, e.g. for baptisms or gathering of culturally significant plants
			Tourism and recreation		Sites of value for tourism and recreation in the wetland, often associated with scenic beauty and abundant birdlife
			Education and research		Sites of value in the wetland for education or research

A score of between 0 and 4 were given to various criteria for each of the above service. These scores were then added together to determine the overall score for each of the services (Table 5.25 and Table 5.26).

Table 5.25: Classes for the Overall Level of Natural Services Provided by a Wetland

Natural Services and Functions		
Class Boundaries	**Class**	**Class Description**
Within acceptable range		
30 - 36	Very High	Unmodified or approximated natural condition.
24 - 29.9	High	Largely natural with few modifications, but with some loss of natural habitats.
18 - 23.9	Moderate	Moderately modified, but with some loss of natural habitats.
12 - 17.9	Low	Largely modified. A large loss of natural habitats and basic ecosystem functions has occurred.
Outside acceptable range		
6 - 11.9	Very Low	Seriously modified. The losses of natural habitats and basic ecosystem functions are extensive.
0 - 5.9	Non Existent	Critically modified. Modifications have reached a critical level and the system has been modified completely with an almost complete loss of natural habitat.

Table 5.26: Classes for the Overall Level of Human Services Provided by a Wetland

Human Services and Functions		
Class Boundaries	**Class**	**Class Description**
Within acceptable range		
20 - 24	Very High	Local people are extremely dependent on the wetland and benefit from it greatly.
16 - 19.9	High	Local people have a high level of dependence on the wetland and benefit from it considerably.
12 - 15.9	Moderate	Local people are moderately dependent on the wetland and benefit from it from occasionally.
8 - 11.9	Low	Local people have a low dependency on the wetland and seldom benefit from it.
Outside acceptable range		
4 - 7.9	Very Low	Local people rarely rely on the wetland and almost never benefit from it.
0 - 3.9	Non Existent	Local people have no interaction with the wetland and never receive any benefits from it.

5.7.5.1 Ecosystem Services Assessment of the Kankoma Dambo

The wetland ecosystem services associated with the Kankoma dambo, along with the level of service provided to communities and the environment are graphically depicted in Figure 5.12.

Although the hydrology at the dambo has been severely impacted by impoundments and agricultural practices in the area, it still provides a medium level of flood attenuation and streamflow regulation. The dambo provides a medium to high level of sediment trapping and erosion control.

The overall ability of the dambo to provide nitrate, phosphate and toxicant assimilation is medium to low.

Although a large number of indigenous species are still present on site, exotic species have invaded the wetland areas. These likely originate from surrounding agricultural areas and seed dispersal through means of vehicles. The wetland's ability to maintain biodiversity therefore ranks relatively low.

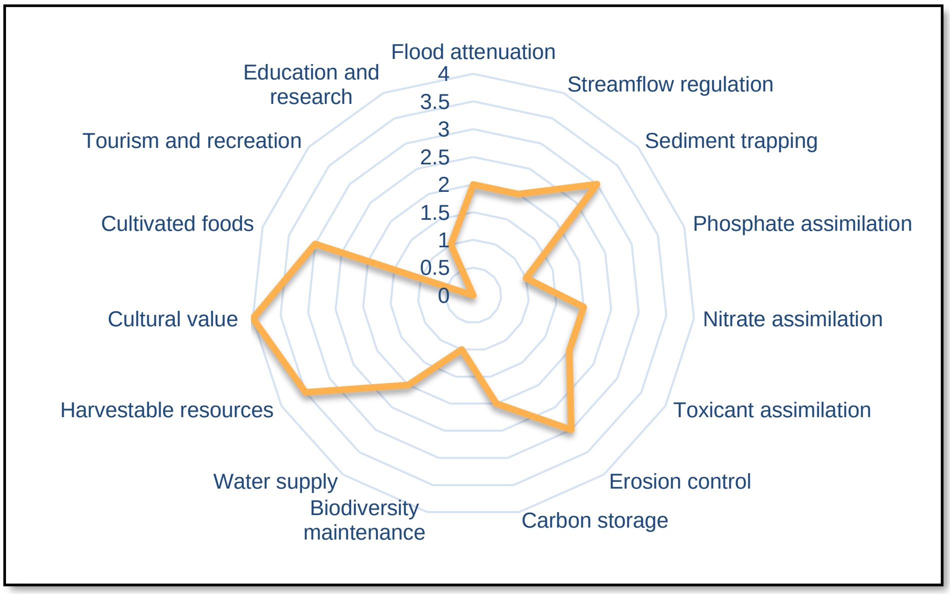


Figure 5.12: Ecosystem Services Associated with the Kankoma Dambo

5.7.5.2 Ecosystem Services Assessment of the Kovuma Dambo

The wetland ecosystem services associated with the Kovuma dambo, along with the level of service provided to communities and the environment are summarised in Figure 5.13.

As the hydrology at the dambo has been severely impacted by impoundments and agricultural practices in the area, it currently provides a low level of flood attenuation and a medium level of streamflow regulation. The dambo provides a medium level of sediment trapping and erosion control.

The overall ability of the dambo to provide phosphate assimilation is low, while nitrate and toxicant assimilation is medium.

As with Kankoma dambo, a large number of indigenous species are still present on site, although exotic species have invaded the wetland areas. These likely originate from surrounding agricultural areas and seed dispersal through means of vehicles. The wetland's ability to maintain biodiversity therefore ranks low.

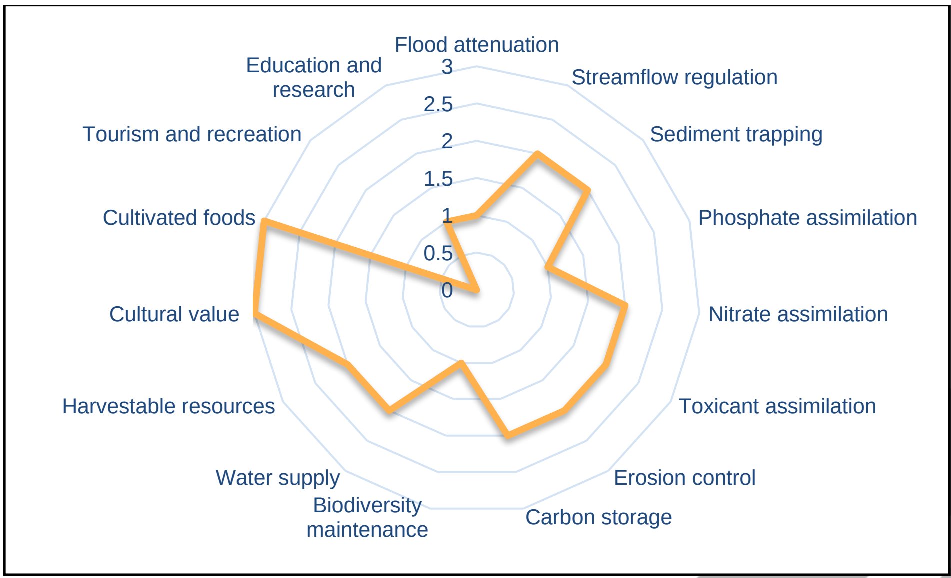


Figure 5.13: Ecosystem Services Associated with the Kovuma Dambo

5.7.5.3 *Ecosystem Services Assessment of Dambo 1*

The wetland ecosystem services associated with Dambo 1, along with the level of service provided to communities and the environment are summarised in Figure 5.14.

The hydrology at Dambo 1 has been transformed by impoundments and agricultural practices in the area, and it currently provides a low level of flood attenuation and streamflow regulation. The dambo also provides a low level of sediment trapping and erosion control.

The overall ability of the dambo to provide phosphate and toxicant assimilation is low, while nitrate and assimilation is medium.

Harvestable resources are regarded as low, while the ability to support cultivated foods is high, which is evident through the extensive subsistence farming that takes place in the wetland.

A few small areas of indigenous vegetation are still present on site and a large number of exotic species have invaded the dambo. The wetlands ability to maintain biodiversity therefore ranks low.

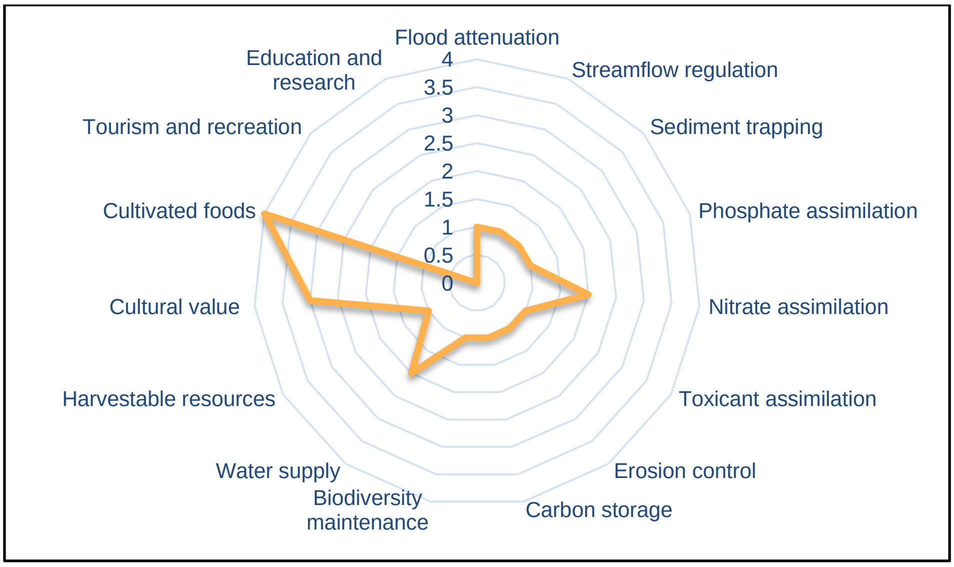


Figure 5.14: Ecosystem Services Associated with Dambo 1

5.7.6 Riparian Vegetation Assessment

The assessment of riparian vegetation was conducted using the Riparian Vegetation Response Assessment Index (VEGRAI) methodology (Kleynhans *et al.*, 2007 as cited in Hudson Ecology, 2019b).

VEGRAI is designed for qualitative assessment of the change of riparian vegetation to impacts in such a way that qualitative ratings translate into quantitative and defensible results. The mechanism of the VEGRAI assessment is depicted in Figure 5.15.

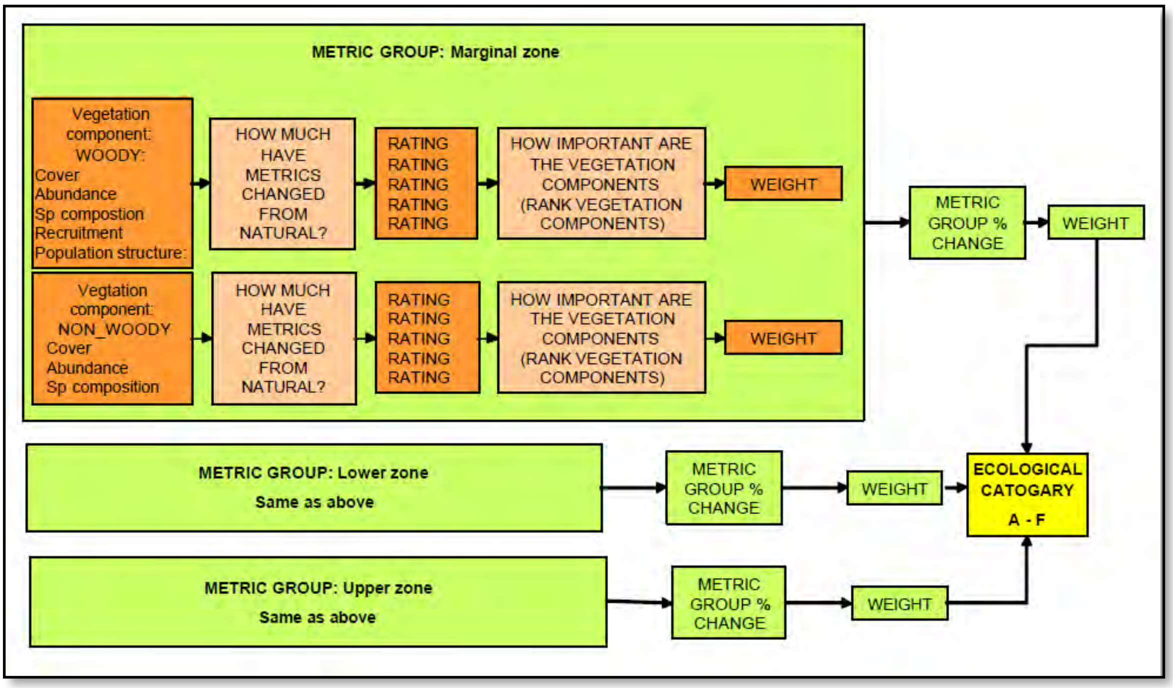


Figure 5.15: VEGRAI Assessment Methodology

The ecological categories determined through the VEGRAI assessment are described in Table 5.27.

Table 5.27: Ecological Categories for EcoStatus Components

Ecological Category	Description	Score (% of Total)
A	Unmodified, natural.	90–100
B	Largely natural with few modifications. A small change in natural habitats and biota may have taken place but 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 modified. Modifications have reached a critical level and the biotic 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

5.7.6.1 General Riparian Floristic Attributes

The most common species recorded in the riparian vegetation communities are *Acacia polyacantha, Acacia sieberiana, Burkea africana, Combretum molle, Piliostigma thonningii, Dichrostachys cinerea, Trichilia emetica, Psidium guajava, Bauhinia thonningii, Gmelina arborea, Blumea alata, Senna alata, Eriosema ellipticum, Euclea crispa, Helichrysum kraussii, Lippia javanica, Maytenus heterophylla, Flueggea virosa, Diospiros heterophylla, Bidens biternata, Bidens pilosa, Conyza welwitschii, Helichrysum species, Oldenlandia corymbosa, Ranunculus multifidus, Senecio strictifolius, Solanum delagoense, Tagetes minuta, Verbena bonariensis, Aristida junciformis, Cynodon dactylon, Heteropogon contortus, Hyparrhenia filipendula, Pogonarthria squarrosa, Sporobolus pyramidalis* and *Phragmites mauritianus*.

5.7.6.2 Riparian Assessment of Monitoring Site 1

Riparian monitoring site 1 (MML1) (refer Figure 5.11) consists of a relatively broad area of flow with moderately sloping banks on which vegetation would easily colonise and recruit (see also Plate 5.8). All zones were well-developed, and recruitment was moderate.

Photo: Adrian Hudson

Plate 5.8: Riparian Monitoring Site 1

The area is not severely degraded, and the marginal lower and upper zones are well colonised with few exotic species. Land use in the area is predominantly agricultural and pastoral farming, however it does not affect the riparian zone as in other areas.

The trajectory of change in the present ecological state has been assessed as stable.

The results of the VEGRAI assessment for MML1 are summarised in Table 5.28.

Table 5.28: VEGRAI Assessment Scores for Riparian Monitoring Site 1

Riparian Vegetation Metric Group	Calculated Rating	Reasons
Marginal	88.0	Marginal vegetation, very low species diversity. May be due to recent heavy rains and will need to be monitored in order to determine whether this is a natural state.
Lower Zone	82.0	Lower vegetation moderately impacted by denudation, erosion and introduction of exotic species
Upper Zone	85.0	Upper zone moderately impacted by the introduction of exotic species and cultivation of crops
Level 4 VEGRAI (%)	85.0	
VEGRAI Ecological Category	**B**	
Average Confidence	4.0	

5.7.6.3 Riparian Assessment of Monitoring Site 2

Riparian monitoring site 2 (MML2) (refer Figure 5.11 for location) consists of a relatively narrow area of flow, with moderately sloping banks on which vegetation would easily colonise and recruit (Plate 5.9). This site is located up stream of the Kamuzu Dam II outlet into the Lilongwe River.

The vegetation in the area has been disturbed by construction of a bridge in the past. For this reason, the vegetation surveyed for the purposes of this study was the vegetation at the transect site itself as well as vegetation further upstream of the site.

Land use in the area is predominantly agricultural and pastoral farming.

The area is currently somewhat degraded due to the introduction of a number of exotic species and agriculture being practiced on the banks of the river. The exotic species in the area, in fact, contribute to approximately 10% of the total number of species identified during the surveys. Furthermore, previous impacts, erosion and removal of riparian vegetation compound the impacts on this area.

Due to these factors and the fact that these impacts are not being remedied or arrested, in order to comply with cautionary principles, the trajectory of change is regarded as negative.

Photo: Adrian Hudson

Plate 5.9: Riparian Monitoring Site 2

The results of the VEGRAI assessment for MML2 are indicated in Table 5.29.

Table 5.29: VEGRAI Assessment Scores for Riparian Monitoring Site 2

Riparian Vegetation Metric Group	Calculated Rating	Reasons
Marginal	54.0	Marginal vegetation very low species diversity. This may be due to the recent heavy rains and will need to be monitored in order to determine whether this is a natural state.
Lower Zone	56.0	Lower vegetation has been moderately impacted by denudation, erosion and introduction of exotic species
Upper Zone	55.3	Upper zone has been moderately impacted by the introduction of exotic species and cultivation of crops
Level 4 VEGRAI (%)	55.1	
VEGRAI Ecological Category	**D**	
Average Confidence	3.0	

5.7.6.4 Riparian Assessment of Monitoring Site 3

Riparian monitoring site 3 (MML3) as pictured in Plate 5.10, is situated downstream of the Kamuzu Dam II outlet into the Lilongwe River and has been somewhat transformed through the introduction of exotic species, agriculture and construction. The marginal zone shows very low species diversity, and the lower and upper zones of the banks show considerable impacts due to removal of natural vegetation, agriculture and the introduction of exotic species.

Photo: Adrian Hudson

Plate 5.10: Riparian Monitoring Site 3

The area is currently considerably degraded due to the introduction of a number of exotic species, historical construction of a bridge and an upstream weir, and other anthropogenic impacts such as agriculture. The exotic species in the area, contribute to almost 20% of the total number of species identified during the surveys. Furthermore, the lack of stochastic events, such as fire and flooding, are causing homogenisation of the riparian vegetation at MML3.

The trajectory of change in the present ecological state of the site is also regarded as negative.

The results of the VEGRAI assessment for MML3 are indicated in Table 5.30.

Table 5.30: VEGRAI Assessment Scores for Riparian Monitoring Site 3

Riparian Vegetation Metric Group	Calculated Rating	Reasons
Marginal	36.3	Marginal vegetation, very low species diversity. May be due to recent heavy rains and will need to be monitored in order to determine whether this is a natural state.
Lower Zone	45.0	Lower vegetation moderately impacted by denudation, erosion and introduction of exotic species.
Upper Zone	32.4	Upper zone moderately impacted by the introduction of exotic species and cultivation of crops.
Level 4 VEGRAI (%)	37.9	
VEGRAI Ecological Category	**E**	
Average Confidence	4.0	

5.7.6.5 Riparian Assessment of Monitoring Site 4

Riparian monitoring site 4 (MML4) consists of a relatively narrow area of flow with steeply sloping banks and a very incised almost canal-like channel (Plate 5.11). This incising of the channel is caused by the release of water by the Kamuzu Dam, which has completely altered the hydrology of the river downstream of the release point of the dam. Because of the sloping of the bank and the incised canal, the marginal zone is poorly developed, and erosion is a serious issue on the banks of this part of the river. These issues are further exacerbated by the sand mining occurring in the area.

Photo: Adrian Hudson

Plate 5.11: Riparian Monitoring Site 4

All zones were well-developed and recruitment was low to moderate, greatly affected by the anthropogenic impacts and erosion in the area. The marginal zone has been depleted due to the incision of the channel, the lower zone has been severely affected by sand mining and changes in hydrological regime and the upper zones have been utilised for agriculture resulting in the invasion of exotic species and erosion.

Land use in the area is predominantly agricultural and pastoral farming.

The area is currently considerably degraded due to the introduction of a number of exotic species and transformation due to agriculture, sand mining and the change in hydrology caused by the Kamuzu Dam. The exotic species in the area, contribute to a total of almost 15% of the total number of species identified during the surveys.

Table 5.31 indicates the results of the VEGRAI assessment for MML4.

Table 5.31: VEGRAI Assessment Scores for Riparian Monitoring Site 4

Riparian Vegetation Metric Group	Calculated Rating	Reasons
Marginal	28.4	Marginal zone most important for year-round refuge habitat, overhanging vegetation important for habitat creation / variability. This vegetation community has been severely impacted by the changes in hydrology, as well as anthropogenic impacts such as sand mining.
Lower Zone	32.6	Lower zone has high seasonal importance for breeding habitat, also shading of aquatic habitats. Anthropogenic impacts such as overutilisation and the effect of releases from the Kamuzu Dam have resulted in severe erosion and loss of habitat in this area.
Upper Zone	29.2	Not directly important for instream habitat, but bank stability indirectly important, possibly some shading and litter input. Overitilisation has resulted in denudation of large areas of this habitat and this is also evident in the high level of erosion
Level 4 VEGRAI (%)	30.1	
VEGRAI Ecological Category	**E**	
Average Confidence	3.9	

5.7.6.6 Riparian Assessment of Monitoring Site 5

Riparian monitoring site 5 (MML5) consists of a relatively narrow area of flow with steeply sloping banks and a very incised almost canal-like channel (Plate 5.12). This incising of the channel is caused by the release of water from the Kamuzu Dam, which has completely altered the hydrology of the river downstream of the release point of the dam.

Because of the sloping of the bank and the incised channel, the marginal zone is poorly developed, and erosion is a serious issue on the banks of this part of the river as it is at MML4.

The area is quite severely degraded; the marginal zone has become a monoculture due to the incision of the channel allowing only larger species, such as in this case *Phragmites* sp., to flourish. The lower zone has been severely affected by the invasion of exotic species and changes in hydrological regime, and the upper zones have been utilised for agriculture resulting in the invasion of exotic species and erosion. The incision of the channel has resulted in the desiccation of the upper and lower zones causing the colonisation of these zones by a number of non- riparian species.

Photo: Adrian Hudson

Plate 5.12: Riparian Monitoring Site 5

Table 5.32 indicates the results of the VEGRAI assessment for MML5.

Table 5.32: VEGRAI Assessment Scores for Riparian Monitoring Site 5

Riparian Vegetation Metric Group	Calculated Rating	Reasons
Marginal	30.1	Marginal zone most important for year-round refuge habitat, overhanging vegetation important for habitat creation / variability. This vegetation community has been severely impacted by the changes in hydrology, as well as anthropogenic impacts such as sand mining.
Lower Zone	30.6	Lower zone has high seasonal importance for breeding habitat, also shading of aquatic habitats. Anthropogenic impacts such as overutilisation and the effect of releases from the Kamuzu Dam have resulted in severe erosion and loss of habitat in this area.
Upper Zone	29.2	Not directly important for instream habitat, but bank stability indirectly important, possibly some shading and litter input. Overitilisation has resulted in denudation of large areas of this habitat and this is also evident in the high level of erosion
Level 4 VEGRAI (%)	32.4	
VEGRAI Ecological Category	**E**	
Average Confidence	3.9	

5.8 Fauna

5.8.1 Herpetofauna

There are 140 species of herpetofauna (reptiles) recorded in Malawi, represented in 22 families. Species diversity for the Project area was relatively low, with only 12 species being recorded during the surveys (Hudson Ecology, 2019a) as listed in Table 5.33. None of the species recorded are restricted in number or distribution, nor are any of the species regarded as protected species by Malawi Legislation or listed on the IUCN Red List.

Table 5.33: Reptiles Recorded in the Study Area

Family	Biological Name	Common Name	Apr 2017	Oct 2017	Feb 2018
AGAMIDAE	*Agama mossambica*	Mozambique agama	✓	✓	✓
COLUBRIDAE	*Dasypeltis scabra*	Egg-eating snake	✓	×	×
COLUBRIDAE	*Philothamnus semivariegatus*	Spotted bush snake	✓	×	✓
CROCODYLIDAE	*Crocodylus niloticus*	Nile crocodile	✓	×	✓
GEKKONIDAE	*Lygodactylus capensis*	Cape dwarf gecko	✓	×	✓
LAMPROPHIIDAE	*Duberria lutrix*	Common slug-eater	✓	×	×
	Amblyodipsas polylepis	Common purple-glossed snake	✓	✓	×
	Lycophidion capense	Cape wolf snake	✓	✓	✓
SCINCIDAE	*Trachylepis margaritifera*	Rainbow skink	✓	✓	✓
	Trachylepis varia	Variable skink	✓	✓	✓
VIPERIDAE	*Causus rhombeatus*	Rhombic night adder	✓	×	✓
	Bitis arietans	Puff adder	✓	✓	✓

5.8.2 Amphibia

There are 91 species of anurans (frogs and toads) recorded in Malawi. Only five species of anurans were recorded during the April 2017 field surveys as indicated in Table 5.34 (Hudson Ecology, 2019a).

Due to the dry prevailing conditions during the October 2017 surveys the amphibian species diversity was further reduced during this period, but did recover to some extent during the February 2018 surveys. None of the species recorded are classified as being restricted in abundance or distribution, although Malawi does host a number of endemic species, and none of the species recorded are listed under the IUCN Red List.

Table 5.34: Amphibian Species Recorded in the Study Area

Family	Biological Name	Common Name	Apr 2017	Oct 2017	Feb 2018
BREVICIPITIDAE	*Breviceps mossambicus*	Mozambique rain frog	✓	×	✓
BUFONIDAE	*Amietophrynus gutturalis*	African common toad	✓	✓	✓
COLUBRIDAE	*Amietophrynus garmani*	Garman's toad	✓	×	×
HYPEROLIIDAE	*Hyperolius pusillus*	Water lily reed frog	✓	×	×
HYPEROLIIDAE	*Kassina senegalensis*	Senegal kassina	✓	✓	✓

5.8.3 Avifauna

To date, 646 avifauna (bird) species from 78 families, comprising 456 residents, 94 intra-African migrants of regular occurrence (most of which probably breed in Malawi), 77 regular and 12 vagrant Palaearctic[5] species have been documented in Malawi. Over a third of all bird species in Malawi are considered to be uncommon or rare and of at least limited conservation concern. Ninety-four (94) birds in Malawi are restricted range species, found in only one or a few biomes, but there are no true national endemic bird species (Hudson Ecology, 2019a).

Only 56 species of avifauna were recorded during the field surveys and are listed in Table 5.35. None of the species recorded are restricted in range or abundance, and none of the species recorded are currently listed on the IUCN Red List.

Table 5.35: Avifauna Species Recorded in the Project Area

Biological Name	Common Name	Apr 2017	Oct 2017	Feb 2018
Acrocephalus schoenobaenus	Sedge warbler	✓	×	✓
Mirafra rufocinnamomea	Flappet lark	✓	✓	✓
Hayon senegalensis	Woodland kingfisher	✓	✓	✓
Corythornis cristatus	Malachite kingfisher	✓	✓	✓
Dendrocygna bicolor	Fulvous whistling-duck	✓	×	✓
Alopochen aegyptiaca	Egyptian goose	✓	✓	×
Apus affinis	Little swift	✓	×	✓
Ardea cinerea	Grey heron	✓	✓	✓
Burhinus capensis	Spotted thick-knee	✓	✓	✓
Vanellus coronatus	Crowned lapwing	✓	✓	✓
Anastomus lamelligerus	African openbill	✓	×	×
Cisticola lais	Wailing cisticola	✓	✓	✓
Cisticola aberrans	Rock-loving cisticola	✓	✓	×
Cisticola natalensis	Croaking cisticola	✓	✓	✓
Apalis thoracica	Bar-throated apalis	✓	×	✓
Cisticola fulvicapilla	Piping cisticola	✓	✓	×
Urocolius indicus	Red-faced mousebird	✓	✓	✓
Streptopelia capicola	Ring-necked dove	✓	✓	×
Streptopelia semitorquata	Red-eyed dove	✓	✓	✓
Coracias caudatus	Lilac-breasted roller	✓	✓	✓
Centropus senegalensis	Senegal coucal	✓	×	✓
Chrysococcyx cupreus	African emerald cuckoo	✓	×	×
Dicrurus adsimilis	Fork-tailed drongo	✓	✓	✓
Emberiza tahapisi	Cinnamon-breasted bunting	✓	✓	✓
Estrilda astrild	Common waxbill	✓	✓	✓
Uraeginthus angolensis	Southern cordon-bleu	✓	×	✓

[5] One of the eight biogeographic realms on the Earth's surface. Comprising Eurasia north of the Himalayas, together with North Africa and the temperate part of the Arabian peninsula.

Biological Name	Common Name	Apr 2017	Oct 2017	Feb 2018
Serinus mennelli	Black-eared seedeater	✓	✓	✓
Hirundo rustica	Barn swallow	✓	×	✓
Delichon urbicum	Common house martin	✓	×	×
Lanius collurio	Red-backed shrike	✓	✓	✓
Lybius torquatus	Black-collared barbet	✓	✓	✓
Pogoniulus chrysoconus	Yellow-fronted tinkerbird	✓	✓	✓
Motacilla aguimp	African pied wagtail	✓	✓	✓
Nectarinia famosa	Malachite sunbird	✓	✓	×
Chaomitra senegalensis	Scarlet-chested sunbird	✓	✓	✓
Numida meleagris	Helmeted guineafowl	✓	✓	✓
Oriolus auratus	African golden oriole	✓	×	×
Passer griseus	Northern grey-headed sparrow	✓	✓	✓
Petronia superciliaris	Yellow-throated petronia	✓	×	✓
Coturnix delegorguei	Harlequin quail	✓	×	✓
Campethera abingoni	Golden-tailed woodpecker	✓	✓	✓
Batis molitor	Chinspot batis	✓	✓	×
Ploceus ocularis	Spectacled weaver	✓	×	×
Ploceus cucullatus	Village weaver	✓	✓	✓
Euplectes orix	Southern red bishop	✓	✓	✓
Euplectes albonotatus	White-winged widowbird	✓	×	✓
Pycnonotus barbatus	Common bulbul	✓	✓	✓
Gallinula chloropus	Eurasian moorhen	✓	✓	×
Crecopsis egregia	African crake	✓	×	✓
Lamprotornis chalybaeus	Greater blue-eared starling	✓	✓	✓
Cinnyricinclus leucogaster	Violet-backed starling	✓	✓	✓
Creatophora cinerea	Wattled starling	✓	×	✓
Passer domesticus	House sparrow (*Exotic)*	✓	✓	✓
Bostrychia hagedash	Hadada ibis	✓	✓	✓
Turdus libonyana	Kurrichane thrush	✓	×	×
Upupa epops africana	African hoopoe	✓	✓	✓
Zosterops senegalensis	African yellow white-eye	✓	✓	✓

5.8.4 Mammals

A total of 195 mammal species from 37 families have been recorded in Malawi, to date. Only 28 species of mammalia were recorded during the April and October 2017 field surveys, and are listed in Table 5.36. None of these species are classified as species of conservation importance. The number recorded is far lower than the expected number of species for this area and can be attributed to a number of factors:

- Destruction of habitat.

- Introduction of domestic animals which outcompete and predate indigenous species.
- Overutilisation of mammal species as a food source.
- Reduction of prey species (particular prey species for larger mammalian predators, which would compete with humans in rural Africa) (Hudson, 2019a).

Table 5.36: Mammal Species Recorded in Project Area

Family	Biological Name	Common Name	Apr 2017	Oct 2017	Feb 2018
ORYCTEROPODIDAE	*Orycteropus afer*	Aardvark	✓	✓	✓
GALAGIDAE	*Galago moholi*	Mohol bushbaby	✓	×	×
CERCOPITHECIDAE	*Chlorocebus pygerythrus*	Vervet monkey	✓	×	×
HYSTRICIDAE	*Hystrix africaeaustralis*	Cape porcupine	✓	×	✓
THRYONOMYIDAE	*Thryonomys gregorianus*	Lesser cane rat	✓	×	✓
SCIURIDAE	*Paraxerus flavovittis*	Striped bush squirrel	✓	×	×
NESOMYIDAE	*Dendromus melanotis*	Gray climbing mouse	✓	×	×
	Dendromus mesomelas	Brant's climbing mouse	✓	×	✓
	Steatomys pratensis	Fat mouse	✓	✓	×
	Cricetomys gambianus	Gambian pouched rat	✓	✓	×
	Saccostomus campestris	South African pouched mouse	✓	×	✓
MURIDAE	*Acomys spinosissimus*	Spiny mouse	✓	✓	×
	Otomys angoniensis	Angoni vlei rat	✓	✓	×
	Tatera leucogaster	Bushveld gerbil	✓	✓	×
	Aethomys kaiseri	Kaiser's rock rat	✓	×	×
	Dasymys incomtus	African marsh rat	×	✓	✓
	Grammomys dolichurus	Woodland thicket rat	✓	×	×
	Lemniscomys rosalia	Single-striped grass mouse	✓	✓	✓
	Mastomys natalensis	Natal multimammate mouse	✓	✓	✓
	Pelomys fallax	Creek groove-toothed swamp rat	✓	✓	×
	Rhabdomys pumilio	Four-striped grass mouse	✓	✓	✓
SORICIDAE	*Crocidura cyanea*	Reddish-gray musk shrew	✓	✓	×
	Crocidura hirta	Lesser red musk shrew	✓	×	×
	Sylvisorex megalura	Climbing shrew	✓	✓	×
HERPESTIDAE	*Galerella sanguinea*	Slender mongoose	✓	✓	×
	Helogale parvula	Common dwarf mongoose	✓	✓	×
MUSTELIDAE	*Ictonyx striatus*	Striped polecat	✓	×	×

Of the mammal species previously recorded in Malawi, 16 are listed in the IUCN Red Data List. Most of these animals are found in protected areas and their long-term survival outside protected areas may be significantly impacted by human activities.

A number of these species may occur outside of protected areas and possibly in the study area. These species are further discussed in Section 5.8.5.

5.8.5 Fauna Species of Conservation Importance

A total of 67 animal species, currently considered as species of conservation importance, thus either endemic to Malawi or listed on the IUCN Red List (IUCN, 2018 as cited in Hudson Ecology, 2019a), occur in Malawi.

Of these species:

- Reptile species constitute 10 of the species of concern, of which two are listed on the IUCN Red List, six are listed as endemics and two are both listed on the IUCN Red List and as endemic species.
- Anuran species constitute nine of the species of concern, of which seven are listed on the IUCN Red List, two are listed as endemics and three are listed on the IUCN Red List and as endemic species.
- Avifauna species constitute 32 of the species of concern, of which all are listed on the IUCN Red List and none are endemic species.
- Mammal species constitute 16 of the species of concern, of which 15 are listed on the IUCN Red List, and one is listed on the IUCN Red List and as endemic species.

Of the ten reptile species of concern:

- One is listed as critically endangered, three are listed as endangered and eight are listed as endemic.
- Nine species have a low probability of occurrence in the study area and one has a high probability of occurrence.

Of the nine amphibian (anuran) species of concern:

- Three are listed as vulnerable, one is listed as near threatened, three are listed as data deficient and five are listed as endemic.
- Eight species have a low probability of occurrence in the study area and one has a high probability of occurrence.

Of the thirty-two avian species of concern:

- Three are listed as critically endangered, seven are listed as endangered, six are listed as vulnerable, 15 are listed as near threatened and one is listed as data deficient. No avian species are listed as endemic.
- Twelve species have a low probability of occurrence in the study area, two have a moderate probability of occurrence and 18 have a high probability of occurrence.

Of the sixteen mammal species of concern:

- One is listed as critically endangered, two are listed as endangered, four are listed as vulnerable, four are listed as near threatened and five are listed as data deficient. One species is listed as endemic.
- Eleven species have a low probability of occurrence in the study area, two have a moderate probability of occurrence and three have a high probability of occurrence.

5.9 Aquatic Biology

Baseline biomonitoring[6] was undertaken by GCS Water and Environmental Consultants (Pty) Ltd in the wet season from 18 to 22 April 2017, at the end of the dry season from 11 to 16 October 2017, and again in the wet season from 12 to 19 February 2018 (GCS, 2017; GCS, 2018; GCS, 2019). Refer to Appendices G to I for copies of these reports.

Biomonitoring was undertaken at six sites during 2017, and these correspond with the riparian monitoring sites discussed in Section 5.7.6 (refer Figure 5.11) for location.

During the survey in February 2018 two additional sites, namely Sites MML4 and MML5, were assessed downstream of Site MML3 on the Lilongwe River.

The surveys included an assessment of:

- *In-situ* water quality.
- General habitat integrity.
- Habitat suitability for the macroinvertebrate community.
- Aquatic macroinvertebrate community integrity.
- Diatom analysis.
- Whole effluent toxicity (WET) testing.

This was carried out in order to determine the PES of the aquatic resources in the vicinity of the Project area and define areas of aquatic ecological sensitivity. The assessment of the macroinvertebrate integrity was undertaken using the South African Scoring System Version 5 (SASS5) protocol (GCS, 2017).

5.9.1 *In-situ* Water Quality Parameters

Water quality has a direct impact on the aquatic biota residing within river systems and therefore the data obtained during *in situ* testing is used to aid in the interpretation of the biomonitoring results. The biota-specific water quality variables measured during the assessment include pH, temperature, dissolved oxygen (DO) and electrical conductivity (EC). The *in-situ* water quality results were compared against the Malawi Drinking Water Specification (2005), the WHO Drinking Water Quality Guidelines (2017) and the Target Water Quality Ranges (TWQRs) stipulated in the South African Water Quality Guidelines (SAWQG) for Aquatic Ecosystems (DWAF, 1996). The South African guidelines provide specific standards for spatial and temporal variations in the water quality variables and was used in the absence of similar guidelines in Malawi.

The *in-situ* field measurements recorded during the aquatic biomonitoring surveys are presented in Table 5.37.

[6] Aquatic biomonitoring is the science of inferring the ecological condition of rivers, lakes, streams, and wetlands by examining the organisms that live there.

Table 5.37: *In-situ* Water Quality Recorded During Biomonitoring Surveys

Parameter	Guideline	Date	MML1	MML2	MML3	MML4	MML5	MMDR	MMD1 KAN	MMD2 KO
pH	6.5 – 8.5	Apr 17 (Wet)	7.27	7.21	7.8	-	-	7.57	9.83	7.53
		Oct 17 (Dry)	7.1	7.62	7.4	-	-	5.64	6.45	dry
		Feb 18 (Wet)	7.17	7.64	8.11	7.87	8.24	6.38	7.1	6.78
Temperature (ºC)	5 – 30	Apr 17	25.6	23.4	23.5	-	-	23.5	26.4	23.5
		Oct 17	26.6	27.9	24	-	-	22.6	29.8	dry
		Feb18	26.3	26.9	27.5	27.9	30.8	25.8	27.5	26.1
EC (mS/m)	<150	Apr 17	4	18	5	-	-	31	11	35
		Oct 17	17	45	12	-	-	44	44	dry
		Feb18	69	60	145	53	43	46	253	163
TDS (mg/L)	<1,000	Apr 17	26	117	32.5	-	-	201.5	71.5	227.5
		Oct 17	110.5	292.5	78	-	-	286	156	dry
		Feb18	58.5	448.5	942.5	344.5	279.5	299	1,644.5	1,059.5
DO (mg/L)	>5	Apr 17	8.2	8.1	8	-	-	8.2	7	7.2
		Oct 17	10.1	14.4	11.1	-	-	9	0	dry
		Feb18	7.0	7.8	7.5	7.3	7.2	5.6	6.2	6.4

5.9.1.1 pH

Most fresh waters are usually relatively well buffered with a pH range from 6 to 8 (Davies and Day, 1998 as cited in GCS, 2017) and are slightly alkaline due to the presence of bicarbonates of the alkali and alkaline earth metals (DWAF, 1996). The pH target for fish health should range between 6.5 and 9.0, as most species will tolerate and reproduce successfully within this pH range (Alabaster and Lloyd, 1982 as cited in GCS, 2017). No acceptable range for aquatic ecosystems has been determined by the Malawi Government and the acceptable pH range of between 6.5 and 8.5 was deemed appropriate for use as a guideline for the Project.

An elevated pH was recorded during the wet season (2017) at MMD1 KAN (Kankoma dambo) and is likely to have been caused by increased biological activity as a result of eutrophication of the system. A pH value of more than 9 usually indicates eutrophic conditions (nutrient enrichment) (Davies and Day, 1998 as cited in GCS, 2017). This is likely to be a result of runoff from agricultural lands containing fertilizer and possibly from the domestic use of the water within the dambo for washing, releasing phosphates into the system, which is likely to limit the colonisation of aquatic biota.

pH levels below the guideline levels were observed at sites MMDR and MMD1 KAN during the dry season (2017) and at MMDR during the 2018 wet season. These lowered pH levels may possibly be due to the nitrification of ammonium (conversion of ammonium to nitrate in soils by bacteria) likely to be present within these water bodies due to fertilizers containing ammonium such as urea, which is one of the fertilizers that is likely being applied to the agricultural lands in the vicinity of the sites (GCS, 2018). This is also supported by a decline in the DO level at MMDR. The deposition of faeces and urine from livestock watering is also likely to be another source of ammonium in the area. During the process of nitrification, hydrogen (H+) is released, increasing acidity. This is likely to limit the diversity and sensitivity of the aquatic macroinvertebrate communities that occur at these sites to some extent.

The higher pH level recorded at MML5 is slightly alkaline, likely originating from the release of phosphate ions as a result of faecal deposition from frequent livestock watering practices occurring at this site.

According to the guidelines by DWAF (1996), spatial and temporal variations in pH level along a watercourse should not vary by more than 5%, as this may limit the integrity of the aquatic community. A 13.1% increase in the pH level was observed between MML1 and MML3 and a 6.1% increase between MML2 and MML3 during the 2018 wet season survey. This is also likely due to garment washing, runoff from surrounding villages and agricultural lands, and frequent livestock watering.

5.9.1.2 Temperature

Temperature of water affects the overall physiological processes of organisms, such as the rate of development, reproductive periods and emergence time of organisms. Temperature varies with season and the life cycles of many aquatic macroinvertebrates are cued to temperature (GCS, 2017).

Rapid changes in temperature may severely affect aquatic organisms and lead to mass mortality. Less severe temperature changes in water bodies may have sub-lethal effects or lead to an alteration in the existing aquatic community. The temperatures of inland waters in South Africa generally range from 5ºC to 30ºC (DWAF, 1996). As no reference information is available on the temperature ranges of inland waters in Malawi, and standard guidelines for temperature for aquatic organisms are not specified by the Malawi Drinking Water Specification (2005) or the WHO (2017), the above target range of 5 to 30ºC was deemed appropriate for use as a guideline for the Project.

Generally, temperature values fall within the guideline range, and values are normal for the time of day and season during which sampling occurred. The temperature levels at these sites are therefore unlikely to limit the aquatic integrity at these points.

5.9.1.3 Electrical Conductivity and Total Dissolved Solids

Electrical conductivity (EC) is a measure of the ability of water to conduct an electrical current, and is the result of the presence in water of ions such as carbonate, bicarbonate, chloride, sulfate, nitrate, sodium, potassium, calcium and magnesium, all of which carry an electrical charge (DWAF, 1996). It is a rapid and useful substitute measure of the total dissolved solids (TDS) concentration of water with a low organic content. For the purpose of interpretation of the biological results collected during the biomonitoring surveys, the TDS concentrations were calculated using the following generic constant (DWAF, 1996):

$$TDS\ (mg/L) = EC\ (mS/m\ at\ 25^{\circ}C) \times 6.5$$

According to Davies and Day (1998), as cited in GCS (2017; 2018 and 2019), freshwater organisms usually occur where TDS values are less than 3,000 mg/L. The Malawi Drinking Water Specification (2005) and the WHO (2017) recommend TDS levels of less than 1,000 mg/L for drinking water.

The Malawi Drinking Water Specification stipulates EC levels of less than 150 mS/m.

It is evident that EC levels have increased at all sites over the three surveys, with significant increases in the Kankoma and Kovuma dambos during the 2018 survey, which exceed the Malawi Drinking Water Specification guideline values for drinking water. Sources may include runoff containing nutrients such as nitrate, phosphate and ammonium ions from the surrounding villages and agricultural lands, as well as from frequent livestock watering.

Spatial and temporal variations in EC level along a watercourse that varies by more than 15% may lead to osmotic stress within aquatic communities (DWAF, 1996 as cited in GCS, 2017).

Spatially, during the 2017 wet season survey a decrease in the EC level was observed of 41.6% between sites MML1 and MML3. The lower EC level at site MML3 may possibly be a result of the higher dilution of salts occurring at this point compared to that occurring at Site MML1 due to the controlled releases of water from the Kamuzu Dam. Inputs from frequent livestock watering may also contribute to the higher EC level at site MML1.

The EC levels between MML2 and MML3 decrease by 73.3% during the dry season survey in 2017, the guideline stipulating that the conductivity along a watercourse should not vary by more than 15% and some effect resulting from osmotic stress is likely to be occurring on the aquatic community entering the Lilongwe River from the Lisungwi River such as migrating fish species. Spatially, the EC level increases by 110.1% between MML1 and MML3 during the 2018 survey, likely resulting from frequent washing of garments with detergents by the local community, as well as runoff from the surrounding villages and agricultural lands. A decrease of 63.4% is evident between MML3 and MML4, indicating the dilution and possible uptake of nutrients in the system by vegetation.

5.9.1.4 Dissolved Oxygen

The maintenance of adequate DO is critical for the survival and functioning of aquatic biota as it is required for the respiration of all aerobic organisms, and DO concentration provides a useful measure of the health of an ecosystem (DWAF, 1996 as cited in GCS, 2017). As no guidelines for DO are specified in the Malawi Drinking Water Specification (2005) or the WHO (2017) guidelines, the median guideline for DO of more than 5 mg/L for the protection of aquatic biota as recommended by Kempster *et al*. (1980) as cited in GCS (2017) was deemed appropriate for use as a guideline for the Project in this regard.

DO levels are above the guideline value at all sites, with the exception of Kankoma dambo, where a value of zero was observed during the dry season (2017). This likely a result of frequent livestock watering within the small pool that occurs at this site. The frequent deposition of faeces from the livestock is likely to have led to a high organic content within the water and the decomposition of this organic matter has likely resulted in the observed depletion of oxygen at this site.

5.9.2 Habitat Integrity

The general habitat integrity of each site was assessed using the Intermediate Habitat Integrity Assessment (IHIA) developed by Kleynhans (1996) and adapted by Kemper (1999) for application in rapid intermediate habitat assessments (GCS, 2017). The method assesses the PES of both the instream and riparian zone habitat integrity in terms of impacts such as water abstraction, flow and channel modifications, inundation and water quality. Scores are allocated according to the extent of the impact related to each factor and the scores for instream and riparian zone integrity are summed and an overall percentage calculated for the PES of the general habitat integrity. The method classifies the PES into one of six classes, ranging from Unmodified/Natural (Class A), to Critically Modified (Class F) (Table 5.38).

Table 5.38: Classification of Present Ecological Sate Classes in terms of General Habitat Integrity (Kemper, 1999)

Class	Description	Score (% of Total)
A	Unmodified. Natural.	90–100
B	Largely natural, with few modifications.	80–89
C	Moderately modified.	60–79
D	Largely modified.	40–59
E	Extensively modified.	20–39
F	Critically modified.	<20

During the survey in April 2017, instream impacts observed at MML1, MML2 and MML3 included small impacts on water quality, moderate impacts on flow at Site MML1, moderate impacts from inundation at all three sites, and exotic macrophytes at MML2 and MML3. Moderate impacts resulting from flow modifications at MMDR was evident, as well as large impacts as a result of water abstraction, bed and channel modifications, water quality modifications and exotic macrophyte encroachment. Both systems at MML2 and MML3 have been impacted on by the presence of road bridges, resulting in the limited impacts on the beds and channels of these rivers. At MMD1 KAN, a small instream impact has occurred as a result of water quality modifications. Moderate impacts resulting from water abstraction, bed and channel modifications, water quality modifications, inundation, and exotic macrophyte encroachment have occurred at MMD2 KO.

A large impact was observed in the riparian zone during the April 2017 survey at MML1 as a result of inundation. A moderate impact as a result of inundation has also occurred at MML2 and moderate impacts have resulted from indigenous vegetation removal and exotic vegetation encroachment at MML3. Site MMDR has been largely impacted on by indigenous vegetation removal, exotic vegetation encroachment, bank erosion, water abstraction, channel modifications and water quality modifications. Site MMD1 KAN has experienced a small impact with regards to water quality modifications and MMD2 KO has been largely impacted on by indigenous vegetation removal, exotic vegetation encroachment and flow modifications.

Impacts on instream habitat integrity observed in October 2017 at MML1 and MML3 include small impacts on the river bed, channel and water quality. Large impacts due to frequent livestock watering and moderate impacts due to the establishment of exotic macrophytes were also evident at MML1 during the dry season survey. Moderate impacts due to water releases from the dam, flow modification, and inundation were observed at MML3. Small impacts as a result of water abstraction, flow, bed and channel modifications were evident at MML2, as well as moderate impacts due to water quality modifications and livestock watering activities. Site MMDR has been largely impacted on by water abstraction for irrigation purposes, the presence of exotic macrophytes, bed and channel modifications due to cultivation activities and the presence of the road bridge crossing the site. Moderate impacts as a result of flow and water quality modifications were also noted. Canalisation of the system has also severely increased the level of inundation at this site. Small impacts have occurred at MMD1 KAN as a result of water abstraction, bed modification and the presence of exotic macrophytes. Moderate impacts due to frequent livestock watering resulting in water quality modifications have also occurred at this site. The flow has been severely impacted upon at MMD2 KO as a result of canalisation of the system and the presence of a road bridge at the site. The site has also been moderately impacted on by water abstraction for irrigation purposes, bed and channel modifications, as well as exotic macrophyte encroachment due to the disturbance.

Within the riparian zone, moderate impacts were observed in the October 2017 survey at MML1 due to indigenous vegetation removal and bank erosion resulting from livestock watering activities practiced on a frequent basis. This disturbance has in turn lead to small impacts on water quality and exotic vegetation encroachment. Limited impacts have occurred at MML2 resulting from flow and channel modifications. This zone has been moderately impacted on by indigenous vegetation removal and bank erosion. Moderate impacts have occurred at MML3 due to indigenous vegetation removal and exotic vegetation encroachment. An increase in water volume and flow velocity is evident at this site due to water releases from the dam resulting in inundation. As mentioned, the road bridge at this site has also resulted in a limited impact on the banks of the channel. Soil erosion is however limited at this point due to bank stabilisation by riparian vegetation.

The riparian zone at MMDR has been largely impacted by indigenous vegetation removal, exotic vegetation encroachment, bank erosion, water abstraction, flow and channel modifications and inundation. A large impact resulting from indigenous vegetation removal due to overgrazing by livestock has occurred at MMD1 KAN. This has resulted in moderate levels of soil erosion and the encroachment of exotic vegetation. Site MMD2 KO has also been largely impacted on by indigenous vegetation removal, exotic vegetation encroachment, erosion and flow modifications. The site has been moderately impacted on by water abstraction and channel modifications.

During the February 2018 survey the overall scores obtained at MML1, MML2, MML3, MMD1 KAN and MMD2 KO were lower compared to the previous wet season survey in 2017. This is mainly a result of increased water quality modifications due to significant increases in EC levels.

Small instream impacts have occurred at MML4 as a result of solid waste disposal from livestock watering activities, along with a moderate impact on water quality and large impacts due to water releases, flow, bed and channel modifications and inundation. Severe impacts relating to the manual harvesting of river sand by local communities were evident within the riparian zone. This includes indigenous vegetation removal and channel modification which have subsequently led to large impacts on the river banks including erosion, incision and channel widening. This has caused a large amount of silt to enter the instream channel resulting in a lack of exposure of rocky substrate which is required by many macro-invertebrate species for survival. Further large impacts due to sand harvesting activities at the site include inundation and flow modifications within the riparian zone. This is evident in the significantly large pools of water that have formed within this zone over time resulting in instability and a high potential for bank collapse. The formation of several trenches was also evident on both banks. The riparian habitat is also moderately impacted by exotic vegetation encroachment and water quality modifications.

Instream impacts at MML5 include moderate impacts due to water quality modifications and solid waste disposal from frequent livestock watering, and large impacts resulting from water releases, flow, bed, channel modifications and inundation. The riparian zone has been moderately impacted on by indigenous vegetation removal, exotic vegetation encroachment and water quality modifications, along with large impacts on flow due to channel modifications as a result of bank incision and erosion caused by frequent livestock watering. This has also led to the widening of the channel at this point and the deposition of large amounts of silt within the channel, resulting in the lack of exposure of rocky substrate at this site as observed at MML4.

The general habitat integrity at each of the monitoring sites during the wet season survey in April 2017 was classified as moderately modified at MML1 and MML2, largely natural with few modifications at MML3, critically modified at MMDR, unmodified and natural at MMD1 KAN and largely modified at MMD2 KO (Table 5.39).

During the dry season survey in October 2017, the habitat integrity at these sites were regarded as being largely natural with few modifications at MML1 and MML2, moderately modified at MML3, extensively modified at MMDR, largely natural with few modifications at MMD1 KAN and largely modified at MMD2 KO.

Table 5.39: Habitat Integrity Classification of Monitoring Sites

Biomonitoring Site	Sampling Period	IHIA Scores (%)			Class
		Instream Score	Riparian Score	Overall Score	
MML1	April 2017	79.0	80.7	79.9	C
	October 2017	86.2	86.8	86.5	B
	February 2018	69.7	84.5	77.2	C
MML2	April 2017	79.0	80.1	79.6	C
	October 2017	80.4	80.0	80.2	B
	February 2018	72.4	72.5	72.5	C
MML3	April 2017	81.3	79.6	80.5	B
	October 2017	78.8	74.6	76.7	C
	February 2018	47.4	61.1	54.3	D
MML4	February 2018	42.8	16.9	29.9	E
MML5	February 2018	42.7	38.9	40.9	D
MMDR	April 2017	18.5	5.07	11.8	F
	October 2017	35.4	17.0	26.3	E
	February 2018	27.7	14.3	21.0	E
MMD1 KAN	April 2017	96.8	97.6	97.2	A
	October 2017	88.8	75.1	82.0	B
	February 2018	63.6	84.5	74.1	C
MMD2 KO	April 2017	51.2	34.1	42.7	D
	October 2017	61.9	44.1	53.3	D
	February 2018	36.1	36.6	36.4	E

5.9.3 Habitat Suitability

The integrity of the instream and riparian habitat has a direct influence on the structure of the aquatic community. The Integrated Habitat Assessment System (IHAS) version 2 of 1998 was developed by McMillan (as cited in GCS, 2017) for use in conjunction with the SASS5 protocol. The IHAS was applied at each biomonitoring site in order to assess the specific habitat suitability for aquatic macroinvertebrates and aid in the interpretation of the SASS5 results. The habitat scoring system takes into consideration both the sampling habitat and the general stream condition. Scores for the IHAS index were interpreted according to the following guidelines:

- <65%: habitat diversity and structure inadequate for supporting a diverse aquatic macroinvertebrate community.
- 65–75%: habitat diversity and structure adequate for supporting a diverse aquatic macroinvertebrate community.
- >75%: habitat diversity and structure highly suited for supporting a diverse aquatic macroinvertebrate community.

The contribution of each biotope, namely 'stones in current', 'vegetation' and 'gravel, sand and mud', as well as the physical condition of the stream is calculated in order to determine the final IHAS score, which reflects the overall habitat integrity of the site. This allows for the identification of each biotope from most to least prevalent.

The results of the IHAS assessment conducted at the biomonitoring sites during the wet (high flow) season survey in April 2017, the dry (low flow) season survey in October 2017 and the wet season survey in February 2018 are presented in Table 5.40.

Table 5.40: IHAS Results for Biomonitoring Sites

Biomonitoring Site	Sampling Period	IHAS Biotopes Assessed					IHAS Score (%)
		Stones in Current	Vegetation	Gravel, Sand and Mud	Physical Stream Condition	Total Habitat Score	
MML1	April 2017	0	13	7	27	7	**47**
	October 2017	0	5	10	22	14	**37**
	February 2018	0	15	12	27	27	**54**
MML2	April 2017	18	9	8	19	35	**54**
	October 2017	16	9	13	34	40	**72**
	February 2018	17	10	16	28	43	**71**
MML3	April 2017	14	11	15	29	14	**69**
	October 2017	0	4	10	28	25	**52**
	February 2018	14	9	11	25	34	**59**
MML4	February 2018	0	8	12	22	20	**42**
MML5	February 2018	0	9	9	20	18	**38**
MMDR	April 2017	0	0	2	28	14	**30**
	October 2017	0	11	8	23	21	**42**
	February 2018	0	0	9	21	9	**30**
MMD1 KAN	April 2017	0	10	10	21	42	**41**
	October 2017	0	7	6	14	15	**27**
	February 2018	0	0	9	18	9	**27**
MMD2 KO	April 2017	0	11	9	21	10	**41**
	October 2017*	-	-	-	-	-	**-**
	February 2018	0	12	11	21	23	**44**

* Site MMD2 KO was dry during the October 2017 survey, therefore no IHAS score was calculated.

5.9.3.1 Habitat Suitability Results from April 2017

The IHAS results indicated that MML3 on the Lilongwe River obtained the highest score during the wet season survey in 2017 with regards to habitat suitability required for the colonisation of the macroinvertebrate community. The habitat integrity at MML1, MML2 and MMDR during the same period was found to be inadequate in supporting a diverse macroinvertebrate community. This is likely to be attributed to the flood conditions observed at MML1 and MML2, and due to channel modification and diversion at MMDR. Flood conditions were also observed at MML3, however, as the site was downstream of a road bridge, the flow was intercepted by the bridge pillar occurring instream beside the left bank which allowed for slower, more diverse flow, and therefore, more suitable habitat for the community. The habitat integrity at MMD1 KAN and MMD2 KO was also found to be inadequate in supporting a diverse macroinvertebrate community, however, as these systems do not contain flowing water and lacked the stones biotope, results from the application of the IHAS at these points are not considered a true reflection of the state of the habitat. Application of the IHIA (section 5.9.2) is therefore likely to give a more accurate indication of the general habitat integrity at these sites.

5.9.3.2 Habitat Suitability Results from October 2017

The IHAS results during the dry season survey in October 2017 as well as the 2018 survey indicated that MML2 on the Lisungwi River obtained the highest score with regards to habitat suitability required for the colonisation of the macroinvertebrate community. The habitat integrity at this site was considered to be adequate in supporting a diverse macroinvertebrate community at the time of the assessments. The habitat integrity at the remainder of the sites was however, found to be inadequate in supporting a diverse macroinvertebrate community.

The stones biotope was absent at MML1 during this survey and the availability of marginal vegetation was very limited. This was as a result of flow only being present towards the left bank, which was incised and thus preventing the availability of overhanging vegetation. Aquatic macrophytes were also unavailable within the channel as a result of the low flow of the system at this time. Muddy substrate was abundant at this point and the water was silty.

They system was slow-flowing and deep resulting in limited diversity in flow and depth profiles.

Very deep, fast-flowing water occurred at MML3, likely due to releases from the Kamuzu Dam. This has resulted in high flow conditions during the dry season, significantly affecting the availability and suitability of habitat for the macro-invertebrate community at this point. Abundant marginal vegetation was present with some leafy vegetation providing cover for the community.

Habitat at MML2 consisted of all three biotopes: stones; gravel, sand and mud; and vegetation. Large cobbles, boulders and small pebbles were sampled in and out of current, along with marginal and aquatic vegetation, although the marginal vegetation mainly consisted of stems and shoots, providing limited cover for macro-invertebrates. Adequate sand, gravel and mud deposits were present in the stream. The system consisted of moderately fast-flowing, clear water with good diversity in depth and flow. The riparian vegetation consists of a mix of grasses, shrubs and reeds.

Both the vegetation biotope and gravel, sand and mud biotope were sampled at MMDR. The stones in current biotope was lacking at this point, however, stones out of current were sampled. Some marginal and aquatic vegetation was available for sampling within the narrow, canalised stream and muddy substrate dominated the site at this point. Stagnant pools of clear water were present with limited diversity in depth. The riparian vegetation consisted of grasses, shrubs and some small reeds.

Similarly, only the vegetation and gravel, sand and mud biotopes were available for sampling at site MMD1 KAN. Both the marginal and aquatic vegetation were limited at the time of assessment due to overgrazing by livestock. Muddy deposits dominated the site within the shallow, stagnant pool. Riparian vegetation consisted of grass, however bare areas were present where the grass was heavily overgrazed, resulting in soil erosion.

5.9.3.3 Habitat Suitability Results from February 2018

The habitat conditions on the Lilongwe River indicated some variation in habitat integrity between the sites, increasing in suitability from MML1 to MML3, after which a decreasing trend is evident further downstream at Sites MML4 and MML5. This is likely to have an influence on the structure of the aquatic communities present at these sites.

The habitat suitability at Site MML1 has increased by 14.8% from the wet season in 2017 to the survey in 2018. The stones in current biotope was absent at MML1 during both wet season surveys. This is likely to have resulted from the siltation of the channel due to bank incision and erosion caused by frequent livestock watering as well as due to sediment build-up resulting from the presence of the downstream dam wall, which has likely inhibited sediment transport by the flow regime. The availability of marginal vegetation was very limited, although more abundant in the form of aquatic macrophytes and leafy vegetation during the 2018 survey. Muddy substrate was abundant during both surveys. They system was slow-flowing and deep resulting in limited diversity in flow and depth profiles, which is likely to limit the diversity of aquatic macroinvertebrates.

The habitat at MML2 consisted of all three biotopes, namely stones in current, vegetation and gravel, sand and mud. Large cobbles, boulders and small pebbles were sampled in and out of current, along with marginal and aquatic vegetation, although the marginal vegetation mainly consisted of stems and shoots, providing limited cover for macroinvertebrates. Adequate sand, gravel and mud deposits were present in the stream. The system consisted of moderately fast-flowing, clear water with good diversity in depth and flow. The riparian vegetation consists of a mix of grasses, shrubs and reeds. Impacts in the form of bank erosion and incision are however increasing at this point over time.

Very deep, fast-flowing water occurred at MML3 likely due to releases from the Kamuzu Dam. This has resulted in high flow conditions during the dry season, significantly affecting the availability and suitability of habitat for the macroinvertebrate community at this point. As with MML1, rocky substrate was not available for sampling at MML3, which was due to the inundation observed at this site. Abundant marginal vegetation was however present with some leafy vegetation providing cover for the community. However, vegetation cover has reduced by 14% between the two surveys. Gravel, sand and mud was also available. Depth and flow diversity were limited, and the water was very silty. Excellent bank cover allowed for good bank stability minimising the potential for erosion at this site.

The habitat integrity at MML4 and MML5 was inadequate in supporting a diverse macroinvertebrate community. This is mainly due to the high water level present at both sites resulting in limited depth and flow diversity, which is likely a result of the controlled releases from the Kamuzu Dam. In addition, the gradual siltation of the channel from soil erosion due to extensive sand harvesting activities at MML4 and the incision of the banks caused by livestock watering at MML5, has resulted in the lack of rocky substrate exposure at both sites during the 2018 survey.

Only the gravel, sand and mud biotope was available for sampling at MMDR. The narrow, canalised stream was very shallow at the time of survey and muddy substrate dominated the site at this point. Isolated clumps of algae were evident, and the water was discoloured. Some marginal and aquatic vegetation was available for sampling within the narrow, canalised stream and muddy substrate dominated the site at this point. Stagnant pools of clear water were present with limited diversity in depth. The riparian vegetation consisted of grasses, shrubs and some small reeds. Plantations occur upstream of this point, replacing most of the indigenous vegetation and giving rise to soil erosion.

Similarly, only the gravel, sand and mud biotope was available for sampling at MMD1 KAN, and a significant decrease in habitat integrity 34.1% has occurred since April 2017. This is likely due to the significant decrease in the volume of water and the lack of overhanging marginal and aquatic vegetation during the current survey due to overgrazing by livestock. Both the marginal and aquatic vegetation were limited at the time of assessment due to overgrazing by livestock. Muddy deposits dominated the site within the shallow, stagnant pool.

The habitat integrity at MMD2 KO was also found to be inadequate in supporting a diverse macro-invertebrate community. However, the integrity of the habitat at the site has increased by 7.3% since April 2017.

5.9.4 Macroinvertebrate Integrity Assessment

The monitoring of the integrity of the macroinvertebrate community of an aquatic ecosystem forms an integral part in monitoring of integrity of that ecosystem for the following reasons:

- The relatively sedentary nature of the community enables the detection of localised disturbances.
- The relatively long life-cycles of ±1 year allows for the integration of pollution effects over time.

- The heterogeneity of the community allows for several phyla to be represented, and therefore responses to environmental impacts are detectable in terms of the community as a whole (GCS, 2017).

The SASS5 index, designed specifically for the evaluation of low/moderate flow hydrology, was used in the biomonitoring survey to determine the macroinvertebrate integrity. The total SASS5 score provides an indication of the diversity of the macroinvertebrate community, and the average score per taxon (ASPT) indicates community sensitivity.

The index is based on the presence of aquatic invertebrate families and the perceived sensitivity to water quality changes of these families. Different macroinvertebrate families show different sensitivities to pollution. These sensitivities range from highly tolerant families such as the Muscidae, specifically house flies and Psychodidae, specifically moth flies; to highly sensitive families such as the Oligoneuridae, specifically brushlegged mayflies (GCS, 2017).

According to Van der Merwe (2003), as cited in GCS (2017), a broad explanation of the sensitivity scales are as follows:

- 1 – 5: Highly tolerant to pollution.
- 6 – 10: Moderately tolerant to pollution.
- 11 – 15: Very low tolerances to pollution.

Results from the IHAS index (see section 5.9.3) were used to aid in the interpretation of the SASS5 results by taking into account the effects of habitat variation on the macroinvertebrate community integrity.

Table 5.41 presents the interpretation guidelines used for this assessment which is based on the methodology applied by Tambala *et al*. (2016) in order to retain consistency for comparative purposes. Sites MMD1 KAN and MMD2 KO within the dambos are considered sandy as these systems lack rocky substrate, whilst MML1 and MML3 on the Lilongwe River, MML2 on the Lisungwi River and MMDR on Dambo 1 are considered to be rocky systems.

Table 5.41: Interpretation of ASPT Scores

Class	Description	ASPT (Sandy)	ASPT (Rocky)
A	Unmodified. Natural.	>6.9	>7.9
B	Largely natural, with few modifications.	5.8–6.9	6.8–7.9
C	Moderately modified.	4.9–5.8	6.1–6.8
D	Largely modified.	4.3–4.9	5.1–6.1
E/F	Seriously to critically modified.	<4.3	<5.1

The results of the macroinvertebrate integrity assessment conducted using the SASS5 index are presented in Table 5.42. It must be noted that habitat diversity downstream of the Kamuzu Dam on the Lilongwe River is significantly limited due to the inundation of this system as a result of water releases from the reservoir. The system is likely to be inundated for most parts of the year, limiting low flow seasonality and likely preventing the establishment of many invertebrate taxa with a preference for shallow riffle, rapid and run habitats.

Table 5.42: SASS5 Results for Biomonitoring Sites

Biomonitoring Site	Sampling Period	Aspect			PES Class
		SASS5 Score	Number of Taxa	ASPT	
MML1	April 2017	49	12	4.1	E/F
	October 2017	63	14	4.5	E/F
	February 2018	88	19	4.6	E/F
MML2	April 2017	44	9	4.9	E/F
	October 2017	80	20	4	E/F
	February 2018	83	14	5.9	D
MML3	April 2017	74	11	6.7	C
	October 2017	69	15	4.6	E/F
	February 2018	58	10	5.8	D
MML4	February 2018	58	14	4.1	E/F
MML5	February 2018	31	8	3.8	E/
MMDR	April 2017	15	3	5	E/F
	October 2017	16	4	4	E/F
	February 2018	24	7	3.4	E/F
MMD1 KAN	April 2017	71	15	4.7	D
	October 2017	11	3	3.7	E/F
	February 2018	46	11	4.1	E/F
MMD2 KO	April 2017	54	12	4.5	D
	October 2017*	-	-	-	-
	February 2018	50	13	3.8	E/F

* Site MMD2 KO was dry during the October 2017 survey, therefore no IHAS score was calculated.

5.9.4.1 Macroinvertebrate Integrity Results from April 2017

The macroinvertebrate integrity was regarded as being in moderately modified (Class C) state at MML3 during the wet season survey in April 2017, which was the highest class obtained for all sites across all three surveys. Site MML3 obtained the highest SASS5 and ASPT score of 74 and 6.7, respectively, indicating a high macroinvertebrate diversity and sensitivity. This was mainly attributed to the slower, more diverse flow and habitat compared to the upstream site MML2, due to the presence of the instream road bridge pillar, as mentioned previously.

During the 2017 wet season, MMDR, was considered to have a macroinvertebrate community integrity in a severely to critically modified (Class E/F) state, and achieved the lowest SASS5 score indicating that the diversity of the community was found to be poor at this site.

The integrity of the macroinvertebrate community at MMD1 KAN and MMD2 KO were found to be in a largely modified (Class D) state during the April 2017 survey. This was likely a result of the limited habitat diversity due to the lack of flowing water and the absence of the stones habitat. The elevated pH level at MMD1 KAN and the slightly elevated EC level at MMD2 KO was also likely to contribute to this state. Site MMD1 KAN obtained a higher SASS5 and ASPT score compared to MMD2 KO, which was likely a result of better habitat availability and water quality at MMD1 KAN. A good diversity of macroinvertebrates occured at MMD1 KAN, and the sensitivity of the macroinvertebrate community was slightly higher at MMD1 KAN compared to the community present at MMD2 KO. The lower sensitivity at MMD2 KO was likely a result of the slightly elevated EC level measured at this point.

Spatial variation on the Lilongwe River during the April 2017 survey indicated a 33.7% increase in the SASS5 score between MML1 and MML3, which was indicative of increased macroinvertebrate diversity at MML3. This is likely a result of better habitat availability at MML3. The ASPT score also increased in a downstream direction by 38.8% between MML1 and MML3, which was also likely a result of the better habitat availability at MML3.

5.9.4.2 Macroinvertebrate Integrity Results from October 2017

During the dry season survey in October 2017, the macroinvertebrate integrity at all sites was regarded as being in a severely to critically modified (Class E/F) state, with MML2 obtaining the highest SASS5 score. Results obtained at MML1 indicated a slightly lower macroinvertebrate diversity and sensitivity reflected in the lower SASS5 and ASPT scores attained at this site compared to the downstream site MML3 on the Lilongwe River. This was likely related to the impact of frequent livestock watering and subsequent overgrazing on the habitat integrity at MML1. The resulting bank incision and erosion has impacted on the availability of vegetation cover for the macroinvertebrate community, and has also resulted in siltation within the channel, which has possibly contributed to the lack of the stones biotope at this point. The deposition of faeces within the channel at MML1 was also likely to have impacted on the water quality, reflected in the lower ASPT score. Furthermore, the higher dilution of salts at MML3 from the increase in water volume as a result of controlled releases from the Kamuzu Dam, was likely to have contributed to the higher ASPT score obtained at this site.

Habitat availability and diversity downstream of the Kamuzu Dam on the Lilongwe River was found to be limiting and is reflected in a lower SASS5 score at MML3, compared to the score obtained at MML2 on the Lisungwi River, which is not impacted by these releases, thus allowing for a habitat integrity that is adequate in supporting a more diverse macroinvertebrate community at MML2. However, the higher ASPT score at MML3 indicated a greater sensitivity, and hence better water quality, occurring within the Lilongwe system compared to MML2 on the Lisungwi River. This was likely related to lower EC levels occurring at MML3 compared to MML2 as a result of the higher dilution of salts. The higher EC level occurring at Site MML2 is likely due to upstream impacts unrelated to the Project area, including runoff from the surrounding villages and agricultural lands resulting in increased nutrients within the system.

The low SASS5 scores obtained at MMDR and MMD1 KAN in the October 2017 survey may also be attributed to poor habitat diversity reflected in the low IHAS scores of 42 and 27, respectively. Similar to MML2, the low ASPT scores obtained at these sites are likely a result of higher EC levels reflecting the presence of salts in the system. This was likely to have resulted in osmotic stress at these sites, limiting the diversity and sensitivity of the aquatic macroinvertebrate community to some extent.

Spatial variation indicated an 8.6% increase in the SASS5 score between MML1 and MML3 on the Lilongwe River, which reflects a less diverse macroinvertebrate community at MML1 as a result of the impacted habitat at this point. A 13.75% decrease in SASS5 score was evident between MML2 and MML3 due to limited habitat availability and diversity at MML3 resulting from impacts from the release of water. The ASPT score, however, increased by 15% between the two sites, indicating greater sensitivity at MML3. This is likely a due to the lower EC concentration at Site MML3 resulting from the higher dilution of salts at this point as mentioned above.

5.9.4.3 Macroinvertebrate Integrity Results from February 2018

During the 2018 survey the macroinvertebrate integrity was regarded as being in a Severely to Critically Modified (Class E/F) state at all sites, except for MML2 and MML3, which was regarded as in a Largely Modified (Class D) state. It was evident that the SASS5 scores decreased in a downstream direction on the Lilongwe River indicating a decrease in macroinvertebrate diversity from Site MML1 to MML5. This was likely a result of a decline in habitat diversity downstream of the Kamuzu Dam on the Lilongwe River, due to the inundation of this system as a result of water releases from the reservoir. The inundation of the system prevents the establishment of many invertebrate taxa with a preference for shallow riffle, rapid and run habitats.

Since the first wet season survey in April 2017, the macro-invertebrate integrity has remained in a Severely to Critically Modified (Class E/F) state at Site MML1. At Site MML2, an improvement in the integrity was observed, from a Severely to Critically Modified (Class E/F) state, to Largely Modified (Class D) state during the 2018 survey. A decline in the integrity is however, evident at Site MML3, from a Moderately Modified (Class C) state in April 2017 to a Largely Modified (Class D). The integrity at Site MMDR has remained in a Severely to Critically Modified (Class E/F) state, however a decline in condition is evident at Sites MMD1 KAN and MMD2 KO, from a Largely Modified (Class D) state during the previous survey to a Severely to Critically Modified (Class E/F) state.

A 20.6% increase in ASPT score was evident between Sites MML1 and MML3 indicating the occurrence of more sensitive taxa at Site MML3 compared to Site MML1. This was unlikely to be a result of better water quality at Site MML3 as a 110.1% increase in EC level and a 13.1% increase in the pH level was evident between Sites MML1 and MML3. The higher ASPT score at Site MML3 was more likely to be due to the presence of the stones biotope at this site, which is absent at Site MML1, and provides habitat for sensitive macroinvertebrate species from the families Ephemeroptera and Trichoptera, most of which have a strong affinity for rocky substrate.

5.9.5 Diatom Analysis

Diatoms are single-celled photosynthesising algae widely used as indicators of river and wetland health as they provide a rapid response to specific physico-chemical conditions in water and are often the first indication of change. The presence or absence of indicator taxa can be used to detect specific changes in environmental conditions such as eutrophication, organic enrichment, salinisation and changes in pH. They are therefore useful for providing an overall picture of trends within an aquatic system as they show an ecological memory of water quality over a period of time. Diatom samples were prepared for microscopy and counted for ecological analysis.

The Specific Pollution Index (SPI) (CEMAGREF, 1982) as cited in GCS (2017) and the Biological Diatom Index (BDI) (Lenoir and Coste, 1996) were used in the diatom assessment and were calculated using OMNIDIA software. In addition, the percentage of pollution tolerant valves[7] (%PTV) and ecological descriptor indices (Van Dam *et al*., 1994) as cited in GCS (2017) were also applied in this study to indicate possible impacts of organic pollution. The limit values and associated ecological water quality classes used in this study to interpret the SPI and BDI scores are indicated in Table 5.43. For the SPI and BDI the maximum value is 20, where a score of zero indicates an increasing level of pollution or eutrophication.

Table 5.43: Limit Values and Ecological Water Quality Classes used in Specific Pollution Index and Biological Diatom Index

Index Score	Class
>17	High quality
13–17	Good quality
9–13	Moderate quality
5–9	Poor quality
<5	Bad quality

[7] Valves are the siliceous unit that lies at each end of the frustule (external layer of the diatom). The valve morphology is used to classify diatoms.

The %PTV has a maximum score of 100, where a score of zero indicates no organic pollution and a score of 100 indicates definite and severe organic pollution Table 5.44.

Table 5.44: Interpretation of %PTV Scores

%PTV	Description
<20	Site free from organic pollution.
21–40	There is some evidence of organic pollution.
41–60	Organic pollution is likely to contribute significantly to eutrophication.
>61	Site is heavily contaminated with organic pollution.

5.9.5.1 Diatom Analysis from April 2017

During the wet season survey in 2017, a total of 101 diatom species were recorded. The diatom assemblages indicated overall 'bad' ecological water quality consisting of different proportions of highly pollution tolerant species (GCS, 2017). Results from the analysis are attached in Appendix G. The diatom index scores are summarised in Table 5.45.

Table 5.45: Diatom Index Scores Indicating the Ecological Water Quality, April 2017

Site	%PTV	SPI	BDI	Quality
MML1	41.5	4.22	3.38	Bad
MML2	26.3	4.01	3.25	Bad
MML3	8.3	4.58	3.49	Bad
MMDR	53.5	4.54	3.07	Bad
MMD1 KAN	48.3	4.19	2.75	Bad
MMD2 KOV	-		-	-

Site MMD1 KAN primarily indicated a salt tolerant community (*Craticula halophila* and *Nitzschia archibaldii*), with nutrient tolerant species also dominant (*Nitzschia palea*). A lower abundance of small naviculoid cells were present indicating an impact related to organic pollution (*Sellaphora pupula* and *Sellaphora seminulum*). The community at this site indicated bad ecological water quality and definite organic pollution (GCS, 2017).

Site MML1 indicated impacts related to decreased pH (*Nitzschia acidoclinata*), with the PTV score (41.5%) showing significant organic pollution (*Eolimna minima*). The dominant species are indicative of an environment that is highly polluted.

The dominant combination of *Amphora montana*, *Navicula recens* and *Surirella angusta* indicates that MML2 is impacted by increased pH (alkalinity) and nutrients, organics and potentially heavy metals (GCS, 2017). *Nitzschia archibaldii* is a cosmopolitan species found in circumneutral, polluted waters with moderate electrolyte content and is reported to be tolerant of lead (Pb) and zinc (Zn) (Taylor *et al*., 2007). The indices indicate bad prevailing water quality conditions with light organic pollution and a eutrophic state.

Site MML3 indicates species with a tolerance for salts and nutrients and a bad water quality. The PTV score (8.3%) shows no organic pollution, and ecological descriptors (Van Dam *et al*., 1994) indicate eutrophication. The site was dominated by *Fragilaria capucina* var. *vaucheriae*. This benthic cosmopolitan taxon is found in circumneutral mesotrophic waters with moderate to high electrolyte content (Taylor *et al*., 2007 as cited in GCS, 2017).

The sample from MMDR indicated an impact related primarily to salinity (*Nitzschia archibaldii*, *Nitzschia nana* and *Gomphonema parvulum*) and nutrients (*Nitzschia palea*). The site fell into a bad class and ecological descriptors indicate that the site is eutrophic and comprised of nitrogen heterotrophic tolerant species needing periodically elevated concentrations of organically bound nitrogen. The PTV value of 53.5% indicates definite organic pollution.

5.9.5.2 Diatom Analysis from October 2017

A total of 60 diatom species were recorded during the dry season survey in 2017. The diatom assemblages indicated an overall moderate ecological water quality at the time, consisting of different proportions of pollution tolerant species. The exception was at MMD1 KAN which consisted dominantly of highly pollution tolerant valves and moderate proportions of organically tolerant diatom species. Site MMD1 KAN attained the lowest water quality class (poor), however, an improvement was noted between the seasons from April to October 2017, but the scores still indicated organic inputs on the low end of the tolerant valve scale. Results from the analysis are attached in Appendix H. The diatom index scores are summarised in Table 5.46.

Table 5.46: Diatom Index Scores Indicating the Ecological Water Quality, October 2017

Site	%PTV	SPI	BDI	Quality
MML1	13.7	12.5	12.2	Moderate
MML2	21.4	10.8	14.3	Moderate
MML3	20.3	10.9	12.4	Moderate
MMDR	17.7	11.8	12.8	Moderate
MMD1 KAN	32	8	9.4	Poor
MMD2 KOV	-		-	-

Site MML1 was in a moderate state, showing impacts related to a decreased pH with the %PTV score (13.7%) reflecting low levels of organic pollution (*Eolimna minima*). The dominant species at the site were *Navicula cryptocephala* (pH), *Navicula radiosa* (pH) and *Orthoseira roeseana* (sub-aerial and incidental). An improvement was noted between seasons at from bad to moderate quality.

The dominant combination of *Achnanthidium* spp. and *Nitzschia* spp. at MML2 indicate that this site has possibly been recently disturbed and is impacted by increased nutrients. The indices indicate moderate prevailing water quality conditions, with moderate organic pollution and a eutrophic state. An improvement was however noted between seasons from bad to moderate quality.

Results for MML3 indicate species with a tolerance for salts and nutrients and a moderate water quality. The %PTV (20.3%) score reflects moderate organic pollution and ecological descriptors (Van Dam *et al*., 1994) indicating eutrophication. The cosmopolitan *Navicula* and *Nitschia* spp. suggest nutrient impacts with moderate electrolyte content (Taylor et al., 2007). Similarly to Site MML1, an improvement was noted between seasons at this site from bad to moderate quality.

Site MMDR indicated an impact primarily related to nutrients (*Nitzschia amphibia*, *Nitzschia palea*). The site fell into a moderate class and ecological descriptors indicate that the site is eutrophic and comprised of nitrogen autotrophic tolerant taxa, which tolerate elevated concentrations of organically bound nitrogen. The %PTV value (17.7%) indicates low–moderate organic pollution. The water quality at the site reflected an improvement from bad to moderate quality from the previous season.

Similar to the previous season, MMD1 KAN indicated a salt tolerant community (*Gomphonema parvulum*), with nutrient tolerant species also dominant (*Nitzschia amphibia* and *Nitzschia palea*). The community at this site indicated poor ecological water quality and definite organic pollution. Although the site was in a poor state, an improvement was noted in the water quality between seasons from bad to poor.

5.9.5.3 Diatom Analysis from October 2017

A total of 65 diatom species were recorded at the eight sites and the dominant diatom species recorded at all sites included *Nitzschia* sp. and *Gomphonema parvulum*. Based on the diatom community analyses, the water quality at each site appeared to have some pollution-related impacts and the overall water quality was moderate for all sites. According to temporal diatom analysis trends, the ecological water quality has shown a general improvement from the April 2017 to the February 2018 surveys and a stable trend between the October 2017 and the February 2018 survey. Results from the analysis are attached in Appendix I. The diatom index scores are summarised in Table 5.47.

Table 5.47: Diatom Index Scores Indicating the Ecological Water Quality, October 2017

Site	%PTV	SPI	BDI	Quality
MML1	10.2	9.8	12	Moderate
MML2	26.4	10.9	11.6	Moderate
MML3	9.6	11	15.4	Moderate
MML4	5.1	11	10.5	Moderate
MML5	3.1	11.8	14.2	Moderate
MMDR	10.9	12.3	11.6	Moderate
MMD1 KAN	0	9.8	13.6	Moderate
MMD2 KOV	17.3	9.7	11.2	Moderate

Site MML1 was dominated by *Nitzschia* sp. which points to eutrophic, polluted (α-mesosaprobic to polysaprobic) freshwater. The dominance of *Navicula* sp. suggests alkaline, low temperature, eutrophic running water with medium-high conductivity and species from this genus are commonly found in organically polluted water. The presence of *G. parvulum* indicates impacts associated with agricultural run-off and is adapted to withstand physical disturbance and benefits from organic enrichment. The presence of *Orthoseira roeseana* points to aerial habitats indicating that this site may experience periodic drying out. The diatom assemblage at this site indicates alkaline, eutrophic conditions with electrolyte-rich content. The %PTV score was relatively low indicating that there was a serious impact associated with organic pollution at the time of the survey. A slight decrease in the level of organic pollution was evident since the previous survey.

The overwhelming dominance of *G. parvulum* and G*. rhombicum* at MML2 points to impacts associated with agricultural run-off. The subdominant, *N. symmetrica* and *Navicula* sp. points to eutrophic, electrolyte-rich waters and both taxa are tolerant of strongly polluted conditions. The presence of *Achananthidum* sp. was recorded in high proportions over a wide range of trophic levels and is usually absent from moderately- to strongly-acidic or very electrolyte-poor environments. The %PTV score was relatively high (and has increased from the previous surveys) indicating that there was some impact associated with organic pollution.

Site MML3 was dominated by *Achnanthidium* sp. which points to calcium-bicarbonate rich, mesotrophic to eutrophic freshwater with medium-high conductivity. The subdominance of *Nitzschia* sp. and *N. amphibia* points to eutrophic freshwater and are tolerant to strongly polluted conditions. The diatom community at this site points to meso- to eutrophic conditions with moderate electrolyte content. Owing to the presence of *Achnanthidium* sp. and the relatively low %PTV score, this site appears to have a low impact associated with organic pollution.

This site at MML4 was dominated by *Navicula* sp. which suggests alkaline, low temperature, eutrophic running water with medium-high conductivity and species from this genus are commonly found in organically polluted water. The subdominance of *Cyclotella meneghiniana* points to eutrophic, electrolyte rich rivers. The subdominance of *Orthoseira roeseana* and *Navicula erifuga* points to brackish conditions and both species are adapted to intermittently wet conditions.

MMDR ws dominated by *Nitzschia* sp. and *N. sigma* which points to eutrophic, electrolyte-rich and brackish conditions. The subdominance of *Pinnularia gibba* points to calciumbicarbonate-poor freshwater and may occur in rivers strongly impacted by waste water. However, the %PTV score was relatively low indicating that there was no serious impact associated with organic pollution.

The overwhelming dominance of *Nitzschia* sp. at Kankoma dambo points to eutrophic, polluted (α-mesosaprobic to polysaprobic) freshwater. The subdominance of *Pinnularia marchica* points to alkaline, strongly eutrophic, moderately polluted running waters with medium electrolyte content, particularly developed under conditions of cold water temperature. The diatom community at this site points to alkaline, meso- to eutrophic conditions with moderate electrolyte content and owing to the presence of *Nitzschia*, there appeared to be some form of pollution impact at this site. The %PTV score indicates that there was no evidence of organic pollution suggesting that some other form of pollution was impacting this site.

At the Kovuma dambo there was an overwhelming dominance of *Nitzschia* sp., which points to eutrophic, polluted (α-mesosaprobic to polysaprobic) freshwater. The subdominance of *G. parvulum* and *Gomphonema* sp. indicated oligosaprobic and mesosaprobic, oligo- to eutrophic, electrolyte-poor freshwater and points to impacts associated with agricultural run-off.

5.9.6 Whole Effluent Toxicity

Acute (and short-chronic) bio-toxicity testing is undertaken by exposing biota to water sourced from the sampling sites in order to determine the potential risk of these waters to the biota/biological integrity of the receiving water bodies. A hazard class is determined based on the percentage of mortalities (or inhibition-stimulation) of the exposed biota. The toxicity hazard relates to the aquatic biotic integrity and in no way represents toxicology towards humans or other mammals.

Standard, internationally accepted methods and materials were applied in order to conduct acute and short-chronic toxicity testing and hazard classification based on four trophic levels (four taxonomic groups) at each of the selected sites/samples. For this purpose, *Vibrio fischeri* (bacteria), *Selenastrum capricornutum* (micro-algae), *Daphnia magna* (crustaceans) and *Poecilia reticulata* (fish) were used as test organisms prior to hazard classification.

The *Selenastrum* was subjected to a growth inhibition test, while the *Vibrio fischeri* was subjected to bioluminescent testing. *Daphnia* and *Poecilia* were subjected to acute toxicity testing.

For the *Daphnia magna* and *Poecilia reticulata* screening tests, a risk/hazard category was determined by application of the hazard classification according to the Direct Estimation of Ecological Effect Potential (DEEEP) method (DWAF, 2003). This risk category equates to the level of acute/chronic risk posed by the receiving aquatic resource. These categories are indicated in Table 5.48.

Table 5.48: Hazard Classification System for *Daphnia magna* and *Poecilia reticulata* Screening Tests

Percentatge Mortality	Class	Description
None of the tests indicate a toxic effect.	I	No Acute Hazard
A statistically significant Percentage Effect (EP) is reached in at least one test, but the effect level is below 50%.	II	Slight Acute Hazard
The 50% EP (EP50) is reached or exceeded in at least one test, but the effect level is below 100%.	III	Acute Hazard
The 100% EP (EP100) is reached or exceeded in at least one test.	IV	High Acute Hazard
The 100% EP (EP100) is reached or exceeded in all tests.	V	Very High Acute Hazard

The results from the toxicological testing are summarised in Table 5.49.

Table 5.49: Summary of Toxicological Testing Results

Sampling Point	Sampling Period	*Vibrio fischeri* (% inhibition/ stimulation)	*Selenastrum capricornutum* (% inhibition/ stimulation)	*Daphnia Magna* (% mortality)	*Poecilia reticulata* (% mortality)	Hazard Class
MML1	Apr 2017	-11	-1	25	0	Class II
	Oct 2017	-20	-11	5	13	Class II
	Feb 2018	-12	5	-5	-8	Class I
MML2	Apr 2017	3	-3	90	0	Class III
	Oct 2017	-24	-20	10	25	Class II
	Feb 2018	-9	12	0	0	Class I
MML3	Apr 2017	-12	-10	95	0	Class III
	Oct 2017	15	-14	15	42	Class II
	Feb 2018	-9	13	0	0	Class I
MML4	Feb 2018	-13	18	0	-8	Class I
MML5	Feb 2018	-18	10	0	0	Class I
MMDR	Apr 2017	-35	-34.58	100	0	Class IV
	Oct 2017	-21	-3	5	17	Class II
	Feb 2018	-16	14	-10	0	Class I
MMD1 KAN	Apr 2017	-21	-9.29	10	0	Class II
	Oct 2017	-40	8	0	42	Class II
	Feb 2018	-32	5	0	0	Class II
MMD2 KO	Apr 2017	-9	0	25	0	Class II
	Oct 2017	Dry				
	Feb 2018	-26	**	-5	0	Class II
Kamuzu Dam II	Feb 2018	-18	17	0	0	Class I

Results from the tests conducted during February 2018 indicated that the water poses no acute hazard (Class I) to the aquatic communities at Sites MML1 through to MML5, MMDR or the Kamuzu Dam II. The water at Kankoma dambo (MMD1 KAN) and Kovuma dambo (MMD2 KO) however, were found to pose a slight acute hazard (Class II).

The levels of bacterial growth inhibition were low at all sites, with the exception of MMD1 KAN and MMD2 KO, where bacterial growth inhibition is above 20%. Low levels of algal stimulation were evident at all sites. Low mortality rates of *D. magna*, which represents the macro-invertebrate community, were evident at MML1, MMDR and MMD2 KO. Low mortality rates of *P. retuculata*, which represents the fish community, have also been recorded at MML1 and MML4. This is supported by the metal analysis results that indicate a guideline exceedance in the lead (Pb) concentration measured in *O. lidole* from MML1 and the chromium (Cr) concentration measured in both *A. calliptera* and *O. lidole* from MML1 and in *O. lidole* from MML4 (see also section 5.9.9).

Since the previous wet season assessment in April 2017, the toxicological hazard has improved from a slight acute hazard (Class II) condition to a no acute hazard (Class I) condition at MML1, from an acute hazard (Class III) condition to a no acute hazard (Class I) condition at MML2 and MML3 and from a high acute hazard (Class IV) condition to a no acute hazard (Class I) condition at MMDR during the current assessment. The toxicological hazard has remained in a slight acute hazard (Class II) condition at MMD1 KAN and MMD2 KO.

5.9.7 Fish Community Integrity

5.9.7.1 Fish Habitat Assessment

The fish habitat assessment evaluates the potential of habitat at a given site to provide suitable conditions for a fish species to occur there. This provides a framework within which the presence, absence and frequency of occurrence of species can be interpreted. The assessment was carried out by evaluating the habitat according to the diversity of the velocity-depth classes and the presence of various types of cover within each of these velocity-depth classes (GCS, 2019). Any impacts that may influence the habitat integrity for fish were also considered. The four velocity-depth classes assessed at each site are provided in Table 5.50, along with five cover classes.

Table 5.50: Velocity-Depth and Cover Classes

Velocity-Depth Classes	Cover Classes
Slow–Deep	Overhanging Vegetation
Slow–Shallow	Undercut Banks and Root Wads
Fast–Deep	Stream Substrate
Fast–Shallow	Aquatic Macrophytes
	Water Column

Notes: Slow: <0.3 m/s; Fast: >0.3 m/s; Shallow: <0.5 m; Deep: >0.5 m.

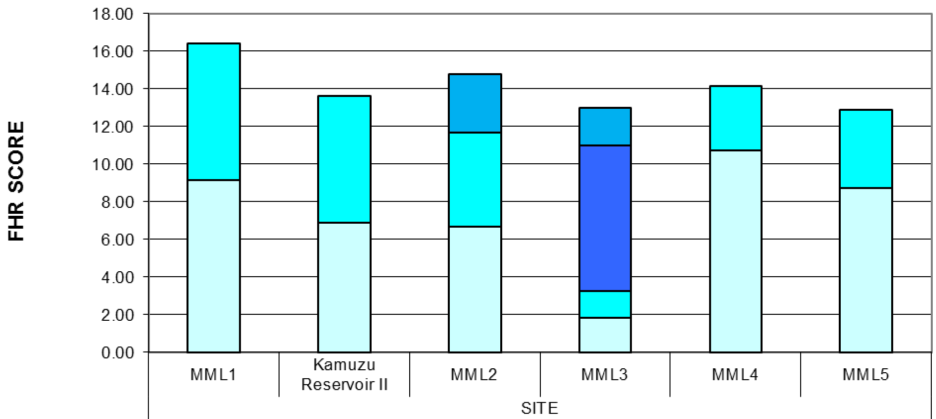
The relative abundance of these classes (adapted from Rankin, 1995 as cited in GCS, 2019) was rated at each site according to the scores provided in Table 5.51.

Table 5.51: Abundance Scoring of Velocity-Depth and Cover Classes

Descriptor	Occurrence (% of Area Covered)	Relative Abundance Score
None	0	0
Rare	0-5	1
Sparse	5-25	2
Common	25-75	3
Abundant	75-90	4
Very Abundant	90-100	5

The quantity and diversity of cover available for the fish community at each site was graphically expressed in a stacked bar chart as the fish habitat rating (FHR) for each velocity-depth class.

The FHR results from the February 2018 (high flow) survey are presented in Figure 5.16. This includes data from the upstream site MML1 on the Lilongwe River; the Kamuzu Dam; site MML2 on the Lisungwi River; and sites MML3, MML4 and MML5 on the Lilongwe River.



	MML1	Kamuzu Reservoir II	MML2	MML3	MML4	MML5
Fast – Shallow	0.00	0.00	3.11	2.00	0.0	0.0
Fast - Deep	0.00	0.00	0.00	7.73	0.0	0.0
Slow - Shallow	7.29	6.75	5.00	1.45	3.4	4.1
Slow - Deep	9.14	6.88	6.67	1.82	10.7	8.8

Figure 5.16: Quantity and Diversity Cover Available for Fish Community for each Velocity-Depth Class (Wet Season 2018)

In terms of the quantity and diversity of cover available for the fish community, it is evident that slow-deep conditions dominate at MML1, followed by slow-shallow conditions (Figure 5.16). The fish expected at the site are likely to be limited to fish with a high intolerance for fast-flowing water and to a much lesser degree, species with a high intolerance for shallow habitats. Cover in the form of overhanging vegetation, sandy stream substrate and undercut banks is common within the slow–deep velocity-depth class, along with sufficient water depth within the water column, decreasing the risk of aerial predation. Overhanging vegetation and aquatic macrophytes are abundant within the slow–shallow velocity-depth class, providing excellent cover for fish species, although the shallow water column within this class allows for some risk of aerial predation. The presence of the dam wall downstream of this point also presents a significant migration barrier to fish, thus limiting their movement to a large degree (GCS, 2019).

At the Kamuzu Dam II, slow–deep conditions also dominate, with the main form of cover for fish being the deep water column. Fish species with a high intolerance for fast-flowing water and very shallow habitats are therefore likely to occur within the reservoir. The slow–shallow velocity-depth class is common along the edges of the reservoir where an abundance of overhanging vegetation and aquatic macrophytes are available for cover. The water along the edges is approximately 1 m deep, affording more protection to fish species in relation to the shallower water at the edges of the system at MML1.

A greater diversity of cover is accessible to the fish community at MML2, with the availability of the fast–shallow velocity-depth class at this point, in addition to the slow–deep and slow–shallow classes (Figure 5.16). The fish expected in this area at the current time are likely to be limited to species with a high intolerance for very deep, fast-flowing water. Cover in the form of rocky stream substrate is available in high abundance within each of the velocity-depth classes present at this site, particularly within the fast-shallow and slow-shallow classes. Overhanging marginal vegetation is abundant within the slow-shallow and slow-deep classes, and common within the fast–shallow class, however, leafy vegetation is not available in the shallows, thus providing limited cover for fish at these points. Undercut banks and root wads are however very common within all classes which allows for good cover within this reach of the Lisungwi River. The depth of the water column within the slow-deep class also contributes to this cover.

Fast-deep conditions dominate at MML3, followed by fast-shallow, slow–deep and slow–shallow conditions in a few small areas, resulting from the presence of the road bridge pillars. Fish species with high intolerance values for shallow habitats and slow-flowing water are therefore likely to occur at this site. The most abundant type of cover available to fish at this site includes the water column and overhanging vegetation within the fast-deep velocity-depth class. Undercut banks are common within the fast-deep class providing some cover for fish. Rocky and sandy substrate is also considered good cover within the fast-deep class and to a lesser extent within the slow–deep, slow–shallow and fast–shallow classes as the size of the rocks appear to be smaller within these classes.

Site MML4 is dominated by slow–deep conditions within the main channel, followed by slow–shallow conditions within some areas along the banks of the system. Fish species with a high intolerance for fast–flowing water and very shallow habitats are likely to occur at this site. Abundant cover in the form of the deep water column and overhanging vegetation occurs within the slow–deep class, and to a lesser extent within the slow–shallow class. Undercut banks are common within both classes however, stream substrate cover is sparse at this site due to the lack of rocky substrate exposure. Similar conditions occur at MML5 in that the slow–deep velocity-depth class dominates at this point however, the slow-shallow class occurs over a larger area, which is due to the widening of the channel as a result of significant bank incision by livestock watering activities. As a result, the fish community expected to occur at this point are likely to have a high intolerance for very fast-flowing water. As with MML4, abundant cover occurs in the form of overhanging vegetation and the water column, although marginal vegetation is less abundant and the water depth is shallower within the slow-shallow class due to bank erosion and channel widening. As a result, undercut banks are more abundant within this class at MML4. Stream substrate cover is also sparse at this site due to the lack of rocky substrate exposure.

5.9.7.2 The Fish Response Assessment Index (FRAI)

The Fish Response Assessment Index (FRAI) developed by Kleynhans (2007) (cited in GCS, 2019) was used in determining the integrity of the fish community in the vicinity of the Project. The use of fish communities in the monitoring of aquatic ecosystems have been widely used to determine the overall condition of aquatic ecosystems.

Fish were sampled within the habitat available at each site using the electroshocking technique. Additional techniques were applied if necessary, including gill and cast netting. All fish sampled were identified and released back into the system if a sample was deemed unnecessary.

The FRAI is an assessment index based on the principle that the response of fish species to various stressors within an ecosystem will in turn lead to changes in the fish species assemblage from the reference condition. These stressors may result from changes in environmental habitat, physico-chemical water quality, hydrology or geomorphology within the ecosystem. The FRAI makes use of the fish intolerance and preference database that was compiled in 2001 (Kleynhans, 2003) and the Fish Reference Frequency of Occurrence (FROC) database compiled by Kleynhans *et al.* (2007) (as cited in GCS, 2019). These databases include reference data for freshwater fish species which are integrated into the FRAI. The index compares habitat preference, intolerance to habitat changes and present frequency of occurrence of a particular fish species to the reference frequency of occurrence in order to calculate the ecological category of the river reach.

As reference fish species lists for the Lilongwe River, including the Kamuzu Dam, and Lisungwi River system could not be derived from the FROC database nor was information on the frequency of occurrence of fish species within these systems available from existing literature, the data obtained during the 2018 wet season survey are to be utilised as reference values for future surveys.

5.9.7.3 Reference Conditions

As reference fish species lists could not be derived from the fish FROC database or existing literature, a baseline ecological category for fish could not be determined at this time. The reference fish community, along with the associated FRAI abbreviation code, relative abundance, determined FROC and FROC confidence value for each species is presented in Table 5.52.

The reference species list includes 15 indigenous fish species for the Lilongwe River system and five indigenous species for the Lisungwi River system. Reference species within the Lilongwe system include *Astatotilapia calliptera* (Eastern River Bream), *Chiloglanis neumanni* (Neumann's Rock Catlet), *Clarias gariepinus* (Sharptooth Catfish), various *Enteromius* species, including *E. choloensis* (Silver Barb*), E. kerstenii* (Redspot Barb), *E. macrotaenia* (Broadband Barb), *E. paludinosus* (Straightfin Barb), *E. toppini* (East Coast Barb) and *E. trimaculatus* (Threespot Barb); *Labeobarbus johnstonii* (Johnstonii Yellowfish), *Mastacembelus shiranus* (Malawi Spinyeel), *Opsaridium tweddleorum* (Dwarf Sanjika), *Oreochromis karongae* (Karonga tilapia), *Oreochromis lidole* (Lidole) and *Pseudocrenilabrus philander* (Southern Mouthbrooder). Reference species within the Lisungwi River system include *Chiloglanis neumanni*, *Clarias gariepinus*, *Labeobarbus johnstonii*, *Mastacembelus shiranus* and *Oreochromis lidole*.

Of these fish species, five are included in the FRAI index, namely, *Clarias gariepinus*, *Enteromius paludinosus*, *Enteromius toppini, Enteromius trimaculatus* and *Pseudocrenilabrus philander*. For those not included in the index, species of the same genus with similar preferences, tolerances and environmental requirements were used to represent these species in the index, with the exception *of Astatotilapia calliptera* as fish of the same genera are not available in the index. In this case, fish from the same family with similar preferences and tolerances was used to represent this species in the index (GCS, 2019). Therefore, *Astatotilapia calliptera* is represented by *Oreochromis placidus* (OPLA). In the case of the Longtail Spiny Eel, *Mastacembelus shiranus,* however, a representative of the same family is not available as the only family of eels that occur within the FRAI index are the Freshwater Eels, *Anguillidae*. These eels are of the same Class, *Actinopterygii*, commonly known as the Ray-Finned fishes, but are of a different order, namely the *Anguilliformes*, or Eels and Morays*. M. shiranus* belongs to the Order *Synbranchiformes*, or Spiny-Eels. As both eels are tropical, freshwater species with a tolerance for brackish water, similar preferences exist between the two. *M. shiranus* is therefore represented by *Anguilla mossambica* (AMOS), the Longfin Eel, in the index as this species also has a preference for flowing water within shallow, rocky substrate.

Table 5.52: Reference Fish Species List Derived during the February 2018 Wet Season (High Flow) for Lilongwe River

Species	FRAI Code	Relative Abundance*	Determined FROC**	Confidence[#]
Lilongwe River (incl. Kamuzu Dam)				
Astatotilapia calliptera	OPLA	2	4	5
Chiloglanis neumanni	CPAR	1	1	5
Clarias gariepinus	CGAR	1	2	4
Enteromius choloensis	BEUT	1	2	4
Enteromius kerstenii	BBRI	1	1	4
Enteromius macrotaenia	BRAD	2	2	4
Enteromius paludinosus	BPAU	2	2	4
Enteromius toppini	BTOP	2	2	4
Enteromius trimaculatus	BTRI	2	2	4
Labeobarbus johnstonii	BNAT	1	1	4
Mastacembelus shiranus	AMOS	1	3	4
Opsaridium tweddleorum	OPER	2	3	4
Oreochromis karongae	ONIL	2	2	4
Oreochromis lidole	OMOS	3	5	4
Pseudocrenilabrus philander	PPHI	1	1	3
Lisungwi River				
Chiloglanis neumanni	CPAR	2	1	3
Clarias gariepinus	CGAR	1	1	3
Labeobarbus johnstonii	BNAT	1	1	3
Mastacembelus shiranus	AMOS	2	1	3
Oreochromis lidole	OMOS	1	1	3

*Abundance: 1 = 1 to 5 fish / 2 = 6 to 50 fish / 3 = >50 fish
**FROC: 1 = 20% / 2 = 40% / 3 = 60% / 4 = 80% / 5 = 100%
[#]Confidence: 1 = Low / 2 = Low to Moderate / 3 = Moderate / 4 = Moderate to High / 5 = High

A. calliptera occurs in a wide variety of riverine and marshy habitats. The *Chiloglanis sp.* show high preferences for fast-flowing water with rocky substrate and *C. gariepinus* is completely omnivorous and has a high preference for slow-flowing water. Similarly, the *Enteromius* species prefer slow flows and have a high preference for overhanging vegetation, whereas *L. johnstonii* has a preference for moderate to fast-flowing water. *M. shiranus and O. tweddleorum* have a high affinity for shallow, rocky and sandy substrate. *O. karongae* and *O. lidole* were sampled in slow-shallow and slow-deep habitats indicating an affinity for slow-flowing water. *P. philander* has a preference for slow and shallow habitats, overhanging vegetation and undercut banks (GCS, 2019).

5.9.8 Mollusc Assessment

Lake Malawi is one of the major centres of endemism with regards to freshwater molluscs in Africa (Day and De Moor, 2002) as cited in GCS (2019). Within Lake Malawi, there are 27 species of freshwater gastropod fauna (univalves), 17 of which are endemic to the area. Of these 17 species, 15 are prosobranchs and 2 are pulmonates. With regards to freshwater bivalve fauna, eight species occur within Lake Malawi, three of which are endemic. Reference species lists for molluscs within the

Lilongwe River system, including the Kamuzu Dam, and the Lisungwi River, also could not be derived from existing literature as reference information is not available. Species within the family Mollusca were sampled within the biotopes available at each site using a net with a pore size of 1,000 micron. However, no species were available for sampling at MML2 on the Lisungwi River. The reference mollusc species list for the Lilongwe River reach and the Kovuma and Kankoma dambos is presented in Table 5.53, along with the respective common names or synonyms for each species (if applicable), the relative abundance, the determined FROC and the FROC confidence value.

Table 5.53: Reference Mollusc Species List Derived during the February 2018 Wet Season (High Flow) for Lilongwe River System and Dambos

Species	Comon Name / Synonym	Relative Abundance*	Determined FROC**	Confidence#
Lilongwe River (incl. Kamuzu Dam)				
Biomphalaria pfeifferi	Bloodfluke planorb	2	2	2
Bulinus globosus	*Physa globosus*	2	4	3
Chambardia wahlbergi	*Aspatharia wahlbergi*	1	1	2
Coelatura mossambicensis	N/A	1	2	3
Gyraulus connollyi	N/A	1	1	2
Lanistes ellipticus	N/A	1	2	2
Lymnaea natalensis	*Radix natalensis*	2	3	3
Dambos				
Bulinus globosus	*Physa globosus*	2	3	3

*Abundance: 1 = 1 to 5 molluscs / 2 = 6 to 50 molluscs / 3 = >50 molluscs
**FROC: 1 = 20% / 2 = 40% / 3 = 60% / 4 = 80% / 5 = 100%
#Confidence: 1 = Low / 2 = Low to Moderate / 3 = Moderate / 4 = Moderate to High / 5 = High

5.9.9 Metals Analysis

Two fish species, namely, *Astatotilapia calliptera* and *Oreochromis lidole*, were selected for baseline tissue metal analysis as a result of the occurrence of these species at most of the sites. Two specimens were collected from each site where possible, in order to obtain a mean metal concentration for each species occurring at each site to ensure greater accuracy in the results.

Bivalve molluscs (mussels) are sessile, filter-feeding organisms, able to accumulate within their tissues both organic and inorganic pollutants such as pesticides, hydrocarbons, metals, etc. present in the water and have therefore also been sampled. As live bivalves were found to be sparse in the area during the time of assessment, only one sample could be analysed.

In addition, sediment was sampled from the Kamuzu Dam II and analysed in order to provide an indication of metal concentrations within the sediment of the reservoir as it is likely to be one of the first receptors of potential contamination in terms of aquatic ecosystems.

Benthic and other sediment-associated organisms may be negatively affected by these metals in both a lethal and sublethal manner. This in turn, directly or indirectly, affects other species such as fish, wildlife and humans by direct consumption or bioaccumulation through the food chain (US EPA, 2001).

The metal concentrations within the fish and mollusc tissue samples were evaluated against the Quality Guidelines for Human Consumption (EU, 2006) and the Median International Standards for Trace Elements (CEPA, 2000 and FAO, 1983). The concentrations within the sediment sample were evaluated against the Sediment Quality Guidelines (consensus-based) by MacDonald *et al*. (2000), the Canadian Council of Ministers of the Environment (CCME, 2001) and US EPA (2006).

Results of the baseline metal concentrations within the sediment sampled from the Kamuzu Dam are presented in Table 5.54.

Table 5.54: Metal Analysis Results in Sediment Sampled from the Kamuzu Dam

Metal	Guideline Value (mg/kg)	Sediment Sample (mg/kg)
		Kamuzu Dam
Aluminium	-	53,294.8
Arsenic	9.79 (US EPA, 2006; MacDonald *et al*., 2000) and 5.9 (CCME, 2001)	1.6
Chromium	43.4 (US EPA, 2006; MacDonald *et al*., 2000) and 37.3 (CCME, 2001)	328.4
Copper	31.6 (US EPA, 2006; MacDonald *et al*., 2000) and 35.7 (CCME, 2001)	79.5
Iron	20,000 (US EPA,2006)	73,250.50
Manganese	460 (US EPA, 2006)	1,234.9
Lead	35.8 (US EPA, 2006; MacDonald et al., 2000) and 35 (CCME, 2001)	5.99

Chromium, copper and manganese exceeded the relevant guideline values, indicating an impact may be occurring from existing sources or activities in the catchment area.

Results of the baseline metal concentrations within the native bivalve mollusc, *Coelatura mossambicensis*, sampled from MML4 are presented in Table 5.55, and indicate none of the guideline concentration values were exceeded in the sample.

Table 5.55: Metal Analysis Results in Bivalve Mollusc Sampled from the Lilongwe River

Metal	Guideline Value* (mg/kg)	Mollusc Sample (mg/kg)
		MML4
Aluminium	-	53.34
Arsenic	1.4	0.03
Chromium	1	0.06
Copper	20	0.63
Iron	-	58.03
Manganese	-	6.1
Lead	1.5** and 2	0.02
Selenium	0.3	0.16

Note: * All guidelines values from CEPA (2000) and FAO (1983)
** Guideline value of 0.3 from EU (2006)

The results of the baseline metal analysis conducted on whole fish tissue samples of *Astatotilapia calliptera* from Sites MML1, MML2, MML3, MML4 and the Kamuzu Dam II, and *Oreochromis lidole* from Sites MML1, MML4 and the Kamuzu Dam are indicated in Table 5.56.

Lead (Pb) concentration measured in *O. lidole* from MML1 exceeded the EU Guideline Levels (2006). In addition, the chromium (Cr) concentration guideline level (CEPA, 2000 and FAO, 1983) was exceeded in both *A. calliptera* and *O. lidole* from MML1 and in *O. lidole* from MML4. This suggests that some impact may have been occurring from existing sources or activities at these points during the survey.

Table 5.56: Baseline Metal Analysis Results of Whole Fish Tissue Sampled

Metal	Guideline Value* (mg/kg)	Sample								
		MML1		MML2	MML3	MML4			Kamuzu Dam	
		Astatotilapia calliptera	*Oreochromis lidole*	*Astatotilapia calliptera*	*Astatotilapia calliptera*	*Astatotilapia calliptera*	*Oreochromis lidole*	*Coelatura mossambicensus*	*Astatotilapia calliptera*	*Oreochromis lidole*
Aluminium	-	1,716.70	7,175.20	45.98	229.64	301.53	1,666.29	53.34	33.83	74.86
Arsenic	1.5	0.29	0.81	0.05	0.14	0.28	0.24	0.03	0.04	0.07
Chromium	1	1.66	4.18	0.25	0.63	0.31	11.37	0.06	0.04	0.02
Copper	20	2.08	9.58	1.09	0.89	2.36	1.63	0.63	0.61	1.62
Iron	-	1,627.60	6,864.80	100.43	259.37	373.87	1,458.10	58.03	76.05	127.69
Manganese	-	59.19	186.1	29.63	98.19	407.82	66.9	6.1	17.02	37.32
Lead	0.3** and 2	0.28	1.29	0.04	0.04	0.06	0.26	0.02	0	0.14
Selenium	2	0.62	0.34	0.65	0.31	0.09	0.82	0.16	0.37	0.36

Note: * All guidelines values from CEPA (2000) and FAO (1983)
** Guideline value of 0.3 from EU (2006)

5.10 Surface Water

5.10.1 Catchment Areas

Malawi's drainage system is divided into 17 Water Resources Areas (WRAs), which are subdivided into 78 Water Resources Units (WRUs).

The Project area is situated within the designated Linthipe Water Resources Area (WRA 4) with a catchment area totalling 8,885 km^2. The Linthipe WRA comprises a number of river basin WRUs. The Project is located in the Lilongwe WRU (4D) with a sub-catchment area totalling 1,615 km^2 (Figure 5.17).

Sub-catchments in the Project area are indicated in Figure 5.18.

5.10.2 Rivers, Streams and Dams

The Lilongwe River borders the southern and eastern sides of the Project site. The Lilongwe River flows eastwards into the Kamuzu Dam and from the dam flows northeast to the City of Lilongwe (refer Figure 1.1 and Figure 5.1).

The Kamuzu Dam is located directly to the south of the Project on the Lilongwe river and is divided into Kamuzu Dam I and Kamuzu Dam II. The Kamuzu Dam (through the Lilongwe River) is the main supply of water to the City of Lilongwe. The 18 m high Kamuzu Dam I has a storage capacity of approximately 5.2 Mm^3. The 24 m high Kamuzu Dam II has a storage capacity of approximately 19 Mm^3.

The two dams have a combined catchment area of approximately 1,870 km^2 and act as water balancing reservoirs for the Lilongwe River. The Project infrastructure covers less than 2% of this area.

5.10.3 Surface Water Uses

Existing surface water uses in and around the Project area include:

- Drinking water – it is understood that occasionally people drink water from Kamuzu Dam II and the Lilongwe River, although the majority of the villages in the area have hand pumped wells which represents their source of drinking water.
- Fishing – several people were observed fishing in the Kamuzu Dam during field surveys.
- Washing – local communities were observed washing clothes in the Lilongwe River.
- Recreation – several people were observed swimming and bathing in Kamuzu Dam II, close to the Kamuzu Dam II spillway at Malingunde bridge.
- Livestock watering – cattle and goats drink from the dambos and the Lilongwe River (SLR, 2019a).

5.10.4 Surface Water Quality

Surface water quality sampling has been undertaken by Sovereign since April 2017 to establish a baseline profile of the surface water quality in the Project area, and is ongoing. Since 2018 sampling has been undertaken approximately every quarter.

The sample collection points include dambos, the Lilongwe River and the Kamuzu Dam at locations upstream and downstream of the Project, and are shown in Table 5.57 and Figure 5.19.

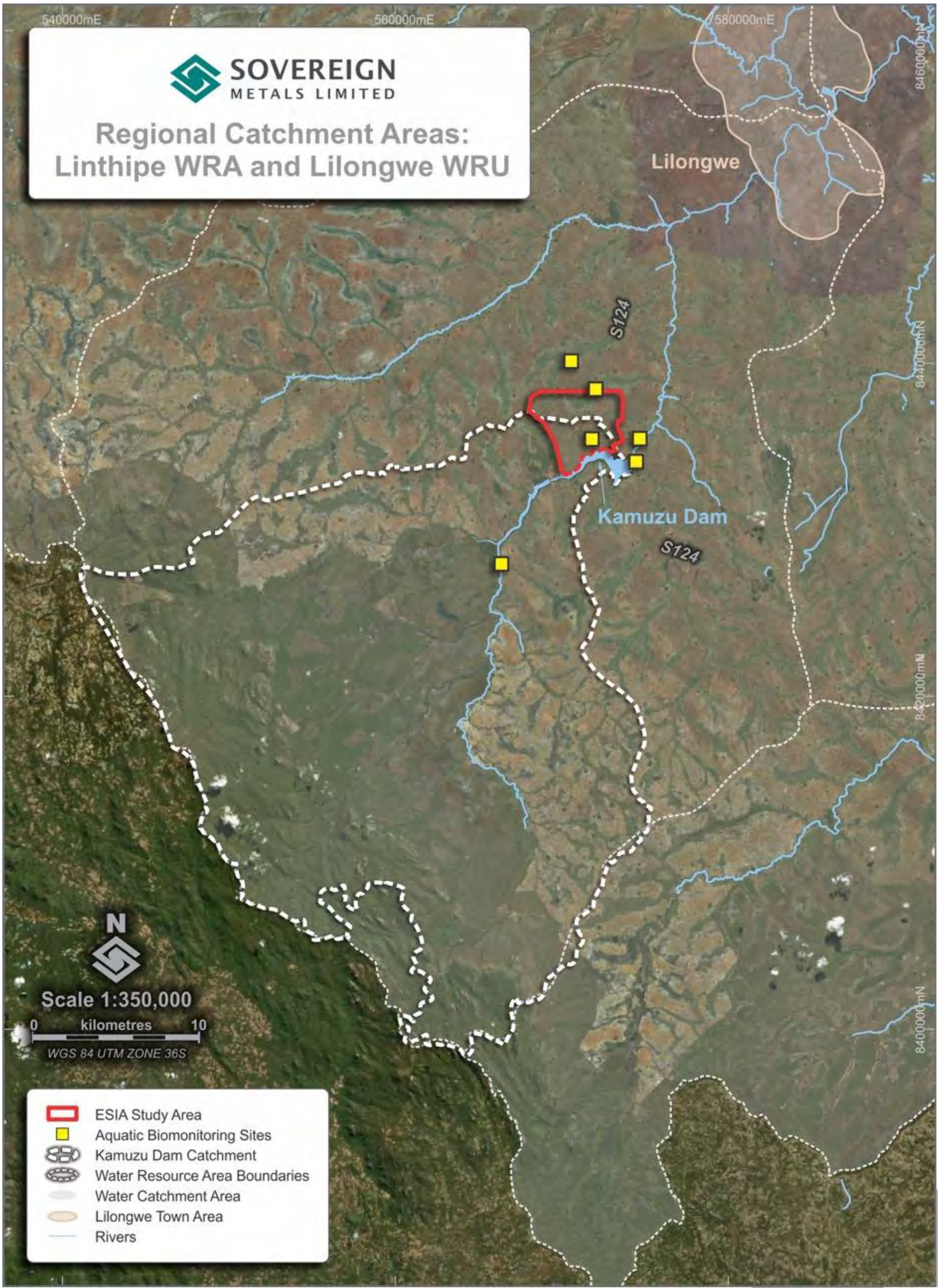


Figure 5.17: Regional Catchment Areas: Linthipe WRA and Lilongwe WRU

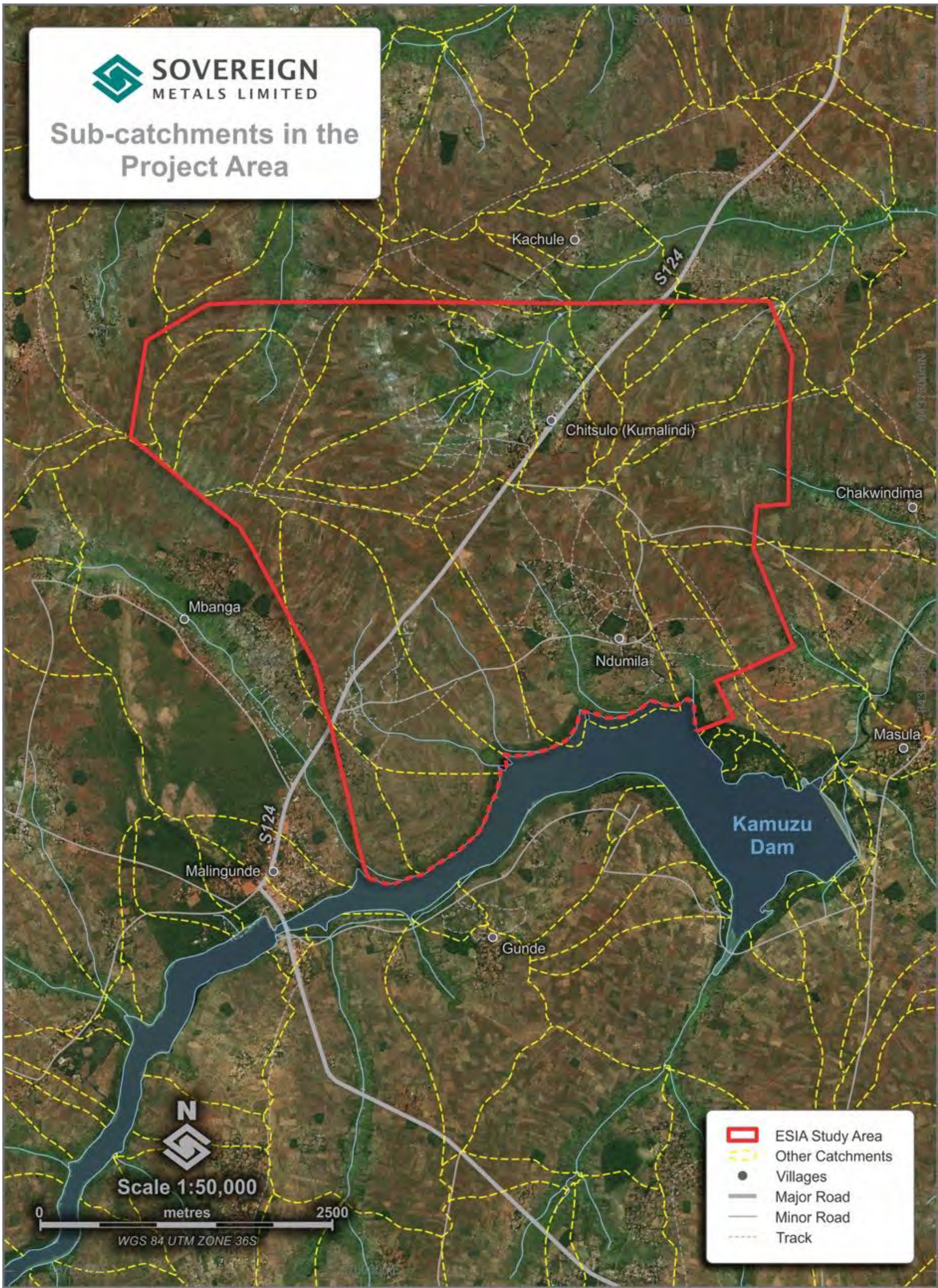


Figure 5.18: Sub-catchments of the Project Area

Table 5.57: Surface Water Sampling Locations

Site Identification	Coordinates UTM 36S		Description
	X	Y	
MMST1	571796	8435449	Located on Dambo 1 (refer section 5.7.1) to the west of the open pits, draining towards the Kamuzu Dam.
KZ1	569291	8432780	Located upstream of the Project at Kamuzu Dam I spillway.
KZ2	571398	8434442	Located upstream of the Project at Kamuzu Dam II, before Dambo 1.
KZ4	573794	8438206	At Kamuzu Dam II outlfow.
KZ5	574717	8435445	On the Lilongwe River downstream from Kamuzu Dam, after inflow from a feeder tributary from south (unaffected catchment).
SWQ1	569744	8440059	At Kankoma dambo north of the Project (outside the affected catchments).
SWQ2	568843	8440065	At Kankoma dambo north of the Project (outside the affected catchments).
SWQ3	572018	8438441	At Kovuma dambo, north of TSF.
SWQ4	574766	8436351	On unnamed dambo/drainage line feeding the Lilongwe River, southeast of the TSF.
SWQ5	575770	8438956	Downstream on Kovuma dambo before confluence with the Lilongwe River.
SWQ6	574530	8443383	Downstream of SWQ1 and SWQ2 on Kankoma before confluence with Lilongwe River.
SWQ7	576746	8444986	Most downstream site on the Lilongwe River, outside of Project area.
SWQ8	576671	8443951	Downstream location on the Lilongwe before the confluence with Kankoma dambo.
SWQ9	576104	8438352	Upstream of the confluence between the Lilongwe River and Kovuma dambo.
SWQ10	576293	8439001	Lilongwe River downstream of the confluence with Kovuma dambo.

Samples were analysed by an accredited laboratory, WaterLab, in South Africa. The results of the analyses are detailed in Appendix J.

The results were compared against the following guidelines:

- WHO Guidelines for Drinking Water Quality (WHO, 2017).
- Malawi Drinking Water Specification - Malawi Standard (MS214:2005).
- IFC Mining Effluent Guidelines, 2007.

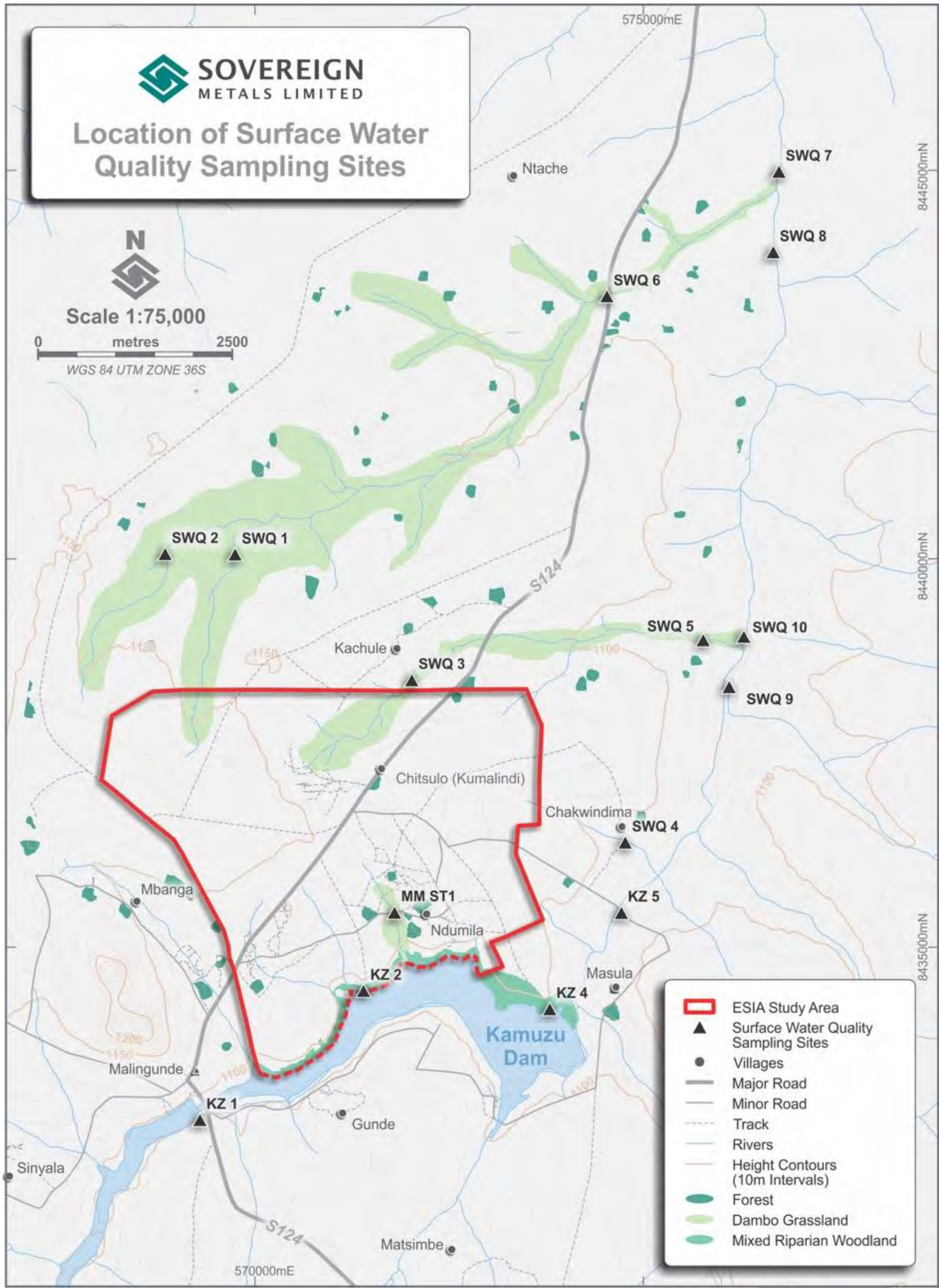


Figure 5.19: Location of Surface Water Quality Sampling Sites

5.10.4.1 *Surface Water Quality Results*

During the wet season sampling in October 2017 and February 2018, the results of most of the parameters assessed were within all three guidelines, with the exception of turbidity, aluminium, iron, manganese and antimony. Of all the sites, MMST1 and SWQ3 had the highest concentration for the parameters exceeding standards.

During the May and September 2018 sample run, most parameters were within all three guidelines, except for a few sites which exceeded guidelines for iron, faecal coliform, aluminium, manganese and zinc.

When comparing the sites sampled in both the wet seasons (April 2017 and February 2018) and dry seasons (October 2017, May 2018 and September 2018) there are more parameters exceeding one or more standards (any of the three) in the wet season than in the dry season. This difference can be attributed to the rains in the wet season washing away/ mobilising/ diffusing polluted material to the surface water resources sampled (SLR, 2019a; refer Appendix K).

- pH

pH levels below the guideline levels were observed at sites MMST1 during the wet season (October 2017 and February 2018) and during the dry season (May 2018). As indicated in Section 5.9.1.1, these lowered pH levels may possibly be due to the nitrification of ammonium (conversion of ammonium to nitrate in soils by bacteria) as a result of the use of fertilizers containing ammonium such as urea, which is one of the fertilizers that is likely being applied to the agricultural lands in the vicinity of the sites (GCS, 2018).

- Turbidity

All of the samples showed elevated turbidity above the MS214 drinking water specifications during the wet season sampling, which can be attributed to extensive susistence farming resulting in natural vegetation coverage being stripped and large areas of soils exposed (SLR, 2019a). The large areas of exposed soils result in easily erodible soil surfaces in the catchments which flow to the water resources which were sampled. Turbidity can also be attributed to inorganic parameters i.e. aluminium, iron and manganese levels, which also exceeded all three guidelines.

- Aluminium

The elevated aluminium, iron and manganese levels can also be attributed to the natural prevalence of these elements which are abundant in natural soils (WHO, 2017).

Aluminium exceeded the Malawi Drinking Water Specification and the WHO Guidelines at most of the sites, particularly during the wet season sampling in April 2017.

- Iron

Iron exceeds the Malawi Drinking Water Specification and the IFC Mining Effluent Guidelines at most of the sites, with all sites exceeding the MS Drinking Water Specification in the February 2018 sample run.

During the dry season sampling (October 2017, May 2018 and September 2018) all samples, except KZ4 and SWQ5, exceeded the Malawi Drinking Water Specification for iron.

- Manganese

Manganese exceeded the Malawi Drinking Water Specification and the WHO Guidelines at almost all of the sites, noticeably so during the February 2018 (wet season) survey.

- Sulfate

Only SWQ1 exceeded the Malawi Drinking Water Specification for sulfate during the wet season (February 2018) sampling run. At SWQ6, downstream on the same dambos as SWQ1, a high sulfate level was also recorded, although not exceeding the Malawi Drinking Water Specification. The high sulfate levels are not recorded at any other sites located in the area, therefore, the source of sulfate can potentially be attributed to anthropogenic sources or farming methods.

- Total Suspended Solids

Total suspended solids (TSS) exceeded the IFC Mining Effluent Guidelines during the dry season sampling in October 2017, May 2018 and September 2018, for the location MMST1. Furthermore, at SWQ3, the TSS exceeded the IFC Guidelines in September 2018, which can be attributed to activities by the community, particularly preparation of land for the coming wet season (SLR, 2019a).

- Antimony

Antimony concentrations were elevated at all sites during the October 2017 sampling period, but not during April 2017, which exceeded the WHO Guidelines. Considering that antimony was not recorded again at elevated levels in surface water at the same sites, these levels could be attributed to potential sample contamination.

5.11 Groundwater

5.11.1 Hydrogeological Units

The hydrogeological units identified in the Project area are described in the groundwater specialist report by SLR (2019b), as attached in Appendix L as follows:

- Saprolite: The saprolite unit is formed by silty clays with poor hydraulic conductivities; the Saprolite is considered to be an aquitard; this can store large volumes of groundwater, but restricts groundwater flow (poor inter-pores connectivity).
- Saprock: The saprock represents one of the aquifers and consists of a mixture of weathered basement and saprolite; the permeability of the units is higher than the saprolite and provides a reasonable water resource in the area.
- Weathered basement: The weathered basement constitutes the main aquifer at Malingunde and is represented by weathered basement; as the fresh rock of Malingunde basement is considered impermeable, the groundwater accumulates into the pores of the weathered rock on the top of the fresh rock surface; the weathered basement is a good target for water supply boreholes.

5.11.2 Groundwater Levels

Goundwater levels were measured as part of the groundwater quality sampling that has been undertaken by Sovereign since early 2017. Figure 5.20 shows the interpreted groundwater level contours over the Malingunde Project area (SLR, 2019b). Generally, the water levels vary from 0 m in zones of low elevations to 30 meters below ground level (mbgl) in zones with higher elevations. In the proposed mine area, the groundwater levels are between 6 and 14 mbgl.

Analysis of data collected during the groundwater quality sampling indicate that the water levels below ground level, for the majority of the boreholes, decreased slightly during the dry season.

Figure 5.20: Interpreted Groundwater Levels at Malingunde

5.11.3 Groundwater Quality

Groundwater quality sampling has been undertaken by Sovereign since April 2017 to establish a baseline profile of the groundwater quality in the Project area, and is ongoing. Since 2018 sampling has been undertaken approximately every quarter. Sample collection points are shown in Figure 5.21.

Samples were analysed by an accredited laboratory, WaterLab, in South Africa. The results of the analysis are detailed in Appendix M.

The results were compared against the following guidelines:

- WHO Guidelines for Drinking Water Quality (WHO, 2017).
- Malawi Drinking Water Specification - Malawi Standard (MS214:2005).
- IFC Mining Effluent Guidelines (IFC, 2007).

5.11.3.1 Groundwater Quality Results

Most of the parameters assessed on all samples are within all three sets of guidelines, with the exception of the following (SLR, 2019b):

- Total suspended solids (TSS) (19% of samples).
- Nitrate (NO_3) (2% of samples).
- Faecal coliform (35% of samples).
- Aluminium (Al) (32% of samples).
- Iron (Fe) (51% of samples).
- Manganese (Mn) (57% of samples).
- Antimony (Sb) (14% of samples).
- Lead (Pb) (4% of samples).
- Zinc (Zn) (3% of samples).

- Aluminium, Iron and Manganese

Aluminium exceeded the Malawi Drinking Water Specification and the WHO Guidelines at most of the sites in the wet and dry seasons.

Iron exceeded the Malawi Drinking Water Specification at most of the sites during the wet and dry season. The IFC Mining Effluent Guideline for iron is exceeded mostly on sites located to the south of the proposed TSF (MMCW005, DD3, MMCW001 and MG-GW-01).

Manganese exceeded the Malawi Drinking Water Specification at most of the sites with the highest concentrations measured in MG-GW-08 and MG-GW-10 located north of the proposed TSF. At a number of sites the WHO Guidelines were also exceeded.

The elevated aluminium, iron and manganese levels can be attributed to natural prevalence as these elements are abundant metallic elements in natural soils (WHO, 2017). As the water samples were not filtered in the field, the elevated concentrations may also be attributed to colloidal material in the water sample.

- Nitrate

The concentrations of nitrate (NO_3) measured in the groundwater exceeded the Malawi Drinking Water Specification in two samples located to the south of the proposed TSF (DD2 and MMCW004) during the first monitoring event undertaken in April 2017, just after the wet season. The NO_3 concentration has since then not exceeded the guideline values.

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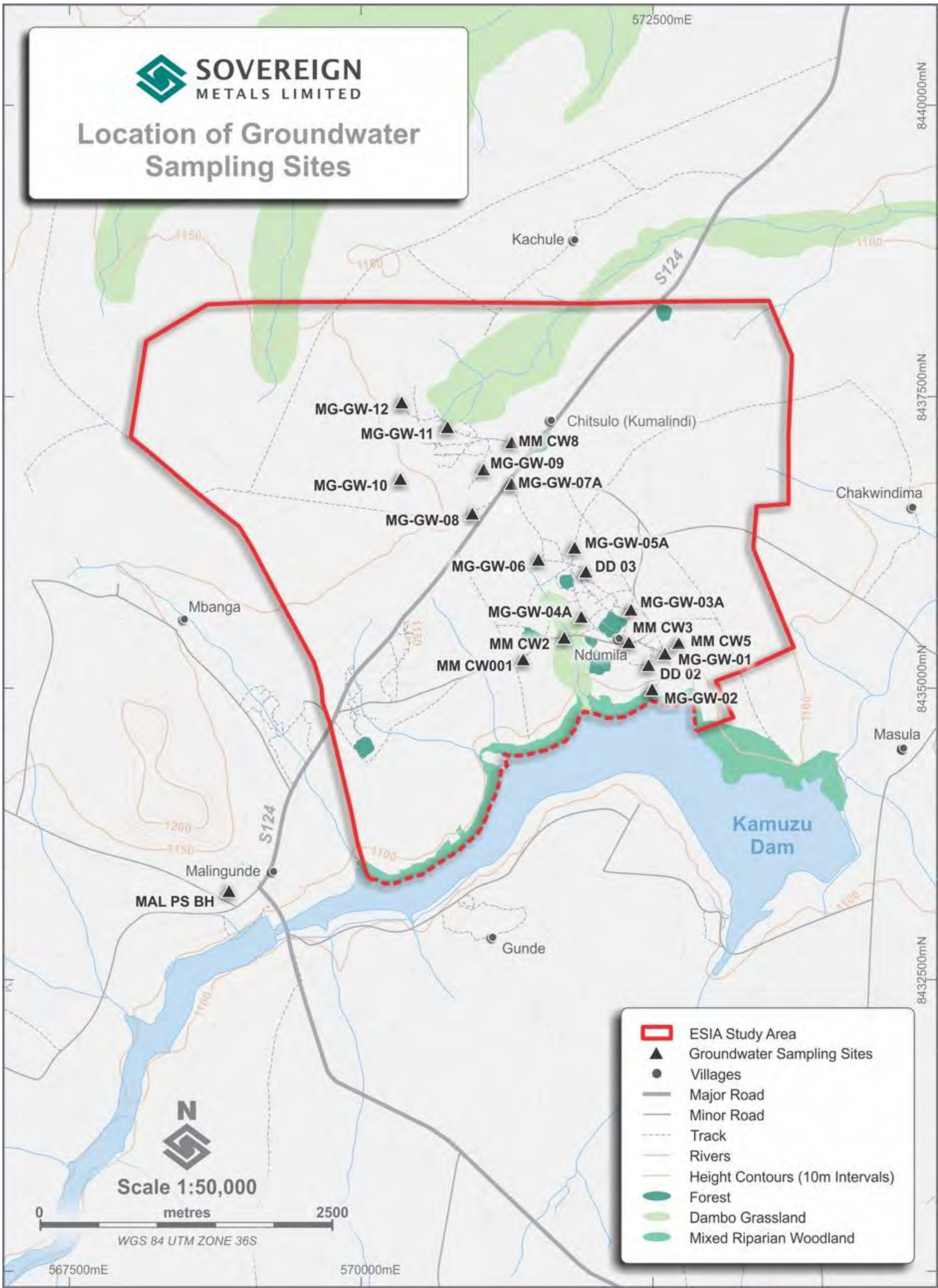


Figure 5.21: Location of Groundwater Quality Sampling Sites

- Lead

The lead concentration in the majority of the sampling locations has remained below the Malawian Standard Drinking Water Specification and WHO Guidelines during the monitoring period. Exceedances of the guideline values in boreholes located north of the proposed TSF were detected during two of the monitoring events. Concentrations measured during the September 2018 monitoring campaign were all below the guideline values.

- Antimony

Elevated antinomy levels were recorded in October 2017at all the groundwater monitoring sites, exceeding the WHO Guidelines, and similarly were recorded in the surface water (SLR, 2019a). Considering that antimony was not recorded again at elevated levels in ground or surface water at the same sites, these levels could be attributed to potential sample contamination.

- Zinc

Zinc concentrations exceeding the IFC Mining Effluent Guideline value was measured in DD3, MMCW004 and MMCW008 during the October 2017 monitoring event. Subsequent analysis results were all at least one order of magnitude below this guideline value.

- Suspended Solids

The concentrations of total suspended solids (TSS) exceeded the IFC Mining Effluent Guideline value at three monitoring locations south of the proposed TSF (MMCW001, MMCW005 and MMCW006). During the monitoring event undertaken at the end of the dry season (September 2018) six monitoring points indicated exceedances of the guideline value.

5.12 Air Quality

Monitoring of background air quality was undertaken between December 2017 and July 2018 as part of the air quality impact assessment by Digby Wells (2019a; refer Appendix N). Baseline monitoring was undertaken in respect of:

- Particulate matter (PM) – particulate matter with aerodynamic diameter greater than 30 micron, known as total suspended particulate (TSP), as well as particulate matter with aerodynamic diameter less than 10 micron and 2.5 micron (PM_{10} and $PM_{2.5}$).
- Gases – benzene, toluene, ethyl-benzene and xylene (BTEX), sulfur dioxide (SO_2), nitrogen dioxide (NO_2) and carbon monoxide (CO).

The monitoring locations are indicated in Figure 5.22 and are labeled SML01 to SML07 (dust), BTEX (Malingunde and BKGD) and AQ-Mesh (real-time monitor that measures PM_{10}, $PM_{2.5}$. NO_2, SO_2 and CO simultaneously).

5.12.1 Particulate Matter

5.12.1.1 Dust Fallout

Dust fallout was measured at various sites following the methodology prescribed in *ASTM D1739-98 (2010) – Standard Test Method for Collection and Measurement of Dust Fallout (Settleable Particulate Matter)* and adopted in South Africa, as no Malawi-specific guidelines or standards in this respect currently exist. The selection of sampling sites was in accordance with the guideline, which stipulates monitoring at a nearby sensitive receptor along with sites covering the main compass points around the ESIA study area.

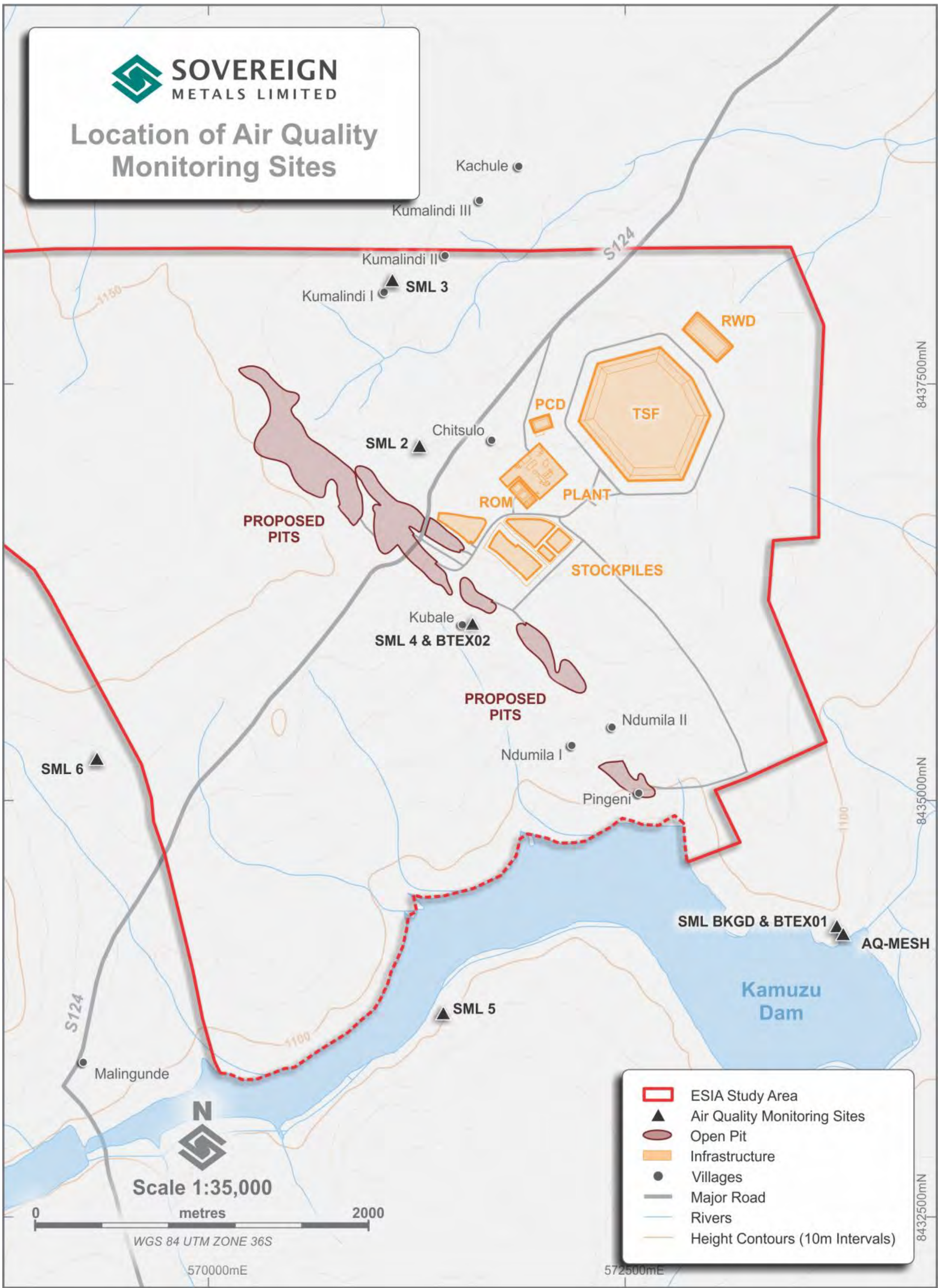
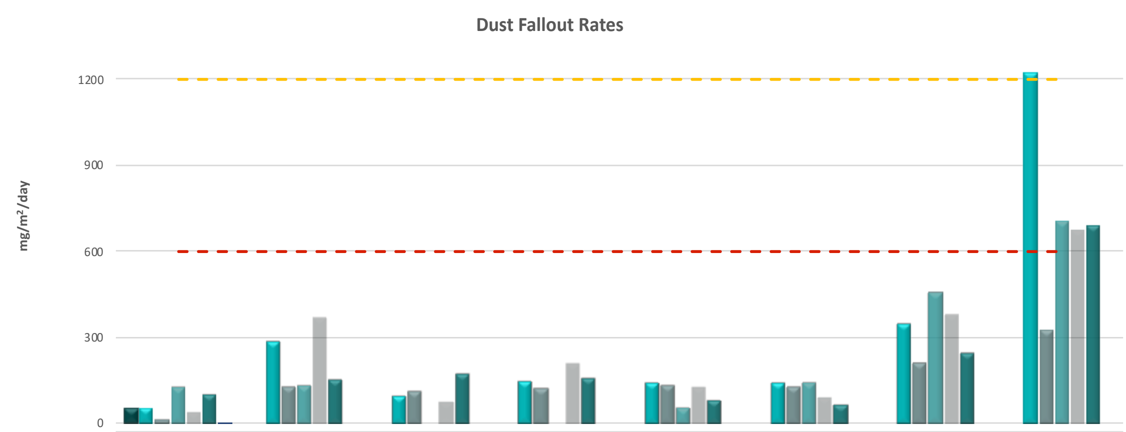


Figure 5.22: Location of Air Quality Monitoring Sites

The dust deposition rates measured in the ESIA study area for the months of December 2017 to July 2018 are presented in Figure 5.23. These results were analysed and compared with the South African National Dust Control Standard which provides standards for residential and non-residential areas.

Deposition rates measured were below the recommended residential limit of 600 mg/m²/day until June 2018. In July, which is in the middle of the dry season, four sites out of a total of five with data exceeded the residential limit. The red dotted line represents the limit below which the dust fallout levels are permissible for residential areas. The yellow dotted line represents the limit below which the dust fallout levels are permissible for non-residential areas.



	Dec-17	Jan-18	Feb-18	Mar-18	Apr-18	May-18	Jun-18	Jul-18
SML 01	50							
SML 02	56	284	98	149	141	143	346	1219
SML 03	14	127	110	124	131	125	209	323
SML 04	128	131			54	141	454	700
SML 05	40	366	77	207	127	93	378	672
SML 06	103	150	173	155	79	64	246	684
SML 07	2							
Residential limit	600	600	600	600	600	600	600	600
Industrial limit	1200	1200	1200	1200	1200	1200	1200	1200

Figure 5.23: Dust Fallout Rates at Sampling Locations

5.12.1.2 PM_{10}/$PM_{2.5}$ Concentration

A representative monitoring site was selected near the Kamuzu Dam II wall, where the real-time particulate monitor (AQ-Mesh®) was installed, with capability to monitor PM_{10} and $PM_{2.5}$ simultaneously. In order to capture the ambient airborne particulate matter concentration in the ESIA study area, the instrument resolves pollutants concentrations into hourly and daily averaging periods (Digby Wells, 2019a).

Although the instrument was set up in February of 2018, it struggled to maintain connectivity due to the intermittent / complete loss of telecommunication signals. Connectivity was established in February/March, but was lost in April and only temporarily re-established again in August 2018 for a period of three weeks.

PM_{10} levels observed in the months of February and March 2018 were below the Malawi Standard for Ambient Air Quality (MS737:2005) value of 25 µg/m³, with only two exceedances observed. However, in August 2018, several exceedances were observed. In total, 156 days of data have been collected and exceedance of the MBS limit of 25 µg/m³ occured on 54 days.

The levels of $PM_{2.5}$ measured showed a similar signature. $PM_{2.5}$ levels were observed to be higher than the WHO Air Quality Guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide (2005) level of 25 µg/m³; no limit is provided for this averaging period in the Malawi Standard. These exceedances occurred in April and August 2018. In total, 26 exceedances of the $PM_{2.5}$ guideline was observed. The reason for the exceedances observed may be due to localised high wind episodes eroding fine particulate matter from open areas and unsealed roads in the area.

5.12.2 Gaseous Pollutants

5.12.2.1 BTEX

Radiello® cartridges for monitoring of BTEX were set up at two locations; one at a background site (Kamuzu Dam) with limited vehicle access, and the other within Ndumila village where substantial biomass burning takes place for cooking and through bush fires. BTEX levels measured will serve as baseline to future perturbation which will be compared for regulatory and compliance purposes.

Table 5.58 shows the results of the BTEX levels measured from January 2018 to May 2018. The results were compared to the US EPA Integrated Risk Information System (IRIS) inhalation reference concentration (RfC) guidelines (US EPA-IRIS RFC) in order to assess background levels. The ambient levels were within the guideline limits. The results confirm that exposure levels in the Project area are very low with negligible existing impact from ambient air quality. The BTEX levels measurements from the two sites were similar in concentration.

Table 5.58: BTEX Results from Ndumila and Kamuzu Dam

Sampling Period	Benzene (mg/m^3)		Toluene (mg/m^3)		Ethyl-benzene (mg/m^3)		Xylene (mg/m^3)	
	Kamuzu	Ndumila	Kamuzu	Ndumila	Kamuzu	Ndumila	Kamuzu	Ndumila
January 2018	0.0018	0.0018	0.0006	0.0005	0.0010	0.0010	0.0006	0.0006
February 2018	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
March 2018	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
April 2018	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
May 2018	0.0008	0.0006	0.0006	0.0006	0.0001	0.0001	0.0003	0.0003
US EPA IRIS Limits (mg/m^3)	**0.03**	**0.3**	**1**	**1**	**5**	**5**	**0.1**	**0.1**

5.12.2.2 NO_2, SO_2 and CO

NO_2, SO_2 and CO were measured using the same AQ-Mesh® equipment as particulate matter. The instrument was scheduled to monitor ambient levels continuously, but malfunctioned due to loss of internet connectivity which the instrument strongly relied on to transmit data to the server.

The ambient NO_2 concentrations measured are very low compared to the Malawi Guideline 1-hour limit of 230 $\mu g/m^3$. In August 2018 connectivity was established again and the instrument sampled for a period of three weeks. The concentrations measured were shown to be lower than the Malawi Guideline limit, with no exceedance observed. These records will serve as baseline to which future measurements can be compared with to assess impacts and compliance (Digby Wells, 2019a).

The 24-hour SO_2 ambient concentrations were very low and below the Malawi Guideline limit of 210 $\mu g/m^3$. In total, six exceedances were measured during the month of August, otherwise ambient concentrations were often below the Malawi Guideline limit. Although the activities taking place on that day could not be verified, it is thought that the traffic volume may have been higher on those days, leading to the high concentrations of SO_2 measured.

The 8-hour CO levels measured from the month of February to December 2018, were below the Malawi Guideline limit of 10,310 $\mu g/m^3$.

5.13 Noise

Existing ambient noise levels in and around the Project area were measuerd during the dry season in May 2018, as part of the noise impact assessment by dBAcoustics (2019). Measurements were taken in accordance with ISO 1996:2003, BS 4142 using a digital Larson Davis 831 – Class 1 meter with Logging, Environmental 1/1, 1/3 Octave Band and percentiles Sound Level Meter (Class 1). On taking measurements the device-meter scale was set to the "A"-weighted measurement scale which enables the device to respond in the same manner as the human ear.

As there are currently no Malawi-specific standards in respect of noise surveys, this survey was performed in accordance with the South African National Standard (SANS) 10103 of 2008 recommended method for evaluating the environmental noise impact on surrounding communities with respect to annoyance: "*The measurement and rating of environmental noise with respect to land use, health, annoyance and speech communication (SANS 10103:2008)*".

The measuring points for the study area were selected to be representative of the prevailing ambient noise levels for the area and included all the noise sources such as distant traffic noise, domestic and agricultural activities, but excluded traffic noise, which was intermittent in the vicinity of the measuring point at the time of the survey. The measuring points are illustrated in Figure 5.24.

Existing noise in the area was largely as a result of; intermittent traffic noise from the gravel roads, domestic activities, subsistence farming activities, insects, birds and wind noise.

The Malawi Standard for Acoustics – Noise Pollution Tolerance Limits (MS 173:2005) details the maximum day-time and night-time noise levels permissible in Malawi (Table 5.59). These standards were used as benchmark levels to evaluate the existing ambient noise, as well as projected noise levels, at the different receptors near the Project.

Table 5.59: Maximimum Permissible Noise Levels - MS173:2005

Area Category	Limit in dB (Maximum Level)	
	Day-time	Night-time
Industrial zone	75	70
Commercial zone	65	55
Residential zone	55	45
Silence zone*	50	40

Note: *Silence zones generally apply to churches, hospitals, etc.

The results of the environmental noise survey (Table 5.60) include all the noise sources currently in the area. L_{eq} is the average noise level for the specific measuring point over a period of time, the L_{max} is the maximum noise level and the L_{min} is the minimum noise level registered during the noise survey for the specific area expressed in dBA. It should be noted that it is practice to compare the L_{eq} to the noise limits as stipulated in Table 5.59, and not the L_{max}.

The existing noise levels did not exceed the limit values for residential areas at any site during the survey.

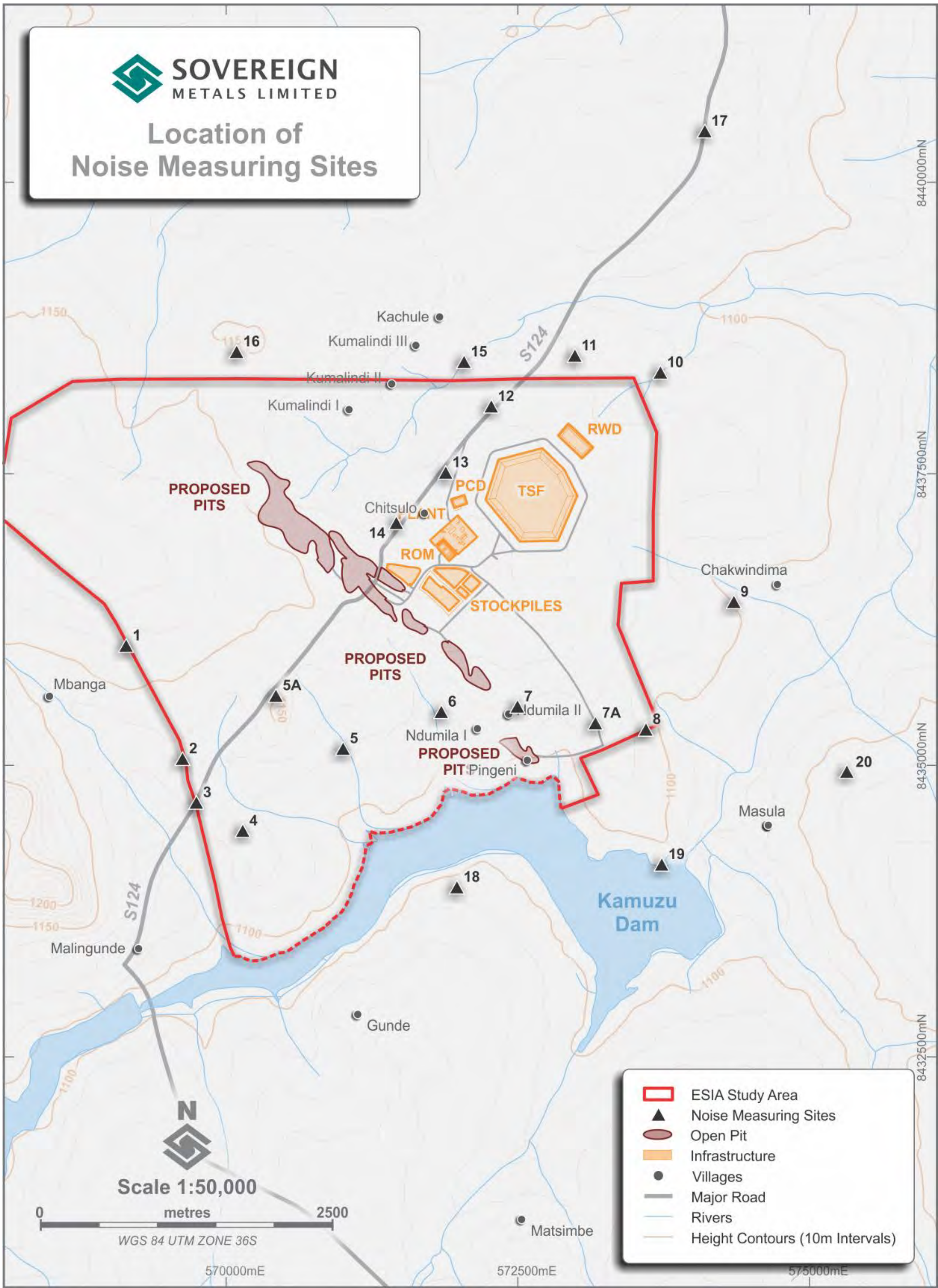


Figure 5.24: Location of Noise Measurement Points

Table 5.60: Measured Background Day and Night-time Noise Levels in the Project Area

Measuring Point	Day-time (dBA)			Night-time (dBA)		
	L_{eq}	L_{max}	L_{min}	L_{eq}	L_{max}	L_{min}
1	41.5	64.0	34.5			
2	44.1	76.8	29.7			
3	43.9	61.3	33.2	36.9	54.7	31.5
4	43.5	65.2	38.8	39.1	63.2	30.8
5	39.4	57.1	32.1			
5A	38.5	58.5	29.4			
6	40.1	59.8	29.6			
7	37.7	58.4	28.6			
7A	41.4	71.7	32.9	38.5	45.6	34.0
8	36.9	65.4	26.5			
9	36.9	55.3	28.4			
10	44.1	76.8	29.7			
11	48.3	70.0	33.7	43.3	46.5	40.6
12	43.5	63.4	30.9			
13	44.0	67.2	28.4	37.5	51.8	33.7
14	45.1	62.1	38.0	34.8	61.3	40.5
15	40.8	56.5	31.4			
16	39.2	68.5	29.9	44.1	57.3	38.1
17	54.7	75.4	30.8	42.6	60.3	38.9
18	48.3	70.0	33.7			
19	40.2	62.1	34.9			
20	36.4	57.0	25.8			

5.14 Archaeology and Cultural Heritage

The central region of Malawi, in which the Lilongwe district is located, is one of the culturally richest regions in the country that have yielded rare and important cultural heritage resources. This is due to its vast plains and perennial rivers that drained the area, thereby creating a conducive environment for human and animal habitation (PGS Heritage, 2019).

The archaeological records for the area have documented human evolution from the earlier to late Stone Age and also from early to late Iron Age. Slave trade and its abolition legacy are also embedded in the area. Studies through collaborative research projects sponsored by UNESCO and the Department of Antiquities have led to the discovery of rock paintings, and Stone Age and Iron Age sites. One notable discovery is Chongoni Rock Art World Heritage Site, which is situated on the same plains of the central region about 85 kilometres from the project area (PGS Heritage, 2019). Previous research in the plains that have yielded Stone Age to Iron Age materials, such as flake, pottery, beads and tuyere[8] pipes.

To ensure an accurate record of the archaeological and cultural heritage in the Project area is compiled, a cultural heritage impact assessment was undertaken in 2018 by PGS Heritage. Refer to Appendix O for a copy of the report.

[8] A tube or pipe usually made with clay, through which air is blown into a furnace or hearth. Air or oxygen is injected into a hearth under pressure from bellows or a blowing engine or other devices.

5.14.1 Msinja Sacred Cultural Landscape and Shrine

The most notable cultural feature in the Malingunde area is the living and vibrant *Msinja* cultural landscape with deep roots in the traditions of the local people who live within and around it. The Msinja cultural landscape and the associated traditional religious shrine is dated to as early as the 13th century when the *Chewa* arrived in this part of Africa (PGS Heritage, 2019). Msinja was a religious city which functioned as a centre of national worship for the *Chewa* people. It was the site of the great Rain Shrine of the Chewa tribe where sacrifices were offered for rain-making and thanks-giving during heavy harvest (Rangeley, 1952) as cited in PGS Heritage (2019). The original sacred site was located on top of Dzalanyama, in Kaphirintiya hill. On the site, there is a sacred forest in which there is a rock with imprints on it, and it is believed by the Chewa to be the footprints of the first man and woman (McFarren, 1986) as cited in PGS Heritage (2019).

The stretch of land from the hills of Kaphirintiya to the lowland on the Malawian side (eastern side of the hill) is referred to as Msinja because it is alleged that when the first Chewa people arrived in the area, they heard the sound of pounding of mortars, *kusinja*, but they could not see any people. The proto-Chewa Shrine at Kaphirintiya was managed by a woman priestess with the title of '*Makewana'*, the mother of all people (Nthara, 1973) as cited in PGS Heritage (2019). The priestess was of the *Banda* clan and was not allowed to be married since she was considered to be the wife of '*Chisumphi'* (the priestess or God head). The role of Makewana was to mediate between Chisumphi and the Chewa nation, directing prayers to their deity (Chisumphi) (Van Breugel, 2001) as cited in PGS Heritage (2019). Makewana also acted as a secular authority in all matters, apart from religious aspects, before the arrival of the *Phiri* clan who invaded them and took over the secular authority of the land (Rangeley, 1952). However, she was assisted by a male priest called '*Kamundi Mbewe'* who was also her protector and *'Tsang'oma'*, the drum beater, who used to call people to the shrine and a number of young girls called '*Matsano'* who have not reached puberty stage. All people who were involved in the affairs of the shrine used to wear black clothes.

Carlos Wiese, a German official in the Portuguese service described the shrine at Msinja as the "Mecca of the Maravi". This was because all the *Chewa* chiefs from Zambezi in Mozambique, Lwangwa in Zambia, to Kasunga in Malawi, Lake Malawi and beyond, made their annual pilgrimages to Msinja to pray for rains and posterity in their homes. Msinja was a very popular and busy city. In 1830, Gamito, a Portuguese traveller, noticed some commercial activity taking place at Msinja. It is also reported that David Livingstone visited Msinja in 1867 (PGS Heritage, 2019).

Msinja city was well designed. At the centre was the temple where sacrifices were offered. The sacred temple was served by various functionaries. Five officials, who included Makewana, formed the nucleus of Msinja city, (Schoffeleers, 1999) as cited in PGS Heritage (2019). They lived at the centre of the city very close to the temple. Other functionaries lived in 11 villages that surrounded the city. These villages were similar to what we now call locations or residential areas (Rangeley, 1952) as cited in PGS Heritage (2019).

5.14.2 The Nyau Sacred Cult and Dambwes

Since the original and predominant population living in the Project area is the Chewa, they are commonly referred to as *Nyau* societies. The Nyau is a secret and sacred cult, involving the ritual dance practiced among the Chewa people in Malawi. These people keep their dancing costumes in sacred places called *dambwes*; forest patches which also act as meeting places of the Nyau secret societies. This tradition has been included on the United Nations Educational, Scientific and Cultural Organization (UNESCO) Representative List as a masterpiece of intangible cultural heritage under the 2003 Intangible Cultural Heritage Convention, and thus it has a global significance.

5.14.3 Settlement History

It was revealed that the Chewa people migrated to Malawi from Zaire (now the Democratic Republic of the Congo) in the 16th century. During fieldwork undertaken in June 2018 by PGS Heritage, community leaders explained that the Chewa people have been nomadic throughout history. They claimed that their history can be traced from Sudan before they settled in Zaire. They also said the leader of the Chewa people during the migration from Zaire to Malawi was named Kalonga. Kalonga founded the Maravi Empire in Malawi and established his headquarters in a place called Mankhamba in the Dedza district. He later decided to extend his influence by acquiring more land for his subjects. In order to achieve this, he dispatched a number of his matrilineal relatives to establish settlements in various parts of Malawi (PGS Heritage, 2019).

Elders were not able to indicate when exactly the Chewa people settled in the area, but indicated that their ancestors were attracted to the environment of the area, particularly the proximity to water sources and good fertile land for cultivation. They also narrated that before settling in the Malingunde region, they migrated from Dowa area. During a meeting held in the Chitsulo area, one of the elders indicated that they arrived at Ndumila in 1901.

They further explained that those people who settled in Msinja area were the Ngonis and those who settled in the villages within Malingunde project area were the Chewas, hence they often came into conflict and the Chewa people used to hide in the earthen constructed forts (locally known as chambers) for their protection against the Ngonis. According to the elders, their well-known and best chamber is called Kamchenga, which was used soon after arriving from Dowa district. The other chamber mentioned is called Chindidye, which was also used as a hide-out during conflicts and it was protected by magic (PGS Heritage, 2019).

5.14.4 Intangible Heritage

Other than understanding the settlement history of the area from the local elder’s perspectives, further inquiry focused on understanding the intangible heritage of the area including traditional knowledge systems and other traditional cultural practices.

During consultation with the elders, they reiterated that the Chewa people are known for their masks and the Nyau secret society, as well as their agricultural gardening techniques.

Although sacrifices in the form of food and drinks to the spirits of the ancestors use to be undertaken at sacred ritual sites, these are all located outside the Project area.

Some traditional dances are commonly practiced in the area. This included *Chimtali*, *Chiterera* and *Gule wa Mkulu*[9]. Elders explained that Gule wa Mkulu is performed when a member of the local community who does not have a church dies; when any oldest person dies; occasions when communities erect a tombstone; and sometimes when custodians of the bwalos would like to be entertained.

Chisamba, a ritual ceremony performed during funerals is also common in this area. For young girls who have reached adulthood/puberty, *Thimbwidza*, an initiation traditional practice is usually performed on these young girls.

[9] The Gule wa Mkulu is both a secret cult and a ritual dance performed by people wearing character masks or disguised as animals, who represent the world of the spirits. This ritual performance, which is aimed at preserving traditional values, is practiced among the Chewa people on various occasions. https://www.southworld.net/malawi-gule-wamkulu-dance-of-the-spirits/

5.14.5 Results of Field Survey

A total of nine archaeological sites, eight sacred traditional cultural meeting places, nine burial grounds and 29 archaeological find spots were identified during the field survey in May 2018. The 29 archaeological find spots constitute low density scatters of ceramics or iron slag with a low heritage significance.

Dense vegetation cover and inaccessibility of certain sections made total coverage of the project area difficult and can result in some heritage resource to be undiscovered. Moreover, no subsurface testing was undertaken as part of the baseline survey. More sites may thus lie below the 30 cm plough zone and may remain unexposed. The location of the various sites identified are indicated in Figure 5.25.

5.14.5.1 Identified Cultural Meeting Places (Bwalos)

Cultural meeting places identified during the survey are listed in Table 5.61. More details are available in the Cultural Heritage Impact Assessment (CHIA) in Appendix O.

A typical expample of such a cultural meeting place is illustrated in Plate 5.13

Photo: PGS Heritage

Plate 5.13: View of BWAL008 Located near Ndumila

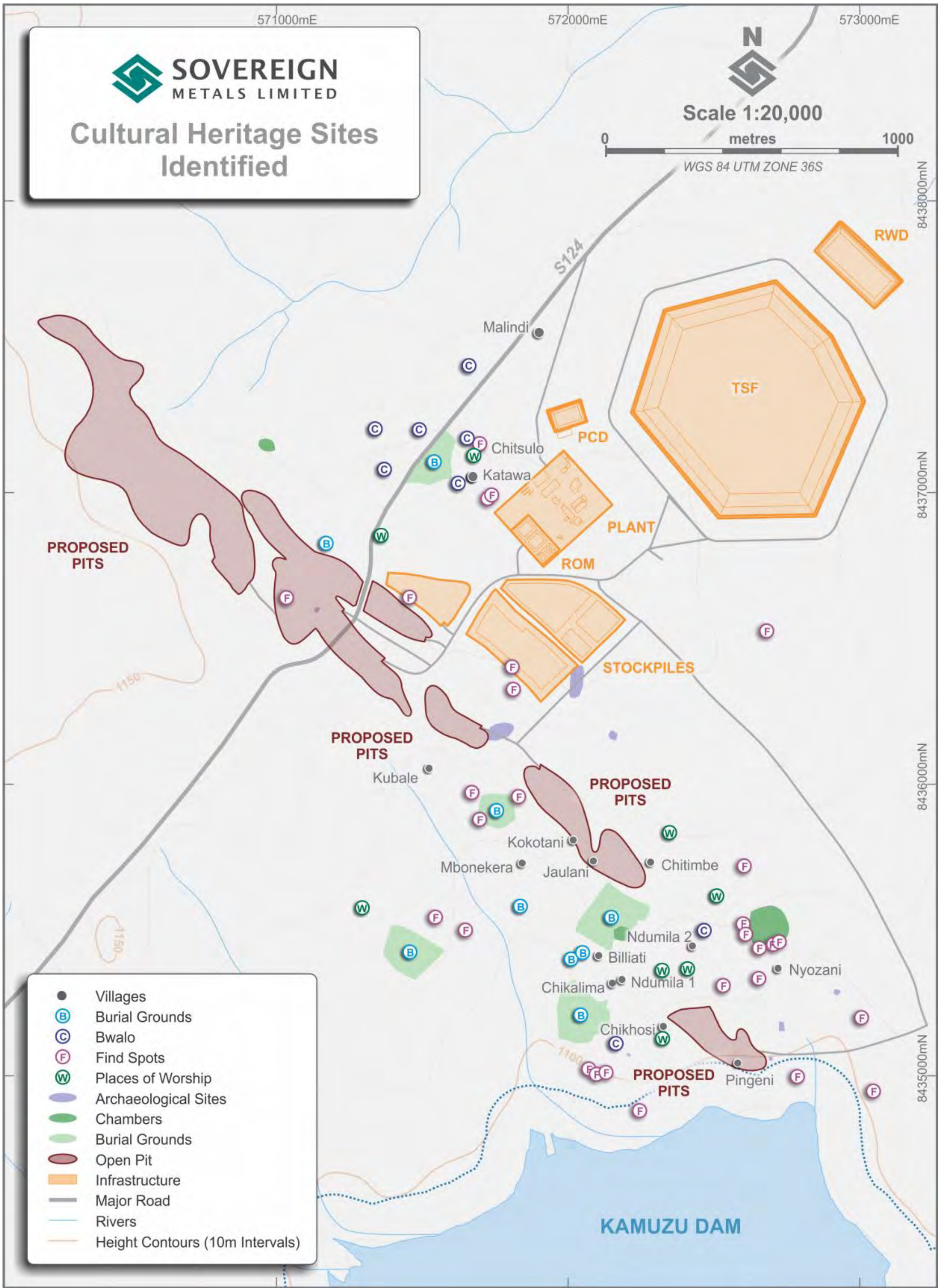


Figure 5.25: Cultural Heritage Sites Identified

Table 5.61: Cultural Meeting Places in the Project Area

Site Number	Description	Significance
BWAL001 Kumalindi I Bwalo	This is a cultural heritage place where Gule wa Mkulu is performed during different occasions. This cultural meeting place is under the chieftaincy of Kumalindi Wafupi[10] under Group Village Headman Chitsulo. It covers an area of approximately 30 m x 30 m. The area has high socio-cultural significance to the local communities around it as it preserves and safeguards the intangible heritage of the Chewa culture.	High
BWAL002 Kumalindi II Bwalo	This is another bwalo where Gule wa Mkulu is performed during different occasions. This cultural meeting place is under the chieftaincy of Kumalindi Watali under Group Village Headman Chitsulo. It is situated adjacent to BWAL001, about 150 m apart and it covers an area of approximately 40 m x 40 m. The area also has high socio-cultural significance to the local communities around it as it preserves and safeguards the intangible heritage of the Chewa culture.	High
BWAL003 Kumalindi III Bwalo	This is another bwalo where Gule wa Mkulu is performed, and other social gatherings take place for different cultural activities. This cultural meeting place is under the chieftaincy of Kumalindi Wapadilawo under Group Village Headman Chitsulo. It is approximately 30 m x 30 m in size. The area also has high socio-cultural significance to the local communities around it as it preserves and safeguards the intangible heritage of the Chewa culture.	High
BWAL004 Chitsulo Bwalo	This is another bwalo where Gule wa Mkulu is performed, and other social gatherings take place for different cultural activities. This cultural meeting place is under the chieftaincy of Group Village Headman Chitsulo. It is approximately 30 m x 20 m in size. The area also has high socio-cultural significance to the local communities around it as it preserves and safeguards the intangible heritage of the Chewa culture.	High
BWAL005 Katawa Bwalo	This is another bwalo where Gule wa Mkulu is performed, and other social gatherings take place for different cultural activities. This cultural meeting place is under the chieftaincy of Katawa, under Group Village Headman Chitsulo. It is approximately 30 m x 20 m in size. The area also has high socio-cultural significance to the local communities around it as it preserves and safeguards the intangible heritage of the Chewa culture.	High
BWAL006 Kamkuwe Bwalo	This is a relatively new bwalo where Gule wa Mkulu is performed, and other social gatherings take place for different cultural activities. This cultural meeting place is under the chieftaincy of Kamkuwe, Group Village headman Chitsulo. It is approximately 30 m x 40 m in size. The area also has high socio-cultural significance to the local communities around it as it preserves and safeguards the intangible heritage of the Chewa culture. However, the area is outside the project area.	High
BWAL007 Chikalima Bwalo	This is a relatively new bwalo where Gule wa Mkulu is performed, and other social gatherings take place for different cultural activities. This cultural meeting place is under the chieftaincy of Kumalindi. It is approximately 20 m x 30 m in size. The area also has high socio-cultural significance to the local communities around it as it preserves and safeguards the intangible heritage of the Chewa culture. However, the area is outside the project area.	High
BWAL008 Pingeni Bwalo	This is a relatively new bwalo where Gule wa Mkulu is performed, and other social gatherings take place for different cultural activities. This meeting cultural place is used by the following villages: Ndumila, Pingeni and Chikhosi. The area also has high socio-cultural significance to the local communities around it as it preserves and safeguards the intangible heritage of the Chewa culture.	High

[10] Chieftaincy names provided by field guide provided by village headman Chitsulo

5.14.5.2 Identified Historical Forts

Historical forts (chambers) identified during the survey are listed in Table 5.62. A typical expample of such a cultural meeting place is illustrated in Plate 5.14.

Photo: PGS Heritage

Plate 5.14: View of the Kamchenga Chamber at Ndumila

Table 5.62: Forts/Chambers in the Project Area

Site Number	Description	Significance
Kamchenga Chamber	This historic fort is located on the northeastern side of Ndumila I village. This is where the Chewa cultural tribe used to hide during tribal wars with other tribal groupings who used to invade the area.	High
Chindidye Chamber	A historic fort located east of Ndumila Mosque. Its earthen wall mounts were intact in some areas. It had approximately a radius of about 90 to 100 m. According to one of the local guides, cultivation inside the fort was prohibited as any form of excavation yields human bones. To preserve the integrity of the area, the communities consider the fort as a graveyard and anyone going there without the Chief's consent is regarded as tresspassing. The presence of archaeological sites and the fort in the area confirms the assumption that humans once occupied the area in the past. Considering the shallow written history of the country, where much of its information is obtained from such resources, the area provides a rare opportunity to unearth the treasures of the nation. The sites are likely to provide valuable scientific and historical knowledge to the nation.	High
Kumalindi Chamber	This historic fort is located in the northeastern side of Ndumila I village. This is where the Chewa cultural tribe used to hide during tribal wars with other tribal groupings who used to invade the area.	High

5.14.5.3 Identified Archaeological Sites

Archaeological sites identified during the survey are detailed in Table 5.63.

Table 5.63: Archaeological Sites in the Project Area

Site Number	Description	Significance
MGP1	An Iron Age site located along the S124 secondary road, with embedded pottery, mostly weathered (Plate 5.15). Some iron slags and Nkope[11] potsherds with comb dragging, incisions and comb stamping were recorded at the site.	High
	 **Photo: PGS Heritage** **Plate 5.15: Remains of Fragmented Ceramics Exposed in Road**	
MGP2	An Iron Age site covering some 20 m^2 in a maize field. The cultural artefacts recorded included decorated Nkope pottery with rims (Plate 5.16). Pottery densities are generally low (<10/m^2). The pottery is highly fragmented as a result of cultivation. This is a possible late 19th to early 20th century settlement.	Medium
	 **Photo: PGS Heritage** **Plate 5.16: Ceramics with Cross Hatching Decoration on the Rim**	
MGP3	An Iron Age Site located in a highly disturbed maize field with scatters of thick decorated and undecorated pottery mostly eroded, >10/m^2 in an	High

[11] Nkope pottery refers to a type of pottery with specific pot profiles, decoration motifs and layouts. Nkope pottery is related to the Urewe tradition of the easern stream migration of the Bantu tribes from Central Africa (circa AD 300-400) - Huffman, T.N., 2007. Handbook to the Iron Age. University of KwaZulu-Natal Press.

<table>
<tr><th>Site Number</th><th>Description</th><th>Significance</th></tr>
<tr><td></td><td>area approximately 70 x 30 m. A few Mkhudzi potsherds with comb dragging, incisions and comb stamping around the rims were recorded.
Various pieces of iron slag and fragments of tuyere pipe were identified (Plate 5.17).</td><td></td></tr>
<tr><td colspan="3">
Photo: PGS Heritage
Plate 5.17: Fragments of Iron Slag and Tuyere Pipe</td></tr>
<tr><td>MGP4</td><td>An Iron Age site located in a highly disturbed cultivated land. Pottery densities are generally low (<5/m^2). Some pottery was decorated while some undecorated and highly fragmented as a result of cultivation. The site is linked with MGP5 where large amounts of decorated ceramics and indications of iron smelting are present</td><td>High</td></tr>
<tr><td>MGP5</td><td>An Iron Age Site located in a highly disturbed maize field with clusters of iron slugs, daga[12] and thick decorated and undecorated pottery which is mostly eroded, >10/m^2 over an area of approximately 30 x 30 m. A few potsherds with comb dragging, incisions and comb stamping around the rims was observed. Indications are that the site is a possible smelting site, as pieces of iron slag and bloom and clay pipe (tuyere) remains of furnace bellows were found (Plate 5.18). The site is probably an extension of MGP4.</td><td>High</td></tr>
<tr><td colspan="3">
Photo: PGS Heritage
Plate 5.18: Iron Slag and Bloom with Decorated Potsherds</td></tr>
</table>

[12] A puddled clay used to plaster the walls and floors of houses in the Iron Age settlements of sub-Saharan Africa. https://archaeologywordsmith.com.

Site Number	Description	Significance
MGP6	An Iron Age Site covering some 40 x 30 m in a cultivated maize field. Some unidentified pottery with rims (Plate 5.19) were recorded at the site with pottery densities of <10/m^2). Pottery samples were collected for further analysis.	High
	 Photo: PGS Heritage Plate 5.19: Undecorated Ceramics with Lip	
MGP7	An historic and Iron Age site located in a maize field with scatters of undecorated pottery with intact rims, >10/m^2 over an area approximately 20 x 30m. Some remains of Tuyere pipes were recorded on the site.	Low
MGP8	The site is from the Iron Age, located in a maize field southwest of the village. It shows a presence of undecorated pottery sherds spread over an 8 m radius.	Medium
MGP9	An Iron Age site covering approximately 50 x 50 m in a maize field. Decorated and undecorated pottery with rims were recorded. Iron slags were also observed at this archaeological site. Pottery densities were generally low (<10/m^2).	Medium
MGP10	The site is characterised by a thick deposit of iron slag and bloom, mixed with fragments of pottery and ash (Plate 5.20). The site is slightly disturbed by farming activity that created a cutting in the deposit. However, the deposit of approximately 1 m in depth is still in primary context and can yield extensive data if documented.	High
	 Photo: PGS Heritage Plate 5.20: In Situ Slag and Pottery	

5.14.5.4 *Graves and Burial Grounds*

Graves are regarded as protected monuments under the laws of Malawi as provided for in the Monuments and Relics Act of 1991. Part 1 section 2(c) of the Act, defines a monument as *"...any grave, tumulus, cairn, place of interment, pit, dwelling, trench, excavation, working, rock, rock-shelter, madden, mound, cave, grotto, rock sculpture, rock painting and wall painting"*.

Burial grounds (*dambwe)* and stand-alone graves identified during the survey are detailed in Table 5.64.

Table 5.64: Burial Grounds and Graves Identified in the Project Area

Site Number	Description	Significance
Kumalindi Burial Ground	Located within Kumalindi village and approximately 350 x 200 m in size.	High
 **Photo: PGS Heritage** **Plate 5.21: View of Kumalindi Burial Ground as Part of the Forested Area to the Left**		
Ndumila Chiefs Burial Ground	Located about 15 m northeast of Ndumila 1 graveyard. It is approximately 15 x 20 m in size and it is reserved for chiefs in the village.	High
 **Photo: PGS Heritage** **Plate 5.22: View of Headstones of the Royal Burial Ground**		

Site Number	Description	Significance
Ndumila 1 Burial Ground	Located within Ndumila 1 village and is approximately 200 x 120 m in size.	High
Ndumila Old Burial Ground	Located about 30 m southwest of Ndumila 1 graves. Approximately 70 x 50 m in size. It has been abandoned and communities have stopped burying people in this location. It was used by the villages of Mkasa, Apingeni, Ndumila 1 Chikalima and Chikhosi	High
Kubale Burial Ground	Located between Kubale village and Mbonekera village and is approximately 200 x 100 m in size.	High
Mbonekera Burial Ground	Located within Mbonekera village. It is approximately 300 x 250 m in size.	High
 **Photo: PGS Heritage** **Plate 5.23: Recent Burial Mounds**		
Chief Chitimbe Grave	Burial place of Chief Chitimbe, one of early settler chiefs of the land. It is situated along the road that connects Chaniya village to Ndumila village within Biliati village.	High
 **Photo: PGS Heritage** **Plate 5.24: Headstone and Dressing of Chief Chitimbe's Grave**		
Gogo Nkhungulo Grave	Burial place of Gogo Nkhungulo, one of the villagers who opted to be buried near his plot. Located within Kumalindi village.	High

Site Number	Description	Significance
Chanika Village Burial ground	Grave yard utilised by Chanika village. Approximately 200 x 200 m in size.	High
MAL042 Burial Ground	Old burial ground some 300 m northwest of the old Ndumila cemetery. Approximately 20 x 20 m in size.	High

5.14.5.5 Place of Worship

During the survey eight places of worship were identified consisting of seven churches and one mosque (refer Figure 5.25).

5.15 Social Environment

5.15.1 Geographic and Administrative Distribution

Although the Project is mainly situated within TA Masumbankhunda, the area of interest considered as part of the social impact assessment (SIA) extended into TA Masula.

Census data for TA Masumbankhunda and TA Masula are not available as they were enumerated as part of TA Chiseka during the 2008 census. However, population sizes have been estimated as 62,900 for TA Masumbankhunda and 107,000 for TA Masula in 1998 (Lilongwe District Council, 2017 as cited in AECOM, 2019a).

Villages in the Project area have a village head (VH), with multiple VHs grouped under a group village head (GVH). GVH and VH are historical titles of hereditary chiefs and are granted legal authority by the Chiefs Act (Cammack*, et al*., 2009 as cited in AECOM, 2019a). The role of the VH is to make key decisions in the interest of the village, to settle disputes (e.g. land disputes or cases of theft), to allocate land, etc. The position is passed down and chosen by family elders.

The survey included 1,045 potentially project affected households (PAH) and 4,454 project affected persons (PAP). The geographic and administrative locations of thse PAHs included in the survey are summarised in Table 5.65, which shows that almost half of the PAHs subscribe to the Chitsulo GVH, followed by those loyal to the GVHs of Chimwendo and Pingeni. The location of the GVHs and PAPs are indicted in Figure 5.26.

Table 5.65: Geographic and Administrative Distribution of Project Affected Households

Group Village Head	Potentially Affectd Households		Population
	Number	%	Number
Chitsulo	488	46.7%	2,082
Chimwendo	198	18.9%	820
Pingeni	166	15.9%	723
Ntanga	58	5.6%	257
Mtali	56	5.4%	225
Kathyokamwendo	31	3.0%	136
Ndumila	29	2.8%	131
Mtata	12	1.1%	48
Manase	7	0.7%	32
Total	**1,045**	**100.0%**	**4,454**

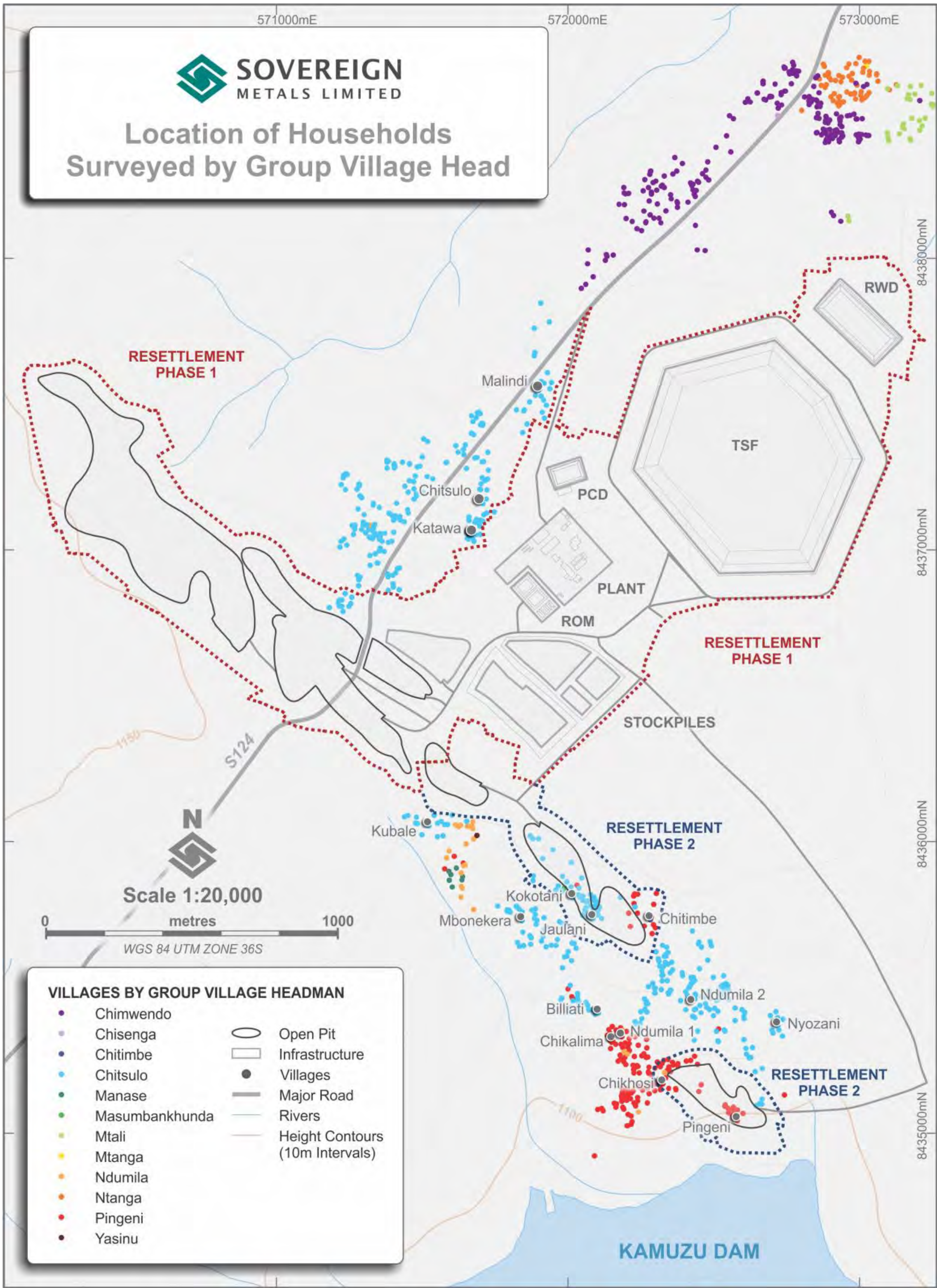


Figure 5.26: Location of Surveyed Households by Group Village Head

It should be noted that a household's loyalty to a group village head or village head is independent of the location of their primary residence (**Error! Not a valid bookmark self-reference.**). For example, households residing within the villages of Ndumila I and II will not necessarily endorse the Ndumila GVH. Instead, they are likely to endorse different GVHs, e.g. the Chitsulo or Ntanga GVH (AECOM, 2019a).

Table 5.66: Endorsement of Group Village Heads Across Villages

	Group Village Head								
Village Name	Chitsulo	Chimwendo	Pingeni	Ntanga	Mtali	Kathyokamwendo	Ndumila	Mtata	Manase
Biliati	85%	-	15%	-	-	-	-	-	-
Chigonawaya / Kathyokamwendo	-	-	-	-	-	100%	-	-	-
Chikalima	-	-	100%	-	-	-	-	-	-
Chikavala	-	100%	-	-	-	-	-	-	-
Chimwendo	-	100%	-	-	-	-	-	-	-
Chinole	-	-	-	-	100%	-	-	-	-
Chinungu	-	-	-	-	-	17%	-	83%	-
Chitimbe	13%	-	88%	-	-	-	-	-	-
Chitsulo	100%	-	-	-	-	-	-	-	-
Geleta	-	100%	-	-	-	-	-	-	-
Jaulani	100%	-	-	-	-	-	-	-	-
Katawa	100%	-	-	-	-	-	-	-	-
Kokotani	96%	-	4%	-	-	-	-	-	-
Kubale	35%	-	7%	-	-	-	43%	-	15%
Kumalindi	99%	-	-	-	-	-	1%	-	-
Mbonekera	100%	-	-	-	-	-	-	-	-
Mning'o	-	-	-	-	-	-	100%	-	-
Msakambewa	-	100%	-	-	-	-	-	-	-
Mtali	-	3%	-	-	97%	-	-	-	-
Mtata	-	-	-	-	-	-	-	100%	-
Ndumila 1	3%	-	93%	-	-	-	5%	-	-
Ndumila 2	99%	-	1%	-	-	-	-	-	-
Njirayatenga	-	-	-	-	-	100%	-	-	-
Ntanga	-	5%	-	92%	3%	-	-	-	-
Total	**47%**	**19%**	**16%**	**6%**	**5%**	**3%**	**3%**	**1%**	**1%**

5.15.2 Demographics

The information presented in the following sub-sections provides an overview of the key demographic characteristics of PAHs across the respective GVH areas. These characteristics indicate that these PAHs are relatively homogenous, regardless of which village they are located in.

5.15.2.1 Age and Gender Distribution

The gender ratio among the PAPs is almost equal (48% male, 52% female). The age / gender distribution is typical of a population that is gradually increasing as a result of natural growth (as opposed to in-migration of – mostly male – job-seekers) (Figure 5.27). The relatively flat base of the pyramid suggests a high population growth rate, which is typical for most parts of rural Africa. This is borne out by the young age profile; 56% of PAPs are under 20 years of age (Table 5.67) and the average age is 24 years. However, there is a considerable variance between the 0–4 year and 5–14 year age groups, with the former being almost 4% lower across gender lines. This could either be the result of a reduced growth rate or increased mortality rates among infants and/or young children. In contrast with the general trend, Ndumila and Manase have relatively young female populations, with Kathyokamwendo boasting the youngest male population.

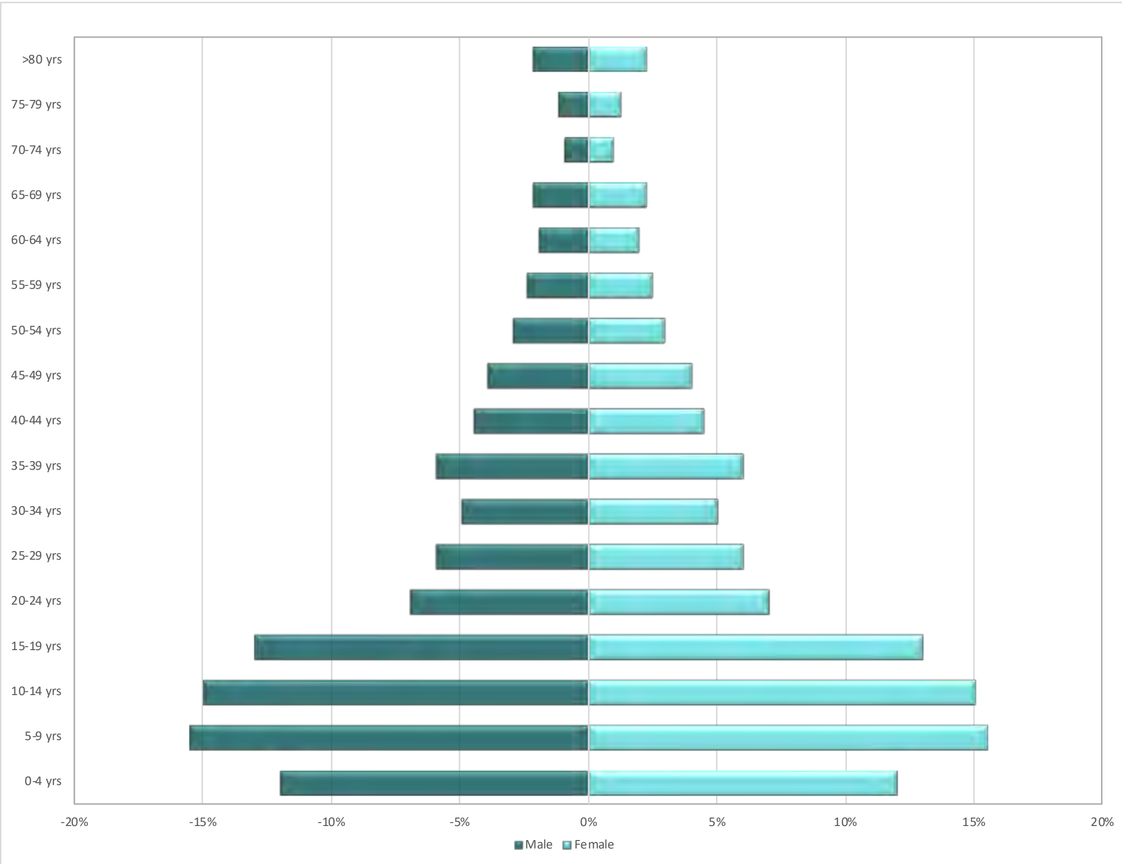


Figure 5.27: Age and Gender Distribution

Table 5.67: Percentage of Potentially Affected Persons Younger than 20 Years

GVH	% of Population
Ntanga	59%
Ndumila	58%
Kathyokamwendo	57%
Chitsulo	56%
Chimwendo	55%
Mtali	54%
Mtata	54%
Pingeni	54%
Manase	53%
Total	**56%**

Just more than half of PAHs are headed by women, most commonly in GVH Kathyokamwendo, Mtali and Ntanga (Table 5.68). A total of 46 of PAHs are headed by children, who are mostly female and younger than 20 years.

Table 5.68: Percentage of Female- and Child-headed Households

Group Village Head	Female		Child		Total*	
	Number	%	Number	%	Number	%
Chimwendo	104	54%	9	5%	107	55%
Chitsulo	267	55%	20	4%	271	56%
Kathyokamwendo	22	71%	2	6%	22	71%
Manase	1	14%	-	-	1	14%
Mtali	35	63%	1	2%	35	63%
Mtata	6	50%	-	-	6	50%
Ndumila	13	54%	1	4%	14	58%
Ntanga	38	66%	3	5%	41	71%
Pingeni	86	52%	10	6%	89	54%
Total	**572**	**55%**	**46**	**4%**	**586**	**57%**

* Thirty-two female headed households are headed by women younger than 20 years old, and are thus included in both categories, but only once in the total figures to avoid double counting.

5.15.2.2 Household Size and Composition

The average household size (calculated by dividing the total number of PAPs by the number of PAHs) is 4 members, with the maximum PAH size of 11 members (Table 5.69). The majority of PAHs have between one and seven members, with only a very small proportion of households comprising more than eight members (Figure 5.28).

Table 5.69: Household Size

Group Village Head	Household members	
	Average	Maximum
Chimwendo	4.1	10
Chitsulo	4.3	11
Kathyokamwendo	4.4	10
Manase	4.6	7
Mtali	4.0	7
Mtata	4.0	7
Ndumila	4.5	8
Ntanga	4.4	9
Pingeni	4.4	10
Total	4.3	11

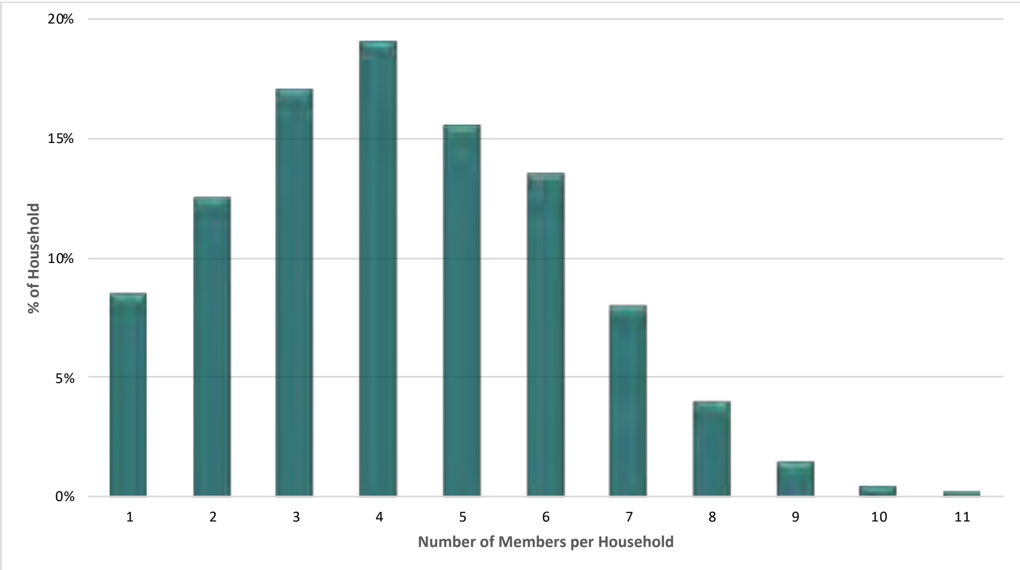


Figure 5.28: Household Size Distribution

The composition of a typical PAH is shown in Figure 5.29, which indicates that it is uncommon for extended family members to share the same home, as less than 10% of PAHs comprise grandchildren, grandparents and other relatives, or persons who are not related to but dependent on the PAH (such as foster children).

Comparing the ratio of children to parents (village head or his/her spouse), one finds that the average couple has between two and three children living with them. This number does not include children who may already have left the household to start their own families elsewhere in the village.

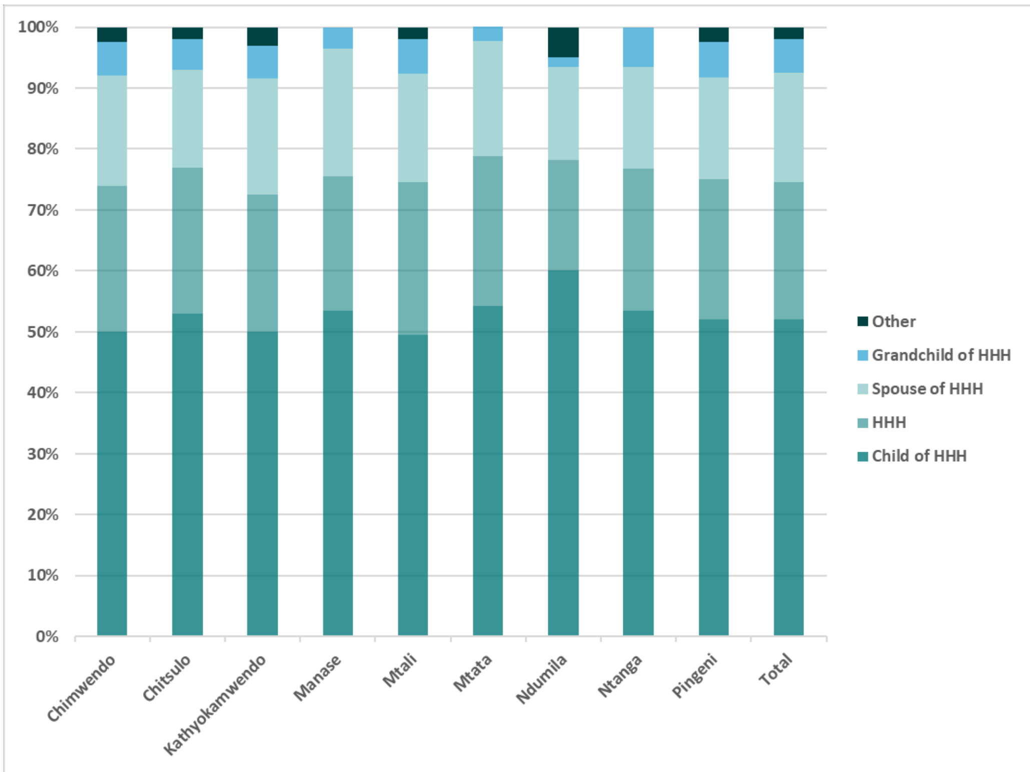


Figure 5.29: Relationship of Household Members to Household Head

5.15.2.3 Civil status

Results from the household survey indicates that more than 70% of PAPs are married by the age of 20 years. Divorce is rare; however, it should be noted that the proportion of divorced or separated females is marginally higher compared to males. There is clear preference for traditional over civil marriages. There is also a higher proportion of widowed females, which could be indicative of higher mortality rates among males.

Polygamy is rare with only 3% of PAHs being of this nature. Generally polygamous households comprise not more than two spouses.

5.15.2.4 Migration

As stated in Section 5.15.2.1, the age profile is indicative of a population that is gradually increasing as a result of natural growth. Table 5.70 supports this by showing that the area has not experienced any significant influx of people in the recent past; the majority of PAHs having lived in their current village for five years or more, with almost all (92%) PAPs being permanent residents at their surveyed household. Only 2% of PAHs have occupied their current place of residence for less than one year. Of the PAHs, 9% have a second home; of these, two thirds are located in the same TA (Masumbankhunda) (Table 5.71).

Table 5.70: Years of Residency in Current Village

Group Village Head	5 or More Years	2–5 Years	1–2 Years	6–12 Months	6 Months or Less
Chimwendo	98%	1%	-	1%	-
Chitsulo	90%	4%	3%	1%	1%
Kathyokamwendo	97%	-	3%	-	-
Manase	100%	-	-	-	-
Mtali	100%	-	-	-	-
Mtata	100%	-	-	-	-
Ndumila	79%	10%	3%	-	7%
Ntanga	97%	2%	2%	-	-
Pingeni	86%	8%	4%	1%	1%
Total	**92%**	**4%**	**2%**	**1%**	**1%**

Table 5.71: Number of PAHs with a Second Home

Group Village Head	Households with Access to a Second Residence	
	Number	% Households
Chimwendo	15	8%
Chitsulo	52	11%
Kathyokamwendo	2	6%
Mtali	4	7%
Mtata	1	8%
Ndumila	4	14%
Ntanga	6	10%
Pingeni	13	8%
Total	**97**	**9%**

5.15.2.5 Ethnicity, Language and Religion

The majority of PAHs are homogenous in terms of ethnicity, language and religion. In terms of home language and ethnicity almost all PAHs (99%) speak Chichewa and classify themselves as members of the Chewa group. The vast majority of PAHs are Christian (95%), with the most prominent denominations being the African Abraham, Catholic, Jehova and Pentecostal denominations.

5.15.2.6 Education

School attendance is high across GVHs, irrespective of gender grouping (Figure 5.30), except for Manase where none of the males attend school. Of children between 5 and 20 years, nearly 80% of girls and boys were reported as currently attending school. School attendance is considerably lower within the Mtata area.

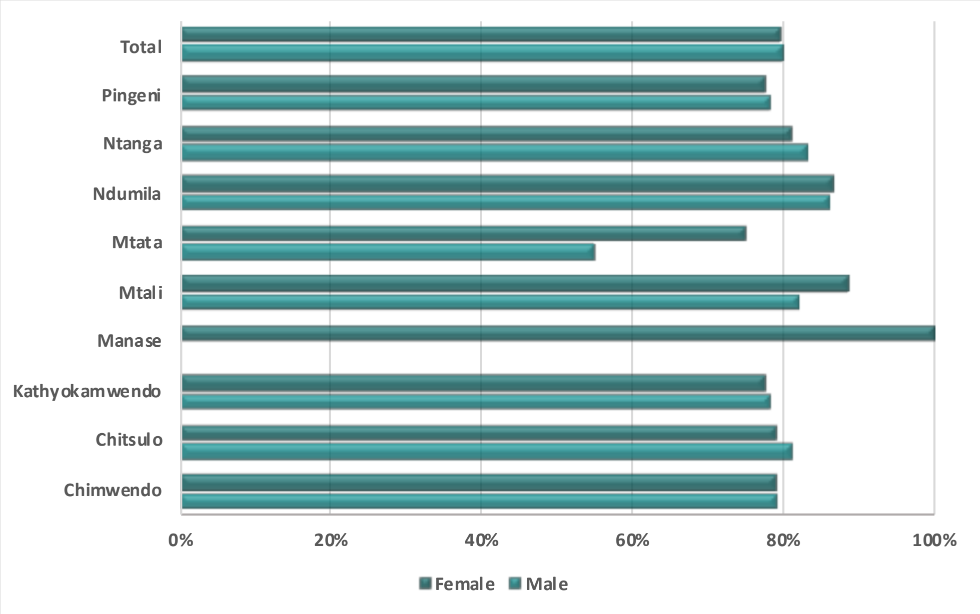


Figure 5.30: School Attendance of Persons Between 5 and 20 Years of Age per Village

This disparity in education between Mtata and the populations within other GVHs is also evident in literacy[13] rates among individuals (Figure 5.31), which is markedly lower in comparison to the other GVH areas. In addition to Mtata, the Mananse, Mtali and Pingeni populations also have a relatively high proportion of adults with no formal education. In contrast more than 50% of the Chimwendo, Kathyokamwendo and Ndumila populations indicated that they have completed secondary school or vocational.

Gender differences in literacy levels are in some cases significant (Figure 5.31). Among the Chitsulo and Chimwendo populations the number of males that have completed primary school or higher is 5% more when compared to their female counterparts, this situation is reversed among the Ntala population.

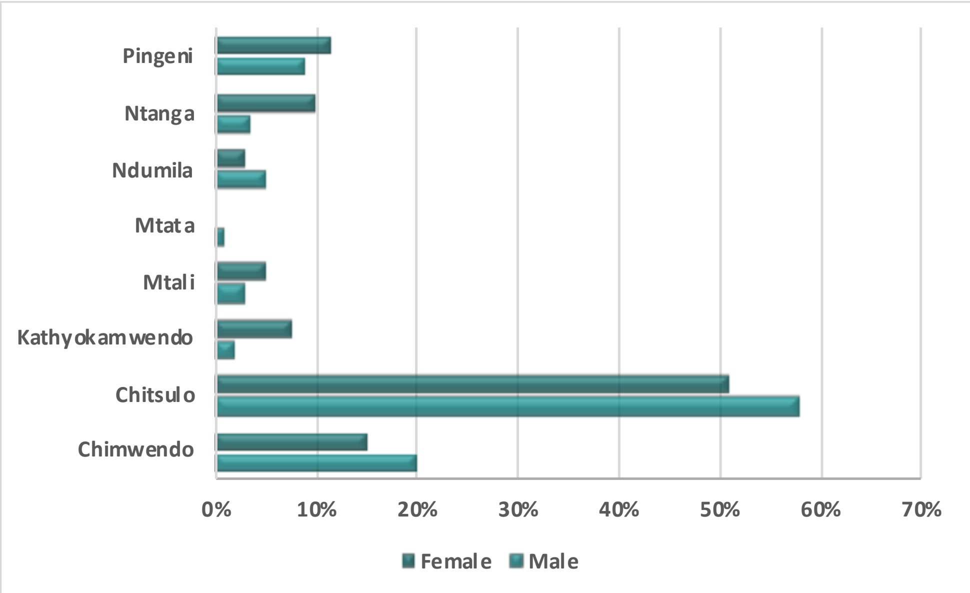


Figure 5.31: Literacy Levels of Persons Older than 8 Years

[13] The ability to read was used as a proxy indicator for literacy.

5.15.3 Land tenure

More than 90% of all households have customary rights to their agricultural plots which they have generally acquired through inheritance - this is slightly less in Pingeni and Ndumila where the proportion of households renting land is slightly higher (Figure 5.32). Less than 5% of PAHs indicated that they purchased their agricultural plots.

Generally, land is held by the household head or their parents (Figure 5.33). The fact that inheritance is the most dominant mechanism of land transfer/acquisition is also reflected in the average duration of ownership, which is more than 20 years across all GVHs, except for Pingeni where it is slightly less.

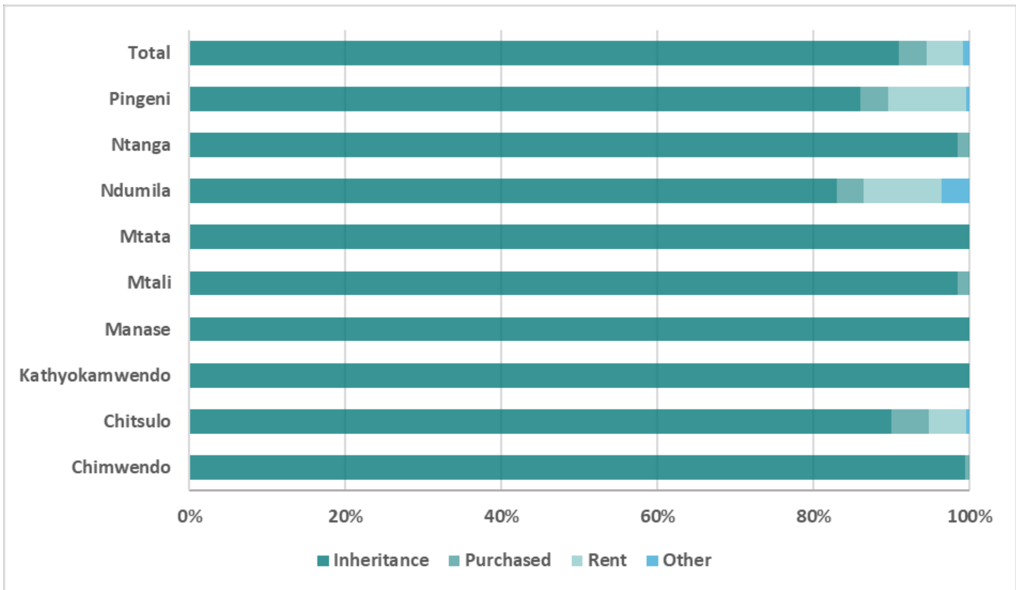


Figure 5.32: Types of Tenure of Agricultural Plots per Village

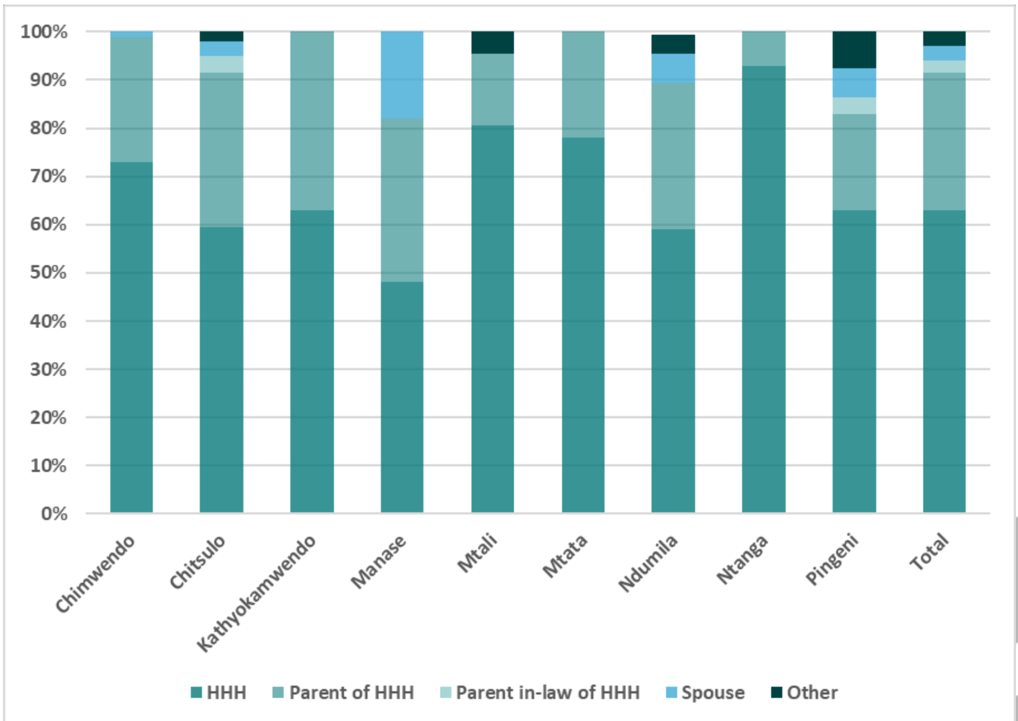


Figure 5.33: Ownership of Agricultural Plots

5.15.4 Livelihoods

For the purpose of the household survey, livelihood was defined as the strategies that households and individuals employ to meet their economic and survival needs. Such strategies may involve cash income, but this is not necessarily the case. A household may also meet its needs by growing its own food or bartering produce for necessities. A household or individual may also engage in more than one form of livelihood, some being cash-based and others being subsistence-oriented.

5.15.4.1 Contribution of Individuals to the Household Economy

Farming is the most common livelihood strategy among all PAPs older than 18 years of age, practiced as primary occupation by 84% of PAPs (Table 5.72). Petty trading with and without a stall is the second most common activity followed by those occupying themselves with domestic work. This pattern correlates with employment figures illustrated in Figure 5.34, which shows the majority of individuals being self-employed (either through farming or trading) and/or seasonally employed. Only a very small proportion of PAPs is formally employed and tend to be male. Among those that are unemployed, females far outnumber their male counterparts.

Table 5.72: Primary Occupations of Persons 18 Years and Older

Occupation	Chimwendo	Chitsulo	Kathyokamwendo	Manase	Mtali	Mtata	Ndumila	Ntanga	Pingeni	Total
Farming	94%	80%	90%	58%	93%	91%	85%	96%	77%	**84%**
Trading no structure	1%	5%	3%	17%	4%	4%	-	-	8%	**4%**
Domestic work	-	5%	-	-	-	-	6%	1%	2%	**3%**
Trading stall	1%	3%	-	-	1%	-	-	2%	-	**2%**
Beer brewing and selling	-	-	-	-	1%	-	-	1%	4%	**1%**
Trading	-	1%	-	-	-	-	-	-	2%	**1%**
Fishing	-	1%	-	-	-	-	6%	-	2%	**1%**
Skilled labourer	1%	1%	2%	-	-	-	2%	-	-	**1%**
Selling charcoal/firewood	1%	-	-	8%	-	-	-	-	1%	**1%**
Small business	-	1%	2%	-	1%	-	-	-	-	**-**
Brickmaking	-		-	8%	-	-	-	1%	1%	**-**
Baker	-	1%	-	8%	-	-	-	-	-	**-**
Other	1%	2%	3%	-	-	4%	2%	-	3%	**2%**

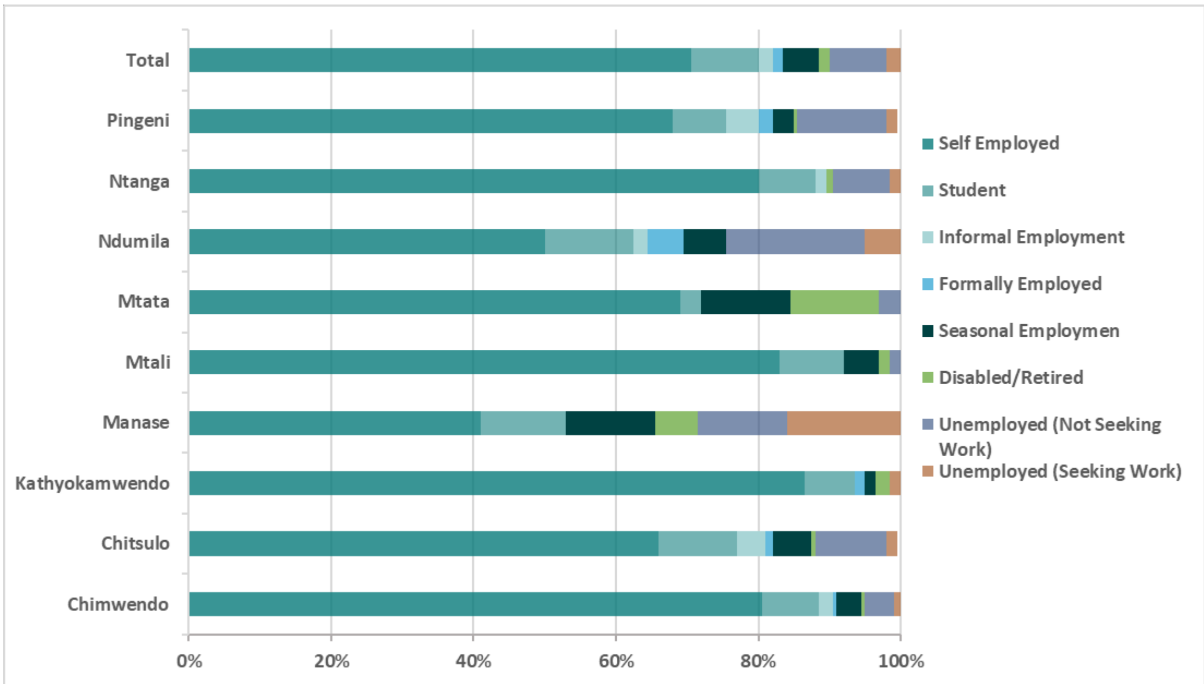


Figure 5.34: Employment Status per Group Village Head

There is some significant disparity both in terms of average income per individuals across GVH areas and gender lines, with the average reported income at Manase, Pingeni and Chitsulo being significantly higher (Table 5.73). The average monthly income among males is almost double compared to what females receive (Table 5.74). There is thus no clear correlation between reported individual income levels and the distribution of livelihood strategies per GVH. However, experience shows that all reported income figures should be interpreted with caution, as these are often subject to exaggeration or numerical error.

Table 5.73: Distribution of Individual Monthly Income Across GVH Areas

Income Bracket (Kwacha)	Chimwendo	Chitsulo	Kathyokamwendo	Manase	Mtali	Mtata	Ndumila	Ntanga	Pingeni	Total
10 000 or less	24%	26%	32%	33%	29%	58%	15%	34%	25%	**26%**
10 001-20 000	25%	20%	11%	22%	27%	17%	33%	17%	25%	**22%**
20 001 - 30 000	15%	15%	24%	-	22%	17%	26%	17%	15%	**16%**
30 001 - 40 000	15%	8%	13%	-	14%	8%	11%	17%	15%	**11%**
40 001 - 50 000	9%	9%	5%	11%	6%	-	7%	7%	4%	**8%**
50 001 - 60 000	2%	4%	11%	11%	-	-	-	-	2%	**3%**
60 001 - 70 000	1%	2%	3%	11%	-	-	-	3%	1%	**2%**
70 001 - 80 000	3%	4%	-	-	-	-	7%	-	3%	**3%**
80 001- 90 000	-	1%	-	-	-	-	-	3%	-	**1%**
90 001 - 100 000	2%	4%	3%	-	-	-	-	-	3%	**3%**
100 000 or more	4%	7%	-	11%	2%	-	-	-	5%	**5%**

Table 5.74: Gender Comparison of Average Monthly Individiual Income Distribution (Kwacha)

Group Village Head	Female	Male	Total
Manase	13,169	35,335	24,252
Pingeni	17,942	28,928	23,536
Chitsulo	14,986	31,024	22,892
Kathyokamwendo	11,134	21,926	16,054
Chimwendo	8,130	18,547	12,968
Ndumila	6,328	16,380	11,276
Mtali	8,061	14,482	11,097
Mtata	4,022	10,561	7,150
Ntanga	2,327	9,249	5,761
Total	**12,595**	**25,599**	**18,946**

5.15.4.2 Household Income

The distribution of total reported household incomes is depcited in Figure 5.35, which shows that the majority of households earn less than 30,000 Kwacha (or USD 40) per month.

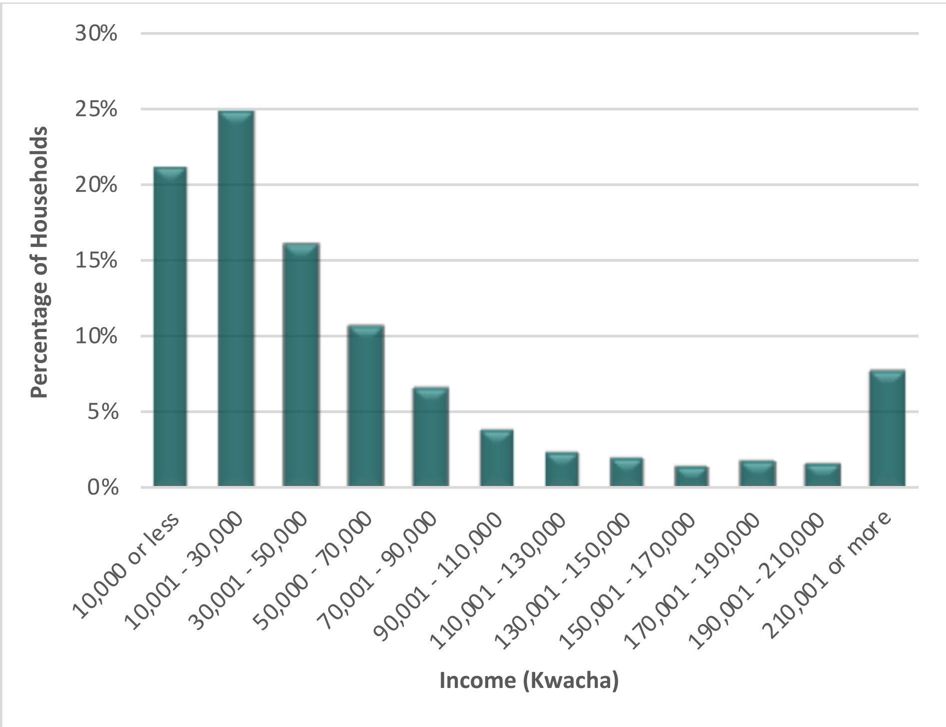


Figure 5.35: Distribution of Monthly Cash Income per Household

As households may simultaneously pursue more than one livelihood strategy, during the survey, respondents were asked to indicate all their households' livelihoods in terms of sources of cash income within the last 12 months (prior to May 2018). As can be seen from Table 5.75, about 42% of PAHs depend on the sales of agricultural produce (crops, vegetable or fruits) and livestock as source of cash income. In contrast to the small proportion of adult individuals earning a monthly income, most households indicated that they had received some form of cash within the month preceding the survey. The distribution of the monthly household income is presented in Table 5.76, which indicates an average amount of 96,508 Kwacha (or 130 USD), with male headed households generally receiving a substantially higher income in across most GVHs, with the only exception being Ndumila.

It should be noted that the average monthly income is often significantly skewed by a small number of households earning relatively large monthly sums, this is evident in the frequency distribution of presented in Figure 5.35, which shows that almost three quarters of PAHs actually reported earning less than 70,000 Kwacha (or 100 USD) in the month prior to the survey.

Table 5.75: Household Sources of Income During the 12 Months prior to May 2018

Source of Income	Chimwendo	Chitsulo	Kathyokamwendo	Manase	Mtali	Mtata	Ndumila	Ntanga	Pingeni	Total
Crop sales	28%	20%	25%	13%	24%	23%	18%	25%	21%	**22%**
Salary	20%	18%	22%	9%	18%	26%	14%	20%	18%	**18%**
Vegetable sales	17%	10%	19%	6%	18%	14%	11%	22%	7%	**12%**
Livestock sales	12%	11%	10%	6%	14%	9%	13%	13%	11%	**11%**
Fruit sales	8%	9%	7%	6%	10%	6%	9%	8%	7%	**8%**
Selling charcoal/firewood	3%	8%	3%	13%	3%	3%	6%	3%	10%	**7%**
Remittances	5%	6%	3%	6%	3%	9%	8%	3%	6%	**6%**
Savings	3%	6%	1%	9%	1%	3%	6%	2%	8%	**5%**
Selling fish	-	3%	1%	3%	4%	-	4%	-	5%	**3%**
Making and selling bricks	1%	3%	2%	6%	2%	6%	3%	1%	3%	**3%**
Sales of animal products	1%	1%	1%	3%	2%	-	3%	2%	1%	**1%**
Selling drinks (e.g. beer)	-	1%	-	6%	-	-	2%	-	1%	**1%**
Other	2%	4%	5%	13%	1%	3%	3%	1%	4%	**3%**

Table 5.76: Average Monthly Household Income (April 2018)

Group Village Head	Household Head Gender		Total
	Female	Male	
Chimwendo	33 656	81 997	55 629
Chitsulo	60 842	135 776	94 470
Kathyokamwendo	31 450	62 567	40 484
Manase	75 000	72 285	72 673
Mtali	39 011	69 743	50 536
Mtata	20 333	35 000	27 667
Ndumila	1 575 143	42 828	835 404
Ntanga	24 382	55 625	35 155
Pingeni	61 652	90 512	75 560
Total	**89 847**	**104 815**	**96 508**

5.15.4.3 Agriculture

The majority of PAHs (97%) indicated that they have access to arable land, with most having access to two agricultural plots on average. PAHs owning two or more fields are concentrated in Pingeni, Ndumila, Manase and Chitsulo.

The size of agricultural plots rarely exceed 1 hectare (ha) and comprise 0.6 ha on average. In most instances, fields are situated within a one hour's walk from the owner's residence. As indicated in Section 5.15.4.1, 84% of individuals older than 18 indicated farming as their primary occupation, while 45% of households depend on land-based activities for various sources of cash income.

Table 5.77: Agricultural Fields – Average, Maximum and Size

Group Village Head	Total Fields	Average No of Fields per Household	Highest No. of Fields per Household	Average Size (ha)
Chimwendo	198	1	3	0.7
Chitsulo	462	2	11	0.6
Kathyokamwendo	31	1	2	0.8
Manase	7	2	3	0.5
Mtali	56	1	2	1.0
Mtata	12	1	2	0.7
Ndumila	29	2	6	0.7
Ntanga	58	1	2	0.6
Pingeni	159	2	11	0.5
Total	**1,012**	**2**	**11**	**0.6**

Fields are mostly reserved for household use, with only about one fifth used for shared cropping. Respondents were asked to indicate the primary crop grown (i.e. the crop covering the largest proportion of all their fields).

Households typically cultivate a limited variety of crops, with maize and groundnuts being the most common across all areas. Other crops incude potatoes, soy beans, sugarcane and tomatoes. The average quantity (kilograms) of each crop produced per annum is summarised per farm size in Table 5.78, which shows a clear correlation between farm area and production levels. Crops are generally grown for selling as well as domestic consumption. Households prefer to sell agricultural produce at Malingunde Market, with a considerable number also selling produce from their homestead or along the road to Lilongwe.

Table 5.78: Average Produce per Farm Size (kg)

Produce	<0.50 ha	0.51–1 ha	1.01–1.50 ha	1.51–2 ha	>2.01 ha	Total
Tobacco	-	8,560	-	-	1,650	**6,586**
Sugarcane	638	2,888	1,000	-	-	**1,249**
Groundnuts	1,110	1,179	1,964	1,790	4,315	**1,228**
Soy	1,200	-	-	-	-	**1 200**
Potato	789	1,133	10,000	-	-	**1,185**
Sweet potatoes	558	1,950		-	-	**906**
Maize	675	1,038	979	1,276	1,420	**842**

Produce	<0.50 ha	0.51–1 ha	1.01–1.50 ha	1.51–2 ha	>2.01 ha	Total
Cassava	608	750	1,000	-	5,000	**811**
Tomatoes	523	125	-	-	-	**476**
Vegetables	418	533	-	-	-	**438**
Beans	235	625	-	-	-	**430**
Intercropped - maize and groundnuts	50	-	600	-	400	**350**
Cabbages	317	-	-	-	-	**317**
Soya	287	400	-	-	-	**304**
Rice	150	-	-	-	-	**150**
Cow peas	125	-	-	-	-	**125**
Fruit trees	-	-	88	-	-	**88**
Bananas	-	50	-	-	-	**50**
Total	**743**	**1 153**	**1 287**	**1 350**	**1 861**	**943**

Households reported good access to agricultural extension services such as improved seed varieties and fertilizer, with more than 80% of PAHs indicating that they are able to purchase both seeds and fertilizer. Households most commonly use chemical fertilizer or combination fertilizers during cultivation (Figure 5.36).

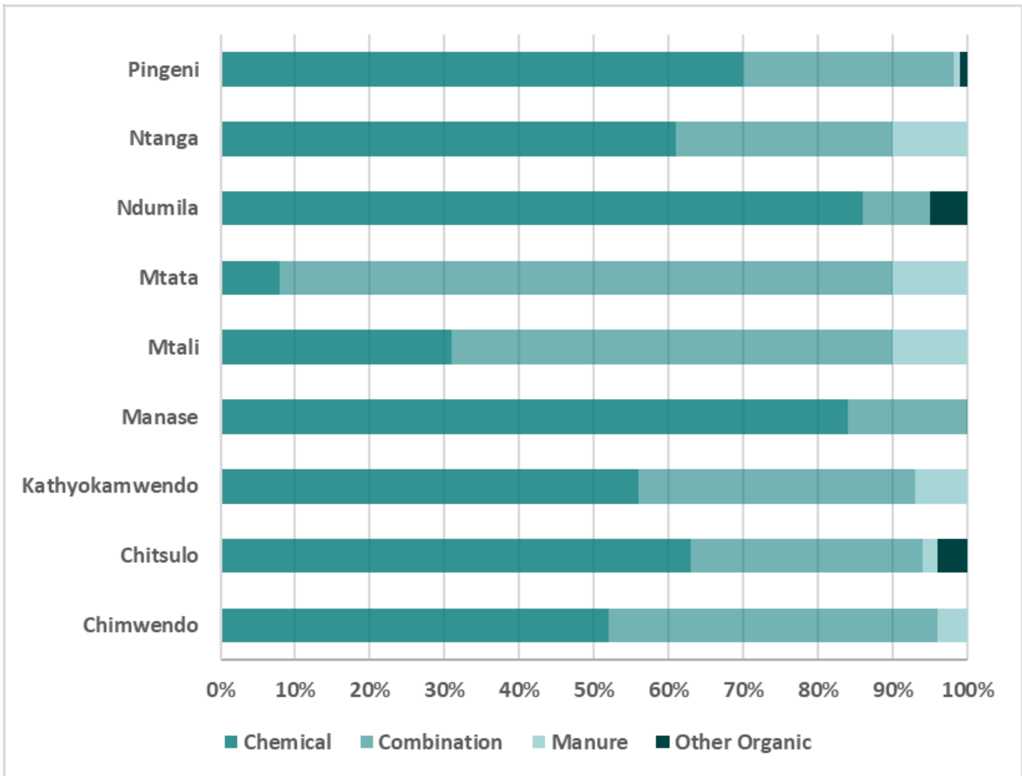


Figure 5.36: Type of Fertilizer Used by Households

5.15.4.4 Economic trees

Most PAHs depend on a variety of fruit, medicinal and other economic tree species found in their environment. Households were asked to indicate the type and number of trees they use for subsistence and/or economic purposes, with cassia, Jacaranda and bananas being the most abundant.

5.15.4.5 Livestock and poultry

Livestock husbandry is fairly common amongst the surveyed households affected, with poultry, goats and pigs being the most common types of animals kept by households

5.15.4.6 Small-scale trading

As mentioned previously, small-scale trading represents a primary occupation for approximately one in ten individuals. Roadside stalls used for such petty trading were evident in most surveyed settlements, while 9% PAHs reported that their residences are also used for business purposes. The main trading or business activities are beer brewing/selling, cooking and selling food, grocery and crop sales (Figure 5.37).

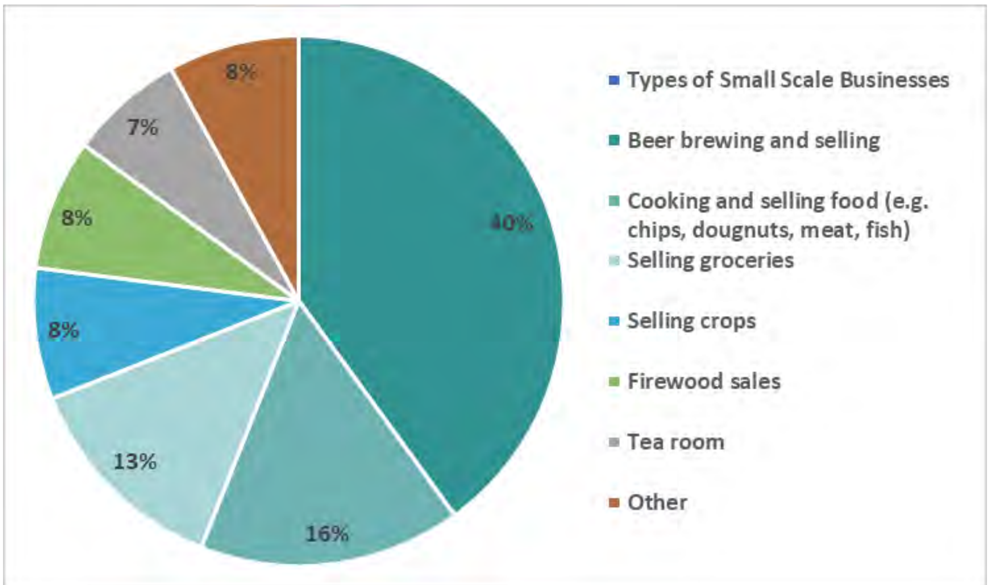


Figure 5.37: Types of Small-scale Businesses

5.15.5 Indicators of Poverty and Vulnerability

Socio-economic attributes that reflect poverty may indicate vulnerability to future negative impacts related to the Project. These attributes include food security, household ownership of moveable assets (which is a proxy indicator of household wealth), identified household needs, disability among PAPs, community health and availability of social networks.

5.15.5.1 Food Security

Of the surveyed households, almost 46% indicated that they had suffered a food shortage at some point during the past year prior to the survey (Table 5.79). GVH areas where the largest proportions of households were exempt from food shortages are Chimwendo and Kathyokamwendo. Food shortages are often seasonal and most frequently encountered during the months of November to March. Household shortages do not differ significantly across male and female headed households. The most commonly reported reasons for shortages reported is lack of household income, droughts or households selling crop reserves.

Table 5.79: Prevalence of Food Shortage

GVH	% Households with Food Shortage	Reasons for shortage					
		Lack of Cash	Drought	Sold Crops for Cash	Shortage of Labour	Shortage of Land to Cultivate	Other
Chimwendo	28%	83%	2%	9%	2%	4%	-
Chitsulo	51%	58%	23%	12%	3%	2%	3%
Kathyokamwendo	26%	100%	-	-	-	-	-
Manase	57%	25%	50%	25%	-	-	-
Mtali	38%	90%	-	5%	5%	-	-
Mtata	67%	88%	-	-	13%	-	-
Ndumila	55%	64%	21%	14%	-	-	-
Ntanga	36%	100%	-	-	-	-	-
Pingeni	61%	49%	31%	17%	-	1%	2%
Total	**46%**	**64%**	**19%**	**12%**	**2%**	**2%**	2%

5.15.5.2 Household Ownership of Moveable Assets

As mentioned, data on household ownership of moveable assets can be useful as a proxy indicator of household wealth, and may be more reliable than reported household income (which can be prone to numerical errors and misrepresentation). Accordingly, data was collected on the numbers of households who own at least one of various types of moveable assets – furniture, cell phones, bicycles, ploughs, hoes, etc. As can be seen from Table 5.80, the most common moveable assets are tools used for farming or to harvest firewood for energy or selling purposes (hoes and axes), bicycles, cell phones and radios.

Table 5.80: Moveable Household Assets (% PAHs Who Own at Least One)

GVH	Hoe	Axe	Bicycle	Radio	Mobile phone	Charcoal Stove	Solar power	Wheelbarrow	TV	DVD Player	Motorbike	Wood Stove	Cart	Sewing machine	Generator	Motor vehicle	Fridge	Gas Stove	Plough
Chimwendo	93	65	55	40	31	28	15	3	8	7	3	3	5	1	4	1	1	1	-
Chitsulo	98	68	60	44	33	20	16	8	8	7	6	5	4	2	1	2	2	1	1
Kathyokamwendo	97	55	45	19	19	10	10	10	-	6	-	-	3	-	-	-	-	3	-
Manase	100	86	71	29	14	-	29	-	-	-	-	14	14	-	-	-	-	-	-
Mtali	95	61	54	34	29	34	9	-	-	-	2	5	-	-	2	-	-	-	-
Mtata	83	67	33	33	8	17	-	-	-	-	-	-	-	-	-	-	-	-	-
Ndumila	97	62	55	38	38	28	21	7	7	14	10	10	3	3	7	7	3	-	-
Ntanga	91	55	40	22	22	28	3	2	-	-	3	-	2	-	-	-	-	-	-
Pingeni	98	64	49	33	14	22	10	7	3	1	1	2	2	2	-	-	1	-	1
Total	**96**	**65**	**55**	**39**	**28**	**23**	**13**	**6**	**6**	**5**	**4**	**4**	**3**	**1**	**1**	**1**	**1**	**1**	**1**

5.15.5.3 Household Needs

During the socio-economic survey, respondents were presented with various aspects and asked to rate these in terms of degree to which they experience these as an individual or communal problem or need. The results which show employment, hunger, poor road conditions/ transport, lack of access to electricity, crime and/or violence as well as excessive harvesting to be the aspects which mostly affect people's quality of life (Table 5.81).

Table 5.81: Aspects that Affect Household's Quality of Life

Aspect	Yes, it is a problem and affects my quality of life (% of PAHs)								
	Chimwendo	Chitsulo	Kathyokamwendo	Manase	Mtali	Mtata	Ndumila	Ntanga	Pingeni
Access health facility	71	81	77	100	59	92	90	69	83
Access to agricultural inputs	74	76	84	71	86	75	83	81	83
Access to markets	67	74	68	71	57	50	76	40	73
Access to school	41	49	55	86	21	50	34	21	36
Access to shops	53	61	48	71	41	25	62	29	57
Alcohol abuse	76	78	90	71	59	42	66	64	78
Availability of land for agriculture	61	47	55	71	43	50	45	57	46
Availability of recreational facilities	59	46	42	71	54	25	38	34	46
Crime or violence	79	81	84	71	68	58	66	71	82
Drinking water	33	32	42	71	21	33	38	17	27
Drug abuse	72	73	84	71	55	42	66	57	70
Electricity	96	75	97	86	95	100	52	93	70
Employment	95	92	97	100	95	92	93	91	94
Housing	56	46	45	71	45	42	48	33	52
Hunger or nutrition	94	89	97	71	96	100	90	95	92
Illegal or excessive harvesting	91	71	87	57	84	92	48	90	59
Poor road conditions	97	91	97	71	96	92	83	93	92
Prostitution	73	75	84	71	55	42	69	60	76
Public transport	95	81	81	71	80	50	83	84	86
Quality education	55	52	55	57	52	33	52	36	43
Quality health care facilities	66	63	65	86	50	25	72	52	69
Quality water	49	49	39	86	27	33	59	31	46
Refuse	53	47	55	43	41	33	48	31	46
Water for irrigation	69	64	58	71	68	42	62	53	69

5.15.5.4 Community Health

Respondents were presented with a list of common health conditions, and were asked to indicate if any of their family members had suffered from the conditions in the past year. As shown in Table 5.82, malaria is by far the most common disease to affect households, with 36% of PAHs having had on average one member recently infected. In most cases, households seek treatment from a doctor or nurse, with the treatment being on-going due to the recurrence of the disease. Other common health conditions are flu, coughs indicating respiratory problems and stomach ailments, for which individuals generally consult a doctor for treatment. Although no households reported sexually transmitted diseases (STDs) or individuals having contracted HIV/AIDS, this does not necessarily imply that there are no individuals suffering from associated symptoms such as hepatitis. HIV/AIDS and STDs are often under-reported due to shame associated with these diseases.

Table 5.82: Prevalence of Common Health Conditions Among Households

Health condition	% of HH Affected	Average Number per Affected HH	Treatment			
			Doctor	Nurse	Home visit	On-going treatment
Malaria	36%	1.3	89%	31%	3%	30%
Flu	4%	1.1	88%	28%	-	16%
Coughs	3%	1.2	85%	21%	-	54%
Stomach ache	3%	1.0	94%	23%	6%	26%
Asthma	3%	1.1	100%	45%	3%	59%
Pneumonia	2%	1.0	85%	41%	-	19%
Anaemia	2%	1.0	100%	64%	8%	36%
Blood pressure	2%	1.0	92%	50%	4%	42%
Back aches	2%	1.0	79%	11%	5%	16%
Diarrhoea	2%	1.1	89%	32%	5%	26%
Headaches	2%	1.0	95%	15%	-	47%
Swollen extremities	1%	1.2	100%	36%	-	36%
Body aches	1%	1.0	92%	31%	-	69%
Rheumatism	1%	1.0	75%	25%	-	83%
Epilepsy	1%	1.0	78%	44%	-	78%
Tuberculosis	1%	1.1	100%	67%	11%	67%
Heart problems	1%	1.0	89%	22%	-	33%
Dental problems	1%	1.0	100%	25%	-	50%
Leg ache	1%	1.0	86%	29%	14%	43%
Skin disease (or skin sores)	0.5%	1.2	83%	33%	-	50%
Ulcers	0.5%	1.0	100%	40%	20%	20%
Kidney problems	0.5%	1.0	100%	60%	20%	80%
Mental illness	0.4%	1.0	75%	25%	-	100%

Analysis of the data showed that the majority of individuals who do get sick are concentrated in three GVH areas, these being Chitsulo, Chimwendo and Pingeni. Table 5.83 indicates that those affected by the aforementioned health conditions have access to a private hospital/health facility, church hospital and health care worker, although transport to these facilities is often limited.

Table 5.83: Utilisation of Health Facilities by Household

GVH	Private Hospital	Church Hospital	Community Health Worker	Government Hospital	Clinic	Mobile Clinic	Healer
Chimwendo	77%	70%	51%	33%	29%	28%	29%
Chitsulo	81%	64%	58%	31%	33%	27%	26%
Kathyokamwendo	68%	77%	55%	48%	42%	42%	39%
Manase	43%	86%	43%	43%	43%	43%	43%
Mtali	86%	64%	64%	21%	20%	21%	20%
Mtata	58%	42%	83%	50%	25%	25%	25%
Ndumila	76%	62%	62%	41%	34%	38%	17%
Ntanga	62%	62%	34%	9%	7%	10%	7%
Pingeni	73%	71%	58%	37%	36%	27%	25%

Almost 60% of PAHs report that their children have received vaccinations, with some significant variation between GVHs. Only 38% of households reported that they own mosquito nets.

5.15.5.5 Disability

During the survey, 13% of PAHs indicated that they have one or more household member who has some form of mental or physical disability. Few of these households have two or more disabled members. Numbers of individuals with various types of disability are shown in Table 5.84. The lack of physical mobility (largely related to old age) is the most common form of disability, followed by those affected by hearing, visual and mental impairments.

Table 5.84: Numbers of Individuals per Type of Disability

GVH	Physical	Hearing	Visual	Mental	Multiple	Total
Chimwendo	11	2	6	8		27
Chitsulo	14	20	10	14	1	59
Kathyokamwendo	3					3
Manase	1	4	3			8
Mtali	2	1	1	1		5
Mtata			2	3		5
Ndumila	2	1	1			4
Ntanga	5	5		2		12
Pingeni	17	3	9	3		32
Total	**55**	**36**	**32**	**31**	**1**	**155**

5.15.5.6 Social networks

The lack of social networks constitutes an indicator of vulnerability, since such networks can play a significant role in terms of providing support and assistance to households who are experiencing difficulties. During the socio-economic survey, most respondents indicated that they have relatives and friends in the village where they live.

Figure 5.38 indicates the degree to which PAHs depend on relatives or friends in the same village for assistance in various household tasks. The graph indicates a high degree of reliance, especially in terms of cultivating fields, looking after the sick as wells as children, sharing resources such as equipment, tools or transport, and to exchange goods or services.

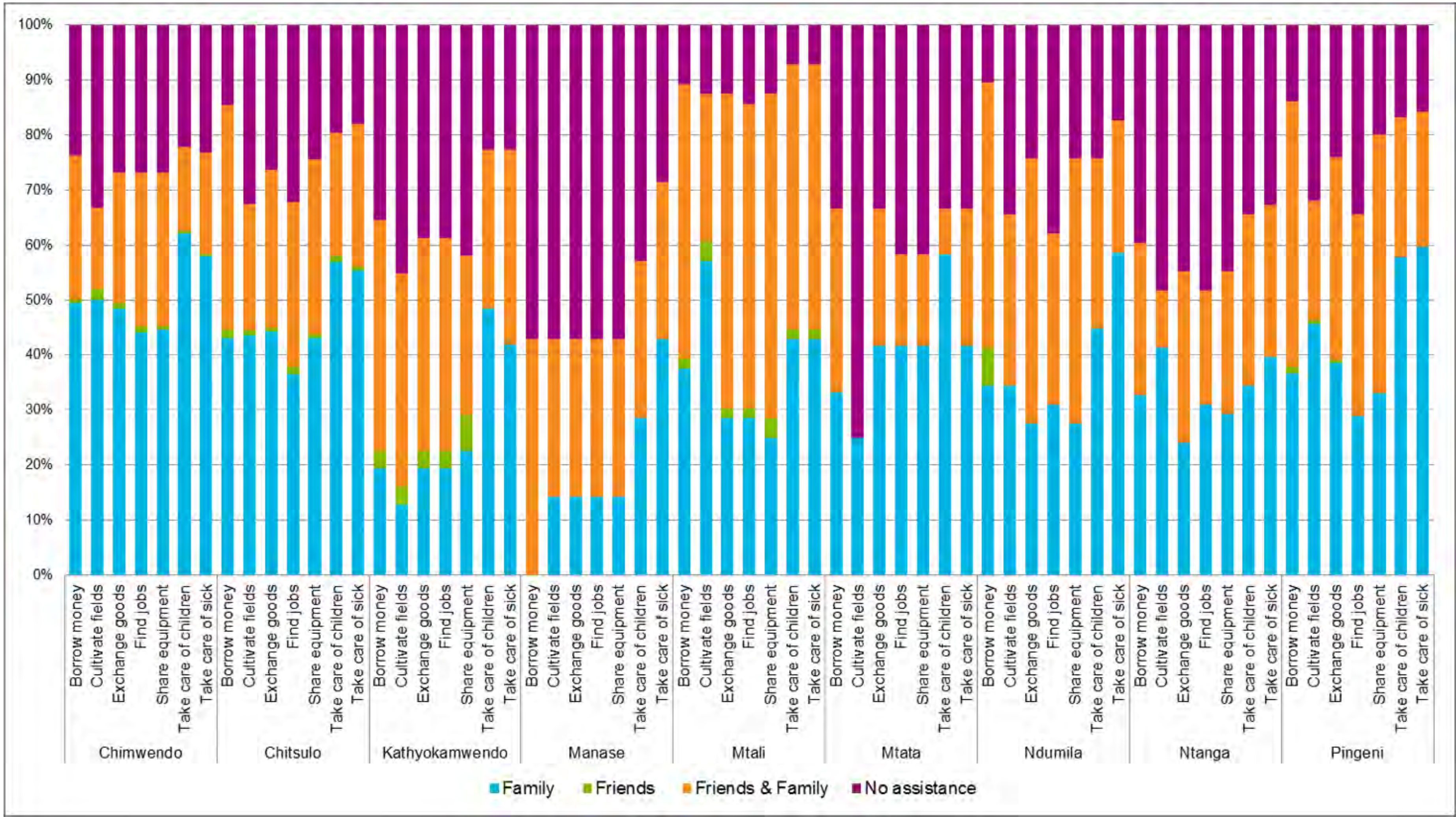


Figure 5.38: Degree of Dependence on Relatives and Friends

5.15.6 Water and sanitation

Water for domestic purposes is mostly obtained from communal boreholes, with a small number of individuals also collecting water from private (or home) boreholes or wells, this trend remains invariant across most of the GVH areas, irrespective of whether it's wet or dry season. The time it takes to reach the water collection points is on average 11 minutes, and also does not vary significantly across seasons and GVH areas. The majority of households indicated that they apply treatment to their water in order to sanitize it prior consumption; where water is treated, this is usually by means of adding bleach (Table 5.85).

Table 5.85: Treatment of Water

% Household Applying Treatment	Type of Treatment			
	Bleach	Boil	Other	Tablet
72%	92%	1%	1%	6%

The types of sanitation facilities used by surveyed households are detailed in Table 5.86. The majority of households have access to private pit latrines. Only about 7% of households indicated that they shared a sanitation facility with one or more households.

Table 5.86: Types of Sanitation

Pit Latrine	Communal Pit Latrine	Shared Facility with Family/Neighbours	None
83%	7%	7%	3%

5.15.7 Energy

Household access and connection to the electrical grid is virtually non-existent throughout the project area. Consequently, households have to rely on alternative energy sources. The most common sources of energy for lighting are flashlights, and the most common source of energy for cooking is wood/charcoal

5.15.8 Ecosystem Services

This section provides a summary of the degree of access which households have to a variety of ecosystem services, such as land, water, hunting or fishing areas etc., as well as access to public services and social amenities. Table 5.87 indicates the degree of availability of various ecosystem services as well as whether these are utilised by households. Table 5.88 details the time it takes to access each of the services as well as the mode of transport used for access.

Table 5.87: Household Utilisation of Eco-system Services

Resource	Chimwendo		Chitsulo		Kathyoka-mwendo		Manase		Mtali		Mtata		Ndumila		Ntanga		Pingeni		Total	
	Non-existent**	Used	Non-existent	Used	Non-existent	Used	Non-existent	Used	Non-existent	Used	Non-existent	Used	Non-existent	Used	Non-existent	Used	Non-existent	Used	Non-existent	Used
Area for firewood	-	100%	-	99%	-	100%	-	86%	-	98%	-	92%	-	93%	-	98%	-	98%	-	**98%**
Medicinal plants	-	99%	2%	87%	-	100%	-	43%	-	100%	-	92%	3%	90%	5%	86%	1%	96%	**1%**	**92%**
Fishing	3%	95%	2%	74%	-	87%	-	71%	2%	66%	25%	67%	7%	72%	5%	79%	2%	75%	**3%**	**78%**
Forest food area	-	99%	1%	89%	-	100%	-	43%	-	100%	-	92%	-	90%	9%	91%	1%	96%	**1%**	**93%**
Fuel for cooking	1%	99%		100%	-	90%	-	100%	-	79%	-	92%	-	100%	-	98%	-	100%	-	**98%**
Hunting area	3%	94%	3%	67%	-	87%	14%	43%	5%	68%	33%	75%	10%	66%	5%	79%	4%	66%	**4%**	**73%**
Main cropping land	-	100%	-	98%	-	100%	-	100%	-	100%	-	92%	3%	100%	-	100%	-	100%	-	**99%**
Water	-	100%	-	100%	-	100%	-	100%	-	100%	-	92%	-	100%	-	100%	-	100%	-	**100%**

** Percentage of households who believe this service does not exist

Table 5.88: Access to Available Ecosystem Services

Service and GVH	Time Required to Access				Mode of Transport				
	Less than 5min	Up to 30min	Up to 1 hour	1 hour or more	On foot	Bicycle	Motor vehicle	Public transport	Other
Area for firewood	14%	49%	32%	6%	76%	19%	1%	3%	1%
Chimwendo	4%	52%	41%	4%	68%	32%	-	1%	-
Chitsulo	22%	48%	23%	7%	81%	11%	1%	5%	2%
Kathyokamwendo	3%	55%	35%	6%	77%	23%	-	-	-
Manase	-	50%	-	50%	67%	-	-	33%	-
Mtali	2%	51%	47%	-	65%	33%	2%	-	-
Mtata	-	82%	-	18%	55%	45%	-	-	-
Ndumila	30%	44%	15%	11%	89%	7%	4%	-	-
Ntanga	2%	35%	61%	2%	61%	37%	-	2%	-
Pingeni	10%	47%	39%	4%	82%	14%	2%	2%	-
Area for medicinal plants	10%	48%	34%	8%	76%	19%	1%	3%	-
Chimwendo	3%	53%	37%	7%	69%	31%	-	1%	-
Chitsulo	17%	48%	25%	10%	81%	11%	1%	6%	-
Kathyokamwendo	3%	55%	35%	6%	77%	23%	-	-	-
Manase	33%	-	-	67%	33%	-	-	67%	-
Mtali	-	50%	48%	2%	68%	30%	2%	-	-
Mtata	-	82%	-	18%	55%	45%	-	-	-
Ndumila	12%	36%	36%	16%	81%	15%	4%	-	-
Ntanga	-	32%	57%	11%	58%	40%	-	-	2%
Pingeni	9%	43%	43%	4%	82%	14%	2%	2%	-
Fishing	2%	61%	30%	6%	68%	24%	1%	4%	3%
Chimwendo	2%	57%	39%	2%	62%	34%	-	1%	3%
Chitsulo	2%	70%	20%	8%	73%	16%	2%	7%	2%
Kathyokamwendo	-	52%	41%	7%	78%	22%	-	-	-
Manase	-	60%	-	40%	60%	-	-	40%	-
Mtali	-	33%	67%	-	46%	49%	3%	-	3%
Mtata	-	60%	-	40%	38%	25%	-	-	38%
Ndumila	-	79%	11%	11%	76%	10%	5%	-	10%
Ntanga	-	19%	74%	7%	46%	50%	-	-	4%
Pingeni	4%	68%	25%	3%	78%	15%	2%	2%	2%
Forest food products	10%	39%	39%	12%	71%	23%	3%	3%	-
Chimwendo	3%	52%	37%	8%	66%	32%	1%	1%	-
Chitsulo	16%	37%	33%	15%	74%	17%	3%	6%	-
Kathyokamwendo	3%	55%	35%	6%	77%	23%	-	-	-

Service and GVH	Time Required to Access				Mode of Transport				
	Less than 5min	Up to 30min	Up to 1 hour	1 hour or more	On foot	Bicycle	Motor vehicle	Public transport	Other
Manase	33%	-	-	67%	33%	-	-	67%	-
Mtali	-	48%	48%	4%	68%	30%	2%	-	-
Mtata	-	82%	-	18%	55%	45%	-	-	-
Ndumila	12%	19%	31%	38%	77%	12%	8%	4%	-
Ntanga	-	25%	65%	10%	58%	36%	2%	-	4%
Pingeni	9%	31%	53%	7%	71%	23%	4%	2%	-
Fuel for cooking	14%	50%	33%	3%	72%	27%	1%	-	-
Chimwendo	6%	65%	29%	-	71%	28%	1%	1%	-
Chitsulo	19%	45%	34%	3%	74%	26%	-	-	-
Kathyokamwendo	-	75%	25%	-	82%	18%	-	-	-
Manase	43%	29%	14%	14%	71%	29%	-	-	-
Mtali	2%	48%	48%	2%	43%	57%	-	-	-
Mtata	-	55%	45%	-	55%	45%	-	-	-
Ndumila	24%	31%	38%	7%	83%	17%	-	-	-
Ntanga	5%	56%	35%	4%	60%	39%	2%	-	-
Pingeni	15%	50%	31%	4%	81%	18%	1%	-	-
Hunting area	1%	44%	42%	13%	65%	24%	2%	4%	4%
Chimwendo	2%	49%	47%	2%	61%	35%	-	1%	3%
Chitsulo	1%	47%	35%	17%	72%	14%	4%	7%	3%
Kathyokamwendo	-	44%	41%	15%	70%	30%	-	-	-
Manase	-	-	-	100%	-	33%	-	67%	-
Mtali	-	37%	60%	3%	39%	50%	3%	5%	3%
Mtata	-	60%	-	40%	33%	22%	-	-	44%
Ndumila	-	44%	25%	31%	68%	16%	5%	-	11%
Ntanga	-	16%	70%	14%	41%	54%	-	-	4%
Pingeni	1%	41%	44%	13%	75%	17%	2%	3%	4%
Main cropping land	13%	75%	9%	2%	92%	7%	1%	-	-
Chimwendo	4%	80%	13%	3%	87%	12%	2%	-	-
Chitsulo	19%	71%	8%	2%	94%	5%		-	-
Kathyokamwendo	-	94%	6%	-	90%	6%	3%	-	-
Manase	43%	29%	14%	14%	86%	14%	-	-	-
Mtali	4%	91%	5%	-	91%	9%	-	-	-
Mtata	-	100%	-	-	100%	-	-	-	-
Ndumila	18%	54%	29%	-	83%	17%	-	-	-
Ntanga	3%	93%	2%	2%	97%	2%	-	2%	-
Pingeni	16%	69%	11%	4%	94%	5%	1%	-	-

Service and GVH	Time Required to Access				Mode of Transport				
	Less than 5min	Up to 30min	Up to 1 hour	1 hour or more	On foot	Bicycle	Motor vehicle	Public transport	Other
Water	51%	45%	3%	1%	96%	4%		-	-
Chimwendo	32%	63%	5%	-	91%	9%	1%	-	-
Chitsulo	51%	45%	4%	1%	98%	2%	-	-	-
Kathyokamwendo	58%	39%	3%	-	97%	3%	-	-	-
Manase	86%	-	-	14%	100%	-	-	-	-
Mtali	63%	30%	7%	-	96%	4%	-	-	-
Mtata	64%	36%	-	-	100%	-	-	-	-
Ndumila	79%	17%	3%	-	97%	3%	-	-	-
Ntanga	60%	40%	-	-	100%	-	-	-	-
Pingeni	56%	42%	1%	1%	96%	4%	-	-	-

5.15.9 Public Services and Social Amenities

This section provides a summary of the degree of access which households have to a variety of public services and social amenities (Table 5.89), e.g. there are 12 households in Mtata; of these households one indicated that they don't use a specific service (i.e. 8%).

Table 5.90 indicates the time it takes to reach each facility.

Table 5.89: Household Utilisation of Public Services and other Amenities

Resource	Chimwendo		Chitsulo		Kathyoka-mwendo		Manase		Mtali		Mtata		Ndumila		Ntanga		Pingeni		Total	
	Non-existent	Not used	Non-existent	Not used	Non-existent	Not used	Non-existent	Not used	Non-existent	Not used	Non-existent	Not used	Non-existent	Not used	Non-existent	Not used	Non-existent	Not used	Non-existent	Not used
Bank credit facility	7%	1%	17%	11%	10%	3%	14%	43%	32%	4%	67%	8%	28%	24%	26%	2%	23%	19%	**18%**	**10%**
Bus stop	-	-	-	-	-	-	-	-	-	-	-	8%	-	-	-	-	-	1%	-	-
Church/Mosque	-	1%	-	3%	-	3%	-	29%	-	2%	-	8%	-	10%	-	3%	-	8%	-	**4%**
Clinic	24%	5%	22%	14%	16%	10%	-	43%	39%	25%	8%	50%	7%	38%	26%	16%	10%	33%	**21%**	**17%**
Flour mill	-	-	-	-	-	-	-	-	-	-	-	8%	-	-	-	-	-	-	-	-
Hospital	1%	-	1%	1%	-	3%	-	-	2%	2%	-	8%	7%	-	-	-	5%	1%	**2%**	**1%**
Administration	7%	1%	15%	8%	10%	3%	14%	43%	30%	2%	50%	8%	21%	17%	26%	-	18%	22%	**16%**	**9%**
Market to buy	-	-	-	-	-	-	-	-	-	2%	-	8%	-	-	-	-	-	-	-	-
Market to sell	-	-	-	-	-	-	-	-	-	2%	-	8%	-	7%	-	-	-	-	-	-
Police	5%	-	11%	7%	6%	3%	-	43%	30%	-	33%	8%	17%	14%	22%	-	12%	22%	**12%**	**8%**
Primary school	-	1%	-	5%	-	6%	-	-	-	4%	-	8%	-	14%	-	2%	1%	4%	-	**4%**
Secondary school	-	1%	-	7%	-	6%	-	-	-	16%	-	17%	3%	17%	-	9%	1%	5%	-	**6%**
Shops	1%	-	-	-	-	-	-	-	-	-	-	8%	-	-	2%	-	1%	-	-	-
Vocational training	45%	5%	39%	18%	48%	10%	-	57%	54%	25%	25%	50%	28%	41%	69%	16%	33%	36%	**41%**	**20%**

Table 5.90: Household Utilisation of Public Services and Other Amenities

Resource and GVH	Time required to access				Mode of transport				
	Less than 5min	Up to 30min	Up to 1 hour	1 hour or more	On foot	Bicycle	Motor vehicle	Public Transport	Other
Bank credit facility	7%	6%	20%	68%	18%	20%	23%	25%	14%
Chimwendo	2%	14%	23%	61%	17%	24%	26%	26%	6%
Chitsulo	10%	5%	22%	64%	18%	21%	24%	24%	13%
Kathyokamwendo	-	-	-	100%	13%	23%	20%	37%	7%
Manase	33%	-	-	67%	25%	-	-	50%	25%
Mtali	-	-	-	100%	2%	17%	30%	20%	31%
Mtata	-	-	-	100%	-	9%	9%	45%	36%
Ndumila	14%	-	21%	64%	18%	14%	27%	18%	23%
Ntanga	-	5%	12%	83%	16%	26%	18%	16%	25%
Pingeni	10%	2%	22%	66%	24%	14%	18%	27%	16%
Bus stop	10%	45%	38%	7%	68%	31%	1%	-	-
Chimwendo	16%	60%	24%	-	68%	31%	-	1%	-
Chitsulo	11%	38%	44%	7%	66%	33%	1%	-	-
Kathyokamwendo	-	81%	19%	-	81%	19%	-	-	-
Manase	-	29%	57%	14%	29%	71%	-	-	-
Mtali	2%	70%	29%	-	68%	32%	-	-	-
Mtata	-	100%	-	-	91%	9%	-	-	-
Ndumila	3%	21%	62%	14%	76%	24%	-	-	-
Ntanga	21%	64%	14%	2%	81%	19%	-	-	-
Pingeni	1%	32%	48%	19%	67%	31%	2%	1%	-
Church/Mosque	13%	77%	9%	2%	91%	9%	-	-	-
Chimwendo	7%	79%	14%	-	88%	12%	-	-	-
Chitsulo	16%	73%	9%	1%	90%	9%	1%	-	-
Kathyokamwendo	3%	93%	3%	-	90%	10%	-	-	-
Manase	20%	60%	-	20%	80%	-	-	-	20%
Mtali	16%	76%	7%	-	91%	9%	-	-	-
Mtata	-	100%	-	-	100%	-	-	-	-
Ndumila	8%	73%	15%	4%	100%	-	-	-	-
Ntanga	7%	88%	5%	-	100%	-	-	-	-
Pingeni	12%	80%	5%	4%	92%	8%	-	-	-
Clinic	2%	41%	51%	6%	40%	32%	11%	10%	8%
Chimwendo	2%	60%	36%	2%	44%	25%	17%	12%	3%
Chitsulo	2%	29%	63%	6%	36%	35%	6%	12%	10%
Kathyokamwendo	-	78%	22%	-	57%	25%	18%	-	-
Manase	-	-	100%	-	25%	75%	-	-	-
Mtali	-	85%	15%	-	33%	12%	38%	5%	12%
Mtata	-	60%	40%	-	50%	50%	-	-	-
Ndumila	6%	69%	6%	19%	72%	6%	6%	-	17%
Ntanga	-	56%	41%	3%	24%	37%	24%	8%	6%
Pingeni	4%	26%	57%	13%	45%	38%	-	6%	12%
Flour mill	4%	38%	47%	12%	61%	38%	1%	-	-
Chimwendo	15%	72%	13%	-	84%	15%	-	1%	-

Resource and GVH	Time required to access				Mode of transport				
	Less than 5min	Up to 30min	Up to 1 hour	1 hour or more	On foot	Bicycle	Motor vehicle	Public Transport	Other
Chitsulo	1%	20%	67%	12%	48%	51%	1%	-	-
Kathyokamwendo	6%	84%	10%	-	87%	13%	-	-	-
Manase	-	29%	57%	14%	43%	57%	-	-	-
Mtali	4%	88%	9%	-	89%	11%	-	-	-
Mtata	-	91%	9%	-	82%	18%	-	-	-
Ndumila	3%	17%	52%	28%	52%	45%	3%	-	-
Ntanga	12%	83%	5%	-	84%	16%	-	-	-
Pingeni	-	8%	61%	30%	51%	47%	2%	-	-
Hospital	-	9%	75%	15%	26%	68%	2%	3%	1%
Chimwendo	2%	19%	75%	5%	30%	63%	3%	3%	1%
Chitsulo	-	6%	78%	16%	26%	69%	2%	2%	1%
Kathyokamwendo	-	13%	83%	3%	20%	70%	3%	3%	3%
Manase	-	14%	71%	14%	14%	86%	-	-	-
Mtali	-	9%	87%	4%	16%	80%	-	4%	-
Mtata	-	-	100%	-	18%	73%	-	9%	-
Ndumila	4%	11%	56%	30%	21%	72%	3%	3%	-
Ntanga	-	10%	83%	7%	21%	69%	5%	3%	2%
Pingeni	-	4%	62%	34%	28%	67%	-	3%	2%
Local administration	-	4%	28%	68%	11%	29%	23%	24%	13%
Chimwendo	1%	14%	25%	60%	17%	25%	26%	26%	5%
Chitsulo	-	1%	33%	65%	9%	32%	24%	23%	12%
Kathyokamwendo	-	-	4%	96%	7%	30%	17%	43%	3%
Manase	-	-	67%	33%	-	50%	-	50%	-
Mtali	-	-	-	100%	-	18%	29%	20%	33%
Mtata	-	-	-	100%	-	18%	-	55%	27%
Ndumila	-	11%	22%	67%	17%	21%	21%	21%	21%
Ntanga	-	5%	12%	84%	16%	29%	17%	14%	24%
Pingeni	-	-	36%	64%	12%	32%	19%	22%	14%
Market to buy	1%	15%	70%	14%	41%	57%	2%	1%	-
Chimwendo	2%	25%	67%	6%	34%	63%	2%	1%	-
Chitsulo	1%	14%	71%	15%	45%	52%	2%	1%	-
Kathyokamwendo	-	32%	61%	6%	42%	58%	-	-	-
Manase	-	29%	57%	14%	43%	57%	-	-	-
Mtali	-	15%	85%	-	16%	82%	2%	-	-
Mtata	-	9%	91%	-	18%	82%	-	-	-
Ndumila	7%	14%	59%	21%	59%	38%	3%	-	-
Ntanga	-	9%	88%	3%	28%	66%	3%	3%	-
Pingeni	1%	8%	60%	31%	47%	51%	1%	1%	-
Market to sell	1%	12%	72%	15%	38%	60%	2%	1%	-
Chimwendo	2%	26%	67%	6%	34%	63%	3%	1%	-
Chitsulo	1%	8%	76%	16%	39%	58%	2%	1%	-
Kathyokamwendo	-	32%	61%	6%	45%	55%	-	-	-
Manase	-	29%	57%	14%	43%	57%	-	-	-

Resource and GVH	Time required to access				Mode of transport				
	Less than 5min	Up to 30min	Up to 1 hour	1 hour or more	On foot	Bicycle	Motor vehice	Public Transport	Other
Mtali	-	15%	85%	-	16%	80%	4%	-	-
Mtata	-	9%	91%	-	18%	82%	-	-	-
Ndumila	4%	15%	59%	22%	56%	41%	4%	-	-
Ntanga	-	5%	90%	5%	26%	67%	3%	3%	-
Pingeni	1%	5%	63%	32%	44%	54%	1%	1%	-
Police	1%	4%	39%	56%	14%	48%	21%	8%	9%
Chimwendo	2%	13%	38%	47%	19%	54%	24%	2%	1%
Chitsulo	-	2%	44%	55%	12%	49%	22%	8%	10%
Kathyokamwendo	-	4%	36%	61%	7%	63%	17%	13%	-
Manase	25%	-	25%	50%	25%	25%	-	50%	-
Mtali	-	3%	26%	72%	7%	48%	29%	4%	13%
Mtata	-	-	43%	57%	-	100%	-	-	-
Ndumila	5%	5%	40%	50%	16%	28%	20%	24%	12%
Ntanga	-	4%	22%	73%	19%	43%	16%	10%	12%
Pingeni	-	1%	35%	64%	18%	37%	18%	15%	13%
Primary school	22%	65%	11%	1%	97%	3%	-	-	-
Chimwendo	7%	80%	12%	1%	94%	6%	-	-	-
Chitsulo	26%	61%	12%	1%	96%	3%	-	-	-
Kathyokamwendo	-	72%	28%	-	97%	3%	-	-	-
Manase	57%	43%	-	-	100%	-	-	-	-
Mtali	-	72%	24%	4%	100%	-	-	-	-
Mtata	-	82%	18%	-	100%	-	-	-	-
Ndumila	20%	76%	-	4%	96%	4%	-	-	-
Ntanga	2%	82%	16%	-	100%	-	-	-	-
Pingeni	48%	50%	1%	1%	100%	-	-	-	-
Secondary school	1%	25%	48%	26%	51%	48%	-	-	1%
Chimwendo	2%	43%	37%	19%	56%	44%	-	-	-
Chitsulo	-	19%	57%	24%	48%	51%	-	-	1%
Kathyokamwendo	-	41%	24%	34%	76%	24%	-	-	-
Manase	-	-	86%	14%	43%	57%	-	-	-
Mtali	-	23%	43%	34%	40%	53%	-	-	6%
Mtata	-	30%	40%	30%	50%	50%	-	-	-
Ndumila	-	35%	43%	22%	42%	54%	4%	-	-
Ntanga	-	11%	49%	40%	60%	40%	-	-	-
Pingeni	1%	25%	41%	34%	53%	47%	-	-	-
Shops	16%	54%	25%	5%	72%	27%	-	-	-
Chimwendo	5%	74%	21%	-	78%	22%	-	1%	-
Chitsulo	18%	49%	29%	4%	69%	30%	1%	-	-
Kathyokamwendo	32%	48%	19%	-	77%	23%	-	-	-
Manase	-	29%	57%	14%	43%	57%	-	-	-
Mtali	11%	57%	32%	-	70%	29%	2%	-	-
Mtata	-	100%	-	-	100%	-	-	-	-
Ndumila	17%	45%	24%	14%	69%	28%	3%	-	-

Resource and GVH	Time required to access				Mode of transport				
	Less than 5min	Up to 30min	Up to 1 hour	1 hour or more	On foot	Bicycle	Motor vehicle	Public Transport	Other
Ntanga	9%	79%	9%	4%	83%	17%	-	-	-
Pingeni	24%	37%	24%	15%	73%	27%	-	-	-
Vocational training	1%	34%	57%	8%	44%	22%	10%	13%	11%
Chimwendo	3%	75%	18%	3%	59%	13%	16%	9%	2%
Chitsulo	-	12%	79%	9%	34%	31%	5%	15%	14%
Kathyokamwendo	-	69%	31%	-	71%	11%	18%	-	-
Manase	-	33%	33%	33%	67%	33%	-	-	-
Mtali	-	92%	8%	-	45%	-	38%	5%	12%
Mtata	-	-	100%	-	67%	17%	-	17%	-
Ndumila	-	22%	33%	44%	12%	24%	6%	12%	47%
Ntanga	-	56%	33%	11%	65%	4%	18%	6%	6%
Pingeni	-	31%	63%	6%	42%	25%	-	19%	14%

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Chapter 6: Stakeholder Engagement

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6 Stakeholder Engagement

A comprehensive stakeholder engagement process was implemented as part of the ESIA process, as well as consultation in respect of the RAP.

6.1 Objectives of Stakeholder Engagement

The objectives of engaging stakeholders during the ESIA process include the following:

- **Creating an understanding of the Project:** an open, inclusive and transparent process of culturally appropriate engagement and communication will be undertaken to ensure that stakeholders are well informed about the Project. Information will be disclosed as early and as comprehensively as possible.

- **Involving stakeholders in the assessment:** stakeholders will be included in the scoping of issues, the identification of impacts, the generation of mitigation and management measures, and the review of the ESIA report. They also play an important role in providing local knowledge and information as baseline data that will inform the impact assessment.

- **Building relationships:** through supporting open dialogue, engagement helps establish and maintain a productive relationship between the ESIA team and stakeholders; and eventually between stakeholders and the operating mining company.

- **Engaging vulnerable groups:** an open and inclusive approach to consultation increases the opportunity of stakeholders to provide comment on the Project and to voice their concerns. Some stakeholders, however, need special attention during the consultation process due to their vulnerability. Special measures will be considered to ensure that the perspectives of vulnerable stakeholders are heard and considered.

- **Ensuring compliance:** the process is designed to ensure compliance with both local regulatory requirements and the IFC performance standards. One of the key outcomes of engagement should be free, prior and informed consultation of stakeholders, where this can be understood to be:
  - free: engagement free of external manipulation or coercion and intimidation;
  - prior: engagement undertaken in a timely way, for example the timely disclosure of information before a development is undertaken and or participation is sought regarding the identification of issues of concern; and
  - informed: engagement enabled by relevant, understandable and accessible information.

6.2 Stakeholder Identification

Stakeholders who may potentially be affected by or have an interest in the Project were identified and a database developed. Details of individual stakeholders were compiled in a stakeholder register which has been updated periodically throughout the ESIA engagement process. The information kept on the database is for ease of use, but details are never shared with any third-party.

As part of the stakeholder identification and analysis process, it is important to identify individuals and groups who may find it more difficult to participate and those who may be differentially or disproportionately affected by the Project because of their marginalised or vulnerable status. It is also important to understand how each stakeholder may be affected – or perceives he/she may be affected – so that engagement can be tailored to inform them and address their views and concerns in an appropriate manner.

Table 6.1 details the various stakeholder groups that were identified following the announcement of the Project in December 2017, which was the first step in the environmental scoping phase. These stakeholder groups were expanded on throughout the ESIA according to the individuals and groups who were consulted and/or registered as stakeholders, also referred to as interested and affected parties (I&APs).

A complete list of stakeholders consulted during the process is included as Appendix P.

Table 6.1: Categories of Stakeholder Groups Identified

Stakeholder Category	Stakeholder Groups	Interest in the Project
Government	National regulatory bodies, including, among others: Ministry of Natural Resources, Energy and Mining; Environmental Affairs Department (EAD); Department of Mines; Ministry of Land, Housing and Urban Development; Department of Lands and Valuation; Department of Antiquities	National government is of primary importance in terms of establishing policy, granting permits or other approvals for the Project, and monitoring and enforcing compliance with Malawian law throughout all stages of the Project life-cycle.
	District regulatory bodies and key parastatal authorities: Lilongwe District Council; Lilongwe Water Board	One district authority and several parastatal organisations (e.g. Lilongwe District Council and Lilongwe Water Board) are impacted by the Project and will be informed of progress and plans in their areas, to consider the Project activities in their policy-making, regulatory and other duties and activities.
Traditional authorities (TAs)	Chiefs and village heads	Local community leaders, acting as representatives of their local community. Meetings with TAs will follow local customs and will be held prior to any wider communication in local communities to respect the prevailing political and social structures.
Communities	Project affected communities including registered and customary land owners, residents and occupiers of land, people who use and access land resources	Households and communities that may be directly or indirectly affected by the Project and its activities.
Vulnerable groups	Women and children headed households, elderly, disabled, youth, ethnic minorities, etc.	Vulnerable groups may be affected by the Project by virtue of their physical disability, social or economic standing, limited education, and/or lack of access to land.
Civil society and NGOs	Associations, groups, community-based organisations (CBOs), cultural groups and NGOs	Organisations with direct interest in the Project, and its social and environmental aspects and that are able to influence the project directly or through public opinion. Such organisations may also have useful data and insight, and may be able to become partners to the Project in areas of common interest.
Commerce and industry (including the media)	Local businesses and entrepreneurs affected by potential social and/or environmental impacts, and potential suppliers and contractors	Individuals or organisations with direct economic interest in the Project. This may be through gaining contracts with the Project or due to economic impacts caused by the Project.
Bilateral and multilateral organisations	Development agencies and financial institutions	A range of different international organisations may have an interest in the Project.

6.3 Stakeholder Engagement Process during Scoping Phase

6.3.1 Background Information Document

A background information document (BID), including a registration and comment form, was compiled in English and translated into Chichewa. The BID contained information on the Project, ESIA process, stakeholder engagement and ESIA team, and invited stakeholders to complete the registration form and submit comments as part of the process. It also provided contact details where additional information could be obtained.

A copy of the BID was made available at the Project announcement meetings in December 2017 and distributed to stakeholders on the database who were unable to attend these meetings.

Additional copies of the BID were also made available at the District Council offices and provided to the TAs to distribute among community members.

Copies of the BID in English and Chichewa are attached in Appendix Q.

6.3.2 Project Announcement

The Project and ESIA process was announced through a series of stakeholder meetings during the scoping phase from 4 to 7 December 2017, as detailed in Table 6.2. These meetings aimed at engaging stakeholders at national, district and local level.

Table 6.2: Project Announcement Meetings During Scoping Phase

Meeting	Venue	Date
Environmental Affairs Department; Department of Mines	Environmental Affairs Department	Monday, 4 December 2017 at 10:00
Various Ministries and Government Departments; Member of Parliament for Malingunde; Friends of Malingunde	Cross Roads Hotel	Monday, 4 December 2017 at 14:00
Lilongwe District Council	District Council Offices	Tuesday, 5 December 2017 at 10:00
Lilongwe Water Board	Lilongwe Water Board	Wednesday, 6 December 2017 at 10:00
Non-government Organisations; Community Services Organisations (CSOs); CBOs	Cross Roads Hotel	Wednesday, 6 December 2017 at 14:00
Traditional Authorities; District Council representatives	District Council	Thursday, 7 December 2017 at 10:00

The purpose of these meetings was to provide stakeholders with information about the Project; introduce the ESIA team and proponent; explain the ESIA process that will be undertaken; and give them an opportunity to raise questions and issues. A presentation was given at these meetings, which was based on the information contained in the BID, and a copy of the PowerPoint presentation was made available to stakeholders on request. Refer to Appendix R for copies of the presentation given at these meetings.

Comments received from stakeholders during the scoping phase were compiled and a comments and response report and was included in the ESR.

6.3.3 Environmental Scoping Meetings

A series of meetings were held on completion of the scoping phase between 7 and 9 March 2018 to present and discuss the contents of the draft ESR. The availability of the ESR and the environmental scoping meetings were also advertised in *The Nation* and *The Daily Times* newspapers on 19 February 2018 (Appendix S). Invitations to attend these meetings were sent to stakeholders who have previously registered their details with the stakeholder team. Copies of the non-technical summary of the ESR (in English and Chichewa) were distributed along with the invitations to I&APs.

Posters (in Chichewa) were put up in communities around the Project area in early March 2019 prior to the meetings to reach directly affected stakeholders. These posters contained the same information as the adverts published in February 2018.

The aims of these meetings were to:

- Present a summary of the contents of the draft ESR.
- Identify key issues and concerns that require further assessment during the ESIA phase.
- Present the specialist studies to be undertaken.
- Discuss the extent of, and approach to, the detailed ESIA phase.

The meetings held during the scoping phase with the various stakeholder groupings that were invited, are listed in Table 6.3. Although these meetings focussed on specific groupings of I&APs, all stakeholders were welcome to attend.

Table 6.3: List of Environmental Scoping Meetings

Meeting	Date / Venue
Ministries: • Ministry of Natural Resources, Energy and Mining • Ministry of Lands, Housing and Urban Development • Ministry of Agriculture, Irrigation and Water Development • Ministry of Transport and Public Works • Ministry of Local Government and Rural Development **Government Departments:** • Environmental Affairs Department • Department of Mines • Department of Antiquities • Department of Roads • Department of Lands and Valuation • Department of Irrigation and Water Development **Parastatals:** • Malawi Roads Authority • Lilongwe Water Board • National Water Resource Authority (NWRA) • Malawi Energy Regulatory Authority (MERA) **Other:** • Chamber of Mines and Energy • Member of Parliament	Wednesday, 7 March 2018 at 10:00 Cross Roads Hotel
Lilongwe District Council **TA Masumbankhunda - in the Project Area** • Development Committees (village and area) • Chiefs	Wednesday, 7 March 2018 at 14:00 District Council Offices
TA Chigwirizano - Along Access Road • Development Committee (village and area) • Chiefs	Thursday, 8 March 2018 at 10:00 District Council Offices
NGOs / CBOs / CSOs	Thursday, 8 March 2018 at 14:00 Cross Roads Hotel
Community meetings in the Project Area	Friday, 9 March 2018 at 09:00 Near Kumalindi Village
Information meeting with the media	Friday, 9 March 2018 – 14:00 Cross Roads Hotel

A presentation was given at these meetings, which contained a summary of the issues identified in the ESR. In addition, a copy of the non-technical summary of the ESR was made available at these meetings. A copy of the presentation given at the meetings is attached in Appendix R.

A copy of the PowerPoint presentation was made available to stakeholders on request.

6.3.4 Grievance Mechanism

Stakeholder engagement is a two-way process. Therefore, it is important to ensure that there is a grievance mechanism to allow stakeholders affected by or interested in the Project to present their input (e.g. opinions, requests, suggestions, feedback and grievances) for consideration and, if required, seek redress.

A grievance mechanism was developed (Appendix T) and the details communicated to stakeholders during the scoping phase consultation meetings, as well as meetings held during the ESIA phase. A dedicated representative (e.g. community liaison officer) will be appointed for the Project once a decision has been made whether the Project will proceed. The community liaison officer will be responsible for management of stakeholder engagement and implementation of the grievance mechanism. Grievances will be passed through the officer in the first instance, who will be responsible for passing the grievance on to the appropriate person according to the Project grievance mechanism.

The grievance mechanism will be updated and implemented throughout the life of the Project.

6.3.5 Review of Draft Environmental Scoping Report

This draft ESR was made available to the public for review and comments between 5 March and 13 April 2018. The availability of the draft ESR was advertised in the Nation and Daily Times newspapers on 19 February 2018. Copies of the advertisements are attached in Appendix S.

Hard copies of the report were made available to be viewed at:

- Offices of C12 Consultants – Office Number 7, Skyband Complex, off Paul Kagame Rd, Lilongwe.
- Offices of the Environmental Affairs Department.
- Lilongwe District Council Offices.
- Masumbankhunda Traditional Authority.

An electronic copy was also made available on Sovereign's website http://sovereignmetals.com.au/building-malingunde/.

A copy of the report on CD could also be requested from McCourt Mining's offices in Lilongwe and was distributed at the environmental scoping meetings to stakeholders on request.

Comments and queries were incorporated in the comments and response report (Appendix U), and the draft ESR was amended where required. The revised ESR was submitted to the Environmental Affairs Department for review and approval of the terms of reference.

6.4 Stakeholder Engagement Process during ESIA Phase

6.4.1 Consultation During Fieldwork

As part of its commitment to ongoing consultation with stakeholders affected by the Project, a series of meetings were held between 5 and 10 August 2018. The purpose of these meetings was to provide feedback on the current status of the Project, discuss planned fieldwork activities (particularly exploration drilling) during the second half of 2018, and to serve as a platform to engage with stakeholders on potential resettlement as a result of the Project.

The meetings held as part of this consultation, along with the various stakeholders invited to attend, are detailed in Table 6.4. All of these meetings were attended by the Department of Mines, as well as the Lilongwe District Council.

Table 6.4: List of Meetings Held During 2018 Fieldwork Program

Meeting	Date / Venue
RAP Committee **Ministries:** • Ministry of Natural Resources Energy and Mining • Ministry of Finance and Economic Development • Ministry of Lands, Housing and Urban Development • Ministry of Agriculture, Irrigation and Water Development • Ministry of Transport and Public Works • Ministry of Local Government and Rural Development **Government Departments:** • Environmental Affairs Department • Department of Mines • Department of Antiquities • Department of Roads • Department of Lands and Valuation • Department of Surveys • Department of Irrigation and Water Development **Parastatals:** • Malawi Roads Authority • Lilongwe Water Board • National Water Resource Authority (NWRA) • Malawi Energy Regulatory Authority (MERA) • ESCOM **Other:** • Chamber of Mines and Energy • Member of Parliament (Mr. Peter Dimba) • Environmental District Officer • District Lands Officer	Monday, 6 August 2018 at 10:00 Korean Garden Lodge
NGOs / CBOs / CSOs	Monday, 6 August 2018 at 14:00 Korean Garden Lodge
TAs / ADCs / VDCs / GVHs of the following villages: • Kumalindi • Kubale and surrounds • Ndumila • Chimwendo • Ntanga / Kavuma **Other:** • Department of Mines • Department of Lands • Environmental District Officer • District Lands Officer	Tuesday, 7 August 2018 at 10:00 Kumalindi Church Meeting held in Chichewa
Information meeting for the media	Tuesday, 7 August 2018 at 14:00 Korean Garden Lodge

Meeting	Date / Venue
Kumalindi village **Other:** • Department of Mines • Environmental District Officer • Lands representatives	Wednesday, 8 August 2018 at 10:00 Kumalindi Village Meeting held in Chichewa
Ndumila village and surrounds **Other:** • Department of Mines • Environmental District Officer • Lands representatives	Thursday, 9 August 2018 at 10:00 Ndumila Village Meeting held in Chichewa
Chimwendo village **Other:** • Department of Mines • Environmental District Officer • Lands representatives	Thursday, 9 August 2018 at 14:00 Ndumila Village Meeting held in Chichewa
Ntanga / Kavuma village **Other:** • Department of Mines • Environmental District Officer • Lands representatives	Friday, 10 August 2018 at 10:00 Ntanga Village Meeting held in Chichewa

A provisional agenda for the meeting along with a fact sheet of the 2018 fieldwork program (in both English and Chichewa) were circulated to all invitees prior to the meetings.

A presentation was given at these meetings and is attached in Appendix R.

Comments and issues raised during these meetings were included in the comments and response report attached in Appendix U.

6.4.2 Media Site Visit

On request of a number of media organisations, a site visit to the Project area was organised for journalists of a range of newspaper outlets and TV stations. The site visit was held on 5 September 2018 during which works undertaken as part of the fieldwork programme could be observed. Representatives of the District Council, the Department of Mines and the TA also attended the site visit.

6.4.3 Review of Draft ESIA Report

This draft ESIA report was made available to the public for review and comments on 13 May 2018. An electronic copy is available on Sovereign's website http://sovereignmetals.com.au/building-malingunde/. Hard copies of the report can be viewed at:

- Offices of C12 Consultants – Office Number 7, Skyband Complex, off Paul Kagame Rd, Lilongwe.
- Offices of the Environmental Affairs Department.
- Lilongwe District Council Offices.
- Masumbankhunda Traditional Authority.

A copy of the report on USB flash drive can also be obtained from McCourt Mining's offices in Lilongwe.

The availability of the draft ESIA report was advertised in the *Nation* and *Daily Times* newspapers during the week of 29 April 2019.

Stakeholders may submit comments and queries relating to this report and the Project until 17 June 2019. Comments received will be incorporated into the revised comments and response report, and the ESR will be amended where deemed necessary. A revised version will be submitted to the Environmental Affairs Department in July 2019 for review and approval.

6.4.4 ESIA Review Meetings

A series of meetings will be held between 10 and 14 June 2019 to present and discuss the contents of the draft ESIA report, as well as the RAP.

Chapter 7: Impact Prediction and Evaluation

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7 Impact Prediction and Evaluation

The impacts assessed in this chapter are based on potential issues identified during the environmental scoping phase (as detailed in the ESR), as well as various specialist investigations carried out as part of the ESIA. The identified impacts were also informed by key issues raised by stakeholders during the stakeholder engagement process.

In the assessment of an impact, various approaches were used, including professional judgement, quantitative models, technical analysis of data and experience of similar projects elsewhere. These assessments are also informed by the views and opinions of the various specialists and stakeholders.

It this chapter, the potential impacts prior to mitigation are described and the significance of these impacts evaluated according to the impact assessment method described in Section 7.1. The description of impacts is generally based on a scenario where very little or no mitigation has been applied.

Mitigation measures (or enhancement measures in the case of beneficial impacts) are then proposed, and the significance of the residual impact evaluated. Residual impact is defined as the level of impact that would remain after the implementation of mitigation measures.

7.1 Impact Assessment Method

The impact assessment methodology requires that each potential impact identified is clearly described and then evaluated using the following criteria:

- Extent (spatial scale) - whether the impact will affect the national, regional or local environment or only that of the Project site.
- Duration (temporal scale) - how long the impact will last.
- Magnitude (severity) - whether the impact to natural, cultural or social processes will be of high, moderate or low severity.
- Probability (likelihood of occurrence) - how likely that impact is to occur.

To determine the environmental significance (importance) of each identified potential impact, the consequence of the impact and the probability of it occurring is determined. The consequence is regarded as the combination of the extent, duration and magnitude of the impact.

A numerical value has therefore been assigned to these three criteria (Table 7.1) to enable the consequence to be calculated as a numerical value.

The following formula is used to calculate the environmental consequence of each impact:

Consequence = Duration + Extent + Magnitude

Table 7.1: Consequence Criteria

	Description	Criteria	Score
Duration	**Permanent / Unknown**	Impact or change will remain permanently.	**5**
	Long-term	Impact remains for longer than 10 years; Impact will still occur in the closure phase, but will not remain permanently.	**4**
	Medium-term	Impact duration is 5-10 years.	**3**
	Short-term	Impact duration is < 5 years.	**2**
	Transient	Very short duration.	**1**
Extent	**National / Unknown**	Affects the resources of the country; impact experienced nation-wide.	**4**
	Regional/District	Affects the resources of the region or district.	**3**
	Local	Affects the area surrounding the Project and nearby villages.	**2**
	Site-specific	Localised; confined within the mining licence area.	**1**
Magnitude	**Very High / Unknown**	Extreme effect – where natural, cultural or social functions or processes cease in full. Receptors have high sensitivity and very little resilience to impact.	**10**
	High	Severe effect – where natural, cultural or social functions are fundamentally altered and do not function in full. Minor adaptation by receptors may be possible but there is high sensitivity to the impact.	**8**
	Moderate	Moderate effect – where natural, cultural or social functions continue, albeit in a noticeably modified way. Some degree of adaptation by receptors is possible.	**6**
	Low	Minimal effect – affects the environment in such a way that natural, cultural or social functions and processes can readily adapt to the impact.	**4**
	Negligible	Minimal or negligible effect. Receptors have low sensitivity to the impact.	**2**

The consequence of an environmental impact is determined based on the calculated score (rating) as per Table 7.2.

Table 7.2: Consequence Scale

Level	Environmental	Social	Rating
Very High	Severe long-term environmental impact which extends to regional or national level. Extensive clean-up required after incidents. Rehabilitation efforts proven to be unsuccessful. Severe breach of Government regulations or non-compliance with likely suspension of operations	Extreme impact on community. High number of concerns, complaints or interest from local community. Major increase in the risk of health effects resulting in increased incidence of multiple disabling illnesses among employees and community.	17 - 19
High	Major environmental impact. Impact may extend beyond the lease boundary. Significant clean-up effort required using site and external resources. Ongoing or recurring breach of regulations and standards. Rehabilitation difficult or unlikely to be successful.	Major impact on community. Increasing rate of complaints, repeated complaints from the same area (clustering). Significant increase in the risk of health effects resulting in increase in incidence of disabling illnesses among employees and community.	14 - 16
Moderate	Moderate environmental impact confined within the lease boundary. Medium term (typically within a month) clean-up. Multiple repeat exceedances of regulatory requirement. Rehabilitation and closure of moderate difficulty.	Moderate impact on community. Regular rate of concerns or complaints, repeated complaints from the same area (clustering). Increase in the risk of health effects resulting from acute, short term exposure or progressive chronic condition, infectious disease.	11 - 13
Low	Low environmental impact contained within area impacted by operations. Short term (typically within a week) clean-up. Single repeat exceedance of regulatory requirement related	Low impact on community. Small numbers of sporadic complaints. Small increase in the risk of health effects resulting in increase in incidence of health effect resulting from acute,	8 - 10

Level	Environmental	Social	Rating
	to low impact activity. Single exceedance of regulatory requirement for high impact activity.	short term exposure or progressive chronic condition, infectious disease.	
Very Low	No or very low environmental impact confined to a small area within the area impacted by operations. Clean-up undertaken within a few hours. Single exceedance of regulatory requirement (e.g. licence, permit or consent condition; legislation or regulation) related to low impact activity.	No or very low impact on community. Isolated complaints possible. No discernible increase in the likelihood of effects on community health.	4 - 7

The likelihood of the impact occurring is determined using the criteria in Table 7.3.

Table 7.3: Likelihood / Probability of Impact Occurring

	Description	Criteria
Probability	**Almost Certain / Don't Know**	The impact is expected to occur; Consequence is likely to be of a high frequency; >90% chance.
	Highly Likely	The impact will probably occur or has occurred elsewhere before; >50% chance of occurrence during the project.
	Likely	The impact will occur under certain circumstances; Approximately 30 - 50% chance of occurrence during the project.
	Unlikely	The impact could occur under certain circumstances that are not likely to occur; Consequence could occur within a one to five-year timeframe; <30% chance of occurrence in this period.
	Rare	Consequence may occur in exceptional circumstances; Consequence has rarely occurred in the industry and is not expected in the life of the project; < 5% chance of occurrence.

The matrix in Figure 7.1 is then used to determine the overall significance of environmental and social impacts, based on the overall consequence and probability of each impact.

The assessment approach considers the impact prior to any potential management controls or mitigation measures, and then assesses the residual impact following the implementation of controls and mitigation strategies. The significance rating, as determined by using the matrix, is based on the consequence and likelihood as determined in Table 7.2 and Table 7.3.

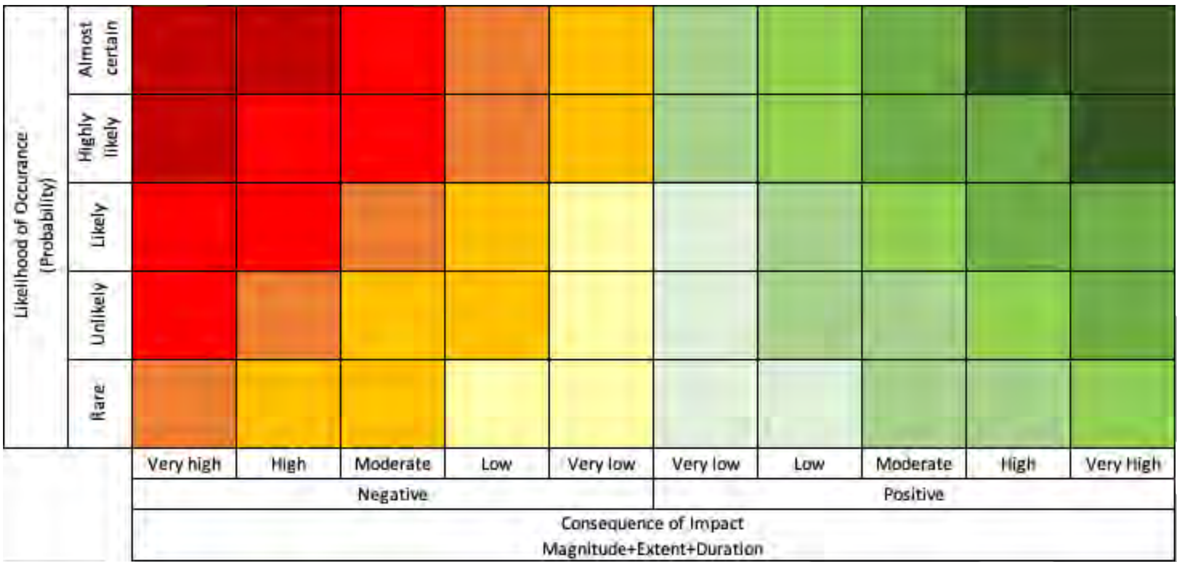

Figure 7.1: Significance Determination Using Consequence vs Likelihood Assessment

The interpretation of the significance determined is described in Table 7.4.

Table 7.4: Interpretation of Significance Analysis

Significance of the Residual Impact	Implications for Project	
	Positive Impacts	Negative Impacts
Very low significance	Negligible effects	Negligible effects
Low significance	Some benefits	Acceptable effect
Moderate significance	Appreciable improvements to, or will sustain, existing resources	Effect is serious enough to cause concern. Changes to project design should be considered.
High significance	Very substantial improvement to existing resources	Unacceptable effect. The project should not proceed unless the design is changed so that the significance of this impact is reduced to acceptable levels.
Very high significance	Extremely beneficial and enduring effect.	An automatic fatal flaw. The project should not proceed unless the design is changed so that this impact is eliminated, or its significance is reduced to acceptable levels.

7.2 Soils

7.2.1 Loss of Soil through Erosion

During the construction phase, site clearing is necessary for the preparation of surface infrastructure development, which requires vegetation to be removed and topsoil stripped and stockpiled. Topsoil will also be stripped during the operations phase as part of the scheduled development of open pits and haul roads.

Soil will be prone to erosion where vegetation has been removed during the construction phase, as dominant soil types in the study area are moderately to highly erodible (Digby Wells, 2018). The loss of vegetation cover will increase the risk of erosion, as runoff potential will be increased and exacerbate erosion. Where soil has been eroded it reduces the overall soil depth and as a result the land capability.

During the operations phase, the unsealed access road to site and internal haul roads will require regular maintenance. These roads will be graded to create a more even surface and to ensure roads shed water away from the centre after rain. The movement of heavy vehicles and machinery along these roads will cause compaction, which reduces infiltration and increases the risk of erosion.

Topsoil stockpiles will further be susceptible to erosion due to exposed surfaces.

When soil is removed, the naturally occurring soil horizons in the soil profile are disturbed and the physical properties are changed. It is highly unlikely that the soil profile and conditions could be reconstructed exactly upon rehabilitation, especially in cases where less permeable subsurface horizons consisting of clay or rock were present initially. The change in properties could lead to increased erosion potential during the decommissioning and closure phase, in the event that adequate rehabilitation measures are not implemented.

The assessment of the significance of impacts without mitigation, recommended mitigation and the residual impact are summarised as follows:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Permanent	Site-specific	High	High	Almost Certain	Very High
Mitigation Measures					
• Minimise vegetation clearance and land disturbance to that which is necessary for development of the Project. • Establish and enforce a 'permit to disturb' or 'permit to clear' system. • Topsoil (first 0.3 m of the soil profile) must be stripped and stockpiled separately from subsoil, as the topsoil contains the seedbank and natural fertility. • Strip soils according to the approved soil stripping methodology. • Topsoil stockpiles are to be kept to a maximum height of 3 to 4 m. • Minimise handling of stripped topsoil to ensure the soil's structure does not deteriorate significantly. • Revegetate stockpiles as soon as possible with indigenous grass to reduce the risk of erosion, and to reinstitute the ecological processes within the soil. • Install and maintain stormwater management measures to manage surface runoff prior to discharge to the receiving surface water bodies. • Implement the use of construction barriers such as silt fencing to contain sediment. • Take corrective action in the event of observed erosion.					
Residual Impact					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Short-term	Site-specific	Moderate	Low	Likely	Low

Residual Impact

Although the risk of erosion of topsoil will remain over the life-of-mine and post closure due to the erodibility of soil on site, the magnitude of this impact will be reduced significantly through mitigation measures and as vegetation is re-established to stabilise landforms.

Some unexpected localised erosion may still be expected in areas where erosion management measures were not deemed necessary. Such localised erosion can be remediated over the short term through revegetation and erosion control blankets.

7.2.2 Reduction in Soil Fertility

When organic matter is removed, either by the clearing of an area for development or by erosion, the soil's fertility is reduced and as a result soil acidity could increase (FAO, 2005). Stockpiling of topsoil during construction and operations may further result in changes to the chemical properties as a result of the anaerobic conditions in these stockpiles. These changes in the soil's chemical properties may lead to a reduction in soil fertility, and impact on the potential of the soil as a resource, unless properly managed.

Changes in soil fertility could result in additional management measures being required, prior to using these soils in rehabilitation activities on site. As phosphorus (P) levels on site are already very low and are expected to decrease as a result of stockpiling, fertilisation may be required to establish good crop stand and growth during rehabilitation. In addition, the soil organic carbon content of the soils in the Project area are low and would require an external nutrient input source during closure (Digby Wells, 2018) to ensure successful revegetation.

The assessment of the significance of impacts without mitigation, recommended mitigation and the residual impact are summarised as follows:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Permanent	Site-specific	High	High	Almost Certain	Very High
Mitigation Measures					
• Minimise vegetation clearance and land disturbance to that which is necessary for development of the Project. • Topsoil (first 0.3 m of the soil profile) must be stripped and stockpiled separately from subsoil, as the topsoil contains the seedbank and natural fertility. • Strip soils according to the approved soil stripping methodology. • Topsoil stockpiles are to be kept to a maximum height of 3 to 4 m. • Revegetate stockpiles as soon as possible with indigenous grass to reduce the risk of erosion, and to reinstitute the ecological processes within the soil. • Assess chemical properties of soils through laboratory analysis before use in rehabilitation to determine whether application of fertiliser and nutrient sources is required.					
Residual Impact					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Long-term	Site-specific	Low	Low	Likely	Low

Residual Impact

No residual impact is expected to remain after rehabilitation and revegetation of Project areas, particularly with the addition of fertiliser containing phosphorous and an appropriate nutrient source to replace soil organic carbon.

7.2.3 Compaction of Soil

Compaction of the soils are likely to occur as a result of repeated movement of vehicles during the construction and operations phases. This reduces aeration and infiltration rates, and diminishes the ability for plant roots to penetrate the compacted soil, which impacts on vegetation growth. Reduced vegetation cover can, in turn, lead to an increase in soil erosion.

During the decommissioning and closure phase, demolition and removal of infrastructure will take place and rehabilitation of disturbed areas undertaken. Vehicle movements over the rehabilitated surfaces could cause compaction and, in turn, reduce the success of revegetation efforts. However, with implementation of appropriate management measures, significantly compacted surface areas are unlikely to remain.

The assessment of the significance of impacts without mitigation, recommended mitigation and the residual impact are summarised below:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Long-term	Site-specific	Moderate	Moderate	Almost Certain	High
Mitigation Measures					
• Stripping of topsoil should be undertaken when the soil is dry, where practicable, to reduce compaction. • Ensure vehicles remain on dedicated roads and avoid unnecessary movements over terrain not earmarked for infrastructure. • Designed and implemented appropriate stormwater management measures to prevent soil erosion. • Revegetate disturbed areas adjacent to roads to reduce the risk of erosion, and to reinstitute the ecological processes within the soil. • Assess rehabilitated areas for compaction, fertility and possible erosion, and take corrective action where necessary.					

Residual Impact					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Long-term	Site-specific	Low	Low	Likely	Low

Residual Impact

No residual impact is expected to remain after rehabilitation as compacted areas will be contour ripped, topsoil returned and areas revegetated.

7.2.4 Loss of Land Capability and Use

When topsoil is removed from the pit, TSF and infrastructure areas, the land capability will be lost and land use will change from crop production (intensive cultivation) to mining. The land capability during the construction and operations phases will be reduced from Class II to Class VIII in the open pit areas, TSF and processing plant and associated infrastructures (Digby Wells, 2018). It is anticipated that an area of approximately 260 ha of agricultural fields and residential housing will be required for the development of infrastructure during the construction and operations phase.

The assessment of the significance of impacts without mitigation, recommended mitigation and the residual impact are summarised below:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Permanent	Site-specific	Very High	High	Almost Certain	High
Mitigation Measures					
• Minimise land disturbance to that which is necessary for development of the Project. • Establish and enforce a ‘permit to disturb’ or ‘permit to clear’ system. • Develop and implement a progressive rehabilitation and closure plan that identifies final land uses and rehabilitation strategies in consultation with communities and regulators.					
Residual Impact					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Long-term	Site-specific	Low	Low	Likely	Low

Residual Impact

The open pits (an area of approximately 47 ha) will remain as voids upon closure and are anticipated to fill with groundwater. These areas will, therefore, permanently change from Class II as it will not be returned to its original land use. As part of the development of a closure plan for the operations, various options for the sustainable use of the open pits will be investigated, which may include e.g., irrigation and aquaculture, depending on the viability of these options. It is the intention that all other areas will be rehabilitated and returned to the community for use in agricultural activities.

7.2.5 Contamination of Soil

Vehicles and equipment associated with construction and operations will require hydrocarbon fuel, lubricating oil and coolants. There is the potential for contamination of soil to occur through accidental spills or leaks during vehicle servicing, use, storage, handling, refuelling and disposal of fuel and oil.

Furthermore, contamination of soil may occur as a result of accidental spills of hazardous chemicals required for the Project.

The assessment of the significance of impacts without mitigation, recommended mitigation and the residual impact are summarised as follows:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Long-term	Site-specific	High	Moderate	Highly Likely	High
Mitigation Measures					
• Ensure vehicles remain on dedicated roads and avoid unnecessary movements over terrain not earmarked for infrastructure. • Ensure vehicles and equipment are well-maintained and servicing carried out in dedicated areas with drip trays, oil collection and pollution control systems. • Store reagents in appropriately bunded areas. • Clean up spillages as soon as practicable. • Remove contaminated soils and place in a designated area for remediation treatment.					
Residual Impact					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Transient	Site-specific	Negligible	Very Low	Likely	Very Low

Residual Impact

No residual impact from spillage of hydrocarbons or chemicals is expected with appropriate clean-up and remediation of soils proposed to take place as soon as practicable.

7.3 Potential for Acid Mine Drainage

Based on observations by Sovereign during exploration drilling, acid forming minerals were observed in fewer than 1% of the boreholes. These observations support the material testing results, which indicated highly weathered lithologies with low acid potential and low neutralising potential. The low acid potential (<0.3% S) indicates that the materials are unlikely to be capable of sustained acid generation, and this was confirmed by the NAG tests, which indicated a near-neutral pH even after intense oxidation of the samples.

Oxidation of sulfide as a result of exposure to oxygen and water is generally limited to the surface of the tailings material on the TSF. Deeper into the tailings material a lack of oxygen will constrain the oxidation of sulfide. Indications from geochemical testing of tailings samples are that the pH is not likely to decrease below 3 for an extended period of time

Results from geochemical modelling, in general, suggest that acid mine drainage and metal leaching are unlikely to be a significant issue on site. However, the modelling indicates that the TSF seepage quality is anticipated to be pH neutral with water quality guideline exceedances expected for aluminium and fluoride. Both aluminium and fluoride are expected to exceed the Malawian Drinking Water Specification (2005), with fluoride also exceeding the WHO Standard for Drinking Water (2017). Modelling of the potential impact on groundwater quality was undertaken based on these elements of concern (refer Section 7.8.2).

The assessment of the significance of impacts without mitigation, recommended mitigation and the residual impact are summarised as follows:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Long-term	Site-specific	Low	Low	Unlikely	Moderate

Mitigation Measures					
• Consider establishment of site/field kinetic testing of waste material and tailings material in order to develop site specific drainage characteristics, and geochemical and geohydraulic properties of the material. • Divert all non-contact stormwater around the TSF. • All stormwater generated within the footprint of the TSF should be controlled and internally managed. • Monitor quality of water draining from the TSF on a quarterly basis.					
Residual Impact					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Short-term	Site-specific	Low	Very Low	Unlikely	Very Low

7.4 Biodiversity

7.4.1 Disturbance to Vegetation Communities

Cultivated lands will be the only vegetation community lost during the construction phase and as part of ongoing development of the open pits. An estimated 130 ha of cultivated lands will be directly impacted by the Project footprint, while an additional 130 ha (approximately) will fall within the exclusion zone around Project infrastructure. Although the exclusion zone may not be directly disturbed by infrastructure, cultivation of crops and agricultural activities will not be permitted within this zone. This constitutes 14.8% of this vegetation community within the ESIA study area.

As these cultivated lands continuously change and are not regarded as indigenous vegetation, the environmental significance of this unmitigated impact is considered to be low.

The current Project layout will result in limited disturbance of the dambo grassland (wetlands) vegetation community for the construction of stormwater management infrastructure, while no disturbance of forest fragment or fine-leaf woodland vegetation communities is expected.

The assessment of the significance of impacts without mitigation, recommended mitigation and the residual impact are summarised below:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Long-term	Site-specific	Negligible	Very Low	Almost Certain	Low
Mitigation Measures					
• Minimise vegetation clearance to that which is necessary for development of the Project. • Reduce disturbance footprint as much as possible. • Establish and enforce a 'permit to disturb' or 'permit to clear' system. • Undertake rehabilitation or return cleared areas to cultivation at closure. • Develop and implement a rehabilitation management plan.					
Residual Impact					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Short-term	Site-specific	Negligible	Very Low	Almost Certain	Low

Residual Impact

An area of approximately 47 ha of cultivated land will be cleared for the open pits. As these pits will not be backfilled and therefore can't be revegetated, this clearance will be permanent. However, as this vegetation community is regarded as highly transformed, this is not regarded as a significant impact.

7.4.2 Loss of Biodiversity

Loss of biodiversity can occur directly through vegetation clearing and destruction of habitat for construction activities. As per section 7.4.1, cultivated lands will be the main vegetation community lost during the construction phase of the mine. Furthermore, this vegetation community is regarded as highly transformed and supports very low levels of biodiversity.

A limited amount of vegetation clearing will take place within Kovuma dambo and Dambo 1 for the purpose of constructing clean water diversion drains. This clearance, along with changes in the hydrological regime, may result in the loss of biodiversity and habitats, although very localised in nature.

Loss of biodiversity can also be the indirect result of erosion, a change in environment through changes in hydrological regimes, and the exclusion of local species by competition with exotic species.

Faunal groups will likely suffer a general loss of biodiversity due to varied impacts, such as: increased mortality from vehicle movements; loss and fragmentation of habitat due to the Project layout; and various forms of pollution associated with traffic and development. This will usually be greatest for small, slow-moving species, e.g., amphibians, tortoises and snakes, while terrestrial species or burrowing species will suffer higher mortalities than arboreal or aerial species. The reptile fauna comprises some species relatively tolerant of development. Many bird species in the region are tolerant of low to medium disturbance, and are likely to suffer less mortality, except where important breeding or roosting sites are lost (Hudson Ecology, 2019c).

The remaining mammal diversity in the region consists of small mammals. With the exception of introduced rodents and bats, most mammals in the region are poor colonisers and require protected habitats to maintain viable population levels. Due to disturbance resulting from habitat loss there will also be an increase in animal mortality as animals move away from the region.

It must be noted that, due to most of the development footprint occurring in transformed, cultivated land, the impact will be considerably lower than were it to occur in natural vegetation, such as forest fragments. These areas are especially important as refuges and bird breeding areas and any impact on these vegetation communities would have a higher significance.

The assessment of the significance of impacts without mitigation, recommended mitigation and the residual impact are summarised as follows:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Permanent	Site-specific	Low	Low	Almost Certain	Moderate

Mitigation Measures

- Ensure that a qualified environmental officer or ecologist oversees all vegetation clearing in order to relocate any conservation significant species that may occur, however unlikely.
- Minimise vegetation clearance to that which is necessary for development of the Project.
- Undertake habitat clearance during winter, as far as practicable, when birds are not breeding.
- Establish and enforce a ‘permit to disturb’ or ‘permit to clear’ system.
- Avoid clearing or damaging wetlands, and limit river and stream crossings as far as possible.
- Protect abiotic habitats, such as rock outcrops, which shelter many reptile species.
- Prohibit hunting and capture of fauna by Project employees.
- Prohibit exploitation of sensitive reptiles, e.g. chameleons.
- Educate personnel about the necessity of protecting fauna, specifically snakes.
- Develop and implement a plan to monitor fauna species fatalities.
- Develop and implement a rehabilitation management plan.

Residual Impact					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Long-term	Site-specific	Negligible	Very Low	Likely	Low

Residual Impact

With the implementation of proposed mitigation measures, the impact on biodiversity will be reduced significantly. However, localised loss of some fauna species can still be expected, particularly as a result of collision with vehicle and fragmentation of habitat. Small, slow-moving species such as amphibians, tortoises and snakes can be expected to be more prone to impacts.

7.4.3 Loss of Flora Species of Concern

Activities associated with construction and operations are unlikely to result in the loss of species of conservation significance, or other species that are important to ecosystem functioning. Cultivated lands will be the predominant vegetation community that will be lost during the life-of-mine, and this vegetation community is least likely to host species of concern. In addition, no species of concern were found in this area during the surveys.

However, should species of concern be identified in the disturbance footprint during construction, the environmental significance of this unmitigated impact would be moderate negative.

The assessment of the significance of impacts without mitigation, recommended mitigation and the residual impact are summarised as follows:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Permanent	Local	Moderate	Moderate	Rare	Low
Mitigation Measures					
• Ensure a qualified environmental officer or ecologist oversees all vegetation clearing in order to relocate any conservation significant species that may occur, however unlikely. • Minimise vegetation clearance to that which is necessary for development of the Project. • Establish and enforce a 'permit to disturb' or 'permit to clear' system. • Collect seeds of any species of concern found during ground clearing and, where feasible, relocate saplings or seedlings of these species. • Develop and implement a rehabilitation management plan.					
Residual Impact					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Short-term	Site-specific	Low	Very Low	Rare	Very Low

7.4.4 Loss of Fauna Species of Conservation Concern

Among fauna species of conservation concern historically occurring in the study area, a number of species have a moderate to high probability of occurrence in the study area (Hudson Ecology, 2019a). Within the Project footprint, however, the probability of occurrence of these species is greatly reduced due to the lack of suitable habitat for these species. The occurrence of species of concern can never be completely dismissed, even in cases such as this Project, where no fauna species of concern were recorded within the study area.

The assessment of the significance of impacts without mitigation, recommended mitigation and the residual impact are summarised as follows:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Permanent	Local	Low	Moderate	Likely	Moderate
Mitigation Measures					
• Avoid clearing or damaging wetlands, and limit river and stream crossings as far as possible. • Protect abiotic habitats, such as rock outcrops, which shelter many reptile species. • Prohibit exploitation of sensitive reptiles, e.g. chameleons. • Educate personnel about the necessity of protecting fauna, specifically snakes. • Undertake habitat clearance during winter, as far as practicable, when birds are not breeding. • Ensure a qualified environmental officer or ecologist oversees all ground clearing. • Develop and implement a plan to monitor fauna species fatalities.					
Residual Impact					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Long-term	Site-specific	Negligible	Very Low	Likely	Low

7.4.5 Impact on Local Fauna Migrations

Linear developments, including haul roads, local access roads and above-surface pipelines could disrupt the movement of species within their normal home ranges, or the seasonal movements of migratory species. Habitat fragmentation may require species to undertake long movements between patches of suitable habitat in search of mates, breeding sites or food. At such times they may suffer increased mortality, either directly by road vehicles, or from their natural predators due to increased exposure.

Reptiles, small mammals and amphibians do not undertake long distance migrations, but these groups may undertake short seasonal movements. Many snakes undertake movements between winter hibernation sites and their summer foraging areas. Amphibians are known to experience the highest levels of mortalities associated with the presence of roads among vertebrates. This is mainly attributed to seasonal group migrations to and from their breeding sites. Some amphibians, particularly toads, are explosive breeders, and move in groups to the breeding ponds. At such times they may suffer heavy casualties while crossing roads (Hudson Ecology, 2019c).

The assessment of the significance of impacts without mitigation, recommended mitigation and the residual impact are summarised as follows:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Long-term	Site-specific	Moderate	Moderate	Highly Likely	High
Mitigation Measures					
• Avoid sensitive habitat corridors such as drainage lines and wetlands, where practicable. • Incorporate, where practicable, underpasses and culverts in road designs that allow the movement of animals. This is of particular importance along drainage lines, which form natural corridors for faunal movements. • Limit vehicle movements after dark, where practicable, as much of the surviving fauna is nocturnal, e.g. bats, most snakes, small rodents, amphibians, etc. • Use dipped headlights at night, where safety guidelines allow, to reduce light pollution into adjacent habitat. • Enforce speed restriction on roads. • Educate drivers regarding their role in impacting on animals and the need to minimise collisions with animals at all times. • Monitor and assess significance of animal road mortalities and review mitigation measures on an annual basis.					

Residual Impact					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Long-term	Site-specific	Negligible	Very Low	Likely	Low

Residual Impact

It is anticipated that the most significant impact to fauna migrations is likely to be collisions with vehicles. The collisions are often unavoidable due to an increase in vehicle traffic. However, due to the relatively low biodiversity encountered in the area, the residual impact on fauna migrations is considered to be low.

7.4.6 Competition by Invasive Species and Exotic Fauna

The removal of existing vegetation creates 'open' habitats or niches that will be colonised by pioneer plant species. While this is part of a natural process of regeneration, which would ultimately lead to the re-establishment of a secondary vegetation cover, it also favours the establishment of undesirable species in the area, as these species often outcompete indigenous species (Hudson Ecology, 2019c). These species are generally introduced along transport lines, and by human and vehicle movements in the area during construction, operations and decommissioning phases. Once established, these species are typically very difficult to eradicate and may then invade, posing a threat to the neighbouring ecosystems.

As an indirect impact, these species often ultimately colonise wetland areas as these wetlands are the ultimate receiving environment for runoff water, which may contain seeds. Over time this impact could affect the region or district or even further afield.

Development of the Project and the associated access and haul roads create suitable corridors for the introduction of alien species. Introduced urban rodent pests such as the house mouse (*Mus musculus*), house rat (*Rattus rattus*) and the Norwegian rat (*Rattus norvegicus*) are likely to occur during the construction and operations phases in areas where food sources are prevalent, such as near kitchens and waste management facilities. These species generally tend to survive alongside human habitation, and don't spread in natural areas.

The assessment of the significance of impacts without mitigation, recommended mitigation and the residual impact are summarised as follows:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Permanent	Local	High	High	Highly Likely	High
Mitigation Measures					
• Ensure vehicles and equipment are clean of invasive plants and seed before entering the Project site, particularly wetland areas. • Eradicate exotic invasive plants as they appear by mechanical or chemical means. • In wetland areas, physically remove, contain, dry and burn all identified alien invasive species seedlings. • Use indigenous species during rehabilitation or, if unlikely to be successful, exotic species that are not invasive. • Monitor the project area for any new invasive plants. • Prepare and implement an exotic and invasive species management plan.					
Residual Impact					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Short-term	Local	Low	Low	Likely	Low

7.4.7 Loss of Ecosystem Services Provided

Removal of vegetation communities due to mining activities may result in the loss of ecosystem services associated with each habitat and vegetation type. This is especially relevant since the local communities are heavily reliant on these areas as a source of food and traditional medicine, construction materials, fuel wood and as a source of income through activities such as charcoal production.

Increased stormwater runoff and discharge of water to dambos will lead to an increase in water level, flow velocities and sediment loads within dambo habitats, which in turn, may alter the flood attenuation, streamflow regulation, sediment trapping and erosion control service provision of these systems.

The assessment of the significance of impacts without mitigation, recommended mitigation and the residual impact are summarised below:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Long-term	Local	Moderate	Moderate	Highly Likely	High
Mitigation Measures					
• Enable collection of seeds establishment of a nursery of indigenous flora for use in areas to be rehabilitated, and in surrounding areas that will not be mined. Seedlings from nurseries could potentially be obtained from community/third parties or mine managed nurseries. • Involve local communities in the collection of seed, cultivation of indigenous plant species and develop a community program to support revegetation on their own land and farms. • Develop and implement Livelihood Restoration Strategies as part of the Resettlement Action Plan. • Ensure stormwater management berms and silt traps are installed in such manner to prevent gully formation. • Line steep slopes on stormwater channels with turf reinforcement matting to avoid erosion.					
Residual Impact					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Long-term	Site-specific	Low	Low	Likely	Low

Residual Impact

As the majority of ecosystem services provided are associated with wetlands in the area, disturbance to these areas are likely to result in the largest impact to these services. Progressive rehabilitation of these wetland areas (once discharge to a particular wetland area is no longer required) will ensure the reestablishment of these services to at least similar conditions as to those prior to implementation of the Project.

7.5 Wetlands

7.5.1 Erosion Impacts to Dambos

Areas cleared of vegetation do not attenuate water thus allowing runoff water with higher energy levels to enter wetlands, in turn increasing the amount of erosion caused by the water runoff.

During construction, discharge of water to the dambos is not expected. However, dewatering of the pits will be required during operations and excess water will be discharged to the environment. Although water will be reused in the process where possible, the mine will become water positive from Year 2. The daily discharge volumes over the life-of-mine are summarised in Table 7.5.

Table 7.5: Discharge Volumes

Scenario	Reuse (m³/d)	Discharge (m³/d)	Reuse (m³/d)	Discharge (m³/d)
	Pits		Return Water Dam	
Dry Season Year 0	28	0	26.7	0
Wet Season Year 0	0	95	67.9	32.7
Dry Season Year 8	50	79	26.7	0
Wet Season Year 8	0	199	67.9	32.7
Dry Season Year 15	50	276	26.7	0
Wet Season Year 15	0	391	67.9	32.7
Average for life-of-mine	30	150	46	0

Water from the northern pits will be discharged to the Kovuma dambo, north of the Project area. Water from the central pits will be discharged to Dambo 1, which ultimately drains towards the Kamuzu Dam II, while water from the most southern pits will be discharges to a drainage line to the east of the pits. These large volumes of water, if discharged via a single point, are likely to cause erosion through incising of the wetland, ultimately creating a channel in the wetland, which may in turn result in desiccation of the outer limits of the wetland and subsequent encroachment of terrestrial species (Hudson Ecology, 2019d).

The assessment of the significance of impacts without mitigation, recommended mitigation and the residual impact are summarised below:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Permanent	Local	Moderate	Moderate	Likely	Moderate
Mitigation Measures					
• Minimise area of disturbance to what is necessary for development of the Project. • Ensure appropriate stormwater management measures are designed and implemented to prevent erosion. • Divert stormwater around work sites and other disturbed areas. • Investigate the use of sustainable drainage systems (SUDS) to control surface water run-off, such as grass swales, ponds or infiltration trenches. • Install sediment barriers (e.g., sediment fences or turf buffer strips) downslope of construction areas and stockpiles to filter coarse sediments. • Install settlement ponds or sediment traps to collect run-off from the site and let suspended solids settle so these can be removed prior to discharge. • Investigate the use of multiple discharge and/or low volume release points in order to prevent incision of wetlands. • Minimise vehicle access points to areas, where possible. • Revegetate all denuded areas as soon as possible after construction is completed. • Develop and implement an erosion monitoring and management plan.					
Residual Impact					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Short-term	Local	Low	Low	Unlikely	Low

Residual Impact

Silt traps have been designed to discharge water at a rate of between 0.3 and 0.6 m³/s. Design considerations for silt traps include management measures such as erosion control blankets, turf reinforcement matting and riprap. These measures are considered to be adequate to minimise erosion impacts. Progressive rehabilitation of these wetland areas (once discharge to a particular wetland area is no longer required) will also ensure no residual erosion impacts remain upon closure.

7.5.2 Sedimentation of Wetlands

Dambos in the Project area act as natural sediment traps and assist in limiting sediment input to the Lilongwe River and Kamuzu Dam. It is also expected that the dambos always maintain capacity to trap sediments as the dambo sands are regularly harvested for building material (SLR, 2019a).

Sedimentation, like erosion is a direct impact, likely to originate from two sources associated with the Project. Cleared, compacted and unpaved areas are likely to increase the amount of sediment generated from these areas and transported to the wetlands by surface runoff during both the construction and operations phases. Water being pumped from the pits and discharged to the environment is likely to contain increased amounts of sediment, which may also be deposited in wetland areas.

In the event that discharge occurs at a higher flow rate compared to baseline rates, turbidity of water in the dambos may increase, which in turn could result in a modification of dambo habitat.

Excessive sediment could adversely affect terrestrial and aquatic life in the wetlands, and/or cause flooding by blocking channels.

The assessment of the significance of impacts without mitigation, recommended mitigation and the residual impact are summarised as follows:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Medium-term	Local	Moderate	Moderate	Likely	Moderate
Mitigation Measures					
• Minimise area of disturbance to what is necessary for development of the Project. • Install sediment barriers (e.g., sediment fences) downslope of construction areas and stockpiles to filter coarse sediments. • Investigate the use of sustainable drainage systems (SUDS) to control surface water run-off, such as grass swales, ponds or infiltration trenches. • Install settlement ponds or sediment traps to collect run-off from the site and let suspended solids settle so these can be removed prior to discharge. • Revegetate or cover topsoil stockpiles, where feasible, to prevent sediment form being washed away. • Revegetate all denuded areas as soon as possible after construction is completed. • Sediment control facilities should be designed and operated for a final Total Suspended Solids (TSS) discharge of 50 mg/L, taking into consideration background conditions and opportunities for overall improvement of the receiving water body quality. • Develop and implement an erosion monitoring and management plan.					
Residual Impact					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Short-term	Local	Low	Low	Unlikely	Low

Residual Impact

Considering that pit water is classified as silty water (in the stormwater management) and will be reused or managed through silt traps before discharge, the pit dewatering rates (average 0.016 m^3/s or 16 L/s) from all three pits) indicate that the design flows for the silt traps are adequate (i.e. designed for 0.3 and 0.6 m^3/s) to treat the silty water before discharge into the dambos. Therefore, no residual sedimentation impacts are expected, should recommended management measures be implemented and adequately maintained.

7.5.3 Changes in Hydrology due to Discharge of Water

Water pumped from the pits, and subsequently released into the wetlands, will be a constant process which is likely to change the nature of these wetlands. Currently the dambos are seasonal wetlands, which dry out in the dry season and are then inundated again in the wet season. The constant release of water into the wetlands is likely to result in these wetlands becoming permanent wetlands, although this will only be for the period for which this takes place, i.e. until the end of operations.

This will potentially result in these wetlands losing vegetation species which do not survive in permanently inundated wetlands and gain species that prefer these conditions.

The assessment of the significance of impacts without mitigation, recommended mitigation and the residual impact are summarised as follows:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Medium-term	Local	Moderate	Moderate	Likely	Moderate
Mitigation Measures					
• Investigate the use of sustainable drainage systems (SUDS) to control surface water run-off, such as grass swales, ponds or infiltration trenches. • Install settlement ponds or sediment traps to collect run-off from the site and let suspended solids settle so these can be removed prior to discharge. • Investigate the use of multiple discharge and/or low volume release points in order to prevent incision of wetlands.					
Residual Impact					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Medium-term	Local	Negligible	Very Low	Likely	Very Low

Residual Impact

It is anticipated that any changes in wetland vegetation will be of a temporary nature for the duration of operations. Once hydraulic conditions return to similar conditions to those prior to Project implementation, it is expected that wetland vegetation could re-establish over time.

7.6 Aquatic Ecology

7.6.1 Change in Integrity of Aquatic Habitat and Instream Biota

The implementation of stormwater management measures to contain dirty water originating from the infrastructure catchments, inevitably reduces the available catchment area for runoff to the surface water resources. This leads to a reduction in runoff reporting to the dambos and then the Kamuzu Dam and the Lilongwe River (SLR, 2019a).

At the same time, discharge of pit water during the operations phase and increased erosion potential is likely to lead to increased flow and sediment loads entering the dambo (wetland) and aquatic (Lilongwe River) habitats.

Sedimentation from erosion and discharge of pit water within the Lilongwe River will add to the existing siltation observed within the system, likely increasing the loss of suitable habitat for certain macro-invertebrate communities, impacting on the integrity of these communities.

These hydrological and water quality modifications within the dambo and aquatic habitats due to altered flow velocities and an increase in turbidity levels may impact on the integrity of the habitat and instream biota.

The assessment of the significance of impacts without mitigation, recommended mitigation and the residual impact are summarised as follows:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Medium-term	Local	High	Moderate	Almost Certain	High
Mitigation Measures					
• Ensure appropriate stormwater management measures are designed and implemented to divert runoff from erosion prone areas. • Implement isolation techniques for in-stream works, such as berms or diversion channels to limit the exposure of disturbed sediments to the water. • Apply turf reinforcement matting to steep slopes to control erosion. • Include flow dissipation measures at discharge points. • Avoid placement of topsoil stockpiles directly adjacent to drainage lines and implement erosion control measures. • Design and maintain stormwater settling facilities and sediment traps according to internationally accepted good engineering practices, including provisions for capturing of debris and floating matter. • Remove sediment from sediment traps on a regular basis. • Sediment control facilities should be designed and operated for a final TSS discharge of 50 mg/L, taking into consideration background conditions and opportunities for overall improvement. • Discharge from dewatering boreholes or the pits will mimic natural conditions as far as possible. • Undertake rehabilitation of construction areas in dambos upon completion of the construction. Ensure exposed soils are revegetated with indigenous dambo vegetation.					
Residual Impact					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Short-term	Site-specific	Moderate	Low	Unlikely	Low

Residual Impact

As stated in Section 7.7.2, a reduction of approximately 0.16% in the quantity of runoff is expected (SLR, 2019a). Although the hydraulic conditions may change to some extent, this reduction in volume is regarded as negligible. In addition, it is expected that the hydrological regime will return to conditions similar to those prior to Project implementation, and aquatic habitat would reestablish with wetland rehabilitation.

7.6.2 Loss of a Portion of the Kovuma and Dambo 1 Habitat Resulting in the Loss of Instream Biota

Limited disturbance at the head of the Kovuma dambo and Dambo 1 will be required for the construction of stormwater management infrastructure. Temporary dewatering of these areas and soil compaction may be required during the construction phase. This will likely result in the loss of a portion of the habitat and subsequently instream biota.

The formation of gullies within the dambo may also occur from continuous discharge of water to the dambo (refer Section 7.5.1), which may alter instream conditions and lead to a loss of biota.

The assessment of the significance of impacts without mitigation, recommended mitigation and the residual impact are summarised as follows:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Permanent	Local	High	High	Highly Likely	High

Mitigation Measures					
• Clearly demarcate areas to be cleared. • Limit site clearance activities to that of the Project footprint. • Minimise access corridors in sensitive areas such as riparian vegetation. • Minimise alteration of existing flow paths as much as possible. • Prohibit vehicles from driving through dambo areas. • Maintain natural drainage paths to the extent possible. • Dambo habitat, including vegetation and rocks, should only be disturbed if absolutely necessary for construction purposes. • Demarcate sensitive zones outside of the construction area and restrict access by Project personnel. • Restrict the duration and timing of in-stream construction activities to low flow periods, and avoid periods critical to biological cycles of flora and fauna (e.g., migration, spawning, etc.) to the extent possible. • Design and maintain stormwater settling facilities and sediment traps according to internationally accepted good engineering practices, including provisions for capturing of debris and floating matter. • Undertake rehabilitation of construction areas in dambos upon completion of the construction. Ensure exposed soils are revegetated with indigenous dambo vegetation.					
Residual Impact					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Long-term	Site-specific	Moderate	Moderate	Likely	Moderate

Residual Impact

Progressive rehabilitation of impacted dambos (once discharge to a particular wetland area is no longer required) will ensure habitat is returned to at least similar conditions as to those prior to implementation of the Project. The residual impact after closure is therefore considered to be low.

7.6.3 Loss of Instream Biota due to Deterioration of Water Quality

If not managed properly, contamination of dambos from accidental spillage of hydrocarbons and hazardous substances could lead to a reduction in local aquatic biodiversity.

Water from the pit dewatering, which is subsequently released into the wetlands, is likely to contain impurities and pollutants such as diesel and lubricants from vehicles working in the pit, as well as high loads of sediment.

These impacts may also extend into the Lilongwe River and Kamuzu Dam, if not contained, and have an adverse impact on the integrity of instream biota.

The assessment of the significance of impacts without mitigation, recommended mitigation and the residual impact are summarised as follows:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Short-term	Local	Moderate	Low	Highly Likely	Moderate
Mitigation Measures					
• Divert stormwater from potentially contaminated areas. • Ensure vehicles and equipment are well-maintained and servicing carried out in dedicated areas with concrete floors and pollution control systems. • Install oil and grease traps or sumps at refuelling facilities, workshops and fuel storage depots. • Restrict access of vehicles to dambo area and drainage lines to minimise any discharges of hydrocarbons. • Store all chemicals and fuel in bunded areas with 110% storage capacity of the maximum capacity of the largest tank or drum, or 25% of the total volume, whichever is larger. • Clean up spillages as soon as practicable.					

• Ensure spill kits are readily available at on-site chemical and fuel storage areas at all times. • Sediment control facilities should be designed and operated for a final Total Suspended Solids (TSS) discharge of 50 mg/L, taking into consideration background conditions and opportunities for overall improvement of the receiving water body quality. • Undertake bi-annual toxicity testing in the aquatic features to monitor potential water contamination from on-site activities.					
Residual Impact					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Short-term	Site-specific	Low	Very Low	Likely	Very Low

Residual Impact

Considering that pit water will be managed through silt traps to treat the silty water before discharge into the dambos, sediment will settle out and can readily be removed to minimise the contamination. Oil traps will be effective in the removal of hydrocarbons and the residual impact is therefore regarded as very low.

7.7 Surface Water

The local surface water resources are considered to be of moderate sensitivity, due to the proximity of the Project site to the various dambos feeding the Lilongwe River (2 km away) and the Kamuzu Dam located 150 m meters from the proposed most southern pit. The Kamuzu Dam is of high importance as it is the main water supply for Lilongwe, the capital city of Malawi.

7.7.1 Deterioration in Water Quality of Surface Water Resources

Contamination of water resources may occur during the construction phase as a result of sediment transport from large areas where vegetation clearance has taken place, as well as runoff from areas where spillages of hydrocarbons, paints, construction materials and waste have taken place.

During the operations phase, runoff from the tailings and pit waste areas containing elevated aluminium, iron and sediment may result in deterioration of water quality in drainage lines and the Lilongwe River. In addition, contamination may occur from runoff from operational areas where accidental spillages of fuels, solvents and chemicals have taken place. During this phase, discharge of water from the pits that contain elevated levels of suspended solids will also occur to the environment.

It is possible that during decommissioning and post-closure decant from the pits may occur, resulting in poor water quality entering surface water resources.

Contamination events could be ongoing or recurring in nature, particularly in the unmitigated scenario. In the construction and decommissioning phases these potential contamination sources are temporary and diffuse in nature, usually existing for a few weeks to a few months. Even though the sources are temporary in nature, related potential contamination can be long-term. The operational phase will present more long-term potential sources and the closure phase will present temporary and long-term sources.

Unmitigated runoff from the project site could directly affect dambos feeding into the Kamuzu Dam as well as dambos feeding into the Lilongwe River downstream of the dam. In the wet season the dambos are used by local communities for fishing, washing, swimming and livestock watering. Contamination of the dambos could directly affect the quality of water in the Kamuzu Dam and the Lilongwe River, of which the dam is the main water supply for Lilongwe, the capital city of Malawi. Baseline water qualities already indicate elevated turbidity and levels of faecal coliform, iron, aluminium, manganese, zinc and antimony. Depending on the extent of the spillage or runoff, in the absence of mitigation the project would contribute to the already elevated baseline levels.

The assessment of the significance of impacts without mitigation, recommended mitigation and the residual impact are summarised below:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Long-term	Regional	Moderate	High	Likely	High

Mitigation Measures

- Separate clean and dirty water by implementing stormwater management structures.
- Ensure stormwater form dirty catchments are contained and reused at the processing plant, effectively reducing the catchment area to local watercourses.
- Ensure water from pit dewatering boreholes or the pit is managed through silt traps to settle silt before discharge.
- Design and maintain stormwater settling facilities and sediment traps according to internationally accepted good engineering practices, including provisions for capturing of debris and floating matter.
- Remove sediment from sediment traps on a regular basis.
- Sediment control facilities should be designed and operated for a final TSS discharge of 50 mg/L, taking into consideration background conditions and opportunities for overall improvement.
- Ensure vehicles and equipment are well-maintained and servicing carried out in dedicated areas with concrete floors and pollution control systems.
- Install oil and grease traps or sumps at refuelling facilities, workshops and fuel storage depots.
- Store all chemicals and fuel in bunded areas with 110% storage capacity of the maximum capacity of the largest tank or drum, or 25% of the total volume, whichever is larger.
- Clean up spillages as soon as practicable.
- Ensure spill kits are readily available at on-site chemical and fuel storage areas at all times.
- Undertake regular surface water quality monitoring as per the monitoring plan.

Residual Impact					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Long-term	Local	Low	Low	Unlikely	Low

Residual Impact

Sediment control facilities will be operated to ensure water discharged to surface water resources (including the Kamuzu Dam and Lilongwe River) contains a maximum TSS of 50 mg/L. Due to the comparatively small volumes of water that could be discharged (maximum 200 m^3/day or approximately 73,000 m^3 per year) to the Kamuzu Dam II with a storage capacity of approximately 19 Mm^3, it is anticipated that discharge will not significantly contribute to changes in water quality of the Dam or the Lilongwe River.

7.7.2 Impact on Water Runoff

During the construction and operations phases, the Project could result in changes to natural surface water flow patterns. The establishment of infrastructure, development of the open pits and stormwater management measures would reduce the quantity of runoff that would normally have entered the catchments by approximately 0.16% (SLR, 2019a).

Although capturing of dirty stormwater runoff for the life of the operations would reduce flows in the catchment, it is likely that the mine will become water positive within the first few years of mining. As a result, there may be a need to discharge excess water to the environment. In the absence of dedicated on-site storage, discharge of pit dewatering water and excess process water to the environment would increase flows within the system. Over the life-of-mine, the average discharge from the pits will be approximately 150 m^3/d, while discharge from the RWD is likely to only take place during the wet season at a rate of approximately 33 m^3/d.

The discharge of excess water could result in the alteration of the flow regimes of the dambos and the Lilongwe River. In the wet season the dambos are used by local communities for fishing, washing, swimming and livestock watering. Increased flows within the system could alter the functioning of the system, result in flooding making the dambos unsafe and impassable during the wet season, and potentially affecting the use of the dambos by surface water users.

During decommissioning and post-closure, restoring drainage patterns to a self-sustaining system would contribute to catchment runoff. In addition, potential decant of water from the pits could increase flows within the system.

The assessment of the significance of impacts without mitigation, recommended mitigation and the residual impact are summarised below:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Permanent	Regional	Moderate	High	Likely	High
Mitigation Measures					
• Implement water conservation and water demand management measures to ensure as much water as possible is collected and reused, minimising the release of any treated storm flows whilst reducing abstraction from sources. • Ensure stormwater form dirty catchments are contained and reused at the processing plant, effectively reducing the catchment area to local watercourses. • Discharge from dewatering boreholes or the pits will mimic natural conditions as far as possible.					
Residual Impact					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Short-term	Regional	Low	Low	Unlikely	Low

Residual Impact

Restoration of drainage patters will be undertaken during decommissioning and closure to a self-sustaining system that resembles conditions that existed prior to Project implementation. Although drainage patterns around the pit voids will be altered permanently, it is not anticipated that this will result in a significant change post-closure.

7.8 Groundwater

A 3-dimensional numerical model was constructed for the Project using '*FEFLOW*', a finite element numerical code used for simulating groundwater flow and contaminant transport. FEFLOW is the most suitable code for use in mining applications and allows building accurate simulations of mining in transient mode (SLR, 2019b).

7.8.1 Reduction in Groundwater Availability

The open pits will extend below the groundwater table, and therefore inflow of groundwater into the pits is expected during operations and at closure. To enable workable dry conditions for efficient mining, dewatering will be required during the operations phase. This dewatering will result in a lowering of the groundwater that will extend beyond the immediate footprint of the open pits. Once mining in a particular pit is complete, dewatering will cease, and the pit left to fill with water.

Predictive simulations for the cone of drawdown (lowering of the groundwater levels) were undertaken for a period of 100 years as follows:

- Year 5 of mining
- Year 10 of mining

- Year 16 of mining (end of mining)
- Year 25 (9 years post-mining)
- Year 50 (34 years post-mining)
- Year 100 (end of simulation)

These drawdown simulations are indicated in Figure 7.2 to Figure 7.7.

A lowering of groundwater levels will reduce the amount of groundwater in the underlying aquifer. This, in turn, will impact on the availability of groundwater for use by the local communities, who rely on groundwater for domestic and subsistence agricultural purposes.

The cone of drawdown is predicted to reach a maximum depth and extent at the end of mining period (Year 16 of simulation) around the central open pits. The water levels are expected to have a fast recovery period for the first nine years after mining has ceased after which the recovery rate will slow down as the hydraulic head decreases (from Year 25 onwards). The predicted extent and depth of the cone of drawdown for the selected years are indicated in Table 7.6.

Table 7.6: Extend and Depth of Cone of Drawdown

Year	Max. Cone of Drawdown Extent (Distance from Pit)	Max. Cone of Drawdown Depth
5	1,100 m	20 m
10	1,158 m	21 m
16	1,220 m	27 m
25	1,140 m	1 to 5 m
50	1,120 m	1 to 5 m
100	500 m	1 to 5 m

A number of community boreholes and hand dug wells are located within the simulated cone of drawdown. Although hand dug wells are not directly connected to the aquifer in which dewatering will take place, vertical flow does occur. It is expected that a partial to complete loss of water would be experienced in boreholes and hand dug wells within the zone of impact (distance from the pit as described in Table 7.6).

Given that the dambos are fed by rain and surface water runoff, and are not hydraulically linked to any of the aquifers, a drop in groundwater levels is not expected to impact on the availability of water within the dambos.

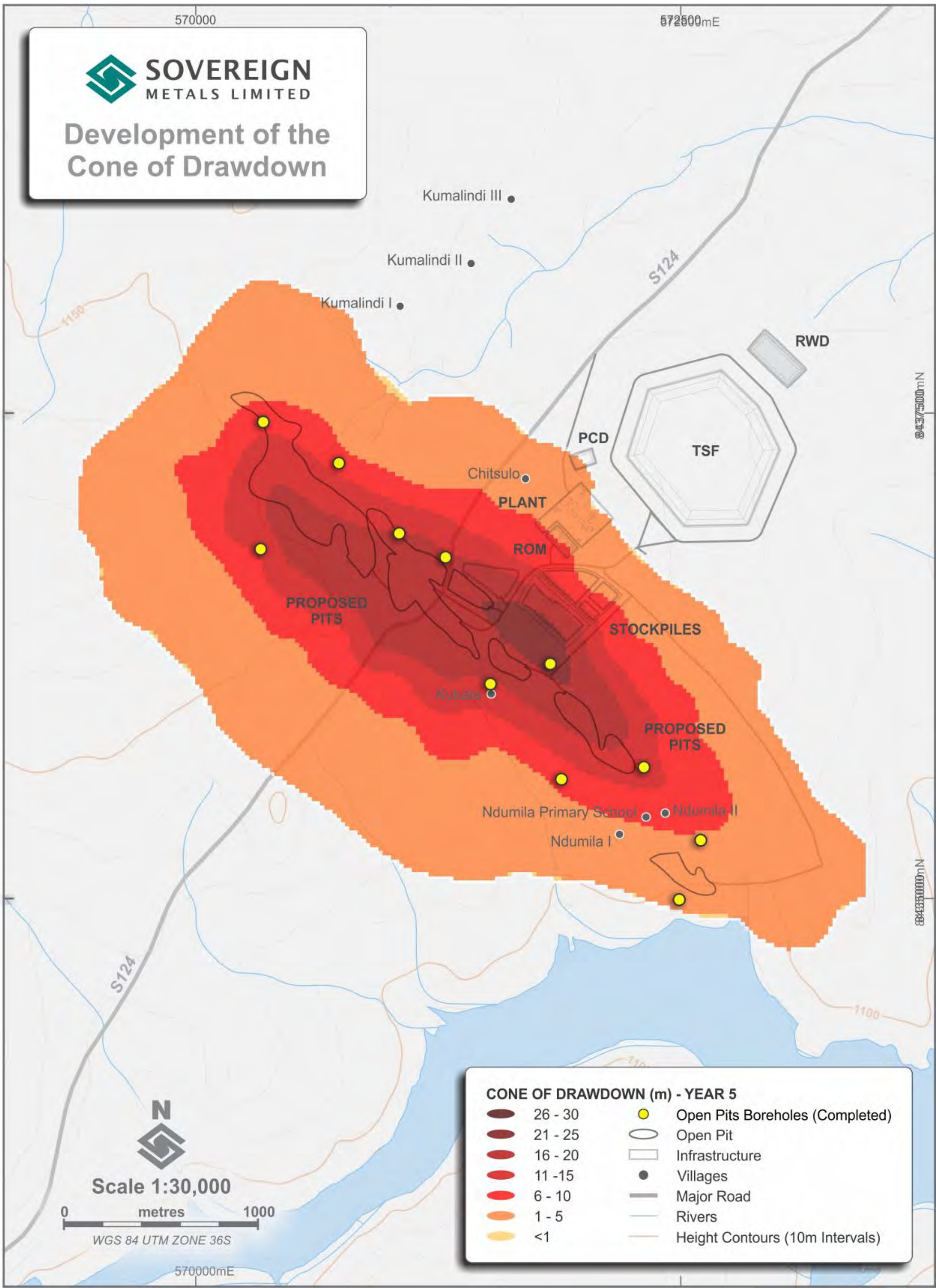

Figure 7.2: Cone of Drawdown at the End of Year 5

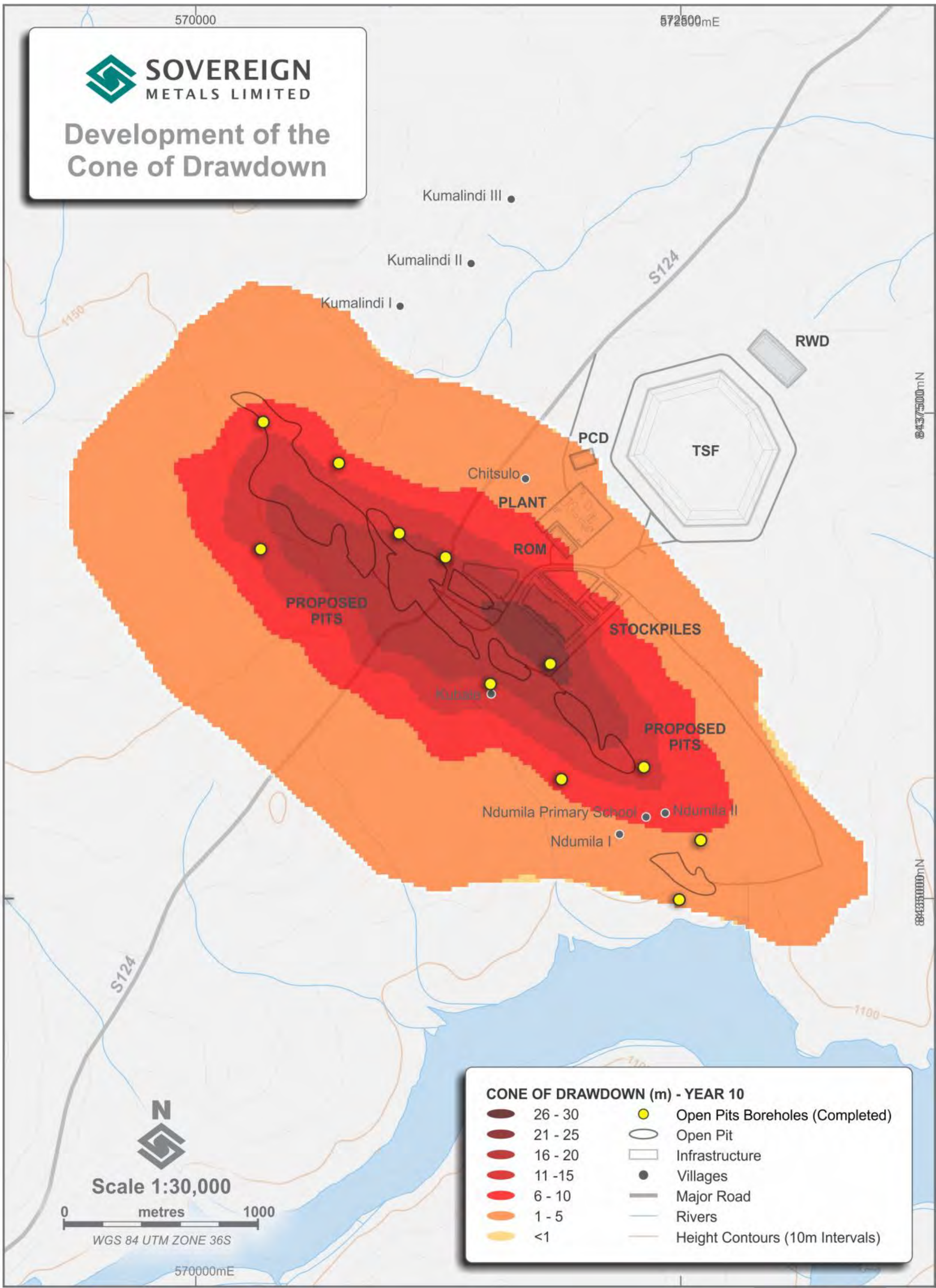

Figure 7.3: Cone of Drawdown at the End of Year 10

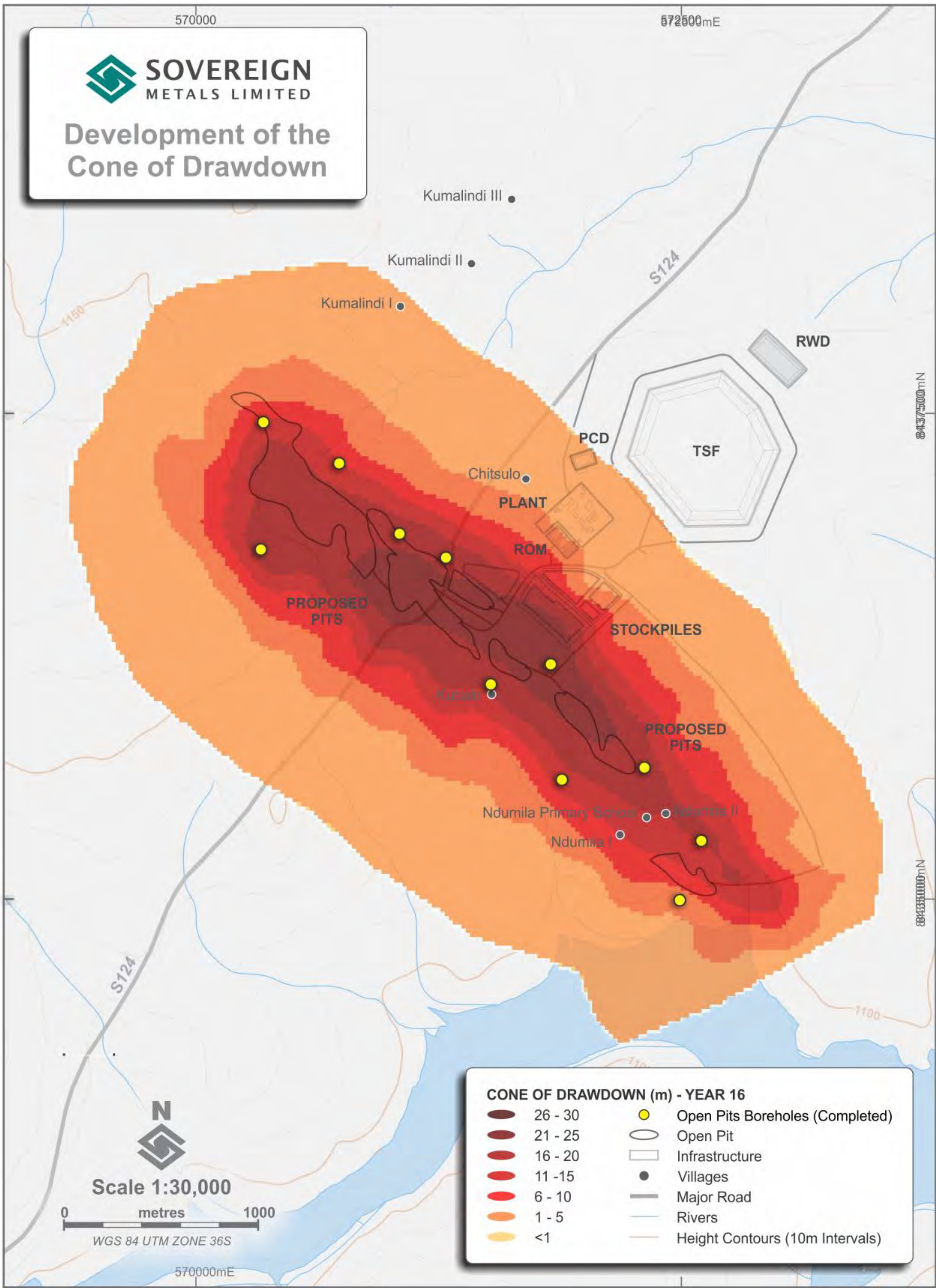

Figure 7.4: Cone of Drawdown at the End of Year 16

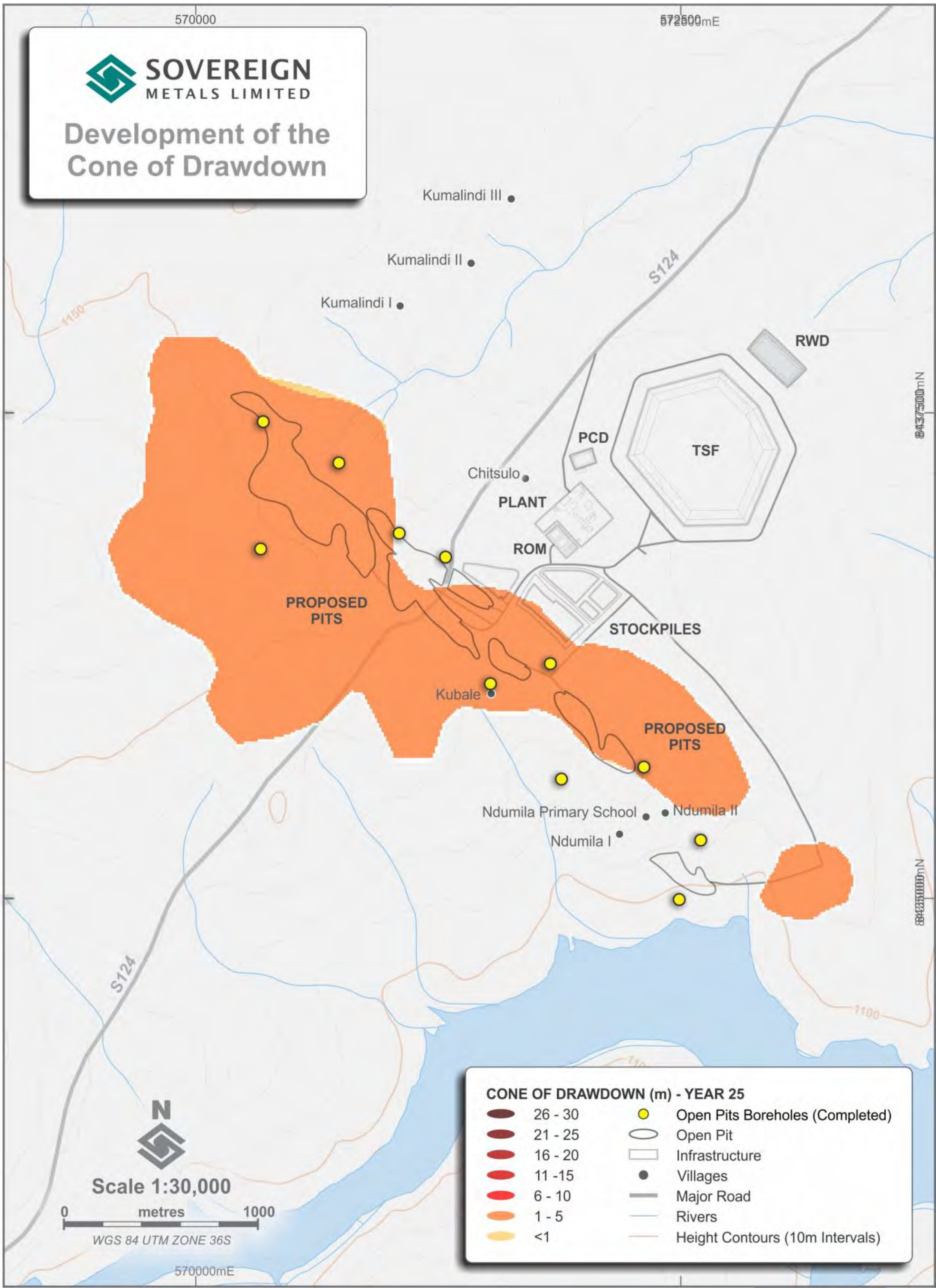

Figure 7.5: Cone of Drawdown at the End of Year 25

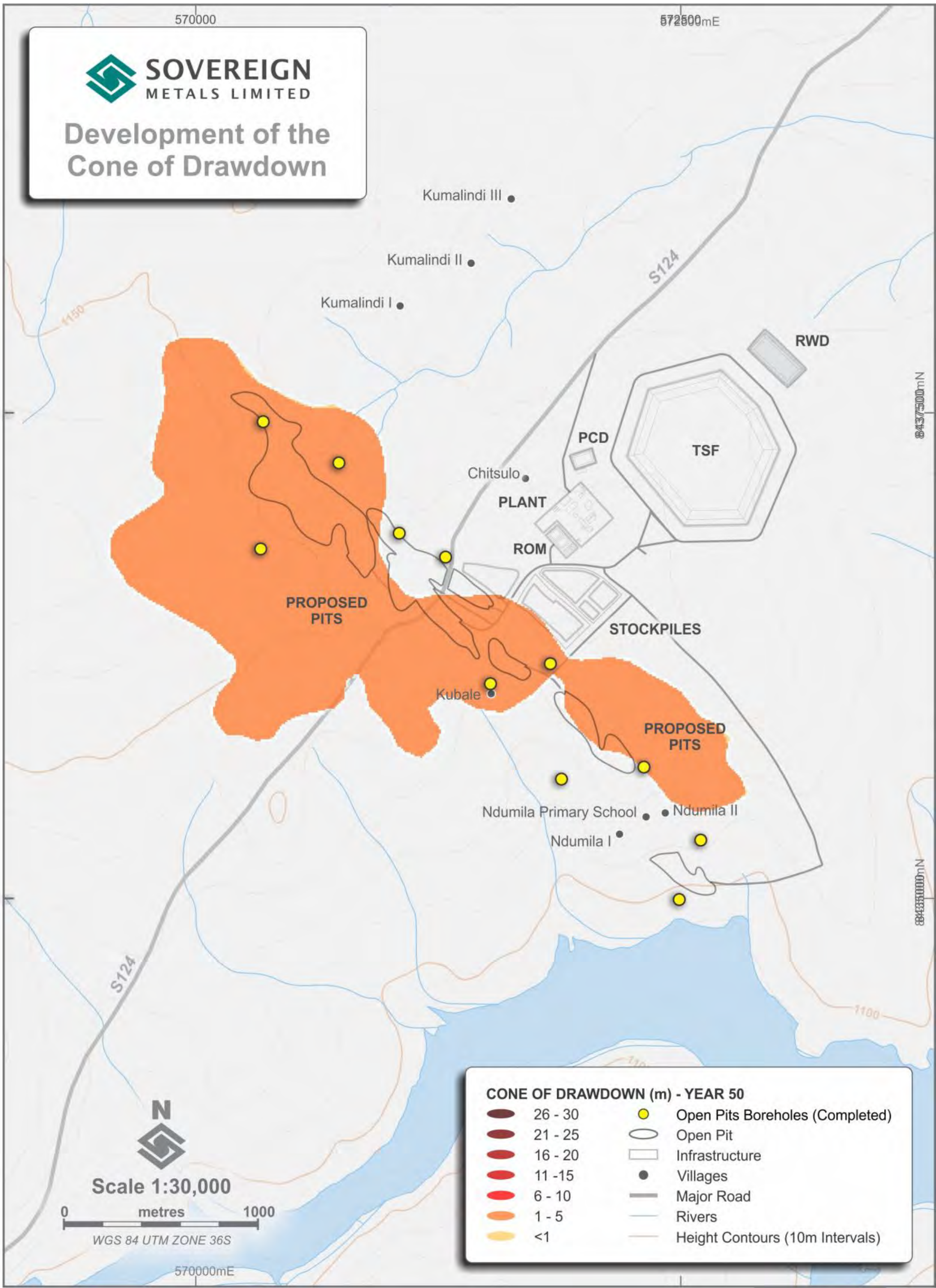

Figure 7.6: Cone of Drawdown at the End of Year 50

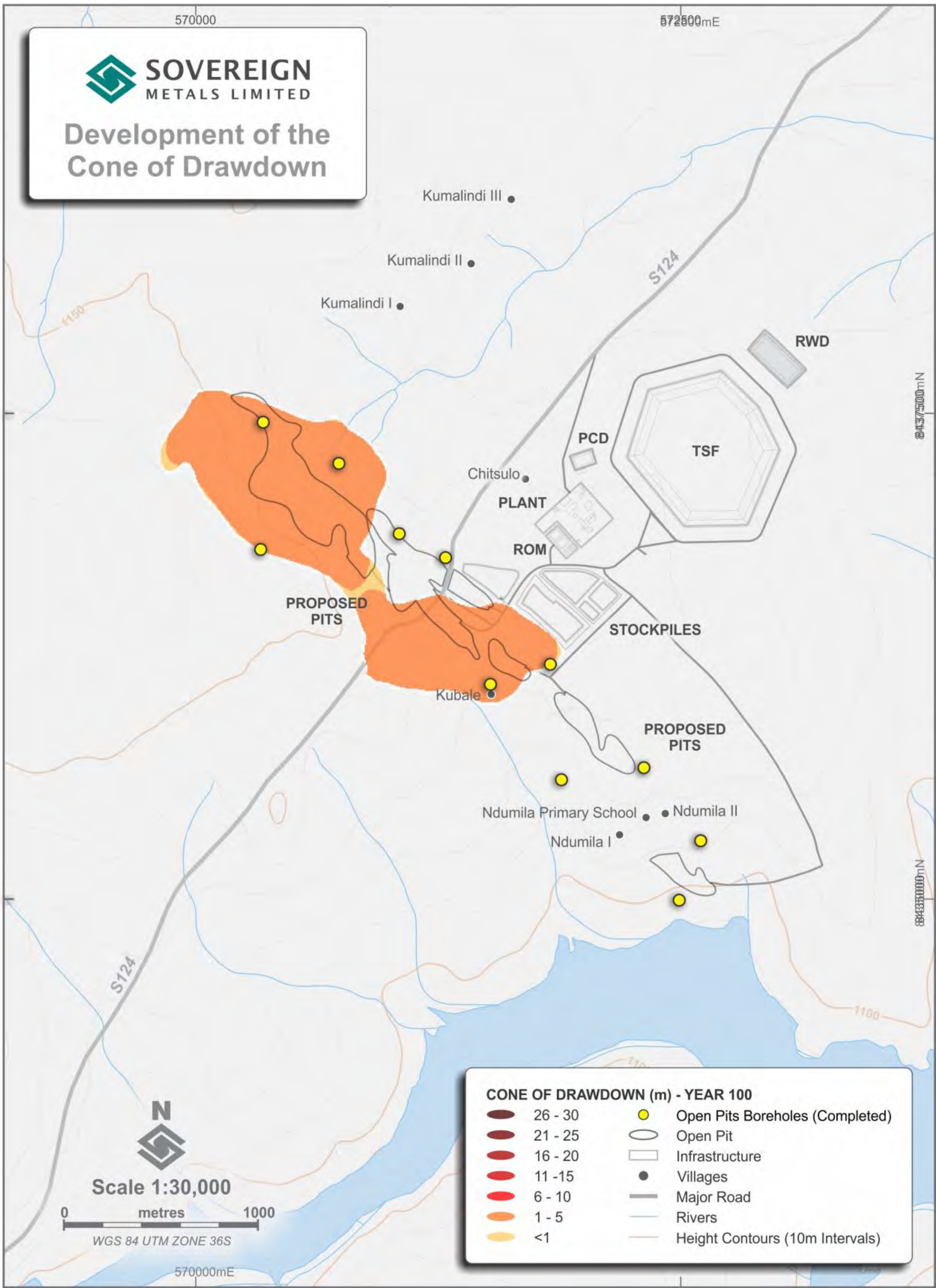

Figure 7.7: Cone of Drawdown at the End of Year 100

Although the drawdown modelling in Figure 7.4 extends over the Kamuzu Dam, this does not imply that there will be a reduction of this magnitude in the level of the dam, and is simply a function of the modelling output. Modelled groundwater levels in this area indicate that the aquifer is located between 1 and 5 mbgl. The reduction in groundwater at this point is expected to be less than 1 m, as indicated by the drawdown levels. Due to low permeability in the Project area, it is unlikely that dewatering from the southern open pits will result in a significant impact on the Kamuzu Dam. This is supported by Figure 7.8, which illustrates the level of the pit in relation to Kamuzu Dam. In addition, water from dewatering of these pits will be discharged back to the Kamuzu Dam via Dambo 1.

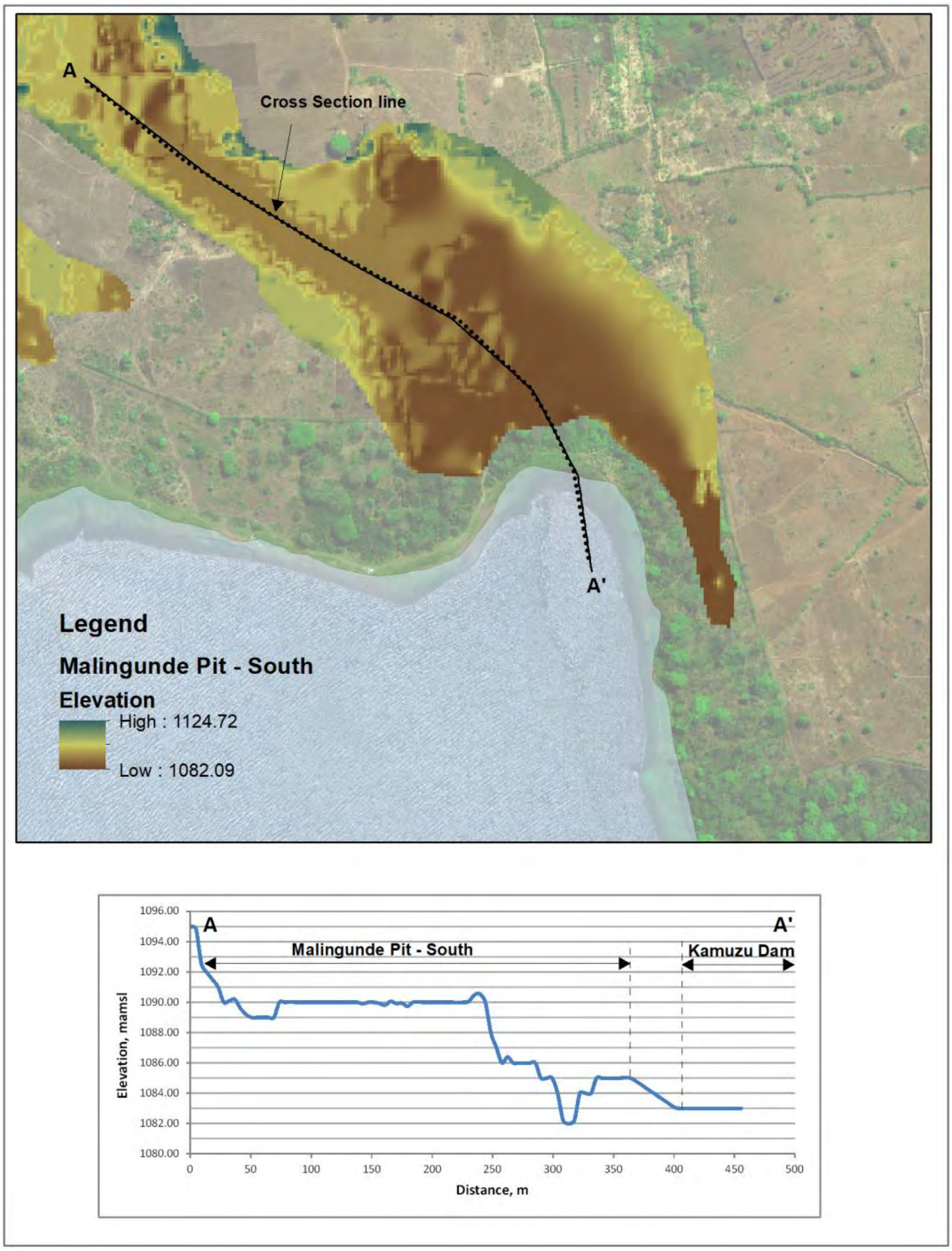

Figure 7.8: Cross-section of Southern Pit in Relation to Kamuzu Dam

The assessment of the significance of impacts without mitigation, recommended mitigation and the residual impact are summarised below:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Long-term	Local	Very High	High	Almost Certain	Very High
Mitigation Measures					
• Establish and maintain an effective groundwater monitoring system. • Provide access to alternative water sources to affected communities.					
Residual Impact					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Transient	Local	Low	Very Low	Unlikely	Very Low

Residual Impact

As indicated, the maximum drawdown is expected toward the end of the life-of-mine. Upon closure groundwater levels will return to levels similar to what was encountered prior to Project implementation. Drawdown of between 1 and 5 m will remain long-term after closure in the northern extent of the open pits. However, no existing community boreholes were identified in this area that would be adversely affected.

7.8.2 Potential Contamination of Aquifers

Contamination of groundwater from various sources during the construction and operations phases has the potential to directly impact the quality of water in the aquifers below the Project site, which in turn could negatively impact groundwater users within the zone of impact and potentially result in health impacts, as groundwater in the area is used for domestic purposes.

Two types of pollution sources were broadly considered. The first is diffuse pollution which includes ad hoc spills and discharges of contaminating substances, such as fuel and reagents. The other type is point source pollution which includes more long-term pollution associated with permanent structures such as the TSF.

In the construction phase potential contamination sources are temporary in nature, usually existing for a few weeks to a few months. Although these sources may be temporary, the potential contamination may be long-term. The operations phase will present potential sources that are present over the longer term, as well as the closure phase with final land forms that will remain permanently and may have the potential to change groundwater quality through long-term seepage.

The most significant potential for groundwater quality impact is associated with the TSF. Leach tests were used to estimate seepage quality from the proposed TSF and is predicted to be pH neutral, with aluminium and fluoride are expected to exceed the Malawian Drinking Water Specification (2005) and fluoride also exceeding the WHO Standard for Drinking Water (2017). Baseline water quality already exceeds these standards for aluminium in some of the sampled sites. Although iron was elevated in some of the analysis undertaken, iron will precipitate out of the tailings water and unlikely to impact the groundwater quality.

Contaminant loads were estimated for the TSF for the constituents that exceeded the water quality guidelines (aluminium and fluoride) and for sulfate (SO_4) and are summarised in Table 7.7.

Table 7.7: Potential Contaminant Loads from the TSF

	Al		F		SO_4	
Seepage Rate	Seepage Quality	Load	Seepage Quality	Load	Seepage Quality	Load
m^3/year	mg/L	kg/year	mg/L	kg/year	mg/L	kg/year
16,618	1.32	22	3.4	56.5	80	1,330

The simulated groundwater modelling therefore focussed on potential impacts from the TSF. No other significant sources of contamination are known to occur in the vicinity of the Project and therefore cumulative impacts are not expected.

Predictive simulations for the migration of a seepage plume from the TSF were undertaken for the same periods as the cones of drawdown.

The seepage plume simulations are indicated in Figure 7.9 to Figure 7.14. The migration of the simulated plume mimics the topography of the land with a flow towards the east and north east.

The predicted maximum extent of the seepage plume from the TSF is outlined in Table 7.8.

Table 7.8: Extent of Seepage Plume

Simulation Year	Max. Seepage Plume Extent
5	147 m
10	213 m
16	235 m
25	348 m
50	610 m
100	1,053 m

A seepage plume at concentrations above the Malawian Drinking Water Standards for aluminium and fluoride is predicted to extend off-site, approximately 550 m downgradient of the TSF by Year 100. The extent is understood as the limit where simulated concentrations have a zero value.

No known groundwater users are known to occur within this predicted impact zone.

The assessment of the significance of impacts without mitigation, recommended mitigation and the residual impact are summarised as follows:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Long-term	Local	High	High	Likely	High
Mitigation Measures					
• Implement appropriate operational interventions to reduce the point source contamination potential. • Investigate the installation of scavenger wells to contain and minimise the migration of contamination as part of the detailed design. • Establish a no-go area around the TSF where the use of groundwater is prohibited.					
Residual Impact					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Medium-term	Local	Low	Low	Unlikely	Low

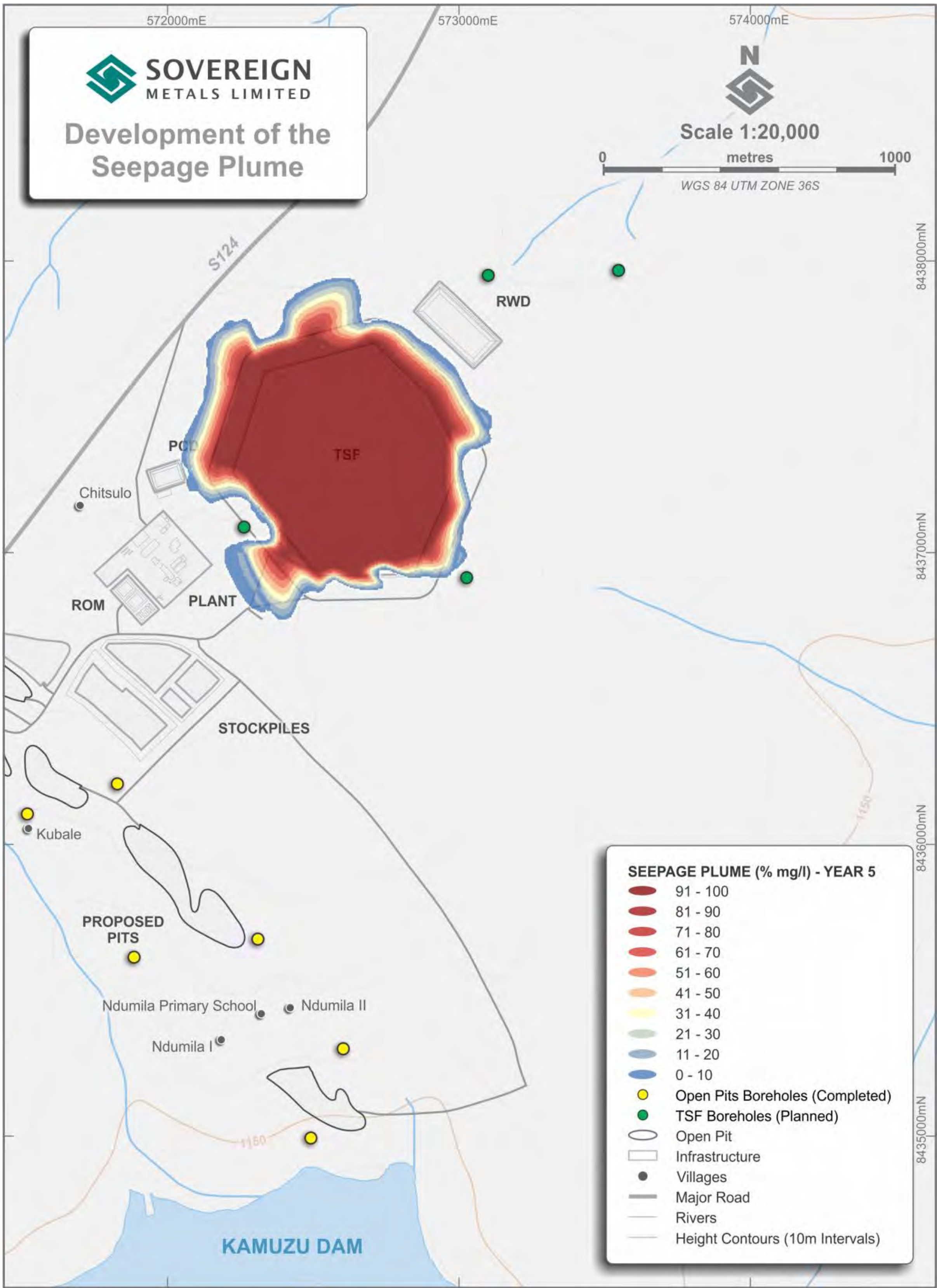

Figure 7.9: Seepage Plume at the End of Year 5

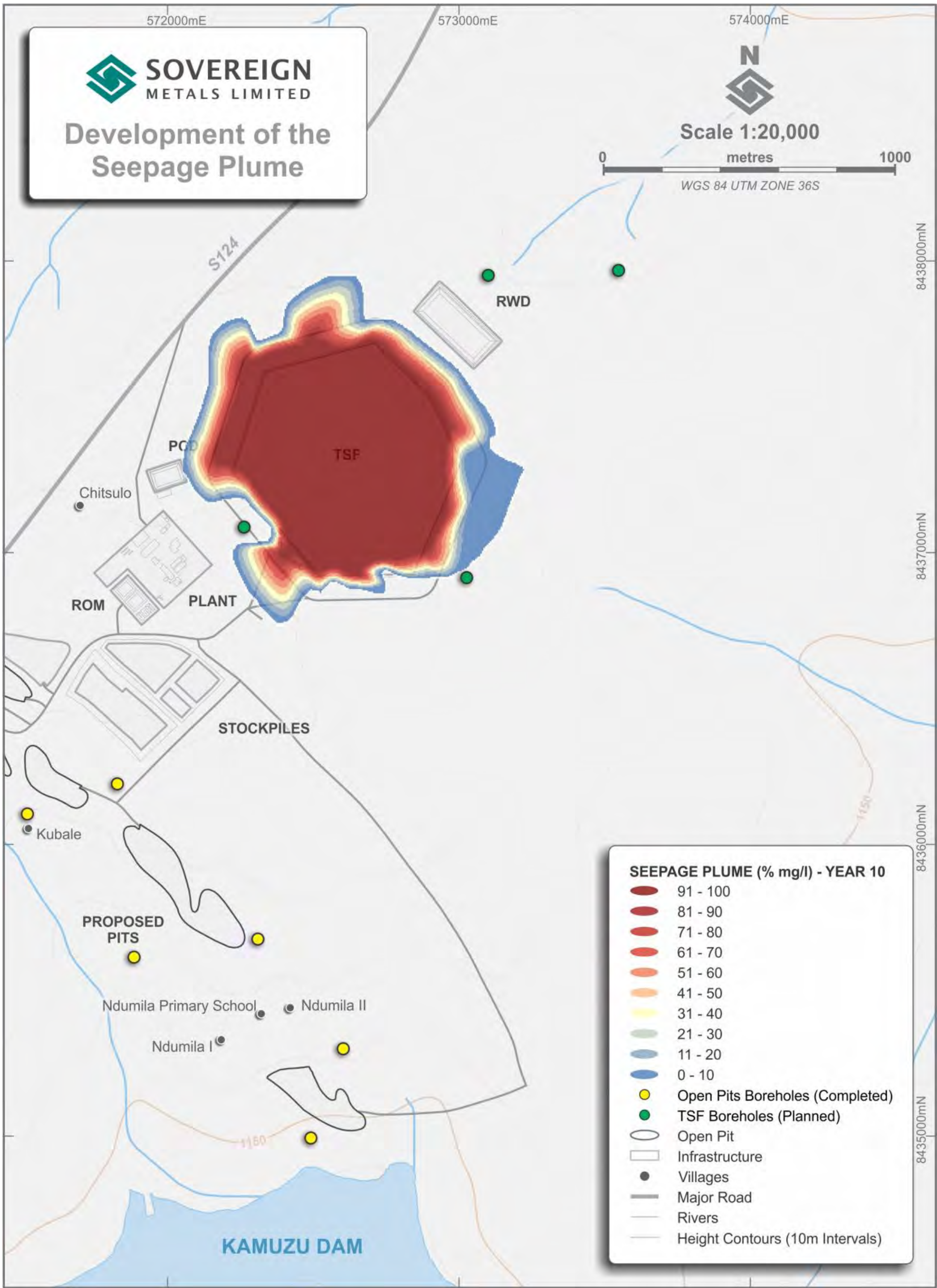

Figure 7.10: Seepage Plume at the End of Year 10

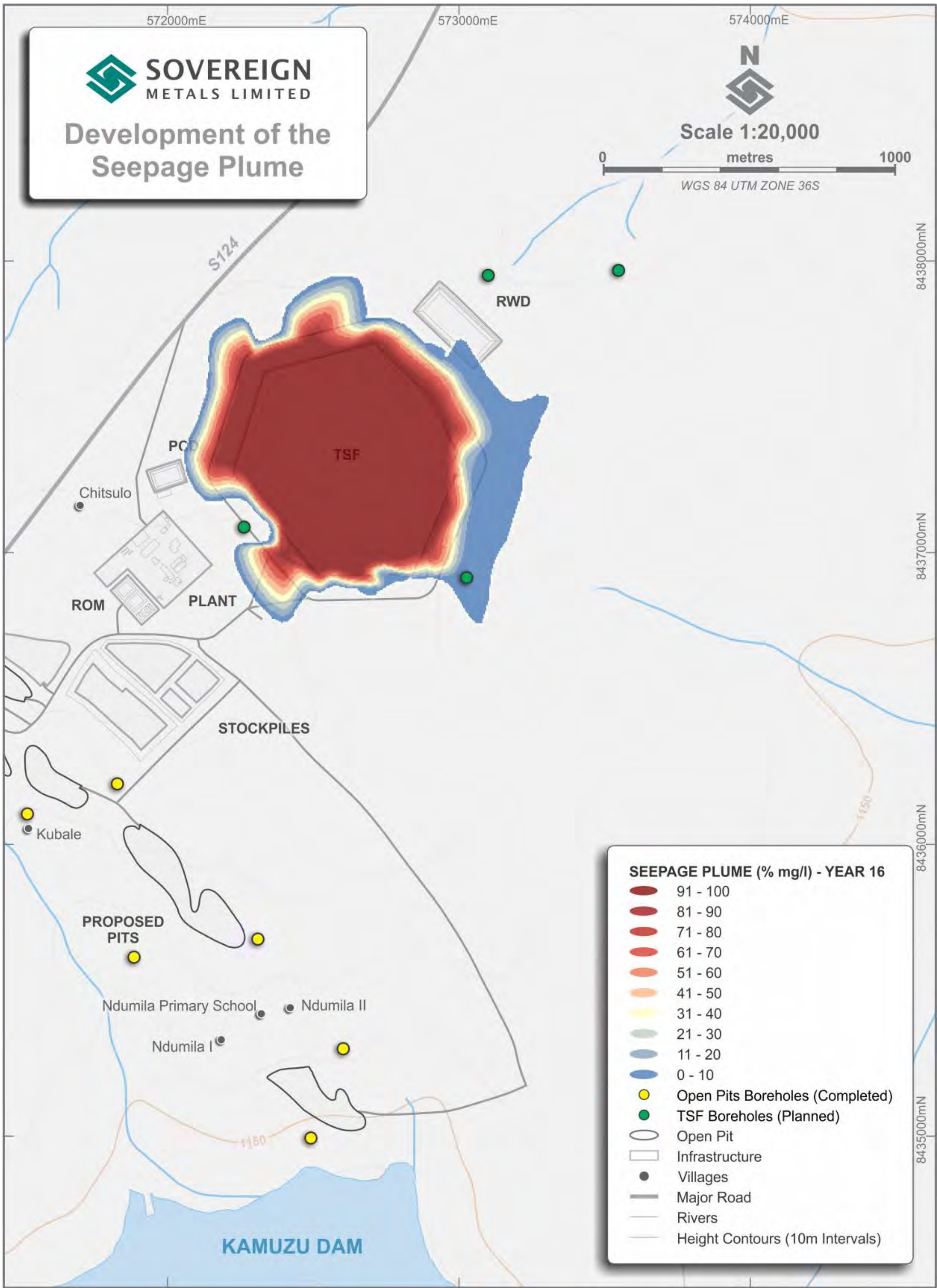

Figure 7.11: Seepage Plume at the End of Year 16

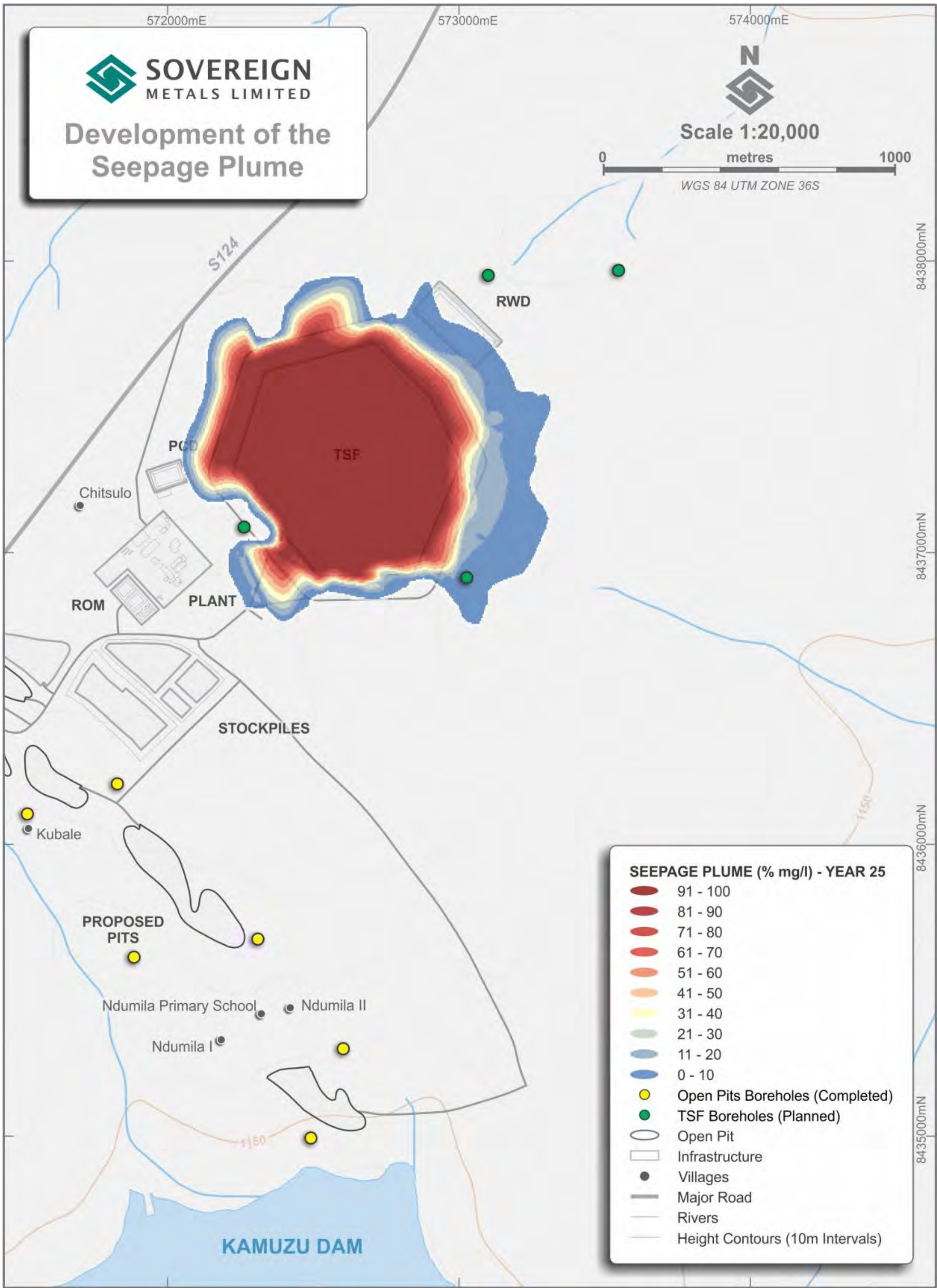

Figure 7.12: Seepage Plume at the End of Year 25

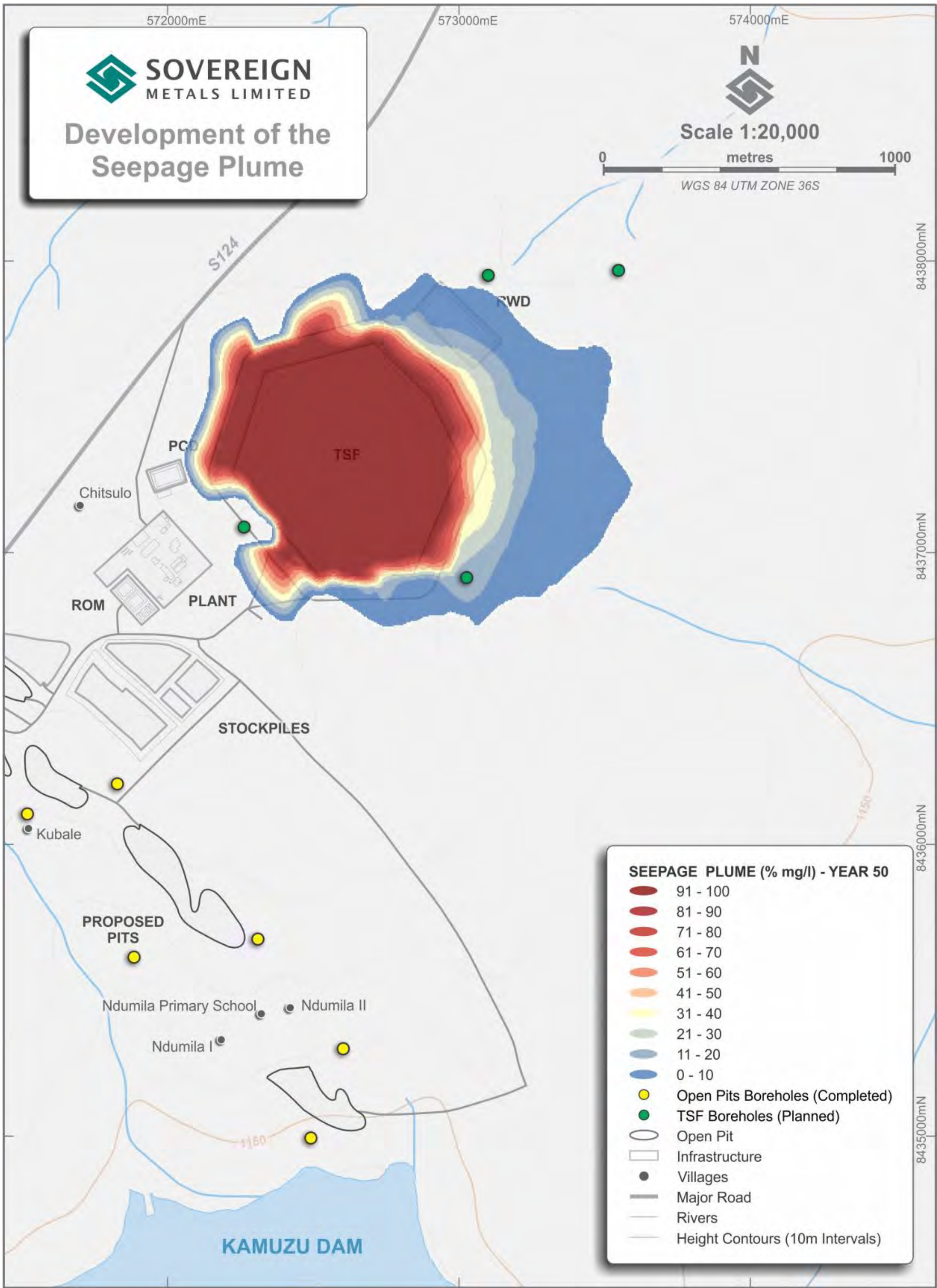

Figure 7.13: Seepage Plume at the End of Year 50

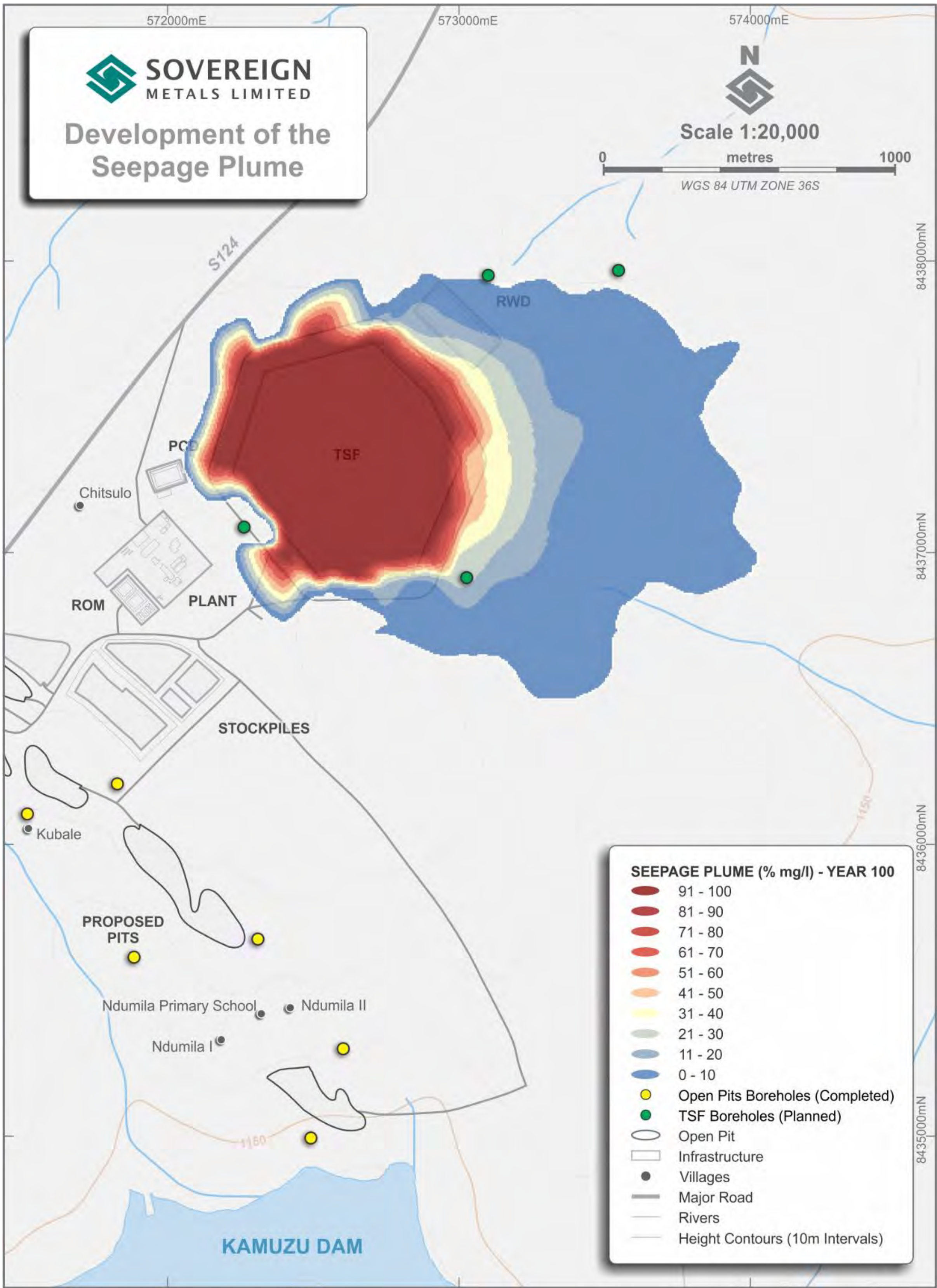

Figure 7.14: Seepage Plume at the End of Year 100

Residual Impact

As previously stated, a seepage plume at concentrations above the Malawian Drinking Water Standards for aluminium and fluoride is predicted to extend approximately 550 m downgradient of the TSF by Year 100. However, no known community boreholes are located within this predicted impact zone and the impact is regarded as low. Monitoring boreholes will be installed to monitor groundwater quality. In the event that an impact on groundwater quality is detected, additional management measures will be implemented to ensure the impact is ameliorated. Should community boreholes downgradient prove to be impacted by seepage, alternative water sources will be provided to impacted groundwater users.

7.9 Air Quality

Air quality dispersion modelling was undertaken as part of the air quality impact assessment by Digby Wells (2019b) using the AERMOD modelling system (refer Appendix N). The modelling considered the worst-case scenario (without mitigation measures in place) and is a graphical representation of ground level concentrations (GLC) (in µg/m^3) for various pollutants, and total suspend particle (TSP) rates (presented in mg/m^2/day).

7.9.1 Increase in Total Suspended Particles PM_{10} and $PM_{2.5}$

Clearing of vegetation, soil stripping, excavation, hauling, tipping and spreading of materials (including soils and construction materials) on site during the construction phase will be a source of emissions that may impact on ambient air quality. These activities often result in the generation of fugitive dust comprising TSP, PM_{10} and $PM_{2.5}$, especially from unsealed roads and open surfaces. The aforementioned activities will be transient and localised in nature, and is expected to have limited or low impact on the ambient air quality during the construction phase.

During the operations phase, the main activities that will contribute to emissions include; excavation, hauling of material, stockpiling of material, sizing and screening, wind erosion from stockpiles and the use of generators.

7.9.1.1 Predicted Increase in $PM_{2.5}$

The modelled GLC of $PM_{2.5}$ as a result of the operations are indicted in Figure 7.15 ($PM_{2.5}$ daily) and Figure 7.16 ($PM_{2.5}$ annual).

Since Malawi does not have regulated standards for $PM_{2.5}$ daily concentrations, the WHO Air quality guidelines (2005) for particulate matter, ozone, nitrogen dioxide and sulfur dioxide were used to assess impacts in the Project area. Areas where the 24-hour WHO guideline concentration of 25 µg/m^3 are expected to be exceeded are indicated in Figure 7.15. The GLC predicted at the selected sensitive receptors were below the respective daily and annual limit values (Table 7.9), except at Kumalindi and Chitsulo (due to its proximity to Project activities and infrastructure). The predicted annual GLCs were compared with the Malawi guideline limit of 8 µg/m^3, and areas with exceedance are indicated in Figure 7.16.

Table 7.9: Predicted $PM_{2.5}$ Concentrations at Sensitive Receptors

Site ID	X	Y	Daily Averaging Period (WHO: 25 µg/m^3)	Annual Averaging Period (MS: 8 µg/m^3)
Chikavala	572803.16	8438466.32	11.3	0.7
Chitsulo	571688.51	8437474.07	68.4	12.8
Malingunde	569377.51	8433434.23	11.	0.6
Ndumila	572298.23	8435146.33	17.5	1.2
Mningo	568479.59	8436257.24	6.7	0.8

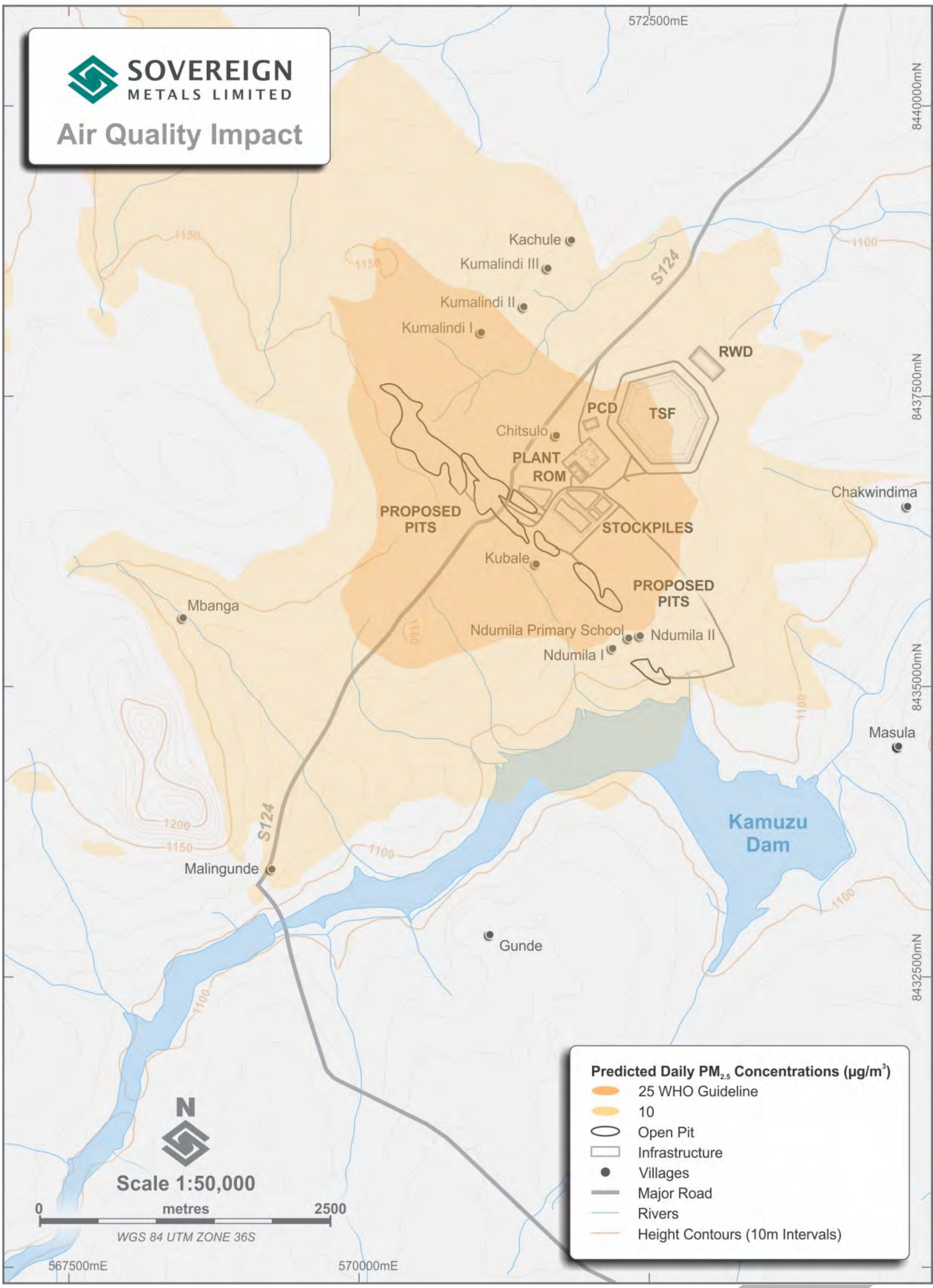

Figure 7.15: Predicted Daily $PM_{2.5}$ Concentrations (µg/m³)

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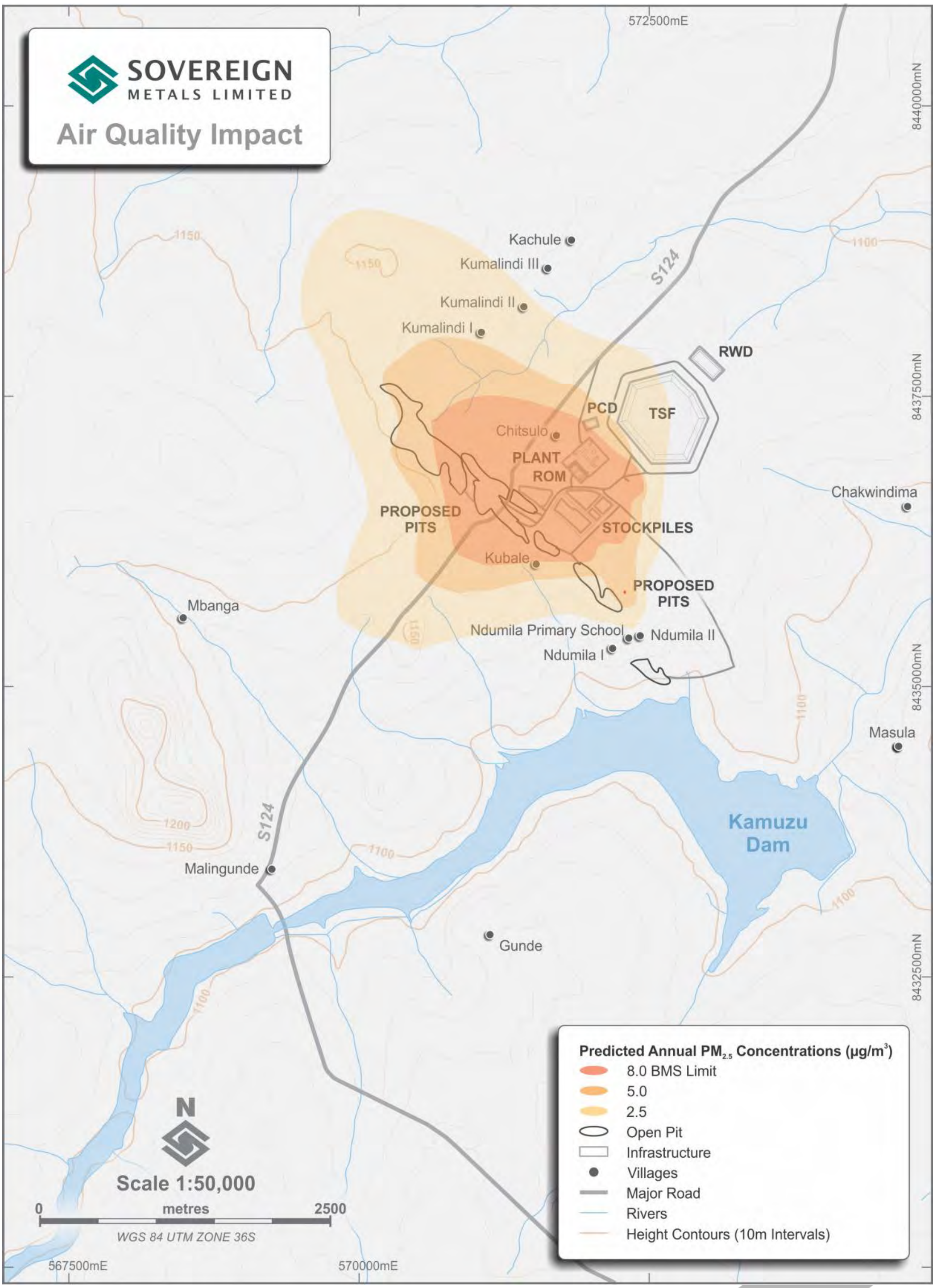

Figure 7.16: Predicted Annual $PM_{2.5}$ Concentrations (µg/m^3)

7.9.1.2 Predicted Increase in PM_{10}

The predicted PM_{10} 4-hour ground level concentrations are shown in Figure 7.17 (PM_{10} daily) and Figure 7.18 (PM_{10} annual). Malawi Standard Ambient air quality – limits for common pollutants (MS737:2005)

The Malawi standard for 24-hour concentration of 25 µg/m³ is expected to be exceeded at the communities of Chikavala (39.5 µg/m³), Chitsulo (154.6 µg/m³) Ndumila (68.4 µg/m³), and Malingunde (37.9 µg/m³) (Table 7.10). The predicted annual GLCs were compared with the WHO guideline of 20 µg/m³, as there is no Malawi-specific limit for this averaging period. No exceedances were observed at selected receptors, except at Chitsulo (Figure 7.18). The predicted daily and annual GLCs at the selected sensitive receptors are depicted in Table 7.10.

Table 7.10: Predicted PM_{10} Concentrations at Sensitive Receptors

Site ID	X	Y	Daily Averaging Period (MS: 25 µg/m³)	Annual Averaging Period (WHO: 20 µg/m³)
Chikavala	572803.16	8438466.32	39.5	2.7
Chitsulo	571688.51	8437474.07	154.6	47.3
Malingunde	569377.51	8433434.23	37.9	2.1
Ndumila	572298.23	8435146.33	68.4	4.2
Mningo	568479.59	8436257.24	24.4	2.8

* Red indicates exceedance of the limit

7.9.1.3 Predicted Increase in TSP

The predicted dust deposition rates (represented as TSP) are shown in Figure 7.19. In the absence of applicable Malawi-specific guidelines for dust deposition, the South African standard [National Dust Control Regulations (2013), published in Government Notice 827 in Gazette 36974 on 1 November 2013] were used to compare the modelled results against. Results from the model simulation for the dust deposition rates confirms that areas where the residential and non-residential limits of 600 mg/m²/day and 1,200 mg/m²/day are expected to be exceeded are located within 2 km of the Project activities without mitigation measures in place (worst case scenario) (Figure 7.19). The modelling results with mitigation measures applied was are depicted in Figure 7.20. These results demonstrate that, if appropriate mitigation measures are implemented, the distance from the Project where exceedances are expected is reduced to 823 m from the Project.

Deposition rates at the selected receptors were below the residential limit of 600 mg/m²/day, except at Chitsulo (Table 7.11). Note that this table shows the deposition rates before and after mitigation measure have been implemented, and the relative effectiveness of the measures applied.

Table 7.11: Predicted Dust Deposition Rates at Sensitive Receptors

Site ID	X	Y	Monthly Averaging Period (SA Standards: 600 / 1200 mg/m²/day)	Monthly Averaging Period (SA Standards: 600 / 1200 mg/m²/day) with mitigation
Chikavala	572803.16	8438466.32	164	27
Chitsulo	571688.51	8437474.07	1,244	794
Malingunde	569377.51	8433434.23	135	23
Ndumila	572298.23	8435146.33	408	64
Mningo	568479.59	8436257.24	257	44

* Red indicates exceedance of the limit

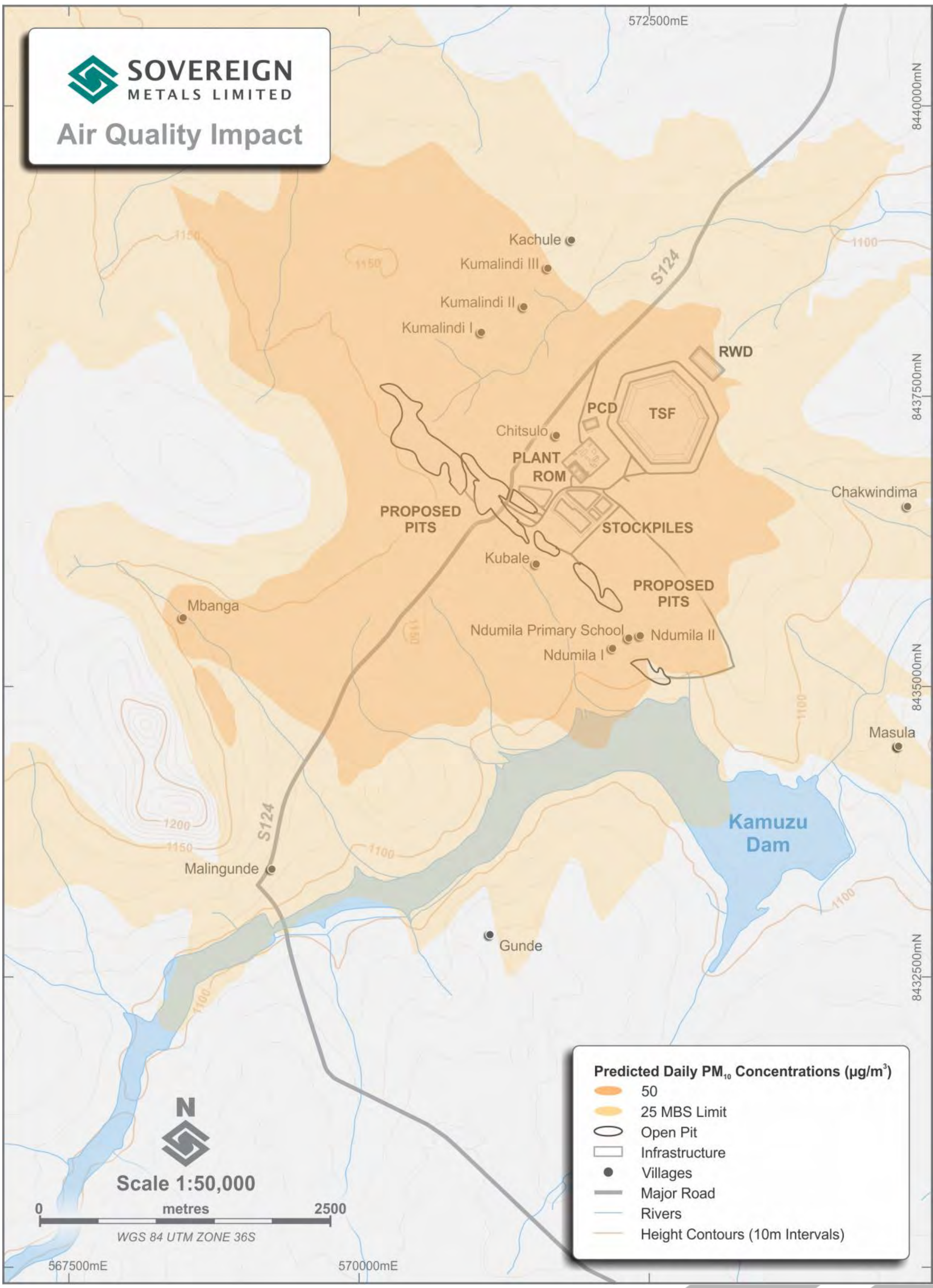

Figure 7.17: Predicted Daily PM_{10} Concentrations (μg/m^3)

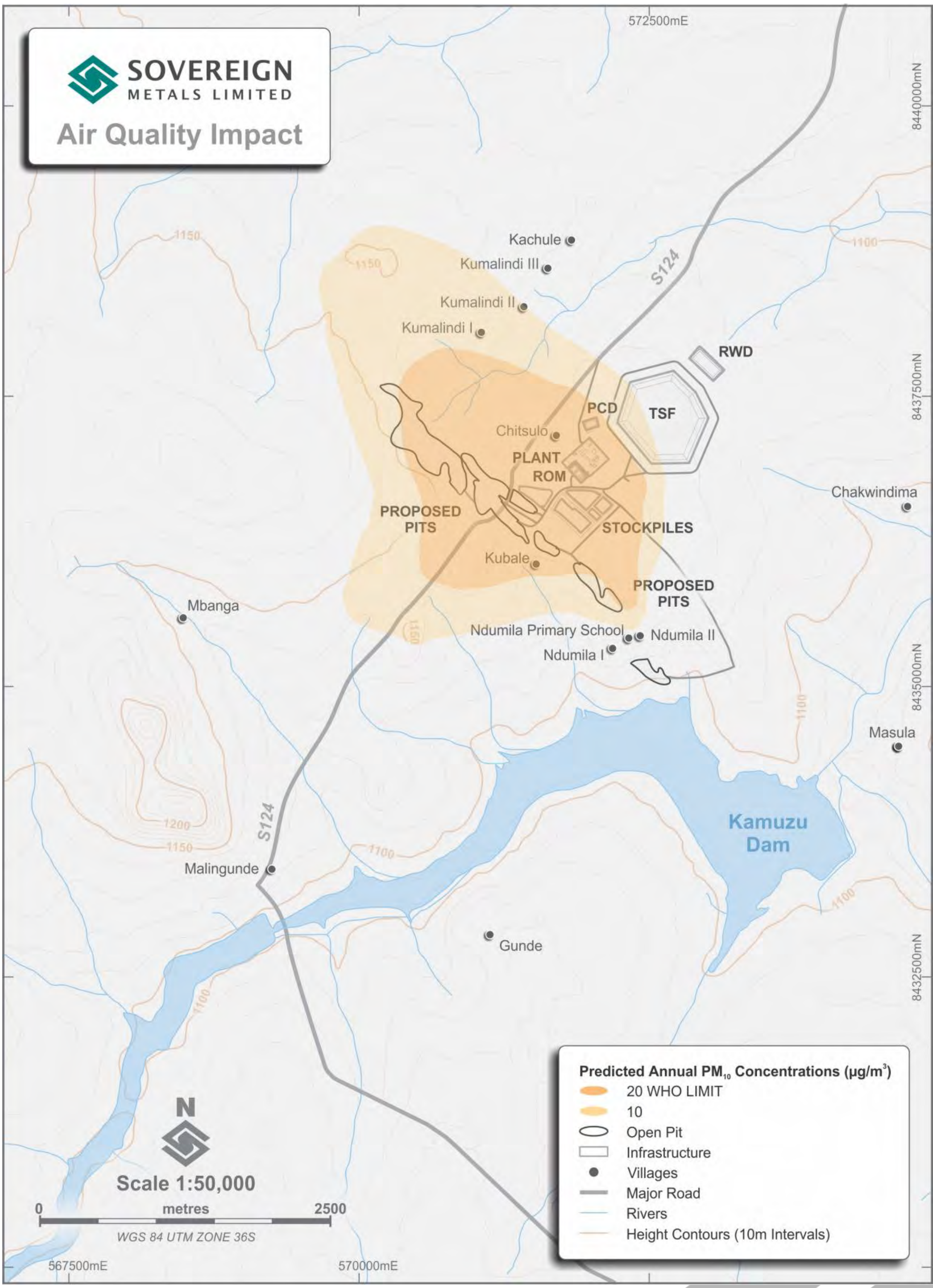

Figure 7.18: Predicted Annual PM_{10} Concentrations (µg/m³)

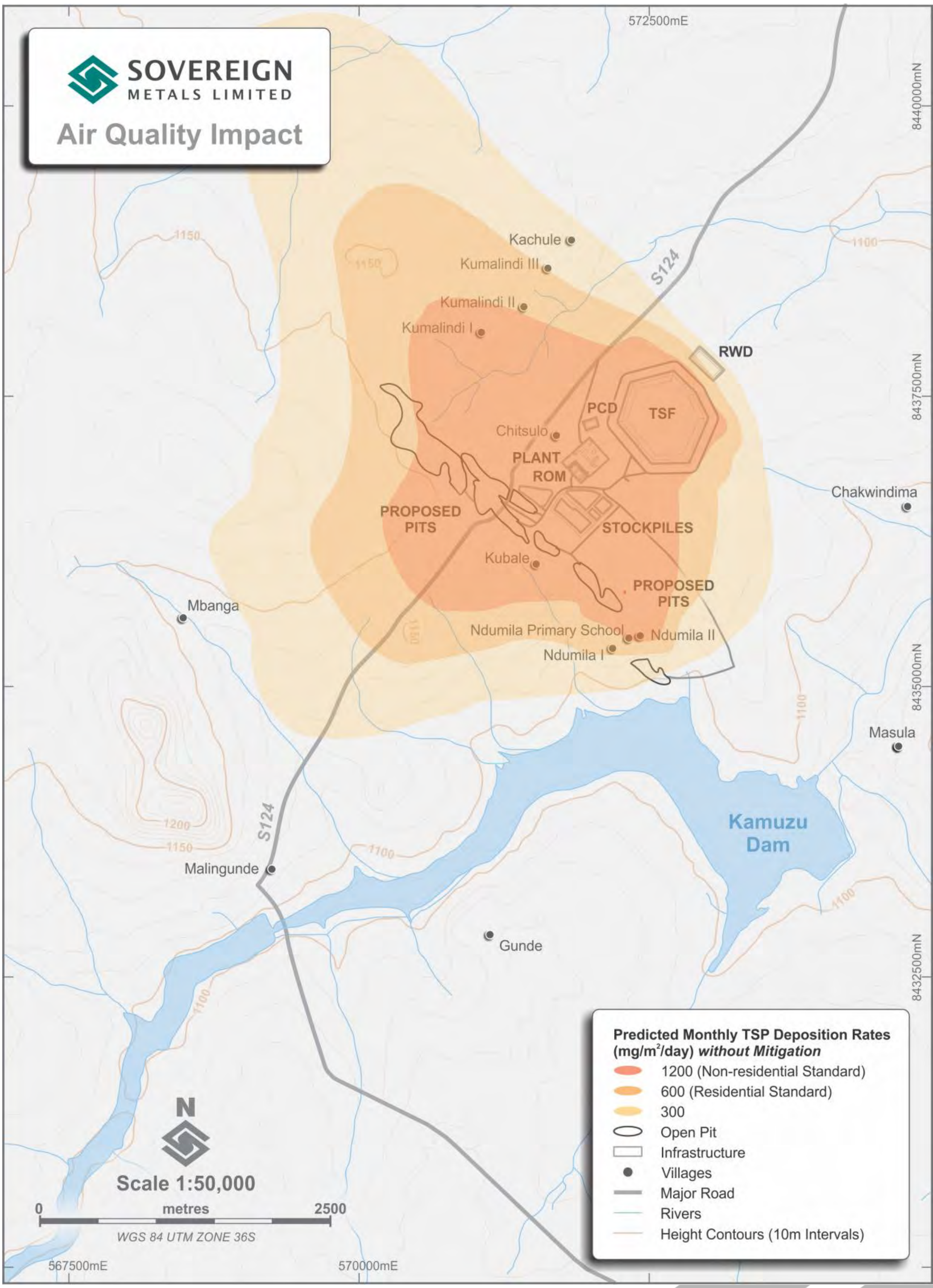

Figure 7.19: Predicted Monthly TSP Deposition Rates (mg/m^2/day) without Mitigation

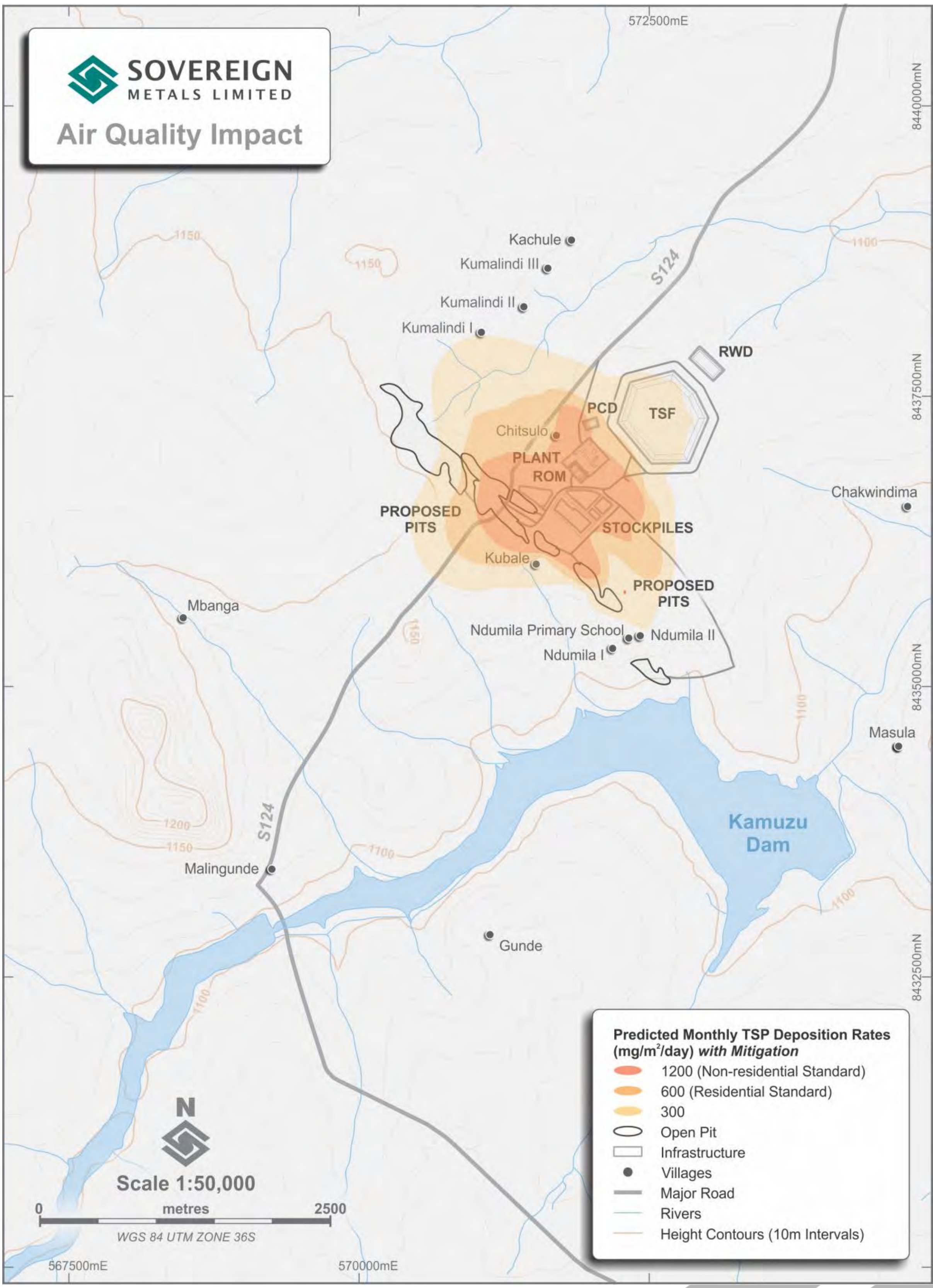

Figure 7.20: Predicted Monthly TSP Deposition Rates (mg/m²/day) with Mitigation

7.9.1.4 Assessment of Significance of Impact

The model predictions indicate that emissions during the operations phase are likely to result in exceedances of standards and applicable guidelines for TSP, PM_{10} and $PM_{2.5}$. Although the exceedances/impacts are confined within the ESIA study area, villages such as Chikavala, Kumalindi, Ndumila, and Malingunde are likely to experience increases in particulates.

The main sources of dust during operations are emissions from mine haul roads and stockpiling of material (Digby Wells, 2019b), and the impact from these activities are expected to be as follows:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Long-term	Local	Moderate	Moderate	Highly Likely	High
Mitigation Measures					
• Apply wetting agents, dust suppressant or binders on unsealed roads and exposed areas. • Minimise vegetation clearance and land disturbance to that which is necessary for development of the Project. • Limit activities that have high potential for dust creation on windy days (wind speed ≥ 5.4 m/s), where practicable. • Enforce adherence to set speed limits. • Minimise drop heights for materials when loading and at tipping points.					
Impact with Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Long-term	Site-specific	Low	Low	Likely	Low

During the decommissioning and closure phase, activities resulting in the generation of dust are largely associated with the demolition of infrastructure, transport and handling of materials, and reshaping of landforms. The impacts on the local ambient air quality are expected to be similar to that of the construction phase, and will be short-term and localised in nature as summarised below.

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Short-term	Local	Low	Low	Likely	Low
Mitigation Measures					
• Apply wetting agents, dust suppressant or binders on unsealed roads and exposed areas. • Limit activities that have high potential for dust creation on windy days (wind speed ≥ 5.4 m/s), where practicable. • Enforce adherence to set speed limits. • Minimise drop heights for materials when loading and at tipping points. • Rehabilitate cleared areas as soon as practicable.					
Impact with Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Short-term	Site-specific	Negligible	Low	Unlikely	Very Low

Residual Impact

Construction and operation of the Project is likely to result in localised exceedances of emissions criteria of particulate matter, however, short-term. Implementation of the recommendation mitigation measures, particularly the application of wetting agents and dust suppressants is expected to satisfactorily reduce emissions at nearby sensitive receptors. However, increased emissions are still likely at Project facilities.

7.9.2 Increase in Sulfur Dioxide (SO_2)

Model predictions confirm that the GLC for SO_2 are all expected to be below the Malawi limits for the different averaging periods (Figure 7.21 and Figure 7.22). Although the predicted impacts from this pollutant are low based on model simulations, background levels higher than the Malawi limit have been recorded on site and additions from mining related could further increase these levels. The predicted concentrations at sensitive receptors are indicated in Table 7.12).

Table 7.12: Predicted SO_2 Concentrations at Sensitive Receptors

Site ID	X	Y	1-hr Averaging Period (MBS: 520 µg/m³)	24-hr Averaging Period (MBS: 210 µg/m³)	1-yr Averaging Period (MBS: 50 µg/m³)
Chikavala	572803,16	8438466,32	5.9	0.5	0.01
Chitsulo	571688,51	8437474,07	14.2	4.4	1.3
Malingunde	569377,51	8433434,23	4.8	0.5	0.03
Ndumila	572298,23	8435146,33	7.4	0.4	0.01
Mningo	568479,59	8436257,24	8.1	1.1	0.09

7.9.3 Increase in Nitrogen Dioxide (NO_2)

The 1-hour NO_2 GLCs are expected to be higher than the Malawi limit value of 230 µg/m³ at the communities of Chikavala (298.7 µg/m³), Chitsulo (644.6 µg/m³), Malingunde (233.4 µg/m³) and Mningo (262.2 µg/m³) as indicated in Table 7.13. Emissions of this pollutant can be mitigated by the use of catalytic converters, which has the ability to reduce emissions by up to 80% (Kalam *et al.*, 2009 as cited in Digby Wells, 2019b).

With dilution and dispersal over time, the predicted NO_2 1-year GLC was below the Malawi limit of 60 µg/m³ (Figure 7.24).

Table 7.13: Predicted NO_2 Concentrations at Sensitive Receptors

Site ID	X	Y	1-hr Averaging Period (MBS: 230 µg/m³)	1-yr Averaging Period (MBS: 60 µg/m³)
Chikavala	572803,16	8438466,32	298.7	1.4
Chitsulo	571688,51	8437474,07	644.6	36.4
Malingunde	569377,51	8433434,23	233.4	1.7
Ndumila	572298,23	8435146,33	194.8	1.2
Mningo	568479,59	8436257,24	264.2	4.4

* Red indicates exceedance of the limit

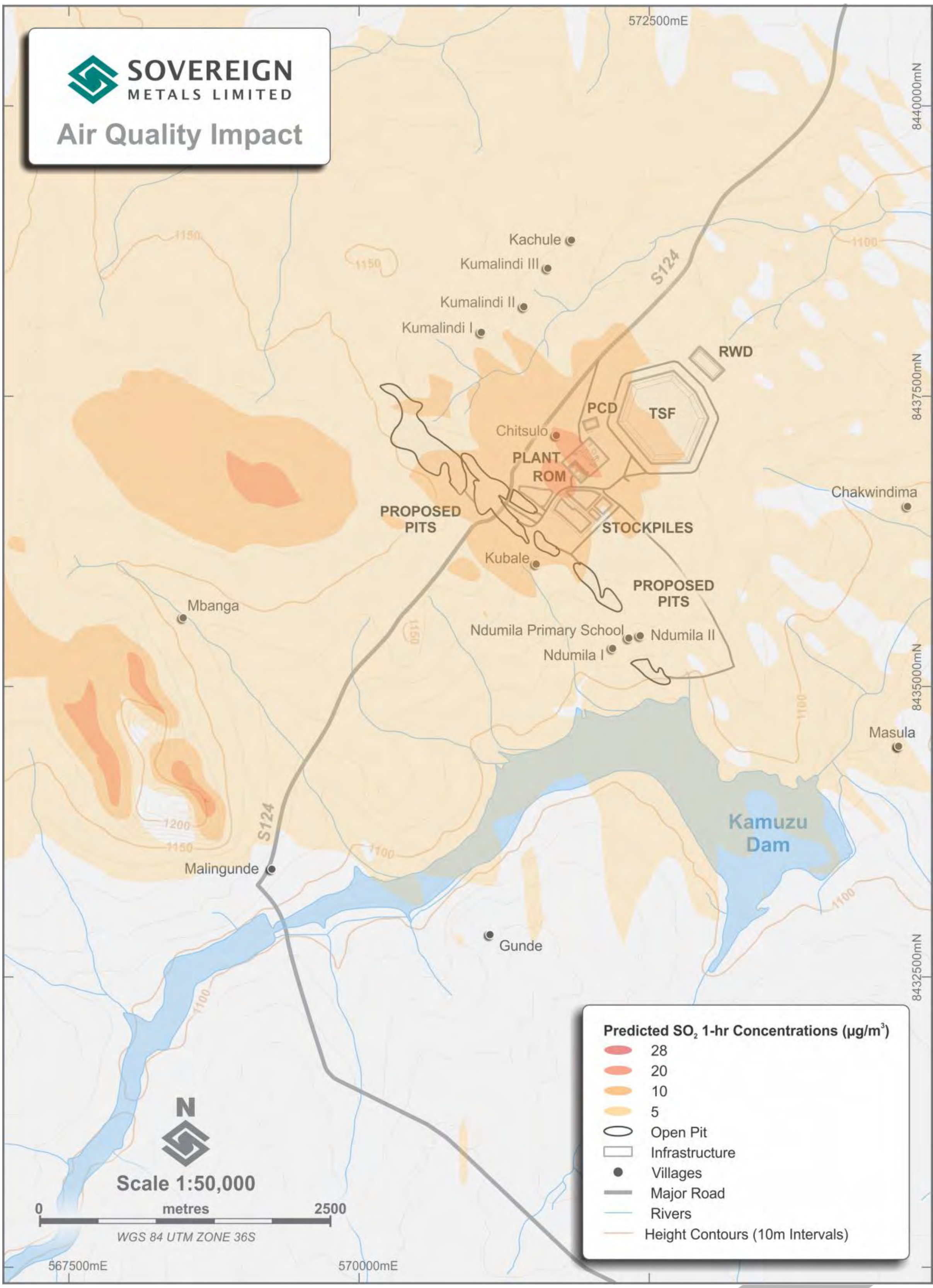

Figure 7.21: Predicted SO_2 1-hr Concentrations (µg/m^3)

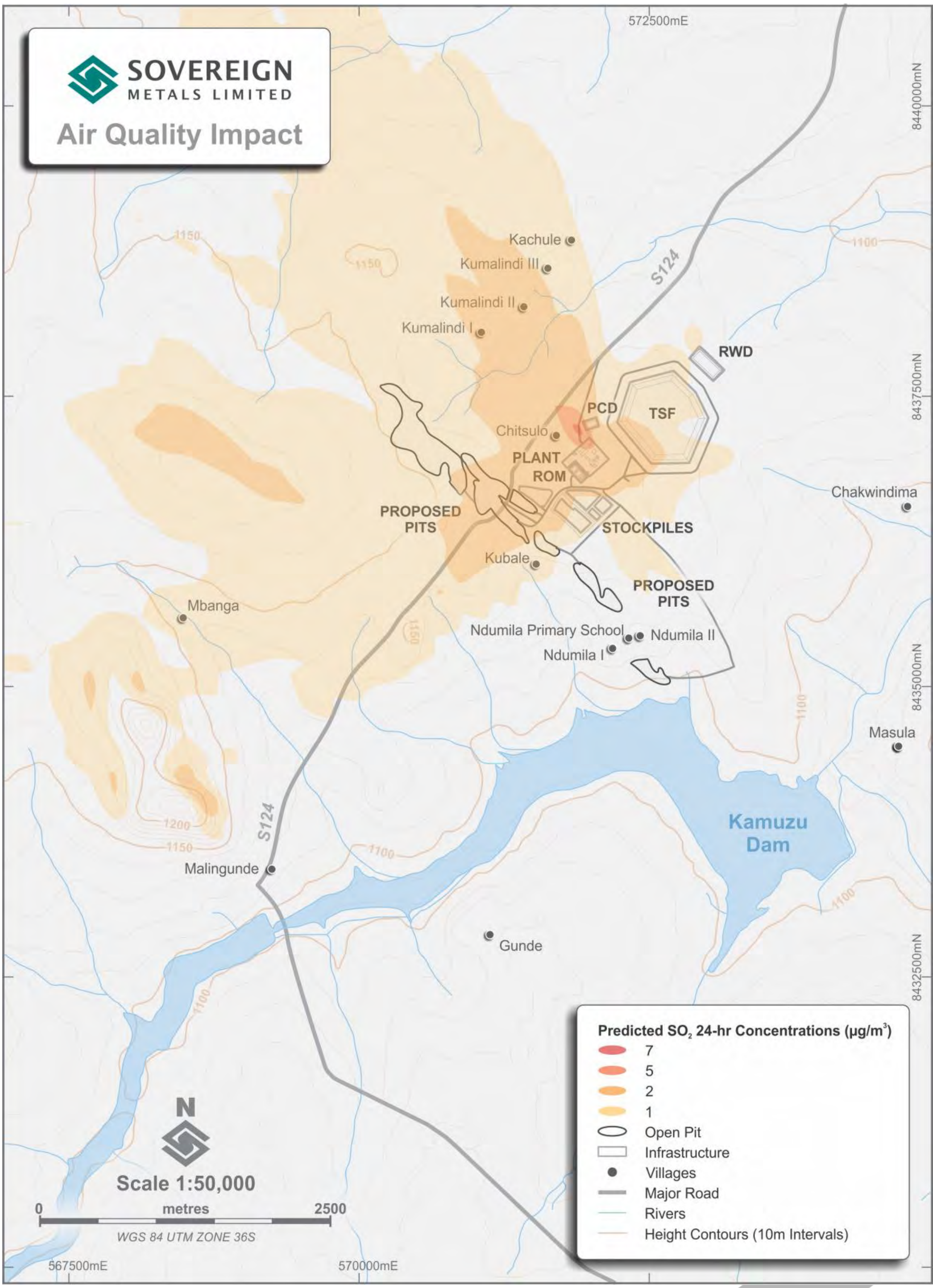

Figure 7.22: Predicted SO_2 24-hr Concentrations (µg/m³)

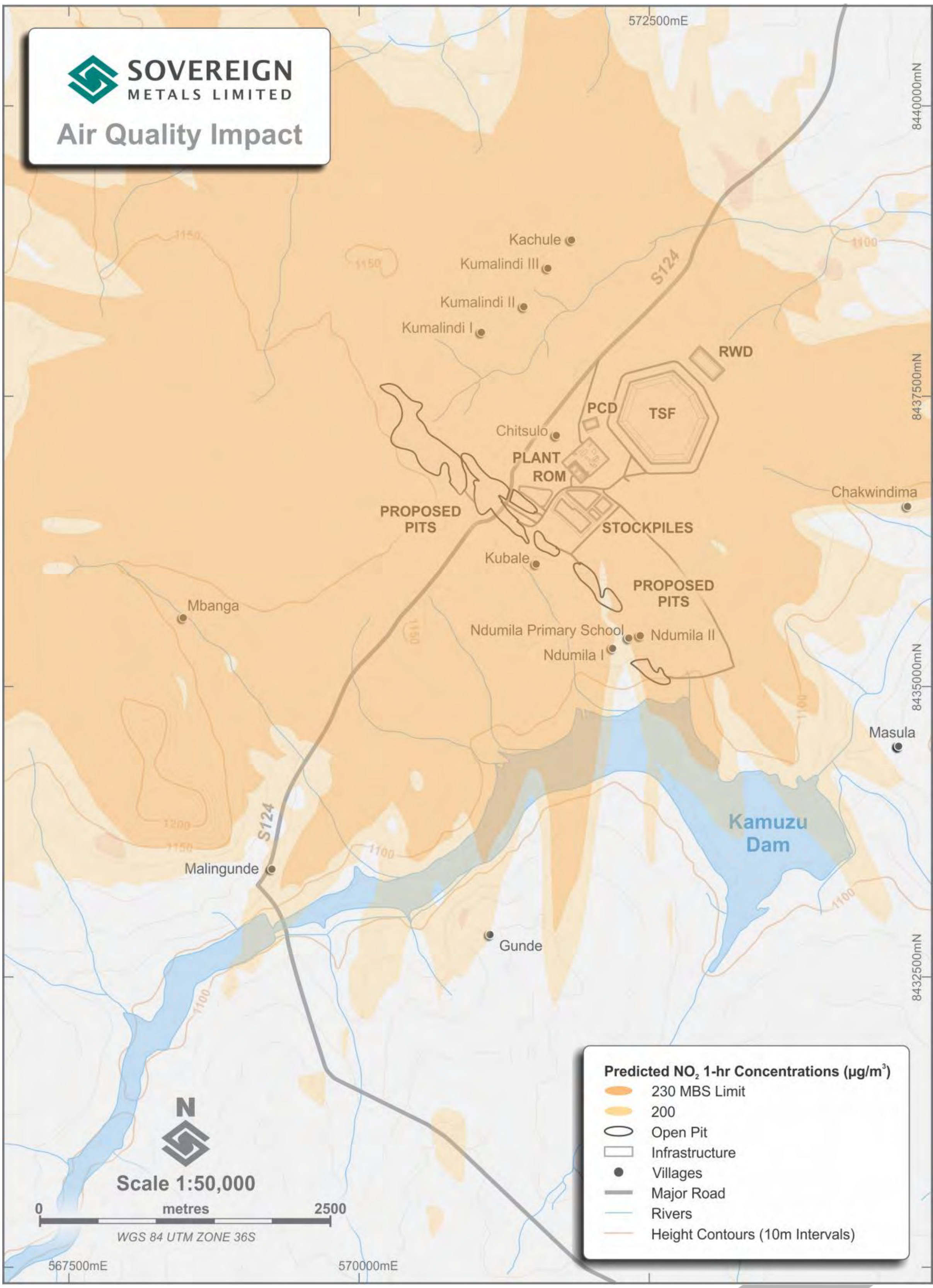

Figure 7.23: Predicted NO_2 1-hr Concentrations (µg/m^3)

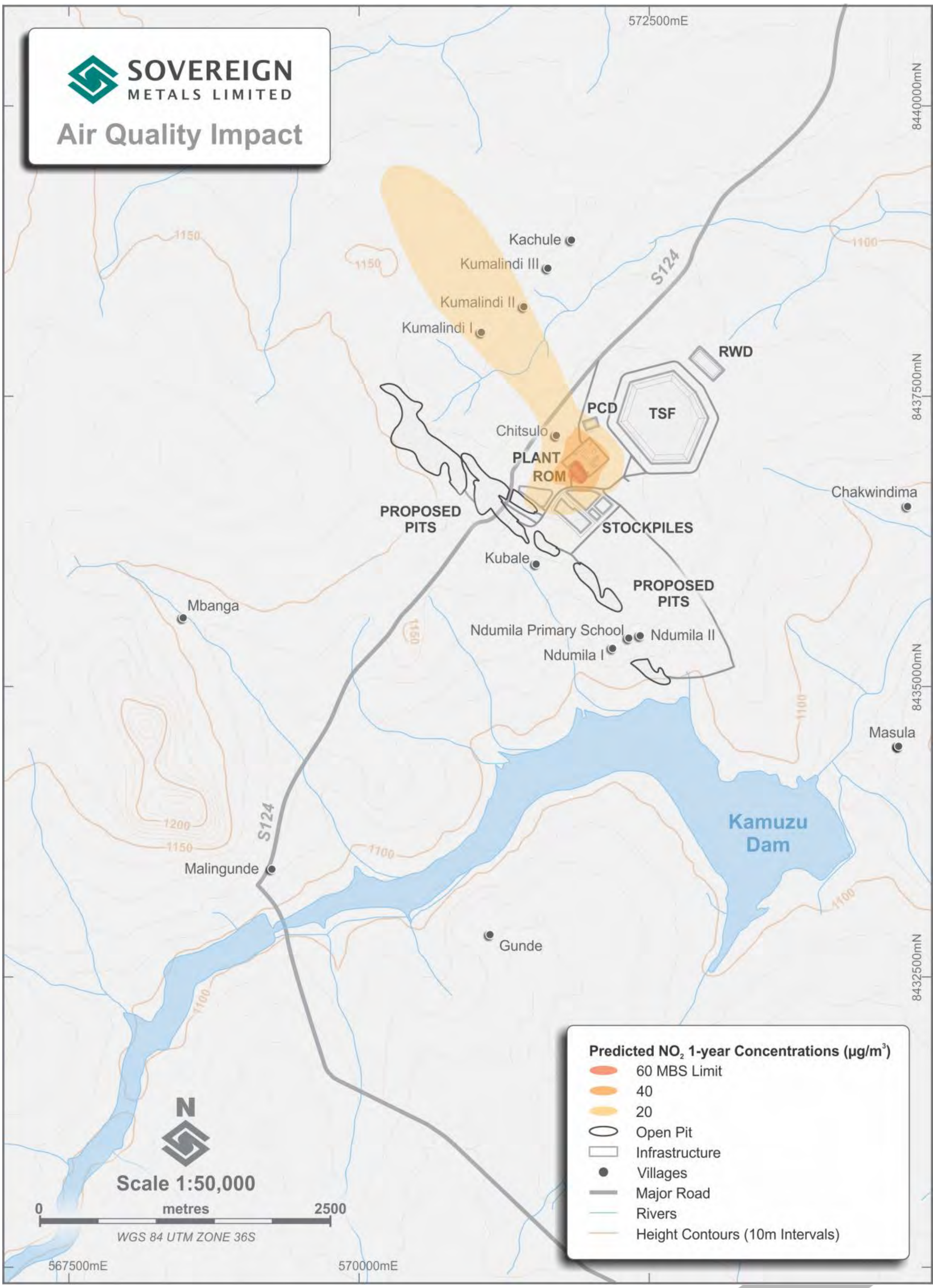

Figure 7.24: Predicted NO_2 1-year Concentrations (µg/m³)

7.9.3.1 Assessment of Significance of Impact

The model predictions indicate that emissions during the operations phase are likely to result in exceedances of standards and applicable guidelines for NO_2. Although the exceedances/impacts are confined within the ESIA study area, villages such as Chikavala, Kumalindi, Ndumila, and Malingunde are likely to experience increases.

The main sources of these emissions are from the use of diesel generators (Digby Wells, 2019b), and the impact from these activities are expected to be as follows:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Long-term	Local	Moderate	Moderate	Highly Likely	High
Mitigation Measures					
• Use catalytic converters to reduce the levels of NO_2 emitted. • Use low sulfur fuel, where available. • Ensure the generator sets are maintained and operate at optimal conditions.					
Impact with Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Long-term	Site-specific	Negligible	Very Low	Rare	Very Low

Residual Impact

Operation of diesel generators as power supply to the Project is likely to result in localised exceedances of emissions criteria of NO_2, however, short-term. Implementation of the recommendation mitigation measures is expected to satisfactorily reduce emissions at nearby sensitive receptors. However, increase emissions are still likely at Project facilities. In addition, power from diesel generators will be replaced by electricity from the national grid after the first few years of operation, which will further reduce the level of exceedance.

7.9.4 Increase in Carbon Monoxide (CO)

Model predictions confirm that the 1-hr CO GLC and 8-hr CO GLC will not exceed the Malawi limit values of 40,100 µg/m^3 and 10,310 µg/m^3, respectively, on site or at nearby sensitive receptors. The levels predicted are considered to be insignificant, with negligible impacts on the surrounding environment (Figure 7.25 and Figure 7.26). The predicted 1-hr CO and 8-hr CO GLCs at the selected receptors are depicted in Table 7.14.

Table 7.14: Predicted CO concentrations at Sensitive Receptors

Site ID	X	Y	1-hr Averaging Period (MBS: 40,100 µg/m^3)	8-hr Averaging Period (MBS: 10,310 µg/m^3)
Ndumila	572298,23	8435146,33	24.2	5.4
Mningo	568479,59	8436257,24	37.6	14.9
Chikavala	572803,16	8438466,32	25.4	7.2
Malingunde	569377,51	8433434,23	23.7	7.9

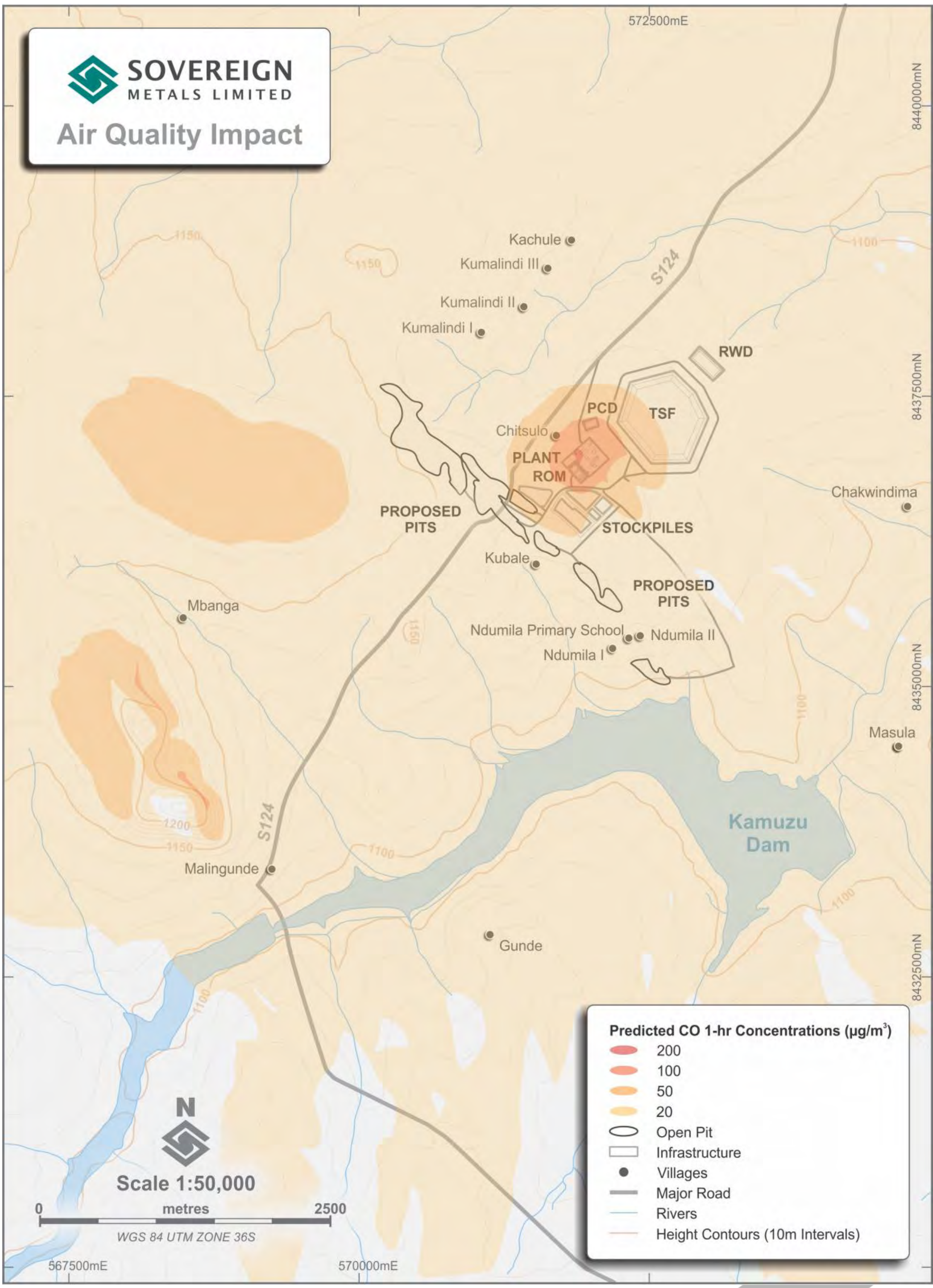

Figure 7.25: Predicted CO 1-hr Concentrations (µg/m³)

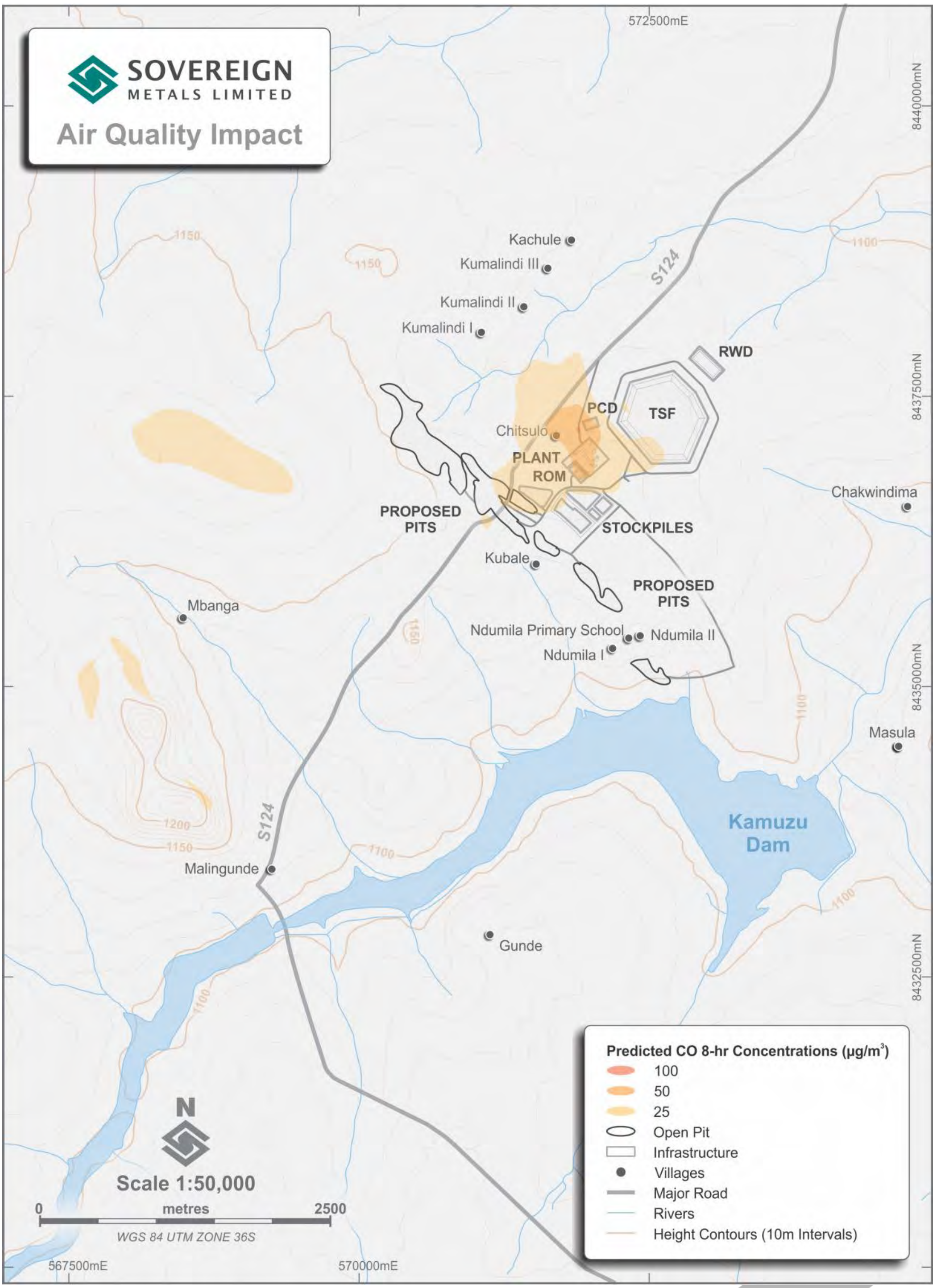

Figure 7.26: Predicted CO 8-hr Concentrations (µg/m³)

7.10 Greenhouse Gas

An estimate of the greenhouse gas footprint resulting from the Project was undertaken by Digby Wells in 2019 (refer Appendix V). The assessment used the World Resources Institute (WRI) and World Business Council for Sustainable Development's (WRI/WBCSD) Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard (2004) (GHG Protocol) method and ISO14064-2 to estimate GHG emissions from the Project. The GHG Protocol is a comprehensive global standardised framework to measure and manage GHG emissions from private and public sector operations and value chains (Digby Wells, 2019b).

The GHG Protocol requires the accounting and reporting of six GHGs covered by the Kyoto Protocol; carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6). For GHG estimations for this study, emissions from HFC, PFC and SF_6 (halogenated gases) were omitted as these are associated with e.g., refrigeration equipment, foams, solvents, aerosols, semiconductors, electrical switchgear and tyres.

The main parameters contributing to the Project's GHG footprint include:

- Commercial diesel (hydrocarbon).
- Sewerage produced and treated.
- Land use change.
- Electricity from the national grid.

The total estimated GHG emissions for the Project are summarised in Table 7.15.

Table 7.15: Total GHG Emissions for the Project

Stage	Construction Phase	Operational Phase Stage 1 (Yrs 1-3)	Operational Phase Stage 2 (Yrs 4+)
Emission Source	**tonnes CO_2-e per annum**	**tonnes CO_2-e per annum**	**tonnes CO_2-e per annum**
SCOPE 1			
Diesel: total emissions from all diesel	6,213	14,646	5,326
Diesel: emissions from fleet	761	2,746	4,136
Diesel: emissions from power generation	5,452	11,900	1,190
Cement	497	-	-
Wastewater treatment (sewage)	23	11	11
Downstream transport and distribution (trucking product)		199	199
Land use change	930	-	-
SCOPE 2			
Purchased electricity	-	-	8,546
Total Emissions (Scope 1 & 2)	13,878	29,504	19,410

A summary of emission intensities for the Project based on tonnages of ore mined and milled and total tonnes mined (ore plus waste rock) is given in Table 7.16.

Table 7.16: Summary of Emission Intensities for the Project

Scope 1, Scope 2 GHG emission intensity	Units	Construction Phase	Operational Phase Stage 1 (Yrs 1-3)	Operational Phase Stage 2 (Yrs 4+)
Ore mined	tonnes	-	600,000	600,000
Emission intensity	*tonne CO_2-e per '000 tonne ore mined*	-	*49.17*	*32.35*
Ore milled	tonnes	-	600,000	600,000
Emission intensity	*tonne CO_2-e per '000 tonne milled*	-	*49.17*	*32.35*
Tonnes mined (ore and waste)	tonnes	416,000	1,178,000	1,156,000
Emission intensity	*tonne CO_2-e per '000 tonne mined*	*33.36*	*25.04*	*16.79*

According to the website Climatelinks.org, Malawi's total GHG emissions in 2011 was estimated to be approximately 10.85 million metric tonnes of carbon dioxide equivalent (Mt CO2-e), which is equivalent to 0.02% of global GHG emissions. Of these GHG emissions, 56 percent was attributable to land-use change and the forestry sector, followed by agriculture, waste, and industrial processes, which contributed 44%.

Residual Impact

The assessment indicates that the Project will contribute 0.18% of Malawi's GHG emissions from Year 4 until the end of the life-of-mine. This is not considered a significant contribution compared to other sources of emissions in the country.

7.11 Noise Impact

7.11.1 Calculation of Noise Intrusion

An increase in noise at nearby receptors is expected as a result of a range activities on site, including vegetation clearing, construction of roads, assembly of the processing plant, establishing of the ROM pad, construction of the TSF, mining activities in the pit, power generations, haul of ore, operation of the processing plant and loading of product onto trucks.

The noise levels from the various Project activities to the nearby settlement areas were added in a logarithmic manner using modelling software to determine the overall sound intrusion at the various identified receptors. These noise levels were based on typical noise levels experienced elsewhere on similar projects.

The magnitude of the noise intrusion was assessed using the classification as per Table 7.17.

Table 7.17: Noise Intrusion Level Criteria

Increase Δ-dBA	Magnitude	Colour Code
0 <Δ≤ 1	Not audible	
1 <Δ≤ 3	Very Low	
3 <Δ≤ 5	Low	
5 <Δ≤ 10	Medium	
10 <Δ≤ 15	High	
Δ> 15	Very High	

The calculated noise from the Project at the different receptors in the area were compared to the Malawi Noise Pollution Tolerance Limits (MS 173:2005) in the assessment of the significance of impacts. These general tolerance limits for environmental noise during the day and night time periods are illustrated in Table 7.18.

In addition, the IFC EHS Guidelines (IFC, 2007), which implement the WHO guideline values (WHO, 1999) were taken into consideration. The guideline values are specified as either a fixed noise limit (Table 7.18) or an increase of no more than 3 dB over ambient noise levels at the nearest receptor off-site. The guidelines advise that, where noise levels attributable to an installation or operation exceed the guideline values at the façade of the nearest noise receptor, appropriate noise mitigation measures should be adopted.

Table 7.18: Noise Tolerance Levels

Category / Receptor	Maximum Level (Limit in dB)	
	Day-time	Night-time
Malawi Noise Pollution Tolerance Limits		
Residential area	55	45
Silence zone	50	40
IFC EHS Guidelines		
Residential, institutional and educational	55	45

7.11.2 Noise Intrusion During Construction Phase

The calculated noise intrusion levels (increase in noise) during the construction phase in the vicinity of the settlement areas are illustrated in Table 7.19. The cumulative noise intrusion during the construction phase assumed that all construction activities would take place simultaneously and is therefore the worst-case scenario. It was estimated that this noise level would be 1.7 dBA at Chitsulo (located between the S124 and the processing plant), while the cumulative noise intrusion levels as well as the individual noise intrusion levels at other identified noise receptors are estimated to be below 1.0 dBA, which is considered insignificant.

Table 7.19: Noise Intrusion Levels During Construction

Settlement areas	Site clearing and grubbing	Civil construction	Construction of internal roads	Assembly of processing plant	Building activities	Construction of TSF	Construction of soil stockpile	Construction of ore stockpiles	Cumulative noise level[1]	New ambient daytime noise level[2]	Daytime noise intrusion (dBA)[3]
Maliri Village	12.4	11.4	10.6	14.4	7.4	12.3	8.9	10.3	20.4	37.0	0.1
Ntanga Village	15.4	14.4	12.4	17.4	10.4	16.7	12.0	14.7	23.7	37.1	0.0
Kachule Village	15.2	14.2	14.5	17.2	10.2	14.7	13.4	12.7	23.4	40.6	0.1
Kumalindi Village	28.0	27.0	30.0	30.0	23.0	19.9	23.6	17.9	35.7	45.6	0.7
Chitsulo Village	31.2	30.2	27.6	33.2	6.2	20.5	26.6	18.5	37.5	42.5	1.7
Chakwindima	12.1	11.1	9.7	14.1	7.1	12.9	9.0	10.9	20.4	37.0	0.1
South of Dam Wall	9.5	8.5	6.9	11.5	4.5	8.8	7.7	6.8	17.5	36.9	0.1
Gunde Village	10.1	9.1	7.4	12.1	5.1	8.1	9.3	6.1	18.0	37.0	0.1
Malingunde	8.7	7.7	6.0	10.7	3.7	6.2	7.6	4.2	16.4	36.9	0.0
Mbenga Village	10.7	9.7	8.4	12.7	5.7	7.9	9.9	5.9	18.4	41.5	0.0
North of Pit K	22.5	21.5	19.7	24.5	17.5	16.2	23.9	14.2	30.3	39.7	0.9
South of Pit O (Chanika)	20.9	19.9	16.8	22.9	15.9	15.6	26.7	13.6	30.1	39.7	0.8

Settlement areas	Site clearing and grubbing	Civil construction	Construction of internal roads	Assembly of processing plant	Building activities	Construction of TSF	Construction of soil stockpile	Construction of ore stockpiles	Cumulative noise level[1]	New ambient daytime noise level[2]	Daytime noise intrusion (dBA)[3]
Kubale Village	19.0	18.0	15.0	21.0	14.0	15.3	22.1	13.3	27.3	39.5	0.5
East of Pit Q	19.4	18.4	15.5	21.4	14.4	15.4	24.0	13.4	28.2	39.5	0.6
Ndumila II	17.0	16.0	13.7	19.0	12.0	14.5	18.7	12.5	25.2	39.4	0.3
Ndumila I	15.7	14.7	12.2	17.7	10.7	12.7	17.4	10.7	23.8	39.3	0.2

Notes: 1: Total of noise levels from activities at the different noise receptors.
2: Cumulative noise level from activities plus the prevailing ambient noise level.
3: Refer Table 7.17 for classification of level of intrusion.

The assessment of the significance of impacts without mitigation, recommended mitigation measures and the residual impact are summarised as follows:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Short-term	Site Specific	Moderate	Low	Unlikely	Low
Mitigation Measures					
• Limit construction activities to day-time hours. • Ensure vehicles and equipment are well-maintained. • Ensure equipment and/or machinery comply with the manufacturer's specifications on acceptable noise levels, which may not exceed 85 dBA. • Equip vehicles with low frequency reverse signals, rather than reverse beepers, where possible and if in compliance with health and safety requirements. • Undertake noise monitoring to determine whether ambient noise levels at nearby receptors exceed prevailing noise levels + 3.0 dBA (as per the IFC Environmental Health and Safety Guideline Values, 2007).					
Residual Impact					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Short-term	Site Specific	Low	Very Low	Unlikely	Very Low

7.11.3 Noise Intrusion During Operations Phase

Noise intrusion levels during the operations phase were calculated based on the sequencing of mining of the open pits as described in Section 2.5.2. The intrusion levels calculated (Table 7.20 through to Table 7.24) assumed a direct line of sight and that activities take place at surface. These levels, therefore, illustrate the worst-case scenario.

Calculations undertaken using the noise model, indicated that the noise level is generally expected to be approximately 55.2 dBA at a distance of 50 m from the rim of the open pits when open pit mining activities take place. This noise level, in some instances, represents an increase of between 10 dBA and 15 dBA. A 10 dBA change in the sound level is perceived as twice as loud as the original.

Pre-stripping activities at surface would normally be undertaken for a relatively short period of two to three months. In most instances, the mining equipment would be at least 5 m below ground (or deeper) after this period and the noise intrusion would reduce as equipment moves further below the surface.

As the majority of the mining activities are not concentrated on the edge of the pit, a 30 m set-back was assumed for illustrative purposes. At this distance (80 m from the activities to the nearest potential receptors) the noise levels at various depths will be as follows:

Depth Below Ground Level	Noise Level at 80 m Away
2 m	51.4 dBA
4 m	45.2 dBA
8 m	38.7 dBA
16 m	36.5 dBA

At a distance of 110 m from the mining activities in the pit, the noise levels will be as follows:

Depth Below Ground Level	Noise Level at 110 m Away
2 m	48.4 dBA
4 m	44.2 dBA
8 m	37.2 dBA
16 m	33.5 dBA

The noise intrusion levels at receptors in and around the Project area were calculated for various scenarios over the life of the mine.

7.11.3.1 Noise Intrusion from Northern Pits and Processing Plant

The magnitude of the calculated noise intrusion levels during mining in the northern extent of the ore body, in conjunction with the processing plant (assuming all mining activities will take place simultaneously) are illustrated in Table 7.20. The highest cumulative noise intrusion level was estimated to be 1.5 dBA at Kumalindi, 3.5 dBA at Chitsulo (between the S124 and the processing plant), 2.2 dBA at households along the western edge of Kumalindi and 1.2 dBA at Chanika Village. The noise intrusion level at all the other settlement areas will be below 1.0 dBA which will be insignificant.

The cumulative noise intrusion level at Chitsulo exceeded the recommended threshold allowable exceedance by the IFC (2007) of 3 dBA.

Table 7.20: Daytime Noise Intrusion Levels During Operations – Most Northern Pits and Processing Plant

Settlement areas	Activities in the pit	Power generator	Load haul trucks	Haul ore to plant	ROM pad	Processing plant	Load product onto trucks	Access road to the plant	Cumulative noise level[1]	New ambient daytime noise level[2]	Daytime noise intrusion (dBA)
Maliri Village	16.1	16.9	13.9	12.8	12.9	16.9	6.9	2.8	23.2	37.1	0.2
Ntanga Village	18.2	19.9	16.9	17.2	15.9	19.9	9.9	7.2	26.2	43.6	0.1
Kachule Village	19.9	19.7	16.7	15.2	15.7	19.7	9.7	5.2	26.2	40.9	0.1
Kumalindi Village	27.9	32.5	29.5	20.4	28.5	32.5	22.5	10.4	39.6	45.0	1.5
Chitsulo Village	28.1	38.4	31.9	29.7	30.9	34.9	24.9	24.0	41.7	44.3	3.5
Chakwindima	14.3	16.6	13.6	13.4	12.6	16.6	6.6	3.4	22.8	37.1	0.2
Downstream of Dam Wall	12.9	14.0	11.0	9.3	10.0	14.0	4.0	-0.7	20.3	36.5	0.1
Gunde Village (S of Kamuzu)	15.7	14.6	11.6	8.6	10.6	14.6	4.6	-1.4	21.3	36.5	0.1
Malingunde	16.2	13.2	10.2	6.7	9.2	13.2	3.2	-3.3	20.5	44.0	0.0
Mbenga Village	19.9	15.2	12.2	8.4	11.2	15.2	5.2	-1.6	23.2	43.5	0.0

Settlement areas	Activities in the pit	Power generator	Load haul trucks	Haul ore to plant	ROM pad	Processing plant	Load product onto trucks	Access road to the plant	Cumulative noise level[1]	New ambient daytime noise level[2]	Daytime noise intrusion (dBA)
North of Pit K	36.6	27.0	24.0	16.7	23.0	27.0	17.0	6.7	35.2	39.1	2.2
South of Pit O (Chanika)	26.5	25.4	22.4	16.1	21.4	25.4	15.4	6.1	32.1	38.1	1.2
Kubale Village	21.9	23.5	20.5	15.8	19.5	23.5	13.5	5.8	29.4	37.6	0.7
East of Pit Q	23.1	23.9	20.9	15.9	19.9	23.9	13.9	5.9	29.9	37.7	0.8
Ndumila II	20.4	21.5	18.5	15.0	17.5	21.5	11.5	5.0	27.5	37.4	0.5
Ndumila I	20.0	20.2	17.2	13.2	16.2	20.2	10.2	3.2	26.4	37.3	0.4

Notes: 1: Total of noise levels from activities at the different noise receptors.
2: Cumulative noise level from activities plus the prevailing ambient noise level.

The assessment of the significance of impacts without mitigation, recommended mitigation measures and the residual impact are summarised below:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Long-term	Local	Moderate	Moderate	Likely	Moderate

Mitigation Measures

- Ensure vehicles and equipment are well-maintained.
- Ensure equipment and/or machinery comply with the manufacturer's specifications on acceptable noise levels, which may not exceed 85 dBA.
- Identify noise sources in excess of 85 dBA at the pit and screen off acoustically.
- Equip vehicles with low frequency reverse signals (vibrating type signals), rather than reverse beepers, where possible and if in compliance with health and safety requirements.
- Install adequate silencers on all exhaust systems.
- Ensure power plant is enclosed and acoustically screened off.
- Undertake regular maintenance of haul roads to ensure a relatively smooth driving surface.
- Place berm or barrier of at least 4 m high between the processing plant and Chitsulo village as acoustic screening measures
- Undertake noise monitoring to determine whether ambient noise levels at nearby receptors exceed prevailing noise levels + 3.0 dBA (as per the IFC Environmental Health and Safety Guideline Values, 2007).

Impact with Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Long-term	Local	Low	Low	Likely	Low

The modelled noise levels (prior to implementation of mitigation measures) are indicated in Figure 7.27.

Residual Impact

Noise modelling has indicated that construction of an earth berm between the open pit mining activities and nearby noise receptors will significantly reduce the noise intrusion levels It is anticipated that the noise intrusion level at a distance of 50 m from the rim of the open pits, will not exceed 3 dBA in the event that a noise berm of approximately 4 m high is placed at a distance of 10 m from the rim of the open pit.

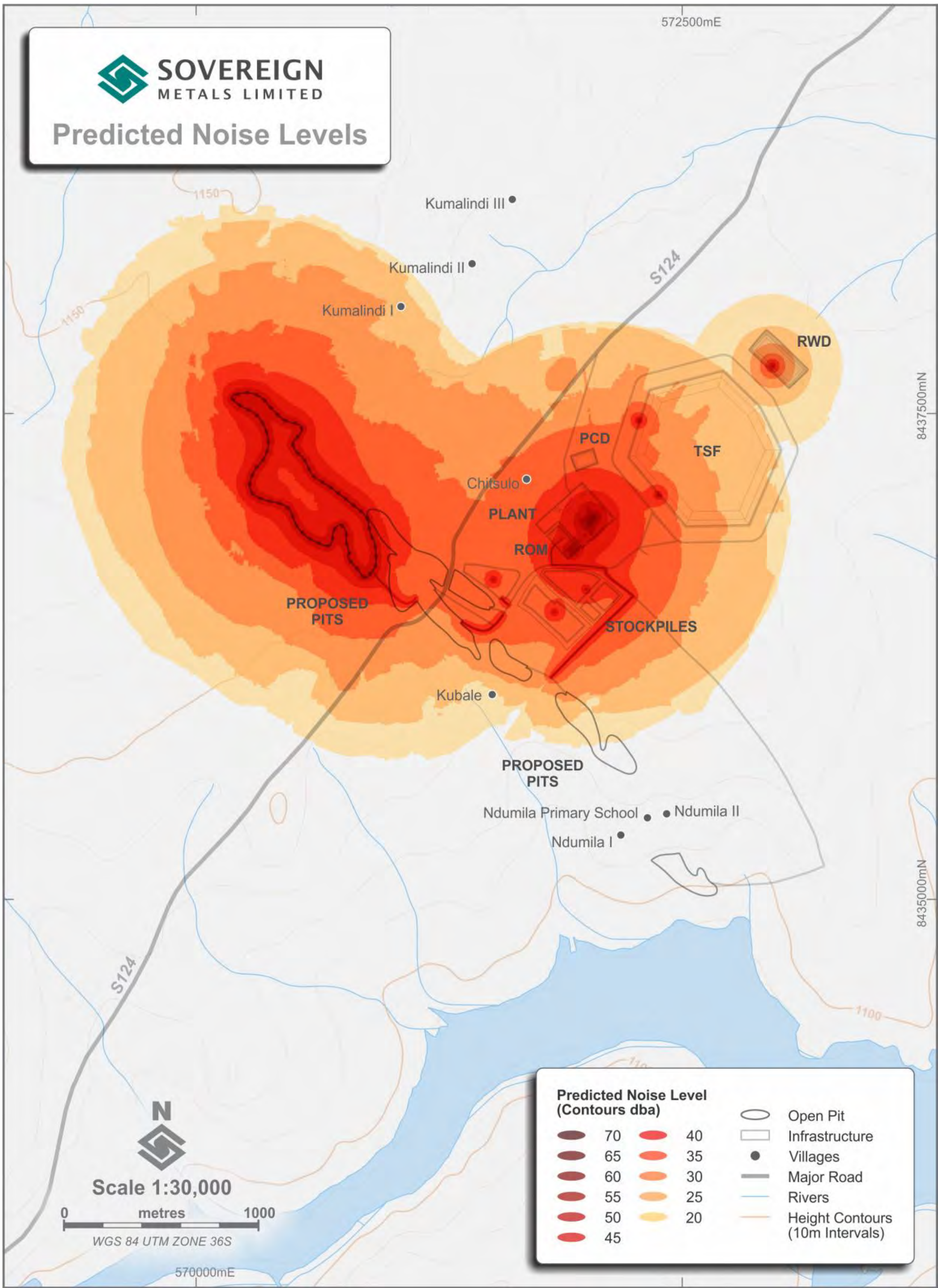

Figure 7.27: Expected Noise Levels from Processing Plant and Mining in Most Northern Pits

7.11.3.2 Noise Intrusion from Pits Adjacent to the S124 Secondary Road and Processing Plant

The magnitude of the calculated noise intrusion levels during mining in the pits adjacent to the S124 secondary road, in conjunction with the processing plant, are illustrated Table 7.21. The calculated noise level at a distance of 55 m from the rim of the pit will be 51.2 dBA, an increase of 14.5 dBA from the prevailing noise level, and 45.2 dBA at 110 m from the pit. This increase exceeds the maximum recommended 3 dBA increase in noise as per the IFC EHS Guidelines (2007).

The mitigated noise level was calculated, assuming the construction of an earth berm of 4 m high at a distance of 20 m from the rim of the pit. The construction of this berm will reduce the noise at 110 m away to 38.7 dBA. Construction of an earth berm of 4 m in height will ensure noise levels do not increase significantly beyond 50 m from the rim of the pit.

Table 7.21: Daytime Noise Intrusion Levels During Operations – Pits Directly North and South of S124 and Processing Plant

Settlement areas	Activities in the pit	Power generator	Load haul trucks	Haul ore to plant	ROM pad	Processing plant	Load product onto trucks	Access road to the plant	Cumulative noise level[1]	New ambient daytime noise level[2]	Daytime noise intrusion (dBA)
Maliri Village	15.6	16.9	13.9	12.8	12.9	16.9	6.9	2.8	23.2	37.1	0.2
Ntanga Village	18.5	19.9	16.9	17.2	15.9	19.9	9.9	7.2	26.2	43.6	0.1
Kachule Village	20.3	19.7	16.7	15.2	15.7	19.7	9.7	5.2	26.3	41.0	0.2
Kumalindi Village	51.2	32.5	29.5	20.4	28.5	32.5	22.5	10.4	51.4	52.0	8.5
Chitsulo Village	28.1	38.4	31.9	29.7	30.9	34.9	24.9	24.0	41.7	44.3	3.5
Chakwindima	14.7	16.6	13.6	13.4	12.6	16.6	6.6	3.4	22.9	37.1	0.2
Downstream of Dam Wall	13.3	14.0	11.0	9.3	10.0	14.0	4.0	-0.7	20.4	36.5	0.1
Gunde Village (S of Kamuzu)	15.8	14.6	11.6	8.6	10.6	14.6	4.6	-1.4	21.3	36.5	0.1
Malingunde	15.7	13.2	10.2	6.7	9.2	13.2	3.2	-3.3	20.3	44.0	0.0
Mbenga Village	20.0	15.2	12.2	8.4	11.2	15.2	5.2	-1.6	23.2	43.5	0.0
North of Pit K	51.2	27.0	24.0	16.7	23.0	27.0	17.0	6.7	51.2	51.4	14.5
South of Pit O (Chanika)	38.0	25.4	22.4	16.1	21.4	25.4	15.4	6.1	38.7	40.9	4.0
Kubale Village	26.2	23.5	20.5	15.8	19.5	23.5	13.5	5.8	30.5	37.8	0.9
East of Pit Q	28.3	23.9	20.9	15.9	19.9	23.9	13.9	5.9	31.7	38.0	1.1
Ndumila II	24.3	21.5	18.5	15.0	17.5	21.5	11.5	5.0	28.6	37.5	0.6
Ndumila I	23.8	20.2	17.2	13.2	16.2	20.2	10.2	3.2	27.6	37.4	0.5

Notes: 1: Total of noise levels from activities at the different noise receptors.
2: Cumulative noise level from activities plus the prevailing ambient noise level.

The assessment of the significance of impacts without mitigation, recommended mitigation measures and the residual impact are summarised below:

<table>
<tr><th colspan="6">Impact without Mitigation</th></tr>
<tr><td>Duration</td><td>Extent</td><td>Magnitude</td><td>Consequence</td><td>Probability</td><td>Significance</td></tr>
<tr><td>Long-term</td><td>Local</td><td>High</td><td>High</td><td>Likely</td><td>High</td></tr>
<tr><th colspan="6">Mitigation Measures</th></tr>
<tr><td colspan="6">
• Ensure vehicles and equipment are well-maintained.
• Ensure equipment and/or machinery comply with the manufacturer's specifications on acceptable noise levels, which may not exceed 85 dBA.
• Identify noise sources in excess of 85 dBA at the pit and screen off acoustically.
• Equip vehicles with low frequency reverse signals (vibrating type signals), rather than reverse beepers, where possible and if in compliance with health and safety requirements.
• Install adequate silencers on all exhaust systems.
• Ensure power plant is enclosed and acoustically screened off.
• Undertake regular maintenance of haul roads to ensure a relatively smooth driving surface.
• Place berm or barrier of 4 m high between operations and Chitsulo and Kumalindi villages as acoustic screening measures, at a set-back distance of 10 m from the pit.
• Relocate houses within a minimum of 50 m from the rim of the pit.
• Undertake noise monitoring to determine whether ambient noise levels at nearby receptors exceed prevailing noise levels + 3.0 dBA (as per the IFC Environmental Health and Safety Guideline Values, 2007).
</td></tr>
<tr><th colspan="6">Impact with Mitigation</th></tr>
<tr><td>Duration</td><td>Extent</td><td>Magnitude</td><td>Consequence</td><td>Probability</td><td>Significance</td></tr>
<tr><td>Medium-term</td><td>Local</td><td>Low</td><td>Low</td><td>Likely</td><td>Low</td></tr>
</table>

The modelled noise levels (without mitigation measures) are indicated in Figure 7.28.

Residual Impact

Noise modelling has indicated that construction of an earth berm between the open pit mining activities and nearby noise receptors will significantly reduce the noise intrusion levels It is anticipated that the noise intrusion level at a distance of 50 m from the rim of the open pits, will not exceed 3 dBA in the event that a noise berm of approximately 4 m high is placed at a distance of 10 m from the rim of the open pit.

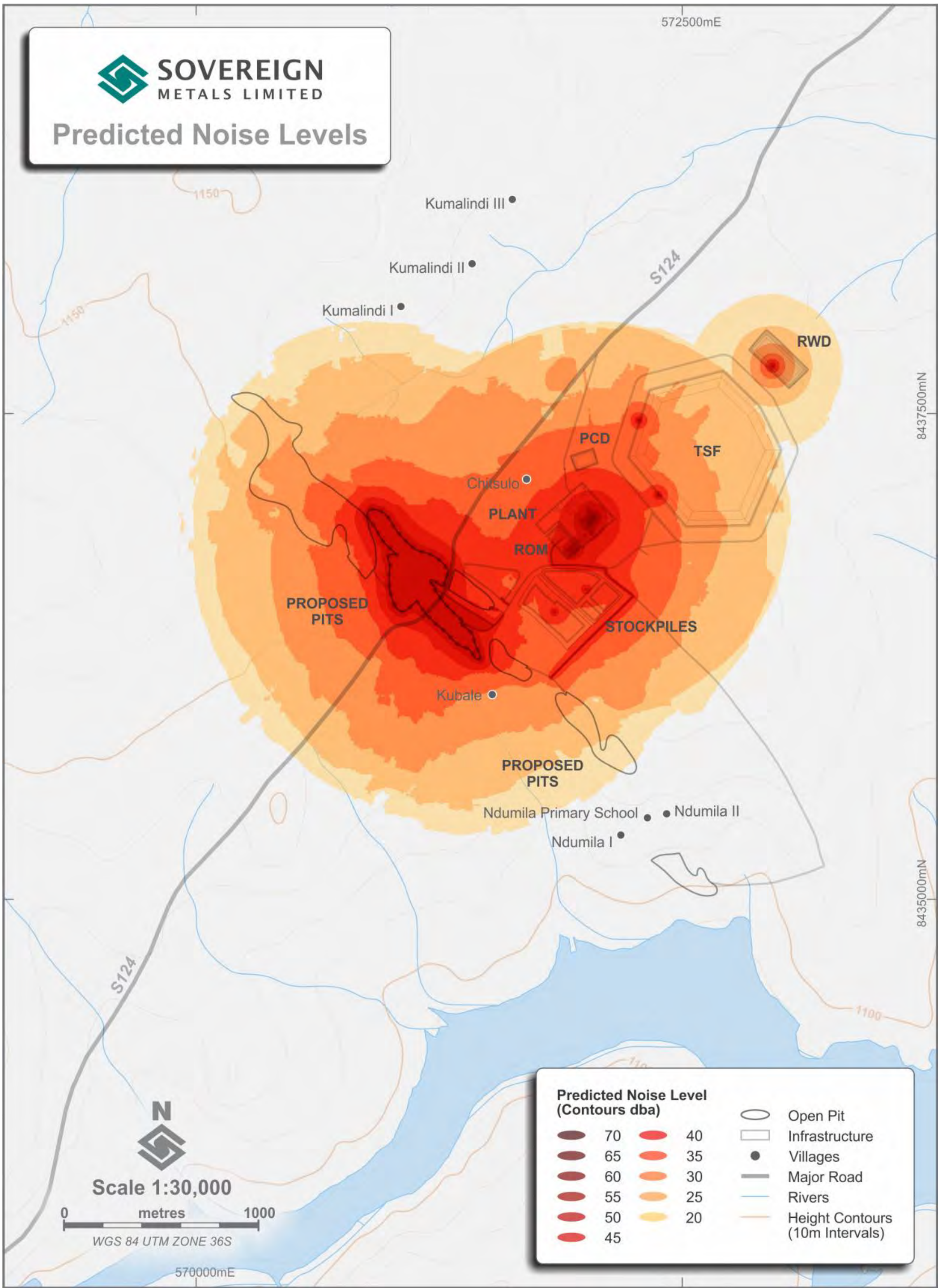

Figure 7.28: Expected Noise Levels from Processing Plant and Mining in the Vicinity of the S124 Secondary Road

7.11.3.3 Noise Intrusion from Pit O and Processing Plant

The magnitude of the calculated noise intrusion levels during mining in Pit O (located in the centre of the Project area) in conjunction with the processing plant, are illustrated Table 7.22. The calculated noise level at 81 m from the pit to the nearest receptor is 47.8 dBA. The noise intrusion level at this point from mining activities is 10.9 dBA and the cumulative noise intrusion level from all activities is 11.3 dBA. This increase exceeds the maximum recommended 3 dBA increase in noise as per the IFC EHS Guidelines (2007).

Table 7.22: Daytime Noise Intrusion Levels During Operations – Pit O and Processing Plant

Settlement areas	Activities in the pit	Power generator	Load haul trucks	Haul ore to plant	ROM pad	Processing plant	Load product onto trucks	Access road to the plant	Cumulative noise level[1]	New ambient daytime noise level[2]	Daytime noise intrusion (dBA)
Maliri Village	15.0	16.9	13.9	12.8	12.9	16.9	6.9	2.8	23.1	37.1	0.2
Ntanga Village	17.8	19.9	16.9	17.2	15.9	19.9	9.9	4.9	26.1	43.6	0.1
Kachule Village	17.8	19.7	16.7	15.2	15.7	19.7	9.7	4.7	25.8	40.9	0.1
Kumalindi Village	30.5	32.5	29.5	20.4	28.5	32.5	22.5	17.5	38.2	44.6	1.1
Chitsulo Village	28.1	38.4	31.9	29.7	30.9	34.9	24.9	24.0	41.7	44.3	3.5
Chakwindima	16.3	16.6	13.6	13.4	12.6	16.6	6.6	1.6	23.2	43.5	0.2
Downstream of Dam Wall	15.4	14.0	11.0	9.3	10.0	14.0	4.0	-1.0	20.9	37.0	0.1
Gunde Village (S of Kamuzu)	17.8	14.6	11.6	8.6	10.6	14.6	4.6	-0.4	22.0	36.6	0.2
Malingunde	16.3	13.2	10.2	6.7	9.2	13.2	3.2	-1.8	20.6	36.5	0.0
Mbenga Village	18.6	15.2	12.2	8.4	11.2	15.2	5.2	0.2	22.6	43.5	0.0
North of Pit K	30.9	27.0	24.0	16.7	23.0	27.0	17.0	12.0	34.4	38.9	2.0
South of Pit O (Chanika)	47.8	25.4	22.4	16.1	21.4	25.4	15.4	10.4	47.9	48.2	11.3
Kubale Village	29.7	23.5	20.5	15.8	19.5	23.5	13.5	8.5	32.2	38.2	1.3
East of Pit Q	33.3	23.9	20.9	15.9	19.9	23.9	13.9	8.9	34.6	38.9	2.0
Ndumila II	26.6	21.5	18.5	15.0	17.5	21.5	11.5	6.5	29.6	37.6	0.7
Ndumila I	25.5	20.2	17.2	13.2	16.2	20.2	10.2	5.2	28.4	37.5	0.6

Notes: 1: Total of noise levels from activities at the different noise receptors.
2: Cumulative noise level from activities plus the prevailing ambient noise level.

The assessment of the significance of impacts without mitigation, recommended mitigation measures and the residual impact are summarised below:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Long-term	Local	High	High	Likely	High
Mitigation Measures					
• Ensure vehicles and equipment are well-maintained. • Ensure equipment and/or machinery comply with the manufacturer's specifications on acceptable noise levels, which may not exceed 85 dBA. • Identify noise sources in excess of 85 dBA at the pit and screen off acoustically. • Equip vehicles with low frequency reverse signals (vibrating type signals), rather than reverse beepers, where possible and if in compliance with health and safety requirements. • Install adequate silencers on all exhaust systems. • Undertake regular maintenance of haul roads to ensure a relatively smooth driving surface. • Place berm or barrier of 4 m high between Chanika village and the pit as acoustic screening measure, at a set-back distance of 10 m from the pit. • Relocate houses within a minimum of 50 m from the rim of the pit. • Undertake noise monitoring to determine whether ambient noise levels at nearby receptors exceed prevailing noise levels + 3.0 dBA (as per the IFC Environmental Health and Safety Guideline Values, 2007).					
Impact with Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Medium-term	Local	Low	Low	Likely	Low

The modelled noise levels (without mitigation measures) are indicated in Figure 7.29.

Residual Impact

Noise modelling has indicated that construction of an earth berm between the open pit mining activities and nearby noise receptors will significantly reduce the noise intrusion levels It is anticipated that the noise intrusion level at a distance of 50 m from the rim of the open pits, will not exceed 3 dBA in the event that a noise berm of approximately 4 m high is placed at a distance of 10 m from the rim of the open pit.

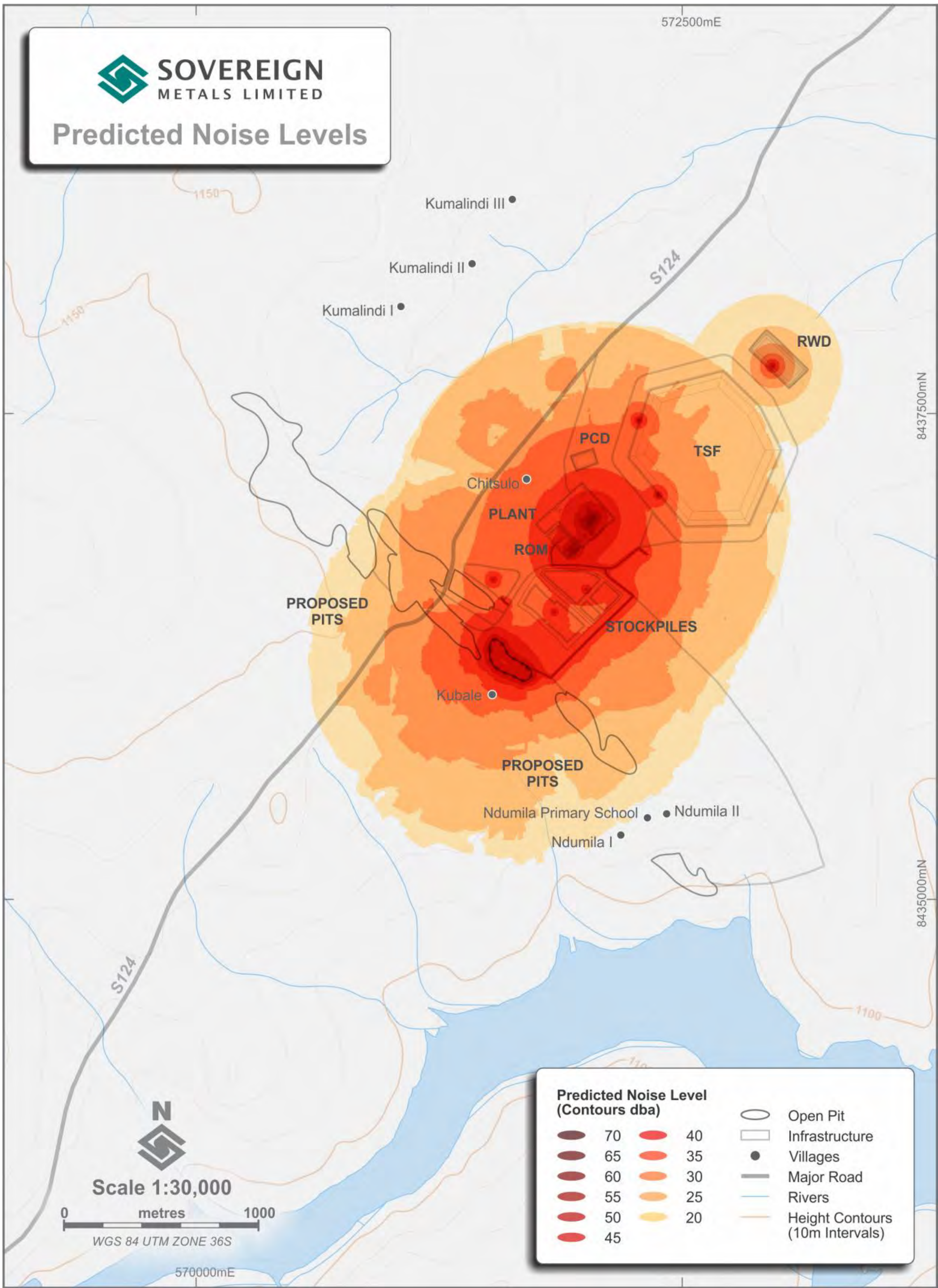

Figure 7.29: Expected Noise Levels from Processing Plant and Pit O

7.11.3.4 Noise Intrusion from Pits P & Q and Processing Plant

The magnitude of the calculated noise intrusion levels during mining in Pit P and Pit Q (located in the vicinity of Kubale and Ndumila villages) in conjunction with the processing plant, are illustrated in Table 7.23. The calculated noise intrusion level south of the pit is 11.3 dBA at a distance of 81 m from the rim of the pit. This increase exceeds the maximum recommended 3 dBA increase in noise as per the IFC EHS Guidelines (2007). The unmitigated predicted ambient noise level will also exceed the Malawi Noise Pollution Tolerance Limits (2005).

Table 7.23: Daytime Noise Intrusion Levels During Operations – Pits P & Q and Processing Plant

Settlement areas	Activities in the pit	Power generator	Load haul trucks	Haul ore to plant	ROM pad	Processing plant	Load product onto trucks	Access road to the plant	Cumulative noise level[1]	New ambient daytime noise level[2]	Daytime noise intrusion (dBA)
Maliri Village	15.0	16.9	13.9	12.8	12.9	16.9	6.9	2.8	23.0	37.1	0.2
Ntanga Village	17.5	19.9	16.9	17.2	15.9	19.9	9.9	7.2	26.1	43.6	0.1
Kachule Village	17.0	19.7	16.7	15.2	15.7	19.7	9.7	5.2	25.7	40.9	0.1
Kumalindi Village	24.3	32.5	29.5	20.4	28.5	32.5	22.5	10.4	37.6	44.5	1.0
Chitsulo Village	28.1	38.4	31.9	29.7	30.9	34.9	24.9	24.0	41.7	44.3	3.5
Chakwindima	17.3	16.6	13.6	13.4	12.6	16.6	6.6	3.4	23.4	37.1	0.2
Downstream of Dam Wall	16.5	14.0	11.0	9.3	10.0	14.0	4.0	-0.7	21.2	36.5	0.1
Gunde Village (S of Kamuzu)	18.2	14.6	11.6	8.6	10.6	14.6	4.6	-1.4	22.1	36.6	0.2
Malingunde	16.0	13.2	10.2	6.7	9.2	13.2	3.2	-3.3	20.4	44.0	0.0
Mbenga Village	17.5	15.2	12.2	8.4	11.2	15.2	5.2	-1.6	22.2	43.5	0.0
North of Pit K	26.2	27.0	24.0	16.7	23.0	27.0	17.0	6.7	32.9	38.4	1.5
South of Pit O (Chanika)	42.3	25.4	22.4	16.1	21.4	25.4	15.4	6.1	42.6	43.6	6.7
Kubale Village	51.2	23.5	20.5	15.8	19.5	23.5	13.5	5.8	51.2	51.4	14.5
East of Pit Q	51.2	23.9	20.9	15.9	19.9	23.9	13.9	5.9	51.2	51.4	14.5
Ndumila II	50.0	21.5	18.5	15.0	17.5	21.5	11.5	5.0	50.0	50.2	13.3
Ndumila I	33.4	20.2	17.2	13.2	16.2	20.2	10.2	3.2	34.0	38.7	1.8

Notes: 1: Total of noise levels from activities at the different noise receptors.
2: Cumulative noise level from activities plus the prevailing ambient noise level.

The assessment of the significance of impacts without mitigation, recommended mitigation measures and the residual impact are summarised below:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Medium-term	Local	High	High	Likely	High
Mitigation Measures					
• Ensure vehicles and equipment are well-maintained. • Ensure equipment and/or machinery comply with the manufacturer's specifications on acceptable noise levels, which may not exceed 85 dBA. • Identify noise sources in excess of 85 dBA at the pit and screen off acoustically. • Equip vehicles with low frequency reverse signals (vibrating type signals), rather than reverse beepers, where possible and if in compliance with health and safety requirements. • Install adequate silencers on all exhaust systems. • Undertake regular maintenance of haul roads to ensure a relatively smooth driving surface. • Place berm or barrier of 4 m high between Kubale and Ndumila villages and the pit as acoustic screening measure, at a set-back distance of 10 m from the pit. • Relocate houses within a minimum of 50 m from the rim of the pit. • Undertake noise monitoring to determine whether ambient noise levels at nearby receptors exceed prevailing noise levels + 3.0 dBA (as per the IFC Environmental Health and Safety Guideline Values, 2007).					
Impact with Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Medium-term	Local	Low	Low	Likely	Low

The modelled noise levels (without mitigation measures) are indicated in Figure 7.30.

Residual Impact

Noise modelling has indicated that construction of an earth berm between the open pit mining activities and nearby noise receptors will significantly reduce the noise intrusion levels It is anticipated that the noise intrusion level at a distance of 50 m from the rim of the open pits, will not exceed 3 dBA in the event that a noise berm of approximately 4 m high is placed at a distance of 10 m from the rim of the open pit.

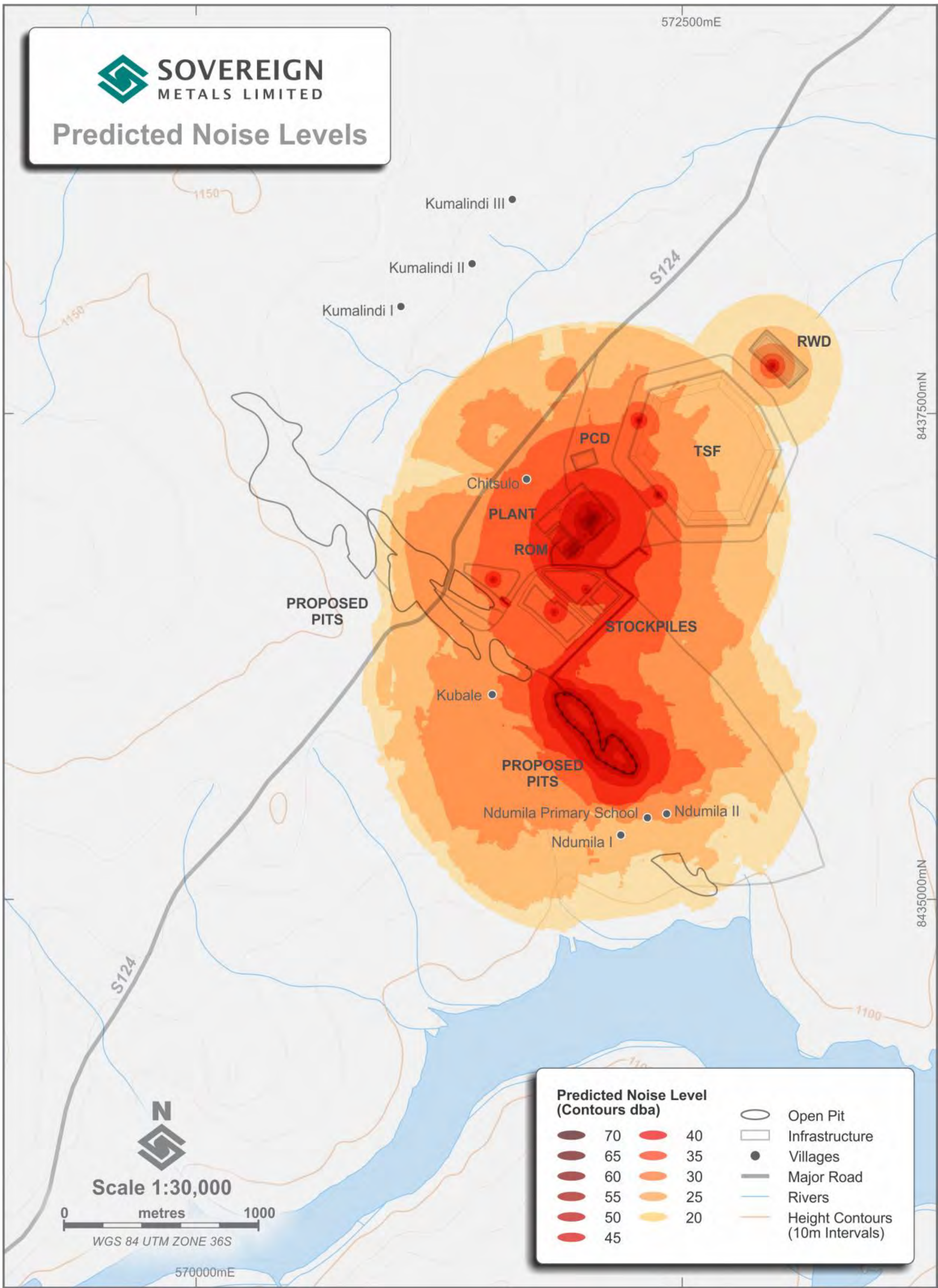

Figure 7.30: Expected Noise Levels from Processing Plant and Pits P and Q

7.11.3.5 Noise Intrusion from Southern Pit and Processing Plant

The magnitude of the calculated noise intrusion levels during mining in the southern extent of the ore body, in conjunction with the processing plant, are illustrated in Table 7.24. The calculated noise level from the pit to Ndumila village was 51.2 dBA and the noise intrusion level from activities in the pit is expected to be 14.3 dBA. This increase exceeds the maximum recommended 3 dBA increase in noise as per the IFC EHS Guidelines (2007). The unmitigated predicted ambient noise level will also exceed the Malawi Noise Pollution Tolerance Limits (2005).

Table 7.24: Daytime Noise Intrusion Levels During Operations – Most Southern Pits and Processing Plant

Settlement areas	Activities in the pit	Power generator	Load haul trucks	Haul ore to plant	ROM pad	Processing plant	Load product onto trucks	Access road to the plant	Cumulative noise level[1]	New ambient daytime noise level[2]	Daytime noise intrusion (dBA)
Maliri Village	13.6	16.9	13.9	12.8	12.9	16.9	6.9	2.8	22.9	37.1	0.2
Ntanga Village	16.0	19.9	16.9	17.2	15.9	19.9	9.9	7.2	25.9	43.6	0.1
Kachule Village	15.3	19.7	16.7	15.2	15.7	19.7	9.7	5.2	25.5	40.9	0.1
Kumalindi Village	21.0	32.5	29.5	20.4	28.5	32.5	22.5	10.4	37.5	44.5	1.0
Chitsulo Village	28.1	38.4	31.9	29.7	30.9	34.9	24.9	24.0	41.7	44.3	3.5
Chakwindima	17.6	16.6	13.6	13.4	12.6	16.6	6.6	3.4	23.5	37.1	0.2
Downstream of Dam Wall	18.4	14.0	11.0	9.3	10.0	14.0	4.0	-0.7	22.0	36.6	0.2
Gunde Village (S of Kamuzu)	20.9	14.6	11.6	8.6	10.6	14.6	4.6	-1.4	23.4	36.6	0.2
Malingunde Trading Centre	16.3	13.2	10.2	6.7	9.2	13.2	3.2	-3.3	20.6	44.0	0.0
Mbenga Village	17.4	15.2	12.2	8.4	11.2	15.2	5.2	-1.6	22.1	43.5	0.0
North of Pit K	21.4	27.0	24.0	16.7	23.0	27.0	17.0	6.7	32.3	38.2	1.3
South of Pit O (Chanika)	28.0	25.4	22.4	16.1	21.4	25.4	15.4	6.1	32.4	38.2	1.3
Kubale Village	36.3	23.5	20.5	15.8	19.5	23.5	13.5	5.8	37.0	40.0	3.1
East of Pit Q	37.7	23.9	20.9	15.9	19.9	23.9	13.9	5.9	38.2	40.6	3.7
Ndumila II	51.2	21.5	18.5	15.0	17.5	21.5	11.5	5.0	51.2	51.4	14.5
Ndumila I	51.2	20.2	17.2	13.2	16.2	20.2	10.2	3.2	51.2	51.4	14.5

Notes: 1: Total of noise levels from activities at the different noise receptors.
2: Cumulative noise level from activities plus the prevailing ambient noise level.

The assessment of the significance of impacts without mitigation, recommended mitigation measures and the residual impact are summarised below:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Short-term	Local	High	High	Likely	High
Mitigation Measures					
• Ensure vehicles and equipment are well-maintained. • Ensure equipment and/or machinery comply with the manufacturer's specifications on acceptable noise levels, which may not exceed 85 dBA. • Identify noise sources in excess of 85 dBA at the pit and screen off acoustically. • Equip vehicles with low frequency reverse signals (vibrating type signals), rather than reverse beepers, where possible and if in compliance with health and safety requirements. • Install adequate silencers on all exhaust systems. • Undertake regular maintenance of haul roads to ensure a relatively smooth driving surface. • Place berm or barrier of 4 m high between Ndumila I and Ndumila II and the pit as acoustic screening measure, at a set-back distance of 10 m from the pit. • Relocate houses within a minimum of 50 m from the rim of the pit. • Undertake noise monitoring to determine whether ambient noise levels at nearby receptors exceed prevailing noise levels + 3.0 dBA (as per the IFC Environmental Health and Safety Guideline Values, 2007).					
Impact with Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Short-term	Local	Low	Low	Likely	Low

Residual Impact

Noise modelling has indicated that construction of an earth berm between the open pit mining activities and nearby noise receptors will significantly reduce the noise intrusion levels It is anticipated that the noise intrusion level at a distance of 50 m from the rim of the open pits, will not exceed 3 dBA in the event that a noise berm of approximately 4 m high is placed at a distance of 10 m from the rim of the open pit.

7.11.3.6 Night-time Noise Intrusion from Processing Plant

The calculated night-time noise intrusion levels from activities around the plant area are illustrated in Table 7.25. The cumulative noise intrusion level at Kumalindi and Chitsulo is expected to be 3.8 dBA and 6.7 dBA, respectively. This increase exceeds the maximum recommended 3 dBA increase in noise as per the IFC EHS Guidelines (2007). The prevailing ambient noise levels at the remainder of the noise receptors are below 1.5 dBA which is insignificant.

Table 7.25: Night-time Noise Intrusion Levels During Operations – Processing Plant

Settlement areas	Processing plant	Power generator	ROM pad	Load product onto trucks	Access road to plant	Cumulative noise level[1]	New ambient daytime noise level[2]	Daytime noise intrusion (dBA)
Maliri VIllage	16.9	16.9	12.9	6.9	2.8	22.3	35.2	0.2
Ntanga Village	19.9	19.9	15.9	9.9	7.2	25.5	35.5	0.3
Kachule Village	19.7	19.7	15.7	9.7	5.2	25.1	35.4	0.3
Kumalindi Village	32.5	32.5	28.5	22.5	10.4	36.5	38.8	3.8
Chitsulo Village	34.4	38.4	30.4	29.0	24.0	40.7	41.7	6.7
Chakwindima	16.6	16.6	12.6	6.6	3.4	22.2	35.2	0.2

Settlement areas	Processing plant	Power generator	ROM pad	Load product onto trucks	Access road to plant	Cumulative noise level[1]	New ambient daytime noise level[2]	Daytime noise intrusion (dBA)
Downstream of Dam Wall	14.0	14.0	10.0	4.0	-0.7	19.5	35.1	0.1
Gunde Village (S of Kamuzu)	14.6	14.6	10.6	4.6	-1.4	19.9	35.1	0.1
Malingunde	13.2	13.2	9.2	3.2	-3.3	18.6	35.1	0.1
Mbenga Village	15.2	15.2	11.2	5.2	-1.6	20.4	35.1	0.1
North of Pit K	27.0	27.0	23.0	17.0	6.7	31.9	36.7	1.5
South of Pit O (Chanika)	25.4	25.4	21.4	15.4	6.1	30.4	36.3	1.1
Kubale Village	23.5	23.5	19.5	13.5	5.8	28.5	35.9	0.7
East of Pit Q	23.9	23.9	19.9	13.9	5.9	29.0	36.0	0.8
Ndumila II	21.5	21.5	17.5	11.5	5.0	26.6	35.6	0.5
Ndumila I	20.2	20.2	16.2	10.2	3.2	25.3	35.4	0.4

Notes: 1: Total of noise levels from activities at the different noise receptors.
2: Cumulative noise level from activities plus the prevailing ambient noise level.

The assessment of the significance of impacts without mitigation, recommended mitigation measures and the residual impact are summarised below:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Short-term	Local	High	Moderate	Likely	Moderate
Mitigation Measures					
• Ensure equipment and/or machinery comply with the manufacturer's specifications on acceptable noise levels, which may not exceed 85 dBA. • Identify noise sources in excess of 85 dBA at the pit and screen off acoustically. • Place berm or barrier at a set-back distance of 10 m from the processing plant. • Undertake noise monitoring to determine whether ambient noise levels at nearby receptors exceed prevailing noise levels + 3.0 dBA (as per the IFC Environmental Health and Safety Guideline Values, 2007).					
Residual Impact					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Short-term	Local	Low	Low	Likely	Low

Residual Impact

Noise modelling has indicated that construction of an earth berm between the open pit mining activities and nearby noise receptors will significantly reduce the noise intrusion levels It is anticipated that the noise intrusion level at a distance of 50 m from the rim of the open pits, will not exceed 3 dBA in the event that a noise berm of approximately 4 m high is placed at a distance of 10 m from the rim of the open pit.

7.11.4 Calculation of Noise Impact from Road Traffic

Vehicles along the access road create an intermittent increase in the prevailing ambient noise level along the transport route, after which it returns to the prevailing ambient noise level. The calculation of increased traffic noise was based on the number of heavy vehicles per hour resulting from the Project.

In the absence of Malawi-specific standards, SANS 10210 of 2004, the South African national standard for the calculating and predicting of road traffic noise was used to calculate the noise level expected to be generated by the traffic along the access road.

The calculation of the increase in the traffic generated noise levels during the construction phase was based on a total of 10 vehicles per hour of which 5 will be heavy-duty vehicles and 5 will be light vehicles. The increase in noise during the operations phase assumed a total of 20 additional vehicles may be expected, of which 5 will be heavy-duty vehicles and 15 will be motor vehicles.

The calculated traffic noise level at 50 m from the road will be 46.3 dBA during the construction phase and 47.9 dBA during the operations phase.

The assessment of the significance of impacts without mitigation, recommended mitigation measures and the residual impact are summarised below:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Long-term	Local	Moderate	Moderate	Likely	Moderate
Mitigation Measures					
• Ensure equipment and/or machinery comply with the manufacturer's specifications on acceptable noise levels, which may not exceed 85 dBA. • Undertake regular servicing of all equipment and vehicles. • Install and maintain speed control measures along access roads. • Limit vehicle movement along access road at night. • Install noise suppression mechanisms e.g. exhaust mufflers on heavy vehicles and equipment and monitor their effectiveness.					
Impact with Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Long-term	Local	Low	Low	Likely	Low

7.12 Health Risk

Open pit mining activities, such as those proposed for the Project, are known to be responsible for various environmental disturbances, which have the potential to release hazardous substances to the environment. The potential for human exposure to these substances, and the health risk associated with increased exposure to mainly airborne and water-borne contaminants, were assessed by EnviroSim Consulting (2019b). The human health risk and impact assessment undertaken as part of the ESIA is attached in Appendix W.

7.12.1 Human Health Impact from Inhalation Exposure to Criteria Pollutants

Evidence from epidemiological studies exist that link daily cardiovascular deaths with the concentrations of particulates (measured as PM_{10} or $PM2_{.5}$), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), and carbon monoxide (CO) in air (EnviroSim, 2019b). The four pollutants are included in a group of air pollutants generally referred to as 'criteria pollutants'.

Evidence exists indicating that airborne particulate matter, including PM_{10} and $PM_{2.5}$, exert a range of adverse health effects that are diverse in scope, severity, duration, and clinical significance, but mainly impacts the cardio-respiratory system (EnviroSim, 2019b). A critical review by the UK Committee on the Medical Effects of Air Pollutants (COMEAP, 2006) indicated that long-term exposure to particulate matter (for years or decades) was associated with elevated total, cardiovascular, and infant mortality, and also with respiratory symptoms and effects on lung growth and immune system function. Short-term studies showed consistent associations of exposure to daily concentrations of particulate matter with mortality and morbidity on the same day or the subsequent days. Patients with asthma; chronic obstructive pulmonary disease (COPD); pneumonia and other respiratory diseases; cardio-vascular diseases; and with diabetes were especially affected.

In terms of short-term exposure, the respiratory tract is the primary organ system affected by exposure to SO_2. Acute responses may occur within the first few minutes after commencement of inhalation. Effects include severe bronchoconstriction and symptoms such as wheezing or shortness of breath are observed (WHO, 2005 as cited in EnviroSim, 2019b). Effects are generally short-lived and lung function returns to normal once exposure has ceased, within some minutes to hours. Adverse effects indicated by epidemiological studies include exacerbation of asthma, increases in respiratory symptoms and decreases in lung function (WHO, 2005). Environmental exposure to SO_2 is not limited to respiratory effects, but also to cardiovascular effects.

With regard to health, NO_2 is the most significant of the several oxides of nitrogen (NO_x) that may occur in the ambient atmosphere. Controlled clinical studies showed that, in general, concentrations in excess of 1,880 µg/m^3 are necessary to induce changes in pulmonary function in healthy adults. Since these concentrations almost never occur in ambient air, examination of the effects of nitrogen dioxide has focused on people with pre-existing lung disease. Numerous studies on people with asthma, chronic obstructive pulmonary disease or chronic bronchitis have shown that exposure to low levels of NO_2 can cause effects on lung function. Asthmatics are the most responsive group to NO_2 studied to date, although controlled studies on the effects of short-term exposure on the symptoms and severity of asthma have not led to clear findings (WHO, 2005 as cited in EnviroSim, 2019b).

The modelled particulate and gaseous pollutant concentrations for different averaging times (i.e., hourly, daily or yearly average concentrations) as per the air quality impact assessment were used in the health risk and impact assessment to determine the potential risk associated with an increase in criteria pollutants.

The predicted particulate concentrations without dust emission controls at various receptors are listed in Table 7.26.

Table 7.26: Simulated Ground Level Concentrations of Contaminants of Concern

Receptor Location	Daily (24-hour) Maximum			Hourly (1-hour) Maximum			Annual Average		
	PM_{10}	NO_2	CO	SO_2	NO_2	CO	$PM_{2.5}$	SO_2	NO_2
Chitsulo/Kumalindi	436.1	91.1	12.4	11.9	670.0	50.5	28.4	11.4	15.3
Kubale	68.4	10.8	1.8	7.4	194.8	24.3	1.3	3.8	1.0
Kachule	44.3	76.3	6.9	5.5	286.0	26.6	1.5	5.5	18.7

Calculations indicated that particulate matter would have the greatest effect on personal risks to health impacts. This effect of particulates on personal risks is more significant short term exposures.

In the case of daily risks, the estimated personal risk of cardiovascular mortality doubles (increases of over 100%) at locations directly north of the processing plant from exposure to the daily maximum concentrations of unmitigated PM_{10}.

In general, mitigation of airborne PM_{10} concentrations will result in a considerable decrease in estimated risks when compared to unmitigated concentrations. The estimated increase in personal risk for non-accidental mortality relating to short term exposure to particulates can be reduced to below 10% by mitigating particulate emissions by 50%.

Cumulative increases in risk from short-term exposure to PM_{10}, SO_2, NO_2 and CO show a similar potential increase of 26% for total non-accidental mortality north of the processing plant, while exposure at all other receptor locations show an increase of between 5% and 7%.

Evaluation of long-term exposure to criteria pollutants, showed a small but measurable increase in personal risk of total non-accidental mortality and cardiopulmonary mortality. The highest estimated increase in baseline risk from a single pollutant is 15.7% for total non-accidental mortality from long-term exposure to annual average concentrations of $PM_{2.5}$, north of the processing plant. The cumulative increase in the risk of total non-accidental mortality from the combined exposure to $PM_{2.5}$, SO_2, and NO_2 is 30.7% at this same receptor. However, the cumulative risk at all other receptors are below 6.5%. For cardiopulmonary mortality the estimated increase in the cumulative risk is below 1% at all receptors.

The estimated increase in the baseline risk of lung cancer mortality is less than 1% at all receptor locations, even without mitigation measures applied.

The significance of the increase in personal risk referred to above, is a qualitative statement on the increase estimated as compared to a baseline risk, and is a function of the size of the exposed population. The baseline risk of non-accidental mortality in Malawi equates to approximately one death per day in every 70,000 people. An incremental increase of for example 20% in the individual risk of non-accidental mortality due to exposure to air pollution, would result in one (1) additional death only if the population exposed to the air pollution includes 120,000 people. As the population of the areas directly affected by the Project is significantly smaller, around 4,500 people, the actual risk of additional deaths occurring therefore become proportionally smaller.

Nevertheless, as qualitative measure of significance, a 20% increase in the individual personal risk of a particular effect (as compared with the baseline incidence of that effect), is taken as significant. This is done so that any potential problem areas may be identified. Based on this interpretation, the estimated increases in annual personal risks associated with modelled concentrations of criteria pollutants from the Project, are not considered to be significant in most of the affected areas, for all health endpoints evaluated. However, the cumulative short-term risks of both non-accidental mortality and cardiovascular mortality is estimated to increase by more than 20% in the area just north and south of the southern mining pit area. The largest contribution to this increase is from the exposure to unmitigated concentrations of PM_{10} and NO_2. If mitigation in the form of dust abatement is applied, the cumulative increase in risk attributable to PM_{10} is expected to be reduced to below 10%.

The assessment of the significance of impacts without mitigation, recommended mitigation measures and the residual impact are summarised below:

<table>
<tr><th colspan="6">Impact without Mitigation</th></tr>
<tr><td>Duration</td><td>Extent</td><td>Magnitude</td><td>Consequence</td><td>Probability</td><td>Significance</td></tr>
<tr><td>Long-term</td><td>Local</td><td>High</td><td>High</td><td>Likely</td><td>High</td></tr>
<tr><th colspan="6">Mitigation Measures</th></tr>
<tr><td colspan="6">• Develop and implement dust abatement measures for unpaved roads, materials handling and uncovered stockpiles.
• Implement emissions control measures on fuel burning generator sets to reduce NO₂ emissions.
• Implement resettlement of households within 50 m of operational areas.
• Review extent of exclusion zone in consultation with air quality and health specialist on an annual basis.</td></tr>
<tr><th colspan="6">Residual Impact</th></tr>
<tr><td>Duration</td><td>Extent</td><td>Magnitude</td><td>Consequence</td><td>Probability</td><td>Significance</td></tr>
<tr><td>Long-term</td><td>Local</td><td>Low</td><td>Low</td><td>Unlikely</td><td>Low</td></tr>
</table>

7.12.2 Non-cancer (Systemic) Health Impact from Inhalation Exposure to Particle-associated Arsenic and Nickel

Particulate matter (dust) was identified (Digby Wells, 2019a) as one of the potential impacts to the atmospheric pathway from the Project (refer section 7.9.1). It is reasonable to assume that there may be concerns regarding the composition of the particulate matter, and specifically the effects of potentially hazardous constituents of the particulates on the health of affected communities. In order to identify the constituents of the particulate matter, information available for the source materials (i.e., overburden, ore and tailings) was used. Results from compositional analysis performed as part of the geochemical specialist report (SLR, 2018a) were used for this purpose. Only elements of which the concentrations were above the limit of detection, as well as elements that are of importance in terms of potential health impact, were considered. The mineralogical composition of the overburden, reported by SLR (2018a), indicate the waste rock consists primarily of aluminium silicate minerals. Several potentially hazardous elements, such as arsenic, cobalt and thorium were also present in trace amounts.

In order to estimate the concentrations of these elements to which communities in the Project area could be exposed, the modelled airborne concentrations of particulate matter (Digby Wells, 2019a) was used, which indicate that the highest average concentrations of PM_{10} to which the closest residential community could be exposed on any particular day of the year is between 140 and 190 µg/m^3.

Using the mineralogical composition (SLR, 2018a), concentrations in airborne particulate matter were estimated and compared to health-risk based screening values, where values were available. Table 7.27 present a summary of the screening data.

Table 7.27: Elements Present in Dust Dispersed from the Project

Constituent	Element Concentration (mg/kg)		Estimated Element Concentration in Air (µg/m^3)		Screening Value
	Overburden	Ore	Overburden	Ore	µg/m^3
Arsenic	5.01	4.3	9.52E-04	8.17E-04	6.6E-02 - 6.6E-04[1]
Cadmium	<0.400	<0.400	3.80E-05	3.80E-05	5.00E-03[1]
Chromium (total)	172	117	3.27E-02	2.22E-02	1.00E-01[3]
Cobalt	23	21	4.37E-03	3.99E-03	1.00E-01
Copper	63	79	1.20E-02	1.50E-02	1.00E+02[6]
Lead	13	15	2.47E-03	2.85E-03	5.00E-01[1]
Manganese	194	226	3.69E-02	4.29E-02	1.50E-01[1]
Mercury	<0.400	<0.400	3.80E-05	3.80E-05	1.00E+00[1]
Nickel	607	620	1.15E-01	1.18E-01	2.50E-02[1]
Thorium	1.98	0.919	3.76E-04	1.75E-04	9.70E+00[5]
Uranium	3.53	3.25	6.71E-04	6.18E-04	4.00E-02[4]
Vanadium	398	430	7.56E-02	8.17E-02	1.00E+00[2]

1. WHO Guidelines (µg/m³) (2005) chronic guidelines (1 year+)
2. WHO Guidelines (µg/m³) (2005) acute & Sub- acute guidelines (24hr)
3. US ATSDR Maximum Risk Levels intermediate exposure (up to 1 year)
4. US ATSDR Maximum Risk Levels chronic exposure (up to 1 year)
5. US ATSDR Toxicological Profile for Thorium (ATSDR,1990)
6. The Californian Office of Environmental Health Hazard Assessment acute Reference Exposure Levels

The comparison showed that airborne concentrations of nickel and arsenic, if the lower value in the range is used, exceed the screening criteria, and was therefore selected as contaminants of concern.

Arsenic is widely distributed in the environment from natural sources and is naturally present at low levels in soil, water and air. Arsenic can be released into the air when minerals containing arsenic are processed or smelted, or when materials containing arsenic are burned. Airborne particles that contain arsenic, can settle on the ground, surface water and plants.

Analysis of the toxic effects of arsenic is complicated by the fact that arsenic can exist in several different oxidation states and many different inorganic and organic compounds. According to the U.S. Agency for Toxic Substances and Disease Registry (ATSDR), most cases of human toxicity from arsenic have been associated with exposure to inorganic arsenic. Organic forms of arsenic are generally considered to be less toxic than inorganic forms (ATSDR, 2007 as cited in EnviroSim, 2019b).

Non-cancer effects associated with inhalation exposure to airborne arsenic include respiratory irritation, nausea, skin and neurological effects. There are limited quantitative data on non-cancer effects in humans exposed to inorganic arsenic by the inhalation route. Animal data similarly identify effects on the respiratory system as the primary non-cancer effect of inhaled inorganic arsenic compounds, although only a few studies are available.

Nickel occurs naturally in the environment in combination with oxygen or sulphur. Particulates containing nickel can be released to the environment through mining and mineral processing operations.

Exposure to nickel and nickel compounds may occur through inhalation of dust and particles, ingestion of food and drinking water containing nickel, and by absorption through the skin. Exposure to nickel causes a variety of non-carcinogenic toxic effects including contact dermatitis, asthma, and reproductive toxicity in humans (EnviroSim, 2019b).

The estimated annual average ground level concentrations of particle-associated arsenic and nickel at affected sensitive receptors identified are given in Table 7.28.

Table 7.28: Simulated Ground Level Concentrations of Particle-associated Arsenic and Nickel

Receptor Location	Arsenic Concentration (µg/m^3)	Nickel Concentration (µg/m^3)
Chitsulo	2.18E-03	2.63E-01
Kubale	3.43E-04	4.12E-02
Kachule	2.24E-04	2.67E-02

Hazard quotients calculated indicate the probability of non-cancer health effects as a result of exposure to these substances, is low. Exposure to particulate associated nickel, under unmitigated conditions, in the area just north of the processing plant are indicated as potentially conducive to acute health effects.

The assessment of the significance of impacts without mitigation, recommended mitigation measures and the residual impact are summarised below:

<table>
<tr><th colspan="6">Impact without Mitigation</th></tr>
<tr><td>Duration</td><td>Extent</td><td>Magnitude</td><td>Consequence</td><td>Probability</td><td>Significance</td></tr>
<tr><td>Long-term</td><td>Local</td><td>High</td><td>High</td><td>Likely</td><td>High</td></tr>
<tr><th colspan="6">Mitigation Measures</th></tr>
<tr><td colspan="6">• Develop and implement dust abatement measures for handling of overburden material and ore, and uncovered stockpiles.
• Implement resettlement of households within 50 m of operational areas.
• Review extent of exclusion zone in consultation with air quality and health specialist on an annual basis.</td></tr>
<tr><th colspan="6">Residual Impact</th></tr>
<tr><td>Duration</td><td>Extent</td><td>Magnitude</td><td>Consequence</td><td>Probability</td><td>Significance</td></tr>
<tr><td>Long-term</td><td>Local</td><td>Low</td><td>Low</td><td>Unlikely</td><td>Low</td></tr>
</table>

7.12.3 Increased Cancer Incidence from Inhalation Exposure to Particle-associated Arsenic and Nickel

Calculations as part of the cancer risk assessment performed on the estimated concentrations of arsenic and nickel associated with airborne particulates, indicate risks are largely negligible, except in the case of exposure to unmitigated concentrations of particle-associated nickel in the area of north of the processing plant and in the vicinity of Kubale. Here cancer risk is in the acceptable risk range.

The assessment of the significance of impacts without mitigation, recommended mitigation measures and the residual impact are summarised below:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Long-term	Local	Negligible	Low	Rare	Very Low
Mitigation Measures					
• Develop and implement dust abatement measures for handling of overburden material and ore, and uncovered stockpiles. • Implement resettlement of households within 50 m of operational areas. • Review extent of exclusion zone in consultation with air quality and health specialist on an annual basis.					
Residual Impact					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Long-term	Local	Negligible	Low	Rare	Very Low

7.12.4 Human Health Impact from Exposure to Contaminated Drinking Water

Section 7.8.2 discusses the potential contamination of groundwater from sources associated with the Project and identifies the most significant potential contamination is associated with the TSF. All other possible sources will be designed to prevent and contain contamination.

The results presented in the hydrogeological report (SLR, 2019b) is based on an assumption that a 100% of the contaminant load would enter the groundwater (i.e. worst-case scenario). The model further assumes a non-reactive characteristic to the ‘load’, which means that the contaminant entering the groundwater is assumed not to react or mix with the groundwater, and will not attenuate in space or time.

The SLR (2019) report indicates that the seepage plume developing from the TSF will migrate in an easterly direction, following the groundwater flow direction, and is predicted to reach a maximum extent of 1,053 m from the TSF.

It is therefore reasonable to assume that members of the public could potentially be exposed to contaminants introduced to the aquatic pathways from the Project. For this assessment, the concentrations of contaminants present in baseline groundwater and those predicted in seepage and runoff from the tailings, were evaluated, considering members of the public that utilise the water as their only source of drinking water as potential receptors.

The contaminants of concern that identified from the geochemical investigation report (SLR, 2018b) is aluminium and fluorine, which are predicted to reach concentrations in the water entering the aquifer below the TSF of between 1.32 mg/L and 3.4 mg/L, respectively.

Both aluminium and fluorine are non-carcinogenic and was evaluated for systemic health effects only. Normally, the risk of exposure to non-carcinogens through ingestion is expressed through a hazard quotient (HQ), which is the exposure concentration averaged over the period of exposure divided by the reference dose (RfD) or tolerable daily intake (TDI). Where a HQ exceeds 1, health effects may occur and the situation requires further investigation.

Based on the calculation of these HQs, exposing members of the public to the process water present in the tailings and in the return water dam, however unlikely, should be prevented. Although aluminium concentrations in the water are expected to be low enough not to have a measurable effect on health, fluorine present in the water is shown to have the potential to result in adverse health effects.

Results further indicate that ingestion exposure to the existing groundwater and surface water is unlikely to result in adverse health effects to chronic water users from exposure to baseline concentrations of Al and F. However, peak concentrations of both Al and F measured in groundwater and surface water are approaching values of health significance and any contribution from the tailings would likely lead to concentrations that has the potential to result in adverse health effects in sensitive individuals that drink the water.

The assessment of the significance of impacts without mitigation, recommended mitigation measures and the residual impact are summarised below:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Long-term	Local	Moderate	Moderate	Rare	Very Low
Mitigation Measures					
• Implement mitigation measures to minimise potential for groundwater contamination. • Review extent of exclusion zone in consultation with geohydrologist and health specialist on an annual basis.					
Residual Impact					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Long-term	Local	Negligible	Low	Rare	Very Low

7.13 Social Impact

AECOM SA (Pty) Ltd conducted a detailed social impact assessment (SIA) and resettlement survey as part of the ESIA.

Villages within the Project's footprint include Kumalindi, Chitimbe, Jaulani, Kokotani, Ndumila, Pingeni and Chikosi, which will be impacted by land acquisition required for the Project and any access road developed by the Project

McCourt Mining has committed to developing a resettlement action plan (RAP) to address all aspects related to the mitigation, compensation and management of impacts associated with the physical and economic displacement of households in the Project area. The RAP was prepared to conform to both Malawian legislation and international best practice standards (i.e. IFC PS5). The RAP is a stand-alone document and will be submitted separately to the Department of Lands and Valuation within the Ministry of Lands, Housing and Urban Development. A copy of the draft report is attached as Appendix Y.

The objective of the RAP is to:

- Develop and implement a fair, transparent and negotiated compensation agreement in full partnership with affected parties and other stakeholders.
- Ensure consistency in implementing resettlement and compensation activities.
- Restore livelihoods affected by the Project.
- Ensure that vulnerable people receive additional assistance when required.

Impacted households/individuals will be provided with the option to receive in-kind or cash compensation for the loss of household assets and land tenure. Those households/individuals that opt for cash compensation will be offered training in basic financial literacy and management.

The RAP will include a livelihood restoration programme (LRP) that addresses the standards prescribed in IFC PS5. The development and implementation of the RAP and LRP would ensure that impacted communities are adequately compensated, and additional supportive measures are put in place, which would enable local communities to re-establish traditional agricultural activities. The LRP will include measures to address the needs of vulnerable groups and re-establish livelihoods, with a particular emphasis on transitional support in the short-term when impacts support requirements may be particularly acute.

The LRP will also include monitoring measures to help verify that income and living standards of affected people are restored to at least pre-Project levels, or are improved. Livelihood restoration must consider the risk of future extreme climate events, such as droughts and floods, and its potential impact on measures to restore livelihoods. It should also be aligned with any corporate investment projects to enhance sustainability.

7.13.1 Construction Phase Impacts

7.13.1.1 Loss of Residence from Physical Displacement Caused by Land Acquisition

Land acquisition and land clearance activities will involve the demolition and removal of built structures, clearance of vegetation and the establishment of security fencing. In addition, it will include the removal of land ownership, tenure or customary rights to use the land, and the relocation of people who are currently residing within the Project footprint (AECOM, 2019a).

Physical displacement will have a direct impact on affected households, as they will need to find alternative shelter. With limited financial and other assets, re-establishing adequate alternative shelter would only occur over the medium to long-term. In the short-term the affected households could have inadequate housing options and experience a fundamental impact on quality of life. In addition to the direct loss of shelter, other associated impacts include:

- Increased anxiety and stress among those impacted, due to uncertainty related to the future and possible discontentment over the loss of land and homes.
- Communities may potentially lose their sense of identity as some of them move away from their traditional land and resources, and have to adapt to a new way of life in a different place.
- Breakup of existing family or community networks and support groups, often used as coping mechanisms, as a result of displacement.
- Tension with host communities, as those being displaced may move to an area that is already occupied, or may initially move in with family members. This is likely to place pressure on existing resources and infrastructure in the host communities or families, which could lead to tensions and disputes.

It is planned to implement in situ relocation in as many cases as possible – i.e. situating replacement houses and farms at suitable locations in the same village. In such cases the impacts typically associated with long-distance relocation could be avoided. However, nearby relocation might not be possible for some households considering the complex socio-political environment, households loyalty to local and traditional leaders vary drastically and could likely limit the degree to which they could be incorporated into nearby and neighbouring villages.

Vulnerable groups such as the elderly and child-headed households are likely to be disproportionally affected by these impacts. Special consideration should be given to vulnerable households, such as providing relocation assistance for elderly or child-headed households.

The impact of physical displacement will be adverse and will result in permanent changes to impacted communities' way of life. The magnitude of the impact to households with residences that will be removed as part of Project development will be high, and the overall impact significance will be very high. Impacted households will be provided with support and resources to help them adapt to changes in living conditions.

The assessment of the significance of impacts without mitigation, recommended mitigation measures and the residual impact are summarised as follows:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Permanent	Site-specific	High	High	Almost Certain	Very High
Mitigation Measures					
• Design and locate Project infrastructure in such a way as to minimise displacement, especially infrastructure components such as the TSF, roads and supporting infrastructure which are not dependent on the location of mineral deposits. • Develop and implement RAP consistent with IFC PS5 and GIIP, including financial literacy training. • Undertake resettlement planning and implementation, where practicable, in one attempt for a defined geographic area/footprint to minimise disturbance for communities from resettlement activities and to minimise the risk of double displacement. • Give special consideration to vulnerable households, such as providing relocation assistance for elderly or child-headed households.					
Residual Impact					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Short-term	Site-specific	Moderate	Low	Highly Likely	Moderate

Residual Impact

Approximately 260 ha of land will need to be acquired for the purposes of developing the Project infrastructure as described in Chapter 2.

Based on the findings of the resettlement action plan (RAP) survey, it is evident that clearance of the exclusion zone will displace a total of 367 structures, which belongs to 123 households, almost a third of these structures (108) are homestead compounds or residential buildings with supporting structures (toilets, bathrooms, kraal, granary, store rooms) and 5 structures used for economic purposes. Households facing displacement during Phase 1 are mainly from Kumalindi villages, whereas Phase 2 displacement could potentially affect households from Kubale, Chitimbe, Jaulani, Kokotani, Ndumila II, Pingeni and Chikosi villages. It is important to note that the bulk of physical displacement (99 homesteads) will be as result of acquiring land required for Phase 2 mining activities, whereas Phase 1 activities will likely only displace 9 homesteads.

7.13.1.2 Economic Displacement Caused by Loss of Land, Grazing and Business Assets

In addition to physical displacement, land acquisition and clearance will trigger economic displacement due to the loss of access to assets and resources upon which impacted communities' livelihoods depend, including agricultural fields, grazing areas and business assets such as trading stalls (AECOM, 2019a).

A total of 5 small-scale business structures have been recorded within the exclusion zone; almost half of these form part of household's permanent homesteads. These typically take the form of kiosks, road side trading stalls, facilities to brew and sell beer, and sales of agricultural produce from homes or at village markets, etc. Displacement of structures or facilities used for such business activities would constitute a form of economic displacement, since it would entail a loss of income from those activities until alternative facilities can be established elsewhere.

The loss of economic assets, particularly access to agricultural fields, could result in a loss of income and food supply for those affected. This will include residents of this area as well as those who live elsewhere but who own and/or use land within the exclusion zone. Given the low incomes and the high dependency on agriculture as a primary source of livelihood in the Project area, economic displacement will likely result in a reduced standard of living and quality of life, and is likely to have serious implications for the food security of households. The most impacted will be receptors solely dependent on agriculture as their source of livelihood (approximately 84% of Project affected people), and this will be exacerbated due to the low level of financial and other assets that they have access to and on which they could re-establish livelihoods.

Certain villages located outside of the boundaries of the Project footprint, including Ntanga, Kachule, Tanga and Masula will experience restricted access to some communal resources, assets and infrastructure that remain within the exclusion zone.

Impacted households/individuals will be provided with the option to receive in-kind or cash compensation for the loss of economic assets and resources. Those households/individuals that opt for cash compensation will be offered training in basic financial literacy and management. This will be provided as part of the LRP.

The assessment of the significance of impacts without mitigation, recommended mitigation measures and the residual impact are summarised as follows:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Permanent	Site-specific	High	High	Almost Certain	Very High
Mitigation Measures					
• Design and locate Project infrastructure in such a way as to minimise displacement. • Develop and implement RAP consistent with IFC PS5 and GIIP, including financial literacy training. • Undertake resettlement planning and implementation, where practicable, in one attempt for a defined geographic area/footprint to minimise disturbance for communities from resettlement activities and to minimise the risk of double displacement. • Give special consideration to vulnerable households, such as providing relocation assistance for elderly or child-headed households. • Undertake livelihoods monitoring as part of the LRP. • Align and incorporate LRP with any corporate investment projects to enhance sustainability. • Livelihood restoration must consider risk of future droughts and its potential impact on measures to restore livelihoods.					
Residual Impact					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Short-term	Site-specific	Moderate	Low	Highly Likely	Moderate

Residual Impact

A total of 5 small-scale business structures will be impacted as a result of displacement, and will result in a loss of income from those activities until alternative facilities can be established elsewhere.

Approximately 260 ha of land, which includes land for grazing and agricultural activities will be required for the Project footprint. Current indications are that the Project would fragment a relatively large number of land holdings along the edges of the exclusion zone, which will result in 'orphaned land' that is rendered unviable for continuation of existing use. An additional 40 to 50 ha of orphaned agricultural land may need to be acquired, assuming a worst case scenario where all partially affected properties will need to be acquired in their entirety, as opposed to only the affected section.

A total of 583 agricultural fields comprising approximately 300 ha and belonging to 523 households will be entirely or partially displaced by the Project. The majority of affected fields are located within the Phase 1 area (407) and will be entirely displaced by the project, current indications are that only 84 field will be affected by land acquired for Phase 2 activities.

It is unlikely that land in the immediate vicinity of the Project would be available to replace lost agricultural land on a like-for-like basis and agricultural land further away may need to be acquired to replace land. This will be undertaken during the next phase of the RAP.

Approximately 236,000 economic tress may be impacted during ground clearing.

Alternative strategies to address the loss of agricultural land will also be developed in consultation with the Ministry of Lands, Housing and Urban Development as part of livelihood restoration planning.

7.13.1.3 Loss of Access to Boreholes and Community Assets within the Project Area

The acquisition of land to develop the Project site will require all social infrastructure within the Project footprint to be demolished and cleared. This will lead to the loss of boreholes and other community assets such as land used for harvest of traditional medicine. For example, in Chitsulo and Katawa, communities will lose access to traditional medicine located adjacent to the processing plant. Without mitigation it may mean that communities will have to travel greater distances to access similar assets and infrastructure, and it will place increasing pressure on assets and infrastructure in neighbouring villages.

Vulnerable individuals such as the elderly or disabled, unable to travel greater distances, are likely to be more significantly impacted. Due to their limited mobility they might not be able to travel these increased distances, which could completely preclude them from accessing social infrastructure such as sufficient water sources.

Lost community assets and infrastructure would need to be restored to minimise the detrimental impacts on communities. Consultation with the relevant impacted community will be undertaken to develop the most efficient and tailored approach to asset restoration. The final RAP will include a full inventory of all community assets that will be displaced.

In addition, a stakeholder engagement plan and grievance mechanism will be developed and implemented to identify and mitigate any unexpected impacts on community assets, e.g. due to accidental damage.

The assessment of the significance of impacts without mitigation, recommended mitigation measures and the residual impact are summarised below:

<table>
<tr><th colspan="6">Impact without Mitigation</th></tr>
<tr><td>Duration</td><td>Extent</td><td>Magnitude</td><td>Consequence</td><td>Probability</td><td>Significance</td></tr>
<tr><td>Permanent</td><td>Site-specific</td><td>High</td><td>High</td><td>Almost Certain</td><td>Very High</td></tr>
<tr><th colspan="6">Mitigation Measures</th></tr>
<tr><td colspan="6">• Compile a full inventory of all community assets that will be impacted as part of the RAP.
• Undertake restoration of lost community assets and infrastructure in consultation with the impacted community, and implement as part of the RAP.
• Implement stakeholder engagement plan and grievance mechanism to identify and mitigate any unexpected impacts on community assets.</td></tr>
<tr><th colspan="6">Residual Impact</th></tr>
<tr><td>Duration</td><td>Extent</td><td>Magnitude</td><td>Consequence</td><td>Probability</td><td>Significance</td></tr>
<tr><td>Short-term</td><td>Site-specific</td><td>Moderate</td><td>Low</td><td>Highly Likely</td><td>Moderate</td></tr>
</table>

7.13.1.4 Loss of Local Access Roads and Tracks

The development of the Project infrastructure will likely lead to the disruption of the existing local network of roads, tracks and paths used by local communities, to access agricultural fields, local villages and the Kamuzu Dam, specifically those in and near Kubale and Ndumila in the south, and Chitsulo and Kumalindi towards the north of the Project. New routes would have to be established by affected communities to bypass the Project site.

Direct access will be impeded from some communities (such as villages in and near Chakwindima) to social infrastructure in Malingunde such as food markets, places of worship, schools and health facilities. Although access is still available via the S124, travel distances would increase for these communities. Vulnerable community members that would have to undertake this trip on foot would be especially impacted by reduced connectivity caused by the impact to the road network.

As part of detailed design, Sovereign will be required to identify those roads and tracks that will be cut-off as a result of the Project development and engage with local communities on alternate routes around the Project footprint. The Project will be responsible for the development of the agreed alternate roads and tracks in order to maintain reasonable accessibility to surrounding areas, and to minimise the additional travel time that will be created by this diversion.

The assessment of the significance of impacts without mitigation, recommended mitigation measures and the residual impact are summarised below:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Long-term	Local	Moderate	Moderate	Likely	Moderate
Mitigation Measures					
• Identify roads and tracks that will be cut-off as a result of the Project development. • Engage with local communities on routing for alternate routes around the Project development area. • Develop alternate roads and tracks in order to maintain reasonable accessibility to surrounding areas. • Provide advance notification of Project to local residents through stakeholder engagement mechanisms, including description of impacts to accessibility of surrounding areas.					
Residual Impact					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Short-term	Local	Low	Low	Likely	Low

7.13.1.5 Social Stress as a Result of Uncertainty about the Project and its Potential Impacts

Given the widespread level of illiteracy in the Project area, there is a risk that Project information may not be received or understood by people affected by the Project. This may lead to uncertainty about Project activities, its potential impacts and the future of local communities. This is particularly applicable to land acquisition, and the resettlement and livelihood restoration process, which often result in social stress in impacted communities (IFC, 2012).

The assessment of the significance of impacts without mitigation, recommended mitigation measures and the residual impact are summarised below:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Short-term	Local	High	Moderate	Likely	Moderate

Mitigation Measures					
• Disclose information early and frequently as part of ongoing stakeholder engagement with affected individuals/households and the wider community. • Engage a community liaison officer to work closely with local communities to provide culturally appropriate and timely information, and respond to questions and concerns. • Establish a community advisory group that has representation from communities affected by physical and economic displacement and can help advise Sovereign on the key concerns and requirements of affected people.					
Residual Impact					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Short-term	Local	Moderate	Low	Likely	Low

7.13.1.6 Exacerbation of Issues Regarding Financial Control and Gender Inequality in Local Communities

Gender inequality resulting from imbalanced distribution of finances among the households' members could potential exacerbate issues of inequality and limit women's opportunities to participate in economic opportunities.

Gender inequality and women's empowerment remains a big challenge in Malawi. According to the UNDP[1] Gender Inequality Index 2016 report, Malawi is ranked 145th of 159 countries (AECOM, 2019a). Women are reported to have limited to no decision-making input in many areas. Men predominantly hold land rights and are traditionally in charge of household finances, making them the main potential recipients and distributors of cash compensation payments as part of resettlement. In this sense misspent finances by one member of the family to the detriment of others may lead to a breakdown in family structures or contribute to food insecurity.

Fifty-five per cent (55%) of the households identified in RAP survey are female-headed (single parent households), thus, those households are not considered to be the receptors of this impact. In other cases (i.e. male-headed double-parent households), where practically possible, payment of compensation should be made at the household level (to husband and wife).

The assessment of the significance of impacts without mitigation, recommended mitigation measures and the residual impact are summarised as follows:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Short-term	Local	Moderate	Low	Highly Likely	Moderate
Mitigation Measures					
• Where practically possible, payment of compensation to be made at household level (to husband and wife). • Provide financial literacy training to those who receive compensation payments from resettlement. This will include advice and assistance on how to open bank accounts, especially for savings, how to undertake long-term financial planning, etc. • Identify local NGOs or CBOs that can help with the design and implementation of financial literacy training. • Assist with the formation of local women's groups to provide support specifically for the affected women (e.g. training on finances and household management).					

[1] The UNDP's Gender Inequality Index introduced in 2010 is composed of three dimensions: reproductive health, empowerment and the labour market. Reproductive health is measured by maternal mortality ratio and adolescent birth rates; empowerment is measured by the proportion of parliamentary seats occupied by females and proportion of adult females and males aged 25 years and older with at least some secondary education; and labour market is measured by labour force participation rate of female and male populations aged 15 years and older.

Residual Impact					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Short-term	Local	Low	Low	Likely	Low

7.13.1.7 Reliance on and Subsequent Loss of Income from Fixed-term Employment During Construction

During the construction phase, the Project and its contractors will give preference to local employees, depending on their skills level. The local skills base is considered to be low, with very limited technical skills and low levels of literacy; therefore, it is anticipated that the available jobs that could be taken up by local residents will be largely unskilled or semi-skilled, and include labourer and low-level entry positions in non-technical positions with fixed short-term contracts. Although limited opportunities may be available to local workers, this waged employment will nevertheless result in increased levels of income of the employed individuals, as well as contribute to both individuals' and their households' well-being.

As the Project transitions from construction into the operations phase, the construction short-term workforce will be reduced, which will lead to a reduced income for those workers whose contracts will not be renewed, and to an overall reduction in income of their households.

Although this end of fixed short-term employment is planned and would not be classified as 'collective redundancies', 'dismissals' and/or 'retrenchment' (as defined in IFC PS2), and workers may be no worse-off in terms of income and employment status than they were prior to the Project, the loss of employment at the end of a contract period can still create stress and challenges to the previously employed workers and their families. This impact would be as a result of:

- Workers building up small or no savings made during Project employment, due to low financial literacy and lack of long-term financial management skills.
- Changed consumption behaviour due to short-term income increases.

It is likely that the longer the duration of the contract will be, the more stressful this 'end of employment moment' may become for a worker and his/her family, as the degree of dependency on the Project increases over time.

The assessment of the significance of impacts without mitigation, recommended mitigation measures and the residual impact are summarised as follows:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Short-term	Local	Moderate	Low	Highly Likely	Moderate
Mitigation Measures					
• Advertise the nature, duration and numbers of jobs available during the various Project phases and ensure that local communities understand the Project's employment requirements. • Ensure that all Project workers (including contractors and subcontractors) are made aware of the duration of employment when they are hired. • Provide financial literacy training for project workers. • Provide local employees with reference letters once construction is completed. • Provide certificates of completion for in-house (on-the-job) training passed. • Develop skills training programs for local recruits, with a focus on women and youth, to enable them to apply for permanent positions during the operations phase of the Project.					
Residual Impact					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Short-term	Local	Low	Low	Likely	Low

7.13.2 Construction and Operations Phase Impacts

7.13.2.1 Increased Income Leading to Improved Individual and Household Wellbeing

Approximately 220 workers will be employed at peak demand during construction, of which 160 will be filled by local/Malawian employees. During operations an estimated 230 to 240 local people will be employed.

Local workers from the surrounding Malingunde area will be given preference for job opportunities, depending on their skills level, as it is anticipated that available jobs will be largely low-skilled or semi-skilled. Project employment during construction and operations will increase the level of income of the employed individual and will likely contribute to improved individual and household wellbeing.

The initial magnitude of the impact is expected to be low at a regional level, though at the individual household level will be substantial impact for those who are employed. While mitigation measures will enhance local employment, there is still likely to be some barriers to local employment particularly related to the lack of skills and experience in formal employment. This will moderate how much employment can be delivered locally.

The assessment of the significance of impacts without mitigation, recommended mitigation measures and the residual impact are summarised as follows:

Benefit without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Long-term	Regional	Low	Moderate	Likely	Moderate
Enhancement Measures					
• Develop and implement a Local Employment Plan that prioritises employment of people within and close to the Project area, and outlines transparent measures for making jobs available to local residents and for hiring based on merit. • Monitor levels of local employment (including contractors and subcontractors) • Conduct a review of local employment levels 6 months after start of construction and 1 year after start of operations. Identify opportunities to enhance local employment levels.					
Enhanced Benefit					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Long-term	Local	Moderate	Moderate	Likely	Moderate

7.13.2.2 Multiplier Effects on the Local Economy and Economic Opportunities for Entrepreneurs and Small Businesses

The Project will have several economic benefits through direct and multiplier effects, stimulated by capital expenditure on construction and operations activities. Large scale construction activities will increase the demand for a wide variety of goods and services, and as a result will stimulate and/or sustain growth within the region's manufacturing and service sectors. This economic environment will likely also generate opportunities for micro and small businesses in the immediate area (e.g. shops within Kumalindi and other nearby villages), provided they are formalised and able to meet the procurement requirements of the proposed Project. Regardless of whether these businesses become suppliers to the Project, it is expected that they will experience improved markets and increased numbers of customers for consumable items they sell, and services offered (primarily resulting from the Project-induced influx).

A considerable part of the Project's needs will, however, be highly technical and unlikely to be sourced within the Lilongwe District. For these needs Sovereign will be required to procure from businesses elsewhere in the region, country or internationally (and South Africa being the most probable source for the latter). Such procurement will expose a wider area to the proposed Project's economic stimulus, albeit to a diluted degree.

Any local and regional procurement spend will enhance the positive economic impact of the Project, as the revenue accruing to enterprises will produce beneficial downstream impacts on the local and regional economy. Given that a significant proportion of money derived from wages earned would likely be spent within the local and regional area, it is expected to create substantial flows of revenue within surrounding communities, thus acting as a catalyst for growth in the economy.

In order to enhance this impact, Sovereign will give preference to suitable subcontractors located in the surrounding communities, then in the District, and then only to contractors located elsewhere in the Region, or elsewhere in the Country. While it is anticipated that procurement opportunities for communities adjacent to the Project will be limited, it is in the best interest of the Project and host communities to maximise these opportunities. Due consideration will therefore be given to identification of procurement opportunities and goods/services that could be supplied by local contractors. Services that could be provided by local providers may include provision of foodstuffs, security and catering services, maintenance services for non-technical components (e.g. clearing vegetation from servitudes, etc.), and buildings and facilities maintenance. Where appropriate enterprises do not exist locally, Sovereign will investigate the possibility of developing this service capacity among similar local enterprises, potentially as part of enterprise or business development programmes that could be implemented in future community development initiatives. The feasibility of establishing linkages with institutions other than the local government (such as community-based development projects and non-governmental organisations (NGOs)) will also be investigated.

The assessment of the significance of impacts without mitigation, recommended mitigation measures and the residual impact are summarised below:

<table>
<tr><th colspan="6">Benefit without Mitigation</th></tr>
<tr><td>Duration</td><td>Extent</td><td>Magnitude</td><td>Consequence</td><td>Probability</td><td>Significance</td></tr>
<tr><td>Long-term</td><td>Regional</td><td>Low</td><td>Moderate</td><td>Likely</td><td>Moderate</td></tr>
<tr><th colspan="6">Enhancement Measures</th></tr>
<tr><td colspan="6">Develop and implement a Local Procurement Plan that defines clear, practicable and measurable mechanisms and milestones for local procurement.
Identify procurement opportunities and goods/services that could be supplied by local contractors, as well as processes for prioritising them over district, country or international suppliers.
Investigate the feasibility of establishing business linkages with institutions other than the local government (NGOs, CSOs etc.).</td></tr>
<tr><th colspan="6">Enhanced Benefit</th></tr>
<tr><td>Duration</td><td>Extent</td><td>Magnitude</td><td>Consequence</td><td>Probability</td><td>Significance</td></tr>
<tr><td>Long-term</td><td>Regional</td><td>Low</td><td>Moderate</td><td>Likely</td><td>Moderate</td></tr>
</table>

7.13.2.3 Increased Government Revenue through Royalties and Taxation

The Project will generate government revenues during the operational phase in the form of taxation (30%) and royalties (5% of net sales revenue). Estimated tax payable over the life-of-mine is US$150m, with an additional US$50m in royalties. The overall level of revenue generated by the Project is anticipated to create a noticeable increase to total government revenues. Increased business activity around the Project will also provide increased tax revenue to government. Such an injection into government structures could contribute to the development of the region and district in general, thereby creating conditions conducive to economic growth.

As outlined in Chapter 5, Malawi is a low-income country with a high dependence on agriculture. A new source of revenue not related to agricultural activities will contribute not only to the growth but also to the diversification of the national economy.

Sound financial principles and accounting processes will be used and the Project will publish an annual statement of taxes and royalties paid, in line with good international practice as promoted by the Extractives Industry Transparency Initiative Standards. The Project will make payments of taxes and royalties in a transparent, accurate and timely manner.

While the impact assessment scoring system assesses this as high consequence, this has been revised to moderate based on the judgement that the extent to which this would create positive economic outcomes. The same approach was applied towards the significance level - this has been reduced on a precautionary basis to moderate significance due to the uncertainties.

The assessment of the significance of this benefit is summarised below:

Benefit					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Long-term	National	Moderate	Moderate	Almost Certain	Moderate

7.13.2.4 Project-induced Migration (Influx)

Project-induced migration or influx (the movement of people to an area to take up employment, or in anticipation of employment or other economic opportunities) to the Project area and surrounding villages may lead to reduced individual and community well-being. Influx results in an increased local population, and in some situations can lead to the loss of identity and sense of place in the host communities. It may also result in increased use of land and community resources, and an increase in crime and other social ills, such as alcohol and drug abuse, and prostitution.

It is difficult to estimate precise levels of the Project in-migration in advance. The influx is highly likely to occur due to current levels of poverty and unemployment in the wider region, which will draw people to the area for the economic opportunities created by the Project. The relatively small number of construction workforce requirements (approximately 220 workers at peak demand) and the proximity of the Project site to large population centres (Likuni, Lilongwe) may mean that there will be lower risk of long-term movement of people to the areas close to the Project footprint. In-migration is likely to begin to rise as Project activity increases during the site preparation phase but will likely be most intense during the construction phase.

Project workers, contractors, their families and others looking to benefit from the Project from outside of the host communities may have different backgrounds and cultural values to those of the host communities. This may result in changes to the sense of place and community identity as the way of life within the impacted local communities change. This potential change would inevitably require adaptation by communities.

Introduction of waged labour (even temporarily) may result in movement away from traditional subsistence livelihoods, further affecting cultural identity and sense of community as people may no longer practice livelihoods together and traditional livelihood support networks become weakened.

Increased levels of education and wealth amongst some segments of the population, achieved through direct, indirect or induced employment may lead to increased disparities in standards of living and lifestyles. Such differences may erode a common cultural identity within local communities. Traditional decision making and leadership hierarchies may also be challenged as some members of the population move out of subsistence livelihoods and become more empowered through increased wealth.

Another likely consequence of influx is increased pressure on local housing, social infrastructure and services, including education and healthcare facilities, as well as places of worship. Both education and healthcare facilities within the Project area are currently affected by inadequate infrastructure and resourcing. The main challenges of the healthcare sector include limited human resources due to the low number of doctors, nurses and clinical technicians, poor quality of buildings and equipment, and limited capacity to provide emergency response services. Police resources within the Project area are currently understaffed and unlikely to have the capacity to deal with potentially increased demands for their services. Therefore, the current capacity of the local social infrastructure and services to absorb a higher number of users is extremely limited.

If demand exceeds capacity for these facilities, some residents may want/have to travel greater distances to access similar social infrastructure in neighbouring villages. In this sense, vulnerable individuals such as young children, elderly or disabled are likely to be more significantly impacted. Due to their limited mobility, they may not be able to travel these increased distances, precluding them from accessing this infrastructure.

The assessment of the significance of impacts without mitigation, recommended mitigation measures and the residual impact are summarised as follows:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Short-term	Local	High	Moderate	Highly Likely	High
Mitigation Measures					
• Develop and implement an Influx Management Plan. • Undertake monitoring of influx as part of the Project ESMP in consultation with local government, and continue to provide capacity building support and report on findings. • Communicate steps for hiring workers to local communities in a transparent manner. • Apply a mechanism to verify where job applicants come from (e.g. checking ID cards) so that jobs prioritised for members of local communities are not given to in-migrants. • Prohibit at-gate hiring to reduce the number of people waiting at and around the Project site. • Develop and implement education campaigns and capacity-building training to the employees and local communities on the dangers of alcoholism, drug abuse, domestic violence, prostitution and safe sex, in consultation with relevant government departments. • Provide medical services for Project workers on site to reduce pressure on local health facilities. These services will be designed to respond to first aid cases and to other illnesses and medical requirements of workers. • Engaged with medical and educational authorities during construction and after one year of operation in order to identify if excessive burdens are being placed on them by Project workers, and revise Project provisions as required.					
Residual Impact					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Short-term	Local	Moderate	Low	Highly Likely	Low

7.13.2.5 Presence of Project Workers Leading to Decreased Community Wellbeing

Project induced influx in the region particularly of a predominantly male workforce and male opportunistic migrants have the potential to decrease local communities' wellbeing due to inappropriate behaviour, use of alcohol and drugs, increased incidence of crime and/or increase in prostitution (AECOM, 2019a).

Migrants may be more likely to behave illicitly when they are separated from their families and are operating outside their usual sphere of social control. Furthermore, migrants who cannot find work in the area may resort to criminal activities as a means of subsistence.

Women and minors (especially girls) are considered particularly at risk of sexual and physical assault while men are considered more vulnerable to substance abuse. Alcohol-related violence is one of the key issues currently being reported to the Sinyala Police Station.

The number of women in the Project area engaging in prostitution is reported to be increasing and the ability to earn 'quick money' from prostitution is reportedly seen as one of the only options for unskilled women to earn an independent income. A section of the S124 road between Malingunde trading centre and Likuni was identified as a potential hotspot for prostitution by communities during the baseline study. The introduction of wage-based employment (even limited in scale) and the distribution of cash compensation as part of the resettlement process will increase the circulation of cash in the Project area and the perception of wealth, which, in turn, may also increase the demand for sex workers.

This Plan must include provisions for the influx monitoring, prohibition of at-gate hiring, ongoing engagement with the local communities and implementation of the grievance mechanism to identify and respond to concerns about workers' behaviour.

All workers will be expected to behave in accordance with the Company Code of Conduct that will be enforced through sanctions, including dismissal when appropriate. Finally, worker transportation will be provided to transfer workers to Lilongwe and other key communities, with pick-up and drop-off points designed, to minimise disruption to local residents.

The assessment of the significance of impacts without mitigation, recommended mitigation measures and the residual impact are summarised below:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Short-term	Local	High	Moderate	Likely	Moderate
Mitigation Measures					
• Develop and implement an Influx Management Plan. • Undertake monitoring of influx as part of the Project ESMP in consultation with local government, and continue to provide capacity building support and report on findings. • Communicate steps for hiring workers to local communities in a transparent manner. • Apply a mechanism to verify where job applicants come from (e.g. checking ID cards) so that jobs prioritised for members of local communities are not given to in-migrants. • Prohibit at-gate hiring to reduce the number of people waiting at and around the Project site. • Develop and implement education campaigns and capacity-building training to the employees and local communities on the dangers of alcoholism, drug abuse, domestic violence, prostitution and safe sex, in consultation with relevant government departments. • Implement the grievance mechanism to identify and respond to concerns about workers' behaviour. • Ensure all workers are aware of expectations to behave in accordance with the Company Code of Conduct that will be enforced through sanctions, including dismissal when appropriate. • Provide transportation for workers between the Project site and Lilongwe, as well as other key communities, with designed pick-up and drop-off points, to minimise disruption to local residents.					
Residual Impact					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Short-term	Local	Moderate	Low	Likely	Low

7.13.2.6 Unmet Expectations around Project Employment Opportunities and Other Social Investment Benefits

Over 90% of households in the villages surveyed reported unemployment as a key issue which impacts their quality of life (Section 5.15). For this reason, it is highly likely that local residents will view opportunities for direct and indirect employment created by the Project to be one of the major benefits.

Despite the Project's expressed commitment to local recruitment and training, expectations regarding employment opportunities will likely be significantly higher than what can be provided by the Project. As with many mining and other projects, unmet expectations may cause a sense of disappointment and frustration. If the recruitment process is not managed in a transparent manner, there may be misperceptions that job opportunities are disproportionately given to one segment of the population over another. Perceptions of eligibility may also cause tensions.

Apart from employment creation, the Project would be expected to contribute to community development and invest in local social infrastructure and/or services, as part of a Community and Social Development Strategy. Further tensions may also arise as a result of unmet expectations with respect to perceived tangible community benefits.

The assessment of the significance of impacts without mitigation, recommended mitigation measures and the residual impact are summarised as follows:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Short-term	Local	Moderate	Low	Highly Likely	Moderate
Mitigation Measures					
• Where possible, prioritises employment of people within and close to the Project footprint. • Communicate steps for hiring workers to local communities in a transparent manner. • Develop and implement a Community and Social Development Strategy in consultation with government. • Undertake joint consultation and planning with the affected population on identifying specific community investment activities (including an analysis of community specific needs). • Undertake joint consultation and planning with national and district authorities to understand development plans for the area. • Implement the grievance mechanism to identify and respond to concerns about employment and community development. • Ensure all workers are aware of expectations to behave in accordance with the Company Code of Conduct that will be enforced through sanctions, including dismissal when appropriate. • Provide transportation for workers between the Project site and Lilongwe, as well as other key communities, with designed pick-up and drop-off points, to minimise disruption to local residents.					
Residual Impact					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Short-term	Local	Low	Low	Highly Likely	Moderate

Residual Impact

Overall significance of the impact of unmet expectations around Project employment opportunities and other social investment benefits is assessed as moderate both before and after mitigation applied. This is explained by very high interest of the local residents towards employment opportunities, as well as any kind of community development activities undertaken in the area – overall poverty and unemployment levels are critical (AECOM, 2019a).

7.13.2.7 Inflationary Pressures Caused by Project-related Demand

Influx, procurement by the Project from local suppliers, and increased disposable incomes for Project employees during construction and operations phases have the potential to create inflationary pressures by increasing demand for local goods and services, thereby increasing the cost of living for local communities. Inflation can also be driven by increased expenditure of people who have received payments as part of the compensation process for land acquisition. Increase in prices without a corresponding increase in incomes can make goods and services unaffordable for some households and lead to increased risk of impoverishment, deteriorating standards of living, and food insecurity. Households that are cash poor and depend mainly on subsistence-based activities are particularly at risk and will be more vulnerable to inflationary pressures.

It is difficult to provide a precise evaluation of the impact on inflation as it is determined by many variables, with high levels of uncertainty. However, a key factor is that the Project site is in close proximity to markets in Likuni and Lilongwe from which goods could be transported to respond to increased demand. This limits the likelihood that increased demand could not be met by increased supply and that prices for products such as food and building materials would increase as a result.

Procurement by the Project of large quantities of local produce (e.g. vegetables for use in on-site catering) may result in a noticeable increase in prices for local people.

The assessment of the significance of impacts without mitigation, recommended mitigation measures and the residual impact are summarised below:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Medium-term	Regional	Moderate	Moderate	Highly Likely	High
Mitigation Measures					
• Develop and implement a Local Procurement Plan that must identify the types of products that may be limited in the local economy and avoid or minimise purchasing them at levels that could create inflation. • Monitor costs in local markets during construction and operations, and adapt procurement processes if marked inflation is observed.					
Residual Impact					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Medium-term	Regional	Low	Low	Highly Likely	Moderate

7.13.2.8 Reduced Amenity and Changes in Sense of Place

The construction and operation of the Project will have a number of impacts on the environment, such as noise, light disturbance, reduced air quality, and increased built environment and traffic flow. This will contribute to reduced amenity and change in the sense of place for local residents.

It is anticipated that during the construction phase machinery will operate 6 days a week (Monday to Saturday), generally during day-light hours. During the operations phase mining in open pits will be undertaken 5 days a week (Monday to Friday), and mostly during day-light hours. The processing plant will, however, be operational 24 hours per day, 7 days a week. This will contribute to increase in noise and reduced air quality in proximity to the Project infrastructure.

The noise study shows that cumulative noise intrusion during both construction and operation phases, when all the activities take place at once, are likely to be audible in Chitsulo, Kumalindi, Ndumila and Kubale, and is considered to be low with mitigation (refer section 7.11).

In addition, there will be increased traffic along the S124 access road and the alternate route to be constructed east of the S124, further contributing to reduced amenity and change in sense of place.

The assessment of the significance of impacts without mitigation, recommended mitigation measures and the residual impact are summarised below:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Long-term	Local	Moderate	Moderate	Highly Likely	High

Mitigation Measures					
• Implement recommended mitigation measures related to noise, air quality and visual impact. • Implement stakeholder engagement plan and grievance mechanism to identify and mitigate any community concerns.					
Residual Impact					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Long-term	Local	Low	Low	Highly Likely	Moderate

7.13.2.9 Community Disturbance, Increased Risk of Traffic Accidents and Damage to Roadside Structures and Livestock as a Result of Project Traffic Traveling Along the S124

During the construction and operations phases an increase in traffic along the S124 road is expected. This road will be the main transport route connecting the Project to Lilongwe and will be used for the transport of product, consumables and personnel.

Existing vehicle traffic in the Project area is limited and the main forms of traffic include pedestrians, bicycles, animal-drawn carts, and livestock. Local communities in and near the Project typically walk to key social infrastructure such as schools, markets and health centres, and many take their livestock to the Kamuzu Reservoir to drink water and graze. There is very low presence of cars, buses, trucks and large goods vehicles, and as such the local community are not as accustomed to seeing and interacting with these types of vehicles, as they are likely to be in more urban areas like Likuni or Lilongwe.

Between five and six return-trips per day by large trucks are expected as part of the Project. In addition, a limited number of light motor vehicles, delivery trucks and vehicles, and buses for transport of personnel. The increase in traffic flow of larger vehicles, resulting from Project construction and operational activities, will impact local road users and those receptors living and working alongside the S124 road in a number of ways:

- Increase in noise and dust creation.
- Increase in traffic and journey times.
- Disruption to businesses and day to day activities (e.g. livestock rearing).
- Accidental damage to community assets, crops and livestock which may lead to temporary loss of income.
- Potential injuries to existing road users.

Those receptors living or working directly alongside the S124 will be more adversely impacted.

The assessment of the significance of impacts without mitigation, recommended mitigation measures and the residual impact are summarised below:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Long-term	Regional	Moderate	Moderate	Highly Likely	High
Mitigation Measures					
• Develop and implement a Traffic Management Plan that includes safety measures such as a signals network, driving rules, community awareness raising programmes, and the process of managing and rectifying cases where road users or local residents are injured as a result of Project traffic. • Ensure Project drivers are licensed according to national law. • Restrict speed of vehicles on roads in proximity to villages. • Ensure vehicles are well maintained					

• Implement recommend mitigation measures related to noise and air quality from Project traffic. • Implement stakeholder engagement plan and grievance mechanism to identify and remedy any temporary disturbance and accidental damage.					
Residual Impact					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Long-term	Regional	Low	Low	Likely	Moderate

7.13.2.10 Injury or Death as a Result of Unauthorised Access to Unfenced Project Areas

Key Project security provisions will include perimeter fencing installed around the processing plant and mine services area. Fences will be galvanised fence poles concreted into the ground with galvanised chain-wire security type mesh of approximately 2.1 metres high, with 3 strands of barbed wire at the top of the fence. However, certain Project areas (e.g., the open pits and the TSF) will remain unfenced due to their significant spatial extent.

Electronic gate control will be installed at the processing plant gatehouse. In addition, closed-circuit television (CCTV) will be used in and around key facilities. A team of security personnel will be hired to patrol infrastructure areas and ensure unauthorised access to the Project is prevented.

As the Project has never been used for industrial or mining activities before, the local population is unlikely to be accustomed to the safety aspects and adjustments required to avoid potential hazards related to alteration of the local terrain through the earthworks/excavations, establishment of industrial facilities, utilities, power transmission lines, the presence of mobile and stationary equipment and machinery. This creates a significant risk of accidents if there is unauthorised access to the unfenced areas for any kind of purpose (e.g., purely out of curiosity, with intention to find something valuable that might be further practically used or sold, attempting to undertake artisan small-scale mining[2], etc.). Such cases have a potential to lead to health and safety incidents, i.e. unintentional injuries and fatalities.

The assessment of the significance of impacts without mitigation, recommended mitigation measures and the residual impact are summarised below:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Long-term	Site-specific	Very High	High	Likely	High
Mitigation Measures					
• Develop and implement a Community Health and Safety Management Plan that will identify areas where there is a risk of unauthorised access to hazardous work sites. • Implement appropriate measures to prevent access to potentially hazardous areas, including fencing, barricades and signage. • Undertake regular security patrols around areas where access can more easily be achieved. • Engage with community members to inform and educate them on the safety risks resulting from Project activities. • Clearly demarcate access points and walkways for workers and community members. • Investigate all safety incidents involving community members as soon as practical and revise the Community Health and Safety Management Plan as required. • Implement stakeholder engagement plan and grievance mechanism to identify and address any safety concerns.					

[2] A number of people living in villages near the Lilongwe River are involved in sand mining and brick-making activities. Women and children are also involved in sand mining, mainly as 'runners' which involves emptying and stock-piling sand and taking buckets back to the men. The sand is then sent by truck to Likuni and Lilongwe. This means there is a risk that the locals may try to explore the newly excavated pits for any kind of valuable material they could mine and further use/sell.

Residual Impact					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Long-term	Site-specific	Moderate	Moderate	Unlikely	Moderate

Residual Impact

The pre-mitigated impact is assed as very high in magnitude and high in consequences (considering fatalities could occur as a worst case scenario). Mitigation will to an extent decrease the risk of fatalities and serious injuries. However, given the remaining critical proximity of the residential areas to the unfenced and significantly spatial areas with ongoing mining activities, it is possible that serious injuries could still occur, depending on specific site conditions and the level of general public interest towards new activities happening in the area.

7.13.2.11 Risk of Conflict and Tension Due to the Presence of Security Services

Due to certain Project areas being unfenced (e.g. the open pits and TSF), security personnel regularly patrolling the area will play an important role in minimising health and safety risks from unauthorised access by the community members to these sites, as well as to prevent theft. There is the risk of conflicts and tension between community members and the security staff, as well as potential for injuries that may occur if disproportionate force is used by the security guards. Without mitigation, the use of security personnel could lead to abuses against members of the public. Residents living within the immediate vicinity of the Project's main facilities would typically be most vulnerable to this impact (i.e., residents of Kumalindi, Katawa, Chitsulo, Ndumila (both I and II), Mbonekera, Kubale, Chikalima and Chikhosi).

The assessment of the significance of impacts without mitigation, recommended mitigation measures and the residual impact are summarised as follows:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Long-term	Site-specific	Moderate	Moderate	Unlikely	Low
Mitigation Measures					
• Develop and implement a Security Management Plan and a 'Policy on Acceptable Use of Force'. • All security personnel must be vetted and trained to the international standards as outlined in IFC PS4. • Security personnel will only have responsibility for securing the Project sites and will not operate in local communities. • Refer any incident that requires activity outside of the Project site to local police. • Investigate all security incidents on the Project site in association with local police, and revise the Project's overall approach to security, where necessary. • Implement grievance mechanism to identify and address any security concerns.					
Residual Impact					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Long-term	Site-specific	Low	Low	Unlikely	Low

7.13.2.12 Risk of Inappropriate Labour Practices

There will be a wide range of general labour and working conditions and activity-specific occupational health and safety (OHS) risks associated with all stages of construction and operation. These risks will vary between different construction activities.

Child labour is present throughout Malawi, and common sectors where it is usually observed include agriculture, forestry, hunting, fishing, and construction (brick-making). There is a risk that child labour may be used by companies supplying goods or services to the Project. Typically, the lower down in the 'subcontractor hierarchy' a contractor, the greater the potential for use of child labour due to challenges associated with direct control and monitoring by the Project company. Indirectly, the Project-induced influx may lead to a potential increase in involvement of children in their families' small business activities (e.g. selling tobacco or snacks to the newcomers).

In order to manage OHS risks and potential poor working conditions, the Project will implement a comprehensive health and safety management system. The management system is designed to ensure that OHS risks associated with all construction and operations activities are appropriately identified and controlled.

The control over OHS risks associated with both routine operations and major accident hazards has also been considered as an integral part of the Project feasibility studies. The Project will comply with OHS provisions of the IFC General EHS Guidelines, including provision of OHS induction training to all new employees to ensure they are apprised of the basic site rules of work at/on the site and of personal protection and preventing injury to fellow employees.

The assessment of the significance of impacts without mitigation, recommended mitigation measures and the residual impact are summarised below:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Long-term	Local	Moderate	Moderate	Highly Likely	High
Mitigation Measures					
• Develop a comprehensive health and safety management system compliant with OHSAS 18001, including an Occupational Health and Safety (OHS) Plan • Ensure compliance with OHS provisions of the IFC General EHS Guidelines, including provision of an OHS orientation training to all new employees. • Provision of OHS induction to all new employees and visitors to the site. • Undertake regular OHS training for all employees. • Provide appropriate personal protective equipment (PPE) to all personnel. • Ensure hiring practices adheres to the minimum specified age for potential Project employees. • Undertake selective due diligence of contractors and suppliers to ensure that the Project does not inadvertently support child labour, and ensure wording to this effect is included in terms and conditions of all contractual agreements.					
Residual Impact					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Long-term	Local	Low	Low	Likely	Low

7.13.3 Decommissioning Phase Impacts

7.13.3.1 Dependency on the Project to Sustain the Local Economy

While the Project will likely contribute significantly to economic development and diversification through its lifetime, these positive effects also have an adverse aspect, in that the mine will inevitably close, and this can have significant consequences for an area that has not invested in economic diversification.

A considerable number of people and their families will likely become increasingly dependent on the Project for their livelihood. Employment opportunities associated with the proposed Project will be lost at closure, as will be the corresponding project benefits such as community development programmes (if undertaken).

Retrenchment before the end of life of the Project is another possibility and could be necessitated by downscaling as a result of external forces such as reduced profitability, commodity price fluctuations and technical innovation. At such a time, Project employees may not be able to secure alternative employment. Job losses and retrenchment would lead to a loss of income and local expenditure. Unemployed staff may be unable to pay for loans on houses, education, or service their debts on cars and other acquired assets. Taking into consideration the likely dependency on employee income, the loss of income will have considerable negative impact on the wellbeing of households where employees were the sole breadwinners.

Suppliers could also be affected as the opportunity to sell goods and services to the Project will be lost. This could furthermore affect those companies that supply these businesses with goods and services. This impact will mostly be felt by suppliers at a local and district level. Economic downturn and the resultant loss of employment could also result in increases in social pathologies, such as crime, prostitution and substance abuse.

The decommissioning impacts will be considered as part of a Decommissioning Plan that will be developed by the Project a minimum of two years in advance of the decommissioning activities. The Plan will include a decommissioning supplementary social impact assessment and provisions for a stakeholder consultation process.

The assessment of the significance of impacts without mitigation, recommended mitigation measures and the residual impact are summarised below:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Long-term	Regional	Moderate	Moderate	Almost Certain	High
Mitigation Measures					
• Develop a comprehensive Decommissioning Plan. • Identify critical issues which could affect the on-going sustainability of employee livelihoods and communities during closure, by means of a detailed consultation process. • Identify alternative livelihood and socio-economic development opportunities for employees, as well potentially sustainable community-based development projects. • Provide assistance and/or support for the establishment of sustainable community projects. • Develop employee training programs to enable transitioning to alternative employment opportunities. • Prior to implementing any collective dismissals, carry out an analysis of alternatives to retrenchment. If the analysis does not identify viable alternatives to retrenchment, develop a retrenchment plan to reduce the adverse impacts of retrenchment on workers. The retrenchment plan will be consistent with requirements of the IFC PSs and GIIP, will be based on the principle of non-discrimination and will reflect the Project’s consultation with workers, their organisations, and, where appropriate, the government.					
Residual Impact					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Short-term	Regional	Low	Low	Likely	Low

7.14 Cultural Heritage Resources

The Project will result in irreversible disturbance to some of the archaeological and other cultural heritage sites identified in the project area. The land transformation activities during the development of access roads, clearing of vegetation and demolition of infrastructure for the development of mining facilities, and mining operations are likely to directly and indirectly impact on the historical and archaeological sites, burial grounds and sacred communal gathering places (bwalos), and other intangible cultural values found within the project area. Accidental or intentional disturbance to these sites will have detrimental effects on the local communities, who value this heritage highly.

Unintended damage to burial grounds and sacred communal gathering places is likely to affect local communities if no adequate rituals and reburial ceremonies are carried out in consultation with the local communities.

7.14.1.1 Disturbance of Archaeological Sites

The cultural heritage resources within Project footprint are at risk of being damaged through direct impacts, especially the direct loss of archaeological sites due to permanent removal from their original setting.

During construction direct impacts are foreseen on the archaeological sites MGP1, MGP3, MGP4 and MGP5, mainly Iron Age Sites containing, as well as the grave of Gogo Nkhungulo (refer to Section 5.14.5 for location).

Heritage resources within 150 metres from the mining infrastructure that could be indirectly impacted during the operations phase include the following:

- Burial ground
  - Mbonekera burial ground and forest
  - Ndumila 1 burial ground
  - Kubale burial ground
- Bwalos
  - BWAL007

The assessment of the significance of impacts without mitigation, recommended mitigation measures and the residual impact are summarised as follows:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Permanent	Site-specific	Moderate	Moderate	Almost Certain	High
Mitigation Measures					
• Undertake subsurface probing (test pitting at intervals) of archaeological sites of MGP1 and MGP3-5 to adequately assess their significance and integrity. • Avoid disturbance of archaeological sites and graves within the proposed Project area and beyond the disturbance footprint where possible. • Demarcate and place a buffer of 50 m around sites to be avoided, where practicable. • Follow all procedures for preservation and protection of sites and artefacts of archaeological significance, specified by the Monuments and Relics Act, 1991. • Undertake clearing of sites within the Project disturbance footprint in accordance with the required permits. • Relocate graves that cannot be avoided in accordance with the requirements of the Monuments and Relics Act, 1991 and Public Health Act, 1968. • Adhere to local customs in the event of the relocation of graves. • Undertake consultation with relevant stakeholders prior to commencing relocation. • Develop and implement Chance Finds Procedure as part of a Cultural Heritage Management Plan.					
Residual Impact					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Short-term	Site-specific	Low	Low	Likely	Low

7.14.1.2 Interruption of Access to Cultural Heritage Sites

Indirect impacts may be experienced in the event that the exclusion zone prohibits access to cultural activities such as the sites of churches, burial grounds, ceremonial places (bwalo) and the dambwe (sacred forest areas) of Mbonekera and Ndumila I. However, it is unlikely that access to any of these sites would be prohibited and activities would be allowed to continue with the consent of the Company, although access would need to be managed to avoid potential safety incidents at nearby infrastructure and open pits.

Any suspension of the use of the forests for burial and as dambwe (although not planned as part of the Project) will have a significant influence of the social fabric and intangible heritage of the communities that will be relocated. Implementing a negotiated and mutually agreed upon access protocol that will enable communities to have open access to their forests and burial grounds for cultural ceremonies.

The assessment of the significance of impacts without mitigation, recommended mitigation measures and the residual impact are summarised below:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Long-term	Site-specific	High	Moderate	Almost Certain	High
Mitigation Measures					
• Avoid disruption of access to cultural heritage sites in proximity to the Project area, where possible. • Provide alternative access to sites where disruption of access is unavoidable. • Develop and implement Cultural Heritage Management Plan.					
Residual Impact					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Long-term	Site-specific	Moderate	Moderate	Likely	Moderate

7.15 Visual Impact

An assessment of the visual impact was undertaken by SMEC as part of the ESIA. The visual impact assessment relies on the evaluation of a wide range of criteria, both quantitative (such as viewing distances), and qualitative criteria (such as sense of place). Considering the context of the immediate surroundings of the observer and the visual absorption capacity of the landscape, the visual impacts of the proposed Project will vary from one location to the next. By implication impact ratings will also vary, as is demonstrated by the VIA Index (refer to section 7.15.3).

There are no nature reserves or public places in the immediate vicinity of the Project attracting people by virtue of scenic visual amenities. The character of the landscape as largely a rural agricultural area with dispersed villages whose residents are closely linked to associated agricultural activities, is indicative of a transformed environment with little scenic resources and no individuals or organisations who depend on scenic and recreation resources for their livelihood. However, there is some degree of peacefulness and quietness in landscape where qualities such as clean air and the absence of noise are enjoyed. These qualities are sensitive to the introduction of visual amenities that are different to the current visual environment.

The VIA identified distinct day-time and night-time impacts. Day-time impacts are influenced by situational awareness and visual absorption capacity of the area surrounding the observer. Night-time impacts are directly linked to light pollution and associated nuisance effects.

Given the diversity of possible exposures to the proposed Project a quantified evaluation of impacts is based on a worst-case scenario, i.e. partial or full exposure of mine components or parts thereof.

7.15.1 Visual Exposure

Given the large spatial dimensions of the TSF, the processing plant and stockpiles, these components will become prominent features in the landscape, being representative of the Project as a whole. Viewshed analyses were undertaken to determine the level of visual exposure, based on the layout and design information from the PFS.

The focus was on an analysis of each component to quantify the degree of change within the visual landscape. A viewshed analysis of each component before and after construction was compiled and the results processed into a 'magnitude of change model' to determine the locations of possible high visual exposure (SMEC, 2019).

7.15.1.1 Visual Exposure of the TSF

The TSF is situated near the eastern boundary of Chitsulo village, some 250 m from the S124 road. It is a large feature with a footprint of 46 ha and a height of approximately 29 m above ground level at the lowest point, with the upstream wall raise at an elevation of 1,146.5 mamsl.

The magnitude of change in exposure of the TSF location is calculated as the difference between the current level of exposure and total exposure of the TSF. This will affect 43% of the study area. Users of the S124 main road and residents of the Kumalindi village will be exposed to views of the TSF protruding above the horizon at the location of this facility. Locations on high ground to the west and to the east of Lilongwe River will have full views of the TSF (SMEC, 2019).

7.15.1.2 Visual Exposure of the Stockpiles

The ore stockpiles are situated north of the pits, with a total footprint of 15.4 ha and a height of 10–20 m above ground level.

The change in exposure of the stockpile are will affect 36% of the study area. The stockpile will be shielded by the plant and the TSF to some degree. It will be visible in parts of Chitsulo village and from agricultural fields around the site, especially from high ground to the west (SMEC, 2019).

7.15.1.3 Visual Exposure of the Processing Plant

The processing plant is situated between the stockpiles and the TSF and has a total footprint of close to 8 ha. It will consist of various processing components with the concentrate dryer and stack (29.5 m above ground) being prominent. Being the tallest feature, the position and height of the stack was used in the viewshed analysis.

The change in exposure will affect 60% of the study area. The plant will be highly visible from large parts in the study area especially to the north, east and south, with vertical intrusion of the skyline being dominant in the field of view (SMEC, 2019).

The combined magnitude in change of all the components is illustrated in Figure 7.31.

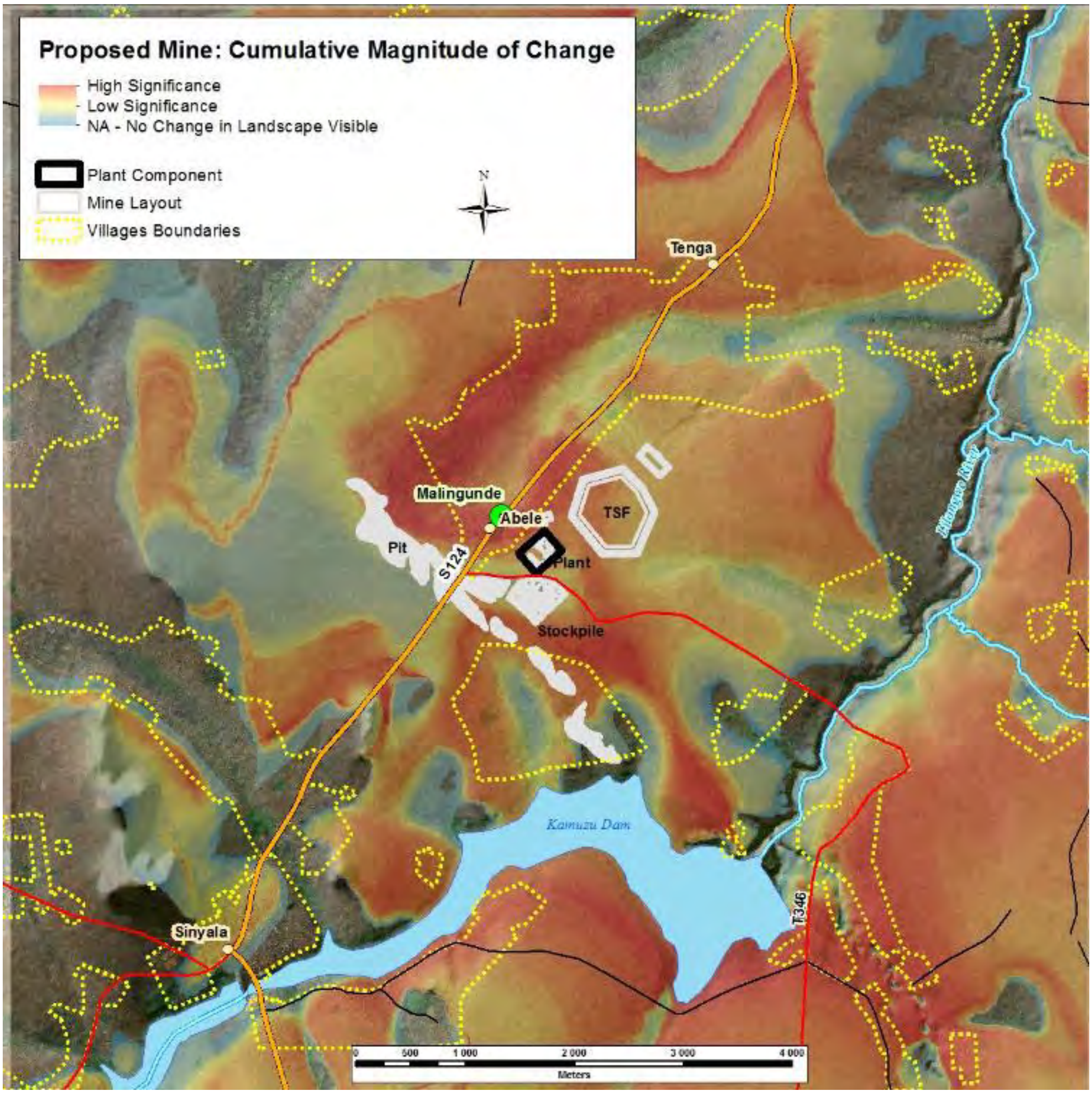

Figure 7.31: Magnitude of Change in the Landscape for all Viewsheds

7.15.2 Proximity Analysis

Visibility of the Project is, apart from the exposure to components thereof, also a function of the distance from or proximity to it. This implies that visual impact will decline with increased distance from the Project. An analysis of this concept shows that the degree of visibility declines at an exponential rate with more than 50% within 25% of the measured distance units from an object in the landscape.

Visual intrusion also diminishes with scenes of higher complexity, e.g. vegetation and other structures in the foreground. As distance increases, the object becomes less of a focal point (more visual distraction), and the observer's attention is diverted by the complexity of the scene.

The following proximity buffers and associated impact zones were defined as part of the VIA:

- 500 m and closer: Very high intrusion
- 500 m – 1,000 m: High intrusion
- 1,000 m – 2,000 m: Moderate intrusion
- 2,000 m – 5,000 m: Low intrusion

7.15.3 Visual Impact Index

The visual impact index is the product of the cumulative viewshed analyses and proximity analysis and is based on the integration of visual exposure levels with distance values of the proximity analysis to arrive at a more realistic differentiation of possible visual impacts. The visual impact index is the product of visual exposure and proximity, thereby giving a unique pattern of severity of change of the visual landscape (Figure 7.32).

The visual impact index is further integrated with sensitive observer locations to determine the spatial extent of possible visual impacts. High visual impacts can be expected in the immediate surroundings of the Project (± 500 m) and further west on higher ground (± 1,000 m). See Figure 7.33.

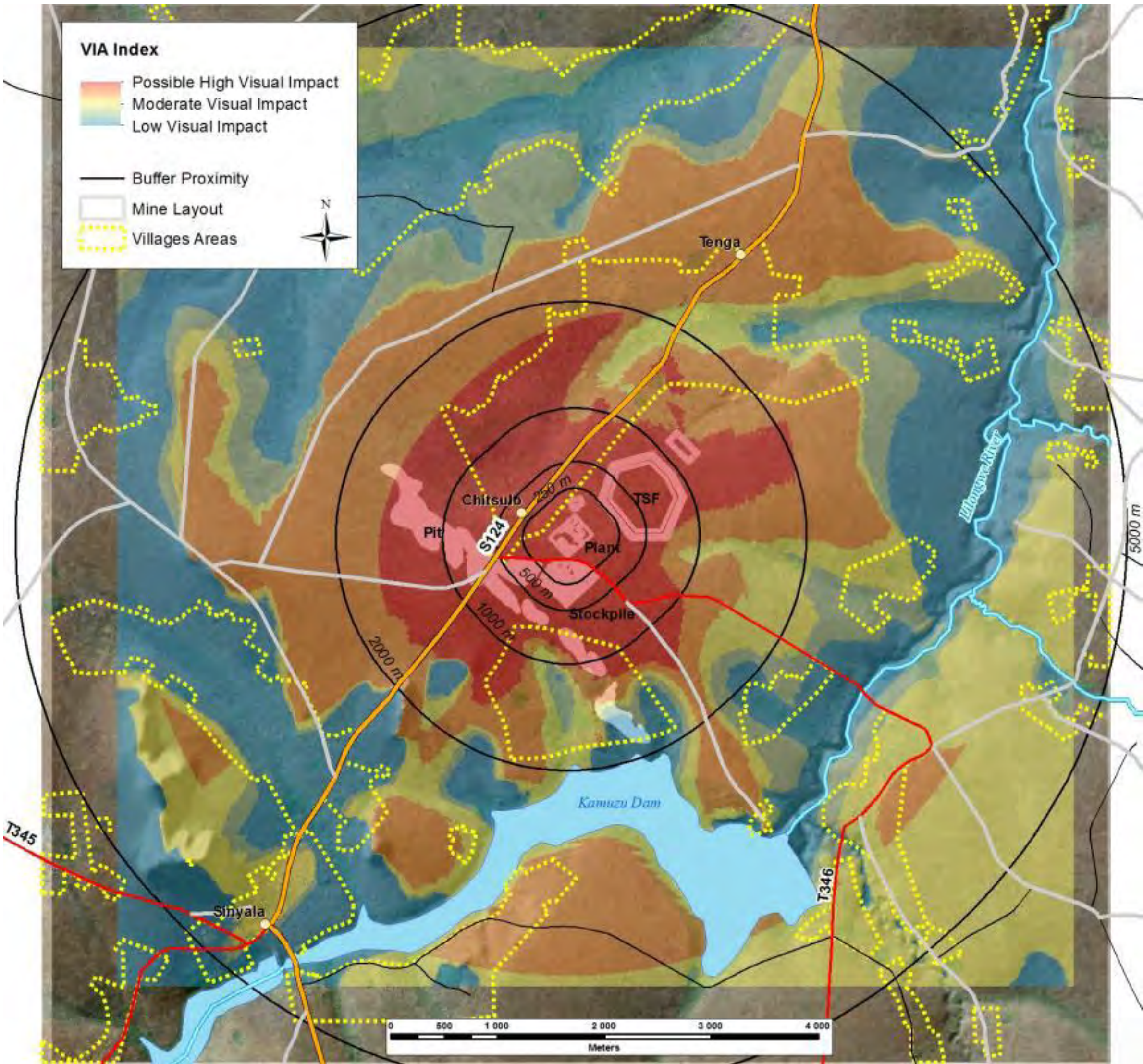

Figure 7.32: Visual Impact Index (Exposure x Proximity)

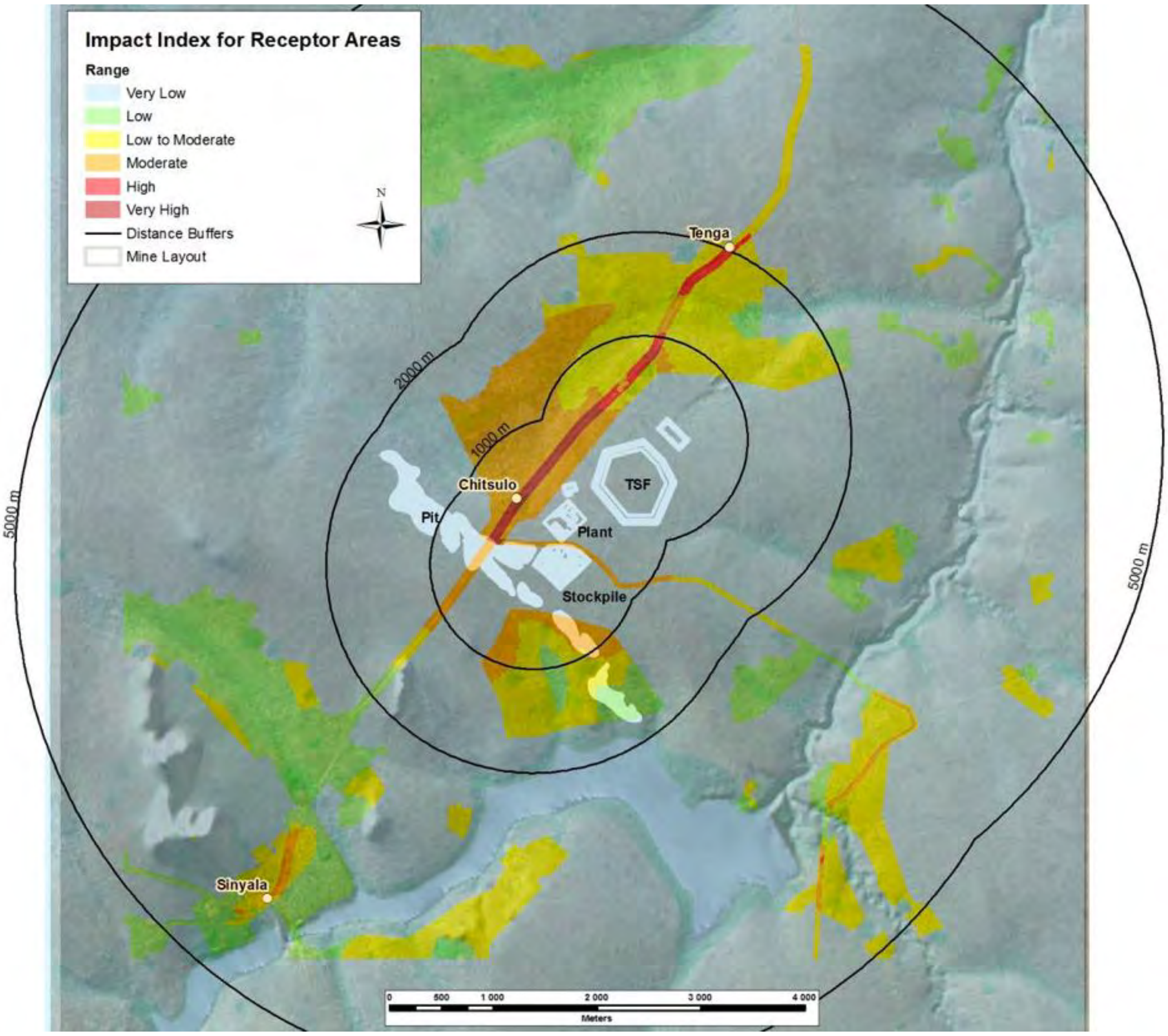

Figure 7.33: Visual Impact Index Applied to Possible Sensitive Receptor Areas

7.15.4 Assessment of Impact Significance

The magnitude of change in visual exposure of the Project site, as a percentage change in visibility of the location before and after construction was determined to be:

Mine Component	% change from 0 visibility to >0 visibility
TSF	43
Processing Plant	60
Stockpiles	36

Visual exposure, and by implication visual impact, will be high to very high within a 1 km radius from the Project. Affected parties include users of the S124 road and residents in adjacent and nearby villages who are not screened by vegetation or structures. Although visibility of the Project is possible across the region, the effect of declined impact with increased distance needs to be considered. Therefore, the impact is expected to be local.

The visual landscape within the study area is characterised by a combination of rural agricultural and rural residential land use activities. There are no mining and industrial activities in the broader region and it is likely that residents in local villages have never seen a mine, have they not travelled. The establishment of mining activities will introduce a new visual experience with a high level of change in the sense of place (genus loci).

Visual impact will range from very high to low in accordance with the visual impact index. In context of the location and concentration of possible sensitive observers in villages and on roads, a high-level impact for these areas can be expected within a range of 1–2 km from the Project.

An interpretation of concerns raised during the stakeholder engagement process is further taken into account to interpret the implications for the Project. No concerns about visual impact were raised; however, concerns raised about noise and dust (which is visual in part) are indicative of some degree of sensitivity.

The visual absorption capacity of vegetation and structures in villages is sufficient to lower the probability of visual impacts from within these areas.

The assessment of the significance of impacts without mitigation, recommended mitigation measures and the residual impact are summarised as follows:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Permanent	Local	Moderate	Moderate	Almost Certain	High
Mitigation Measures					
• Ensure progressive rehabilitation and vegetation of stockpiles and cleared areas takes place. • Develop natural mechanisms of preserving aesthetics and visual setup including leaving individual trees in cleared areas. • Use muted, natural colours that blend in with the environment on painted surfaces, where practicable.					
Residual Impact					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Long-term	Local	Low	Low	Likely	Low

7.15.5 Night-time Lighting Impact

Night-time outdoor lighting will be required, particularly around the processing plant area, providing for necessary operational and security requirements. Light pollution resulting from the illumination of the Project area is a by-product with possible adverse impacts. The current night time experience in the area is characterised by quiet dark nights, given the absence of electricity and very little activity given the darkness of the environment. Night time human activity is limited to occasional drivers on the roads and social gatherings, e.g. at tea rooms and brew houses. It is expected that the introduction of outdoor lighting at the mine will contrast with the current night-time experience and should therefore be considered in the final design and construction of the mine infrastructure.

The level of light, or illumination of the environment, that is needed for different situational settings will vary upon the circumstances. The expected lux (lx) levels of between 5 lx (for pedestrian walkways) and 200 lx (for demanding electrical, machine and piping installations), as described by European Standard EN 12464-2 (CEN, 2007) will be in stark contrast with the current night time level of <=1 lx in the area.

Night-time impacts of light pollution in areas close to the processing plant are serious enough to cause concern. Specific changes to project design should be considered with regard to the mitigation of these impacts.

The assessment of the significance of impacts without mitigation, recommended mitigation measures and the residual impact are summarised below:

Impact without Mitigation					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Permanent	Local	Moderate	Moderate	Almost Certain	High
Mitigation Measures					
• Design effective lighting system to ensure safe visual working environment, taking due consideration of compliance to standards. • Implement the use of down lighting to minimise light pollution. • Utilise security lighting that is movement activated rather than permanently switched on, to prevent unnecessary constant illumination, where possible. • Avoid up-lighting of structures. • Discourage vehicle movement on access roads between sunset and sunrise.					
Residual Impact					
Duration	Extent	Magnitude	Consequence	Probability	Significance
Long-term	Local	Low	Low	Likely	Low

7.16 Summary of Impacts

Table 7.29 provides a summary of the impacts assessed, along with its anticipated impact before and after implementation of mitigation measures.

Table 7.29: Summary of Identified Impacts

Receiving Environment	Impact	Phase	Pre-mitigation Impact	Post-mitigation Impact
Soils	Loss of Topsoil through Erosion	Construction Operations Decommissioning and Closure	Very High	Low
	Reduction in Soil Fertility	Construction Operations	Very High	Moderate
	Compaction of Soil	Construction Operations	High	Low
	Loss of Land Capability and Use	Construction Operations	High	Low
	Contamination of Soil	Construction Operations Decommissioning and Closure	High	Very Low
Soil, Surface Water and Groundwater	Potential for Acid Mine Drainage	Operations Decommissioning and Closure	Moderate	Very Low
Biodiversity	Disturbance to Vegetation Communities	Construction Operations	Low	Low
	Loss of Biodiversity	Construction Operations	Moderate	Low
	Loss of Flora Species of Concern	Construction Operations Decommissioning	Low	Very Low
	Loss of Fauna Species of Conservation Concern	Construction Operations	Moderate	Low
	Impact on Local Fauna Migrations	Construction Operations Decommissioning	High	Low
	Competition by Invasive Species and Exotic Fauna	Construction Operations Decommissioning	High	Low

Receiving Environment	Impact	Phase	Pre-mitigation Impact	Post-mitigation Impact
	Loss of Ecosystem Services Provided	Construction Operations	High	Low
Wetlands	Erosion Impacts to Dambos	Construction Operations	Moderate	Low
	Sedimentation of Wetlands	Construction Operations Decommissioning	Moderate	Low
	Changes in Hydrology due to Discharge of Water	Construction Operations	Moderate	Very Low
Aquatic ecology	Change in Integrity of Aquatic Habitat and Instream Biota	Construction Operations	High	Low
	Loss of a Portion of the Kovuma and Dambo 1 Habitat Resulting in the Loss of In-stream Biota	Construction Operations	High	Moderate
	Loss of In-stream Biota due to Deterioration of Water Quality	Construction Operations Decommissioning	Moderate	Very Low
Surface water	Deterioration in Water Quality of Surface Water Resources	Construction Operations Decommissioning	High	Low
	Impact on Water Runoff	Construction Operations Decommissioning	High	Low
Groundwater	Reduction in Groundwater Availability	Construction Operations	Very High	Very Low
	Contamination of Aquifers	Construction Operations	High	Low
Air Quality	Increase in Total Suspended Particles, PM_{10} and $PM_{2.5}$	Construction Operations	High	Low
	Increase in SO_2, NO_2, CO	Construction Operations	High	Very Low
Noise	Noise Intrusion During Construction Phase	Construction	Low	Very Low
	Noise Intrusion from Northern Pits and Processing Plant	Operations	Moderate	Low
	Noise Intrusion from Pits in Vicinity of S124 Road and Processing Plant	Operations	High	Low
	Noise Intrusion from Pit O and Processing Plant	Operations	High	Low
	Noise Intrusion from Pits P & Q and Processing Plant	Operations	High	Low
	Noise Intrusion from Southern Pits and Processing Plant	Operations	High	Low
	Noise Impact from Road Traffic	Construction Operations	Moderate	Low
Visual Amenity	Visual Impact	Construction Operations	High	Low
	Night-time Lighting Impact	Construction Operations	High	Low
Health Risk	Human Health Impact from Inhalation Exposure to Criteria Pollutants	Construction Operations	High	Low
	Non-cancer (Systemic) Health Impact from Inhalation Exposure to Particle-associated Arsenic and Nickel	Construction Operations	High	Low
	Increased Cancer Incidence from Inhalation Exposure to Particle-associated Arsenic and Nickel	Construction Operations	Very Low	Very Low

Receiving Environment	Impact	Phase	Pre-mitigation Impact	Post-mitigation Impact
	Human Health Impact from Exposure to Contaminated Drinking Water	Operations Decommissioning and Closure	Very Low	Very Low
Community / Social	Loss of Residence from Physical Displacement Caused by Land Acquisition	Construction	Very High	Moderate
	Economic Displacement Caused by Loss of Cultivated Land, Loss of Grazing and Business Assets	Construction	Very High	Moderate
	Loss of Access to Boreholes and Community Assets within the Project Area	Construction	Very High	Moderate
	Loss of Local Access Roads and Tracks	Construction	Moderate	Low
	Social Stress as a Result of Uncertainty about the Project and its Potential Impacts	Construction	Moderate	Low
	Exacerbation of Issues Regarding Financial Control and Gender Inequality in Local Communities	Construction	Moderate	Low
	Reliance on and Subsequent Loss of Income from Fixed-term Employment During Construction	Construction	Moderate	Low
	Project-induced Migration (Influx)	Construction Operations	High	Low
	Presence of Project Workers Leading to Decreased Community Wellbeing	Construction Operations	Moderate	Low
	Unmet Expectations around Project Employment Opportunities and Other Social Investment Benefits	Construction Operations	Moderate	Moderate
	Inflationary Pressures Caused by Project-related Demand	Construction Operations	High	Moderate
	Reduced Amenity and Changes in Sense of Place	Construction Operations	High	Moderate
	Community Disturbance, Increased Risk of Traffic Accidents and Damage to Roadside Structures and Livestock as a Result of Project Traffic Traveling Along the S124	Construction Operations	High	Moderate
	Injury or Death as a Result of Unauthorised Access to Unfenced Project Areas	Construction Operations	Moderate	Low
	Risk of Conflict and Tension Due to the Presence of Security Services	Construction Operations	Moderate	Low
	Risk of Inappropriate Labour Practices	Construction Operations	High	Low
	Increased Incomes from Project Employment Leading to Improved Individual and Household Wellbeing	Construction Operations	Moderate	Moderate
	Multiplier Effects on the Local Economy and Economic Opportunities for Entrepreneurs and Small Businesses	Construction Operations	Moderate	Moderate
	Increased Government Revenue through Royalties and Taxation	Operations		Moderate
	Dependency on the Project to Sustain the Local Economy	Decommissioning	High	Low
Cultural Heritage	Disturbance of Archaeological Sites	Construction Operations	High	Low

Receiving Environment	Impact	Phase	Pre-mitigation Impact	Post-mitigation Impact
	Disturbance of Places of Worship	Construction Operations	Very High	Low
	Interruption of Access to Cultural Heritage Sites	Construction Operations	High	Moderate

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Chapter 8: Management and Monitoring Framework

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8 Management and Monitoring Framework

8.1 Environmental and Social Management Framework

In keeping with the requirements of the IFC Performance Standards on Environmental and Social Sustainability (2012) and the Equator Principles (2013, Sovereign has commited to developing an environmental and social management system (ESMS) that will cover all activities related to the Malingunde Project, as well as its general business activities and practices in Malawi.

Specifically, Paragraph 5 of IFC *Performance Standard 1: Assessment and Management of Environmental and Social Risks and Impacts* states that:

> *The client, in coordination with other responsible government agencies and third parties as appropriate, will conduct a process of environmental and social assessment, and establish and maintain an ESMS appropriate to the nature and scale of the project and commensurate with the level of its environmental and social risks and impacts. The ESMS will incorporate the following elements: (i) policy; (ii) identification of risks and impacts; (iii) management programs; (iv) organizational capacity and competency; (v) emergency preparedness and response; (vi) stakeholder engagement; and (vii) monitoring and review.*

In addition, Principle 4 (*Environmental and Social Management System and Equator Principles Action Plan*) of the Equator Principles states that Equator Principles Financial Institutions (EPFI) require the development of an ESMS for projects being funded which potentially have significant adverse environmental and social risks and impacts.

The ESMS will be updated periodically at appropriate points in the business cycle and over the life-of-mine to ensure that it addresses changes in the Company's operations and remains relevant.

8.2 Environmental and Social Management Plan

As part of the detailed design and planning of the Project, Sovereign will develop a comprehensive environmental and social management plan (ESMP). The ESMP translates the recommended mitigation measures into specific actions that will be carried out by the Project. The aim of the ESMP is to assist in delivering the intended environmental and social outcomes during the construction, operations, and decommissioning and closure phases of the Project.

The ESMP is a dynamic document and will be amended on a regular basis to reflect any changes on site or new and more effective mitigation measures.

A range of policies, management plans, protocols and procedures to manage the environmental and social impacts of the Project will be implemented. Over the life of the Project, this will consist of the Construction Environmental Management Plan (CEMP), Operations Enviornmental Management Plan (OEMP) and Rehabilitation and Closure Management Plan (RCMP) which will be developed and implemented.

The ESMP will consist of a number of individual sub-plans that are based on the key environmental and social aspects identified during the assessment of impacts. Although these are separate plans, they are interrelated and form part of the overall ESMP, and will be implemented as such. These sub-plans include, but are not limited to:

- Topsoil and Erosion Management Plan.
- Water Management Plan.
- Materials and Waste Management Plan.
- Terrestrial and Aquatic Biodiversity Management Plan.
- Wetland Management Plan.
- Exotic and Invasive Species Management Plan.

- Air Quality Management Plan.
- Noise Management Plan.
- Aesthetic and Visual Impact Management Plan.
- Community Health and Safety Management Plan.
- Social Impact Management Plan.
- Resettlement Action Plan.
- Livelihood Restoration Plan.
- Cultural Heritage Management Plan.
- Emergency Preparedness and Response Plan.
- Rehabilitation and Closure Management Plan.

All management plans will contain specific measures, standard operating procedures (SOPs) and company practices to prevent or mitigate the environmental or social impacts that are the focus of a specific plan. These plans will also detail the monitoring requirements for each plan, procedures for identifying non-conformances and the process for resolving these.

The SOPs will provide specific guidance and instructions to employees on the execution of specific activities. These SOPs will be developed with a level of detail commensurate with the complexity of the task, and will take cognisance of the literacy levels, skills and capabilities of the workforce.

8.3 Organisational Structure and Responsibilities for Implementation of the ESMP

All employees are individually and collectively responsible for:

- Supporting the ESMP for the Project by implementing relevant operating procedures and work place practices in day-to-day activities to minimise environmental social impacts.
- Working safely in compliance with Sovereign's workplace health and safety policy and practices, to ensure workplace incidents are minimised.
- Identifying environmental, health and safety issues, incidences and non-conformances and reporting these in keeping with Sovereign's procedures.

During construction and prior to operation Sovereign Management will appoint senior personnel with defined responsibility and authority to ensure the ESMS and ESMP are established, implemented and maintained. Management staff will have specific defined roles and responsibilities in relation to the management of environmental and social aspects, as well as occupational health and safety.

Lines of authority, responsibility and accountability will be established throughout the company by specifying and documenting the scope of area or activity under the control of each functional area or individual.

The key operational roles are indicated in the organisational diagram in Figure 8.1.

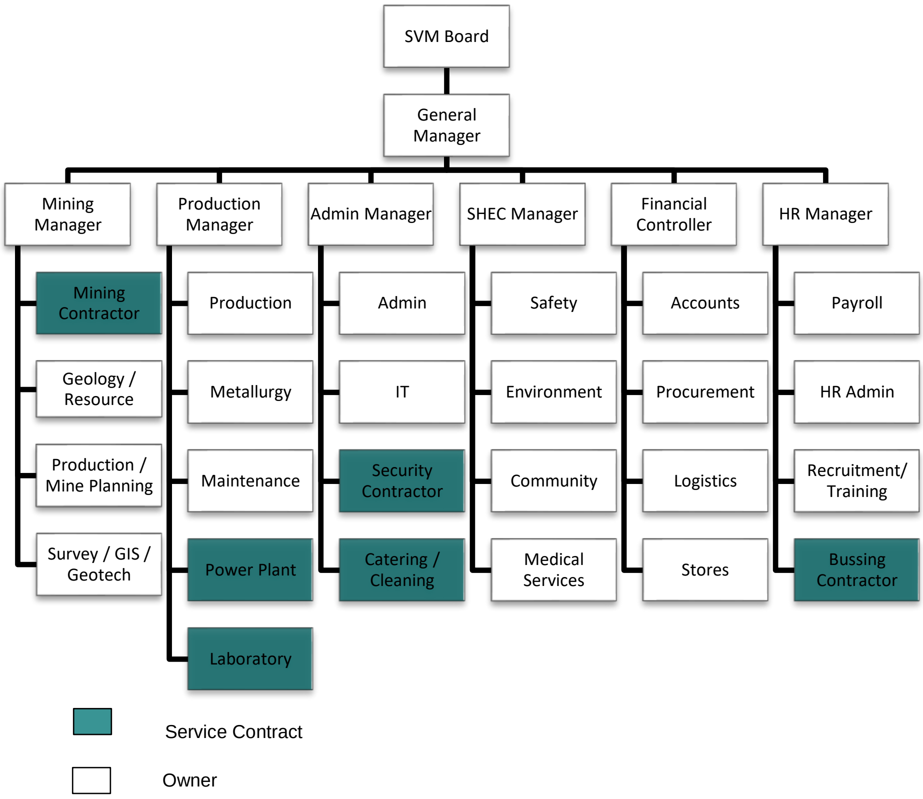

Figure 8.1: Organisational Diagram

The company will be committed to ensuring that the Safety, Health, Environment and Community (SHEC) Department staff are appropriately qualified for undertaking their assigned responsibilities. To fulfill this requirement, the company will recruit competent individuals and appoint an SHEC Manager to advise the company on all matters related to environmental health, and safety management. The SHEC Manager will be assisted by a team that will be responsible for overseeing the day to day activities of environmental management on site.

Typical duties and responsibilities for the SHEC staff will include, *inter alia*:

- Implement the ESMS and management plans in compliance with legislated guidelines.
- Prepare and enforce policies to establish a culture of health and safety.
- Conduct training and presentations on health and safety matters and accident prevention.
- Inspect equipment and machinery to observe possible unsafe conditions.
- Investigate accidents or incidents to discover causes and possible mitigation measures.
- Recommend solutions to issues, improvement opportunities or new prevention measures.
- Report on health and safety awareness, issues and statistics.
- Ensure that environmental monitoring programs are carried out on schedule and correctly.
- Review environmental data and recommend appropriate actions to ensure targets are achieved.
- Monitor environmental compliance of all mine operations.
- Train others in the team and general personnel on mine environmental issues.
- Design and implement restoration of disturbed areas and re-vegetation studies.
- Establish, train and ensure readiness of the emergency response teams.
- Report on environmental data and incidents of significance as per regulations.

- Liaise with the appropriate regulatory authorities on incidences with environmental risks.
- Provide technical and environmental support to mining operations.
- Ensure environmental commitments are met.
- Review (periodically) the existing monitoring system and design.

8.4 Management Measures

The various management plans will be based on the mitigation and management measures as identified in Chapter 7 and summarised in the sections below. These will be developed more fully during the detailed design phase of the Project.

8.4.1 Topsoil and Erosion Management

The objectives for the topsoil and erosion management plan are as follows:

- Minimise land disturbance to that which is necessary for the development of the Project.
- Minimise and control erosion.
- Ensure topsoil availability for future use in rehabilitation.
- Control land disturbance through utilisation of a "permit to disturb" system.

Table 8.1 details the management measures that will be implemented during the various phases of the Project to minimise the impact on soils, landforms and land use. A detailed rehabilitation plan will be prepared prior to construction to ensure progressive rehabilitation is implemented as soon as practicable.

Table 8.1: Topsoil and Erosion Management Pan

Impacts	Activity	Phase	Management Measures	Responsible	Annual Budget (USD)
Loss of topsoil through erosion.	Vegetation clearing; Soil stripping; Stormwater runoff; Construction of processing plant; Construction of TSF and other stockpiles; Construction of access and haul roads; Rehabilitation activities.	Construction Operations Decommissioning and Closure	• Minimise vegetation clearance and land disturbance to that which is necessary for development of the Project. • Establish and enforce a 'permit to disturb' or 'permit to clear' system. • Topsoil (first 0.3 m of the soil profile) must be stripped first and stockpiled separately from subsoil, as the topsoil contains the seedbank and natural fertility. • Strip soils according to the approved soil stripping methodology. • Topsoil stockpiles are to be kept to a maximum height of 3 to 4 m. • Minimise handling of stripped topsoil to ensure the soil's structure does not deteriorate significantly. • Stockpiled soils that are not used immediately in rehabilitation will be protected against erosion, weeds, compaction and contamination. • Cover or revegetate stockpiles as soon as possible with indigenous grass to reduce the risk of erosion, and to reinstitute the ecological processes within the soil. • Install and maintain stormwater management measures to manage surface runoff prior to discharge to the receiving surface water bodies.	SHEC Manager; Construction Manager; Engineering Manager	2,500

Impacts	Activity	Phase	Management Measures	Responsible	Annual Budget (USD)
			• Implement the use of construction barriers such as silt fencing to contain sediment. • Take corrective action in the event of observed erosion. • Rehabilitate disturbed areas as soon as practicable. • Replace soils in the area where these were originally stripped from.		
Reduction in soil fertility.	Stripping and stockpiling of topsoil; Placement of topsoil during rehabilitation.	Construction Operations Decommissioning and Closure	• Minimise vegetation clearance and land disturbance to that which is necessary for development of the Project. • Topsoil (first 0.3 m of the soil profile) must be stripped first and stockpiled separately from subsoil, as the topsoil contains the seedbank and natural fertility. • Strip soils according to the approved soil stripping methodology. • Topsoil stockpiles are to be kept to a maximum height of 3 to 4 m. • Cover or revegetate stockpiles as soon as possible with indigenous grass to reduce the risk of erosion, and to reinstitute the ecological processes within the soil. • Assess chemical properties of soils before use in rehabilitation to determine whether application of fertiliser and nutrient sources is required. • Avoid compaction of soil by repeated movements over stockpiles.	SHEC Manager	2,500
Compaction of soil.	Vegetation clearing; Soil stripping; Construction of infrastructure; Construction of TSF and other stockpiles; Construction of access and haul roads; Rehabilitation activities.	Construction Operations Decommissioning and Closure	• Stripping of topsoil should be undertaken when the soil is dry, where practicable, to reduce compaction. • Ensure vehicles remain on dedicated roads and avoid unnecessary movements over terrain not earmarked for infrastructure. • Ensure appropriate stormwater management measures are designed and implemented to prevent soil erosion. • Revegetate disturbed areas adjacent to roads to reduce the risk of erosion, and to reinstitute the ecological processes within the soil. • Assess rehabilitated areas for compaction, fertility and possible erosion, and take corrective action where necessary.	SHEC Manager; Construction Manager; Engineering Manager	2,500
Loss of land capability and use.	Construction of infrastructure; Construction of TSF and other stockpiles; Mining of open pits.	Construction Operations Decommissioning and Closure	• Minimise land disturbance to that which is necessary for development of the Project. • Establish and enforce a 'permit to disturb' or 'permit to clear' system.	SHEC Manager	2,500

Impacts	Activity	Phase	Management Measures	Responsible	Annual Budget (USD)
			• Develop and implement a progressive rehabilitation and closure plan that identifies final land uses and rehabilitation strategies in consultation with communities and regulators.		
Contamination of soil.	Use, transport and storage of hydrocarbons, hazardous chemicals and wastes.	Construction Operations Decommissioning and Closure	• Ensure vehicles remain on dedicated roads and avoid unnecessary movements over terrain not earmarked for infrastructure. • Ensure vehicles and equipment are well-maintained and servicing carried out in dedicated areas with drip trays, oil collection and pollution control systems. • Store all chemicals and fuel in bunded areas with 110% storage capacity of the maximum capacity of the largest tank or drum, or 25% of the total volume, whichever is larger. • Clean up chemical, hydrocarbon and waste spills as soon as practicable. • Place material safety data sheets (MSDS) close to chemical use and storage areas in order to allow for appropriate management of chemical chemical spills. • Remove contaminated soils and place in a designated area for bioremediation treatment. The cleaned soils will be used for rehabilitation.	SHEC Manager; Construction Manager; Engineering Manager; Production Manager	5,000

8.4.2 Terrestrial Biodiversity Management

The objectives for the biodiversity management plan are as follows:

- Protection of biodiversity resources (terrestrial flora and fauna) from impacts associated with Project activities.
- Educate/sensitise employees on importance of conservation.
- Promote community awareness on importance of conservation.

Table 8.2 details the management measures that will be implemented during the various phases of the Project to minimise the impact on flora and fauna. In addition, a detailed rehabilitation plan will be prepared prior to construction to ensure progressive rehabilitation is implemented as soon as practicable to enhance flora and fauna values.

Table 8.2: Biodiversity Management

Impact	Activity	Project Phase	Management Measures	Responsible	Annual Budget (USD)
Disturbance of vegetation communities	Vegetation clearing; Soil stripping.	Construction Operations	• Minimise vegetation clearance to that which is necessary for development of the Project. • Reduce disturbance footprint as much as possible. • Conduct vegetation clearance in phases. • Establish and enforce a 'permit to disturb' or 'permit to clear' system. • Enable establishment of a nursery of indigenous trees through collection of seed for planting and direct seeding in areas to be rehabilitated, and in surrounding areas that will not be mined. Seedlings from nurseries could potentially be through community/third parties or mine managed nurseries. • Undertake rehabilitation or return cleared areas to cultivation at closure. • Develop and implement a rehabilitation management plan.	SHEC Manager; Construction Manager	2,500
Loss of biodiversity	Vegetation clearing; Soil stripping; Vehicle and machinery movements within the mine site; Transportation of material, goods and personnel along the access road;	Construction Operations	• Ensure that a qualified environmental officer or ecologist oversees all ground clearing in order to relocate any species that may be found during ground clearing. • Minimise vegetation clearance to that which is necessary for development of the Project. • Undertake habitat clearance during winter, as far as practicable, when birds are not breeding. • Establish and enforce a 'permit to disturb' or 'permit to clear' system.	SHEC Manager; Construction Manager	Incl. above

Impact	Activity	Project Phase	Management Measures	Responsible	Annual Budget (USD)
	Accidental spillage of fuel and hazardous materials.		• Avoid clearing or damaging wetlands, and limit river and stream crossings as far as possible. • Protect abiotic habitats, such as rock outcrops, which shelter many reptile species. • Encourage fauna to leave the construction area prior to vegetation clearing by undertaking a walkover of the site, and assist with relocation of animals which have a limited capacity to vacate, such as tortoises etc. • Prohibit hunting and capture of fauna by Project employees. • Prohibit exploitation of sensitive reptiles, e.g. chameleons. • Educate personnel about the necessity of protecting fauna, specifically snakes. • Enable establishment of a nursery of indigenous trees through collection of seed for planting and direct seeding in areas to be rehabilitated, and in surrounding areas that will not be mined. Seedlings from nurseries could potentially be through community/third parties or mine managed nurseries. • Involve local communities in the collection of seed, cultivation of indigenous plant species and develop a community program to support revegetation on their own land and farms. • Undertake rehabilitation or return cleared areas to cultivation at closure. • Develop and implement a plan to monitor fauna mortalities. • Develop and implement a Rehabilitation Management Plan.		
Loss of flora species of concern	Vegetation clearing; Vehicle and machinery movements within the mine site	Construction Operations	• Ensure a qualified environmental officer or ecologist oversees all ground clearing in order to relocate any species that may be found. • Minimise vegetation clearance to that which is necessary for development of the Project. • Reduce disturbance footprint as much as possible. • Establish and enforce a 'permit to disturb' or 'permit to clear' system. • Collect seeds of any species of concern found during ground clearing and, where feasible, relocate saplings or seedlings of these species. • Develop and implement a rehabilitation management plan.	SHEC Manager; Construction Manager	Incl. above

Impact	Activity	Project Phase	Management Measures	Responsible	Annual Budget (USD)
Loss of fauna species of conservation significance	Vegetation clearing; Soil stripping; Vehicle and machinery movements within the mine site.	Construction Operations	• Ensure a qualified environmental officer or ecologist oversees all ground clearing. • Avoid clearing or damaging wetlands, and limit river and stream crossings as far as possible. • Rehabilitate impact on wetlands in the event of any damage. • Ensure quality of water released to the environment complies with relevant water quality guidelines and maintain flow dynamics. • Protect abiotic habitats, such as rock outcrops, which shelter many reptile species. • Prohibit hunting and capture of fauna by Project employees. • Prohibit exploitation of sensitive reptiles, e.g. chameleons. • Educate personnel about the necessity of protecting fauna, specifically snakes. • Undertake habitat clearance during winter, as far as practicable, when birds are not breeding. • Restrict speed of vehicles on roads. • Develop and implement a plan to monitor fauna species fatalities.	Environmental Manager; Construction Manager; Production Manager; Safety Officer	Incl. above
Impact on local fauna migrations.	Vegetation clearing; Construction of infrastructure; Construction of TSF and other stockpiles; Construction of access and haul roads.	Construction Operations Decommissioning and Closure	• Avoid sensitive habitat corridors such as drainage lines and wetlands, where practicable. • Incorporate, where practicable, underpasses and culverts in road designs that allow the movement of animals. This is of particular importance along drainage lines, which form natural corridors for faunal movements. • Limit vehicle movements after dark, where practicable, as much of the surviving fauna is nocturnal, e.g. bats, most snakes, small rodents, amphibians, etc. • Use dipped headlights at night, where safety guidelines allow, to reduce light pollution into adjacent habitat. • Enforce speed restrictions on roads. • Educate drivers regarding their role in impacting on animals and the need to minimise collisions with animals at all times. • Develop and implement a monitoring plan for fauna mortalities as part of the EMP. Monitor and assess significance of animal road mortalities and review mitigation measures on an annual basis.	SHEC Manager; Construction Manager; Production Manager; Safety Officer	2,500

Impact	Activity	Project Phase	Management Measures	Responsible	Annual Budget (USD)
Competition by invasive flora species and exotic fauna	Transportation of material, goods and personnel.	Construction Operations Decommissioning and Closure	• Prepare and implement an Exotic and Invasive Species Management Plan. • Ensure vehicles and equipment are clean of invasive plants and seed before entering the Project site, particularly wetland areas. • Eradicate exotic invasive plants as they appear by mechanical or chemical means. • In wetland areas, physically remove, contain, dry and burn all identified alien invasive species seedlings from the soil by manually pulling them out with as much as possible of their root systems still intact. • Use indigenous species during rehabilitation or, if unlikely to be successful, exotic species that are not invasive. • Develop monitoring programme for areas of weed and alien vegetation infestation. • Implement environmentally acceptable procedures for waste management. • Develop and implement eradication programs of problem animals in consultation with conservation authorities.	SHEC Manager; Construction Manager	2,500
Loss of ecosystem services provided	Vegetation clearing.	Construction Operations	• Enable collection of seeds establishment of a nursery of indigenous flora for use in areas to be rehabilitated, and in surrounding areas that will not be mined. Seedlings from nurseries could potentially be obtained from community/third parties or mine managed nurseries. • Involve local communities in the collection of seed, cultivation of indigenous plant species and develop a community program to support revegetation on their own land and farms. • Develop and implement Livelihood Restoration Strategies as part of the Resettlement Action Plan. • Ensure stormwater management berms and silt traps are installed in such manner to prevent gully formation. • Line steep slopes on stormwater channels with turf reinforcement matting to avoid erosion. • Align with Social Impact Management Plan to determine alternatives such as improved health care, woodlots for charcoaling, construction materials and fuel wood to offset the loss of ecosystem services to the affected communities.	SHEC Manager; Community Manager	Incl. in social management measures

Impact	Activity	Project Phase	Management Measures	Responsible	Annual Budget (USD)
Ecological impacts from dust.	Vegetation clearing; Soil stripping; Open pit mining; Vehicle and machinery movements within the mine site; Transportation of material, goods and personnel along the access road; Transortation of ore along haul roads; Placing of ore on stockpiles.	Construction Operations Decommissioning and Closure	• Minimise clearance of vegetation as much as possible. • Water down unpaved access and haul roads, particularly during high wind and dry weather conditions. • Restrict speed of vehicles on roads to curtail dust entrainment. Vehicle speed should not exceed 50 km/h.	SHEC Manager; Construction Manager; Mining Manager; Safety Officer	Dust management incl. in air quality management measures
Disruption to fauna from increased noise.	Construction and operation of open pit, processing plant and TSF; Construction of access and haul roads; Vehicle and machinery movements within the mine site; Transportation of material, goods and personnel along the access road; Transortation of ore along haul roads.	Construction Operations Decommissioning and Closure	• Limit construction activities to day-time hours. • Ensure vehicles and equipment are well-maintained. • Equip vehicles with low frequency reverse signals, rather than reverse beepers, where possible and if in compliance with health and safety requirements.	SHEC Manager; Construction Manager; Production Manager; Maintenance Manager	Vehicle maintenance incl. in operations budget
Impact on fauna from chemical contamination.	Increased surface runoff containing pollutants; Accidental spillage of fuel and hazardous materials.	Construction Operations Decommissioning and Closure	• Monitor the use of insecticides and herbicides closely with dosages and applications detailed in relevant standard operating procedures and management plans. • Store all chemicals and fuel in bunded areas with 110% storage capacity of the maximum capacity of the largest tank or drum, or 25% of the total volume, whichever is larger. • Clean up chemical, hydrocarbon and waste spills as soon as practicable.	SHEC Manager; Construction Manager; Production Manager; Maintenance Manager	Incl. in soil management measures

8.4.3 Aquatic Biodiversity Management

The objectives for the biodiversity management plan are as follows:

- Protection of aquatic biology from impacts associated with Project activities.
- Educate/sensitise employees on importance of conservation.
- Promote community awareness on importance of conservation.

Table 8.3 details the management measures that will be implemented during the various phases of the Project to minimise the impact on aquatic flora and fauna. A detailed rehabilitation plan will be prepared prior to construction to ensure progressive rehabilitation is implemented as soon as practicable to enhance aquatic flora and fauna values.

Table 8.3: Aquatic Biodiversity Management

Impact	Activity	Project Phase	Management Measures	Responsible	Annual Budget (USD)
Change in integrity of aquatic habitat and instream biota.	Vegetation clearing; Soil stripping and stockpiling; Increased surface runoff containing pollutants; Accidental spillage of fuel and hazardous materials; Discharge of water to the environment from pit dewatering.	Construction Operations	• Clearly demarcate areas to be cleared. • Minimise access corridors in sensitive areas such as riparian vegetation. • Ensure appropriate stormwater management measures are designed and implemented to divert runoff from erosion prone areas. • Implement isolation techniques for in-stream works, such as berms or diversion channels to limit the exposure of disturbed sediments to the water. • Consider application of jute matting to steep slopes to control erosion. • Include flow dissipation measures at discharge points. • Avoid placement of topsoil stockpiles directly adjacent to drainage lines and implement erosion control measures. • Design and maintain stormwater settling facilities and sediment traps according to internationally accepted good engineering practices, including provisions for capturing of debris and floating matter. • Remove sediment from sediment traps on a regular basis. • Sediment control facilities should be designed and operated for a final TSS discharge of 50 mg/L, taking into consideration background conditions and opportunities for overall improvement.	SHEC Manager; Construction Manager; Mining Manager	10,000

Impact	Activity	Project Phase	Management Measures	Responsible	Annual Budget (USD)
			• Discharge from dewatering boreholes or the pits will mimic natural conditions as far as possible. • Undertake rehabilitation of construction areas in dambos upon completion of the construction. Ensure exposed soils are revegetated with indigenous dambo vegetation.		
Loss of a portion of the Kovuma and Dambo 1 habitat resulting in the loss of In-stream biota.	Vegetation clearing; Construction of storwater management in upstream portion of dambos.	Construction Operations	• Clearly demarcate areas to be cleared. • Limit site clearance activities to that of the Project footprint. • Minimise access corridors in sensitive areas such as riparian vegetation. • Minimise alteration of existing flow paths as much as possible. • Prohibit vehicles from driving through dambo areas. • Maintain natural drainage paths to the extent possible. • Dambo habitat, including vegetation and rocks, should only be disturbed if absolutely necessary for construction purposes. • Demarcate sensitive zones outside of the construction area and restrict access by Project personnel. • Restrict the duration and timing of in-stream construction activities to low flow periods, and avoid periods critical to biological cycles of flora and fauna (e.g., migration, spawning, etc.) to the extent possible. • Design and maintain stormwater settling facilities and sediment traps according to internationally accepted good engineering practices, including provisions for capturing of debris and floating matter. • Undertake rehabilitation of construction areas in dambos upon completion of the construction. Ensure exposed soils are revegetated with indigenous dambo vegetation.	SHEC Manager; Construction Manager; Mining Manager	Incl. above
Loss of instream biota due to deterioration of water quality.	Vegetation clearing; Soil stripping and stockpiling; Increased surface runoff containing pollutants; Accidental spillage of fuel and hazardous materials;	Construction Operations	• Limit site clearance activities to that of the Project footprint. • Divert stormwater from potentially contaminated areas. • Ensure vehicles and equipment are well-maintained and servicing carried out in dedicated areas with concrete floors and pollution control systems. • Install oil and grease traps or sumps at refuelling facilities, workshops and fuel storage depots.	SHEC Manager; Construction Manager; Production Manager; Maintenance Manager	20,000

Impact	Activity	Project Phase	Management Measures	Responsible	Annual Budget (USD)
	Discharge of water to the environment from pit dewatering.		• Restrict access of vehicles to dambo area and drainage lines to minimise any discharges of hydrocarbons. • Store all chemicals and fuel in bunded areas with 110% storage capacity of the maximum capacity of the largest tank or drum, or 25% of the total volume, whichever is larger. • Clean up spillages as soon as practicable. • Ensure spill kits are readily available at on-site chemical and fuel storage areas at all times. • Sediment control facilities should be designed and operated for a final Total Suspended Solids (TSS) discharge of 50 mg/L, taking into consideration background conditions and opportunities for overall improvement of the receiving water body quality. • Prohibit all waste from entering any aquatic habitat. • Undertake bi-annual toxicity testing in the aquatic features to monitor potential water contamination from on-site activities.		

8.4.4 Wetland (Dambo) Management

The objectives for the wetland management plan are as follows:

- Protection of wetland biodiversity from impacts associated with Project activities.
- Conservation of ecosystem services associated with wetlands.
- Protection of hydrological regime.
- Educate/sensitise employees on importance of conservation.
- Promote community awareness on importance of conservation.

Table 8.4 details the management measures that will be implemented during the various phases of the Project to minimise the impact on dambos.

Table 8.4: Wetland Management

Impact	Activity	Project Phase	Management Measures	Responsible	Annual Budget (USD)
Erosion impacts to dambos.	Vegetation clearing; Discharge of water to the environment from pit dewatering.	Construction Operations Decommissioning and Closure	• Minimise area of disturbance to what is necessary for development of the Project. • Ensure appropriate stormwater management measures are designed and implemented to prevent erosion. • Divert stormwater around work sites and other disturbed areas. • Investigate the use of sustainable drainage systems (SUDS) to control surface water run-off, such as grass swales, ponds or infiltration trenches. • Install sediment barriers (e.g., sediment fences or turf buffer strips) downslope of construction areas and stockpiles to filter coarse sediments. • Install settlement ponds or sediment traps to collect run-off from the site and let suspended solids settle so these can be removed prior to discharge. • Investigate the use of multiple discharge and/or low volume release points in order to prevent incision of wetlands. • Minimise vehicle access points to areas, where possible. • Revegetate all denuded areas as soon as possible after construction is completed. • Develop and implement a topsoil and erosion monitoring and management plan.	SHEC Manager; Construction Manager; Mining Manager	Incl. in erosion management measures

Impact	Activity	Project Phase	Management Measures	Responsible	Annual Budget (USD)
Sedimentation of wetlands.	Vegetation clearing; Soil stripping; Surface runoff containing incrased sediment loads; Discharge of water to the environment from pit dewatering.	Construction Operations Decommissioning and Closure	• Minimise area of disturbance to what is necessary for development of the Project. • Divert clean water around work sites and other disturbed areas. • Install sediment barriers (e.g., sediment fences or turf buffer strips) downslope of construction areas and stockpiles to filter coarse sediments. • Investigate the use of sustainable drainage systems (SUDS) to control surface water run-off, such as grass swales, ponds or infiltration trenches. • Install settlement ponds or sediment traps to collect run-off from the site and let suspended solids settle so these can be removed prior to discharge. • Revegetate or cover topsoil stockpiles, where feasible, to prevent sediment form being washed away. • Revegetate all denuded areas as soon as possible after construction is completed. • Develop and implement a topsoil and erosion monitoring and management plan.	SHEC Manager; Construction Manager; Mining Manager	Incl. in erosion management measures
Changes in hyrdology of wetlands	Discharge of water to the environment from pit dewatering.	Construction Operations	• Investigate the use of sustainable drainage systems (SUDS) to control surface water run-off, such as grass swales, ponds or infiltration trenches. • Install settlement ponds or sediment traps to collect run-off from the site and let suspended solids settle so these can be removed prior to discharge. • Investigate the use of multiple discharge and/or low volume release points in order to prevent incision of wetlands.	SHEC Manager; Construction Manager; Mining Manager	Incl. in construction budget
Loss of wetland biodiversity and habitat	Vegetation clearing; Erosion; Discharge of water to the environment from pit dewatering; Introduction of exotic species.	Construction Operations Decommissioning and Closure	• Investigate the use of sustainable drainage systems (SUDS) to control surface water run-off, such as grass swales, ponds or infiltration trenches. • Install settlement ponds or sediment traps to collect run-off from the site and let suspended solids settle so these can be removed prior to discharge. • Investigate the use of multiple discharge and/or low volume release points in order to prevent incision of wetlands.	SHEC Manager; Construction Manager; Mining Manager	Incl. in construction budget

8.4.5 Surface and Groundwater Management

The objectives of the water management plan are as follows:

- Prevent contamination of surface and groundwater.
- Optimise water use in mining and other activities.
- Minimise interference with natural drainage systems.
- Minimise impact on community water sources.
- Ensure availability of water for intended use in the area.

Table 8.5 details the management measures that will be implemented during the various phases of the Project to minimise the impact on surface and groundwater. A detailed surface water management system will be designed prior to construction to ensure appropriate separation of clean and dirty water, and will form part of the Water Management Plan.

Table 8.5: Surface and Groundwater Management

Impact	Activity	Project Phase	Management Measures	Responsible	Annual Budget (USD)
Deterioration in water quality of surface water resources.	Vegetation clearing; Soil stripping; Open pit mining activities; Surface water runoff from disturbed areas; Construction and operation of TSF; Discharge of water to the environment from pit dewatering; Discharge from contaminated areas, including TSF, processing plant, contaminated water storage ponds.	Construction Operations Decommissioning and Closure	• Separate clean and dirty water by implementing stormwater management structures. • Ensure stormwater from dirty catchments are contained and reused at the processing plant, effectively reducing the catchment area to local watercourses. • Ensure water from pit dewatering boreholes or the pit is managed through silt traps to settle silt before discharge. • Include flow dissipation measures at discharge points. • Discharge from dewatering boreholes or the pits will mimic natural conditions as far as possible. • Design and maintain stormwater settling facilities and sediment traps according to internationally accepted good engineering practices, including provisions for capturing of debris and floating matter. • Remove sediment from sediment traps on a regular basis. • Sediment control facilities should be designed and operated for a final TSS discharge of 50 mg/L, taking into consideration background conditions and opportunities for overall improvement.	SHEC Manager; Construction Manager; Production Manager; Maintenance Manager; Mining Manager	30,000

Impact	Activity	Project Phase	Management Measures	Responsible	Annual Budget (USD)
			• Ensure vehicles and equipment are well-maintained and servicing carried out in dedicated areas with concrete floors and pollution control systems. • Install oil and grease traps or sumps at refuelling facilities, workshops and fuel storage depots. • Store all chemicals and fuel in bunded areas with 110% storage capacity of the maximum capacity of the largest tank or drum, or 25% of the total volume, whichever is larger. • Clean up spillages as soon as practicable. • Ensure spill kits are readily available at on-site chemical and fuel storage areas at all times. • Undertake monitoring of surface water quality consistent with the surface water monitoring plan.		
Impact on water runoff.	Vegetation clearing; Construction of infrastructure; Development of open pits; Surface water runoff from disturbed areas; Discharge of water to the environment from pit dewatering.	Construction Operations Decommissioning and Closure	• Implement water conservation and water demand management measures to ensure as much water as possible is collected and reused, minimising the release of any treated storm flows whilst reducing abstraction from sources. • Ensure stormwater from dirty catchments are contained and reused at the processing plant, effectively reducing the catchment area to local watercourses. • Discharge from dewatering boreholes or the pits will mimic natural conditions as far as possible.	SHEC Manager; Construction Manager; Mining Manager	Incl. in operations budget
Reduction in groundwater availability.	Development of open pits; Discharge of water to the environment from pit dewatering.	Construction Operations Decommissioning and Closure	• Establish and maintain an effective groundwater monitoring system. • Provide access to alternative water sources to affected communities.	SHEC Manager; Construction Manager; Mining Manager	Incl. in operations budget
Contamination of aquifers.	Seepage from TSF; Seepage from contaminated water in processing plant area; Use and storage of hydrocarbons and hazardous chemicals	Operations Decommissioning and Closure	• Implement appropriate operational interventions to reduce the point source contamination potential. • Investigate the installation of scavenger wells to contain and minimise the migration of contamination as part of the detailed design. • Establish a no-go area around the TSF where the use of groundwater is prohibited.	SHEC Manager; Construction Manager; Mining Manager	30,000

Impact	Activity	Project Phase	Management Measures	Responsible	Annual Budget (USD)
			• Store all chemicals and fuel in bunded areas with 110% storage capacity of the maximum capacity of the largest tank or drum, or 25% of the total volume, whichever is larger. • Clean up chemical, hydrocarbon and waste spills as soon as practicable. • Review extent of exclusion zone in consultation with geohydrologist and health specialist on an annual basis. • Monitor groundwater quality consistent with the surface water monitoring plan.		

8.4.6 Air Quality Management

The objectives of the air quality management plan are to:

- Minimise point and fugitive emissions that could impact on ambient air quality.
- Minimise nuisance dust at nearby receptors from mine activities.

Table 8.6 details the management measures that will be implemented during the various phases of the Project to minimise the impact from dust and emissions. A detailed Air Quality Management Plan will be prepared prior to construction to ensure impacts on communites and employees are minimised.

Table 8.6: Air Quality Management

Impact	Activity	Project Phase	Mitigation	Responsible	Annual Budget (USD)
Increase in total suspended particles, PM_{10} and $PM_{2.5}$	Vegetation clearing; Soil stripping and stockpiling; Stockpiling of ore; Construction and operation of processing plant and TSF; Construction of access and haul roads; Mining in open pits; Transportation of material, goods and personnel; Vehicle and machinery movements within the mine site; Transortation of ore along haul roads.	Construction Operations Decommissioning and Closure	• Minimise vegetation clearance and land disturbance to that which is necessary for development of the Project. • Vegetation clearance and soil stripping to be conducted in phases, where practicable. • Limit activities that have high potential for dust creation on windy days (wind speed ≥ 5.4 m/s), where practicable. • Enforce adherence to set speed limits. • Minimise drop heights for materials when loading and at tipping points. • Construct wind breaks and screens in areas of exposed stockpiles. • Apply wetting agents, dust suppressant or binders on unsealed roads and exposed areas. • Implement resettlement of households within 50 m of operational areas. • Review extent of exclusion zone in consultation with air quality and health specialist on an annual basis. • Rehabilitate cleared areas as soon as practicable.	SHEC Manager; Construction Manager; Mining Manager	15,000
Increase in SO_2, NO_2, CO	Combustion gases and greenhouse gases generated as a result of fuel use by LDVs, trucks and other mobile equipment;	Construction Operations	• Use catalytic converters to reduce the levels of NO_2 emitted. • Use low sulfur fuel, where available. • Ensure generator sets are maintained and operate at optimal conditions. • Implement resettlement of households within 50 m of operational areas.	SHEC Manager; Construction Manager; Mining Manager	Incl. in construction and operations budget

Impact	Activity	Project Phase	Mitigation	Responsible	Annual Budget (USD)
	Electricty generation by diesel generators.		• Review extent of exclusion zone in consultation with air quality and health specialist on an annual basis.		

8.4.7 Noise Management

The objectives for the noise management plan are:

- Minimise noise impacts at sensitive receptors located in proximity to the Project infrastructure.

Table 8.7 details the management measures that will be implemented during the various phases of the Project to minimise the impact on sensitive noise recptors.

Table 8.7: Noise Management

Impact	Activity	Project Phase	Management Measures	Responsible	Annual Budget (USD)
Noise intrusion during construction phase	Vegetation clearing; Soil stripping; Construction of buildings, infrastructure and processing plant; Establishment of open pit; Construction of access and haul roads; Construction of TSF, PCD and RWD.	Construction	• Limit construction activities to day-time hours. • Ensure vehicles and equipment are well-maintained. • Ensure equipment and/or machinery comply with the manufacturer's specifications on acceptable noise levels, which may not exceed 85 dBA. • Install noise suppression mechanisms e.g. exhaust mufflers on heavy vehicles and equipment and monitor their effectiveness. • Equip vehicles with low frequency reverse signals, rather than reverse beepers, where possible and if in compliance with health and safety requirements. • Keep alarm and warning tones on vehicles to be audible within the work area, without unnecessarily creating noise outside the site. • Switch off equipment and vehicles when not in use. • Undertake noise monitoring to determine whether ambient noise levels at nearby receptors exceed prevailing noise levels + 3.0 dBA (as per the IFC EHS Guidelines, 2007).	SHEC Manager; Construction Manager; Mining Manager	Incl. in construction budget
Noise intrusion from open pits and processing plant	Vegetation clearing; Soil stripping and stockpiling; Open pit mining; Stocpiling of ore; Operation of processing plant.	Operations	• Ensure vehicles and equipment are well-maintained. • Ensure equipment and/or machinery comply with the manufacturer's specifications on acceptable noise levels, which may not exceed 85 dBA. • Identify noise sources in excess of 85 dBA at the pit and screen off acoustically. • Equip vehicles with low frequency reverse signals (vibrating type signals), rather than reverse beepers, where possible and if in compliance with health and safety requirements.	SHEC Manager; Mining Manager	5,000 Construction of noise berms incl. in operations budget

Impact	Activity	Project Phase	Management Measures	Responsible	Annual Budget (USD)
			• Install noise suppression mechanisms e.g. exhaust mufflers on heavy vehicles and equipment and monitor their effectiveness. • Keep alarm and warning tones on vehicles to be audible within the work area, without unnecessarily creating noise outside the site. • Switch off equipment and vehicles when not in use. • Ensure power plant is enclosed and acoustically screened off. • Undertake regular maintenance of haul roads to ensure a relatively smooth driving surface. • Place berm or barrier of at least 4 m high between the processing plant and Chitsulo village as acoustic screening measures • Place berm or barrier of 4 m high between operations at the pits in vicinity of the S124 and Chitsulo and Kumalindi villages as acoustic screening measures, at a set-back distance of 10 m from the pit. • Place berm or barrier of 4 m high between Chanika village and Pit O as acoustic screening measure, at a set-back distance of 10 m from the pit. • Place berm or barrier of 4 m high between Kubale and Ndumila villages and Pits P & Q as acoustic screening measure, at a set-back distance of 10 m from the pit. • Place berm or barrier of 4 m high between Ndumila I and Ndumila II and the most southern pit as acoustic screening measure, at a set-back distance of 10 m from the pit. • Relocate houses within a minimum of 50 m from the rim of the pit. • Undertake noise monitoring to determine whether ambient noise levels at nearby receptors exceed prevailing noise levels + 3.0 dBA (as per the IFC EHS Guidelines, 2007).		
Deterioration in ambient noise levels along access road.	Vehicle movements along access roads.	Construction Operations Decommissioning and Closure	• Ensure equipment and/or machinery comply with the manufacturer's specifications on acceptable noise levels, which may not exceed 85 dBA. • Undertake regular servicing of all equipment and vehicles. • Install and maintain speed control measures along access roads. • Limit vehicle movement along access road at night. • Install noise suppression mechanisms e.g. exhaust mufflers on heavy vehicles and equipment and monitor their effectiveness.	SHEC Manager; Construction Manager; Mining Manager	Incl. in contruction and operations budgets

8.4.8 Aesthetics and Visual Impact Management

The objectives for the aesthetics and visual impacts management plan are:

- Minimise the impact on aesthetics and visual amenity from large infrastructure components.
- Minimise the impact from night lighting and glare on nearby residents and communities.

Table 8.8 details the management measures that will be implemented during the various phases of the Project to minimise the visual impact on surrounding communities.

Table 8.8: Aesthetics and Visual Impact Management

Impact	Activity	Project Phase	Management Measures	Responsible	Annual Budget (USD)
Visual exposure to mining infrastructure	Vegetation clearing; Construction of buildings, infrastructure and processing plant; Construction of TSF, PCD and RWD; Stockpiling of ore and topsoil.	Construction Operations Decommissioning and Closure	• Ensure progressive rehabilitation and vegetation of stockpiles and cleared areas takes place. • Develop natural mechanisms of preserving aesthetics and visual setup including leaving individual trees in cleared areas. • Use muted, natural colours that blend in with the environment on painted surfaces, where practicable.	SHEC Manager; Engineering Manager; Mining Manager	Incl. in operations budget
Night-time lighting impact	Night-time lighting around processing plant, TSF and open pits; Vehicle movements along access road.	Operations	• Design effective lighting system to ensure safe visual working environment, taking due consideration of compliance to standards. • Implement the use of down lighting to minimise light pollution. • Utilise security lighting that is movement activated rather than permanently switched on, to prevent unnecessary constant illumination, where possible. • Avoid up-lighting of structures. • Discourage vehicle movement on access roads between sunset and sunrise.	SHEC Manager; Engineering Manager; Maintenance Manager	Incl. in operations budget

8.4.9 Social Impact Management

The main objectives of the management plan are to:

- Minimise impact on surrounding communities.
- Develop good relationships with stakeholders and affected parties.
- Ensure all commitments as are met.
- Assist in community development programs through social corporate responsibility.

Management measures in response to impacts identified in Chapter 7 are provided in Table 8.9. A detailed social management plan will be developed prior to construction of the Project.

Table 8.9: Social Impact Management

Impact	Activity	Project Phase	Management Measures	Responsible	Annual Budget (USD)
Loss of residence from physical displacment caused by land acquisition.	Land acquisition of construction and development of Project infrastructure.	Construction Operations	• Design and locate Project infrastructure in such a way as to minimise displacement, especially infrastructure components such as the TSF, roads and supporting infrastructure which are not dependent on the location of mineral deposits. • Develop and implement RAP consistent with IFC PS5 and GIIP, including financial literacy training. • Undertake resettlement planning and implementation, where practicable, in one attempt for a defined geographic area/footprint to minimise disturbance for communities from resettlement activities and to minimise the risk of double displacement. • Give special consideration to vulnerable households, such as providing relocation assistance for elderly or child-headed households. • Develop and implement a grievance mechanism to facilitate the resolution of affected community concerns and grievances. • Contribute to and assist with community development programs in consultation with relevant authorities, and consistent with approved Community Development Agreement.	Community Manager	Incl. in RAP and Community Development Agreement

Impact	Activity	Project Phase	Management Measures	Responsible	Annual Budget (USD)
Economic displacement caused by loss of cultivated land, grazing and business assets	Land acquisition of construction and development of Project infrastructure.	Construction Operations	• Design and locate Project infrastructure in such a way as to minimise displacement, especially infrastructure components such as the TSF, roads and supporting infrastructure which are not dependent on the location of mineral deposits. • Develop and implement RAP consistent with IFC PS5 and GIIP, including financial literacy training. • Undertake resettlement planning and implementation, where practicable, in one attempt for a defined geographic area/footprint to minimise disturbance for communities from resettlement activities and to minimise the risk of double displacement. • Give special consideration to vulnerable households, such as providing relocation assistance for elderly or child-headed households. • Undertake livelihoods monitoring as part of the LRP. • Align and incorporate LRP with any corporate investment projects to enhance sustainability. • Livelihood restoration must consider risk of future droughts and its potential impact on measures to restore livelihoods.	Community Manager	Incl. in LRP and Community Development Agreement
Loss of access to boreholes and community assets within the project area	Land acquisition of construction and development of Project infrastructure.	Construction Operations Decommissioning and Closure	• Compile a full inventory of all community assets that will be impacted as part of the RAP. • Provide access to the Project area for community members to harvest medicinal plants and rootstock prior to construction for self cultivation. • Develop a strategy to allow controlled access to specific areas, specifically cultural heritage sites. • Undertake restoration of lost community assets and infrastructure in consultation with the impacted community, and implement as part of the RAP. • Implement stakeholder engagement plan and grievance mechanism to identify and mitigate any unexpected impacts on community assets.	Community Manager	Incl. in RAP
Loss of local access roads and tracks.	Construction of buildings, infrastructure and processing plant; Construction of TSF, PCD and RWD;	Construction Operations Decommissioning and Closure	• Identify roads and tracks that will be cut-off as a result of the Project development. • Engage with local communities on routing for alternate routes around the Project development area.	Community Manager	Incl. in contruction costs

Impact	Activity	Project Phase	Management Measures	Responsible	Annual Budget (USD)
	Construction of access and haul roads; Establishment of open pits.		• Develop alternate roads and tracks in order to maintain reasonable accessibility to surrounding areas. • Provide advance notification of Project to local residents through stakeholder engagement mechanisms, including description of impacts to accessibility of surrounding areas.		
Social stress as a result of uncertainty about the Project and its potential impacts.		Construction	• Disclose information early and frequently as part of ongoing stakeholder engagement with affected individuals/households and the wider community. • Engage a community liaison officer to work closely with local communities to provide culturally appropriate and timely information, and respond to questions and concerns. • Establish a community advisory group that has representation from communities affected by physical and economic displacement and can help advise Sovereign on the key concerns and requirements of affected people.	Community Manager	5,000
Exacerbation of issues regarding financial control and gender inequality in local communities.	Land acquisition and compensation.	Construction Operations	• Where practically possible, payment of compensation to be made at household level (to husband and wife). • Provide financial literacy training to those who receive compensation payments from resettlement. This will include advice and assistance on how to open bank accounts, especially for savings, how to undertake long-term financial planning, etc. • Identify local NGOs or CBOs that can help with the design and implementation of financial literacy training. • Assist with the formation of local women's groups to provide support specifically for the affected women (e.g. training on finances and household management).	Community Manager	Incl. in LRP
Reliance on and subsequent loss of income from fixed-term employment during construction.	Employment during construction phase.	Construction	• Advertise the nature, duration and numbers of jobs available during the various Project phases and ensure that local communities understand the Project's employment requirements. • Ensure that all Project workers (including contractors and subcontractors) are made aware of the duration of employment when they are hired. • Provide financial literacy training for project workers. • Provide local employees with reference letters once construction is completed.	Community Manager; Human Resources Manager	20,000

Impact	Activity	Project Phase	Management Measures	Responsible	Annual Budget (USD)
			• Provide certificates of completion for in-house (on-the-job) training passed. • Develop skills training programs for local recruits, with a focus on women and youth, to enable them to apply for permanent positions during the operations phase of the Project.		
Project-induced migration (influx).	Employment opportunities as part of Project construction and operation.	Construction Operations	• Develop and implement an Influx Management Plan. • Undertake monitoring of influx as part of the Project ESMP in consultation with local government, and continue to provide capacity building support and report on findings. • Communicate steps for hiring workers to local communities in a transparent manner. • Apply a mechanism to verify where job applicants come from (e.g. checking ID cards) so that jobs prioritised for members of local communities are not given to in-migrants. • Prohibit at-gate hiring to reduce the number of people waiting at and around the Project site. • Develop and implement education campaigns and capacity-building training to the employees and local communities on the dangers of alcoholism, drug abuse, domestic violence, prostitution and safe sex, in consultation with relevant government departments. • Provide medical services for Project workers on site to reduce pressure on local health facilities. These services will be designed to respond to first aid cases and to other illnesses and medical requirements of workers. • Engaged with medical and educational authorities during construction and after one year of operation in order to identify if excessive burdens are being placed on them by Project workers, and revise Project provisions as required.	Community Manager; Human Resources Manager	25,000
Presence of Project workers leading to decreased community wellbeing.	Employment opportunities as part of Project construction and operations; Project-induced migration.	Construction Operations	• Develop and implement an Influx Management Plan. • Undertake monitoring of influx as part of the Project ESMP in consultation with local government, and continue to provide capacity building support and report on findings. • Communicate steps for hiring workers to local communities in a transparent manner.	Community Manager; Human Resources Manager	Incl. above

Impact	Activity	Project Phase	Management Measures	Responsible	Annual Budget (USD)
			• Apply a mechanism to verify where job applicants come from (e.g. checking ID cards) so that jobs prioritised for members of local communities are not given to in-migrants. • Prohibit at-gate hiring to reduce the number of people waiting at and around the Project site. • Develop and implement education campaigns and capacity-building training to the employees and local communities on the dangers of alcoholism, drug abuse, domestic violence, prostitution and safe sex, in consultation with relevant government departments. • Implement the grievance mechanism to identify and respond to concerns about workers' behaviour. • Ensure all workers are aware of expectations to behave in accordance with the Company Code of Conduct that will be enforced through sanctions, including dismissal when appropriate. • Provide transportation for workers between the Project site and Lilongwe, as well as other key communities, with designed pick-up and drop-off points, to minimise disruption to local residents.		
Unmet expectations around Project employment opportunities and other social investment benefits.	Employment opportunities as part of Project construction and operations	Construction Operations	• Develop and implement a Local Employment Plan as part of the overall recruitment strategy, which prioritises employment of people within and close to the Project footprint and outlines transparent measures for making jobs available to local residents and for hiring based on merit. • Communicate steps for hiring workers to local communities in a transparent manner. • Develop and implement a Community Development Agreement in consultation with government. • Undertake joint consultation and planning with the affected population on identifying specific community investment activities (including an analysis of community specific needs). • Undertake joint consultation and planning with national and district authorities to understand development plans for the area. • Implement the grievance mechanism to identify and respond to concerns about employment and community development. • Ensure all workers are aware of expectations to behave in accordance with the Company Code of Conduct that will be enforced through sanctions, including dismissal when appropriate.	Community Manager; Human Resources Manager	–

Impact	Activity	Project Phase	Management Measures	Responsible	Annual Budget (USD)
			• Provide transportation for workers between the Project site and Lilongwe, as well as other key communities, with designed pick-up and drop-off points, to minimise disruption to local residents.		
Inflationary pressures caused by Project-related demand.		Construction Operations	• Develop and implement a Local Procurement Plan that must identify the types of products that may be limited in the local economy and avoid or minimise purchasing them at levels that could create inflation. • Monitor costs in local markets during construction and first year of operations, and adapt procurement processes if it is noticeable.	Community Manager; Human Resources Manager	–
Reduced amenity and changes in sense of place.	Construction of buildings, infrastructure and processing plant; Construction of TSF, PCD and RWD; Construction of access and haul roads; Establishment of open pits; Vehicle movements along access and haul roads.	Construction Operations Decommissioning and Closure	• Implement recommended mitigation measures related to noise, air quality and visual impact. • Implement stakeholder engagement plan and grievance mechanism to identify and mitigate any community concerns.	Community Manager	–
Community distrubance, increased risk of traffic accidents and damage to roadside structures and livestock as a result of increased traffic.	Vehicle movements along access roads.	Construction Operations Decommissioning and Closure	• Develop and implement a Traffic Management Plan that includes safety measures such as a signals network, driving rules, community awareness raising programmes, and the process of managing and rectifying cases where road users or local residents are injured as a result of Project traffic. • Ensure Project drivers are licensed according to national law. • Restrict speed of vehicles on roads in proximity to villages. • Ensure vehicles are well maintained • Implement recommend mitigation measures related to noise and air quality from Project traffic. • Implement stakeholder engagement plan and grievance mechanism to identify and remedy any temporary disturbance and accidental damage.	Community Manager; Maintenance Manager	–

Impact	Activity	Project Phase	Management Measures	Responsible	Annual Budget (USD)
Injury or death as a result of unauthorised access to unfenced Project areas.	Construction of buildings, infrastructure and processing plant; Construction of TSF, PCD and RWD; Establishment of open pits.	Construction Operations Decommissioning and Closure	• Develop and implement a Community Health and Safety Management Plan that will identify areas where there is a risk of unauthorised access to hazardous work sites. • Implement appropriate measures to prevent access to potentially hazardous areas, including fencing, barricades and signage. • Undertake regular security patrols around areas where access can more easily be achieved. • Engage with community members to inform and educate them on the safety risks resulting from Project activities. • Clearly demarcate access points and walkways for workers and community members. • Investigate all safety incidents involving community members as soon as practical and revise the Community Health and Safety Management Plan as required. • Implement stakeholder engagement plan and grievance mechanism to identify and address any safety concerns.	Health and Safety Manager; Community Manager; Security Contractor	–
Risk of conflict and tension due to the presence of security services.	Provision of security services and presence of security personnel for Project purposes.	Construction Operations Decommissioning and Closure	• Develop and implement a Security Management Plan and a 'Policy on Acceptable Use of Force'. • All security personnel must be vetted and trained to the international standards as outlined in IFC PS4. • Security personnel will only have responsibility for securing the Project sites and will not operate in local communities. • Refer any incident that requires activity outside of the Project site to local police. • Investigate all security incidents on the Project site in association with local police, and revise the Project's overall approach to security, where necessary. • Implement grievance mechanism to identify and address any security concerns.	Health and Safety Manager; Community Manager; Security Contractor	–
Risk of inappropriate labour practices.	Construction and operations of Project; Procurement of goods and services by Project.	Construction Operations Decommissioning and Closure	• Develop a comprehensive health and safety management system compliant with OHSAS 18001, including an Occupational Health and Safety Plan • Ensure compliance with OHS provisions of the IFC General EHS Guidelines, including provision of an OHS orientation training to all new employees.	Health and Safety Manager	Incl. in operations budget

Impact	Activity	Project Phase	Management Measures	Responsible	Annual Budget (USD)
			• Provision of OHS induction to all new employees and visitors to the site. • Undertake regular OHS training for all employees. • Provide appropriate Personal Protective Equipment (PPE) to all personnel. • Ensure hiring practices adheres to the minimum specified age for potential Project employees. • Undertake selective due diligence of contractors and suppliers to ensure that the Project does not inadvertently support child labour, and ensure wording to this effect is included in terms and conditions of all contractual agreements.		
Increased incomes for Project employment leading to imrpoved individual and household wellbeing.	Employment as part of onstruction and operations of Project.	Construction Operations	• Develop and implement a Local Employment Plan that prioritises employment of people within and close to the Project area, and outlines transparent measures for making jobs available to local residents and for hiring based on merit. • Monitor levels of local employment (including contractors and subcontractors). • Conduct a review of local employment levels 6 months after start of construction and 1 year after start of operations. Identify opportunities to enhance local employment levels.	Community Manager; Human Resources Manager	–
Mulitplier effects on the lcoal economy and economic opportunities for entrepreneurs and small businesses.	Procurement of goods and services in the area.	Construction Operations	• Develop and implement a Local Procurement Plan that defines clear, practicable and measurable mechanisms and milestones for local procurement. • Identify procurement opportunities and goods/services that could be supplied by local contractors, as well as processes for prioritising them over district, country or international suppliers. • Investigate the feasibility of establishing business linkages with institutions other than the local government (NGOs, CSOs etc.).	Human Resources Manager; Procurement Manager	–
Dependency on the Project to sustain the local economy.		Decommissioning	• Develop a comprehensive Closure Plan. • Identify critical issues which could affect the on-going sustainability of employee livelihoods and communities during closure, by means of a detailed consultation process. • Identify alternative livelihood and socio-economic development opportunities for employees, as well potentially sustainable community-based development projects.	SHEC Manager; Community Manager; Human Resources Manager	Incl. in Closure Plan and Community Development Agreement

Impact	Activity	Project Phase	Management Measures	Responsible	Annual Budget (USD)
			• Provide assistance and/or support for the establishment of sustainable community projects. • Prior to implementing any collective dismissals, carry out an analysis of alternatives to retrenchment. If the analysis does not identify viable alternatives to retrenchment, develop a retrenchment plan to reduce the adverse impacts of retrenchment on workers. The retrenchment plan will be consistent with requirements of the IFC PSs and GIIP, will be based on the principle of non-discrimination and will reflect the Project's consultation with workers, their organisations, and, where appropriate, the government.		

8.4.10 Cultural Heritage Management

The objectives of the archeology and cultural heritage management plan are to:

- Minimise the disturbance to archaeological sites, cultural heritage sites and graves.
- Ensure the relocation of graves are undertaken in a culturally appropriate manner and in accordance with Malawi legislation.
- Preserve the cultural values of the area.

Management measures in response to impacts identified in Chapter 7 are provided in Table 8.10. A detailed Cultural Heritage Mangement Plan (CHMP), which includes a Chance Finds Protocol will be developed priort to contsruction.

Table 8.10: Cultural Heritage Management

Impact	Activity	Project Phase	Management Measures	Responsible	Annual Budget (USD)
Disturbance of archaeological sites.	Vegetation clearing; Construction of buildings, infrastructure and processing plant; Construction of TSF, PCD and RWD; Construction of access and haul roads; Stockpiling of ore and topsoil; Development of open pits.	Construction Operations Decommissioning and Closure	• Undertake subsurface probing (test pitting at intervals) of archaeological sites of MGP1 and MGP3-5 to adequately assess their significance and integrity. • Avoid disturbance of archaeological sites within the proposed Project area and beyond the disturbance footprint where possible. • Avoid disturbance of graves within the proposed Project area, and beyond the disturbance footprint. • Demarcate and place a buffer of 50 m around sites to be avoided, where practicable. • Follow all procedures for preservation and protection of sites and artefacts of archaeological, significance specified by the Monuments and Relics Act, 1991. • Undertake clearing of sites within the Project disturbance footprint in accordance with the required permits. • Relocate graves that cannot be avoided in accordance with the requirements of the Monuments and Relics Act, 1991 and Public Health Act, 1968 • Adhere to local customs in the event of the relocation of graves. • Undertake consultation with relevant stakeholders prior to commencing relocation. • Develop and implement Chance Finds Procedure as part of a Cultural Heritage Management Plan in the event that previously unrecorded graves are uncovered during construction activities.	Environmental Manager; Community Manager; Construction Manager; Mining Manager	5,000 Cost of relocation of graves incl. in RAP

Impact	Activity	Project Phase	Management Measures	Responsible	Annual Budget (USD)
Disturbance of places of worship.	Construction of buildings, infrastructure and processing plant; Construction of TSF, PCD and RWD; Construction of access and haul roads; Stockpiling of ore and topsoil; Development of open pits.	Construction Operations	• Avoid disturbance of places of worship in proximity to the Project area where possible. • Replace structures where disturbance is unavoidable. • Consultation with relevant stakeholders must be undertaken prior to commencing relocation. • Develop and implement Cultural Heritage Management Plan.Discourage vehicle movement on access roads between sunset and sunrise.	Environmental Manager; Community Manager; Construction Manager; Mining Manager	–
Interruption of access to cultural heritage sites.	Vegetation clearing; Construction of buildings, infrastructure and processing plant; Construction of TSF, PCD and RWD; Construction of access and haul roads; Development of open pits. Stockpiling of ore and topsoil.	Construction Operations Decommissioning and Closure	• Avoid disruption of access to cultural heritage sites in proximity to the Project area, where possible. • Provide alternative access to sites where disruption of access is unavoidable. • Develop and implement Cultural Heritage Management Plan.	Environmental Manager; Community Manager; Construction Manager; Mining Manager	–

8.4.11 Stakeholder Engagement Plan

A management plan to guide stakeholder engagement and public disclosure is important to initiate and sustain constructive external relationships over time, and ensure continuation of the social license to operate. Engagement with stakeholders will continue throughout the life-of-mine on all relevant issues of interest to stakeholders. The engagement plan will be prepared and reviewed periodically to continually inform, meet and manage the expectations and responsibilities to and by various stakeholders. The stakeholder engagement plabn will build on the stakeholder engagement that has been undertaken as part of the ESIA process and will allow for:

- Convening stakeholder meetings throughout all Project phases to ensure stakeholders needs and views are acknowledged and given special consideration.
- Facilitating effective communication with stakeholders in line with their information needs and culture.
- Disseminating information to, and having discussions with, stakeholders on key issues throughout Project life.
- Preparing relevant documents for review by government agencies and other key stakeholders.
- Building strong transparent relations with affected communities.
- Providing relevant, timely and accessible information to stakeholders in an appropriate and understandable format.

8.5 Environmental Monitoring Program

The principal purpose of environmental monitoring and reporting is to provide information necessary to determine the Project's performance against the objectives and targets set as part of the ESMS. Regular monitoring serves as an indication of the efficiency of the mitigation and management measures, as well as compliance with standards, guidelines and conditions imposed by Malawi authorities in response to licence applications.

A detailed monitoring program will be designed as part of the overall ESMS for the Project that will:

- Comply with applicable Malawi legislation, standards and guidelines.
- In the absence of relevant Malawi legislation and standards, adhere to internationally acceptable guidelines such as those recomended by the IFC EHS Guideilnes (2007) and the World Health Organisation.
- Adhere to good international industry practice relating to environmental monitoring.
- Allow periodic reassessment of the Project's impacts (and subsequent review of mitigation and management measures).

The Project will undertake regular monitoring and reporting throughout the life-of-mine, and ensure that sufficient resources are available for effective program implementation. Where appropriate, external contractors or parties may be engaged for provision of additional support in implementing the monitoring and reporting program.

The key aspects identified in this monitoring and reporting program are:

- Soils and erosion.
- Surface water quality.
- Groundwater (quality and level).
- Biodiversity.
- Air quality.
- Noise.

- Socio-economic.
- Health and safety.

8.5.1 Soils, Erosion and Rehabilitation Monitoring

Monitoring of land disturbance, soil management and erosion is required to provide data on the impacts to land, soil and surface water quality. The objectives of this monitoring are to ensure that:

- The Topsoil and Erosion Management Plan is performing as expected.
- Land disturbance is undertaken in approved areas only and minimised, where practicable and that topsoil is stripped and stockpiled in accordance with the approved designs.
- Management measures to avoid erosion and siltation are effective, and corrective action is taken where necessary.
- Where erosion and siltation are detected, corrective action is taken and additional mitigation measures put in place.
- Surface water quality is not adversely affected by Project activities.
- Rehabilitation and revegetation are undertaken progressively and as soon as practicable.
- Continuous progress is made on achieving the closure plan objectives, achieving final closure and leaving a safe, stable and self-sustaining ecosystem post-closure.

Monitoring will be undertaken as follows:

- Visual inspection of the extent of land clearance on a weekly basis.
- Visual inspection of all stockpile areas on a weekly basis and after heavy rainfall events.
- Visual inspection of erosion and sediment control structures on a monthly basis, and after heavy rain events to ensure that these are not silted up.
- Representative soil samples from each topsoil stockpile will be taken for laboratory analysis and records kept for use when undertaking rehabilitation.
- Visual inspections of topsoil on a monthly basis during the first year after placement to determine if vegetation has established from the seed bank. In the event that vegetation establishment has not taken place, undertake additional sampling to determine the required application of fertiliser and seeding.
- Monthly surface water quality monitoring to determine extent of siltation from erosion and discharge.
- Seasonal monitoring of rehabilitation using photo points (to be established) throughout the Project area. The success rate of seedling emergence and survival, weed invasion, browsing levels (i.e., insect and animal attack of regenerating vegetation) and erosion will be monitored, comparing photos taken each year from the monitoring points. This will be supported by ecology surveys every three years to evaluation rehabilitation success between sites and over time.

A map of the project area will be maintained which indicates disturbed and rehabilitated areas, and will be updated regularly in accordance with the monitoring outcomes.

8.5.2 Surface and Ground Water Monitoring

Management measures will be implemented, as per the water management plan, to mitigate potential impacts during all phases of the Project.

Water quality monitoring is required to provide information necessary to determine potential Project impacts to surface and groundwater, which may adversely affect human health, terrestrial and aquatic life. The purpose of water quality and quantity monitoring is to ensure that:

- The objectives of the Water Management Plan are being met.

- Surface water quality is not adversely affected by Project activities.
- Groundwater quality is not adversely affected by Project activites.
- Potential discharge from site is within the prescribed standards.
- Groundwater drawdown does not adversely affect the community.
- Any potential changes to water quality or quantity are identified early to allow appropriate mitigation measures to be put in place.

Water quality monitoring parameters have been selected based on the parameters analysed during the baseline assessment, legislative requirements and information relevant to the Project.

Table 8.11 lists the relevant parameters and guideline values/limits (criteria). Criteria have been included from several guidelines and standards as no single guideline/standard contains target concentrations for all parameters.

Results from analysis will be compared to the baseline data previously collected from the sampling locations and evaluated against the relevant guideline values. Baseline data has indicated that several of the surface water sources are already contaminated and do not necessarily comply with the relevant standards. The aim of the water quality analysis is to determine any changes in concentration of particular parameters, which may be as a result of mining activities.

Table 8.11: Surface and Ground Water Quality Parameters and Guideline Values/Limits

Parameter	Units of Measure	Malawi Drinking Water Specification	WHO – Guidelines for Drinking-water Quality	IFC Mining Effluent Guidelines
pH	pH	5 – 9.5	–	6 – 9
Total suspended solids (TSS)	mg/L	–	–	50
Electrical conductivity (EC)	µs/cm	70 – 150	–	–
Total dissolved solids (TDS)	mg/L	450 – 1,000		–
Alkalinity	$CaCO_3$/L	–	–	–
Turbidity	NTU	0.1 – 1	–	–
Coliforms (Total, Faecal, E. coli)	CFU/100 mL	0	0	
Chloride (Cl)	mg/L	100 – 200	250	–
Fluoride (Fl)	mg/L	0.7 – 1	1.5	–
Nitrate (NO_3)	mg/L	6 – 10	50	–
Nitrite (NO_2)	mg/L	–	–	–
Phosphorous (P)	–	–	–	–
Phosphate (PO_4)	–	–	–	–
Sulfate (SO_4)	mg/L	200 – 600	–	–
Sulfur (S)	mg/L	–	–	–
Aluminium (Al)	mg/L	0.15 – 0.3	0.2	–
Barium (Ba)	mg/L	–	0.7	–
Calcium (Ca)	mg/L	80 – 150	100 – 300	–
Chromium (VI) (Cr)	mg/L	0.05 – 0.1	0.05	0.1
Iron (Fe)	mg/L	0.1 – 0.2	–	2
Magnesium (Mg)	mg/L	30 – 70	–	–
Manganese (Mn)	mg/L	0.05 – 0.1	0.4	–
Nickel (Ni)	mg/L	0.05 – 0.15	0.07	0.5
Potassium (K)	mg/L	25 – 50		

Parameter	Units of Measure	Malawi Drinking Water Specification	WHO – Guidelines for Drinking-water Quality	IFC Mining Effluent Guidelines
Sodium (Na)	mg/L	100 – 200		
Uranium (U)	mg/L	–	0.03	–
Vanadium (V)	mg/L	0.1 – 0.2	–	–
Zinc (Zn)	mg/L	3 – 5	–	0.5
Zirconium (Zr)	mg/L	–	–	–
Thorium	mg/L	–	–	–
Total Petroleum Hydrocarbon TPH C10-C40	mg/L	–	–	–
TPH C10-C28	mg/L	–	–	–
TPH C28-C40	mg/L	–	–	–
Oil and Grease	mg/L	–	–	–

Surface water monitoring will be undertaken as follows:

- Monthly at all dambos and surface water resources at KZ1, KZ4, KZ5, MMST1, SWQ 3, SWQ 5, SWQ 9, and SWQ 10 (refer Figure 5.21) for location.
- Monthly at all discharge points at Kovuma dambo and Dambo 1.
- Monthly at all water storage locations.
- Monthly TSF.
- Flow monitoring on a monthly basis in channels and pipelines and at abstraction and discharge facilities on site, including pit dewatering.
- Monitoring of water levels in dams and channels to ensure the freeboard is maintained. Monitoring will be undertaken monthly through the dry season and weekly through the wet season or after storm events.
- Visual inspection of channels, silt traps, culverts, pipeline, dam walls and dams for signs of erosion, cracking, silting and blockages of inflows, to ensure the performance of the stormwater remains acceptable. Inspection will be undertaken weekly to monthly during the wet season and after storm events, and monthly in the dry season.
- Measure rainfall daily for use in water balance updates.

Groundwater monitoring will be underaken as follows:

- Quarterly at groundwater monitoring points (refer to Figure 5.23 for locations).
- If groundwater is to be extracted at any of the boreholes or from the pit, the quantities extracted is to be monitored using a continuous flow meter/logger.
- Monthly reporting of groundwater levels, through the use of continuous loggers.

Monitoring will be undertaken over the life-of-mine and post-closure.

8.5.3 Biodiversity Monitoring

Biodiversity monitoring will be required to verify the predicted impacts to flora, fauna and aquatic ecology during the life-of-mine, as well as post-closure.

The objectives of the biodiversity monitoring program are to ensure that:

- Potential impacts to biodiversity (that may be directly related to Project activities) are detected early to allow for appropriate mitigation measures to be implemented.

- Prevalence of weed and alien invasive species is monitored and recorded and managed where appropriate.
- Relevant data is collected to confirm the success of rehabilitation activities.

8.5.3.1 Weeds and Invasive Species Monitoring

Areas with a high potential for, or susceptibility to, invasion by weeds and invasive plant species (e.g., areas along roadsides and recently cleared areas) will be monitored biannually. Monitoring for weeds and invasive species will include:

- Inspecting for weed and invasive plant species outbreaks after the wet season and opportunistically after rain events, and determine the extent of localised outbreaks of exotics in and around the Project area.
- Inspecting for weeds and invasive plant species after significant germination events and recording the level of proliferation.

8.5.3.2 Terrestrial Fauna

Fauna monitoring surveys will be undertaken biennually during the wet season to allow assessment of:

- Changes in the abundance, composition or condition of targeted fauna species, particularly conservation significant species.
- Ongoing impacts to fauna as a result of Project activities.
- Increases in the density and distribution of pest fauna.
- Introduction of previously unrecorded pest fauna.

The above will be informed by records of:

- Fauna movements around the TSF area including birds and other species.
- Animal sightings and animal deaths that occur as a direct result of Project activities.

8.5.3.3 Aquatic Ecology

Aquatic biomonitoring indicators will be used to measure the health condition of watercourses as habitat for aquatic flora and fauna. Sensitive macroinvertebrate taxa and biologically sensitive fish species, will be used as bio-indicator species to identify the changes in the abundance, composition or condition of species.

Macroinvertebrate monitoring will involve sampling every two years at those locations sampled during the ESIA as indicated in Figure 5.12. Monitoring will identify any changes to flow sensitive macroinvertebrate communities. Similarly, fish sampling events (preferably conducted during the wet season) will be necessary to monitor possible changes in species populations.

Aquatic habitat conditions will also be monitored and will incorporate trends in dry-season base flow, channel morphology and sediment transport (in conjunction with surface water quality monitoring).

8.5.4 Air Quality Monitoring

A monitoring program will be implemented to determine the impacts associated with the Project on ambient air quality, which could pose potential health and environmental risks.

The objectives of the air quality monitoring program are to ensure that:

- The Air Quality Management Plan is being implemented as expected.
- Air quality is maintained to an acceptable quality in compliance with all applicable legislation, as far as practicable.

- Changes in air quality that may be directly related to Project activities are detected early to allow for appropriate additional mitigation measures to be implemented.

Monthly dust and paticulate monitoring will continue to be undertaken at the locations monitored as part of the ESIA process. Continuous emmissions monitoring will be undertaken on site using appropriate equipment.

Results from the monitoring will be compared to the baseline data previously collected from the sampling locations and evaluated against the relevant guideline values as indicated in Table 8.12, Table 8.13 and Table 8.14.

Table 8.12: WHO (2005) and MBS (2005) Ambient Air Quality Standards

Pollutant	Averaging Period	MBS Limit	WHO Guideline ($\mu g/m^3$)
CO	1 Hour	40.10 (mg/m^3)	-
	8 Hours	10.31 (mg/m^3)	-
SO_2	10 Minutes		500
	1 Hour	0.52 (mg/m^3)	20
	24-hour	0.21 (mg/m^3)	20
	1 Year	0.05 (mg/m^3)	500
NO_2	1-Hour	0.23 (mg/m^3)	200
NO_2	1 Year	0.06 (mg/m^3)	40
PM_{10}	1-year	-	20
	24-hour	25 ($\mu g/m^3$)	50
$PM_{2.5}$	1-year	8 ($\mu g/m^3$)	10
	24-hour	-	25

Table 8.13: Acceptable Dust Fallout Rates (South African Standard)

Restriction Areas	Dust fallout rate ($mg/m^2/day$, 30-days average)	Permitted Frequency of exceeding dust fallout rate
Residential Area	D < 600	Two within a year, not sequential months
Non-Residential Area	600 < D < 1200	Two within a year, not sequential months

Table 8.14: Inhalation-based Health Thresholds for Selected Non-criteria Pollutants

VOC Pollutants	Inhalation Reference Concentration (mg/m^3)
Benzene	0.03 (CASRN:71-43-2)
Ethylbenzene	1 (CASRN:100-41-4)
Toluene	5 (CASRN:108-88-3)
Xylene	0.1 (CASRN:1330-20-7)

8.5.5 Noise Monitoring

Noise monitoring will be undertaken at potentially sensitive receptors during all phases of the Project. Regular monitoring is required to provide information necessary to determine impacts from noise and associated with the Project. The objectives of the noise and vibration monitoring program are to ensure that:

- Ambient noise does not exceed applicable noise criteria at sensitive receptors in the Project area.
- To gather data such that any potential noise and vibration impacts are identified and appropriate additional mitigation measures put in place, where necessary.

Category / Receptor	Maximum Level (Limit in dB)	
	Day-time	Night-time
Malawi Noise Pollution Tolerance Limits		
Residential area	55	45
Silence zone	50	40
IFC EHS Guidelines		
Residential, institutional and educational	55	45
Or where baseline exceeds IFC guideline	3 dB increase over baseline	

8.5.6 Monitoring of Community Impacts

Ongoing monitoring will be conducted to allow identification of any impacts from the Project on stakeholders and socio-economic conditions in the local communities. This may include aspects such as traffic, health and safety, visual impacts, perceptions regarding noise and air quality, and community well-being. This will involve monitoring of stakeholder and community sentiment and socio-economic impacts as part of the Social Impact Management Plan and Community Development Agreement. In addition, monitoring will be required to ensure that the RAP has been implement successfully and the impacts on displaced communities are being managed effectively.

Monitoring of impacts on communities will make use of the following:

- Records of attendance at public events and community meetings to gauge stakeholder perceptions, and identify issues and concerns.
- Articles that appear in the media, particularly local newspapers in the peripheral communities.
- Workforce statistics, including number of ‘local’ and Malawi nationals employed by the Project.
- Number and nature of complaints documented through the Grievance Mechanism. The mechanism will record the person’s name and contact details, communication, action taken to resolve the complaint, outcomes and feedback from complainant.
- Service and goods supply statistics. These will include details regarding:
  - Type and quantity of goods/service.
  - Value.
  - Location of supplier.
- Contributions made by the Project to local communities through the future community development program, including the outcomes of such contributions.
- Community crime rates and concerns regarding crime.
- Review of data recorded at local clinics, which indicates the prevalence of infectious diseases, injuries, and health concerns that may be related to the Project.
- Community engagement, attitudes and interaction.
- Number of new local business opportunities as a result of project activities.
- Access to, and attendance at, social services and facilities (e.g., hospitals, schools).
- Population and demography.

8.5.7 Summary of Monitoring Plan

A summary of the monitoring activites are provided in Table 8.15.

Table 8.15: Summary of Monitoring Activities

Component	Parameter	Guidelines/Standards	Frequency	Responsible	Annual Budget (USD)
Land clearance	Area of clearance in hectares.	Comparison of area cleared against design.	Monthly during construction. Quarterly duirng opertations.	Environmental Manager	Incl. in personnel salaries
Erosion	Visual inspection of construction areas, topsoil stockpiles, ore stockpiles, access and haul roads, sediment traps.		Continuous during construction. Monthly during operations.	Environmental Manager	Incl. in personnel salaries
Topsoil stockpile stability	Visual inspection of extent of vegetation established.		Monthly during first year after placement.	Environmental Manager	Incl. in personnel salaries
Topsoil stockpile fertility	Phosphorus, potassium, sodium, calcium, magnesium, pH.	South African Soil Fertility Guidelines (Fertiliser Association of South Africa, 2016).	Immediately prior to use in rehabilitaiton.	Environmental Manager	2,000
Rehabilitation	Mapping of extent of areas rehabilitated. Photo analysis of rehabilitation areas. Observations of success rate of seedling emergence and survival, weed invasion, browsing levels. Ecology surveys.		Bi-annual (seasonal) photo monitoring after rehabilitation. Three yearly ecology surveys.	Environmental Manager	Incl. in personnel salaries 15,000
Surface water quality	pH, TSS, EC, TDS, alkalinity, turbidity, coliforms, Cl, Fl, NO_3, NO_2, P, PO_4, SO_4, S, Al, Ba, Ca, Cr, Fe, F, Mg, Mn, Ni, K, Na, U, V, Zn, Zr, Th, Total Petroleum Hydrocarbon C10-C40, C10-C28, C28-C40, Oil and Grease	Malawi Drinking Water Specification (2005). WHO – Guidelines for Drinking-water Quality (2017). IFC Mining Effluent Guidelines (2007).	Monthly	Environmental Manager	50,000
Surface water flow volumes	Flow in channels and pipelines.	Design standards.	Monthly	Environmental Manager	Incl. in construction costs

Component	Parameter	Guidelines/Standards	Frequency	Responsible	Annual Budget (USD)
Surface water levels	Water levels in dams and channels to ensure the freeboard is maintained.	Design standards.	Monthly in dry season. Weekly in wet season.	Environmental Manager	Incl. in operational costs
Stormwater management infrastructure	Visual inspection of channels, silt traps, culverts, pipeline, dam walls and dams for signs of erosion, cracking, silting and blockages of inflows.	Good industry practice guidelines.	Weekly to monthly.	Environmental Manager	Incl. in personnel salaries
Groundwater quality	pH, TSS, EC, TDS, alkalinity, turbidity, coliforms, Cl, Fl, NO_3, NO_2, P, PO_4, SO_4, S, Al, Ba, Ca, Cr, Fe, F, Mg, Mn, Ni, K, Na, U, V, Zn, Zr, Th, Total Petroleum Hydrocarbon C10-C40, C10-C28, C28-C40, Oil and Grease	Malawi Drinking Water Specification (2005). WHO – Guidelines for Drinking-water Quality (2017). IFC Mining Effluent Guidelines (2007).	Quarterly	Environmental Manager	20,000
Groundwater use	Volumes extracted	As per groundwater extraction permit conditions.	Continuous	Environmental Manager	Incl. in operational costs
Groundwater levels	Depth below ground level in boreholes		Monthly	Environmental Manager	Incl. in personnel costs
Weed and invasive plant species	Prevalence of weed and invasive plant species. Proliferation of weed and invasive plant species.		Annually after wet season. Opportunistic recrodings. Immediately after germination events.	Environmental Manager	Incl. in personnel salaries
Fauna	Changes in abundance, composition or condition of targeted fauna species. Increases in the density and distribution of pest fauna. Introduction of previously unrecorded pest fauna.		Ongoing - opportunistic sightings.	Environmental Manager	Incl. in personnel salaries

Component	Parameter	Guidelines/Standards	Frequency	Responsible	Annual Budget (USD)
Aquatic fauna	Abundance, composition and condition of sensitive macroinvertebrate taxa and biologically sensitive fish species. Fish tissue metal analysis. Mollusc and snail tissue metal analysis. Sediment metal analysis.	Present Ecological Sate Classes in terms of General Habitat Integrity (Kemper, 1999) South African Scoring System Version 5 (SASS5) South African Water Quality Guidelines (SAWQG) for Aquatic Ecosystems (DWAF, 1996) Fish Response Assessment Index (FRAI) (Kleynhans, 2007) Fish Reference Frequency of Occurrence (FROC) Database (Kleynhans, 2007) Quality Guidelines for Human Consumption (EU, 2006) Median International Standards for Trace Elements (CEPA, 2000 and FAO, 1983) Sediment Quality Guidelines (consensus-based) (MacDonald et al., 2000)	Biennually	Environmental Manager	15,000
Air quality	CO, SO_2, NO_2, PM_{10}, $PM_{2.5}$, dust fallout.	WHO Air Quality Guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide (2005) Malawi Standard (MBS737:2005) Ambient air quality – limits for common pollutants (2005) South African standard [National Dust Control Regulations (2013), published in Government Notice 827 in Gazette 36974 on 1 November 2013]	Monthly (dust and particulate matter). Continuous (CO, SO_2, NO_2).	Environmental Manager	15,000
Noise	Ambient noise levels.	Malawi Noise Pollution Tolerance Limits (MS 173:2005) IFC EHS Guidelines (IFC, 2007)	Ongoing	Environmental Manager	10,000
Commmunity impacts	Stakeholder perceptions, issues and concerns.		Ongoing (reported annually) - Records of attendance at public events and community meetings. Ongoing (reported quarterly) - Articles in the media, particularly local newspapers in the peripheral communities. Ongoing (reported quarterly) - Number and nature of complaints documented through the Grievance Mechanism.	Community Manager	Incl. in personnel salaries
Influx	Change in demographic profile		Every two to three years.	Community Manager	Incl. in personnel salaries

Component	Parameter	Guidelines/Standards	Frequency	Responsible	Annual Budget (USD)
Community	Creation of local job opportunities.		Ongoing (reported annually) - Workforce statistics, including number of 'local' and Malawi nationals employed by the Project. Number of new local business opportunities	Community Manager. Human Resources Manager.	Incl. in personnel salaries
Community	Creation of small business opportunities.		Ongoing (reported annually) - Service and goods supply statistics.	Procurement Manager	Incl. in personnel salaries
Community	Quality of life.		Ongoing (reported quarterly) - Contributions through the community development agreement, including the outcomes of such contributions. Annually - Community crime rates and concerns regarding crime. Annually - Health data from local clinics on the prevalence of infectious diseases, injuries, and health concerns. Annually - Access to, and attendance at, social services and facilities.	Community Manager	Incl. in personnel salaries

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Chapter 9: Rehabilitation and Closure Framework

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9 Rebabilitation and Closure Framework

Early consideration of mine closure has been incorporated into the Project planning to ensure long-term social and environmental impacts are considered, as well as the cost of rehabilitation and environmental management at closure. The aim is to ensure a sustainable end land use for the Project site, once mining has been completed.

Key aspects to ensure successful mine closure include development of:

- A stakeholder consultation strategy.
- An agreed post-mining land use.
- Identification of a closure knowledge base and knowledge gaps.
- Chemical characterisation of tailings and rehabilitation resources.
- Risk assessment and identification of closure issues.
- A closure framework for the assessment of closure performance (including closure objectives, criteria and standards).
- Suitable rehabilitation and decommissioning techniques and plans.
- A strategy for unforeseen circumstances such as unplanned mine closure.
- Closure monitoring.
- Financial provisioning for closure.

A conceptual mine closure plan will be developed, following the ESIA report, and will be submitted to the Department of Mines in support of the mining licence application.

The conceptual closure plan will be updated on a regular basis throughout the life-of-mine to ensure that it remains relevant and an appropriate strategy for closure is in place. Review of the closure plan will be done every four years to ensure that changes to the site or mine planning are incorporated. In addition, the closure cost estimate will be reviewed and the quantum of financial surety be adjusted, where needed.

9.1 Legal and Policy Framework

The Malawi Government does not currently have any specific legislative requirements for mine closure, nor does it have guidelines for mine closure or rehabilitation.

The Mines and Minerals Act of 1981 states that an application for a mining licence shall include, among other, information on measures for the prevention of pollution, the progressive reclamation and rehabilitation of land disturbed by mining and for the minimisation of impacts on surface groundwater and neighbouring land.

However, the Mines and Minerals Act is currently under review by the Malawi Government and a Revised Mines and Minerals Bill was released for comment in 2015. The Bill states that an application for a mining licence would need to include a rehabilitation and closure plan, which contains the following:

- A physical closure plan, which includes dismantling of infrastructure, machinery, equipment and buildings, underground workings and open pit workings.
- An environmental rehabilitation of the land area affected by mining operations including rehabilitation throughout the life of the mine.
- A social mitigation plan for the workforce and affected communities from the beginning of mining operations up to and including post closure.
- Mechanisms for consultation with affected and interested communities and mine workers from the commencement of operations up to and including mine closure.

- Post closure monitoring to ensure the safety and health of affected environment and communities.

9.2 Good International Industry Practice

In the absence of specific legislation and guidelines applicable in Malawi, Sovereign will consider the following guidelines in developing a conceptual closure plan for the Project:

- The IFC Environmental Health and Safety Guidelines for Mining (IFC, 2007) recognise that a detailed mine reclamation and closure plan, which includes both physical rehabilitation and socio-economic considerations, should be an integral part of the project life cycle. The guidelines also stipulate that closure funding arrangements should be put in place and reviewed on an annual basis and the closure funding arrangements adjusted to reflect any changes.
- The International Council on Mining and Metals (ICMM) Toolkit (2008) is a practical guide for the mining and metals sector to ensure mine closure is undertaken in a sustainable manner. The document provides a suite of tools to formulate well-considered decisions when planning for closure, and uses a risk- and opportunity-based approach through the iterative process of preparing for planned closure.
- The Australian Government Leading Practice Sustainable Development Program for the Mining Industry – Mine Closure (2016) provides guidance on the delivery of a defined post-mining land use rather than just closure, and ensuring that planning for this is undertaken as part of longer term considerations with relinquishment as the final objective.
- The Western Australia Department of Mines and Petroleum Guidelins for Preparing Mine Closure Plans (2015) is a practical guide for adopting a risk-based approach to mine closure to ensure key relevant aspects are identified. The guidelines are based on the principle that planning for mine closure should be an integral part of mine development and operations planning and should start early in the life-cycle as part of feasibility studies

9.3 Closure Framework

Sovereign's closure framework will establish its overall goal, objectives, criteria and indicators of success for the closure of the Project and will aim to support the mining lease relinquishment process. The closure framework consists of:

- Goal – defines the overall intended future state and end land-use following mine closure.
- Objectives – clear statements relating to intended environmental and social outcomes of the mine closure program.
- Criteria – describe specific elements that can be measured to have occurred, and that are critical to achieving the objectives. Each objective may have more than one criterion, and a criterion may apply to more than one objective.
- Indicators – these may be either an agreed value that is measurable and is regarded as the minimum that must be achieved.

Closure criteria and indicators are site specific and cover a range of aspects. The aspects of importance to this Project include, *inter alia,* surface water quality, changes in flow regimes of surface water, groundwater quality and levels, future land use, wetland rehabilitation and safety of communities. At this stage (planning) of the Project, closure criteria are conceptual in nature and require further development as planning progresses.

As part of the closure planning, Sovereign will be considering options to rehabilitate disturbed areas in such a manner that the area reflects a landscape that is:

- Safe to humans and animals.
- Geotechnically stable.
- Non-polluting.
- Capable of sustaining the post-mining land use that has been determined in consultation with stakeholders.

In addition, strategies will be developed to minimise adverse socio-economic impacts and maximise socio-economic benefits.

As part of the closure plan, criteria will be developed to determine whether the closure objectives have been met. Measurable indicators will be used to define each criterion and to determine whether closure has been undertaken successfully.

9.4 Stakeholder Engagement

As part of planning for closure, a comprehensive consultation process will be undertaken, consistent with Sovereign's stakeholder management plan.

To date, Sovereign has actively engaged with stakeholders regarding the development of the Project, environmental and social impacts, and potential resettlement. Throughout the life-of-mine consultation with affected communities and relevant stakeholders will continue. Consultation with key stakeholders about closure options should start early to ensure planning for the full lifecycle takes into consideration community concerns.

At the commencement of the Project, a community advisory group will be established with representation from the various villages and key stakeholders, to act as representatives of the community and engage with the Project on various issues such as resettlement and grievances. The function of this advisory group will be extended to provide input into the closure planning and agree on sustainable end land uses.

A detailed stakeholder engagement strategy will be developed prior to closure, with the specific intent to discuss closure aspects in detail. Culturally appropriate communication methods will be developed to ensure detailed information is conveyed to communities in a manner that is understandable.

9.5 Closure Options Selection

Initial outcomes from the feasibility studies undertaken for the Project, indicate that the open pits will remain as voids which will fill with water post-closure. At the same time, the TSF will remain on site and be rehabilitated, while all other infrastructure will be removed, and the area rehabilitated.

However, a number of options may exist which can enhance the use of the area post-closure and ensure a sustainable legacy. These options have not been identified or assessed in detail to date. As part of detailed closure planning, an option analysis of closure alternatives will be undertaken. This will include a review of the risks and opportuntiies associated with each option. These options need to consider a range of potential final land uses and alternatives, and is a key component of future consultation with affected communities.

The closure concepts below only consider the closure and rehabilitation of the site as described above and do not take into consideration any potential future uses of the open pits e.g. establishment of irrigation schemes or aquaculture.

9.6 Closure Objectives

The following overall objectives for closure were established prior to the preparation of the conceptual closure plan and selection of the preferred closure option:

- Ensure physical and chemical stability of the site and remaining infrastructure.
- Ensure the Project site is returned to its pre-mining land use, or where not feasible, an alternative use is considered.
- Minimise long-term risks to public health and safety.
- Ensure surface and groundwater are not adversely impacted over the long-term as a result of the presence of rehabilitated infrastructure, and where impacts are expected that appropriate mitigation be implemented.
- Minimise long-term post-closure maintenance.

9.7 Progressive Rehabilitation

Progressive rehabilitation will be undertaken on any areas no longer required for Project activities or infrastructure, where it is deemed practical to do so.

Cleared areas that are no longer required will be reclaimed and the surface re-contoured, topsoiled, revegetated and appropriate surface drainage will be re-established.

Erosion control measures such as silt fencing and barriers will be installed to minimise erosion caused by wind and heavy rainfall.

A detailed rehabilitation management plan will be developed prior to commencement of construction.

9.8 Closure Plan

The closure of the Project will be completed in three phases:

- Decommissioning.
- Rehabilitation and revegetation.
- Post-closure monitoring and maintenance works.

The Project area and activities will be divided into various "domains". Each domain is treated as a separate entity within the overall closure plan with detailed plans developed for each domain. The likely domains for the Project are based on the conceptual project layout and include the open pit, tailings storage facility, temporary stockpiles, processing plant including offices and buildings, water management infrastructure and offsite infrastructure including access roads, borrow pits etc.

9.8.1 Decommissioning

9.8.1.1 Removal of Infrastructure

Decommissioning will commence once all mining and processing operations have ceased, and will will involve the removal of buildings, infrastructure, facilities, equipment and services (where safe to do so). Items that are reusable and recyclable will be salvaged and taken to a recognised appropriate recycling facility, or alternatively provided to community groups and businesses for reuse. Items with no residual value will be disposed of in accordance with best practices by considering the acceptable health, safety and environmental practices.

9.8.1.2 Hazardous Materials

All chemicals, reagents, lubricants, fuel and explosives will be removed by either returning them to the suppliers or if not practicable, disposed of appropriately. As closure approaches, the Project will gradually reduce its chemical stores on site so that only low volumes remain to be handled during closure.

9.8.1.3 Demolition

All buildings and infrastructure will be physically dismantled, removed from site and repurposed, sold, recycled or disposed of at an appropriate facility.

Structures will be dismantled and recoverable materials will be recycled. Concrete and brickwork will be broken into a size suitable for transportation and disposal. Concrete foundations will be broken up and removed to a depth of 1 m below surface. Sites will be backfilled with suitable cover.

9.8.1.4 Contaminated Soils

To limit the potential for contaminated areas to impact on the surrounding environment, soil contaminated with hydrocarbons will be remediated on site. Remediated soils will be used in rehabilitation activities.

9.8.2 Open Pits

It is anticipated that open pits will remain as voids upon closure and that these voids will fill with water to the natural groundwater level, once dewatering has ceased.

Current geochemical information suggests that the material from the pit walls will not result in acid mine drainage nor will seepage from remnant ore be acidic.

The preferred closure option for the open pits will be dependant on pit wall stability and pit lake water quality considerations, and also dependant upon the outcomes of stakeholder engagement. Options including reshaping the pit walls above the final pit lake level and measures to minimise inadvertent public access to the pits are currently being considered to manage safety and access issues. Assessment of the long-term erosion stability of the pit slopes will be undertaken and, where deemed necessary, measures put in place to minimise erosion.

Further investigation is required to determine if the final pit water quality will be suitable for the potential use of pit lakes by communities as a source of water for irrigation and livestock.

9.8.3 Tailings Storage Facility

All structures, pipelines and fencing will be dismantled, demolished and removed from the area.

The tailings storage facility (TSF) embankments will be reprofiled to create a safe and stable landform. The drainage plan for the TSF top surface needs to be confirmed but would consist of either a gravity discharge configuration or a retention strategy.

Based on the final drainage plan, the final landform will be contoured and where applicable spread with topsoil and revegetated to reduce long term dust generation. Where topsoil is not available, material of suitable quality will be identified and used as cover material or growth medium as part of the rehabilitation and revegetation activities. Erosion of the embankments is a concern and strategies such as 'armouring' with waste rock to minimise this will be considered. Appropriate surface drainage will be re-established around the TSF to prevent scouring of the embankments and toe of the TSF.

9.8.4 Processing Plant

Power and water supply infrastructure to the site will be disconnected and made safe. All buildings, structures and the processing plant will be dismantled, demolished and removed from the area. Equipment and supporting structures that have been dismantled will be salvaged and sold as second-hand equipment or scrap metal where possible. Portable office buildings may be considered for donation to local communities for use as community infrastructure.

Concrete slabs will be either be ripped up and material disposed of in the open pits or TSF, or alternatively broken up and buried under an appropriate layer of cover material that can sustain vegetation.

Hydrocarbon-contaminated soils, if any, will be treated on-site by bioremediation.

Cleared areas will be re-contoured, topsoiled and revegetated.

9.8.5 Temporary Material Stockpile Areas

Towards the end of life-of-mine most of the material stockpiles will be depleted and cleared areas will be rehabilitated.

All remaining excavated material will be collected and disposed of in the open pits or TSF.

Material of suitable quality will be identified and potentially be used as cover material or growth medium as part of the rehabilitation and revegetation activities.

Cleared areas will be re-contoured, topsoiled, revegetated and appropriate surface drainage will be re-established.

9.8.6 Water Management Infrastructure

Process and return water dams will be rehabilitated upon closure and surface water drainage reinstated, where appropriate.

The impoundments' embankments will be breached at the lowest point to prevent further water retention if a gravity drainage plan is selected. The areas will be contoured, ripped, spread with topsoil and revegetated.

Stormwater management channels will be filled with cover material where these are no longer required for future maintenance, and surface drainage re-estalbished.

9.8.7 Access Roads, Haul Roads, Laydown Areas

All hardstand areas, roads and laydown areas will be rehabilitated upon closure.

Areas will be ripped, re-contoured, topsoiled and revegetated. Appropriate surface drainage will be re-established.

9.8.8 Waste Management Facility

Any sites used for disposal of general waste and sewage will be appropriately closed upon decommissioning of the mine.

All all surface waste management infrastructure will be dismantled and demolished, if present.

The surface of the site will be capped with low permeability material followed by topsoil and revegetated with shallow rooted vegetation. Stormwater measures will be implemented upstream of the sites to divert water away from the facilities.

9.9 Site Maintenance and Monitoring

On completion of the final closure measures, a monitoring and maintenance program will be implemented to ensure that the closure measures are robust, have been performed adequately and issues are addressed as soon as practicable. At this stage of the Project, it is assumed that a minimum monitoring period of 10 years will be required post-closure.

Post closure maintenance of the Project site will be required upon the completion of final rehabilitation and demolition works and may include (as required):

- Small scale landform remediation.
- Maintenance of surface drainage system.
- Erosion control on TSF embankments.
- Limited revegetation activities.

- Maintenance of access control.

These maintenance activities will be undertaken to ensure closure objectives are met and rehabilitation activities are successful.

So that site relinquishment can be achieved, predetermined closure criteria will need to be met. A key aspect of this process is a robust monitoring system that provides evidence and assurance that rehabilitation has been successful. Much of the monitoring will be a continuation of the environmental and social monitoring program conducted during operations.

Environmental performance will be monitored during the decommissioning, rehabilitation and post-closure monitoring and maintenance stages of The Project until completion criteria have been met in accordance with this plan.

9.9.1 Land Capability and Vegetation

Monitoring will be carried out in order to determine if the desired land capability and a stable, self-sustaining vegetation community (dominated by species typical of the climax-species present in the adjacent areas) have been established. Quarterly (or more frequently in times of heavy rainfall) inspections of re-vegetated areas will be carried out to assess vegetation establishment and provide for early detection of erosion in recently planted/seeded areas.

Regular evaluation on the revegetation program will be carried out. During these assessments, measurement of growth performance and species abundance will be carried out.

9.9.2 Watercourses

To determine whether the rehabilitated mine site is free draining and that unnecessary impoundment of surface run-off is prevented, monthly site inspections will be undertaken during the wet season and after heavy rainfall events.

9.9.3 Water Quality Monitoring

Surface water quality monitoring will be undertaken on a quarterly basis at the same surface water monitoring points sampled during operations. In addition, water quality sampling of the water in the pit voids will also be taken and analysed.

Groundwater quality monitoring will be undertaken on a quarterly basis at monitoring boreholes established during the operations. Groundwater levels will be reported on a quarterly basis.

If monitoring demonstrates that relevant completion criteria are not met, corrective actions will be identified and implemented until further monitoring demonstrates that the completion criteria have been met.

9.10 Preliminary Closure Costs

The Project will make financial provision for mine closure as part of the Project planning. At this stage of the Project, final closure costs have not yet been determined. These will be dependent on the final layout and extent of the mine facilities and will be developed as part of the DFS.

Chapter 10: Conclusion and Recommendation

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10 Conclusion and Recommendation

The ESIA for the Project has identified and assessed a range of benefits and adverse residual impacts. The assessment was informed be various specialist studies, including soils, geochemistry, terrestrial biodiversity, aquatic ecology, surface and groundwater, air quality, noise, health risks, visual and social impact.

The total capital cost for the development of the Project is estimated at approximately US$49 million, with the total operating costs averaging approximately US$16 million per annum, equivalent to US$323 per tonne of concentrate. Revenue from product sales will average US$62 million per annum over the life-of-mine. The Project will generate government revenues during the operational phase in the form of taxation (30%) and royalties (5% of net sales revenue) as well as flow on benefits through indirect taxation of wages and other indirect taxation benefits. Estimated direct tax payable over the life-of-mine is US$150 million, with an additional US$50 million in royalties.

It is anticipated that the Project will create approximately 220 job opportunities during construction (at peak demand). During operations an estimated 167 people will be employed by the Project. In addition to this, another 80-90 people will be employed directly by subcontractors (including mining, laboratory, fuel farm, power plant, security, bus services, catering and cleaning. Increased income from these employment opportunities is likely to further stimulate local and regional business opportunities.

The significance of the residual impacts varied from very low to moderate (with the implementation of management measures). Mitigation and management measures were proposed that are consistent with good international industry practice and demonstrated that mitigation of impacts is readily achievable. The most significant residual impacts include:

- Physical displacement caused by land acquisition.
- Economic displacement caused by loss of cultivated land, loss of grazing and business assets.
- Loss of access to boreholes and community assets within the Project area.
- Loss of topsoil through erosion.
- Reduction in soil fertility as a result of stockpiling.
- Loss of a portion of the Kovuma and Dambo 1 habitat resulting in the loss of instream biota
- Unmet expectations around Project employment opportunities and other social investment benefits.
- Inflationary pressures caused by project-related demand.
- Reduced amenity and changes in sense of place.
- Community disturbance, increased risk of traffic accidents as a result of Project traffic along the S124.
- Interruption of access to cultural heritage sites.

McCourt is committed to implementing all management measures proposed in this report, as well as developing a detailed ESMP. The ESMP will contain a series of sub-plans focussing on aspects that will require management, along with operational procedures to ensure practical mitigation and management measures are implemented throughout the construction, operations, and decommissioning and closure phases.

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