Submitted to: Gergarub Exploration and Mining (Pty) Ltd.
Attention: Mr Nevan Pillay
P O Box 905757
Windhoek
Namibia.

REPORT:

ESIA REPORT FOR THE GERGARUB MINING PROJECT ON ML 245, //KARAS REGION, NAMIBIA

PROJECT NUMBER: ECC-99-425-REP-25-A

REPORT VERSION: REV 01

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Client Company Name:	Gergarub Exploration and Mining (Pty) Ltd.
Client Name:	Mr Nevan Pillay
Ministry Reference:	APP-000785
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DISCLAIMER

The report has been prepared by Environmental Compliance Consultancy (Pty) Ltd (ECC) (Reg. No. 2022/0593) on behalf of the Proponent. Authored by ECC employees with no material interest in the report's outcome, ECC maintains independence from the Proponent and has no financial interest in the Project apart from fair remuneration for professional fees. Payment of fees is not contingent on the report's results or any government decision. ECC members or employees are not, and do not intend to be, employed by the Proponent, nor do they hold any shareholding in the Project. Personal views expressed by the writer may not reflect ECC or its client's views. The environmental report's information is based on the best available data and professional judgment at the time of writing. However, please note that environmental conditions can change rapidly, and the information's accuracy, completeness, or currency cannot be guaranteed.

EXECUTIVE SUMMARY

Environmental Compliance Consultancy (ECC) has been appointed as the environmental assessment practitioner (EAP) by Gergarub Exploration and Mining (Pty) Ltd (referred to as the Proponent or Gergarub herein) to conduct an environmental and social impact assessment (ESIA) for mining of base metals namely lead, zinc and silver, within mining licence 245 (ML 245).

Gergarub Mining and Exploration (Pty) Ltd owns the Gergarub project (Project), a joint venture agreement between Vedanta Zinc International (51 %), via its Namibian subsidiary Skorpion Zinc Mine, and Rosh Pinah Zinc Corporation, or Rosh Pinah (49 %) (JV).

The proposed Gergarub Project will be an underground mine using the long hole open stoping (LHOS) and Drift and Fill (DAF) with a backfill mining method. The proposed Project will be referred to herein as the "Gergarub Project" or the "Project". Additionally, LHOS will be supplemented with Drift and Fill (DAF) mining which will be used to mine the orebody extremities and maximize the overall recovery of the Mineral Resource.

The project is located in the Oranjemund Constituency, 15km north of the town of Rosh Pinah in the //Karas Region in southern Namibia.

In terms of the Namibian Environmental Management Act, No. 7 of 2007 and its regulations, the Ministry of Mines and Energy (MME) is the competent authority for the proposed Project. Mining operations trigger listed activities in terms of the Act, requiring an environmental clearance certificate.

SCREENING PHASE

The Environmental Management Act, No. 7 of 2007, and its associated 2012 regulations stipulate that an environmental clearance certificate is required before undertaking any of the listed activities that are identified in the Act and its regulations. A high-level desktop study, previous data and scientific reports were utilised during the screening phase to determine the potential environmental and social impacts of the Project, which are listed below:

- Air quality impact assessment;
- Surface water impact assessment;
- Groundwater impact assessment;
- Vegetation impact assessment;
- Fauna impact assessment;
- Bird impact assessment;
- Social impact assessment;
- Archaeological impact assessment; and

– Visual impact assessment.

SCOPING PHASE

The objective of the scoping phase was to obtain a thorough understanding of the biophysical and socioeconomic environment in which the Project is located, often using baseline and specialist studies. It also provided an opportunity for the public to have input into the scope of the assessment. The technical inputs combined with the inputs from the I&APs led to the development of the Terms of Reference (ToR) for the assessment phase.

The following was considered during the preparation of the scoping report:

- Desktop and literature research;
- Site visits by ECC and specialists;
- Environmental monitoring data;
- Specialist baseline studies, including:
  - Soil sampling and analysis;
  - Acid-base accounting (ongoing study)
  - Surface and groundwater studies;
  - Biodiversity study;
  - Noise;
  - Air quality;
  - Road traffic study;
  - Visual impacts on sense of place;
  - Socioeconomic baseline; and
  - Heritage and archaeological study.

TERM OF REFERENCE

The ToR within the scoping report was proposed for the assessment phase and covered the following;

- Soil impact assessment;
- Surface and groundwater impact assessment;
- Noise impact assessment;
- Visual impact assessment;
- Socioeconomic impact assessment;
- Heritage impact assessment;
- Biodiversity impact assessment;
- Traffic impact assessment;
- Air quality impact assessment; and
- Mine-induced blast and vibration assessment.

The methodology used for assessing impacts was described in the scoping report and is included in chapter 6 of this report. A hierarchical decision-making process is followed, to prevent or eliminate, prevent, reduce or offset, mitigate or manage potential impacts. The draft scoping report and draft environmental management plan (EMP) was provided to the public for review for 14 days (19th of July 2023 – 7th of August 2023) before submission of the final scoping report to the competent authority, including MME and ultimately MEFT. All I&AP comments were captured and responded to by providing an explanation or further information in the response table, which was attached as an addendum report to the final scoping report which was submitted to the competent authority on 14 August 2023.

The next stage of the ESIA process was to conduct the impact assessment. This is the draft impact assessment report and has been made available for public review for a period of 7 days in terms of Section 32(1) of the Environmental Management Act (EMA) No.7 of 2007. The final ESIA report and appendices will be prepared and submitted formally to the MME and the MEFT as part of the application for an environmental clearance certificate for the Project. The phases of the ESIA are provided in Figure 1.

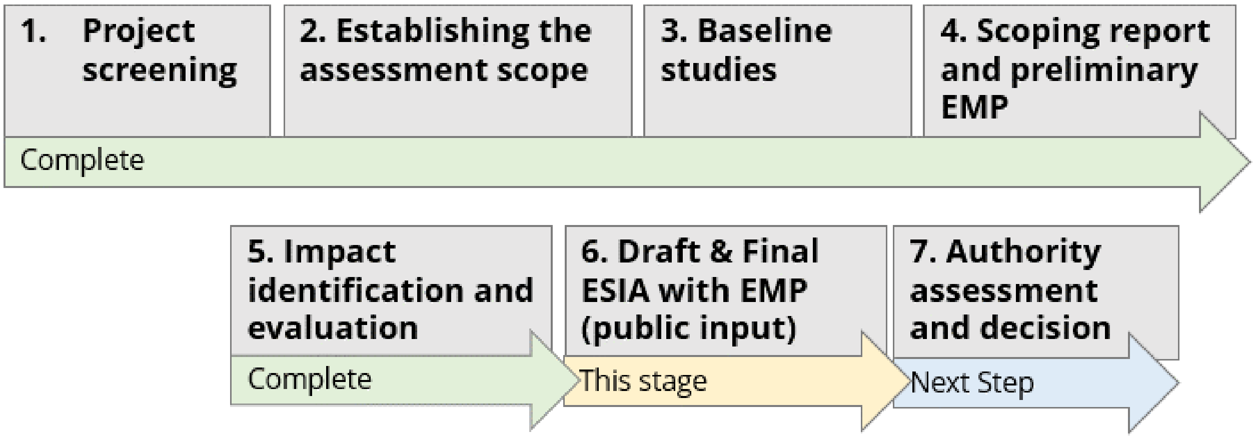

Figure 1 – Namibian ESIA process noting Gergarub progress

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ABBREVIATIONS

Abbreviation	Description
%	percentage
<	less than
>	greater than
˚C	degree celsius
µm	micrometres
AAB	A-mine and B-mine
AMC	AMC Consultants (UK) Limited
ANFO	Ammonium nitrate–fuel oil
BID	background information document
CH_4	methane
CIA	cumulative impact assessment
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
cm	centimetre
CO_2	carbon dioxide
CODC	chronic obstructive pulmonary disease
DAF	drift and fill
dBA	decibels
DEA	Directorate of Environmental Affairs
EAP	environmental assessment practitioner
EC	electrical conductivity
EC	European Community
ECC	environmental clearance certificate
ECC	Environmental Compliance Consultancy (Pty) Ltd
EGL	Effective Grinding Length
EMA	Environmental Management Act No.7 of 2007
EPL	exclusive prospecting licence
EPCM	engineering, procurement and construction management
ESMP	environmental and social management plan
ESIA	environmental and social impact assessment
Fe	iron
Ga	billions (thousand million) of years ago
GDP	gross domestic product
Gergarup	Gergarub Exploration and Mining (Pty) Ltd
GRU	Groundwater Resource Unit
g/t	grams per tonne
H_2S	hydrogen sulphide

Abbreviation	Description
HDPE	High-Density Polyethylene
HIV/AIDS	Human Immunodeficiency Virus
HoV^{TM}	Hill of $Value^{TM}$
IFC	International Finance Corporation
I&AP	interested and affected party
JV	joint venture
kg	kilogram
km	kilometre
km^2	kilometres squared
Kv	kilovolts
L/s	litre per second
L_{Aeq}	equivalent continuous sound pressure level
LHD	Load Haul Dump
LHOS	long hole open stoping
LoM	life of mine
Ltd	limited
m	metre
Ma	million years ago
mamsl	metres above mean sea level
MAWLR	Ministry of Agriculture, Water and Land Reform
mbgl	metres below sea level
MCF	Namibia Mine Closure Framework
MD	Maximum Demand
MDRL	Mineral Deposit Retention Licence
MEFT	Ministry of Environment, Forestry and Tourism
$mg/m^2/day$	milligrams per metres squared per day
ML	mining licence
mm	millimetre
MME	Ministry of Mines and Energy
MoU	Memorandums of Understanding
MSO	Mineable Shape Optimizer
Mt	milling tonnes
Mtpa	million tonnes per annum
MVA	mega volt amperes
MW	megawatts
MWh/day	megawatt per day
m^3	cubic metres
m/s	metre per second
m^3/hr	cubic metres per hour

Abbreviation	Description
$m^3/t/h$	cubic metres per ton per hour
mm/a	mm/a
mm^3	cubic millimetre
m/day	metre per day
mS/m	milliSiemens per meter
N	north
NAmWater	Namibia Water Corporation Ltd
NamPower	Namibian Power Corporation
NB	Nominal bore
NDP5	Fifth National Development Plan
NHC	National Heritage Council
NNE	north northeast
NNW	north northwest
NPC	National Planning Commission
NSRs	noise sensitive receptors
N$	Namibia dollar
NO_x	nitric oxide
OZ	ore zones
Pb	lead
pH	Acidity alkalinity unit
PM	particulate matter
PNZ	Port Nolloth Zone
POP	persistent organic pollutants
PRB	Permeable Reactive Barrier
Pty	proprietary
RAB	rotary air blast
RC	reverse circulation
RPZC	Rosh Pinah Zinc Mine
ROM	run of mine
RWD	return water dam
S	south
SADC	Southern African Development Community
SAG	semi-autogenous grinding
NAAQS	South African National Ambient Air Quality Standards
SO_2	sulphur dioxide
SO_X	sulphur oxides
SPI	Standard Practice Instruction
SQUID	superconducting quantum interference device
SW	southwest

Abbreviation	Description
SSW	south southwest
SZM	Skorpion Zinc Mine
t	tonnes
TB	Tuberculosis
TIA	traffic impact assessment
tpa	tonnes per annum
ToR	term of reference
TSF	tailings storage facility
TSP	total suspended pollutants
USD	United States dollar
VOCs	volatile organic compounds
VTC	vocational training centre
VTEM	Versatile Time Domain Electromagnetic
WBG	World Bank Group
WHO	World Health Organisation
WNW	west northwest
WRD	waste rock dump
w/w	Weight by Weight or Weight for Weight
Zn	zinc

1 INTRODUCTION

1.1 COMPANY BACKGROUND

Environmental Compliance Consultancy (Pty) Ltd (ECC) has been retained by Gergarub Exploration and Mining (Pty) Ltd base metals mining and exploration company jointly owned by Skorpion Mining Company Pty Ltd (5%) and Rosh Pinah Zinc Corporation (49%) referred to hereinafter as the Proponent. ECC is conducting an environmental and social impact assessment (ESIA) for mining of base metals, namely lead and zinc (plus silver), within a proposed mining licence (ML) area (ML 245) located on Mineral Deposit Retention Licence 2616 (MDRL 2616).

The Skorpion Zinc Mine (SZM) was acquired by Vedanta Resources plc (Vedanta) in December 2010. Vedanta is a globally diversified Natural Resources Company with interests in zinc, lead, silver, iron ore, steel, copper, aluminium, power and oil and gas. Trevali Mining Corporation (Trevali) was the majority shareholder of the Rosh Pinah Zinc Mine (RPZC) up until June 2023, whereafter it was acquired by private equity firm Appian Capital Advisory which now has an 89.6% stake in RPZC.

The Proponent has focused on the development of potential zinc, lead, and silver projects in Namibia through extensive exploration programmes. The proposed Gergarub Project will be an underground mine using the long hole open stoping (LHOS) and Drift and Fill (DAF) with a backfill mining method. The proposed Project will be referred to herein as the “Gergarub Project” or the “Project”. Additionally, LHOS will be supplemented with Drift and Fill (DAF) mining which will be used to mine the orebody extremities and maximize the overall recovery of the Mineral Resource.

The proposed Project area is in the Oranjemund Constituency, 15km north of the town of Rosh Pinah in the //Karas Region in southern Namibia shown in Figure 2.

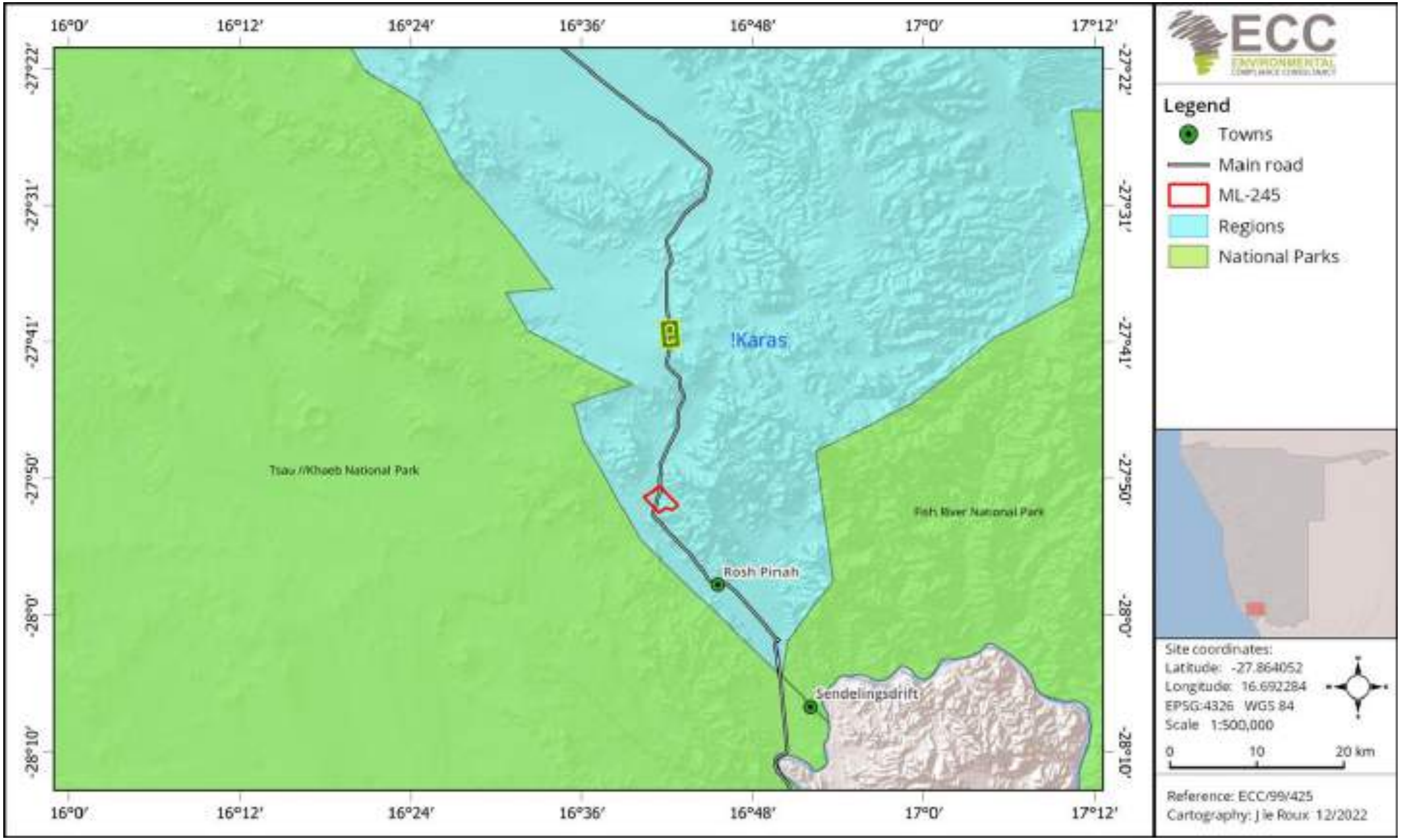


Figure 2 – Project location

1.2 Purpose of the draft environmental and social impact assessment

An environmental and social impact assessment (ESIA) has commenced in terms of the requirements of the Environmental Management Act, No. 7 of 2007, and its associated 2012 regulations. The purpose of this report is to present the findings of the environmental impact assessment phase that forms part of the larger ESIA process.

The scoping report summarises the prescribed ESIA process followed; provides information on the baseline biophysical and socio-economic environments, project description and details; outlines the terms of reference for the assessment phase; and presented a preliminary environmental management plan (EMP). The scoping report and appendices was submitted to the public for review and input on the impacts and the related ESIA terms of reference on the 19th of July 2023. The revised scoping report with public input is submitted to the Ministry of Mines and Energy (MME) as the competent authority for the Project, and the Ministry of Environment, Forestry and Tourism (MEFT) - Directorate of Environmental Affairs (DEA) on the 14th of August 2023.

The draft ESIA provides information on the baseline biophysical and socio-economic environment, project description and details. Additionally, the assessment uses EAP and commissioned environmental specialists' experience to assess potential impacts that the Project may have on the receiving environment that were scoped into the assessment during the scoping phase according to what was outlined in the terms of reference for the ESIA. The draft ESIA will be submitted for public review for a period of 14-days to registered I&APs, the competent authority for the Project the Ministry of Mine and Energy (MME) – Department of Mining and the Ministry of Environment, Forestry and Tourism (MEFT) – Directorate of Environmental Affairs (DEA).

Chapter 1 of the report is an introduction to the proposed project and ESIA. Chapter 2 provides details about the ESIA approach, including the roles of the public and specialists. Chapter 3 provides additional detail on the legal environment and requirements. Chapter 4 provides sufficient detail on the project to identify and assess potential impacts. Chapter 5 provides an overview of the screening and scoping results and related baseline information identifying all relevant biophysical and social aspects. Chapter 6 provides an overview of the methodology for identifying and evaluating impacts. Chapter 7 provides the findings of the impact assessment. Chapters 8 and 9 cover the conclusion and bibliography, respectively.

1.3 The proponent of the proposed project

Gergarub Exploration and Mining (Pty) Ltd is the proponent of the proposed project. The Proponent details are provided in Table 1.

Table 1 - Proponent's details

Company Representative:	Contact Details:
Mr Nevan Pillay Director	Gergarub Exploration and Mining (Pty) Ltd P O Box 90757 Windhoek, Namibia NPillay@vedantaresources.co.za

1.4 ENVIRONMENTAL AND SOCIAL ASSESSMENT PRACTITIONER

Environmental Compliance Consultancy (ECC) (Reg. No. 2022/0593) has prepared this scoping report and the preliminary EMP on behalf of the Proponent.

This report has been authored by employees of ECC, who have no material interest in the outcome of this report, nor do any of the ECC team have any interest that could be regarded as being capable of affecting their independence in the preparation of this report. ECC is independent from the proponent and has no vested or financial interest in the project, except for fair remuneration for professional fees rendered based upon agreed commercial rates. Payment of these fees is in no way contingent on the results of this report, the assessment, or a record of decision issued by the Government. No member or employee of ECC is, or is intending to be, a director, officer, or any other direct employee of Gergarub Exploration and Mining (Pty) Ltd No member or employee of ECC has, or has had, any shareholding in Gergarub Exploration and Mining (Pty).

All compliance and regulatory requirements regarding this report should be forwarded by email or posted to the following address:

Environmental Compliance Consultancy
PO Box 91193, Klein Windhoek, Namibia
Tel: +264 81 669 7608
Email: info@eccenvironmental.com

1.5 ENVIRONMENTAL REQUIREMENTS

The Environmental Management Act, 2007, and its regulations, stipulates that an environmental clearance certificate is required before undertaking any of the listed activities that are identified in the Act and its regulations. Potential listed activities triggered by the Project are provided in Table 2.

Table 2 – Activities potentially triggered by the Gergarub Project

Source: Environmental Management Act, 2007, and its regulations

Listed activity	As defined by the regulations of Act	Relevance to the project
Energy generation, transmission, and storage activities	The construction of facilities for: (1a) The generation of electricity. (1b) The transmission and supply of electricity.	- The proposed Project will connect to the national power grid supplied by NamPower. - Alternatively, the Proponent may consider developing a renewable energy plant (i.e. solar) for the generation of supplementary power. (Section 4.10.1 Power supply)
Waste management, treatment, handling, and disposal activities	(2.1) The construction of facilities for waste sites, and the treatment and disposal of waste. (2.2) Any activity entailing a scheduled process referred to in the Atmospheric Pollution Prevention Ordinance Act, 1976. (2.3) The importing, processing, use and recycling, temporary storage, transit, or exporting, of waste.	- Facilities for the disposal of mine and domestic waste will need to be constructed. - In terms of the Atmospheric Pollution Prevention Ordinance, the bulk storage and handling of mineralised or metallic ore on waste dumps designed to hold 100 000 metric tonnes or more, is defined as a scheduled process. (Section 4.11 Mineral and non-mineral waste)
Mining and quarrying activities	(3.1) The construction of facilities for any process or activities that require a license, right or other form of authorisation, and the renewal of a licence, right or other form of authorisation, in terms of the Minerals (Prospecting and Mining) Act, 1992. (3.2) Other forms of mining or extraction of any	- This listed activity infers the provisions of the Minerals (Prospecting and Mining) Act 33 of 1992. The very nature of the Project is mining, which therefore triggers this listed activity. (Section 4.7 Orebody, mining infrastructure and services)

Listed activity	As defined by the regulations of Act	Relevance to the project
	natural resources, whether regulated by law or not. (3.3) Resource extraction, manipulation, conservation, and related activities.	
Forestry activities	(4.) The clearance of forest areas, deforestation, afforestation, timber harvesting, or any other related activity that requires authorisation in terms of the Forest Act, 2001 (No. 12 of 2001) or any other law.	- Vegetation clearing will be required for site construction and infrastructure establishment. - During operations, vegetation clearing will be required as the Project develops. (Section 4.6 Primary site layout and 5.11Biodiversity)
Water resource developments	(8.5) Construction of dams, reservoirs, levees, and weirs. (8.6) Construction of industrial and domestic wastewater treatment plants and related pipeline systems.	- An estimated amount of water that will be required by the mine monthly is 81 000 m^3 which will be supplied from the Orange River by NamWater via +/- 20km 200 NB pipeline. - Construction of a wastewater treatment plant. (Sections 4.10.2 Water supply4.18 Alternative's considered).
Hazardous substance treatment, handling, and storage	(9.1) The manufacturing, storage, handling, or processing of hazardous substance defined in the Hazardous Substances Ordinance, 1974. (9.2) Any process or activity that requires a permit, licence, or other form of authorisation, or the modification of, or changes to, existing facilities for any process or activity that requires amendment of an existing permit, licence or authorisation, or which requires a new permit,	- Both fuel and hazardous substances are required for mining and processing activities. - Bulk fuel may be required for onsite for refuelling the mining fleet. - Consumer installation certificates are required for bulk fuel storage and dispensing. - Hazardous reagents will be used within the extraction and processing plant. (Section 4.11 Mineral and non-mineral waste4.14 General

Listed activity	As defined by the regulations of Act	Relevance to the project
	licence or authorisation in terms of governing the generation or release of emissions, pollution, effluent, or waste. (9.4) The storage and handling of dangerous goods, including petrol, diesel, liquid petroleum, gas, or paraffin, in containers with the combined capacity of more than 30 cubic meters at one location.	waste)

2 APPROACH TO THE ASSESSMENT

2.1 PURPOSE AND SCOPE OF THE ASSESSMENT

The aim of this assessment is to determine which impacts are likely to be significant. The available data is scoped out to identify any gaps that need to be filled, this enables us to determine the spatial and temporal scope; and to identify the assessment methodology that should be used.

2.2 THE ASSESSMENT PROCESS

The ESIA methodology applied to this assessment has been developed using the International Finance Corporation (IFC) standards and models, in particular, Performance Standard 1: 'Assessment and management of environmental and social risks and impacts' (International Finance Corporation, 2012 and 2017); Namibian Draft Procedures and Guidance for EIA and EMP (Republic of Namibia, 2008); international and national best practice guidelines; and ECC's combined relevant ESIA experience.

Furthermore, this assessment was undertaken for the Proponent in accordance with Namibian legal requirements.

This assessment is a formal process. The potential effects that the Project will have on the biophysical, social, and economic environments are identified, assessed, and reported so that the significance of potential impacts can be taken into account when considering a record of decision for the proposed Project.

Final mitigation measures and recommendations are based on the cumulative experience of the consulting team and the client, taking into consideration the potential environmental and social impacts. The process followed, through the assessment, is illustrated in Figure 3, and is detailed further in the following sections.

1. Project screening

Complete

The first stages in the ESIA process are to undertake a screening exercise to determine whether the Project triggers listed activities under the Environmental Management Act, 2007, and its regulations. The screening phase of the Project is a preliminary analysis, in order to determine ways in which the Project might interact with the biophysical, social, and economic environments.

Stakeholder engagement:
- Registration of the project
- Preparation of the BID

2. Establishing the assessment scope

Complete

Where an ESIA is required, the second stage is to scope the assessment. The main aim of this stage is to determine which impacts are likely to be significant; to scope the available data and any gaps that need to be filled; to determine the spatial and temporal scope; and to identify the assessment methodology.

The scope of this assessment was determined through undertaking a preliminary assessment of the proposed Project against the receiving environment. Feedback from consultation with the public and the Proponent informs this process. The following environmental and social topics were scoped into the assessment, as there was the potential for significant impacts to occur. Impacts that are identified as potentially significant during the screening and scoping phase are taken forward for further assessment in the ESIA process. These are:

BIOPHYSICAL ENVIRONMENT
- Noise and air quality, including dust emissions
- Surface and ground water
- Heritage and culture
- Biodiversity

SOCIAL ENVIRONMENT
- Employment
- Air quality
- Traffic
- Occupational health and safety
- Ground vibration and fly rock from blasting
- Heritage and archaeology
- Noise disturbance assessment
- Visual and sense of place

The following topics were scoped out of the ESIA, and they are therefore not discussed further in this report.
- An assessment of safety impacts or risks associated with exploration are not included within the scope of this assessment and will be addressed by the Proponent in a site-specific safety management plan.

3. Baseline studies

Complete

A robust baseline is required, to provide a reference point against which any future changes associated with a Project can be assessed, and to allow suitable mitigation and monitoring to be identified.

The project area has been studied extensively from 2015-2023 utilising various specialist works for various purposes. This literature was available to be referenced. The Project site-specific area has been studied as part of the ESIA process, and the following has been conducted as part of this assessment:
- Desktop studies
- Consultation with stakeholders
- Specialist studies

The environmental and social baselines are provided in the scoping study.

4. Scoping report and preliminary EMP

Complete

The scoping report documents the findings of the current process and provides stakeholders with an opportunity to comment and continue the consultation that forms part of the environmental assessment. The EMP provides measures to manage the environmental and social impacts of the proposed Project, and outlines the specific roles and responsibilities required in order to fulfil the plan.

This scoping report focuses on describing the ESIA process, project description, baseline description and Terms of Reference for the assessment phase.

This report will be issued to stakeholders and I&APs for consultation, for a period of 7 days, meeting the mandatory requirement as set out in the Environmental Management Act, 2007. The aim of this stage is to ensure that all stakeholders and I&APs have an opportunity to provide comments on the assessment process, and to register their concerns, if any.

5. Impact identification and evaluation

Complete

The key stage of the ESIA process is the impact identification and evaluation stage. This stage is the process of bringing together project characteristics with the baseline environmental characteristics and ensuring that all potentially significant environmental and social impacts are identified and assessed. It is an iterative process that commences at project inception and ends with the final design and project implementation. The impact identification and evaluation stages will be updated in the assessment phase.

The final design of the proposed Project will be assessed, along with alternatives that were considered during the design process in accordance with the Environmental Management Act, 2007. Section 6 in this report sets out the assessment methodology to be used to assess the Project against the environmental and social baselines that would be affected.

6. Draft & Final ESIA and EMP

This Stage

All comments received during the I&AP public review period will be collated in an addendum report, which will accompany the final ESIA report when submitted to the MME and MEFT: DEA. All comments will be responded to, either through providing an explanation or further information in the response table, or by signposting where information exists, or where new information has been included in the ESIA report or appendices. Comments will be considered, and where they are deemed to be material to the decision-making, or might enhance the ESIA, they will be incorporated.

The final ESIA report, appendices, and the addendum report, will be available to all stakeholders, and all I&APs will be informed of its availability for review.

The ESIA report, appendices and addendum will be formally submitted to the competent authority (MME) and the MEFT: DEA as part of the application for an environmental clearance certificate.

7. Authority assessment and decision

Future Stage

The Environmental Commissioner, in consultation with other relevant authorities, will assess if the findings of the ESIA presented in the report are acceptable. If deemed acceptable, the Environmental Commissioner will revert to the Proponent with a record of decision and recommendations.

8. Monitoring and auditing

Future Phase

In addition to the EMP being implemented by the Proponent, a monitoring strategy and audit procedure will be determined by the Proponent and competent authority. This will ensure key environmental receptors are monitored over time to establish any significant changes from the baseline environmental conditions, caused by Project activities

Figure 3 – ESIA process and stages complete.

This ESIA study area has been defined according to the geographic scope of the receiving environment and potential impacts that could arise because of the proposed Project within that area. The receiving environment is a summary term for the biophysical and socioeconomic environment that is described in the baseline chapter. The study area extends beyond the mining licence boundary and includes the nearby receptors such farmsteads and Karibib town.

2.3 STUDY AREA

This EIA study area has been defined according to the geographic scope of the receiving environment and potential impacts that could arise because of the proposed Project within that area. The receiving environment is a summary term for the biophysical and socioeconomic environment that is described in the baseline chapter. The study area extends beyond the mining licence boundary and includes the nearby receptors such as neighbouring farms and the town of Rosh Pinah.

2.4 PUBLIC CONSULTATION

Public participation and consultation are a requirement stipulated in Section 21 of the Environmental Management Act, 2007 and its regulations, for a project that requires an environmental clearance certificate. Consultation is a compulsory and critical component of the ESIA process for achieving transparent decision-making and can provide many benefits. Consultation is ongoing during the ESIA process.

The objectives of the public participation and consultation process are to:

- Provide information on the Project, and introduce the overall Project concept and plan in the form of a background information document (BID)
- Determine the relevant government, regional and local regulating authorities.
- Listen to and understand community issues, record concerns, and questions.
- Explain the process of the ESIA and timeframes involved.
- Establish a platform for ongoing consultation.

Public consultation for the Project commenced on the 21st of February 2023. Adverts were published in the newspaper announcing the dates of the public meetings and encouraging members of the public to sign up as an I&AP for the Project.

The adverts for these public meetings were published in newspapers and the notification of the assessment in terms Regulation 21 of the Act was placed in the following newspapers on the 21st of February 2023 and 28th February 2023:

- The Republikein;
- The Namibian Sun; and
- The Allgemeine Zeitung.

Public meetings were then subsequently held in Windhoek at the Namibian Scientific Society on the 28th of February 2023 and at the Rosh Pinah Community Hall on the 2nd of March 2023.
The records of the public consultation process in the form of a summary report are provided in Appendix B and provides the current list of I&APs, evidence of consultation, including minutes of public meetings, advertisements in national newspapers, and a summary of the comments or questions raised by the public.

2.5 IDENTIFICATION OF KEY STAKEHOLDERS AND INTERESTED AND AFFECTED PARTIES

A stakeholder mapping exercise (see Figure 4), was undertaken to identify individual or groups of stakeholders, and the method in which they will be engaged during the ESIA process. Stakeholders were approached through direct communication (letters and phone calls), the national press, site notices, or directly by email. The list of stakeholders is included in Appendix B.

The draft scoping report was submitted to the competent authority, and all interested and affected parties for their review on the 19th of July 2023. The public review period was open for a period of 14 days from 19th of July 2023 to 7th of August 2023. All comments received were recorded, analysed, and incorporated into the summary report as an addendum to the scoping report.

The final scoping report was submitted to the competent authority (MME) and MEFT and registered I&APs for their review on the 14th of August 2023. This draft ESIA report will be submitted for public review to the competent authority (MME), MEFT and registered I&APs for their review for a period of 14 days from the 14th of February 2024 – 28th of February 2024.

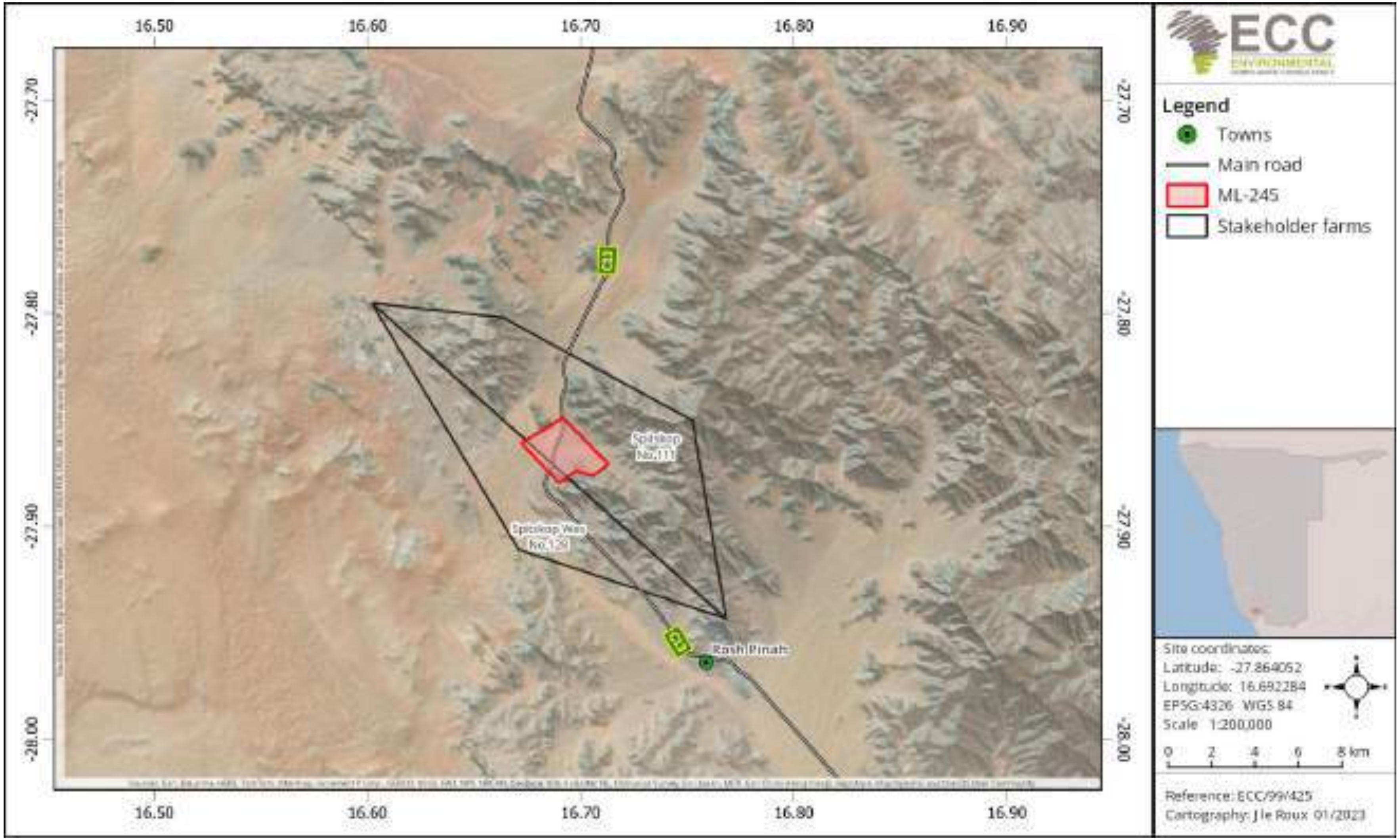


Figure 4 - Map showing neighbouring farms.

3 REVIEW OF THE LEGAL ENVIRONMENT

3.1 RELEVANT NATIONAL LEGISLATION

This chapter outlines the regulatory framework applicable to the proposed Project. As stated in Section 1, environmental clearance is required for any activity listed in the Government Notice No. 29 of 2012 of the EMA. The Proponent holds several current and valid environmental clearance certificates for the exploration phase of the Project.

The Project area is located outside of any national parks, heritage-listed areas, or areas of significance. The Project area is not located within a groundwater-controlled area, as regulated under the Water Management Act of 1956.

A thorough review of relevant legislation has been conducted for the proposed Project. Table 3 below identifies relevant legal requirements specific to the Project. Table 4 provides the national policies and plan and Table 5 lists specific permits for the Project.

3.2 RELEVANT NATIONAL POLICIES AND PLANS

Table 3 - Details of the regulatory framework as it applied to the Gergarub Project

National regulatory framework	Summary	Applicability to the project
Constitution of the Republic of Namibia (1990)	The constitution defines the country's position in relation to sustainable development and environmental management. The constitution refers that the state shall actively promote and maintain the welfare of the people by adopting policies aimed at the following: "Maintenance of ecosystems, essential ecological processes and biological diversity of Namibia, and the utilisation of living, natural resources on a sustainable basis for the benefit of all Namibians, both present, and future."	The Gergarub Project is committed to the sustainable use of the environment, and has aligned its corporate mission, vision, and objectives within the ambit of the Constitution of the Republic of Namibia (1990).
Minerals (Prospecting and Mining) Act No. 33 of 1992	The Act provides for the granting of various licences related to mining and exploration. Section 50 (i) requires: "An environmental impact assessment indicating the extent of any pollution of the environment before any prospecting operations or mining operations are being carried out, and an estimate of any pollution, if any, likely to be caused by such prospecting operations or mining operations." The Act sets out the requirements associated with licence	The proposed mining activity requires an EIA to be carried out, as it triggers listed activities in the Environmental Management Act's regulations. Mining activities shall not commence until all conditions in the Act are met, which includes an agreement with the landowners and conditions of compensation, if applicable. The Project shall be compliant with Section 76 of the Act with regard to records, maps, plans and

National regulatory framework	Summary	Applicability to the project
	terms and conditions, such that the holder of a mineral licence shall comply with. The Act also contains relevant provisions for pollution control related to mining activities and land access agreements and provides provisions that mineral licence holders are liable for any damage to land, water, plant, or animal life, caused by spilling or pollution, and must take all such steps as may be necessary to remedy such spilling, pollution, loss, or damage, at its own costs.	financial statements, information, reports, and returns submitted.
Environmental Management Act, 2007 (Act No. 7 of 2007) and its regulations, including the Environmental Impact Assessment Regulation, 2007 (No. 30 of 2011)	The Act aims to promote sustainable management of the environment and use of natural resources. The Act requires certain activities to obtain an environmental clearance certificate prior to Project development. The Act states that an EIA should be undertaken and submitted as part of the environmental clearance certificate application process. The MEFT is responsible for the protection and management of Namibia's natural environment. The Department of Environmental Affairs, under the MEFT, is responsible for the administration of the EIA process.	This environmental scoping report documents the findings of the scoping phase of the environmental assessment undertaken for the proposed Project. The process has been undertaken in line with the requirements under the Act and its regulations.
Water Resource Management Regulations of 2023, Water Resources Management Act, Act No. 11 of 2013	This Act provides for the control, conservation and use of water for domestic, agricultural, urban, and industrial purposes; and to make provision for the control of certain activities on or in water.	The Act stipulates obligations to prevent the pollution of water. Measures to minimise potential surface and groundwater pollution are contained in the

National regulatory framework	Summary	Applicability to the project
	The Department of Water Affairs, within the Ministry of Agriculture, Water and Land Reform (MAWLR), is responsible for the administration of the Act.	EMP. The Project is obliged to have all permits relevant to its operations under this Act. Abstraction of water from boreholes requires an abstraction permit to be obtained from the Ministry of Agriculture, Water and Land Reform.
Soil Conservation Act, No. 76 of 1969	This Act makes provision for the prevention and control of soil erosion, and for the protection, improvement, and conservation of soil and vegetation.	Land clearing is an unavoidable necessity for the proposed Project, as large areas will be cleared for mining infrastructure. Measures will be included in the EMP to conserve soil and vegetation that will be used as part of the rehabilitation phase of the Project.
The Forestry Act, No. 12 of 2001 as amended by the Forest Amendment Act, No. 13 of 2005	Section 22 deals with the protection of natural vegetation that is not part of the surveyed erven of a local authority area as defined. Section 21 states that no person shall cut, destroy, or remove vegetation that is growing within 100 metres of a river, stream, or watercourse. Section 23 requires a permit from the Director for the clearance of vegetation on more than 15ha on any piece	The Project activities will require vegetation clearing. The Proponent will ensure that all required permits are in place before vegetation removal commences.

National regulatory framework	Summary	Applicability to the project
	of land or several pieces of land situated in the same locality as that which has predominantly woody vegetation or cut or remove more than 500 cubic metres of forest produce from any piece of land in a period of one year.	
National Heritage Act, No. 27 of 2004.	The Act provides provision for the protection and conservation of places and objects with heritage significance. Section 55 compels mining companies to report any archaeological findings to the National Heritage Council. Subsection 9 allows the NHC to issue a consent, subject to any conditions that the Council deems necessary.	There is the potential for heritage-related objects to be found in the mining licence area. Therefore, the relevant stipulations in the Act will be taken into consideration and incorporated into the EMP. In cases where heritage sites are discovered, the 'chance find procedure' will be used.
Labour Act, No. 11 of 2007	The Labour Act, No. 11 of 2007 (Regulations relating to the Occupational Health & Safety provisions of Employees at Work, promulgated in terms of Section 101 of the Labour Act, No. 6 of 1992 - GN156, GG 1617 of 1 August 1997)	The Project shall adhere to all labour provisions and guidelines, as enshrined in the Labour Act. The Project shall also develop and implement a comprehensive occupational health and safety plan to ensure adequate protection for its personnel throughout the Project lifecycle.
Road Traffic and Transport Act, No. 22 of 1999	This Act makes provision for the control of traffic on public roads, the licensing of drivers, the registration and licensing of vehicles, and the control and regulation of road transport users across Namibia.	The Project will involve transportation activities in support of mining activities. The employees and support business shall adhere to national road regulations on public roads. The Proponent will ensure that the diversion of the C13 road will be conducted in compliance with the Act.
Hazardous Substances	This Ordinance provides for the control of toxic	The planned Project will involve the handling

National regulatory framework	Summary	Applicability to the project
Ordinance, No. 14 of 1974	substances and can be applied in conjunction with the Atmospheric Pollution Prevention Ordinance, No. 11 of 1976. This applies to the manufacture, sale, use, disposal, and dumping of hazardous substances, as well as their import and export.	and storage of hazardous substances such as fuels, reagents, and industrial chemicals. The Proponent shall ensure safe handling, transfer, storage, and disposal protocols are developed, implemented, and audited throughout its operations. The Proponent is obliged to ensure that all permits under this Ordinance are obtained prior to Project commencement.
Civil Aviation Act, No. 6 of 2016	Section 55 of the regulations relates to safety and security protocols near aerodromes.	The Project is in proximity to the military air base, and as such, the Proponent will ensure that all regulations regarding safety and security near aerodromes is complied with.
The Atmospheric Pollution Prevention Ordinance, No. 11 of 1976	The Ordinance pertains to the prevention of air pollution, with particular focus on public health, and contains detailed provisions on air pollution matters, including the control of noxious or offensive gases, atmospheric pollution by smoke, dust control, motor vehicle emissions, and other general provisions.	The nature of mining activities generates dust. Activities within the mining operations and processing plant will generate gases, odours, and air pollution. The Proponent will ensure that all measures reasonably practicable will be implemented to reduce and mitigate impacts to air quality, and this will be included in the EMP.

3.3 National Policies and plans

Table 4 - Namibian national policies and plans applicable to the Gergarub Project

Policy or plan	Description	Relevance to the Project
Vision 2030	Vision 2030 sets out the nation's development targets and strategies to achieve its national objectives. Vision 2030 states that the overall goal is to improve the quality of life of the Namibian people aligned with the developed world.	The proposed Project shall aim to meet the objectives of Vision 2030 and shall contribute to the overall development of the country through continued employment opportunities and ongoing contributions to the gross domestic product (GDP).
Fifth National Development Plan (NDP5)	The NDP5 is the fifth in a series of seven five-year national development plans that outline the objectives and aspiration of Namibia's long-term vision. The NDP5 pillars are economic progression, social transformation, environmental sustainability, and good governance.	The planned Project supports meeting the objectives of the NDP5 through creating opportunities for continued employment.
The Harambee Prosperity Plan ii (2021 – 2025)	Second Pillar: Economic advancement – ensuring increasing productivity of priority key sectors (including mining) and the development of additional engines of growth, such as new employment opportunities.	The Project will contribute to the continued advancement of the mining industry and create an additional employment generation engine within the regional and national landscape.
Minerals Policy	The Minerals Policy was adopted in 2002 and sets guiding principles and direction for the development of the Namibian mining sector, while communicating the values of the Namibian people.	The planned Project conforms to the Policy, which has been considered through the ESIA process and the production of this report.

Policy or plan	Description	Relevance to the Project
	The policy strives to create an enabling environment for local and foreign investments in the mining sector and seeks to maximise the benefits for the Namibian people from the mining sector, while encouraging local participation. The objectives of the Minerals Policy are in line with the objectives of the Fifth National Development Plan that includes the reduction of poverty, employment creation, and economic empowerment in Namibia.	The Proponent intends to continue to support local spending and procurement. The Project will comply with the general guidelines of the Policy through the adoption of various legal mechanisms to manage all aspects of the environment effectively and sustainably from the start. The ESIA is one such mechanism to ensure environmental integrity throughout the planned Project's lifecycle.

Table 5 - Permits and licences required for the Gergarub Project.

Permit or licence	Act / Regulation	Related activities requiring permits	Relevant Authority
Environmental clearance certificate	Environmental Management Act, No. 7 of 2007	Required for all listed activities shown in Table 2.	Ministry of Environment, Forestry and Tourism (MEFT)
Mining licence	Section 90 (2) (A) of the Minerals Act, No. 33 of 1992	Written permission from the mining commissioner.	Ministry of Mines and Energy (MME)
Surface rights agreements (mine, infrastructure corridors)	Section 52(1)(A) of the Minerals Act, No. 33 of 1992	Included in the mining license application. Signed by the farmer, RPZC, awaiting final signatures from Vedanta	Ministry of Mines and Energy (MME)
Permission to extract water from Orange River (NamWater)	A permit is issued under Section 44(2) of the Water Resources Management Act, Act No. 11 of	Required to meet water requirements for mining and processing.	Ministry of Agriculture, Water and Land Reform (MAWLR)

Permit or licence	Act / Regulation	Related activities requiring permits	Relevant Authority
	2013), the Water Resource Management Regulations of 2023.		
Wastewater discharge permit	A permit is issued under Section 72 of the Water Resources Management Act, Act No. 11 of 2013, Water Resource Management Regulations of 2023.	Required for discharge of sewage and/or excess industrial or mine wastewater.	Ministry of Agriculture, Water and Land Reform (MAWLR)
Permit for the clearing of land	The Forest Act, 2001 (Act No. 12 of 2001)	This Act governs the removal of vegetation within 100 m of a water course, or removal of more than 15ha of woody vegetation, or the removal of any protected plant species.	Ministry of Agriculture, Water and Land Reform (MAWLR)
Permit for the destruction of heritage objects and artefacts	The Heritage Act, No. 27 of 2004.	This Act relates to interference with heritage artefacts during the Project life. Heritage sites could potentially be located within the proposed mining licence footprint, or along proposed pipeline or powerline routes.	National Heritage Council (NHC)
Application for power connection	Electricity Act 4 of 2007	The mine will require power to be supplied to them by NamPower.	Namibian Power Corporation (NamPower)
Consumer installation certificate for bulk fuel storage	Petroleum Products Regulations	A consumer installation certificate is required for bulk fuel storage and dispensing.	Ministry of Mines and Energy (MME)
Licence for explosives magazine	Minerals (Prospecting and Mining) Act, No. 33 of 1992; Mine Safety Regulations	This is also covered under the accessory works application.	Ministry of Mines and Energy (MME)

Permit or licence	Act / Regulation	Related activities requiring permits	Relevant Authority
Permit for the storage and use of explosives, and the burning of packaging	Minerals (Prospecting and Mining) Act, No. 33 of 1992; Mine Safety Regulations	Necessary for explosives and blasting.	Ministry of Mines and Energy (MME)

4 PROJECT DESCRIPTION

4.1 COMPANY BACKGROUND

Gergarub Mining and Exploration (Pty) Ltd owns the Gergarub project (Project), a joint venture agreement between Vedanta Zinc International (51%), via its Namibian subsidiary Skorpion Zinc Mine, and Rosh Pinah Zinc Corporation, or Rosh Pinah (49%) (JV).

4.2 NEED FOR THE PROJECT

New mining activities contribute to the national and local economies and may have a long-lasting and positive impact on the country's economy. Namibia's economy depends largely on mining. With an economically viable and approved, fully developed Gergarub Zinc Project, the Namibian economy can expect benefits from revenues during the construction phase, royalties, and taxes during the life of mine (LoM), and a positive contribution towards employment. Based on current mine plans, between 300 and 350 people will be employed during expansion construction, and a total of approximately 700 to 800 for the operational phase, providing jobs and livelihoods for them and their families, and local and national service and supply contractors for a minimum of 12 to 15 years.

Gergarub has selected a mining strategy which will contribute the following estimates to the Namibian finances:

- USD 1.95 billion in foreign revenue into Namibia
- USD 224 million in corporate income tax
- USD 42 million in royalties
- USD 14 million in export levies

4.3 EMPLOYMENT

During operations, it is expected that the split for the mining department labour requirement will be as noted below. A detailed labour plan covering all components and departments of the operation will be further developed as the project evolves. The labour compliment for the mining development and early operations comprises of the following:

- 24 Management and technical teams
- 195 Mining operations crews
- 77 Maintenance crews

The labour requirement for operations over the LoM ranges from 700 to 800 employees (550) and contractors (250), although optimization studies are being further produced to better define the labour force. The labour force will be comprised of local workers, including those retrenched by Skorpion. Most people would reside in Rosh Pinah and others would supplement and be accommodated in short-term housing such as guest houses and hostel style lodging. Some of the management and technical team would be from South Africa or other experienced locations, Namibian and regional as much as possible.

4.4 PROJECT BACKGROUND AND EXPLORATION HISTORY

The Proponent holds EPLs, MDRLs, and MLs in Namibia; those relevant to the Gergarub Zinc Project and the mining licence area are shown in Figure 5. The project is located on farm Spitskop 111, along the C13 road between Rosh Pinah and Aus within the Oranjemund constituency, and approximately 10km southeast of the Skorpion Zinc Mine and 15km northwest of the Rosh Pinah (Gergarub Project) Mine, on MDRL2616, which is surrounded by the much larger EPL 2616.

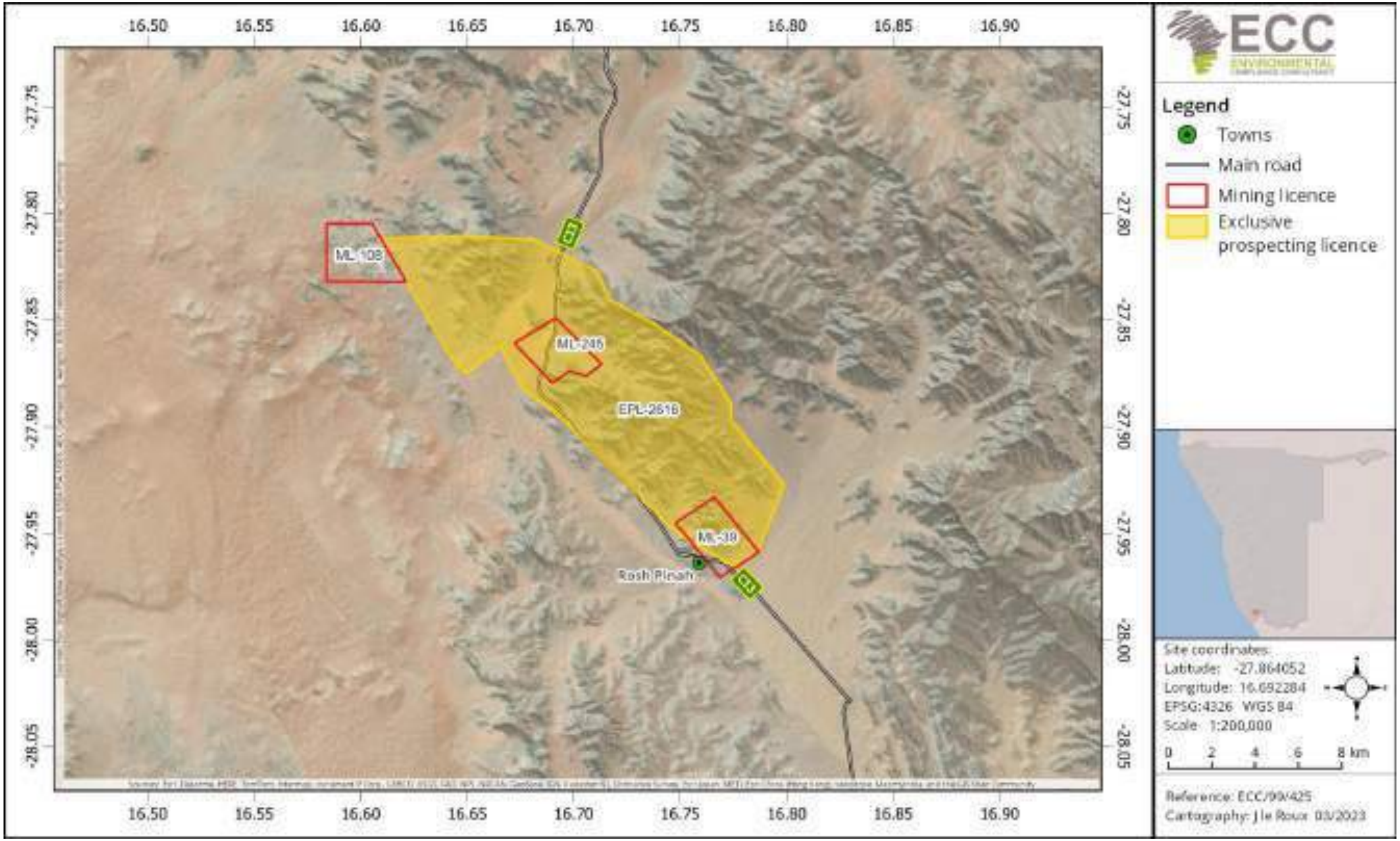


Figure 5 - Tenement boundaries showing mining licences and EPLs.

As early as May 1963, M.D. McMillan commenced mapping the Witputs – Sendelingsdrif area as part of his Ph.D. study at the Precambrian Research Unit at the University of Cape Town and collected rock samples. The weight of the samples indicated the presence of barite (barium sulphate). On further investigation McMillan came upon a rock outcrop stained green by copper oxides, which can be considered as the discovery of the Rosh Pinah deposit. In December 1964, McMillan mapped the outcropping gossans. The assay results returned economic grades of zinc and lead.

Parts of the Project area was explored historically by Anglo American and Bafex Exploration starting in 2008, prior to The Proponent. The Proponent has actively and systematically explored the Project area since 2016, using a variety of exploration methodologies, including, but not limited to, geochemical surveys, soil sampling, limited trenching, and drilling (RAB, RC, and diamond drilling) techniques. (CSA Global, 2021). Within formations of nearby similar geology, and since commencing mining operations in 1969 to the end of 2020, a total of 29 million tonnes have been mined from the various lenses of Rosh Pinah. The average annual production over the last 20 years is approximately 650,000tpa (Figure 6).

Since the discovery of the Rosh Pinah mine, ongoing in-mine exploration continues to play a significant role in extending the LoM. The discovery of the WF3 zone has extended the current LoM and further deep-seated mineralization has potential to increase the life of operations far beyond the current LoM. This experience has helped with exploration and feasibility investigations at Gergarub since its discovery in 2008. The 2022 optimization study by AMC has defined 11 years life of mine, and 10.1Mt reserve at 1Mtpa production rates and NSR cut-off of US$100/t. The 2022 focus on the regional exploration potential on MDRL 2616, is to further investigate and target the geophysical targets (SQUID EM and VTEM) with the aim of extending mineralization in the north-east as well as testing the down dip of the main ore lenses in the west of the deposit.

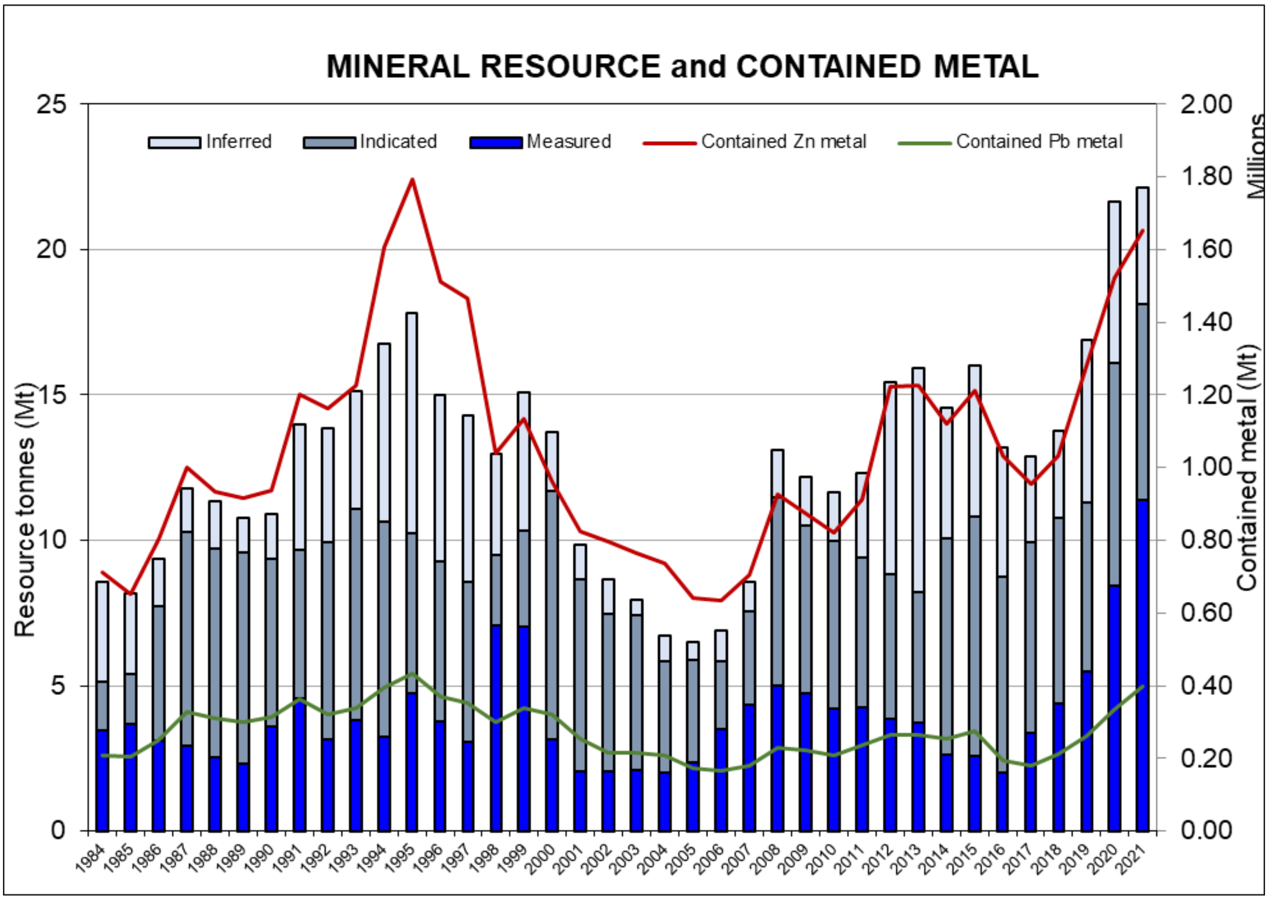


Figure 6 - History of resources and contained metal of the nearby Rosh Pinah Mine

4.5 GEOLOGY AND MINERALISATION

The Gergarub deposit is hosted within the Gariep Belt, which extends from north-western South Africa into southern Namibia. The following geology and mineralization description is based on the Technical Report of the Gergarub Deposit, 2022, Rosh Pinah Zinc and Skorpion Zinc Mine. The Gariep Belt is situated between the Kalahari- and Rio del Plata Cratons, part of the spreading of the Adamastor Ocean. It consists of metamorphosed fill of the Gariep basin, one of several Neoproterozoic basins that evolved around the margins of the Kalahari Craton because of the break-up of a 1.0Ga supercontinent.

The external part of the belt, furthest east, is called the Port Nolloth Zone (PNZ), approximately 770-550MA years old. This zone consists of continental sedimentary successions with subordinate volcanic rocks as described above. The PNZ can be interpreted as three mega-sequences:

- Continental rift deposits (Stinkfontein Subgroup)
- Passive margin deposits (Hilda Subgroup)
- Syn-orogenic deposits (Holgat Formation)

The Gergarub Deposit is situated within the PNZ, more specifically, within the Rosh Pinah Formation of the Port Nolloth Group. The Rosh Pinah Formation hosts two major producing base metal mines as well as many other mineral showings. Structurally, the deposit is situated within a failed graben Easton the eastern margin of the Gariep Basin. The graben developed during the rifting phase and was subsequently filled by the bimodal volcanism associated with the transition from rifting to drifting, as well as lacustrine- and alluvial facies sediments. Subsequently, these deposits were exposed to extreme ductile- and brittle deformation produced by the Gariep Orogeny (~545Ma) which results in recumbent folding, shearing, and thrusting. The Gergarub deposit is covered by 30 - 100m of Tertiary overburden.

There is a distinction between concordant mineralization and discordant mineralization. Concordant ore is in-situ sediment-hosted and rhyolite- or rhyolitic hyaloclastic-hosted mineralization that formed syngenetically on or just below the seafloor. The mineralization occurs in chemically reducing environments together with small scale tectonic features indicating the exhalation of the hydrothermal fluids and precipitation of sulphides and chert onto the seafloor. Discordant ore has been transported as debris-flow and deposited within brecciated lithified volcanic and sedimentary rocks. Mass flow breccias in sulphide ore occur which indicates that these have been re-deposited together with fragments of host rocks. Some rhyolite-hosted mineralization occurs in veins and breccias as stock work feeder zones.

The mineralization is closely associated with the rhyolites, specifically rhyolite domes. There are three main mineralization types:

1. The first type is disseminated mineralization with typical values of <20% sulphides with zinc grades from 2%-6% zinc. Generally, the zinc is related to Fe-rich sphalerite which typically contains 10% iron.
2. The second main mineralization type it is semi-massive sulphide which is banded mineralization with typically 20% to 50% sulphides with zinc grades from 4%-12% zinc. The sphalerite typically contains 2%-7% Fe.
3. The highest-grade mineralization is the massive sulphide with typically 50% to 100% sulphides with zinc grades from 15%-45%. The massive sulphide mineralization commonly contains honey coloured sphalerite with less than 1% Fe, and chocolate- coloured sulphide which contain a higher percentage of iron.

All three types of mineralization are compositionally banded on a 1 - 10mm scale, more so in disseminated and semi-massive ore which is intercalated with quartzite, meta carbonate, and Fe-sulphides (pyrite and pyrrhotite). All sulphides have been recrystallized, with very little effect on chemistry, due to the metamorphism which the deposit has undergone.

The crown pillar separating the open pit from underground operations has been assumed to be extracted towards the end of LoM of the underground portion. Below is a Table 6 summarizing the surface and underground production over LoM.

Table 6 - Gergarub Concept Study Mine Plan Production Potential (Million tonnes)

Mine Section	Tonnage (Mt)	Commercial Operation
Underground Tonnes Mines	6.21	Year 2 to Year 10
Total Ore Mined	23.80	Over LoM

Source: Gergarub Stage 1 Concept Mine Plan, July 2022, ABGM

4.6 PRIMARY SITE LAYOUT

An optimal site layout is based on designing the site around critical landform features such as topography and sensitive areas, while considering the efficiencies required for the mining operation. The proposed site layout is provided in Figure 7.

At this current stage the proponent has provided a preliminary layout which is subject to change. However, the assessment will be carried out subject to the current plans received from the proponent. After the assessment some facets of the site layout may need to change due to recommendations made observed from the proposed mitigation measures.

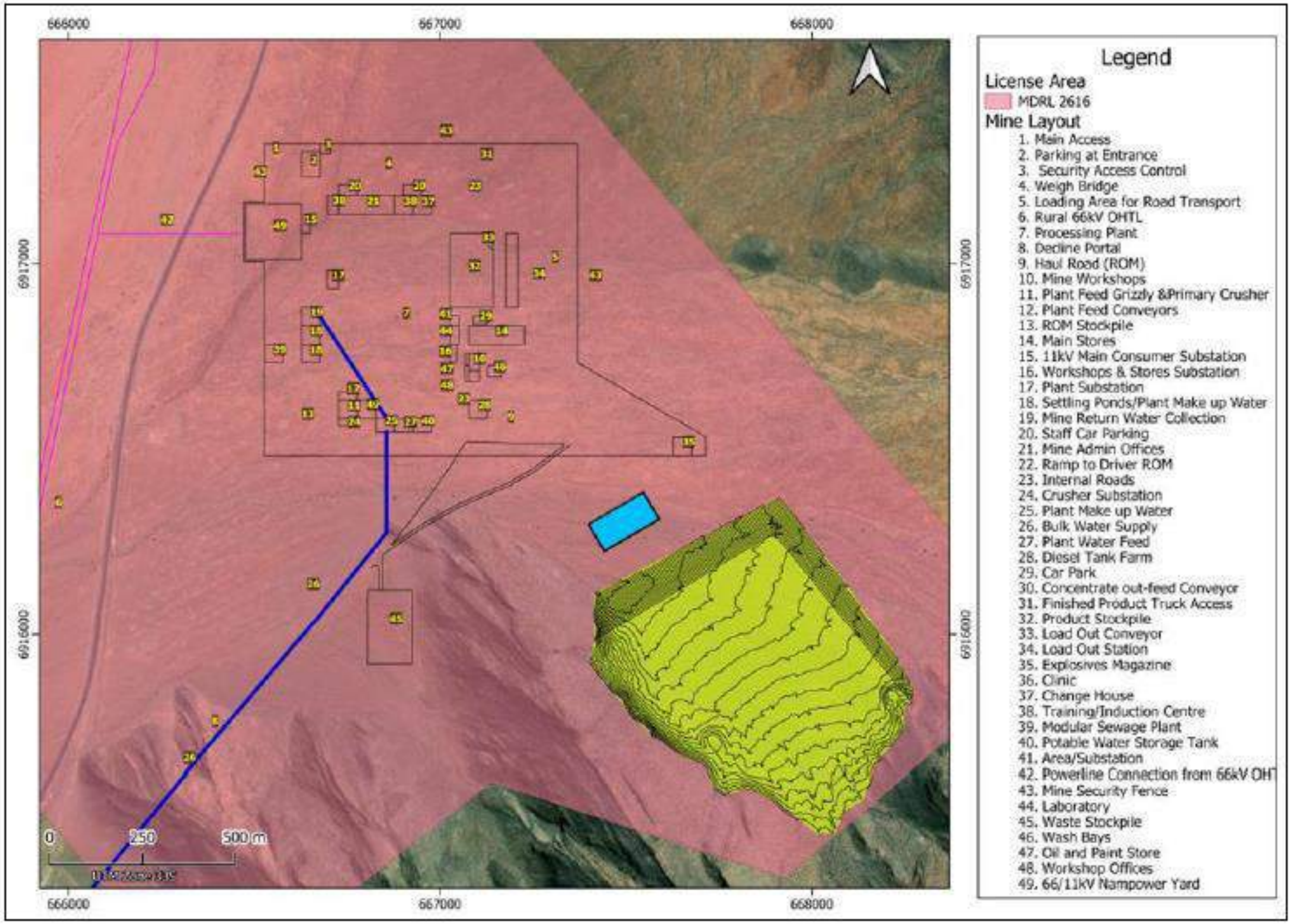


Figure 7 - Conceptual mine layout provided as a DWG file shown as a georeferenced shapefile to offer spatial reference. Numbered items are provided in the legend and the TSF is shown in yellow while the return water dam (RWD) is shown in blue (Umvoto, 2023).

The following items of infrastructure are shown on the site layout (Figure 7):

- NamPower 66kv/11kv transformer and substation.
- perimeter and internal fencing.
- internal road networks.
- decline portal location and ventilation infrastructure.
- backfill plant.
- ROM pad with low-grade ore crushing and sorting plant.
- mine administration offices, including canteen and toilets.
- minor service workshop and stores.
- access control facility with bus stops and car parks.
- open mine pit.
- waste rock dump.
- stormwater diversion channel and catchment ponds.
- settling ponds for water from underground and open pit.
- process water storage for dust suppression.

In developing the site layout, cognisance has been taken of nature reserves, sensitive flora, and other impacts to existing infrastructure.

4.7 OREBODY, MINING INFRASTRUCTURE AND SERVICES

SRK (2021) conducted a mining study as part of the project PEA and PFS. The following components are taken from their study and the *Gergarub Strategy Optimization Study* for Gergarub Mining and Exploration (Pty) Ltd by AMC Consultants, 2022, namely: orebody description, mining method and equipment, mine haulage and design, metallurgy and processing, support infrastructure and services and project infrastructure – general and support.

4.7.1 OREBODY

Gergarub is comprised of two distinct mining areas, with a total of six zones, with Ore Zone 5 (“OZ5”) being closest to surface and the other zones deeper and dipping at angles ranging from 26° to 45°. The orebody has a lateral/strike extent of 520 m with orebody thickness varying from 5m to over 35m in Ore Zones 0 to 4 (“OZ0-4”). Ore Zones 1 to 4 (“OZ1-4”) form a “layered” package that extends from approximately 100 m below surface to 500 m below surface and OZ5 is a separate folded body located approximately 450m away from OZ1-4. It has highly variable geometry, a factor that influenced the mining methods, approach, and continue to influence the detailed designs.

The most recent SAMREC Compliant Mineral Resource Estimate (refer to Table 7), based on exploration conducted between 2008 and 2013. Total Mineral Resource of 18.1 Mt @ 8.7% Zn, 2.3% Pb and 735 g/t Ag was declared (inclusive of Inferred). The total Indicated Resources amounts to 11.4Mt @ 9.1% Zn, 2.5% Pb and 493g/t Ag.

The sulphides are typically comprised of:

- sphalerite,
- pyrite,
- galena and
- minor chalcopyrite

4.7.2 MINING METHOD AND EQUIPMENT

The mining method for Gergarub will be long hole open stope (LHOS) with backfill, mining stopes in an overhand (bottom-up) extraction sequence. LHOS will be supplemented with Drift and Fill (DAF) mining which will be used to mine the orebody extremities and maximize the overall recovery of the Mineral Resource.

Ore is sourced from five moderate to shallow-dipping mineralized ore zones (OZ), separated into two distinct mining areas, OZ1-4 and OZ5. OZ1-4 contains majority of the mining inventory ~81%, and will be prioritized as the primary mining area, OZ5 will be used to supplement production from OZ1-4 to ensure a sustained steady-state production profile of 1.0 Mtpa over the life of mine (LoM).

AMC's Hill of Value™ (HoV™) Strategy Optimization process was used to investigate potential preferred operating parameters for the Project's underground mine with the following results:

- Material above an NSR cut-off of US$100/t for OZ1-4 and OZ5 can be considered strategically optimal to maximize the project value.
- Steady-state ore production of 1.0 Mtpa can be achieved for 8 years of the 11-year LoM.
- Mining with backfill will significantly increase recovery of the available mining inventory, while decreasing the capacity of the tailings storage facility (TSF).
- Using truck haulage (up a 1 in 7 gradient decline) is best suited to the highly variable geometry of the orebody and the low production rate.

The proposed mining method with the inclusion of backfill has the advantages of higher ore production, improved local and regional ground stability, improved mining recovery, reduced dilution and reduced tailings being pumped to the TSF. Mining will progress, where practical, from the centre to the strike extents of each level in a bottom-up sequence. Each stope will be mined and backfilled before mining the next stope in the sequence.

Mineable Shape Optimizer (MSO) software was used to produce stope shapes. Only stope shapes with an average NSR value greater than the strategic US$100/t cut-off value were considered for the mine design. There are two main sources of dilution in the mining of open stopes:

1. Planned dilution, which is the dilution required to achieve a practical stope shape and can include waste to conform with the minimum mining width.

2. Unplanned dilution, which is the dilution that is outside of the planned stope shape and is predominantly due to overbreak associated with blasting practices and geotechnical conditions.

Due to inefficiencies in mining recovery from the stopes, small amounts of mineralized material may also be lost during the final stope cleanout, and additional minor losses may occur in transit from the stopes to the processing plant. Hence, a mining dilution and recovery factor was applied to account for these losses.

Access to OZ1-4 and OZ 5, would be via a single portal and split decline to access the two mining areas. The mine design is based on a typical underground layout with level access extending from the decline, which extend out to the level drives, level infrastructure (ventilation, dewatering, stockpiles, etc.) and production drives.

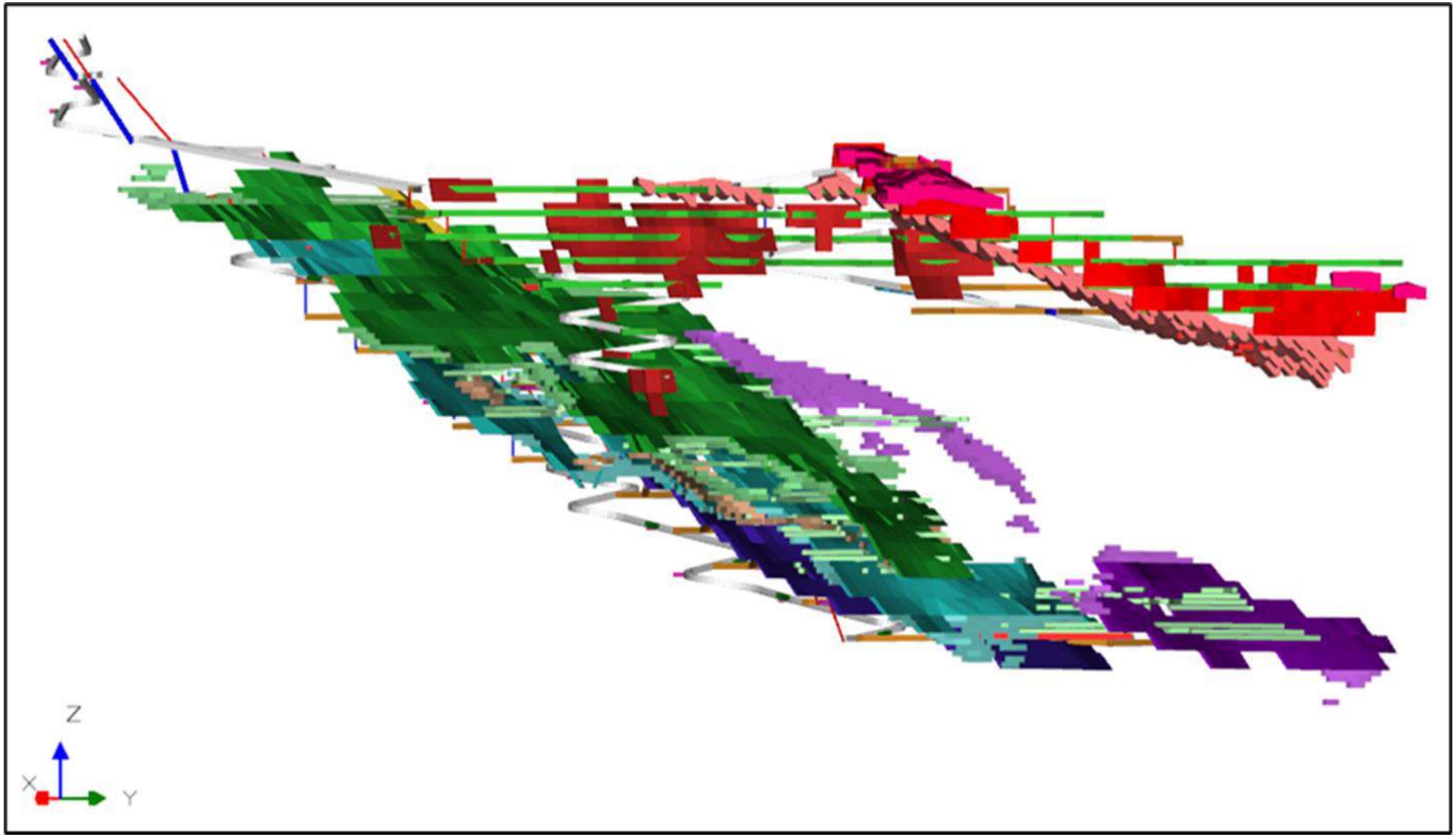


Figure 8 - 3-D view of the Gergarub mine plan.

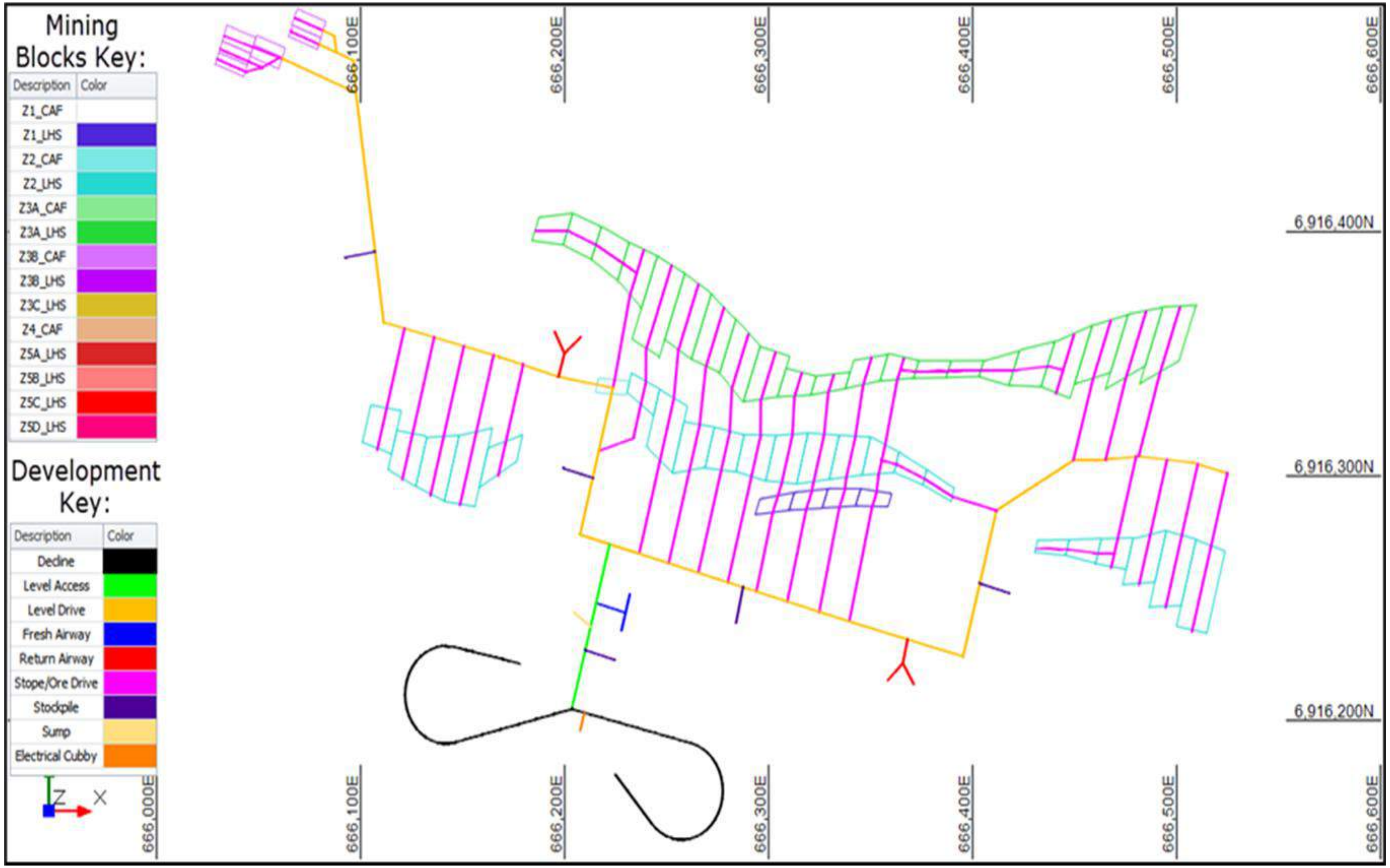


Figure 9 - Typical mine plan layout, Gergarub Mine

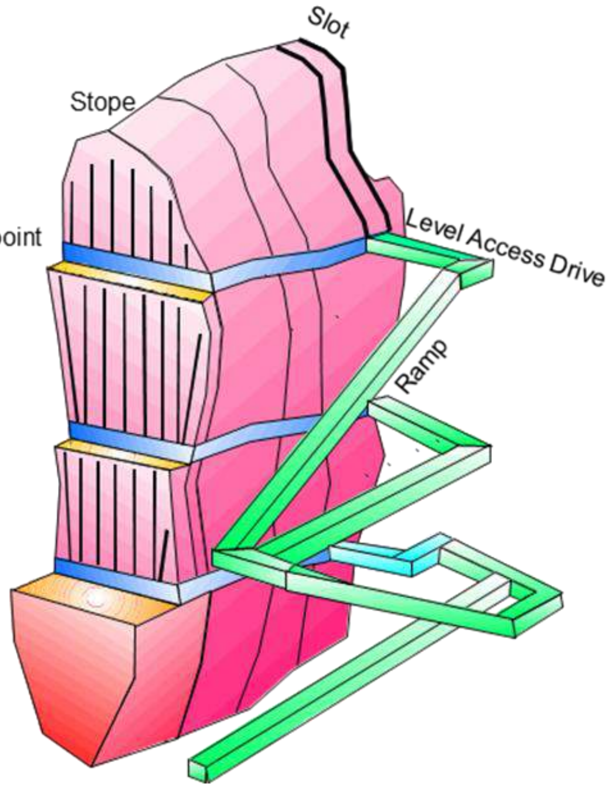


Figure 10 - Sub level open stoping

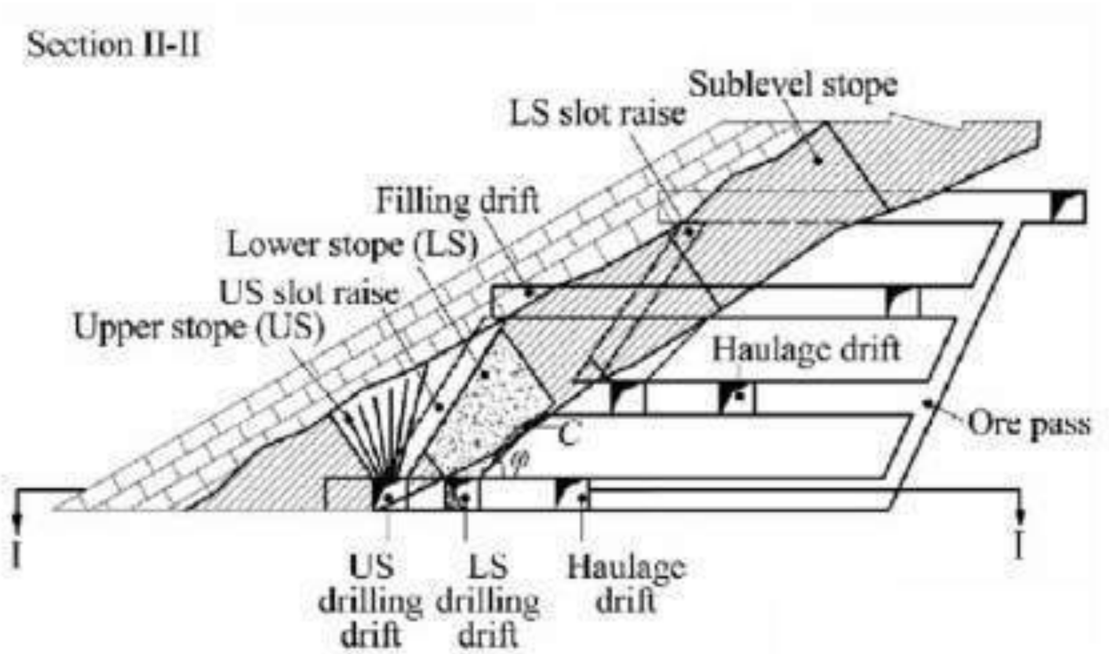


Figure 11 - Drift and fill.

The dilution and mining recovery estimates applied within the mine design and schedule are below in Table 7:

Table 7 - Average dilution and mining recovery estimates

Mining method	Planned Dilution (%)	Unplanned Dilution (%)	Operational Dilution (%)	Mining Recovery (%)
LHOS no backfill	18.2	5.1	4.5	80
LHOS paste backfill	15.1	4.7	4.7	92

Note: Weighted average mining recovery of Primary (94%), Secondary (85%), and Tertiary stopes (60%)

The mine area is relatively dry, with the principal source of water being groundwater inflow (variable quantities based on structural interactions and depth) and service water from the development fleet and production activities.

It was determined that the most economical configuration for effective dewatering will be replicate RPZC's current dewatering approach, which uses underground sumps and a staged pumping system. The rising main infrastructure will be extended as the mine progresses deeper.

Average total pumping rates are expected to be approximately 22L/s in WF3 and 11L/s in AAB. Pumping skids of similar capacity to the existing Warman DWU series are required to maintain this dewatering rate. The total maximum expected groundwater inflow to the mine is approximately 38L/s at the end of the mine life. Provisions have also been made for service water handling. Service water will be produced from all drilling machines and for dust suppression following blasting and mucking. The contribution from service water is expected to be less than 5L/s and is small in comparison to the groundwater inflows.

Power is currently supplied to RPZC mine via two independent feeds. Each feed consists of 2 x 150mm^2 cables at 3.3 kilovolts (kV), with a total capacity of 5.9 mega volt amperes (MVA) (limited by breaker settings). Each feed is capable of 4.2MVA with modified breaker settings. This system is fully redundant as the current draw of the mine is below this level. Both feeds and all associated switchgear are rated for 11kV but are currently running at 3.3kV.

The calculated peak electrical load of the underground mine for the Gergarub Project is approximately 6MVA. Line losses on the existing 3.3 kV feeds to the underground mine are high due to their lengths. It is proposed to change the feeds to 11kV, and each feeder will have a 11/3.3kV transformer installed near the point of utilization to minimize voltage drop and maintain the use of existing 3.3kV equipment to the greatest practical extent.

The function of the underground mine ventilation system is to dilute or remove airborne dust, diesel emissions and explosive gases, and to maintain temperatures at levels necessary to ensure safe production throughout the life-of-mine (LoM). The ventilation system has been designed to meet the requirements of Namibian Regulations and industry best practices.

Paste backfill was selected for the Gergarub Project as it improves both the safety conditions and economics. Paste filling the stopes rather than leaving them void will improve ground stability, increase recovery of the Mineral Resource, and reduce dilution. Paste backfill can be tightly controlled, it requires minimal interference with other mining activities, and provides fast filling rates to reduce stope cycle times. Paste fill will be produced from dewatered tailings mixed with cementitious binder and make-up water to the target density. The online paste fill system will involve the construction of a paste fill plant that uses the tailings stream pumped directly from the processing plant. A paste fill plant operating at approximately 85m^3/hr will provide the necessary yearly backfill demand of the Gergarub Project (approximately 0.45Mm^3) with a plant utilization rate of approximately 60%. Paste filling operations will be possible at higher plant utilization rates for the purpose of filling historical voids.

Laboratory-scale material characterization, rheology and strength test work has been completed to enable design of paste mixes in accordance with strength and reticulation requirements. The test work showed Rosh Pinah tailings cumulative size distributions suitable for producing a paste fill and very good strengths being achieved after 28 days curing. A range of paste fill design strengths and cement additions for vertical and undercut exposures for each of the mining areas have been determined.

Paste fill mixes for bulk paste fill that will not be exposed have also been determined. Based on these design mixes and the paste fill schedule, the expected LoM average cement addition rate is determined to be 3.4% w/w.

The initial management team will include a globally experienced contingent, to ensure that operation start-up is safe and efficient, and that ramp-up targets are met. An approved localisation plan will be established to train and equip the local workforce sufficiently, to enable and ensure a seamless transition of responsibilities over time. The assumption is that most of the equipment operators will unskilled (approximately 80%) and will require training from a basic level, although there are experienced miners and heavy equipment operators in Namibia to draw from. Regardless, the start-up strategy for mining operations takes account of this requirement.

The mine will operate 361 days per annum (allowing for lost days for public holidays and weather delays) on a 24-hour basis with three shifts rotating on an 8-hour duration.

The primary mobile diesel fleet includes development and production drills, loaders (scoops) and haul trucks as well as ancillary equipment.

The average annual mobile fleet requirements:

- 3 development drills
- 2 production drills
- 4 trucks
- 5 loaders
- 13 ancillary equipment

Therefore, there will be 27 mobile fleets in total.

4.7.3 BLAST OPERATIONS

Rock fragmentation will be undertaken by drilling and blasting, with the waste typically requiring blasting with lower powder factors. Blasting will be a core component of the mining operation, impacting all downstream mining and comminution (crushing) processes, and extending into the plant by way of ore recovery and dilution factors.

Blasting can substantially modify and control material flow within the mining operation, including the feed size to the primary crusher. Blast performance must be assessed in terms of the following outcomes:

- Fragmentation, relating to the feed size supplied to the primary crusher, as well as oversize material and the requirement for rehandling of material, and secondary breakage.
- Scoop and haul productivity, including wear and maintenance costs.
- Use of tracked and other equipment to maintain the access and work areas.
- Grade control.
- Primary crusher power consumption, throughput, and maintenance costs.
- Disruption to material flow during muck, haul and crushing that affects equipment efficiency.

The stopes are expected to be 15m by 30m. The material type at the site is suitable for a stoper capable of drilling holes with a diameter of up to 150mm. Stoper burden, spacing and sub-drill design will be functions of the selected powder factor, which is based on the unconfined compressive strength measurement results from the geotechnical study.

A lower relative energy factor was assigned to the waste rock because the waste material needs to be efficiently and economically excavated, hauled, and placed on the waste rock dump. On the other hand, with the ore material's higher relative energy factor, any finer fragmentation could benefit the downstream crushing and milling costs of the Project.

In areas where mining stopes may remain open for extended periods, it is good practice to minimise the fracturing of the back during blasting. In such identified areas, wall control blasting, also known as pre-splitting, can be considered. Pre-splitting was provided within the final pit boundary along the high wall, to create safe working conditions in the lower areas.

4.7.4 DRILLING

Drilling is the first operation performed at most mining operations. Electric hydraulic stoper drills are predominantly used. For this Project, a drill rig has been selected for the production holes, for ore and waste benches, and the wall control blasting holes.

4.7.5 LOAD AND HAUL OPERATIONS

The overall scale of mining envisaged for the Project is a medium-sized mine with an ore production of 1Mtpa. As a result of the extent, orientation and shape of mineralisation, selective mining practices have been incorporated into the ore mining methodology, typical of an underground mining operation.

Waste and ore mining operations will utilise medium-sized scoops – 8t to 20t selective mining class range, combined with a fleet of 30t ramp haul trucks, will be selected.

4.7.6 ANCILLARY EQUIPMENT

Ancillary equipment that is required for functions that fall outside of the primary production equipment's scope, is also necessary for mining operations. Primary production costs are directly impacted by several aspects related to ancillary equipment. Support equipment is the lifeline of reliable and cost-effective mine production, and is required for the following functions or activities:

- Keeping the loading, tipping and haul drifts and road areas maintained and clean, thus prolonging tyre life and making the operation safe.
- Contributing to the mitigation and reduction of outside mobile equipment noise (via good road maintenance).
- Maintaining drifts and haul road conditions, thus prolonging tyre life and making the operation safe.
- Suppressing dust emissions from health, safety, environmental, and financial perspectives.
- Supporting the full equipment maintenance and diesel requirements for remote, track-propelled equipment, and breakdowns.
- Ore, waste, haul and pass drift road preparation and levelling.
- Fuelling of track-mounted equipment, and large or slow-moving equipment.
- Rehabilitation.

The tertiary support equipment fleet consists of units that assist in tasks that are required, to make primary and secondary fleets' work easier and safer. Other functions they complete are not production-related and have no direct impact on production. The tertiary equipment fleet consists of:

- Small trucks used for maintenance activities,

- Light delivery vehicles used to transport management, technical services, and maintenance personnel around the mine,
- Buses used to transport operators and employees,
- Lighting plant to increase visibility during night-time, and
- Pumping equipment for pit dewatering.

4.7.7 OTHER MINING ACTIVITIES AND INFRASTRUCTURE

Most drifts and haul roads, dumps and stockpiles required for the LoM will have to be constructed during the first year of mining. The waste dump will progress by the haul truck tipping on the top elevation of the dump, with the dozer pushing the waste down. These actions will cause the waste dump to progress horizontally over time.

Waste dumps should be progressively rehabilitated with suitable rehabilitation stable slopes, materials, subsoil, and topsoil where possible. Rehabilitation must be performed as soon as possible on the external faces of the waste dump (progressive rehabilitation), to reduce the risk of dump failure, heavy erosion, loss of fines, visual and air quality impacts. Ore stockpile dumps will be constructed in close vicinity to the primary crusher tipping point, to minimise the reclamation costs and meet the environmental management requirements.

Waste rock will be required for the construction of mine infrastructure such as run of mine (RoM) pad and tailings storage dam walls. During normal operations, the ore feed will be achieved by a combination of ore tipped directly into the RoM bin by conveyor or haul trucks from oversize stocks with the RoM loader adding other appropriate ore material from RoM grade control stockpiles.

Mine water management will mainly consist of in-mine and surface run-off control within the mine workings and active mining areas and pumping from the main mine sump and mine area temporary sumps. Dewatering pumps will pump excess water to a suitable holding ponds and tanks ready for use as dust suppression and plant make up water. Water will be 100% recycled.

Drift and haul road dust suppression is considered for the Project and will be handled through a comprehensive dust management system. A suitable product may be applied during drift and haul road construction and maintained on a customised maintenance programme.

4.7.8 MINE HAULAGE AND DESIGN

Mine and haul-conveyor design was developed from the mine optimisation study to produce a practical configuration pit with drifts, ramps, and haul road system. The drift and ramp positioning within the overall mine and haul road design is an integral component of mine design because it influences the waste: ore ratio of the overall design, the performance of the equipment, as well as the operating costs. The positions of the ramps and passes were determined based on the ore configuration and taking into consideration the position of the primary crusher and the waste rock dumps.

Sufficient room for manoeuvring is required to promote safety and maintain continuity in the haulage cycle. The width criterion for a drift haul segment is based on the widest vehicle in use, which is the Caterpillar 1700 scoop, with a minimum operating width of 4.0m. To design for anything less than this dimension would create a safety hazard due to a lack of adequate clearance. In addition, narrow lanes often create an uncomfortable and unsafe driving environment, resulting in slower traffic, and thereby impeding production.

A drift, ramp, and haul road gradient of 1:7 was selected for the Project. The selection of the haul ramp/road gradient was based on international best practice for the type of trucks that will be utilised.

The design, construction and maintenance of drifts, ramps and haul roads have a considerable impact on haulage cost, which makes up a greater percentage of the total mining cost. It is therefore important that appropriate, detailed sets of designs for haul road construction are compiled for the site.

The benefits of an improved haul road design are efficiency of haulage by reduction in cycle time, reduced fuel burn, and reduced truck component wear. It is therefore desirable to generate a minimum site-wide construction standard for both new and existing haul roads. The minimum bench operating width for the pit is limited by the size of the equipment.

Ramp positioning within the mine is an integral component of mine design. It influences the productions cycle timing (drill – muck – blast) and the performance of the equipment, both of which contribute to operating costs and performance on key performance indicators and overall operating performance, including that of the processing plant and refinery.
The exit positions of the ramps were determined taking into consideration the proposed position of the primary crusher and the waste rock dumps.

4.7.9 METALLURGY AND PROCESSING

As per RPA's Technical Report for the Gergarub ML application (2022), Gergarub will construct and commission a 1.0Mtpa concentrator at Gergarub to process the mined ore. Specifications for the concentrator will be aligned with the RPZC concentrator. Key aspects of the concentrator include:

- The metallurgical performance projections for the concentrator indicate an approximate average recovery of 91.1% for zinc, 74.1% for lead, and 51.6% for silver.
- The average zinc concentrate will be 51.2% and the lead concentrate grade will be 58.2%.

- The milling circuit will consist of a SAG mill operating at throughput of 132.5tph. The SAG mill will be a 6.1m x 2.36m EGL with 1.8MW motor and open grate discharge operating in closed circuit with primary and secondary cyclones to produce a combined feed slurry at a P80 particle size of 90μm to the flotation circuit.
- The lead flotation circuit is of conventional design inclusive of a rougher, scavenger, and a cleaner flotation circuit with regrind. The circuit will have an effective capacity of 0.7 m^3/t/h and a required flotation volume of approximately 99m^3.
- The zinc flotation circuit will have a capacity of 2.6m^3/t/h and a required flotation volume of approximately 343 m^3. This will generate an overall residence time of the order of 60 minutes for flotation.

Concentrates - Lead and zinc concentrates will be pumped to individual high-rate thickeners and the underflows filtered in Larox plate diaphragm filters. Filtrate is recovered to process water storage for re-use in the plant. Zinc circuit tailings stream is pumped to a high-rate thickener, water is recovered to the process water storage and thickener underflow pumped to an above ground tailings storage facility.

Figure 12 provides a high-level summary of the Gergarub Project process flowsheet.

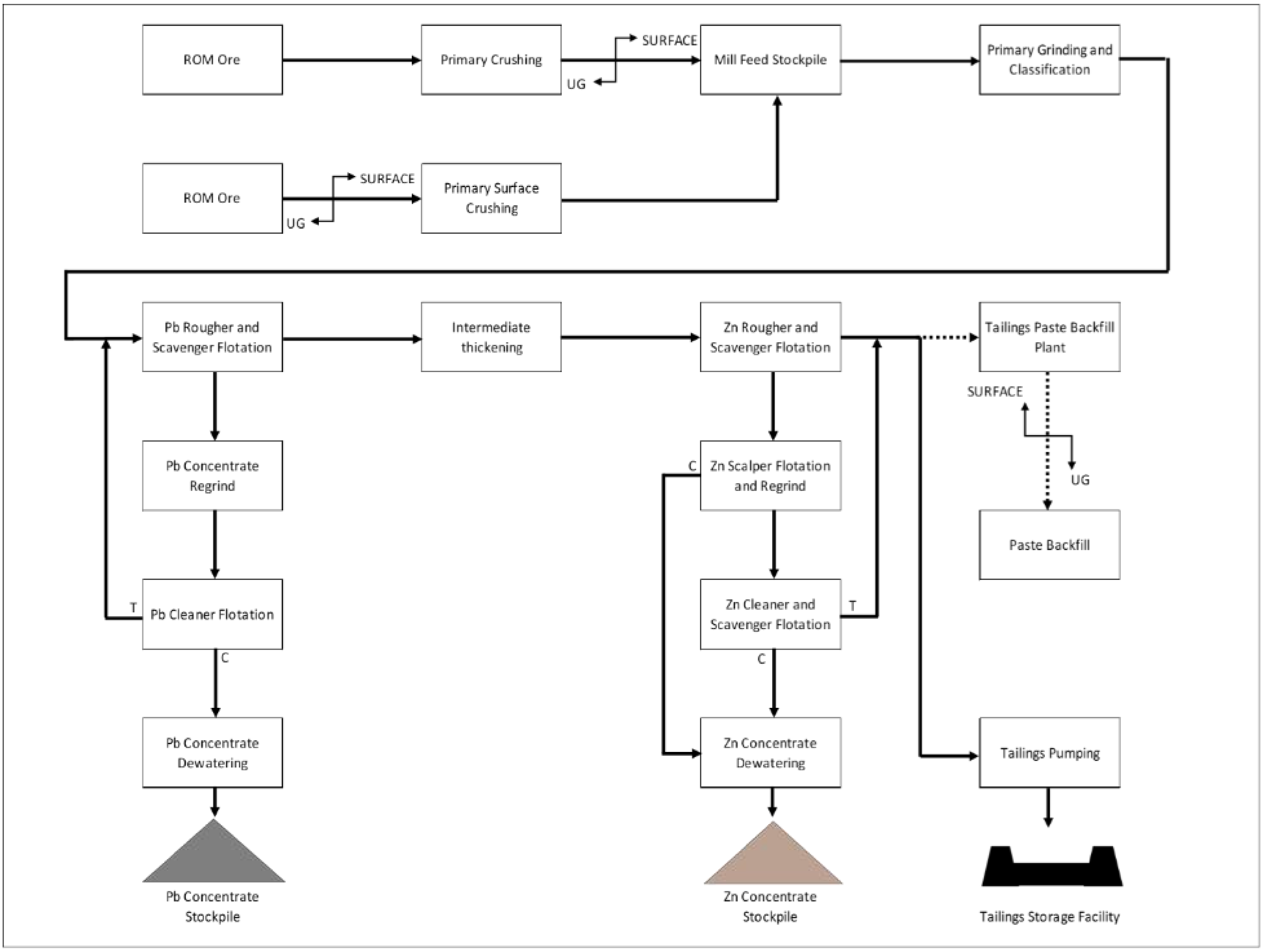


Figure 12 - Simplified flowsheet for the Gergarub Project (Source: DRA 2020)

Locked cycle variability test work on mineralized ore blends has been concluded in a bid to quantify the expected recovery ranges and highlight the degree of variability that can be expected. The locked cycle flotation test work metallurgical projections achieved lead recoveries in the range 68% to 88% at a concentrate grade range of 32% to 60%. Similarly, zinc recoveries in the range 77% to 96% were achieved, with a final zinc concentrate grade ranging between 48% and 56%.

Jameson Cell pilot test work has shown that it is possible to produce a zinc cleaner scalper concentrate with a zinc grade of 50%, with zinc recovery ranging from 55% to 60%, in a single stage, when treating a rougher concentrate with a grade of 28% to 30% zinc.

Metallurgical performance projections have been derived using discounted test work results in combination with Rosh Pinah operational performance data. Experience has shown that for RPZC samples, laboratory bench-scale flotation performance is better than that achieved for full scale operations. For this reason, a discount was applied to the laboratory test data.

The metallurgical performance projections for the Gergarub Project and upgrade indicate that an average lead recovery of 68.5% at a concentrate grade of 50% can be achieved while for zinc an average recovery of 89.6% at 51% concentrate grade is expected. Based on the 2019 to 2021 production data, an average lead recovery of 63.7% at a concentrate grade of 48 % and an average zinc recovery of 83.6% at 50% concentrate grade is expected for current operations prior to the implementation of the Gergarub Project.

4.8 SURFACE INFRASTRUCTURE AND SERVICES

The following was summarised and derived from the *Gergarub Strategy Optimization* Study for Gergarub Mining and Exploration (Pty) Ltd, by AMC, 2022, the *Technical Report of the Gergarub Deposit, Namibia*, by Rosh Pina Mine and Skorpion Zinc Mine, 2022, and with supporting information and explanations from the *Rosh Pinah Expansion "RP2.0" NI 43-101 Feasibility Study* by AMC 202.

4.8.1 ADMINISTRATIVE BUILDINGS

The mine office complex comprises the administration and engineering buildings, which provide working space for management, supervision, geology, engineering, and other operations support staff. The main administration infrastructure at Rosh Pinah includes the following:

- Administration management building.
- Human resources building.
- Security control building.
- Training offices.
- Safety / health / environment building.
- Supply chain receivables, warehouse, and stores facilities.

4.8.2 GEOLOGICAL CORE SHED

All primary and secondary drill cores are photographed before the core is stored at the core shed. Since full core samples are taken in all tertiary drilling (to be sent to the laboratory), the tertiary drill core (or the waste part remaining after sampling) is discarded on the waste dumps and not stored in the core shed.

4.8.3 MINING CHANGE HOUSE

Change house facilities accommodating lockers, change room, showers, and washrooms for the mine, maintenance and processing plant personnel are located at the mine site. Personal protective equipment such as gloves, safety glasses, self-rescuers, hard hats, and cap lamps are provided by RPZC.

4.8.4 SURFACE MAINTENANCE WORKSHOPS AND CRITICAL SPARES

The surface maintenance facilities include:

- Drill and blast workshop;
- Load and haul workshop;
- Underground electrical workshop;
- Plant maintenance workshop;
- Comminution maintenance workshop;
- Surface electrical and instrumentation workshop;
- Transport workshop;
- Trackless equipment wash-bay facilities; and
- Tyre maintenance workshop.

Due to the remote location of Rosh Pinah, the major components and critical spares kept on site include:

- Rock Hammer;
- Jaw Crusher Shaft Assembly (jaw stock);
- Jaw Crusher Wearing components;
- All machinery driving electrical motors;
- All machinery driving gearboxes;
- SAG mill motor;
- SAG mill gearbox;
- SAG mill pinion gear;
- SAG mill girth gear;
- Agitators for flotation plant;
- Plant and underground supply electrical transformers and motors;
- LHD and truck drive components;
- Compressors;
- Various drill drifter hammers; and
- Land Cruiser drive components.

4.8.5 FUEL FACILITY

Diesel fuel is required for the underground mobile mine equipment and surface vehicles. Diesel is stored in two purpose-designed tanks, one with capacity of 82,000 L, the other with capacity of 23,000L. There is a surface refuelling station that allows for refuelling of both light vehicles and heavy-duty mining equipment. A fuel and lube management office are located near to the fuel dispensing facility.

A self-bunded diesel fuel farm has been allowed for Gergarub. The self-bunded units negate the need for bunded areas and only require a level hardstand on which to rest. The tank units will be equipped with their own diesel transfer and dispensing pumps located inside a lockable cabinet on the tanks. The tank capacities will be based on supplying at least three days diesel requirement to Gergarub considering that the Skorpion main diesel facility is located nearby.

4.8.6 EXPLOSIVES MAGAZINE AND BULK EMULSION STORAGE FACILITY

Emulsion or ammonium nitrate fuel-based explosives will be required for development and production blasting. Explosives would be transported to site using supplier transport equipment and personnel. Upon delivery to Gergarub, all explosive products will be transferred to surface storage facilities, which will include separate explosives and detonator magazines.

An appointed magazine master and deputy magazine master would be responsible for the surface magazines including ordering explosives, supplying the underground operations, maintaining the surface magazine in accordance with regulatory requirements, and transport of explosives on-site using specialized vehicles. The management of the explosives and blasting activities underground will be under the care and control of approved and qualified mine personnel.

The explosives magazines will be sized according to the maximum production requirements, and an additional underground explosives magazine may be utilized if necessitated by operational requirements.

The surface explosives magazines have capacity for 1,500 bags of ANFO (25kg per bag) and 50t of bulk emulsion.

The management of the underground explosives store and blasting activities will be under the care and control of approved and qualified mine personnel.

4.9 PROJECT INFRASTRUCTURE – GENERAL SUPPORT

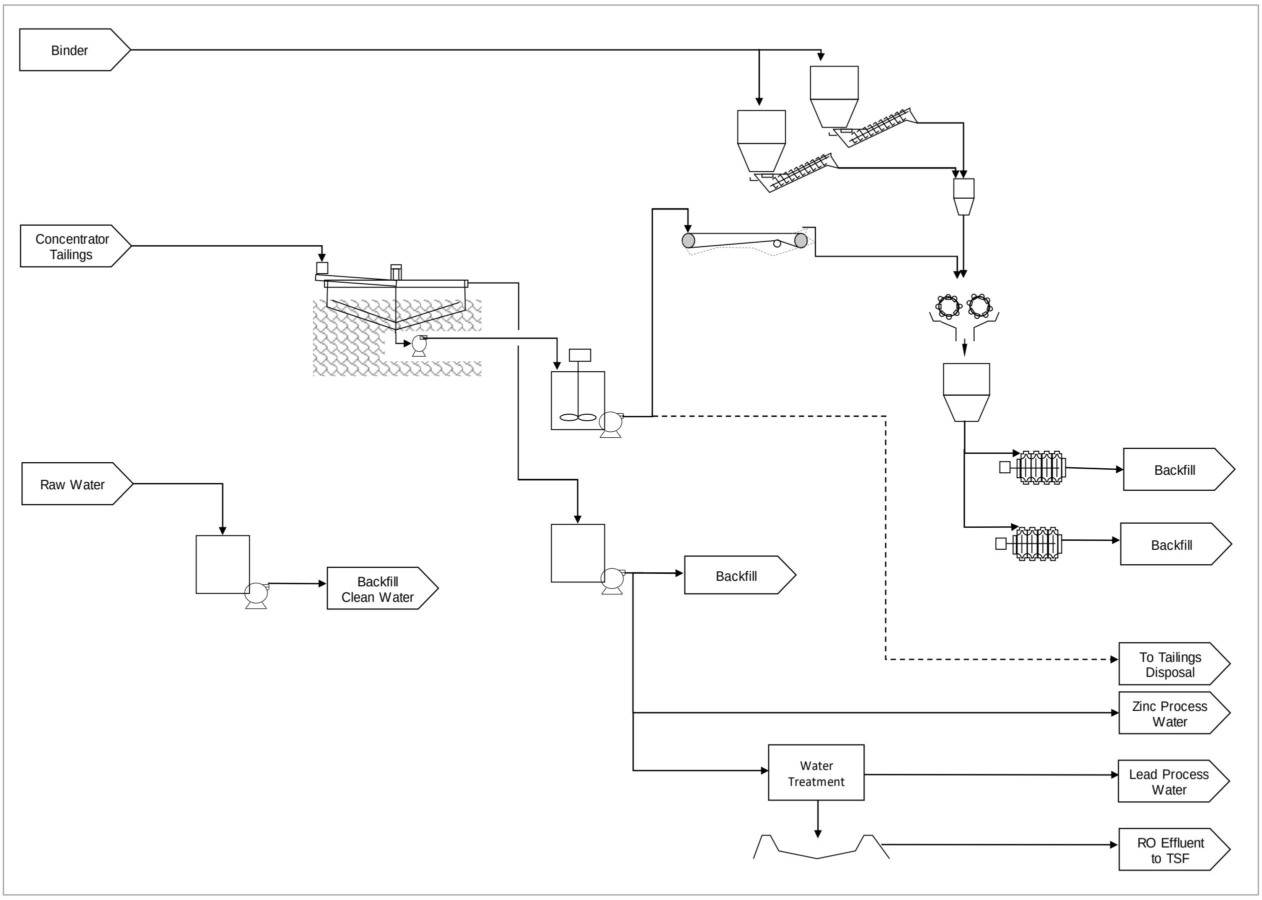
As per the RPA Gergarub Technical Report, 2022, Rosh Pinah is accessible via sealed roads from Windhoek 800 km to the north and from the South African border in the south. The closest commercial airport is located at Oranjemund approximately 105 km south-west of Rosh Pinah, and the nearest railhead is located at Aus on the Lüderitz - Keetmanshoop line, both are accessible by sealed road.

The operating assumption for Gergarub is that most personnel would reside in Rosh Pinah. This would be supplemented with short-term accommodation in the form of guesthouses and hostel-style lodging. The assumption is that additional accommodation facilities would not be constructed as part of the project, with sufficient accommodation capacity available in Rosh Pinah

Gergarub will require a backfill plant for the Gergarub preferred mining method in order to maximize ore recovery (Figure 13). Without backfill, strategic rib, crown and dip pillars would be required, commensurate with geotechnical requirements. Pillars would reduce the overall mineable resource, so the use of an engineered backfill will increase overall recovery of the resource. An efficient backfill cycle is required to ensure that backfill does not become a production bottleneck, and the backfill plant would be designed with sufficient surge capacity to enable the mine production plan.

As part of an updated backfill plant design the following specifications would require further assessment and development:

- Selection of an appropriate backfill, suited to the requirements of LHOS + DAF mining.
- Backfill design and test work, including tailings suitability and backfill strength.
- Backfill plant and reticulation system design and engineering.



Source: DRA 2021.

Figure 13 - Paste fill plant process flow diagram (Source: DRA 2021.)

When paste fill is required underground, thickened tailings will be directed to the paste plant. The paste plant operator will select the paste fill recipe specified for the stope void, including density, cementitious binder dosing rate and delivery rate. Bulk cement will be stored in a steel silo from where it is delivered to the mixer.

4.10 Utilities

4.10.1 POWER SUPPLY

Power to Gergarub would be sourced from the National Power Utility Company of Namibia (NamPower). As further studies for Gergarub's power requirements are developed for the mining strategy, Gergarub will apply to secure power from NamPower. Electrical infrastructure requirements based on the power requirements of the mining strategy will be reviewed and assessed in future studies, this will also include any requirements for off-site NamPower infrastructure upgrades required to supply power to site.

4.10.2 WATER SUPPLY

Water would primarily be sourced from the national supplier. Once further studies for the mining strategy have been completed and the water requirements for Gergarub are determined, Gergarub will apply to the Namibia Water Corporation (NamWater) for the supply of water to site. Water infrastructure designed for peak consumption and water flow requirements will also be reviewed and assessed as part of future studies. The studies would include an integrated assessment of all pumping, water treatment and dewatering infrastructure networks.

Water for Rosh Pinah is sourced from the Orange River by the Namibia Water Corporation (NamWater) via approximately 20 km of pipeline. Raw water consumption rates were estimated using the overall site water balance developed for the feasibility with the inclusion of thickened tailings, paste backfill and water treatment. The modelling shows a reduction in water consumption with the inclusion of paste fill. The total raw water consumption of 1.54 m^3 per tonne milled for current operations (dilute tailings) will reduce to 0.78 m^3 per tonne milled with the inclusion of a tailings thickener, paste backfill and water treatment at the current throughput rate. A further reduction to 0.65 m^3 per tonne milled is expected for the Gergarub Project at a higher throughput rate of 1.3 Mtpa. The water consumption figures outlined above reflect the water requirement for the both the mine and processing plant.

Based on the design mill throughput, the estimated total raw water supply requirement from the Orange River is 90 m^3/hr when the paste fill plant is in operation, increasing to 134 m^3/hr when the paste fill plant is not operational. The annual average raw water requirement is 107 m^3/hr based on the requirement for approximately 63% of the tailings material to be placed underground as paste fill. At the estimated future consumption rate (with inclusion of tailings thickener water treatment at the paste plant), the existing raw water supply system from the Orange River, which has a capacity of approximately 135 m^3/hr, will meet the Gergarub Project needs.

4.11 Mineral and non-mineral waste

The Project is expected to produce waste rock, tailings waste, domestic waste, and hazardous waste as part of its operations. Domestic and hazardous waste management is guided by the procedure "SPI 021 Waste Management on Rosh Pinah Base Metals", which forms part of the certified ISO 14001:2015 EMS. ASEC (ASEC 2019) identify risks associated with the waste disposal, hydrocarbon waste and bioremediation facility. These risks are being effectively managed through an action plan being implemented at Rosh Pinah, experience which informs the Gergarub Mine planning.

Waste rock produced during underground mining is, where possible, disposed of in underground stope voids, or deposited on the surface waste rock stockpile.

4.12 Waste rock

Mine waste rock would be hauled via decline to a surface waste dump, or where possible, placed underground in mined-out stope voids. The mine waste rock mined during the project construction phase would also be used to construct the surface run of mine (RoM) pad.

4.13 Tailings

The mining strategy for Gergarub will require a tailings storage facility (TSF). The historic TSF feasibility design excluded the use of process tailings for mine backfill purposes, however the mining strategy requires backfill for the preferred Gergarub mining method. The requirement for mine backfill will likely reduce the total tailings storage capacity required over the project LoM compared with the SRK FS design.

As part of an updated TSF design the following criteria (non-exhaustive) will be considered:

- Legal framework and regulatory compliance.
- Site selection.
- Environmental considerations:
  - Biodiversity.
  - Heritage / archaeological resources.
  - Ground water impacts.
  - Proximity to surface water resources.
  - Visual impact.
  - Proximity to local communities.
  - Public safety (failure zone assessment)
  - Energy usage and carbon footprint.
- Economic and engineering criteria:
  - Seepage potential.
  - Residue transfer.
  - Failure impact assessment

- o Undermining.
- o Capital costs.
- o Operating costs.
- o Rehabilitation costs.
- o Public acceptance.

The operation of the TSF would remain largely consistent with the SRK FS, with process residue (tailings) transferred from the process plant to the TSF, return water from the process plant and storm water (where appropriate) would be reintegrated with the site water storage facilities. Tailings utilized for backfill would predominantly be sourced directly from the process plant, reducing the total material transferred to and from the TSF.

Tailings slurry from the processing plant is pumped via a pipeline to the TSF and distributed for deposition by means of a ring feed system.

4.14 GENERAL WASTE

Waste will be separated at source, stored in a manner that there can be no discharge of contamination to the environment, and either recycled or reused where possible. On-site facilities will be provided at a dedicated waste storage facility for sorting and temporary storage prior to removal and disposal to appropriate recycling or disposal facilities off-site.

Industrial waste will be sorted on-site and disposed of at appropriate facilities. Hazardous waste includes, but is not limited to, the following: fuels, chemicals, lubricating oils, hydraulic and brake fluid, paints, solvents, acids, detergents, resins, brine, solids from sewage, and sludge. The waste types as set out in the Table 8 below will be generated by the project, a dedicated waste management and recycling facility will need to be built on site that specifically manages these waste types and this will include an incinerator.

Table 8 - Waste specification, storage and end use

Waste type	Waste specifics (example of waste types)	Storage facility	End use
Non-hazardous solid waste (non-mineralised)	Wooden crates, pallets, cable drums, scrap metal, general domestic waste such as food and packaging.	Dust bins in relevant work areas will be provided for different waste types. A waste management contractor will remove dust bins regularly to a dedicated waste handling and storage area.	Waste will be sorted further at a dedicated waste handling and storage area on site. Recyclable waste will be sent to a reputable recycling company. Some items may be distributed directly to the community if possible.

Waste type	Waste specifics (example of waste types)	Storage facility	End use
			The remainder of the waste will be transported by the waste management contractor to a permitted landfill facility which may be constructed on site for example within the WRD.
	Building rubble and waste concrete	Designated rubble collection points will be determined to which contractors will take rubble and concrete.	The waste management contractor will regularly remove the waste from the designated collection points to the footprint of the waste rock dump.
Hazardous contaminated solid waste (non-mineralised).	Treated timber crates, printer cartridges, batteries, fluorescent bulbs, paint, solvents, tar, empty hazardous material containers etc.	Hazardous waste will be separated at source and stored in designated containers in bunded work areas. The waste management contractor will remove these drums regularly to a dedicated waste handling and storage area.	Hazardous waste will be disposed of at the permitted hazardous disposal site (for example in Walvis Bay) by the waste management contractor.
	Hydrocarbons (oils, grease)	Used oil and grease will be stored in drums in bunded areas at key points in work areas. The waste management contractor will remove these drums regularly to a dedicated waste handling and storage area. The yard will have a dedicated used oil storage area which will include a concrete slab, proper bunding and an oil sump. The appointed bulk fuel supplier will collect used oil for recycling.	Used oil will be sent to a reputable recycling company for recycling.

Waste type	Waste specifics (example of waste types)	Storage facility	End use
	Sewage	Sewage treatment will be required	May be reused as greywater for dust suppression
Laboratory waste	Mineral samples, mineral assay samples, chemical fluids, glass, gloves and general laboratory waste samples	Mineral waste samples that are not required to be kept will be disposed of at the tailing storage facility and at an approved mineral disposal landfill. A mineral waste management contractor will remove the waste on a regular basis to a waste handling and storage area.	Hazardous laboratory waste will be collected regularly and transported to a hazardous disposal treatment facility (for example in Walvis Bay). Non- hazardous waste will be disposed of at an appropriate landfill which may be on site.
Medical waste	Syringes, material with blood stains, bandages, etc.	Medical waste will be stored in sealed containers. A waste management contractor will remove these drums regularly to a dedicated waste handling and storage area.	Medical waste will be transported by the waste management contractor to a permitted medical waste treatment facility.

4.15 Effluent and wastewater

Adequate facilities to treat the life of mine sewage generated will be installed as part of the project. Surface water and any available runoff will be 100% recycled and used for the site processes.

4.16 Site communication

Site communications will be used to connect the underground operations with the surface. A control room on the surface would be used to monitor critical infrastructure including ventilation and mine dewatering. Two-way radio communication would be made available throughout the surface and underground operations.

4.17 Accommodation

The operating assumption for Gergarub is that most personnel would reside in the town of Rosh Pinah. This would be supplemented with short-term accommodation in the form of guesthouses and hostel-style lodging. The assumption is that additional accommodation facilities would not be constructed as part of the project, with sufficient accommodation capacity available in Rosh Pinah.

4.18 ALTERNATIVE'S CONSIDERED

The following assumptions have been carried forward in the preparation of the cost estimates:

- The project would proceed on an EPCM basis.
- The project would generally be implemented as per the execution schedule.

All material and equipment will be new and purchased from recognized top-tier vendors.

Mining alternatives were assessed, such as only open pit versus only underground. The underground option is most financially viable based on orebody geometry and grade distribution. In addition, alternate routings of the national road and 66kV power line were assessed and proposed. Alternatives to conventional tank cells or new rougher floatation technologies where assessments are being evaluated further. Tailings storage location alternatives have been and will continue to be evaluated, due to the limited space available within the lease/licence. Options include expanding the lease/licence, co-dispose tailings with overburden and waste rock, and transport tailings to Skorpion.

The most effective transport and storage solution for tailings materials needs to be assessed in greater detail. The proponent needs to conduct a cost analysis and trade off study to determine if dry stacked tailings compared to wet spigot tailings is the best option for the project.

The project has considered the use of tailings to produce paste backfill for the mining voids. This will reduce the volume of tailings material to be stored on surface and will assist in stabilising the underground mine voids during the operational phase which creates further economic opportunities for the project with increased ability for ore recovery. The interaction of water and paste backfill needs to be further reviewed and studied.

The only other alternatives considered were the open pit mining versus underground mining options, and if blended, timing and approach of the transition, as well as the use of paste backfill versus no backfill for the underground open stope mining.

Other alternatives considered are for sequencing and production rates and mining blocks, and alternative power sources such as renewable power such as solar to supplement existing and proposed grid power.

4.19 MINING

The underground mine is planned to be located solely in the primary rock as mining through the surficial material may be very difficult due to stability issues. This means the decline portal and ventilation raise collars will need to be located where the primary rock outcrops on the surface.

Long hole open stoping (LHOS) with backfill to mine the orebody, supplemented with drift and fill (DAF) mining for the orebody extremities (LHOS and DAF) was identified as the most suitable method of mining for this orebody. Long hole open stoping is a form of sub-level open stoping which involves excavating ore in a series of horizontal or sub horizontal levels known as “stopes”. A series of vertical or inclined holes are drilled from the top of the stope to the bottom.

Whilst with drift and fill the drift is developed in the ore and is backfilled using consolidated fill. The following drift is driven adjacent to the previous drift. This carries on until the ore zone is mined out to its full width.

When mining is completed in these areas, voids that do not encumber the mining operation and / or the ventilation network can be used to place paste fill (with lower cement content) to reduce the tailings deposition to the TSF.
Long hole open stope (LHOS) with paste fill is recommended to improve local and regional stability, improve operational recovery, reduce dilution, mitigate void risks, and minimize the tailings being pumped to the TSF (to eliminate or delay TFS expansions).

Mining areas are globally advanced top-down, but within each mining area, stopes are extracted using a bottom-up sequence at 30 m level intervals. A mining area typically spans four levels, ranging from three to five. The mining area grades are sub-divided along strike guided by the lens geometry, mineralization grades, and planned mining sequence to achieve production targets.

4.20 SOCIAL AND COMMUNITY ENGAGEMENT

The town of Rosh Pinah is a mining community, built and managed for the employees working at Rosh Pinah Mine and later from the Skorpion Zinc mine. A joint-venture (50:50) company called RoshSkor was established to manage and operate all town services and infrastructure as a private municipality on behalf of RPZC and Skorpion Zinc.

RoshSkor is responsible for implementing community development projects, though funding is currently jointly funded between RPZC and Skorpion Zinc. There are no funding obligations that would impact the progression of the Gergarub Project. There are no community agreements that require development funds to be provided. All donations are investments and are voluntary and at arms-length from RPZC.

RPZC and Skorpion Zinc assists with the funding for projects that aim to deliver economic independence for the community. Programs include training in basic needlework; hand weaving of carpets; development initiatives in Tutungeni (a township outside of the central

Rosh Pinah town), which involves the upgrade of a school, training of community members for the removal of waste and waste segregation; sanitation system maintenance; and other initiatives.

4.21 REHABILITATION AND CLOSURE

The Minerals Act states that the holder of a mineral license must take all steps to the satisfaction of the Minister to remedy any damage caused by any mining activities. In the case of larger mining operations, the Minister demands guarantees that could be used by the Ministry to remedy damage caused by mining activities. This is in the form of closure financial liability. However, there is currently no mandatory mechanism for the funding of a Final Mine Closure Plan.

In the absence of Namibian legislation, the Proponent will have to develop a Mine Closure Plan based on the South African Legislative Framework for Financial Provisioning, as provided in the Mineral and Petroleum Resources Development Act, 2002 (Department of Mineral Resources). This plan will be updated on a quarterly basis to ensure that it is continuously aligned with current site conditions.

The Proponent will commit to establishing a rehabilitation plan aligned with the upcoming Namibia Mine Closure Framework (MCF) as part of the mine closure plan. An environmental consultant, in conjunction with the Proponent and the specialist consultants working on the mine design, and those undertaking the environmental impact assessment, will prepare a conceptual mine closure plan as part of the EMP requirements and using all existing information and related closure concepts, planning and costing.

5 ENVIRONMENTAL AND SOCIAL BASELINE

5.1 BASELINE DATA COLLECTION

Initial desktop baseline studies relevant to the project formed part of the initial environmental assessments. As part of this assessment, the baseline environmental and social conditions have been studied in detail, with inputs from specialist studies commissioned as part of the previous environmental impact assessment.

5.2 DESKTOP AND FIELD SURVEYS

Initial desktop baseline studies were completed for the project by various consultants and groups in 2015 for the previous impact assessment. Additional desktop and field-based baseline studies were completed in 2023 and built on the project dataset.

5.3 SPECIALIST STUDIES

The following specialist studies were commissioned as set out in Table 9, to determine the current state of the baseline environments and conduct impact assessment studies.

Table 9 - Specialist studies that were completed for the ESIA

Study Area	Purpose
Hydrology	– Water supply – Storm protection – Impact downstream users – Clean and dirty water management systems
Groundwater	– Assess the potential for contamination of aquifers – Provide a model to determine impacts of drawdown and plume mobility – Assess the sustainability of boreholes for water supply if required
Air quality	– Provide emission standards and dust suppression requirements – Assess prevailing wind directions and possible effects of emissions on the process and/or personnel – Model potential air quality impacts
Noise and sense of place	– Identification of possible receptors, and assess levels of noise to which they may be exposed during construction and operations
Traffic	– The traffic impact assessment will study the potential traffic impacts and loading on routes associated with the mining activities – Assessing the capacity of infrastructure and safety aspects of the mine entrance – Assessing the need for an intersection upgrade at the mine entrance, and providing a concept layout plan if necessary

Study Area	Purpose
Visual and tourism	– Assessing the potential visual impacts of a proposed project on the receiving environment
Blast vibration impact	– Assessing the impact of blasting on receptors in the area
Heritage	– Evaluate the site to understand its historical and cultural significance. – Identify and document archaeological and heritage resources within the specific area, while determining the potential impact of the proposed activities on cultural resources. – Propose measures for the preservation, protection, or mitigation of identified cultural resources.

5.4 LAND USE

The deposit is located on the farm Spitzkop 111, along the C13 national road between Rosh Pinah and Aus within the Oranjemund Constituency. It lies approximately 10 km south-east of SZM and 15 km north-west of RPZC.

To the west of the deposit lies Diamond Area 1, a diamond mining area controlled by Namdeb. This area lies within the Tsau ǁKhaeb national park. The east is a small stock farming area. Farms are large due to the low carrying capacity of the land.

The area is mainly characterized by small-scale livestock farming. Over the past two decades, there has been a substantial rise in irrigation farming along the Orange River (Koch et al., 2011). Additionally, the region is home to the Lüderitz harbor, a crucial port for exporting both refined and unrefined minerals.

The closest town to the deposit is an unproclaimed mining town, Rosh Pinah, the economy of which mainly revolves around the two nearby existing mines, SZM and RPZC. Mining activity plays a major part in the economy of the Region, with diamond mining (Namdeb operations) and zinc mining being the two major contributors. The mining town, Rosh Pinah, was established in 1970 and has since provided accommodation for those employed at RPZC and later also the employees of SZM (S. van Zyl et al., 2015).

Surrounding land uses

Several different land uses surrounds the proposed project area shown in Figure 14. This includes the following:

- *Farming:* Gergarub is located on Farm Spitzkop 111, a privately owned farm which is neighboured by a number of commercial farms farming with livestock and game.
- *Conservation and Tourism:* Rosh Pinah is situated between two conservation areas namely the Tsau ǁKhaeb National Park and the Fish River National Park. Even though Rosh Pinah is not a tourist destination itself, it is frequented by tourists passing through en-route to another destination such as the Fish River Canyon. The contrasting geological features of the area provide visually stimulating scenes to passing tourists (Fish Eagle Productions, 2012).
- *Mining:* SZM and its associated infrastructure is located to the northwest of the proposed project area. A number of drilling and exploration activities can be found in the area.
- *Road users:* The C13 National Road traverses the proposed site. This road is used by visitors, tourists and Rosh Pinah residents. The employees of SZM make use of this road daily. The diversion design of the C13 around the mining area should consider the best options for optimal road safety.

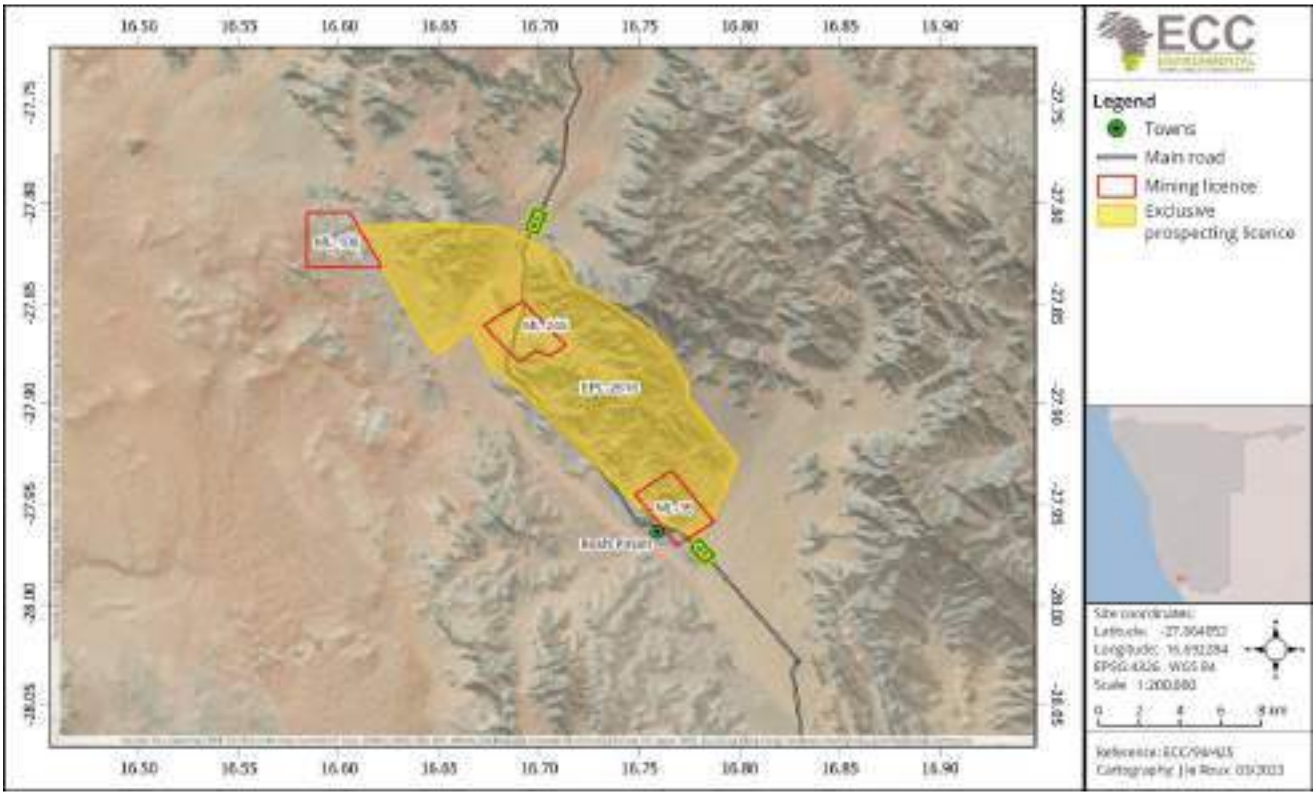


Figure 14 - Current land use of ML 245 and the surrounding areas

5.5 INFRASTRUCTURE AND BULK SERVICES

NamPower has been approached regarding power supply to Gergarub. It has been decided that the existing Obib Transmission Station should be used. In addition, new 66 kV lines from Obib to a new site located within the mining complex will be constructed. The total distance of the new lines is approximately 9 km. This route will run parallel to an existing servitude. From the new distribution station an 11 kV distribution line is fed to a mini substation and the 66 kV to the Portal Substation. Energy consumption is expected to increase by ±300 MWh/day and the monthly Maximum Demand (MD) could increase up to 20 MW.

At present the town of Rosh Pinah, SZM as well as Namzinc Refinery is supplied with water from the Orange River by NamWater. New water supply infrastructure would be required for the extension of the existing water line to the new supply points for Gergarub.

The ore deposit extends underneath the C13 national road (see Figure 15) and mining will take place under the C13 national road.

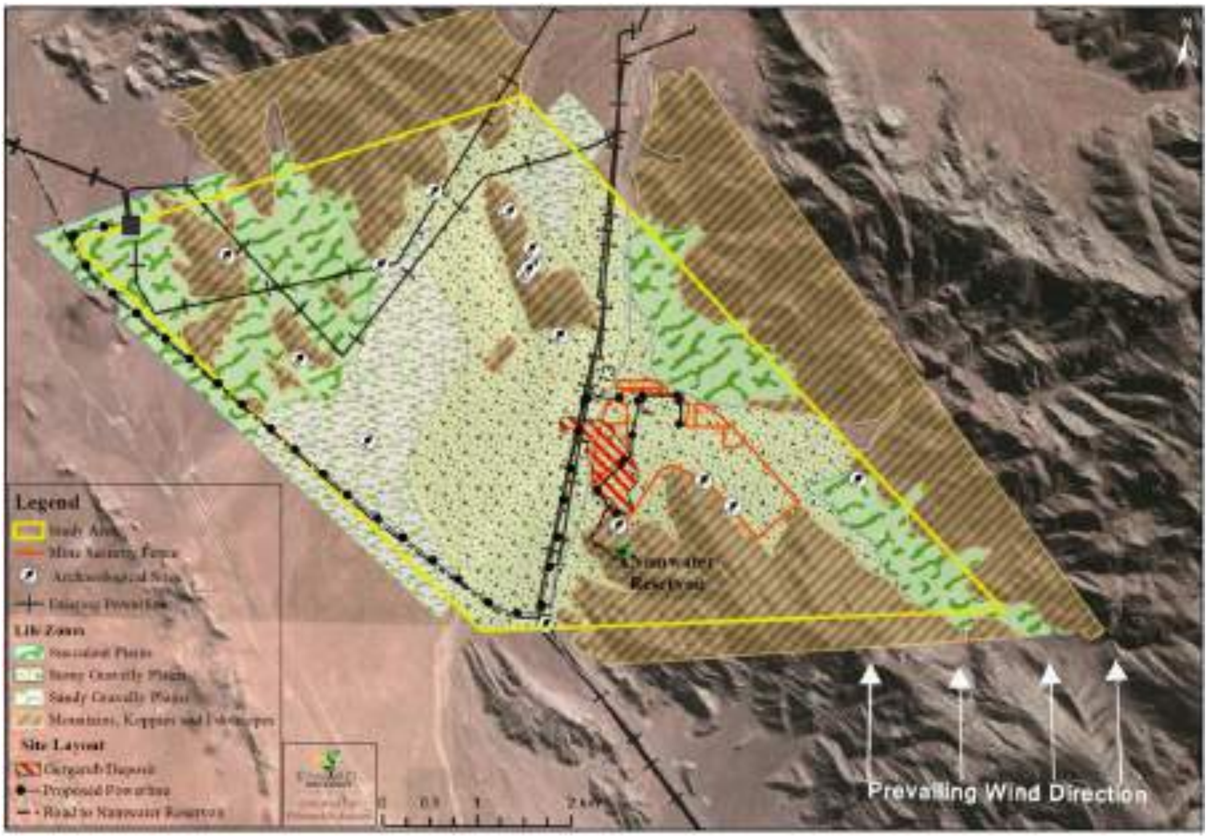


Figure 15 - Location of the Gergarub deposit in relation to the ML and current infrastructure (S. van Zyl et al., 2015)

5.6 BASELINE BIOPHYSICAL ENVIRONMENT

The region is predominantly a small stock farming area. Irrigation farming along the Orange River has increased significantly in the last two decades. The region also hosts the Lüderitz harbour, an important port for the export of refined and unrefined minerals (Koch et al., 2011).

The region is hyper arid with low average rainfall and high temperatures. It receives the majority of its moisture from the coast in the form of fog originating across the Benguela Current. The Succulent Karoo Biome is maintained by this air movement from the coast, and it is known as a biodiversity hotspot. The area is near the Tsau-Khaeb and the Fish River National Parks. It is also located along the tourist route to these parks.

5.6.1 CLIMATE

The climate in the study area is extremely arid with hot and dry conditions and the ecosystem is driven by air movement. Due to the close proximity of the Atlantic Ocean and its cold Benguela current, fog is recorded between 50 to 75 days per year.

5.6.2 TEMPERATURE

Daytime temperatures are hot, reaching more than 40˚C in summer. Nights are cool, becoming cold in winter when temperatures often fall below 0˚C (meteoblue, 2023), shown in Figure 16.

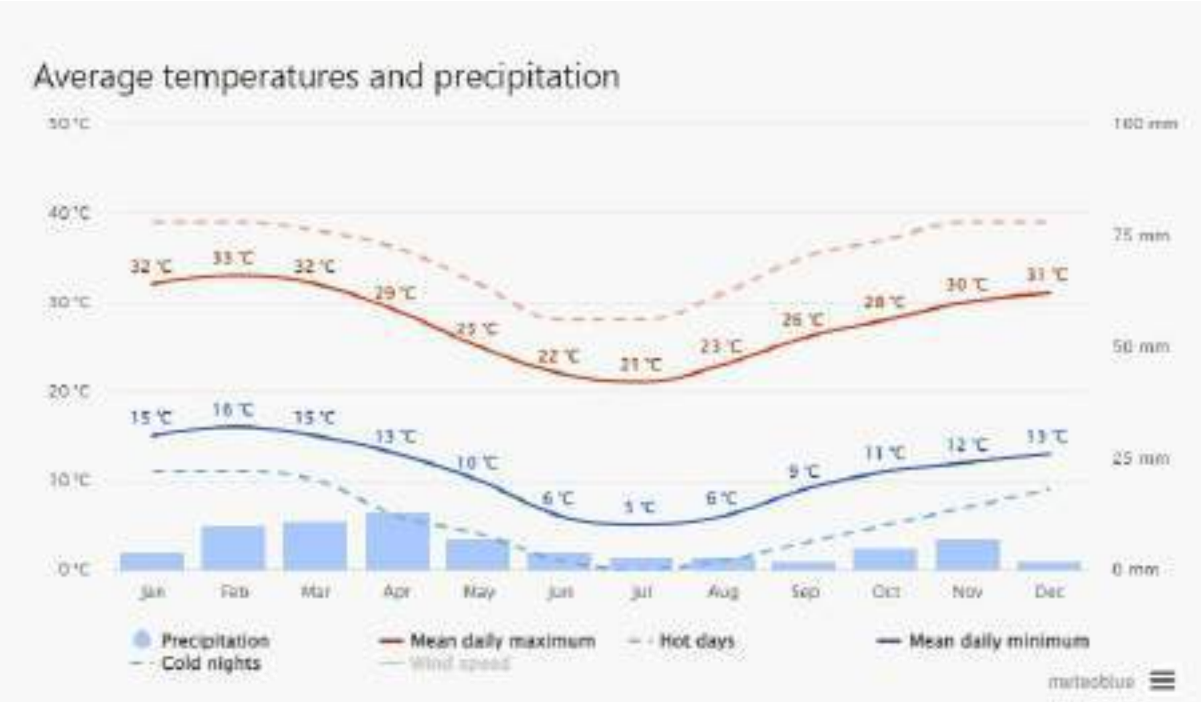


Figure 16 - Average yearly temperatures at ML 245 (meteoblue, 2023)

5.6.3 WIND

The winds in the area are illustrated by the wind rose at SZM for the period January 2003 to April 2008 (Figure 17). A wind rose simultaneously depicts the frequency of occurrence of wind from the 16 cardinal wind directions and in different wind speed classes. Wind direction is given as the direction from which the wind blows, i.e., south-westerly winds blow from the southwest. Wind speed is given in m/s, and each arc in the wind rose represents a percentage frequency of occurrence (39 percent in this case).

In the Rosh Pinah area, the winds are predominantly from the sector south-southeast to south-southwest, with more than 45% of all winds from this direction. Winds from the sector north-northwest to north do occur, but infrequently. Generally, the winds are light with a high frequency of winds less than 6 m/s. However, strong winds do occur, reaching 15 m/s or more. The highest frequency of strong winds is from the south-southeast and south (meteoblue, 2023).

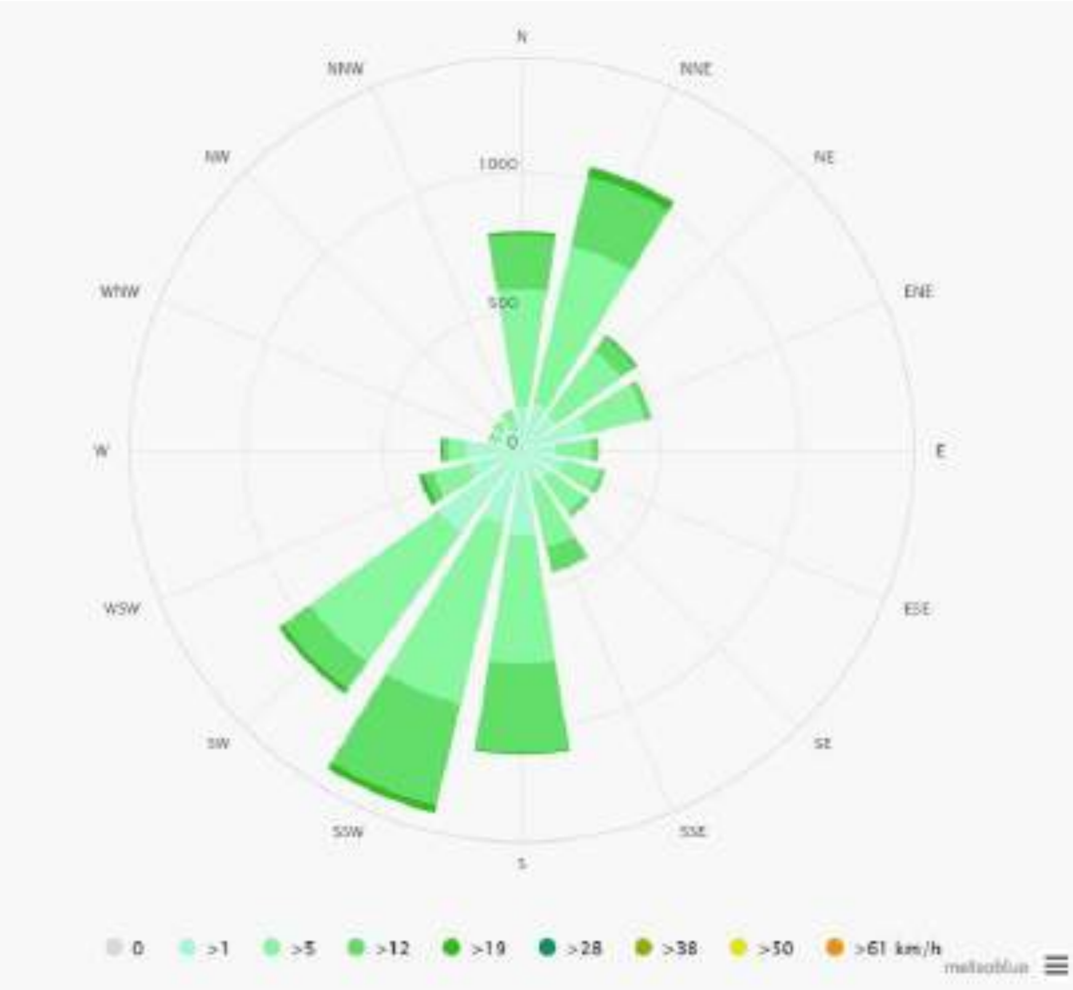


Figure 17 - Prevailing wind direction and wind speed in the ML 245 area (meteoblue, 2023)

5.6.4 RAINFALL AND EVAPORATION

Rain is infrequent with an average of less than 100 mm of rain received annually occurring mainly during the summer between October and February. From January 2003 to April 2008 rain occurred on only 235 days as shown in Figure 18. Most rain events result in rainfall of less than 3 mm however occasional downpours can occur (meteoblue, 2023).

Figure 18 - Average rainfall received annually at ML 245 (meteoblue, 2023)

5.7 AIR QUALITY

Airshed Planning Professionals (Pty) Ltd was appointed by Environmental Compliance Consultancy (ECC) to undertake an air quality impact assessment for the proposed Project in 2023. Air quality monitoring is crucial for determining the potential impacts that planned mining and processing operations may have on an environment. The study objective was to quantify the potential air quality impacts from proposed activities on the surrounding environment and human health (Steyn, 2023).

5.7.1 DUSTFALL LIMITS

The international criteria referenced in the air quality specialist study include those published by the World Bank Group (WBG), the World Health Organisation (WHO), the European Community (EC) and the South African (SA) National Ambient Air Quality Standards (NAAQS). NAAQS provides representative indicators for Namibia because of the comparable environmental and socio-economic aspects between the two countries.

Dust deposition may occur due to windblown dust from various sources such as mine tailings, mining operations and natural sources. The dust deposition limits are not defined in all countries, however, in several SADC countries, including South Africa and Botswana, dust control regulations and dust deposition evaluation criteria have been published to provide guidance in residential and light commercial areas (Steyn, 2023). The bands for dustfall are provided below in Table 10. There may be a possibility to operate within Band 3 for a limited period and authorisation requests are approved for specific activities such as the final removal of a tailings deposit, however the advised bands are band 1 and 2 for residential and industrial environments, respectively.

Table 10 - Bands of dustfall rates (Steyn, 2023)

Band Number	Band Description	30 Day Average Dustfall Rate (mg/m²-day)	Comment
1	Residential	Dustfall rate < 600	Permissible for residential and light commercial
2	Industrial	600 < Dustfall rate < 1 200	Permissible for heavy commercial and industrial
3	Action	1 200 < Dustfall rate < 2 400	Requires investigation and remediation if two sequential months lie in this band, or more than three occur in a year.
4	Alert	2 400 < Dustfall rate	Immediate action and remediation required following the first exceedance. Incident report to be submitted to relevant authority.

5.7.2 EXSISTING SOURCES OF ATMOSPHERIC EMISSIONS

The existing sources of atmospheric emissions that may be of concern includes particulate matter (total suspended pollutants (TSP), PM_{10} and $PM_{2.5}$) from vehicle entrainment on the roads (paved, unpaved, and treated surfaces), windblown dust, and mining and exploration activities (Steyn, 2023). Gaseous pollutants such as SO_2, NO_x, CO and CO_2 released from vehicles and combustion sources may be a concern, however these concentrations are expected to be due to the low combustion sources present in the region. The existing sources of atmospheric emissions are further discussed in this section.

Windblown particulates from several sources such as mine waste facilities and product stockpiles may cause significant, high concentration dust pollution in the vicinity of the proposed Project area which may have noteworthy impact on the surrounding environment and human health. However, wind speed results proved to remain below 10m/s as shown in Figure 19, whereas particulate matter emissions in and around the Project site is likely to occur at a wind speed that exceeds 10m/s. The impact is therefore unlikely to occur.

The Skorpion Zinc mine is approximately 10 km northwest of the Gergarub Project and the mining and exploration activities may produce a variety of atmospheric emissions. Sources of dust during mining and quarrying include drilling and blasting; handling of materials (loading, unloading, and tipping); crushing and screening; windblown dust (from the sources as described above); access roads; and plant stack emissions.

Regional transportation produces air pollution in the form of aerosols, especially heavy-duty vehicles importing and exporting goods between South Africa and Namibia. Lesser contributing air pollutants may be attributed to biomass burning more likely along the densely vegetated northeastern parts of Namibia. Other examples of air pollution may be evaporated sea spray and pollen grains that contribute to atmospheric particulate.

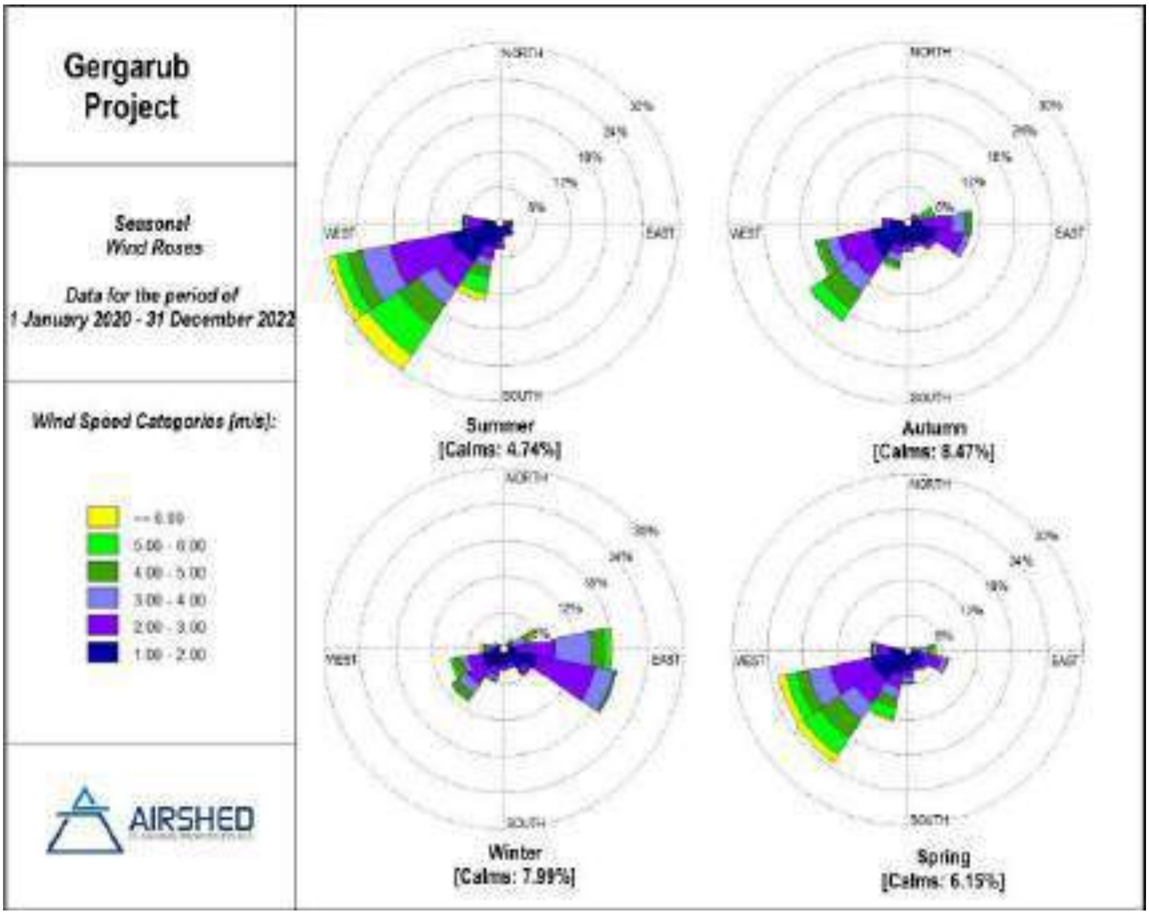


Figure 19 - Seasonal wind rose for the period of 1 January 2020 to 31 December 2022 (Steyn, 2023)

5.7.3 EXSISTING AIR POLLUTANT CONCENTRATIONS IN THE PROJECT AREA

There are currently no ambient PM_{10} and $PM_{2.5}$ monitoring network or dustfall monitoring being conducted at the site.

5.8 LOCAL GEOLOGY AND GEOMORPHOLOGY

The Gergarub deposit is hosted within the Gariep Belt, which extends from northwestern South Africa into southern Namibia. The following geology and mineralization description is based on the Technical Report of the Gergarub Deposit, 2022, Rosh Pinah Zinc and Skorpion Zinc Mine. The Gariep Belt is situated between the Kalahari- and Rio del Plata Cratons, part of the spreading of the Adamastor Ocean. It consists of metamorphosed fill of the Gariep basin, one of a number of Neoproterozoic basins that evolved around the margins of the Kalahari Craton as a consequence of the break-up of a 1.0 Ga supercontinent as illustrated in Figure 20.

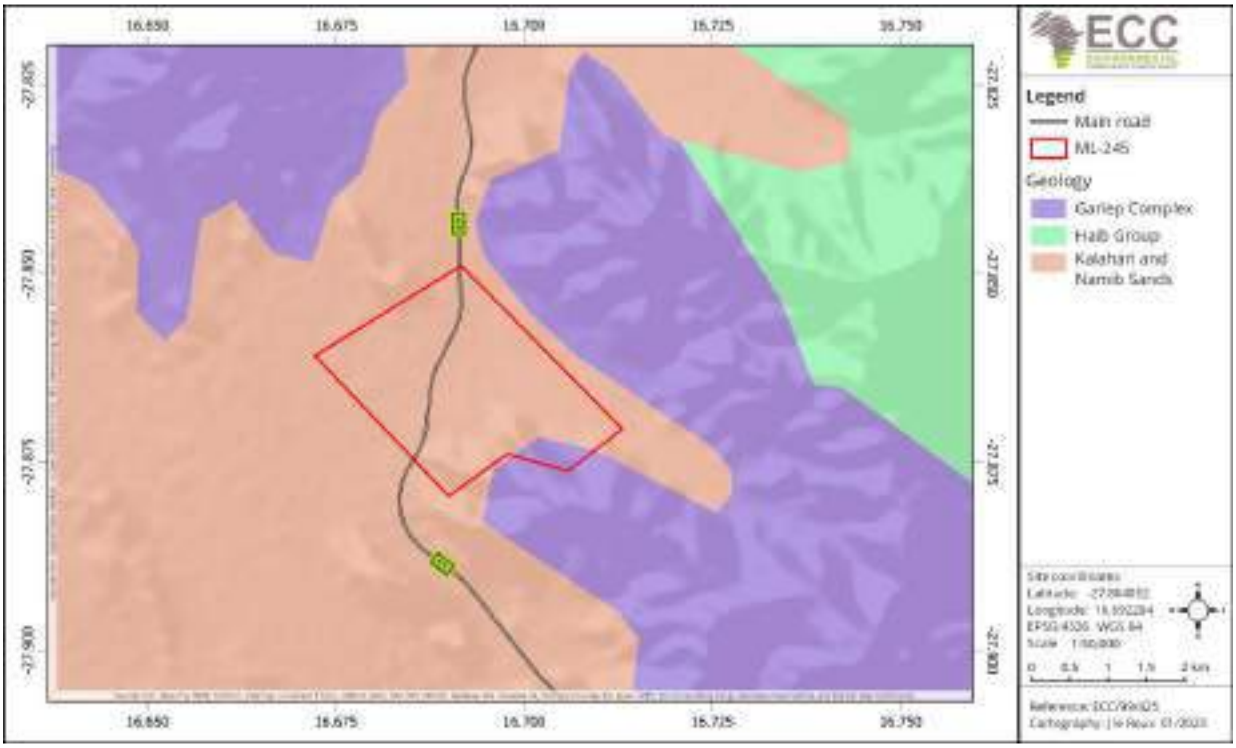


Figure 20 - Geology of ML 245

The external part of the belt, furthest east, is called the Port Nolloth Zone (PNZ), approximately 770 - 550 Ma. This zone consists of continental sedimentary successions with subordinate volcanic rocks as described above. The PNZ can be interpreted as three mega-sequences:

- Continental rift deposits (Stinkfontein Subgroup)
- Passive margin deposits (Hilda Subgroup)
- Syn-orogenic deposits (Holgat Formation)

The Gergarub Deposit is situated within the PNZ, more specifically, within the Rosh Pinah Formation of the Port Nolloth Group. The Rosh Pinah Formation hosts two major producing base metal mines as well as many other mineral showings. Structurally, the deposit is situated within a failed graben Easton the eastern margin of the Gariep Basin. The graben developed during the rifting phase and was subsequently filled by the bimodal volcanism associated with the transition from rifting to drifting, as well as lacustrine- and alluvial facies sediments. Subsequently, these deposits were exposed to extreme ductile- and brittle deformation produced by the Gariep Orogeny (~545 Ma) which results in recumbent folding, shearing and thrusting. The Gergarub deposit is covered by 30 - 100 m of Tertiary overburden (S. van Zyl et al., 2015).

There is a distinction between concordant mineralization and discordant mineralization. Concordant ore is in-situ sediment-hosted and rhyolite- or rhyolitic hyaloclastic-hosted mineralization that formed syngenetically on or just below the seafloor. The mineralization occurs in chemically reducing environments together with small scale tectonic features indicating the exhalation of the hydrothermal fluids and precipitation of sulphides and chert onto the seafloor. Discordant ore has been transported as debris-flow and deposited within brecciated lithified volcanic and sedimentary rocks. Mass flow breccias in sulphide ore occur which indicates that these have been re-deposited together with fragments of host rocks. Some rhyolite-hosted mineralization occurs in veins and breccias as stock work feeder zones (S. van Zyl et al., 2015).

The mineralization is closely associated with the rhyolites, specifically rhyolite domes. There are three main mineralization types:

- The first type is disseminated mineralization with typical values of <20% sulphides with zinc grades from 2%-6% zinc. Generally, the zinc is related to Fe-rich sphalerite which typically contains 10% iron,
- The second main mineralization type it is semi-massive sulphide which is banded mineralization with typically 20% to 50% sulphides with zinc grades from 4%-12% zinc. The sphalerite typically contains 2%-7% Fe,
- The highest-grade mineralization is the massive sulphide with typically 50% to 100 % sulphides with zinc grades from 15%-45%. The massive sulphide mineralization commonly contains honey coloured sphalerite with less than 1% Fe, and chocolate-coloured sulphide which contain a higher percentage of iron.

All three types of mineralization are compositionally banded on a 1 – 10 mm scale, more so in disseminated and semi-massive ore which is intercalated with quartzite, metacarbonate, and Fe-sulphides (pyrite and pyrrhotite). All sulphides have been recrystallized, with very little effect on chemistry, due to the metamorphism which the deposit has undergone.

5.9 TOPOGRAPHY AND SOIL

The region topography is fairly rugged, consisting of plains interrupted by koppies and rocky outcrops and partly bordered by mountain slopes incised by several deep gorges (Mannheimer, 2015). The study area exhibits highly contrasting relief comprising mountainous terrains in the east, southeast, northeast and northwest with a central flat-lying area formed by the Zebrafontein Valley Drainage System (Figure 21).

Elevations range from 1 647 mamsl on Nasepberg in the northeast, to 540 mamsl in the lower Zebrafontein Valley Drainage System in the south. Elevations at the site, which is located in the south-eastern part of the Zebrafontein Valley Drainage System, range from 612 mamsl in the north, to 618 mamsl in the south, 615 mamsl in the east and to 608 mamsl in the west (Constable 2014).

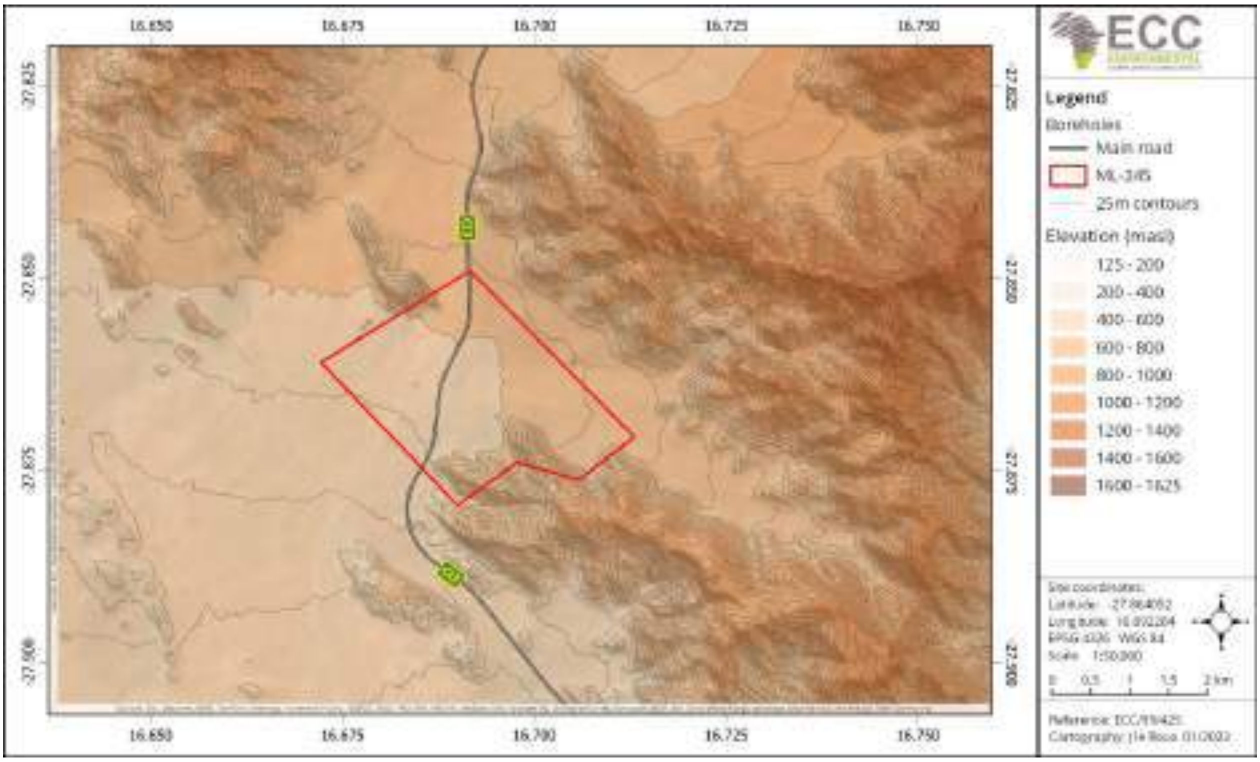


Figure 21 - Topography of ML 245

Towards the west, southwest and south the terrain flattens out into low-lying sandy plains and sand dunes of the southern Namib Desert. The area is comprised of eutric Regosols and lithic Leptosols as the dominant soil type as shown in Figure 22. Regosols are typically found in areas that have extensive eroding lands in arid and semi-arid areas and mountain regions. While Leptosols are characterised by their continuous hard rock within 25cm from the soil surface or a molic horizon with a thickness between 10 – 25 cm directly overlying material with a calcium carbonate equivalent of more than 40 % or less than 10 % fine earth from the soil surface to a depth of 75 cm.

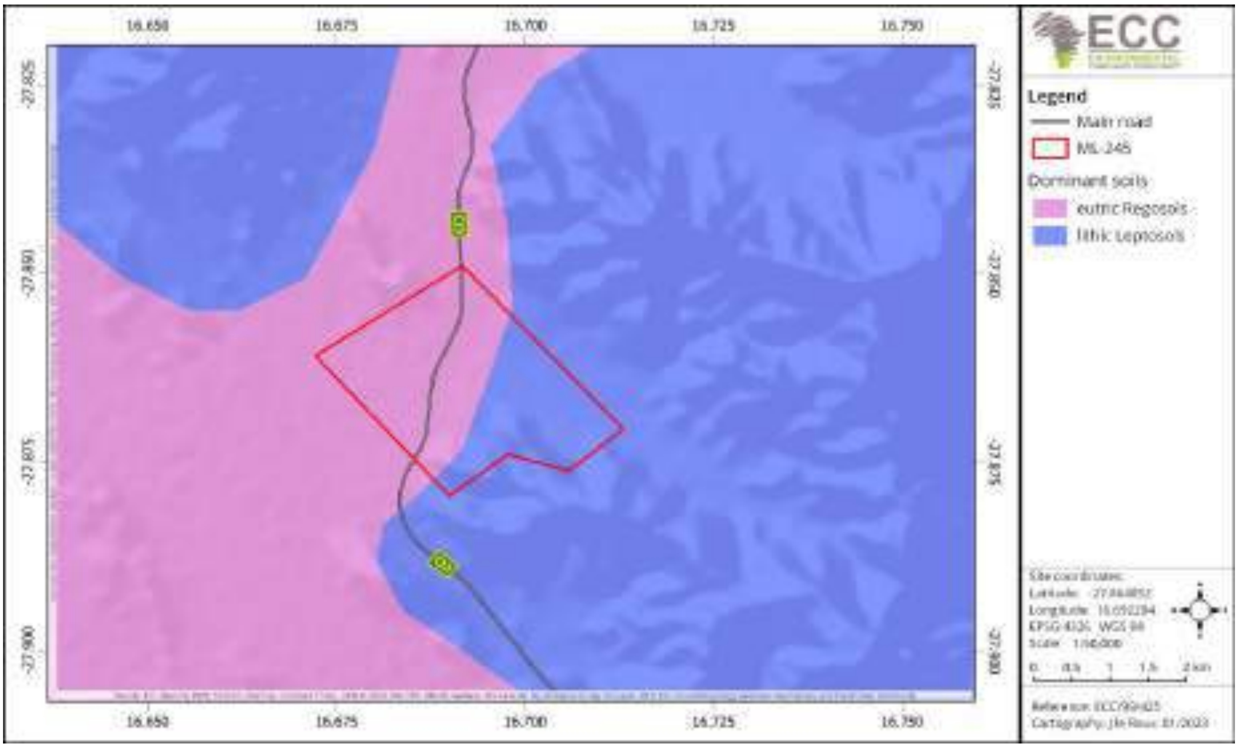


Figure 22 - Soil type of ML 245

5.10 Hydrology and Geohydrology

The prominent natural surface water in the area is the Orange River (perennial river) located approximately 40 km south-east of the study area. The Orange River forms the border between Namibia and South Africa and drains into the Atlantic Ocean at Alexander Bay. Any surface water impacts on the Orange River would have potential international implications (Department of water Affairs and Forestry, 2009).

In the localised area of the proposed Mine, surface water channels consist of a myriad of small non-perennial drainage paths randomly draining over the site and converging only where manmade culverts are constructed under existing roads, shown in Figure 23.

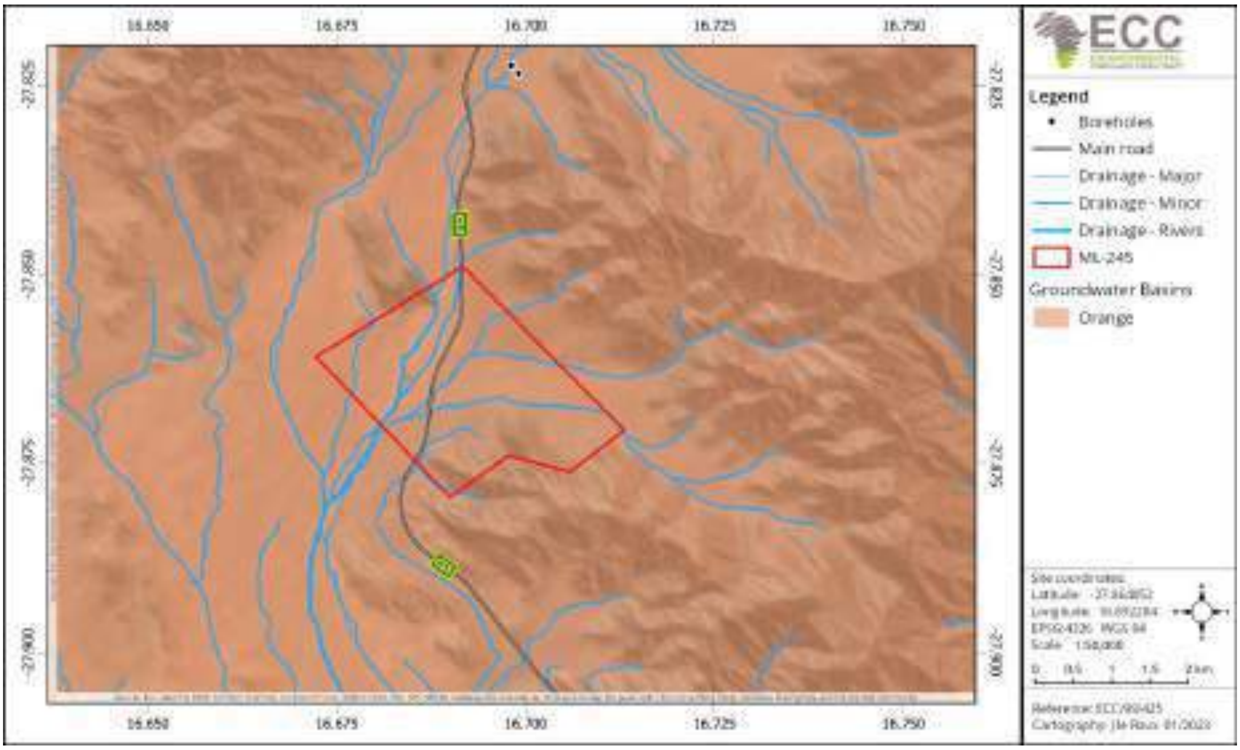


Figure 23 - Hydrological profile of ML 245

The water supplied to RPZC, SZM and Rosh Pinah Town is abstracted with pump sets in a vertical water tower and pumped to a water treatment plant for purification before it is distributed for domestic use to Rosh Pinah residents. There is also a raw water pipeline from the abstraction tower to the SZM.

Site investigations to determine the characteristics of the Gergarub mine area groundwater and aquifers were conducted from April to December 2013 and included hydro census, slug tests, soil infiltration tests, geophysics, drilling, pumping tests and packer tests (Botha & Botha, 2014). It was determined that groundwater is the sole source of water supply to the farms in the study area where small volumes (estimated at <10 m^3/day/borehole) are abstracted from seven boreholes for stock watering and household use. Four hydro census boreholes S2-Homestead, S3-Diepkloofwell, S4-Prospect, and SW5-SüdWitputz31, situated on the adjacent properties, were accessible to measure water levels. These were 71.36, 3.21, 9.06 and 9.94 mbgl, respectively, which was concluded as stable.

A hydro census was conducted by de Bruin et al., (2023) in October 2023 which included a site walkover, groundwater measurements and basic water quality measurements of two boreholes. In comparison with the 2013 hydro census assessment, the 2023 hydro census provided a wider spatial distribution in in terms of water levels and the flow of groundwater across the proposed site and assessments of boreholes represented true depths. It was also found that two boreholes were being pumped - Solar BH (GB-GH-BH1) and Gen (generator) BH (GB-GH-BH3), for use on the drilling site. It was reported by drillers that these boreholes are being pumped at ~3.5 m^3/h (~1.0 l/s) each for most of the day, and that Solar BH only shows ~0.3 m of drawdown, indicating it is in a transmissive area. Average transmissivity was ~19.5 m2/day according to test pumping results (Umvoto Africa, 2023).

During the basic water quality assessment, the pH of the two boreholes were 6.7 and 6.36, electric current (EC) - 304.5 mS/m, 422.1 mS/m and temperatures were 36.0°C and 54.5°C respectively. The EC is slightly above the typical drinking water standards and the high temperature is because of the pipe heating in the sun (Umvoto Africa, 2023).

S3-Diepkloofwell is a shallow dug well situated close to a spring which was dry during the site visit in 2013. Based on these results it is evident that the water levels are shallower towards the north of the site. The average water level measured at the project site was 81 mbgl.

The groundwater is slightly acidic to slightly alkaline with pH ranging from 6.22 to 7.70. Except for iron and manganese, the metals in the water of all the boreholes sampled are very low.

Boreholes GB-GH-BH1 to -BH5 have good water quality with slightly elevated chloride, sulfate, and sodium concentrations. Boreholes GB-GH-BH6 and –BH7 are of poorer quality with calcium, magnesium, sodium, and bromide concentrations above the standards stipulated in the Water Act 54 of 1956 (SA), (1956). The EC ranges from 163-900 Ms/m. According to the drinking water guidelines of the Namibia Water Act (1956) there are four different classes into which water quality has been grouped:

- Group A: Water with an excellent quality
- Group B: Water with acceptable quality
- Group C: Water with low health risk
- Group D: Water with a high health risk, or water unsuitable for human consumption.

The concentration of and limits for the aesthetic, physical and inorganic determinants define the group into which water will be classified. There are four water changes from borehole to borehole at the Gergarub site and are grouped accordingly:

- SPDD108, GB-GH-BH4 and -BH5 are classed in Group B indicating that the water is of ‘acceptable quality’;
- GB-GH-BH1, -BH2 and -BH03, SPDD005, SPDD009, SPDD058_MIN and SPDD271 are classed in Group C indicating that the water has a ‘low health risk’;
- GB-GH-BH6 and -BH7, SPDD013 and SPDD166 are classed in Group D indicating that the water has a higher health risk or that the water is unsuitable for human consumption.

During the hydrological and hydrogeological study observed that the hydrochemistry of GB-GH-BH7 and GB-GH-BH6 were concentrated on the TSF site and were of a much poorer quality compared to other samples. It is advised that this should be further investigated (Umvoto Africa, 2023)

5.10.1 AQUIFER CHARACTERISATION

The hydrological and hydrogeological study (2023) suggests that during mine construction, water inflow when intercepting good aquifer units should be considered. It is suggested that coarser clastic sediments of the upper Gergarub Member may be a source of higher aquifer units especially the fractured zones. The carbonate schist rock tends to be slightly poorer aquifers because of foliation; however, the presences of fractures improve the aquifer properties. The study explains that the aquifer properties of the Spitskop and Koivib intrusives may be highly variable depending on the rate of cooling and thickness (de Bruin et al., 2023). Good aquifer conditions may be achieved due to rapid cooling which leads to increased porosity and emplacement which results in fracturing.

Previous surface infiltration tests predicted infiltration rates of 5-7 m/day over long periods of saturation. Rapid infiltration rates are important to note should the TSF facility experience continuous leakage or spillage. This may cause saturation of the subsurface and fast infiltration of contaminants to groundwater. However, the lack of rainfall and extreme evaporation rates leads to low recharge rates of up to 0.5 mm/a.

5.10.2 GROUNDWATER BASIN

The drainage channel/basin dominating the study area (Figure 23) drains southwards to the Orange River, but relatively permeable surface soils will negate most surface water reaching the Orange River. Potential contaminants within surface water (and emanating from the mine) are therefore likely to pose a greater risk to groundwater than to the Orange River.

The study area is situated in a valley fault zone, the Zebrafontein Fault, within the Gariep Orogenic Belt. SRK has defined a single regional Groundwater Resource Unit (GRU) for the purposes of analysing the groundwater resource potential in the project area. The boundaries of the GRU follows likely groundwater divides (topographical highs, faults, surface water divides) so that the GRU forms a groundwater catchment area and calculations of regional water balance parameters (such as recharge) was undertaken by taking the entire catchment into account.

The area of the GRU is 639 km^2. The groundwater exploitation potential of the GRU was determined and is very low (82 472 m^3/a). This is due to an extremely low rainfall of ~56 mm/a in combination with a low recharge potential ranging between 0.01 and 0.05 mm/a groundwater flow gradient.

The depth of the groundwater in the mining area ranges from ~80 to ~85 metres below ground level (mbgl). The groundwater levels closely follow the general terrain and tend to be highest within the mountainous area, specifically towards the east. The Groundwater flow is directed southwest across the following the Zebrafontein Valley, where it will eventually flow southwards to the Orange River (Umvoto Africa, 2023).

5.11 BIODIVERSITY

The study area lies within a very sensitive ecological area next to the Tsau ǁKhaeb National Park and close to the Fish River National Park in remote southern Namibia.

The landscape surrounding the deposit is part of the northern section of the Succulent Karoo biome which is regarded as a global biodiversity hotspot (Myers et al., 2000) shown in Figure 24 and is thus important in global as well as regional and national terms. This makes only unavoidable damage acceptable. It is extremely sensitive in terms of near-endemic, endemic, and protected plant and animal species and widely recognised as an important area of both diversity and endemism.

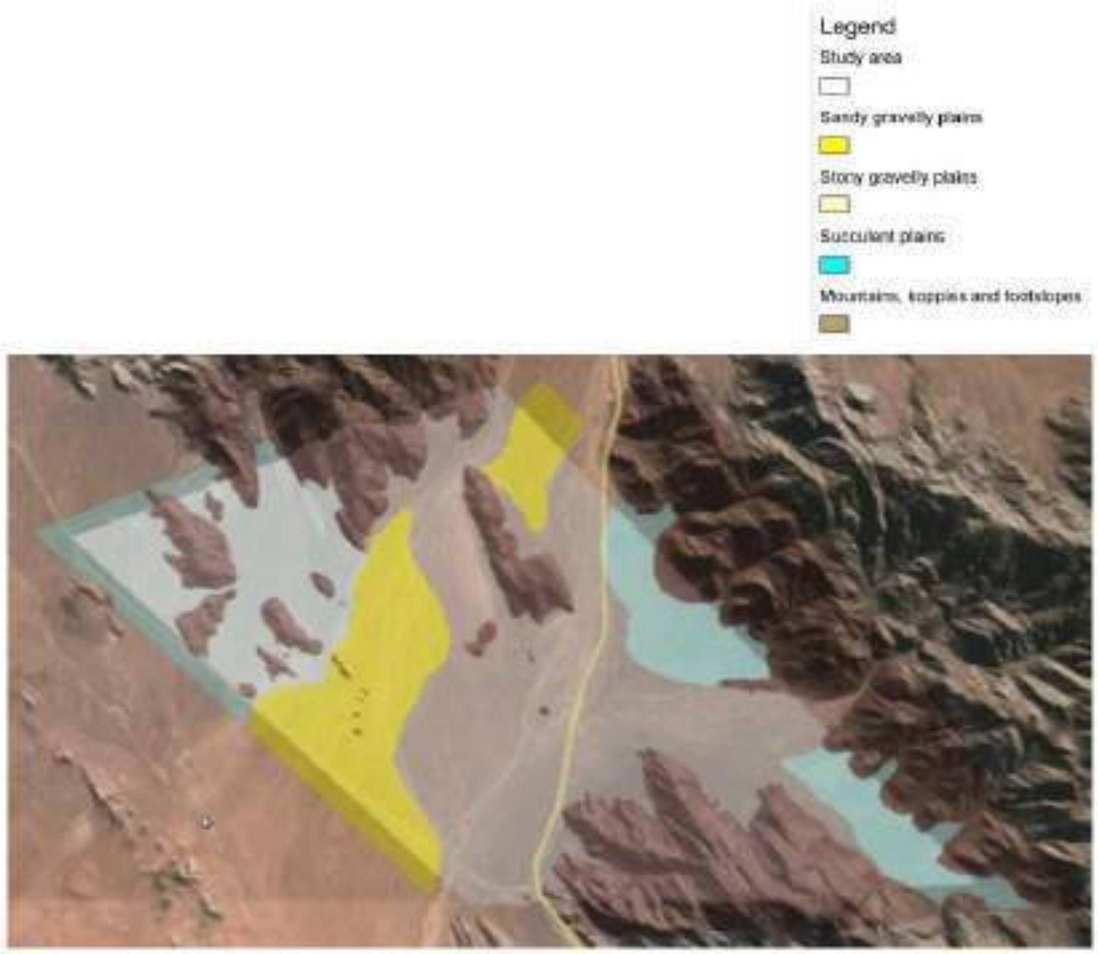


Figure 24 - Four major life zones have been identified in the study area (S. van Zyl et al., 2015)

These life zones have been assessed for overall ecological sensitivity based on expected diversity, occurrence of species of conservation concern, extent of habitat and recovery potential.

Sensitivity of the various habitats was scored using ratings of 1 to 4 for the following aspects:

- Species diversity: (1 = low, 4 = high)
- Occurrence of species of conservation concern: (1 = low, 4 = high)
- Extent of habitat: (4 = less, 1 = more)
- Recovery potential: (4 = low, 1 = high)

The higher the total score is for each life zone, the more sensitive it is (Table 11).

Table 11 - Overall ecological sensitivity

Life zone	Diversity	Presence of species of concern	Extent of life zone	Recovery potential	Total
Sandy-gravelly plains	2	3	1	1	7
Stony-gravelly plains	3	2	2	1	8
Succulent plains	1	1	4	3	9
Mountains, koppies, rocky outcrops and foot slopes	4	4	3	4	15

Thirty-eight faunal taxa of potential concern were identified These include species listed in the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) as well as protected species contained in Schedule 4 of the Nature Conservation Ordinance (No 4 of 1974).

Four species of high conservation concern have been identified. They include:

- The Namaqua Day Gecko – vulnerable because a significant amount of its Namibian range will be affected.
- The Nama Padloper – highly vulnerable species and highlighted by I&Aps.
- The Karoo Korhaan and Ludwig's Bustard - highly susceptible to population decimation through power line collisions causing many fatalities.

5.11.1 FLORA

Mannheimer (2014) identified 10 Red Data plant species as occurring in the study area as well as 54 protected plant species. Within the study area several range-restricted, endemic, near-endemic and protected species occur, including, but not limited to, *Euphorbia melanohydrata*, *Dracophilus dealbatus, Cheiridopsis robusta, Mesembryanthemum pellitum, Hoodia gordonii, Ruschia* spp. *Cephalophyllum ebracteatum, Aridaria noctiflora, Tylecodon reticulate, Jordaaniella cuprea*, and *Pelargonium klinghardtense.*

A detailed and annotated list of the 404 species listed for or observed in the study area during the vegetation assessment is provided in Appendix F showing in which of the four habitats each species is expected, or known, to occur and indicating the known Namibian distribution of species of concern.

5.11.2 FAUNA

The ecological functioning of the affected area is crucial to understand linkages between impacts, and to consider the natural functioning of the area. It also assists in ecological process planning for the site. The footprint of the proposed mining project has increased since the biological and ecological studies were conducted and so greater attention to the drivers and sensitivities will be necessary when re assessing the impacts, mitigations, monitoring and rehabilitation considerations of the project.

Birds as an important part of the fauna of the area and may be affected by habitat destruction. Certain bird species are also prone to power line collisions, something which requires specific attention. The bird species occurring in the area that are at risk in this regard are described in the bird specialist study.

5.12 SOCIO-ECONOMIC BASELINE

This baseline is taken from the socio-economic and human health impact assessments were carried out. According to the 2011 Housing and Population Census, the population of the Karas Region has grown from 29 329 people in 2001 to an estimated 77 421 people in 2011 (National Statistics Agency, 2011). This reflects a growth rate of approximately 1.1 % which is lower than the national average of 1.4 %. An estimated 60 % of the people living in Karas were born there which reflects the large number of migrants from other areas.

Mining is a major economic activity of the Karas Region. Not only has it been key in sustaining towns such as Oranjemund and Rosh Pinah, but remittances have been generated and distributed to other parts of Namibia, and a significant contribution has been made to the national economy through the payment of royalties and taxes. Other economic activities include inputs from fishing, livestock farming, tourism, the port of Lüderitz and services to a lesser extent.

The economy of Rosh Pinah greatly revolves around the two mines. The mines are the main employers in the town and the shops serve either its employees or meet the needs of the mines itself. Not only do these mines stimulate the economic activities of Rosh Pinah, but they also contribute significantly to the economy of the country.

The unemployment rate is very low since the greater majority of the formal town residents are employed at either of the two mines. This is higher in the informal settlement area, and it is estimated that 40% of the Tutungeni residents (Saayman, Bosman, et al., 2015).Those living in Tutungeni are not directly employed at the mines, but some work as domestic workers or at businesses in town. The relatives of mine workers, especially shift workers, often reside in Tutungeni. Considering the arid natural environment, the people cannot rely on natural resources for sustaining their livelihoods.

Currently, the future of the town is uncertain as the Skorpion Zinc Mine is on care and maintenance and the Rosh Pinah Mine, although with encouraging results on expansion, is being purchased by another entity. This will adversely affect the continued existence of the town which is directly reliant on the operations of the mines. The development of the Gergarub mine will thus have a significant impact on the town's sustainability. It could mean that Rosh Pinah residents laid off at the closed mines are re-employed at the new mine (Saayman, Bosman, et al., 2015).

Rosh Pinah currently has one private clinic in town, a State Clinic in the neighbourhood Bethel and a Satellite State Clinic in Tutungeni. The latter acts as a distribution point for tuberculosis treatment known as DOTS. The private clinic, Sidadi, provides both primary and occupational health services. The majority of the employees from the two mines make use of its services, whereas the Tutungeni community mainly visit the State Clinic in Bethel (Saayman, Bosman, et al., 2015).

In 2012, SZM in partnership with the Namibian Government upgraded the facilities of the State Clinic. This clinic oversees an estimated 1 700 patients daily resulting in pressure on available staff, services and infrastructure.

With regards to HIV/AIDS, Sidadi currently has on record 169 positive cases, whereas there are currently more than 500 people on anti-retroviral treatment at the State Clinic. The TB cases are much lower with only 3 to 4 positive cases at Sidadi per year and 12 at the State Clinic. Respiratory diseases including asthma are not common.

The private clinic in Rosh Pinah has 2 fulltime doctors, a fulltime dentist, a physiotherapist and five senior sisters (3 emergency and 2 occupational). There are paramedics at Skorpion Zinc and employees at the mines who have been trained in first aid. In addition, specialists in different fields (such as gynaecologists and ear, nose and throat specialists) visit the clinic on a 3-monthly basis (Saayman, Bosman, et al., 2015)

The public clinic at Tutungeni is understaffed. There is no full-time doctor and only one registered nurse and two enrolled nurses. However, the district is sponsoring one of the nurses. At times there are also student nurses who performing their community service. Serious cases are referred to Lüderitz (Saayman, Bosman, et al., 2015)

5.12.1 DEMOGRAPHIC PROFILE

Rosh Pinah has an estimated population of 7 000 people (Saayman, pers. comm (2013). Approximately half of this population resides in the formal township area, whereas the other half lives in the informal settlement area known as Tutungeni.

The organisation responsible for managing the town and the provision of services is RoshSkor. It is a Joint Venture between RPZC and SZM and maintains the infrastructure while providing water, electricity, sewerage systems and waste removal services. Water, electricity, the road infrastructure in town and especially the sewerage system has reached its full capacity and can only sufficiently deal with the existing load (Saayman, Bosman, et al., 2015).

The formal town only expands when either of the two mines develop and appoint additional employees. With the presence of the two mines, the town is subject to an influx of job seekers. People often come to Rosh Pinah in search of a job but other than at the mines there are limited employment opportunities. Due to the aridity of the natural environment, it cannot sustain livelihoods and unsuccessful job seekers are forced to relocate eventually. The population size of the informal settlement (named Tutungeni) is thus dynamic, growing and decreasing again over time. This settlement is regulated by RoshSkor, and new residents should apply there for land occupation and access to services. Backyard squatting in Tutungeni is also limited.

Based on the fact that the town of Rosh Pinah has not expanded in the last decade and considering the average household size of four people, it is evident that there is no overcrowding. It is known that overcrowding supports the distribution of infectious diseases. It is possible however, that informal houses in certain areas may be overcrowded, although backyard squatting is illegal in Tutungeni (Saayman, Bosman, et al., 2015). The dependency ratio in the Karas Region is relatively high at 65 % (Central Bureau of Statistics, 2010). Dependency ratio is calculated as the number of people below 14 and above 65 years of age (those economically not active) as a percentage of the total population between 15 and 64 years of age.

5.12.2 GOVERNANCE

RPZC and Skorpion Zinc assists with the funding for projects that aim to deliver economic independence for the community. Programs include training in basic needlework; hand weaving of carpets; development initiatives in Tutungeni (a township outside of the central Rosh Pinah town), which involves the upgrade of a school, training of community members for the removal of waste and waste segregation; sanitation system maintenance; and other initiatives.

Should any of the mines cease operations and / or retract funding in the town for community development projects, there may be a risk that the inhabitants of the Rosh Pinah town will require greater funding assistance from the operating mine. All obligations are voluntary and Memorandums of Understanding (MoU) between Skorpion and RPZC allow for gradual transitions, rather than abrupt departures from existing obligations for community funding. MoU's exist to jointly fund and manage the healthcare clinic, ambulance service and two schools.

Risk to the Rosh Pinah operations because of labour actions is low. A three-year labour agreement expiring on 11 March 2024 is in place in respect of all employees within the bargaining unit and this, together with the development and implementation of stakeholder management plans, will assist RPZC to manage this aspect of the operation.

The Rosh Pinah town is not proclaimed so the Namibian Government has no responsibilities for the town nor its inhabitants. There are political pressures to get the town proclaimed and it has been agreed that proclamation will occur among the stakeholders, including the Kharas Regional Council. If proclamation occurs, then RoshSkor would likely be dissolved, and the Namibian Government would assume the costs of managing the town. While this may pose some risks to ongoing service delivery, this transition would also reduce the level of cost currently incurred by RPZC in funding the management of the Rosh Pinah town (e.g., for waste collection, water, and electricity provision).

RoshSkor, the organization that manages the town, has a Board with five members (two from RPZC, two from Skorpion Zinc, and one from RoshSkor) who meet monthly and are charged with responsibility to protect the interests and quality of the town's services:

- Water is provided by NamWater and sourced from the Orange River. Groundwater is not used.
- Power supply is provided by NamPower, who purchase the electricity from Eskom in South Africa. While Eskom is facing challenges, RPZC believe that the revenue received from Namibia provides sufficient incentive for South Africa to continue making electricity available.
- Waste management:
    - Household waste is collected by contractors directly from households and disposed in landfill site; the site was on the mine but has moved to a fenced site – the current disposal cells are near-capacity, so expansion is taking place (an impact assessment has been completed and the site is licensed so this is within the permitted area). There is space in the designated area to continue operating the landfill should the LoM be extended.
    - Hazardous wastes (e.g., used oils and grease are returned to suppliers; medical waste goes to an incinerator in Lüderitz).
    - Skips are provided for large items which eliminates illegal dumping.
- Facilities include a clinic ("one stop shop" staffed by two doctors, paramedic, with an equipped pharmacy / pharmacist; specialists such as orthopedic surgeon, audiologists, and ear-nose- throat surgeons attend from time to time); an ambulance is available to transfer patients to hospital in Lüderitz, if required. It should be noted this clinic is not a viable business on its own and is financially supported by RPZC (N$300 000) and Skorpion Zinc (N$300 000) on a monthly basis.

- Two supermarkets stock food and household goods.
- Four (two Government and two Private) schools provide quality education.

5.12.3 CULTURAL HERITAGE

A heritage assessment conducted in 2015 and a verification update conducted in 2023 by Dr John Kinahan determined that the Gergarub deposit is located within an area of high archaeological sensitivity. Eighteen sites have been identified within the project area (Figure 25) ranging from minor isolated finds to multi-component sites with low threat to direct and certain threats (Kinahan, 2023). There is a high probability of direct or collateral impact on three archaeological sites at Gergarub and a relatively low or medium probability of such impacts on the remaining 15 sites. Of the 3 direct impact sites, there was one burial site (QRS 177/18) that as shown in Figure 26. The burial site was excavated after a permit was issued by the National Heritage Council. The remains recovered from the site are housed in the National Museum of Namibia Archaeology Collection under accession number B4367. The details of the burial sites are as follows:

QRS 177/18
Site coordinates: S 27.86853 E 16.69966
Setting: Foot-slope, outwash fan, coarse gravel
Description: Confirmed burial cairn, 2.1 m Ø circular, with partially intact kerbing and associated with well-worn upper grindstone.
Records: Site record, sketch plan and photographs
Significance rating: 3 – archaeological site
Vulnerability rating: 5 – direct and certain threat

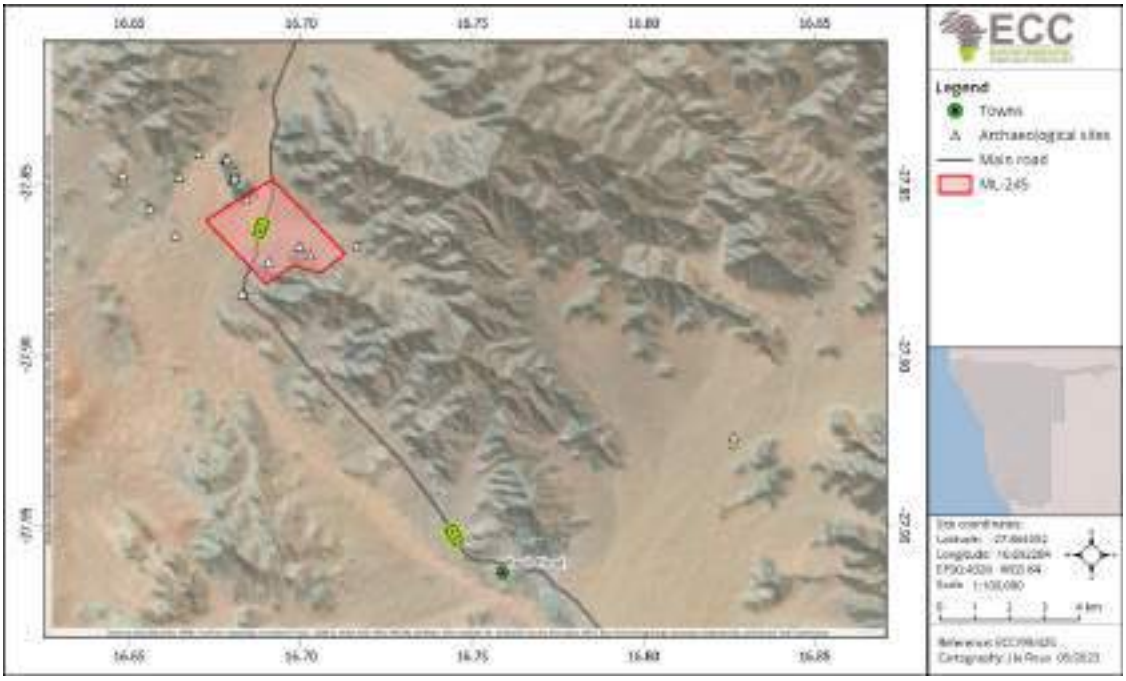


Figure 25 - Location of identified archaeological sites on ML 245

Figure 26 - Physical setting of the archaeological (burial) site QRS 177/18 at Gergarub

5.12.4 NOISE

Noise is defined as unwanted sound transmitted through a compressible medium such as air. Sound, in turn, is defined as any pressure variation that the ear can detect. Human response to noise is complex and highly variable, as it is subjective rather than objective (von Gruenewaldt, 2023). The IFC General Environmental Health and Safety Guidelines on noise address impacts of noise beyond the property boundary of the facility under consideration and provides noise level guidelines.

The IFC states that noise impacts should not exceed levels or result in a maximum increase above background levels of 3 dBA (or the noise level guidelines presented in Table 12) at the nearest receptor location off-site (IFC, 2007). For a person with average hearing acuity, an increase of less than 3 dBA in the general ambient noise level is not detectable. 3 dBA is, therefore, a useful significance indicator for a noise impact.

Table 12 - IFC noise level guidelines

Area	One Hour L_{Aeq} (Dba) 07:00 to 22:00	One Hour L_{Aeq} (Dba) 22:00 to 07:00
Industrial receptors	70	70
Residential, institutional, and educational receptors	55	45

A noise baseline survey was conducted on 2nd and 3rd October 2023 to determine the current noise levels at designated points within the Project's jurisdictions as shown in Figure 27 below. Airshed Planning Professional (Pty) Ltd, a firm that specialise in all aspects of air quality and noise impacts, ranging from nearby neighbourhood concerns to regional impact assessment was commissioned to undertake, model and conduct an assessment process for the Project. The baseline report can be viewed in Appendix I.

Airshed identified six sites that were monitored for day and night-time noise level measurements. The sites were selected after careful consideration of the location of noise sensitive receptors (NSRs), future mining activities as potential noise sources and the IFC guidelines. Generally, noise sensitive receptors include places of residence, community buildings such as schools, hospitals and publicly accessible areas where members of the public may be affected by noise generated by mining, processing and transport activities. Potential noise sensitive receptors identified by Airshed within the project area include industrial sites within the closest residential area (Rosh Pinah) – approximately 12km southeast of the Project (Figure 27). Seven identified noise sensitive receptors are briefly described in Table 13 below.

Table 13 - Description of noise sensitive receptors within the project area

Receptor	Description	Industrial/Residential
1	Building structure	Appear to be industrial
2	Building structure	Appear to be industrial
3	Building structure	Appear to be industrial
4	Old storage facility for scrap metals	Industrial
5	Old storage facility for scrap metals	Industrial
6	Road Authority building (where trucks for inspection)	Industrial
7	Skorpion Zinc Mine gate	Industrial

The ability of the environment to attenuate noise as it travels through the air was studied by considering land use and terrain. The map in Figure 27 shows the sensitive receptors near and/at the proposed Project site.

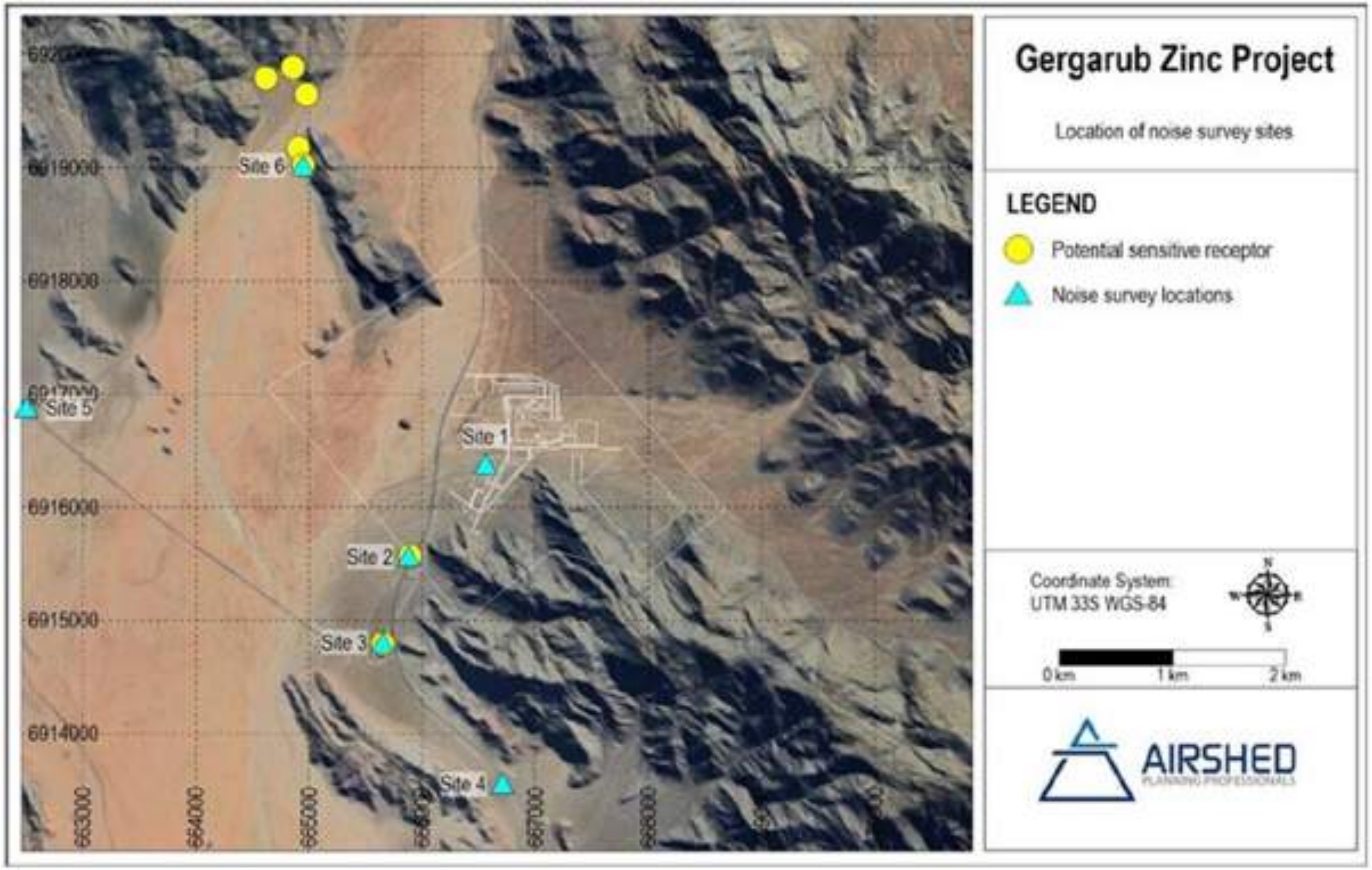


Figure 27 - Field survey sampling sites and noise sensitive receptors

Noise from mobile and non-mobile equipment were estimated using Lw predictions for industrial machinery, where Lw estimates are a function of the power rating of the equipment engine. Crushing and milling noise sources Lw's for the project was obtained from a database for similar operations. Values from the database are based on source measurements carried out in accordance with the procedures specified in SANS 10103. The source inventory, local meteorological conditions and information on local land use were used to populate the noise propagation model (CadnaA, ISO 9613).

The noise sources of the proposed Project are typical of mining operations and include the following:

- Ore and waste handling (loading, unloading) on waste dumps and crusher/plant area;
- Haul truck traffic;
- Diesel mobile equipment use (including reverse warnings); and
- Ore processing activities such as crushing, screening and milling.

5.12.4.1 Atmospheric absorption and meteorology

The main meteorological parameters affecting the propagation of noise include wind speed, wind direction and temperature. These along with other parameters such as relative humidity, air pressure, solar radiation and cloud cover affect the stability of the atmosphere and the ability of the atmosphere to absorb sound energy.

Temperature gradients in the atmosphere create effects that are uniform in all directions from a source. On a sunny day with no wind, temperature decreases with altitude and creates a 'shadowing' effect for sounds. On a clear night, temperatures may increase with altitude, thereby 'focusing' sound on the ground surface. Noise impacts are therefore generally more notable during the night. von Gruenewaldt (2023) further determined that at wind speed of more than 5 m/s, ambient noise levels are mostly dominated by wind generated noise.

There is no meteorological weather station on site, therefore, weather data for the general Rosh Pinah area was retrieved on the public access Meteoblue website for the period of January 2018 to October 2023. The data indicate that the site has an average temperature of 20 °C and relative humidity of 54%. These figures were used in the attenuation modelling.

5.12.4.2 Terrain, ground absorption and reflection

Noise reduction caused by a barrier (i.e. natural terrain, installed acoustic barrier, building) feature depends on two factors namely: the path difference of a sound wave as it travels over the barrier compared with direct transmission to the receiver and the frequency content of the noise (von Gruenewaldt, 2023). Readily available terrain data was obtained from the USGS web site (https://earthexplorer.usgs.gov/) accessed in October 2023. A study was made of STRM 1 arc-sec data.

Sound reflected by the ground interferes with the directly propagated sound. The effect of the ground is different for acoustically hard (e.g., concrete or water), soft (e.g., grass, trees, or vegetation) and mixed surfaces. Ground attenuation is often calculated in frequency bands to consider the frequency content of the noise source and the type of ground between the source and the receiver (von Gruenewaldt, 2023). Based on observations, ground cover was found to be acoustically mixed.

5.12.4.3 Noise survey results

The main findings from the 2023 noise baseline study were as follows:

- The baseline noise levels (LA_{eq}) for the surrounding area range between 36 dBA to 59 dBA for day time and 25 dBA to 56 dBA for night-time, as shown in Figure 28 and Figure 29;
- The baseline noise survey results are within the 70 dBA day and night-time standard IFC threshold bands for industrial receptors; and
- Sensitive noise receptor identified during the field study include industrial sites and residential areas (i.e. Skorpion zinc mine, Road Authority, and the residents of Rosh Pinah).

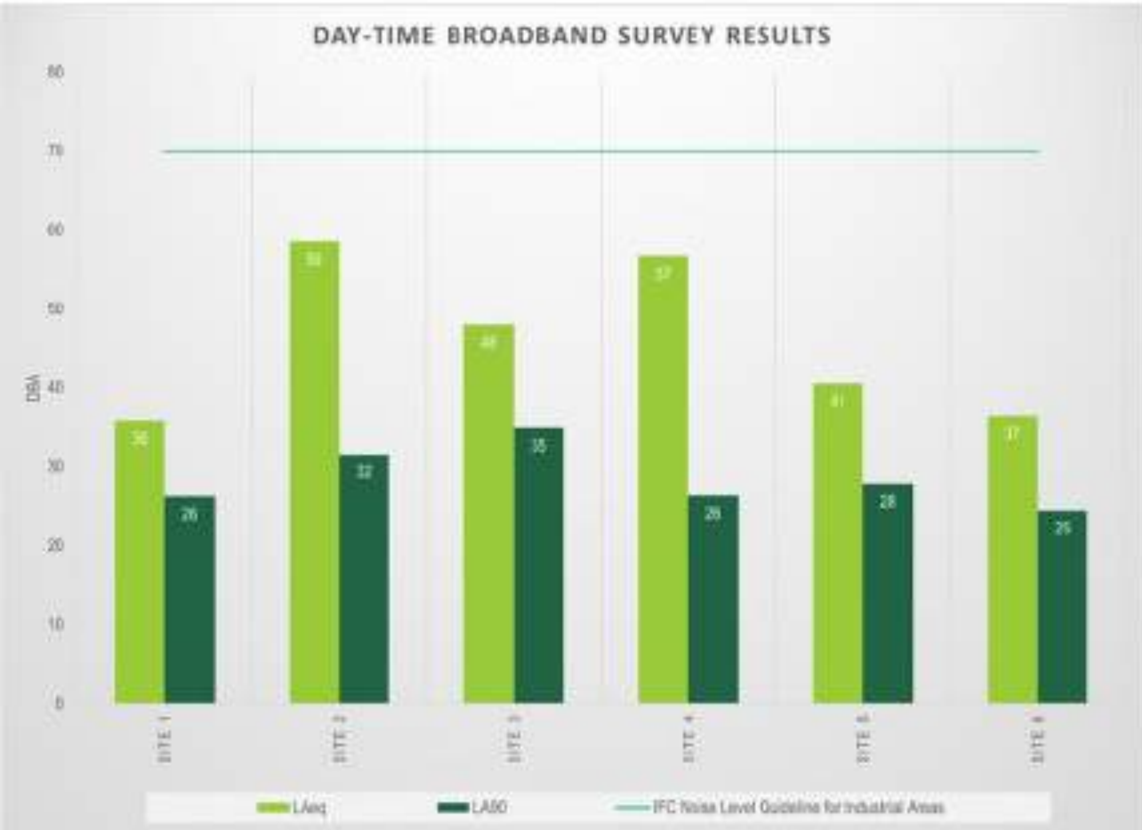


Figure 28 - A graph showing daytime broadband survey results (von Gruenewaldt, 2023)

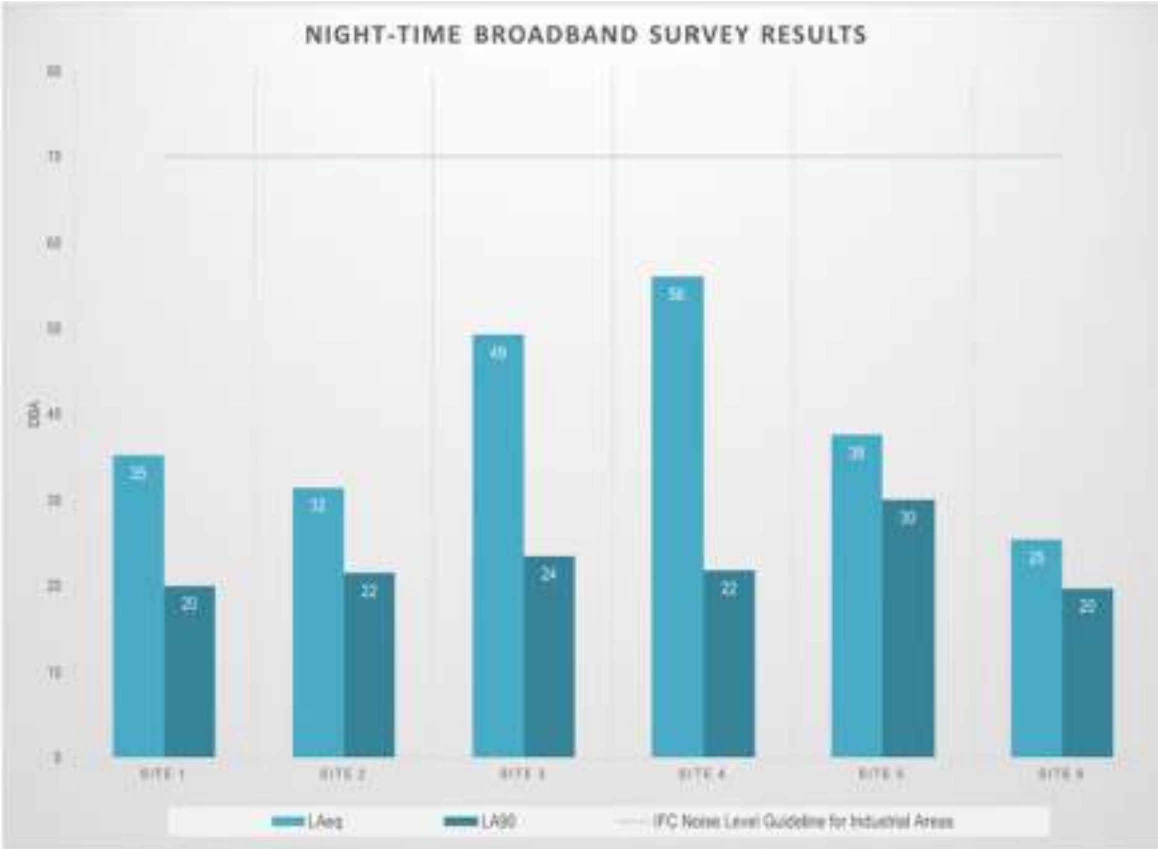


Figure 29 - A graph showing the night-time broadband survey results (von Gruenewaldt, 2023)

The noise field study report provides the base foundation of comparison for the environmental noise impact assessment to be conducted for the Project. Overall, the specialist study has drawn attention to the following aspects and have been included in the environmental noise impact assessment study:

- Investigation and compilation of baseline noise sources and sensitive receptors in the Project area;
- The propagation of noise to be generated during the operational phase of the Project;
- Evaluation of potential noise impact on human receptors due to Project activities; and
- Recommendation of good management practices for implementation during operation to lessen noise impacts.

5.13 Built Environment Baseline

5.13.1 Traffic and Transport

Innovative Transport Solutions (Pty) Ltd conducted a Transport Impact Assessment (TIA) in September 2023 for the Gergarub project. The site vacant site will be accessed using the C13 road.

5.13.1.1 Scenarios analysed

The following scenarios were analysed:

1. **Existing Traffic conditions**

Existing traffic volumes are based on the calculated 30th highest peak hour volumes. It was reported that there are approximately 52 vehicles total in both directions which is fairly low volumes (Figure 30). According to the capacity analysis intersections are currently operating at an acceptable Level-Of-Service LOS A with enough spare capacity (Innovative Transport Solutions (Pty) Ltd, 2024) No upgrades are required as per the specialist study.

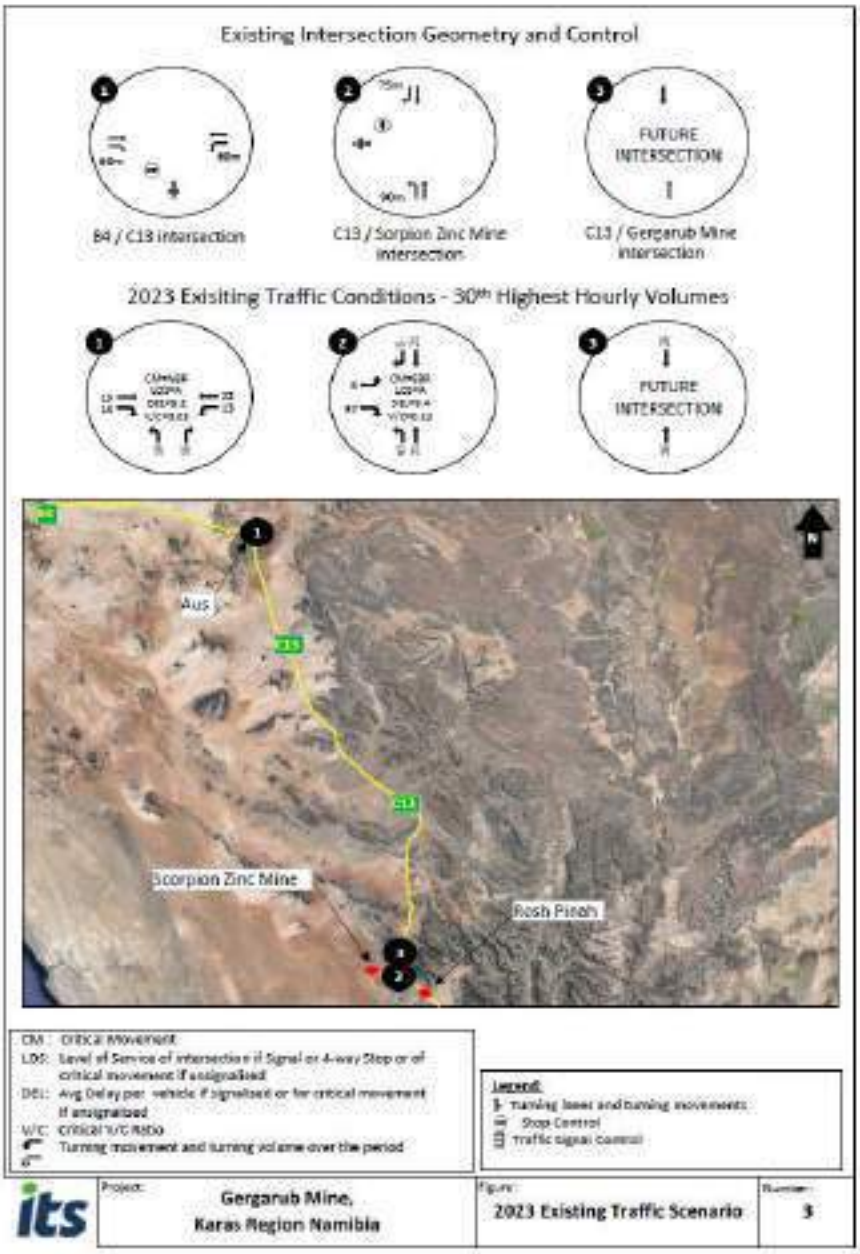


Figure 30 - Scenario- existing traffic conditions (Innovative Transport Solutions (Pty) Ltd, 2024)

2. **2028 Background Traffic conditions**

   The 2028 Background traffic volumes were calculated by escalating the existing traffic flow by 4.5% growth per year over a 5-year period (Figure 31). According to the capacity analysis intersections are expected to continue to operate acceptably (LOS A) with sufficient spare capacity. No upgrades are required as per the specialist study.

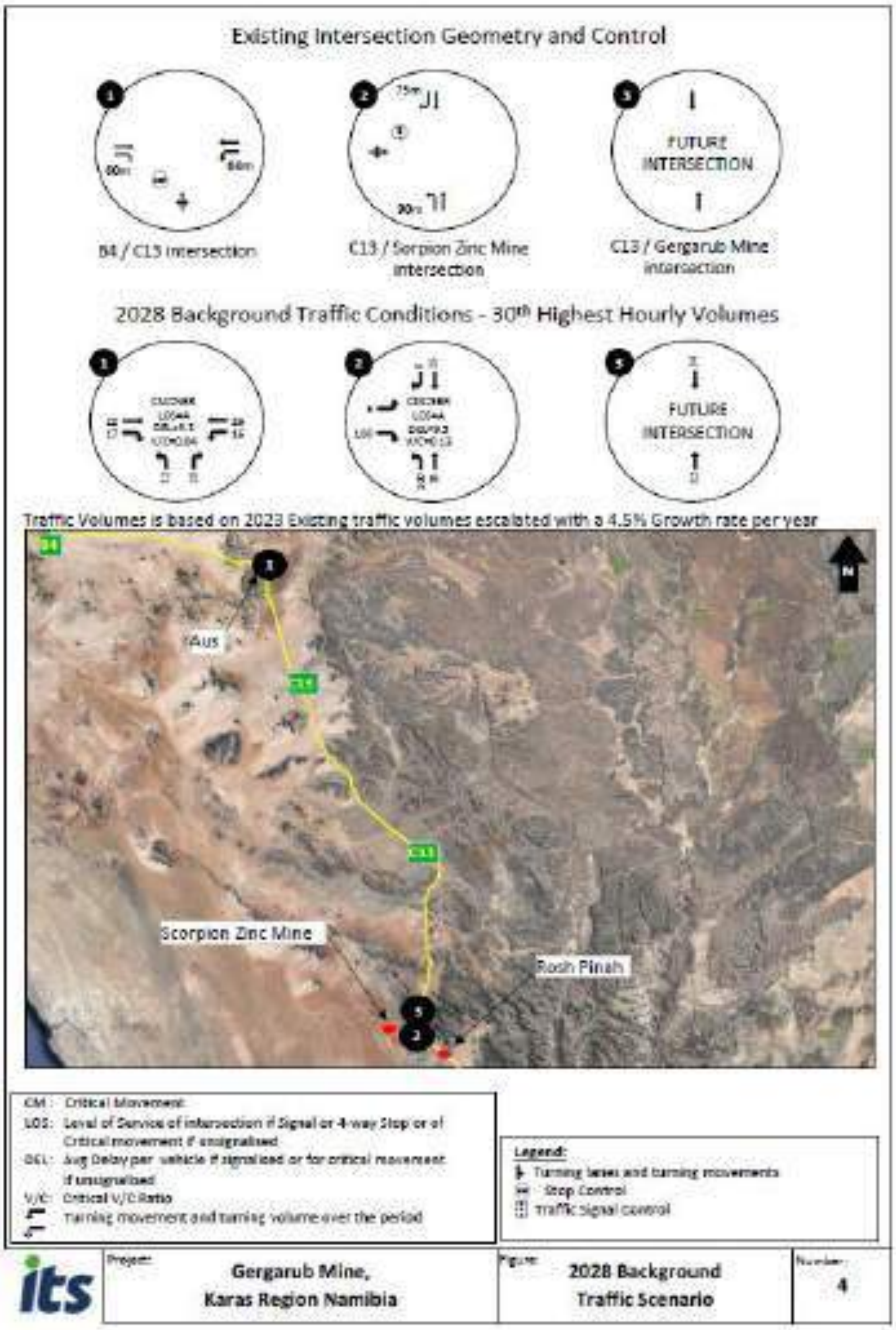


Figure 31 - Scenario 2: Background traffic conditions (Innovative Transport Solutions (Pty) Ltd, 2024)

3. **2028 Total traffic conditions**

The 2028 Total traffic volumes were calculated by adding the foreseen Gergarub Mine development trips onto the 2028 Background Traffic volumes (Figure 32). According to the capacity analysis all study intersections are expected to continue to operate acceptably (LOS A) with sufficient spare capacity. No upgrades are required as per the specialist study.

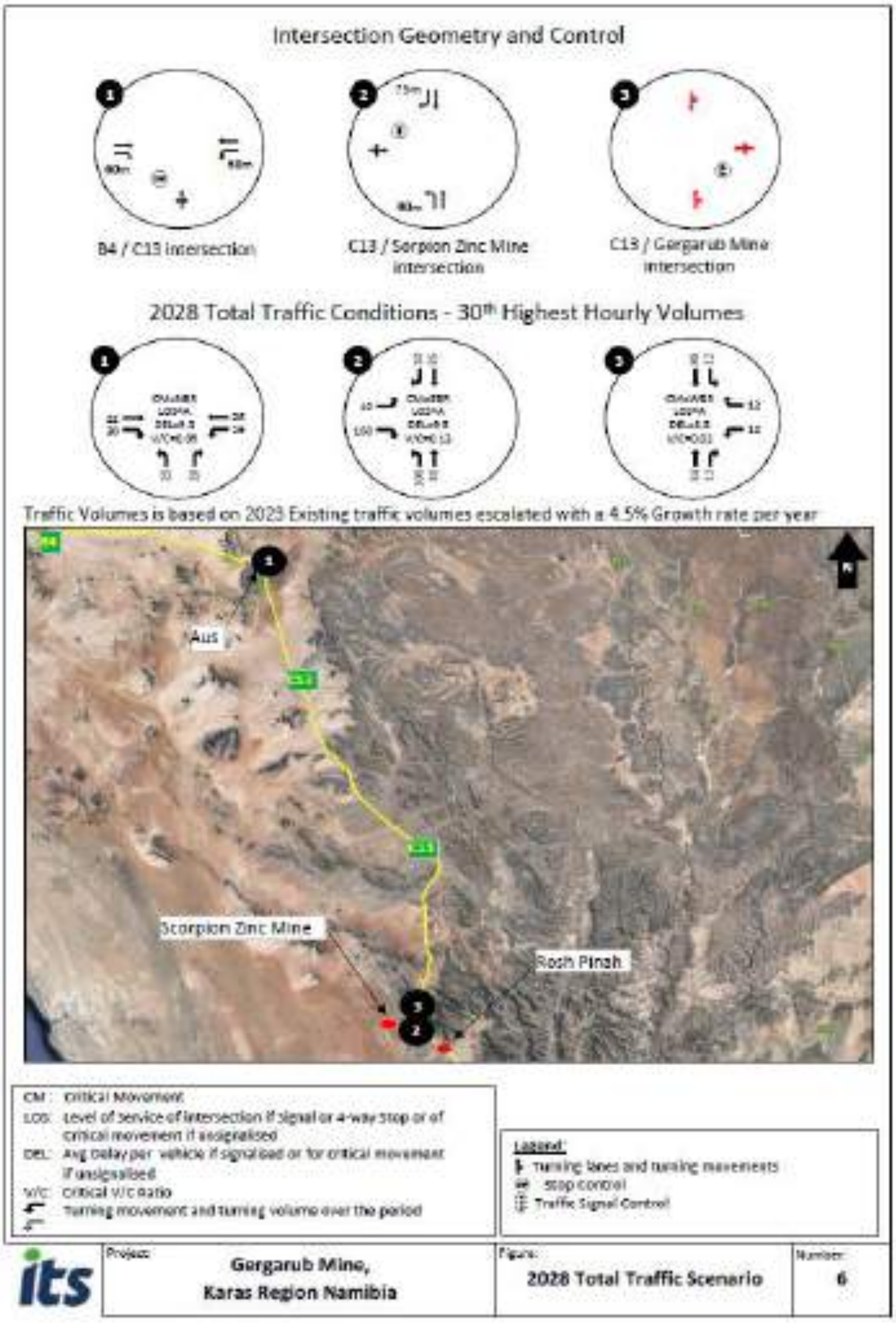


Figure 32 - Scenario 3: 2028 Total traffic conditions (Innovative Transport Solutions (Pty) Ltd, 2024)

4. **2038 Total traffic conditions**

   The 2038 Total Traffic volumes were calculated by increasing the 2028 Background Traffic conditions with a 3% growth rate per year over 10 years with the addition of the Gergarub Mine development trips to the network (Figure 33). The purpose of the test is to predict the sensitivity and safety of the road network. No upgrades are required however, the study recommends that separated turning lanes be constructed at the mine access from a safety point of view.

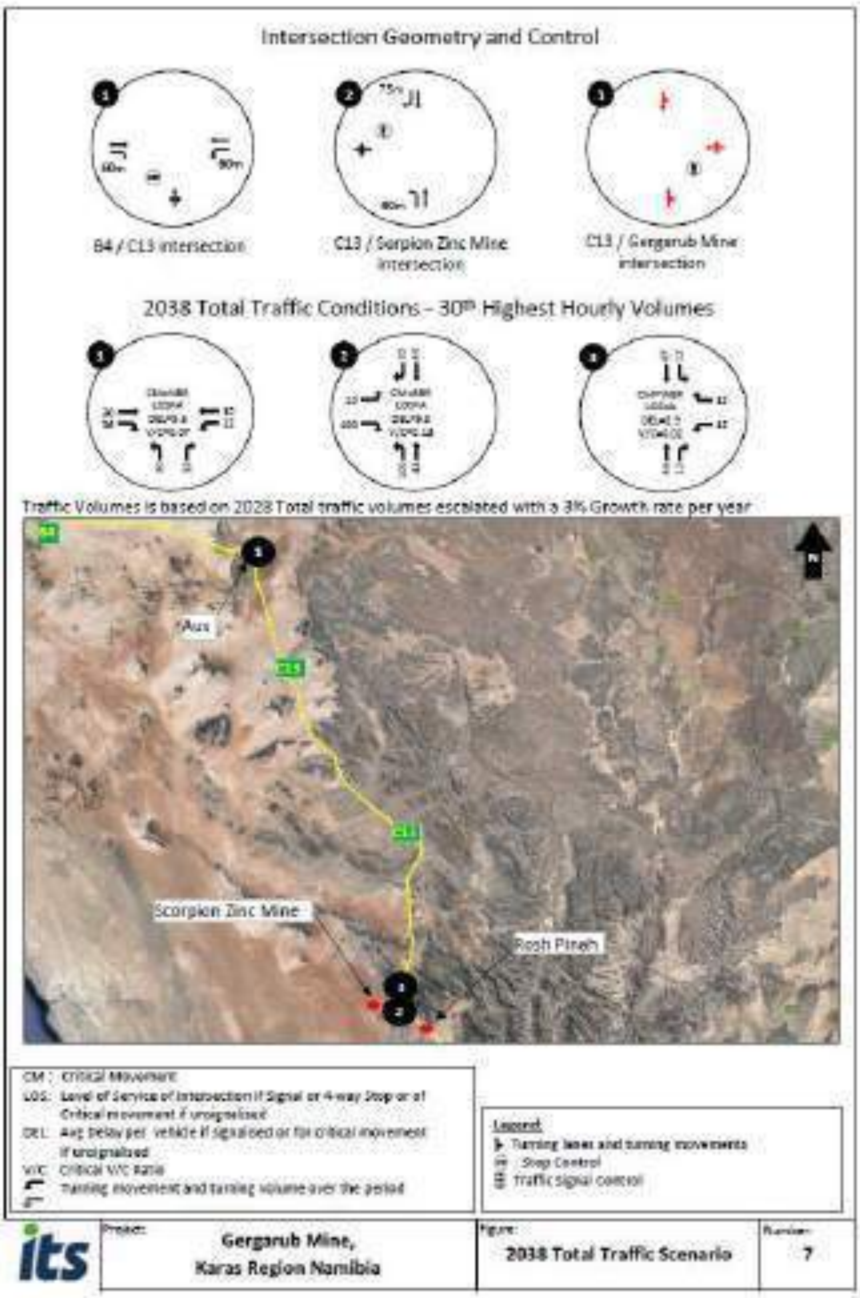


Figure 33 - Scenario 4: 2038 total traffic conditions (Innovative Transport Solutions (Pty) Ltd, 2024)

5.13.1.2 Existing access

There is no existing access from the C13 Road to the proposed mine site, however a vehicular access is planned from the C13 Road, roughly 2.5 km north of the Scorpion Zinc mine access. Although no upgrades are needed as suggested in the previous section, from a precautionary standpoint, it is recommended to construct a separate northbound right-turn lane (30m storage) plus a separated southbound left turn lane (30m storage) at the mine access. Additionally, the speed limit should be reduced along the 80 km/h along the C13 Road toward the Gergarub Mine intersection.
It is recommended that the Shoulder Sight Distance (SSD) for the proposed 80 km/h should be as follows:

- Passenger car – 155 m
- Single unit – 245 m
- Single unit & Trailer – 300 m

The SSD at the mine access is currently evaluated at more than 455 m SSD in both directions on the C13 Road, which is sufficient.

5.13.1.3 Surrounding Roads

Both C13 and B4 Road are surfaced, in good condition and well maintained with signs on road as to be expected as shown in Figure 34.

(a) (b)

Figure 34 - The westbound view along the B4 from the C13/B4 intersection shown at (a); Eastbound view along the B4 from C13/B4 intersection shown at (b) (Innovative Transport Solutions (Pty) Ltd, 2024)

5.13.1.4 Public transport

Majority of the trips to and from the proposed project site will be via public transportation. It is recommended that the appropriate infrastructure be provided for buses on site.

5.13.2 VISUAL

The following visual receptors were identified:

- Tourist activities in the valley that is located on the farm Spitzkop 111.
- Users of the C13, due to the fact that it has become a tourist route.
- Users of the road to the SZM.

The following visual landscapes exist in the study area:

- The valley east of the C13 with the mountain range north-east to south-east of the valley.
- The valley west of the C13 with the mountain ranges west and north of the valley.

Both visual environments are locally esteemed for their above-average visual appeal. They each showcase distinctive panoramas, combining expansive, flat valley views with striking and contrasting mountain scenery. The absence of prominent vegetation in both the valleys and mountains accentuates this stark visual difference. The ongoing project activities might become noticeable and attract attention. It is crucial that structures, operations, and user activities remain subservient to the pre-existing visual attributes. Conformity to the existing resource's characteristics is essential in terms of form, line, colour, texture, scale, and composition (N. van Zyl & Kuliwoye, 2014).

There are minimal contributing factors affecting the focus on the visual landscape. Currently, there is limited pollution evident, and the study area lacks historical landmarks. While wildlife is not a predominant feature, it is observable in the study area (N. van Zyl & Kuliwoye, 2014).

The major industrial and human detractions to the value of the two landscapes are:

- the C13 road and the road to SZM
- the various 400 kV, 66 kV and 33 kV transmission lines that traverse the visual landscape to the west of the C13 road.

The presence of the farm infrastructure such as fencing, and tracks are considered as visual vernacular in this case and not detracting from the quality of the views.

6 IMPACT IDENTIFICATION AND EVALUATION METHODOLOGY

6.1 INTRODUCTION

Chapter 2 provides an overview of the approach used in this ESIA process, and details each of the steps undertaken to date. Prediction and evaluation of impacts is a key step in the ESIA process. This chapter outlines the methods that will be followed, in order to identify and evaluate the impacts arising from the proposed Project. The findings of the assessment will be presented in the full assessment report.

This chapter provides comprehensive details of the following:

- The assessment guidance that will be used to assess impacts.
- The limitations, uncertainties, and assumptions with regards to the assessment methodology.
- How impacts will be identified and evaluated, and how the level of significance will be derived.
- How mitigation will be applied in the assessment, and how additional mitigation will be identified.
- The cumulative impact assessment (CIA) method that will be used.

The aims of this assessment will be to determine which impacts are likely to be significant; to scope the available data and identify any gaps that need to be filled; to determine the spatial and temporal scope; and to identify the assessment methodology.

The scope of the assessment was determined by undertaking a preliminary assessment of the proposed Project against the receiving environment and was obtained through a desktop review, available site-specific literature, monitoring data, and site reports, as set out in this scoping report.

6.2 ASSESSMENT GUIDANCE

The following principal documents will be used to inform the assessment method:

- International Finance Corporation standards and models, in particular performance standard 1: 'Assessment and management of environmental and social risks and impacts' (International Finance Corporation, 2012).
- International Finance Corporation Cumulative Impact Assessment (CIA) and Management Good Practice Handbook (International Finance Corporation, 2013).
- Namibian Draft Procedures and Guidance for EIA and EMP (Republic of Namibia, 2008).

6.3 Limitations, uncertainties and assumptions

The following limitations and uncertainties associated with the assessment methodology will be considered in the assessment phase:

- Topic-specific assessment guidance has not been developed in Namibia. A generic assessment methodology will be applied to all topics using IFC guidance and professional judgement.
- Guidance for CIA has not been developed in Namibia, but a single accepted state of global practice has been established. The IFC's guidance document (International Finance Corporation, 2013) will be used for the CIA.

6.4 Assessment methodology

The ESIA methodology applied to this assessment has been developed by ECC using the International Finance Corporation (IFC) standards and models, in particular performance standard 1: 'Assessment and management of environmental and social risks and impacts' (International Finance Corporation, 2017); Namibian Draft Procedures and Guidance for EIA and EMP (Republic of Namibia, 2008); international and national best practice; and over 25 years of combined ESIA experience. The methodology is set out in Figure 35 and Figure 36.

The evaluation and identification of the environmental and social impacts require the assessment of the Project characteristics against the baseline characteristics, ensuring that all potentially significant impacts are identified and assessed.

The significance of an impact is determined by taking into consideration the combination of the sensitivity and importance/value of environmental and social receptors that may be affected by the proposed Project, the nature and characteristics of the impact, and the magnitude of any potential change. The magnitude of change (the impact) is the identifiable changes to the existing environment that may be negligible, low, minor, moderate, high, or very high; temporary/short-term, long-term, or permanent; and either beneficial or adverse.

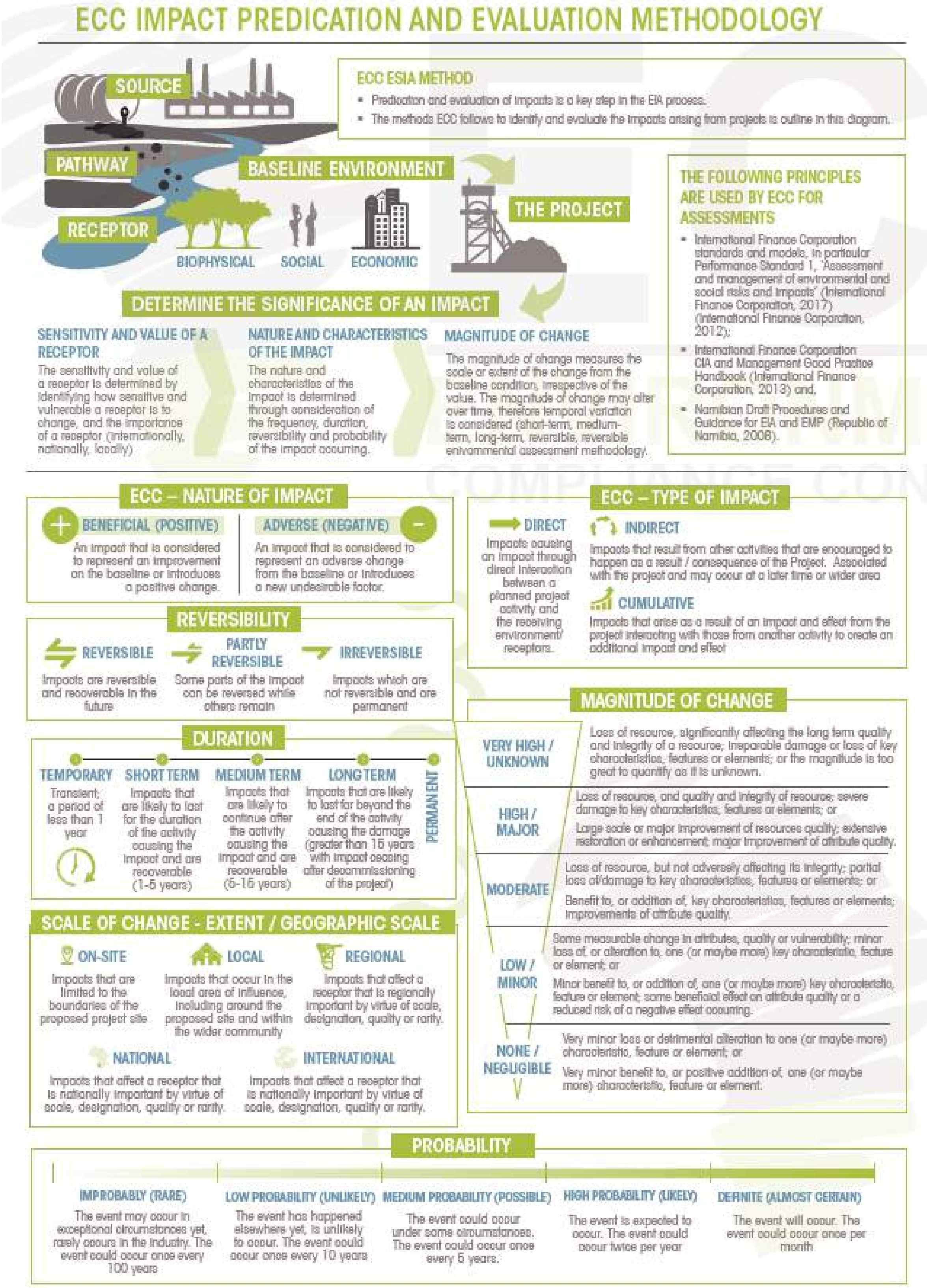


Figure 35 - ECC ESIA methodology based on IFC standards

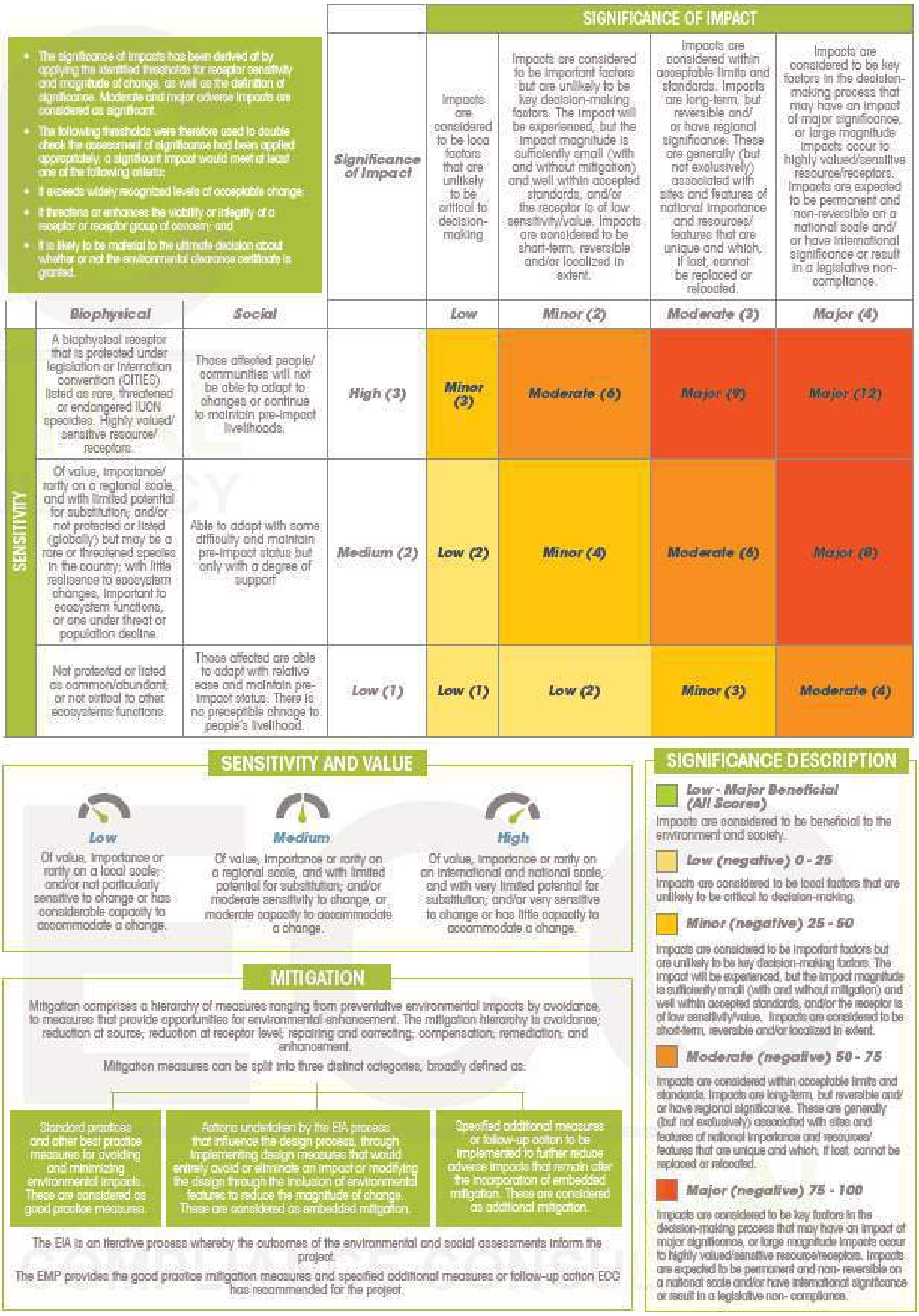


Figure 36 - ECC ESIA methodology based on IFC standards

6.5 CUMULATIVE IMPACTS

Cumulative impacts may arise as a result of other Project activities, or due to the combination of two or more projects in the Project area. A cumulative impact assessment (CIA) will be undertaken by applying the IFC CIA Good Practice Handbook (International Finance Corporation, 2013), which recommends that a rapid CIA is undertaken.

A rapid CIA takes into consideration the challenges associated with a good CIA process, which include a lack of basic baseline data, uncertainty associated with anticipated development, limited government capacity, and the absence of strategic regional, sectoral, or integrated resource planning schemes.

The following five-step rapid CIA process will be followed:
Step 1: Scoping – Determine spatial and temporal boundaries.
Step 2: Scoping – Identify valued environmental and social receptors and identify reasonably foreseeable developments.
Step 3: Determine the present condition of valued environmental and social receptors (The baseline).
Step 4: Evaluate the significance of the cumulative impacts.
Step 5: Identify mitigation measures to avoid or reduce cumulative impacts.

The following information will be applied to the assessment in line with the above steps and IFC guidance:

- The spatial and temporal boundaries of the CIA are the extent of the ML boundaries and the duration of the construction and operation phases of the proposed Project.
- Valued environmental and social receptors that may be affected.
- A review of existing and reasonable, anticipated and/or planned developments has been undertaken, which is based on the information presented in chapter 4.
- The predicted future conditions of sensitive and common environmental and social receptors have been taken into consideration in the assessment.
- The assessment findings will be presented in the assessment report and will have the CIA applied in combination with professional judgment and published environmental assessment reports.
- A review of mitigation and monitoring measures will be undertaken, with any additional ones identified.

7 IMPACT ASSESSMENT FINDINGS & MITIGATION

This impact assessment was completed taking into consideration the input received from stakeholders during the public participation phase. Specialist studies that had previously been conducted were reviewed and reassessed based on the input from the public participation phase. As part of the draft impact assessment, a draft environmental and social management plan (ESMP) was produced to manage residual impacts that cannot be mitigated through the project evolution process.

This chapter presents the findings of the ESIA for the proposed project as per the ESIA process, scope and methodology set out in Chapters 2 and 6. The aim of this ESIA report is to focus on the significant impacts that may arise because of the proposed project. This chapter therefore only considers the significant impacts and or those that may have specific interest to the community and stakeholders. A summary of impacts that are not considered significant is discussed in 7.1.

The list of high level and likely impacts that are considered significant or of interest to the community and stakeholders are as follows:

- Socio-economic: employment and employee occupational health and safety
- Socio-economic: traffic
- Socio-economic: heritage
- Environment: surface and ground water quality and quantity
- Environment: soil, air quality, and noise impacts.

For each potential significant or sensitive impact, a summary is provided which includes the activity that would cause an impact; the potential impacts; embedded or best practice mitigation (stated where required / available); the sensitivity of receptor that would be impacted; the severity, duration, and probability of impacts; the significance of impacts before mitigation and after mitigation measures are applied.

7.1 IMPACTS NOT CONSIDERED SIGNIFICANT

As a result of an iterative project evolution process, mitigation has been incorporated and embedded into the project plan, thereby designing out potential environmental and social impacts or reducing the potential impact so that it is not significant. The ESMP provides best practice measures, management and monitoring for identified impacts. Impacts that have been assessed as not being significant are summarised in Table 14 and are not discussed further, unless otherwise indicated.

Table 14 - Non-significant impacts

Environmental or Social topic	Potential impact	Rational
Social environment		
Visual	Loss of sense of place	Sense of place refers to the relationship people may have to the distinctiveness of locations. The Project site, however, will be located approximately 15 kilometres from the town of Rosh Pinah and will be out of view from the citizens of the town.
Light disturbance	Light disturbance on surrounding neighbours	The Project site will be located 15 kilometres from the town of Rosh Pinah and will be out of view from the town and the inhabitants of the town and therefore the light emitted by the mine will not have a significant impact on the residents of Rosh Pinah.
Land use	Land may no longer be used for farming and agriculture	The farming land is mainly used for small stock farming however the area is very arid and not productive for farming and agriculture. The construction and operation of the mine would not have a significant impact on land use.
Noise and vibration	Nuisance of high levels of noise and vibration from blasting	The mine will generate noise and vibration during blasting and general operation activities however, the mine site is 15 km away from the town of Rosh Pinah and potential sensitive receptors are unlikely to be significantly impacted.
Human Rights	The effects that the mine may have on the human rights of the local community and the impact that the social climate of Rosh Pinah may have on	No residents of Rosh Pinah or settlements will have to be relocated to accommodate the Project. The project will also not be extracting any conflict minerals, and the project is not in an area

Environmental or Social topic	Potential impact	Rational
	the operations of the mine	grappling with conflict or human rights violations.
Infrastructure	The effects of vibration and dust may have on nearby infrastructure	According to the standard blasting patterns used for underground mining it is not expected that any damage would occur to current or future infrastructure within the radius of the blast and vibrations and fly rock.
Tourism	Mining operations may influence the level of tourism attraction to the town	Rosh Pinah is considered a mining town and people visit Rosh Pinah mainly for work or to visit one of the two mines in town.

7.2 Socio-economic environment: Economic

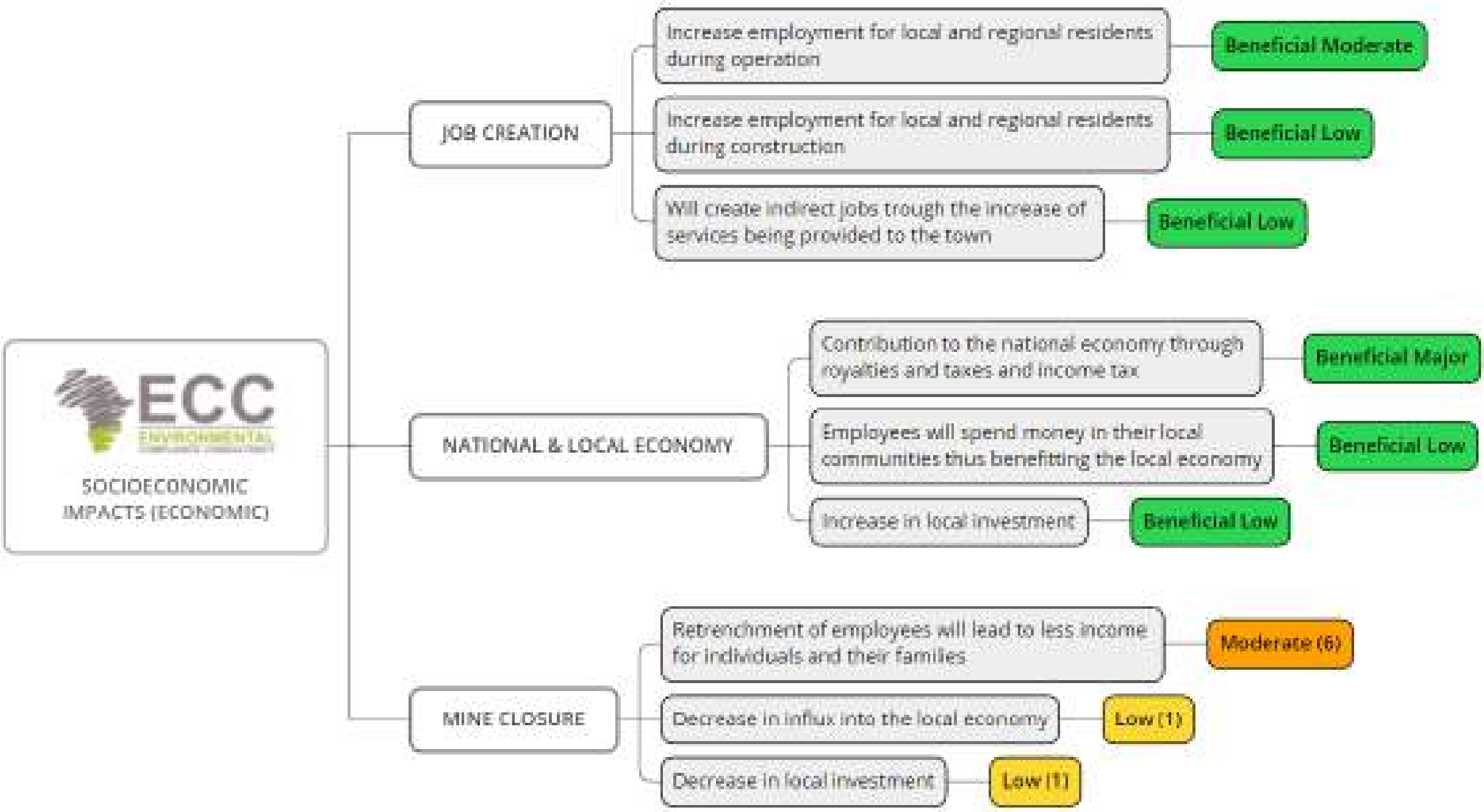


Figure 37 - Socioeconomic impacts

7.2.1 THE IMPACT OF THE PROJECT ON THE NATIONAL AND LOCAL ECONOMY

7.2.1.1 The impact of the Project on the national economy

According to (Africa Development Bank Group, 2023) (The World Bank Group, 2023) GDP is expected to grow throughout 2023 and 2024 mainly due to diamond processing and export, the increased consumption of wholesale goods, manufacturing, services, private investment, and the recovery of the tourism industry. The Gergarub Project will continue to contribute to the national GDP through taxes and royalties paid to the government. The projected royalties project to be generated by the project could amount to N$ 42.5 million per annum. The nature of this impact is beneficial and direct. This impact is however reversible. The magnitude of change is moderate, and the duration of the impact is short-term. The extent of the impact is national, and the value and sensitivity of the impact is high. Therefore, this impact has been rated as a beneficial major.

7.2.1.2 The impact of the influx of workers looking for employment on the local economy

The Gergarub Project is expected to generate approximately 500 jobs during construction and close to 700 jobs during operation. The opening and operation of this mine will also lead to an increase in the local investment in the town and the number of secondary services and jobs that will now become available. Due to this, there will likely be an influx of workers from various towns all over the country in search of a job. This will have various effects on the local economy of Rosh Pinah. The influx of people to the town of Rosh Pinah will lead to increased spending on local businesses which will assist in sustaining the town. The nature of this impact is beneficial and direct. The impact is reversible, and the magnitude of change is moderate. The duration of the impact is short-term, while the extent of the impact is local. The probability of this impact occurring is likely and the value and sensitivity of this impact is low. Therefore, the significance of this impact has been rated as beneficial low.

7.2.2 THE IMPACT OF THE PROJECT ON EMPLOYMENT AND SKILLS DEVELOPMENT

7.2.2.1 The impact of the Project on regional employment and skills development

Unemployment has become a pressing issue in Namibia, the government has therefore made reducing unemployment a priority in the NDP5(National Planning Commission, 2020). The national unemployment rate as of 2018 stands at 33.4% (Namibia Statistics Agency, 2022). According to the (Namibia Statistics Agency, 2014), 74% of the working-age population of the //Karas Region is employed and the //Karas Region accounts for 3.4% of Namibia's total unemployment rate. The //Karas Region is one of the most important mining regions in Namibia, contributing a significant portion to the Gross Domestic Product (GDP). The development of the //Karas Region is economically, closely tied to its rich mineral deposits that provide a significant number of employment opportunities. Individuals employed by the mine will also gain a significant and specialised skill set, unique to working at a mine. The nature of this impact is beneficial and direct. This impact is partially reversible, and the magnitude of change is high. The duration of this impact is short-term, and the extent of this impact is regional. The probability of this impact occurring is likely.

The value and sensitivity of employment are considered high as it is of importance to the country. This impact has been rated as beneficial moderate.

7.2.2.2 The impact of the Project on direct employment

During the construction phase, it is estimated that 550 jobs will be created. Approximately 400 jobs will open during the construction of the mine and associated infrastructure. An additional 150 jobs are expected to be created during the construction of additional housing units if needed. This phase of the Project is expected to last approximately 18 months. The nature of this impact is beneficial and direct. This impact is however reversible, and the magnitude of change is low. The duration of the impact is short-term, and the extent is on-site. The probability of this impact occurring is likely and the value and sensitivity of the impact is low. Therefore, the significance of this impact has been rated as beneficial low.

7.2.2.3 The impact of operations on direct employment

The Project will contribute to sustaining the local and regional economy by employing between 600-680 people from Rosh Pinah and all over the region. This is also an opportunity for retrenched employees from Skorpion Zinc to be re-employed by Gergarub. An increase in long-term jobs with a stable income means that this will benefit the individuals themselves, their families and the community at large. The nature of this impact is beneficial and direct; however, this impact is reversible. The magnitude of change is high, the duration short-term and the extent regional. The probability of this impact occurring is likely and the value of sensitivity of this impact is high. Therefore, the significance of this impact has been rated beneficial moderate.

7.3 THE IMPACT OF THE PROJECT ON INDIRECT EMPLOYMENT

7.3.1.1 The impact of the Project on creating indirect employment for the residents of Rosh Pinah.

This impact has been rated as beneficial low. Various products and services will need to be provided to the mine. This creates an opportunity for current and new business opportunities in Rosh Pinah to provide this product or service. This will provide an income to everyone employed by these businesses thus providing for those individuals and their families. The nature of this impact is beneficial and indirect. This impact is reversible, and the magnitude of change is moderate. The duration of the impact is medium-term, and the extent of the impact is local. The probability of this impact occurring is likely and the sensitivity and value of this impact is low. Therefore, the significance of this impact has been rated as beneficial low.

7.3.2 THE IMPACT OF MINE CLOSURE AND DECOMMISSIONING OF THE PROJECT ON EMPLOYMENT

7.3.2.1 The impact of mine closure and decommissioning on employment and the national and local economy.

The life of mine for the Gergarub Project is 12 years. As the mine begins to near its end of life, direct employment at the mine and indirect jobs associated with mining operations will begin to decrease. Employees of the mine will need to have transferable skills to find different jobs at the end of LoM. Unless retrenched employees can find other jobs in or around Rosh Pinah it will lead to a decrease of spending in the local economy. This will decrease the ability of individuals to provide for themselves and their families. Mine closure and decommissioning of the mine may lead to a decrease in local investment from foreign investors. All of the above-mentioned scenarios may lead to people moving out of the town of Rosh Pinah in search of jobs and better business opportunities, which will further negatively impact the local economy. The nature of this impact is adverse and direct. The impact is reversible, and the magnitude of change is high. The duration of this impact is long-term, and the extent of the impact is regional. Therefore, the significance of this impact has been rated adverse moderate as shown in Table 15.

Table 15 - Socio-economic: Economic impacts

Activity	Receptor	Nature of impact	Value and sensitivity	Magnitude of change	Significance of impact
Increase employment for local and regional residents during construction	Local economy	Beneficial (Positive) Direct Reversible Moderate Short term Regional Almost certain	Medium	Moderate	Beneficial Low
Increase employment for local and regional residents during operation	Local economy	Beneficial (Positive) Direct Reversible Moderate Short term Regional Almost certain	Medium	High/Major	Beneficial Moderate
Contribution to the national economy through taxes and royalties	National economy	Beneficial (Positive) Direct Reversible High/Major	High	High/Major	Beneficial Major

Activity	Receptor	Nature of impact	Value and sensitivity	Magnitude of change	Significance of impact
		Short term Regional Almost certain			
Creation of indirect jobs through the increase of services and products required to sustain the mine and Rosh Pinah	Local economy	Beneficial (Positive) Indirect Reversible Moderate Medium term Local Possible	Low	Low	Beneficial Low
Increase in local investment	Local economy	Beneficial (Positive) Direct Reversible Moderate Short term Regional Possible	Low	Low	Beneficial Low
Retrenchment of employees due to mine closure or decommissioning	Local economy	Adverse (Negative) Direct Reversible High/Major Long term Regional Almost certain	High	Medium	Moderate (6)
Decrease/loss of local investment due to mine closure	Local economy	Adverse (Negative) Indirect Reversible Moderate Long term Local Possible	Moderate	Low	Low (1)
Decrease of local services	Mine closure	Adverse (Negative) Indirect	Moderate	Low	Low (1)

Activity	Receptor	Nature of impact	Value and sensitivity	Magnitude of change	Significance of impact
		Reversible Moderate Long term Local Possible			

7.4 Socio-economic environment: Social

7.4.1 AIR QUALITY IMPACTS

Air quality is determined by the amount and size of solid particulate matter (PM) and chemical pollutants in the atmosphere at a particular period. Particulate matter are tiny particles suspended in the air. These particles originate from dust, dirt or emissions from vehicles, industrial plant smokestacks or smoke from fires. Poor air quality is characterized by high levels of pollutants in the air.

Particulate matter can be categorised according to particulate size total suspended particulate (TSP), PM_{10} and $PM_{2.5}$:

- TSP is a mixture of solid and liquid particles suspended in the air.
- PM_{10} are very small particles found in dust and smoke, these particles have a diameter of 10µm or smaller and are a common air pollutant.
- $PM_{2.5}$ are very small particles found in dust and smoke, these particles have a diameter of 2.5µm or smaller and are a common air pollutant.

Both short-term and long-term exposure to air pollutants can lead to a wide range of diseases such as respiratory diseases (lung cancer, TB, bronchitis, COPD etc.), cardiovascular diseases, stroke etc.

Temperature, wind direction and speed also play a critical role in air quality. Air quality can be worse during winter months pollutants can be trapped close to the surface beneath a layer of dense, cold air. In summer months, heated air rises and disperses pollutants from the Earth's surface through the upper troposphere. Wind direction and speed affect air quality as it moves air pollutants around.

In the location of the proposed Project, the winter months are between May and September, while the predominant wind directions for this area are SSW, NNE, SW, S and N with maximum wind speeds ranging between 28-38 km/h. The town of Rosh Pinah and Rosh Pinah Zinc Mine is located south of the Gergarub Project therefore high levels of pollutants generated by the mine may not only affect on-site employees but pollutants may be transported via wind towards the town reducing the air quality of the town.

The air quality impacts that may arise because of the project before mitigation are presented in Figure 38 below, for illustrative purposes only and are outlined in Table 16.

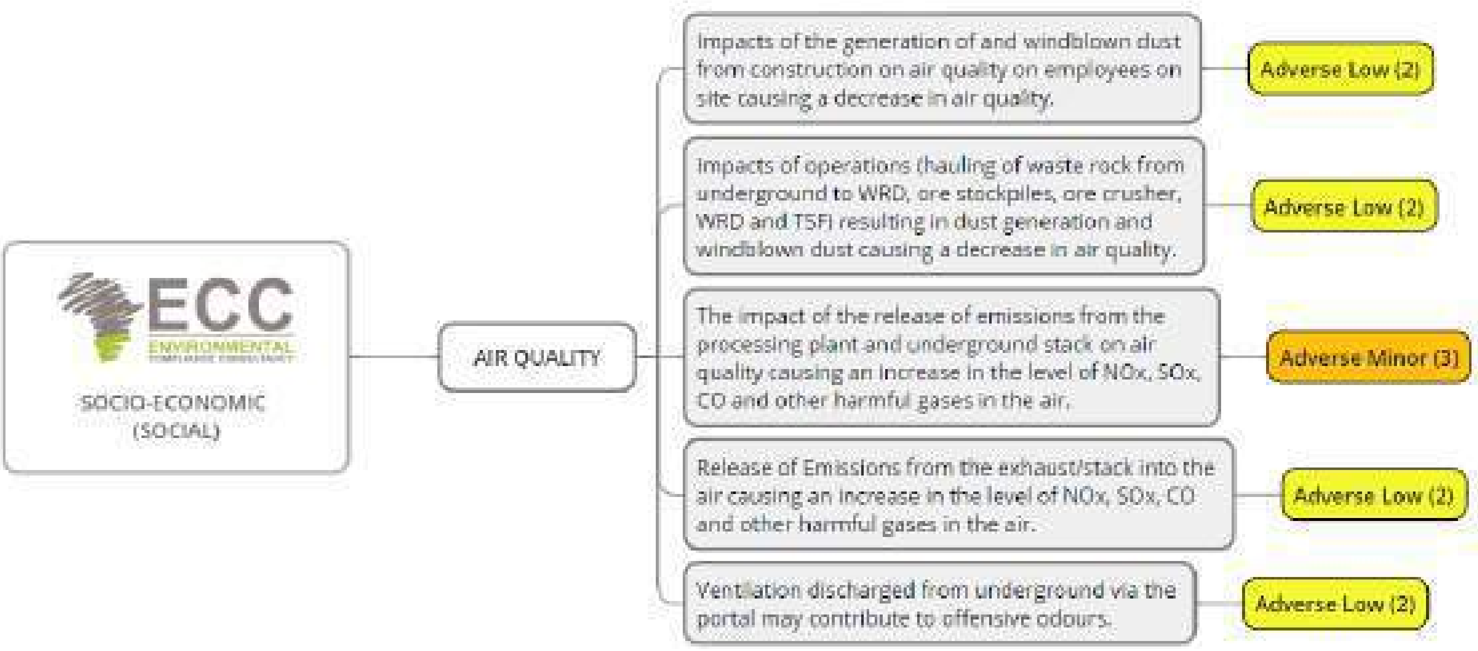


Figure 38 - Impacts on air quality

7.4.1.1 Impacts of the generation of and windblown dust from construction on air quality on employees on site.

During construction, various particulate matter is generated in the form of dust and emissions from the construction of on-site infrastructure including site clearing and preparation, construction of site roads and offices, TSF, processing plants etc. A range of vehicles and equipment are also necessary for construction such as heavy-duty vehicles, mobile cranes, generators, welding machines and fabrication equipment, bulldozers, excavators, cranes, mixers, and tipper trucks. These activities generate dust which may negatively affect the surrounding environment's air quality. The amount of dust emissions is expected to fluctuate significantly daily, influenced by factors such as the intensity of activities, the nature of operations, current meteorological conditions, and proximity to air quality sensitive receptors (AQSRs 1-7). Given the sporadic nature of construction operations, the impact of emissions is anticipated to vary based on the activity levels. The nature of the impact of the construction of site infrastructure will be adverse negative and direct, the impact however will be reversible and recoverable over time. The magnitude of the impact will contribute to minor loss or alteration to the environment's overall air quality. The impact of the dust generated by construction will be temporary and only affect the employees on-site. Nevertheless, this impact is likely to occur and therefore the significance of this impact has been rated Low.

7.4.1.2 2 Impacts of 0perations (hauling of waste rock from underground to WRD, ore stockpiles, ore crusher, WRD and TSF) resulting in dust generation and windblown dust impacts on air quality.

During operations over the LoM, various contributors to a reduction in air quality on-site and in the local vicinity will be produced in the form of dust and emissions (NO_x, SO_x, CO and CO_2). Dust will be generated from various activities such as the hauling of waste rock from underground to the waste rock dump, and the movement of ore from underground to ore stockpiles and crushers. Additional wind-blown dust will be generated from the WRD, tailings. Depending on the direction of the wind and the speed on a particular day this may negatively affect the air quality on-site and on the nearby town of Rosh Pinah. As shown in Figure 39, dustfall out is likely to exceed SA dustfall limits for non-residential areas on an annual basis unless mitigated and as shown in Figure 40 and Figure 41 PM_{10} and $PM_{2.5}$ are likely to exceed annual SA NAAQS guidelines around the shaft and TSF unless mitigated. According to (Airshed Planning Professionals (Pty) Ltd, 2023). Windblown dust from natural exposed surfaces in and at the Project is only likely to result in particulate matter emissions under high wind speed conditions (>10 m/s), and since recorded wind speeds did not exceed 10 m/s, the nature of this impact will be adverse negative and direct. However, the impact is reversible. The magnitude of change is minor as the alteration of air quality is minor. The duration of the impact will be short-term as it is only likely to last for the duration of the activities on site. Nevertheless, the impact is likely to occur. Therefore, this impact has been rated Minor. Gravel roads as vehicles and trucks move continuously along those roads will also dredge up dust, which may affect the air quality locally. The nature of this impact will be adverse negative and direct. However, the impact is reversible. The magnitude of change is minor. The duration of the impact will be short-term as it is only likely to last for the duration of the activities on site. Therefore, the impact is likely to occur. Therefore, this impact has been rated low.

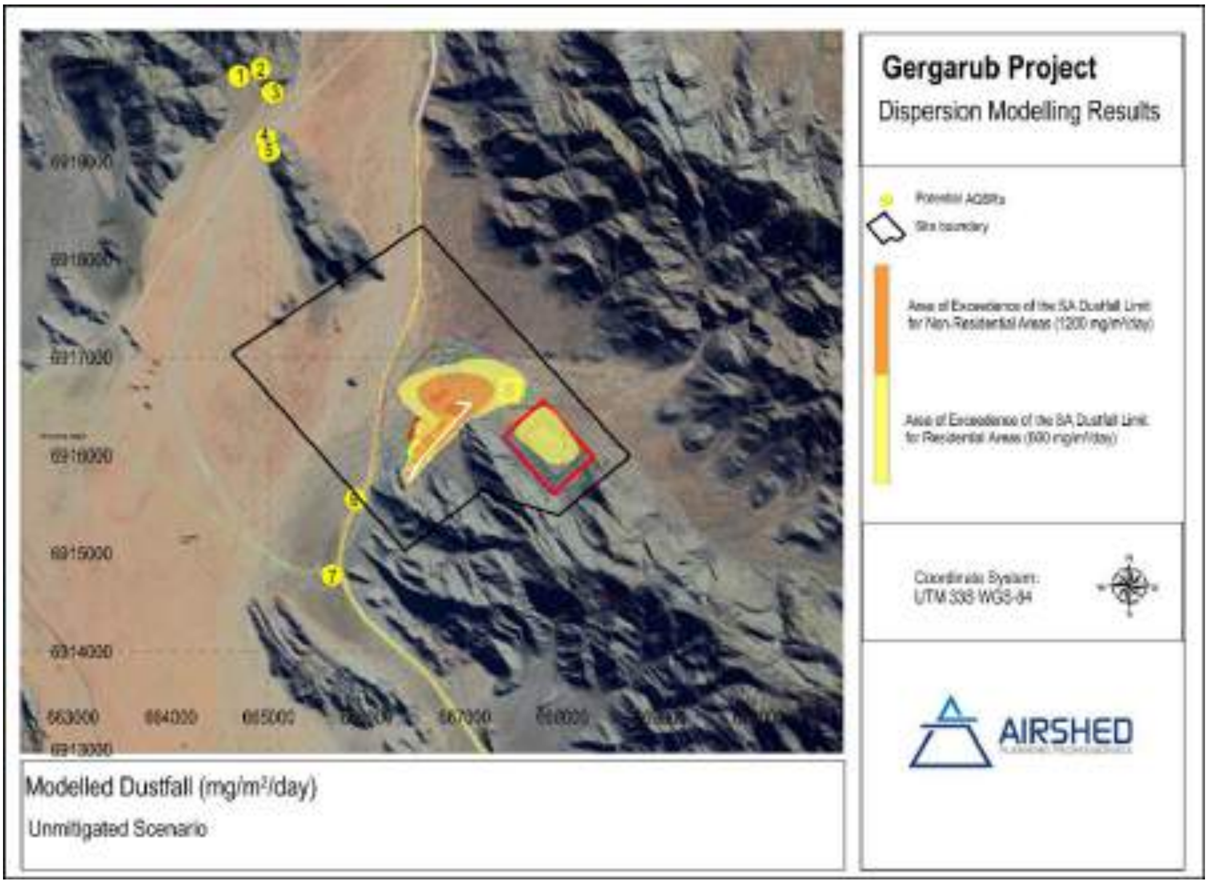


Figure 39 - Modelled dustfall values for unmitigated operations

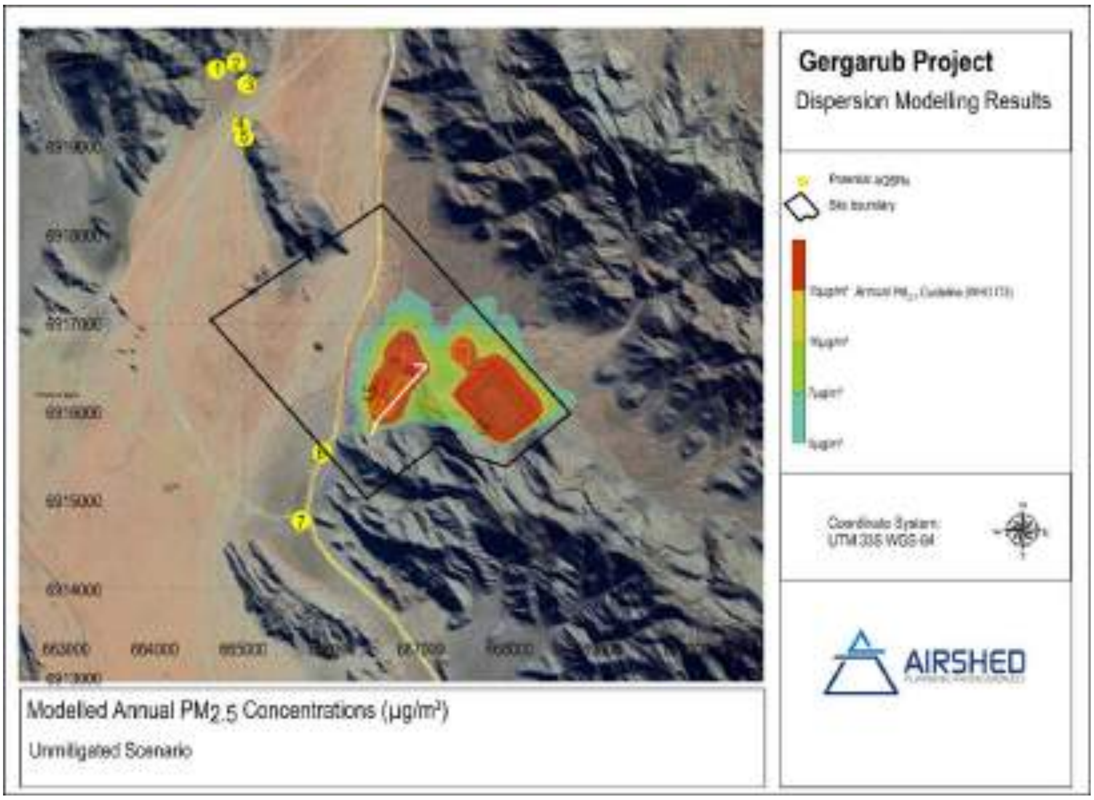


Figure 40 - Modelled ground level concentrations of annual $PM_{2.5}$ AQO for unmitigated operations

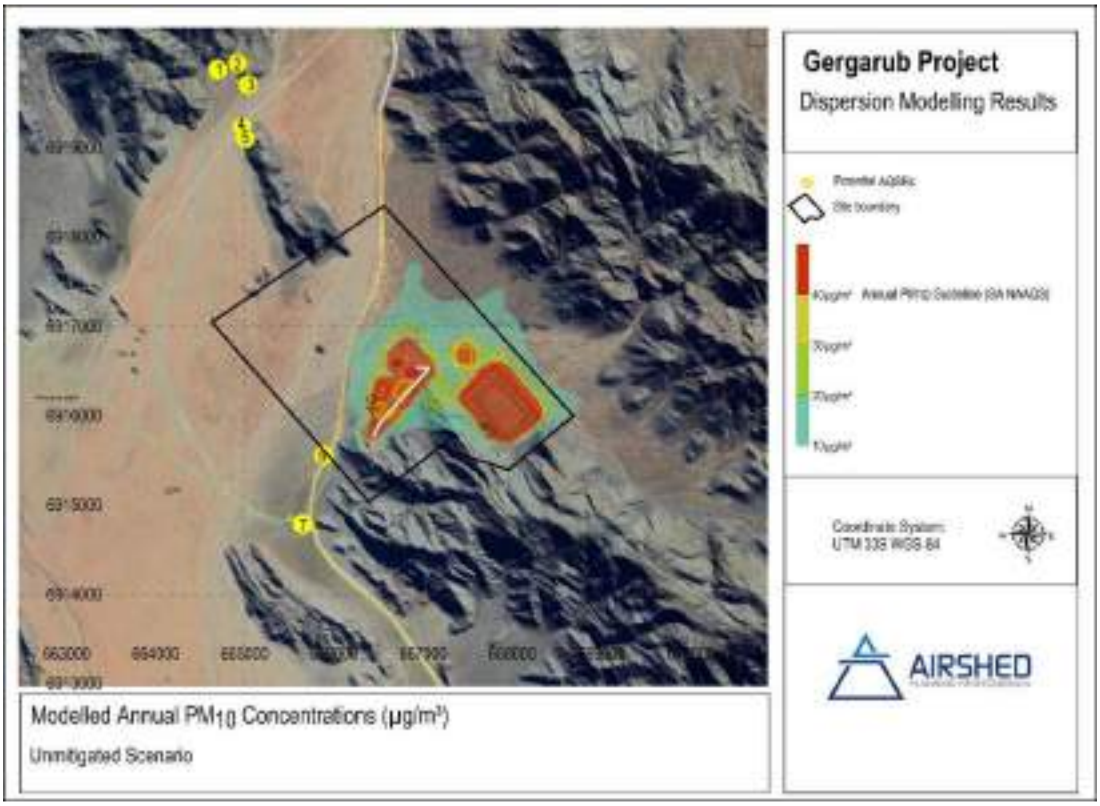


Figure 41 - Modelled ground level concentrations of annual PM_{10} AQO for unmitigated operations

7.4.1.3 The impact of the release of emissions from vehicular emissions on air quality.

The products of combustion, or release of fumes such as include methane (CH_4) and other hydrocarbons, carbon dioxide (CO_2), carbon monoxide (CO), oxides of nitrogen (NO_X), sulphur oxides (SO_X) and hydrogen sulphide (H_2S), and volatile organic compounds (VOCs) from vehicle exhaust emissions or activities such as blasting occur underground. These emissions, dust and soot from the underground mine are vented above ground into the atmosphere through the vent/stack. The release of these emissions and dust into the atmosphere can contribute to decreased air quality both on-site and to nearby receptors such as the town of Rosh Pinah. The nature of this impact will be adverse negative and direct. However, the impact is reversible. The magnitude of change is minor as the alteration of air quality is moderate. The duration of the impact will be short-term as it is only likely to last for the duration of the activities locally. Nevertheless, the impact is likely to occur. Therefore, this impact has been rated Minor.

7.4.1.4 The impact of the release of emissions from the processing plant and underground stack on air quality.

The processing plant is most likely to produce PM and gaseous emissions from machinery such as SO_2, NO_X, CO and CO_2. These emissions will be generated from the crushing and screening process and loading from stockpiles. Zinc processing involves the generation of particulate matter, including small airborne particles that can deeply penetrate the respiratory system, leading to potential respiratory and cardiovascular issues with prolonged exposure. SO_2, a byproduct of zinc processing, contributes to acid rain formation and can cause respiratory irritation. Additionally, processing activities contribute to greenhouse gas emissions (CO_2 and CH_4), and certain zinc mining processes release odorous and volatile compounds, potentially impacting air quality and health. Therefore, the nature of this impact will be adverse negative and direct. However, the impact is reversible. The magnitude of change is minor as the alteration of air quality is minor. The duration of the impact will be short-term as it is only likely to last for the duration of the activities locally. Nevertheless, the impact is likely to occur. Therefore, this impact has been rated adverse low.

7.4.1.5 Release of offensive odours from the stack may negatively impact employees and nearby receptors.

Offensive odours can often be released from the stack of an underground mine. This needs to be monitored as offensive odours can be indicative of a variety of things. Offensive odours can indicate the presence of a build-up of harmful gases such as CH_4, SO_X and NO_X. The extensive presence of these harmful gases reduces the quality of the air in the underground environment and can have detrimental health impacts on the employees working underground. Additionally, offensive odours can be a social nuisance to those in the vicinity of the stack, which can negatively affect the well-being of employees on-site and nearby local communities. The nature of this impact is adverse and direct; however, the impact is reversible. The magnitude of change is minor, duration is short term and extent is local. The value and sensitivity of the impact is low and therefore, the significance of the impact has been rated adverse low.

Table 16 - Impacts of construction and operation on air quality.

Activity	Receptor	Impact	Nature of Impact	Value & Sensitivity	Magnitude of change	Significance of impact
Generation of and windblown dust from construction on air quality on employees on site	On-site employees, Community	Decrease in air quality due to wind-blown dust from construction	Adverse Direct Reversible Minor Temporary On-site Likely	Low	Minor	Low (2)
Operations (hauling of waste rock from underground to WRD, ore stockpiles, ore crusher, WRD and TSF)	On-site employees, Community	Decrease in air quality due to wind-blown dust	Adverse Direct Reversible Minor Short term Local Likely	Low	Minor	Low (2)
Release of emissions from the processing plant and underground stack	Community	Increase in the level of NOx, SOx, CO and other harmful gases in the air	Adverse Direct Reversible Minor Short term Local Likely	Low	Moderate	Minor (3)
Release of Emissions from the exhaust/stack into the air	Community	Increase in the level of NOx, SOx, CO and	Adverse Direct	Low	Minor	Low (2)

Activity	Receptor	Impact	Nature of Impact	Value & Sensitivity	Magnitude of change	Significance of impact
		other harmful gases in the air	Reversible Minor Short term Local Possible			
Ventilation discharged from underground via the portal	On-site community	Contribute to offensive odours	Adverse Direct Reversible Minor Short term Local Possible	Low	Minor	Low (2)

7.4.2 VISUAL IMPACTS

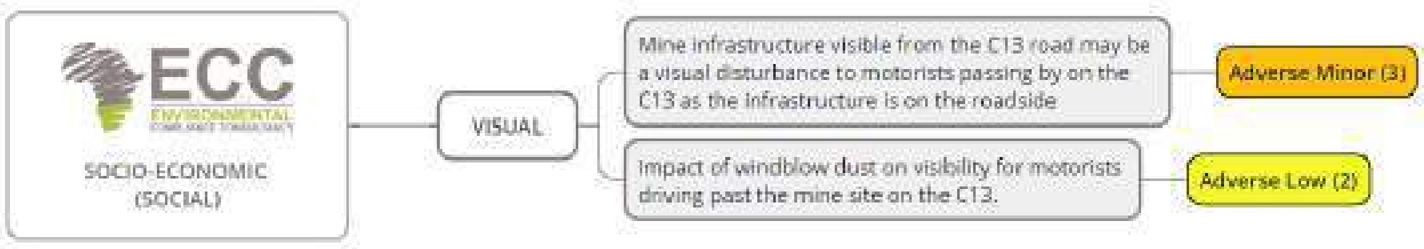


Figure 42 - Visual impacts.

7.4.2.1 Impact of windblow dust during construction and operations on visibility for motorists driving past the mine site on the C13.

Dust generated from the operations onsite along with windblown dust from the WRD, TSF and ore stockpiles may cause a decrease in visibility along the C13 for motorists. This may negatively impact road conditions when approaching the site. The nature of this impact will be adverse, negative, and direct. However, the impact is reversible. The magnitude of change is minor as the alteration of the visual landscape is minor. The duration of the impact will be short-term as it is only likely to last during the duration of Project activities. The extent of the impact is local. Nevertheless, the impact is likely to occur. Therefore, this impact has been rated as adverse low.

7.4.2.2 Mine infrastructure visible from the C13 road may be a visual disturbance to motorists passing by on the C13 as the infrastructure is on the roadside.

The Gergarub site is located right next to the C13 road. All the mine's infrastructure such as the ventilation fans and underground portal entrance, crusher, WRD and TSF will be visible from the road and to passersby. This will result in changes in the pristine visual landscape along the road. The Concentrator Plant will increasingly become the focus of the visual landscape as one approach, while the structure and colour of the waste rock dump will form a conspicuous feature. The nature of this impact will be adverse negative and direct. The impact is irreversible. The magnitude of change is minor as the alteration of the visual landscape is minor. The duration of the impact will be long-term as it is only likely to last long after the Project activities have ceased. However, the extent of the impact is only on-site. Nevertheless, the impact is likely to occur. Therefore, this impact has been rated as adverse minor as shown in Table 17.

Table 17 - Visual impacts

Activity	Receptor	Impact	Nature of Impact	Value & Sensitivity	Magnitude of change	Significance of impact
Construction	Onsite employees	An increase in dust will reduce visibility on the site	Adverse Direct Reversible Minor	Low	Minor	Low (2)

Activity	Receptor	Impact	Nature of Impact	Value & Sensitivity	Magnitude of change	Significance of impact
			Temporary On-site Unlikely			
Operation	Onsite employees	An increase in dust will reduce visibility on the site	Adverse Direct Reversible Minor Short term On-site Unlikely	Low	Minor	Low (2)
Clearing of habitat during construction and operations	Farmers Motorists Tourists	Scarring of pristine landscapes	Adverse Direct Reversible Minor Long term Local Almost certain	Low	Moderate	Minor (3)
Operation	Farmers Motorists Tourists	Changes to the visual landscape of the site with the introduction of ventilation fans and underground portal entrance	Adverse Direct Reversible Minor Long term Local Almost certain	Low	Moderate	Minor (3)
Operation	Farmers Motorists Tourists	The Concentrator Plant will increasingly become the focus of the visual landscape as one approaches	Adverse Direct Reversible Minor Long term Local Almost certain	Low	Moderate	Minor (3)
Operation	Farmers Motorists Tourists	The waste dump forms a dominant standalone feature that differs in texture and potentially in	Adverse Direct Reversible Minor Long term Local	Low	Moderate	Minor (3)

Activity	Receptor	Impact	Nature of Impact	Value & Sensitivity	Magnitude of change	Significance of impact
		colour from the surrounding terrain.	Almost certain			
Operation	Farmers Motorists Tourists	The TSF and protection berm features combined form a feature that will increasingly become the focus of the visual landscape as one approaches it, by being different in form, line, and colour from the mountain valley it is integrated with.	Adverse Direct Reversible Minor Long term Local Almost certain	Low	Moderate	Minor (3)

7.4.3 TRAFFIC IMAPCTS

Figure 43 - Impacts on traffic.

7.4.3.1 Impacts of increased traffic on the road due to the movement of construction vehicles and the transportation of goods during operation to and from the mine site.

During the operation phase, the number of trips on the C13 road between Lüderitz and the mine site and the mine site is 8-hour shifts consisting of three trips per day of busses to and from the mine site, carrying 226 people per shift. Additionally, 30 trucks will be moving between the mine site and Lüderitz per day. The overall traffic volume on this road is expected to be low. There are expected to be a total of 50 trips to and from the site during peak hours. Although no upgrades are proposed at this mine access intersection from a capacity analysis point of view, it is recommended by (Innovative Transport Solutions, 2023) that the speed limit on the C13 be reduced from 120 km/h to 80 km/h within the vicinity of the entry of the mine. In addition to this, bus embayments should be developed with a minimum circulating radii of 15m with lighting and shelter on site. The nature of the impact of these additional heavy vehicles on the road is adverse and direct, while the impact is reversible. The duration of the impact will be short term and the extent of the impact is local. The probability of this impact occurring is possible and the sensitivity of the impact is medium. Therefore, the significance of this impact has been rated as adverse minor as shown in Table 18.

Table 18 - Traffic impacts

Activity	Receptor	Impact	Nature of Impact	Value & Sensitivity	Magnitude of change	Significance of impact
Transport of busses and trucks to and from the mine site during construction and operation	Community road users Visitors to the area New Workforce	Increased traffic volumes on district roads and buses and trucks travelling to and from the mine site will disrupt normal traffic levels	Adverse Direct Regional Moderate Short-term Possible	Medium	Moderate	Minor (4)
Increase in the presence of trucks on the road	C13 Road	Increased heavy vehicles on the road will lead to more potholes and degradation of the road	Adverse Direct Regional Reversible Moderate Short-term Possible	Medium	Moderate	Minor (4)

7.4.4 BLAST AND VIBRATION IMPACTS

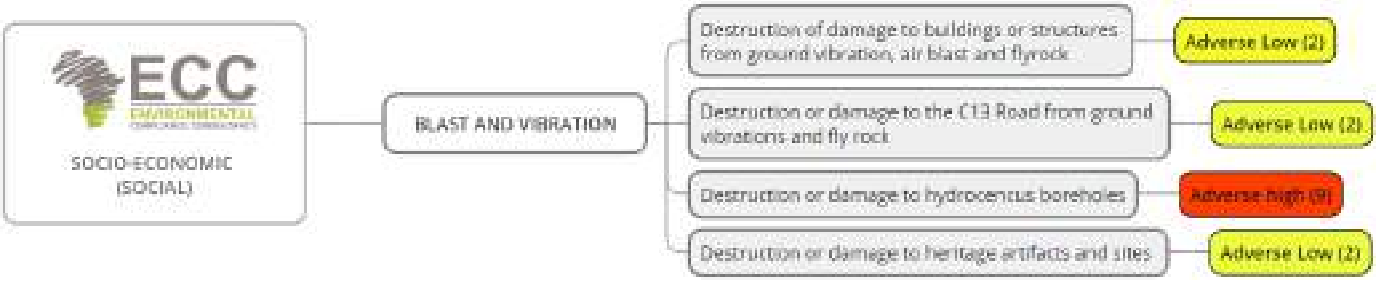


Figure 44 - Blasting and vibration impacts.

7.4.4.1 The impact of blasting and vibration on heritage sites and artifacts

Blasting often leads to air blasts, and fly rock and ground vibrations during initial decline development. These impacts from lasting may negatively impact nearby farmhouses, boreholes, roads, people, and fauna. Vibrations can be felt up to 1420 m from the blasting locations. Since there are no communities within this previously mentioned proximity of the blasting, there is not expected to be any disturbance or impact on any communities or community structures (such as homes). All heritage sites that were previously present on site have been excavated and removed from the site and are therefore no longer at risk of damage from blasting and vibration. The nature of this impact has been rated adverse and direct. The reversibility of this impact is irreversible however the magnitude of the impact is negligible since they have already been removed, they will not be impacted. The duration of this impact is permanent, while the scale of the impact is national as these sites are a national treasure. The probability of heritage sites being damaged by blasting and vibrations is possible. The sensitivity of this impact is medium as it is of value and importance on a national scale. Therefore, this impact has been rated adverse low.

7.4.4.2 The impact of blasting and vibration on existing infrastructure and the built environment.

Overall, it is not expected according to the standard blasting patterns used for underground mining that there will be any damage to current and future infrastructure on site or within the radius of the blast vibrations and fly rock during initial decline development. However, as the blast pattern is subject to change an additional study may need to be conducted once blasting patterns have been finalised. For this reason, this impact is rated adverse and direct, while the reversibility of this impact is reversible. The magnitude of change is minor, and the extent of the impact is on site. The duration of the impact is long term as it may last long after mining activities have ceased. The possibility of this impact occurring is possible and the sensitivity of the impact is low. Therefore, this impact has been rated adverse low. However, there two hydrocensus boreholes that are close to the underground works that may be damaged or destroyed from blasting and vibrations. The nature of this impact is adverse and direct, while the reversibility of this impact is partly reversible. The magnitude of change is moderate, and the extent of the impact is Regional as these boreholes are used to document groundwater within the region. The duration of the impact is long term as this monitoring will be lost until restored which may only occur until after the decommissioning of the site if it is restored at all. The possibility of this occurring is likely, and the value and sensitivity of this impact is high. Therefore, the significance of the change of this impact has been rated an adverse high.

7.4.4.3 The impact of blasting and vibration on the C13 road above the blasting zone.

The main road between Rosh Pinah and Aus, the C13 runs through ML245 and there are currently no plans to re-route/divert the road, the Proponent will be blasting and mining under the C13 Road which may cause damage to the road. Ground vibrations and fly rock may lead to cracks in the road, damage from falling debris or subsidence of the roads. Fly rock may also be of concern to passing traffic. The nature of the impact is adverse and direct; however, the impact is reversible. The magnitude of the impact is moderate, and the duration of the impact is only short-term lasting the LoM. The probability of this impact occurring is possible and the value and sensitivity of the impact is high. Therefore, the significance of the impact has been rated adverse moderate (Table 19).

Table 19 - Blast and vibration impacts.

Activity	Receptor	Impact	Nature of Impact	Value & Sensitivity	Magnitude of change	Significance of impact
Blasting	Built environment	Destruction of damage to buildings or structures	Adverse Direct Partly Reversible Minor Long term Local Possible	Low	Minor	Low (2)
Blasting	Roads	Destruction or damage to the C13 Road from ground vibrations and fly rock	Adverse Direct Reversible Minor Short term Local Possible	Low	Minor	Low (2)
Blasting	Built environment	Destruction or damage to hydrocencus boreholes	Adverse Direct Partly Reversible Moderate Long term Regional Likely	High	Moderate	High (9)
Blasting	Heritage	Destruction or damage	Adverse Direct	Low	None	Low (1)

Activity	Receptor	Impact	Nature of Impact	Value & Sensitivity	Magnitude of change	Significance of impact
		to heritage artifacts and sites	Irreversible None Permanent National Possible			

Considering that the ground vibrations will most likely be the cause of infrastructure damage there should be detailed planning as to how to prevent damage and maintain levels with the accepted parameters. Additionally, the hydrocencus boreholes that may be destroyed or damaged due to ground vibrations from blasting should be removed. Then alternative locations should be found to drill new boreholes to prevent the loss of the collection of groundwater monitoring in the area.

7.4.5 NOISE IMPACTS

Blasting activities produce noise and vibrations during the decline development. Other sources of noise are likely during ore and waste handling, haul truck traffic, diesel mobile equipment uses and ore processing activities such as crushing, screening, and milling. The specific noise impact in the project area before mitigation during mining activities are presented in Figure 45. The noise impact is further discussed in this section.

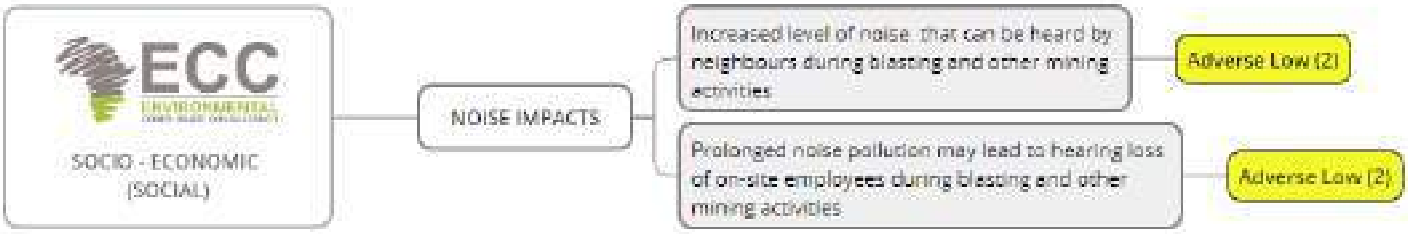


Figure 45 - Specific noise impacts on neighbours and employees during the Gergarub project.

7.4.5.1 Noise impacts on nearby neighbours.

Uncontrolled noise from mining activities may can disrupt the lives of residents, affecting their sleep, communication, and overall quality of life (NoiseNews, 2023). As shown in Figure 46, the only receptor that may be impacted is noise receptor 6 during night-time, which was identified as a road authority building where trucks are regularly inspected. These will be minor impacts as it is expected that this area is likely to receive at most 45 dBA which is much lower than the assessment criteria which is 70 dBA. Other identified residential areas in the vicinity of the mining license will not be impacted as per the IFC guidelines. The nature of the impact is adversely direct, reversible and will occur over a short period.

Mitigations as per the noise impact assessment includes that unnecessary idling should be avoided, other non-routine noisy activities such as construction, start-up and maintenance should be limited to day-time hours. More Mitigations will be explored in the EMP. The magnitude of change is minor, and extent is local. The value and sensitivity of the impact is low and therefore, the significance of the impact has been rated adverse low as shown in Table 20.

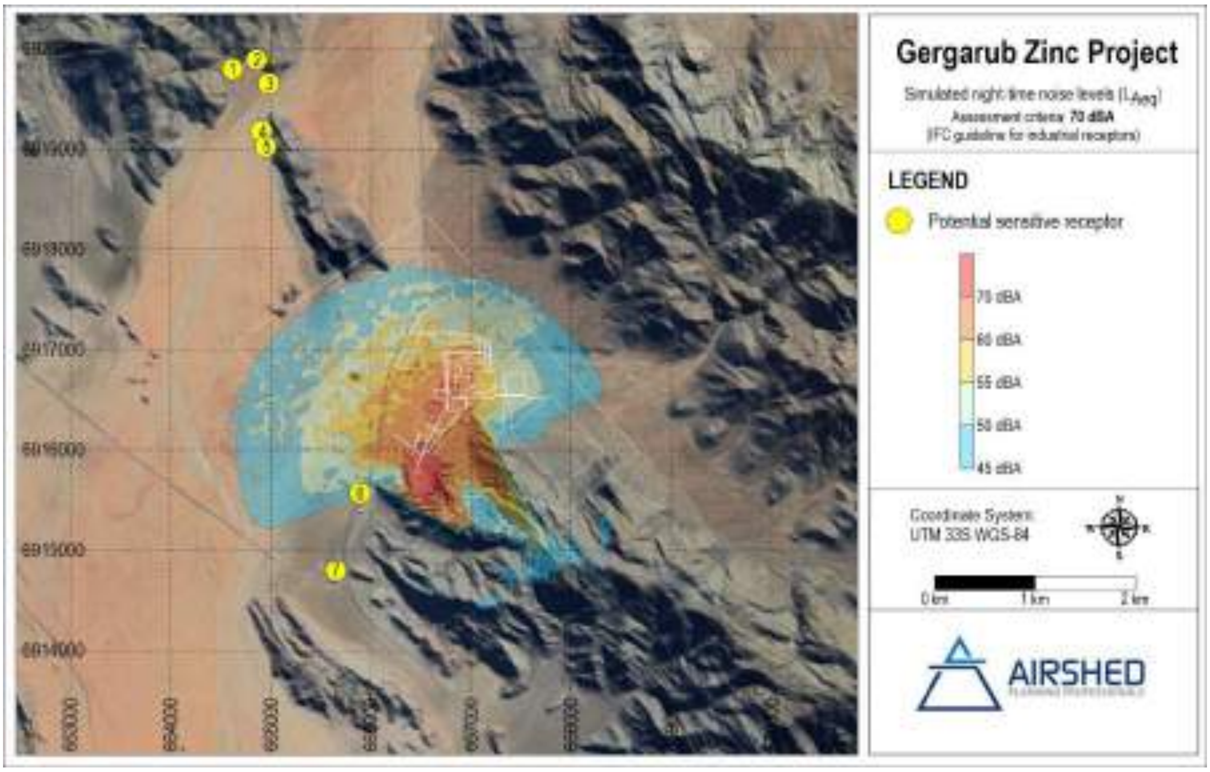


Figure 46 - Stimulated noise levels for the project operational activities

7.4.5.2 Noise impacts on the employees on-site

Prolonged exposure to extreme noise pollution will likely lead to irreversible hearing loss and added health issues. Blasting activities tend to occur over a short period of time. The adverse effects will be direct, irreversible and will be on-site.

The proper PPE should be worn by all on-site employees to prevent damage to their hearing and provide other necessary protection. A noisy complaints register should also be always on-site. The magnitude of change is moderate due to the measurable and irreversible impact on the employee occupational health and safety should this impact occur. The sensitivity of receptor is low as this impact will only occur on-site during working hours. The overall significance of impact is low.

Table 20 - Noise impacts

Activity	Receptor	Impact	Nature of Impact	Value & Sensitivity	Magnitude of change	Significance of impact
Blasting during	Community	Increase level of	Adverse Direct	Low	Minor	Low (2)

Activity	Receptor	Impact	Nature of Impact	Value & Sensitivity	Magnitude of change	Significance of impact
decline development and other mining activities		noise that can be heard by neighbours	Reversible Minor Short term Local Unlikely			
Blasting during decline development and other mining activities	On-site employees	Prolonged noise pollution may lead to hearing loss of employees	Adverse Direct Irreversible Moderate Short term On-site Possible	Low	Moderate	Low (2)

7.4.6 HERITAGE AND CULTURE IMPACTS

The Gergarub Project lies within an area of archaeological significance with 18 identified archaeological heritage sites in a protected landscape area within and near ML 245. However, the Gergarub active mining site does not fall within these landscapes as shown in Figure 48. During the archaeological assessment carried out by Dr John Kinahan (2023), 18 sites were assessed and ranged from minor isolated finds to multi-component sites with low threat to direct and certain threats. The study also described in depth; how one burial site was excavated. The specific impacts to heritage in the project area before mitigation during the construction and operation phases are presented in Figure 47. The potential archaeological heritage and cultural impacts associated with the Project were assessed and are further described below.

Figure 47 - Heritage and cultural impacts during the Gergarub project

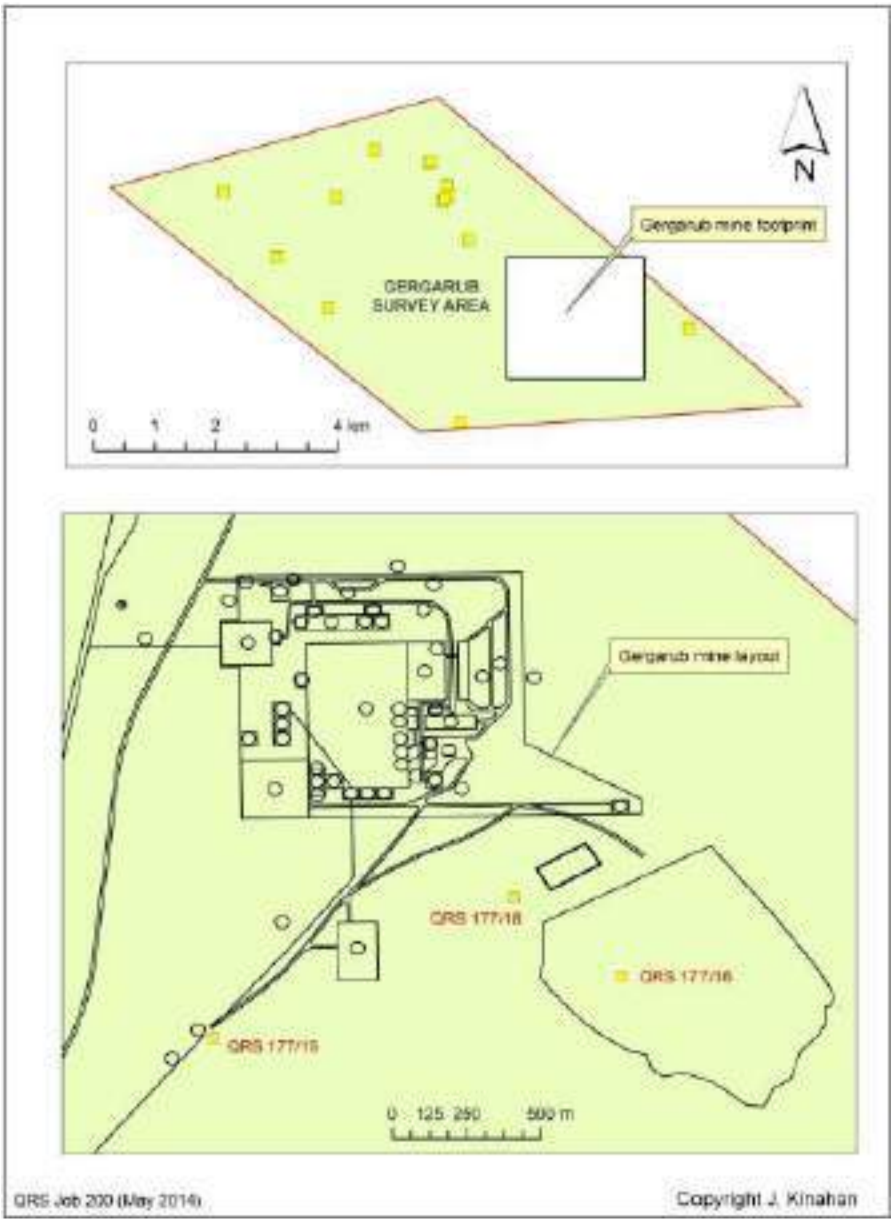


Figure 48 - Heritage sites associated with the Gergarub mine

7.4.6.1 Physical destruction of heritage sites that are near the Gergarub mining project.

It is expected that during the construction phase of the Project, the associated activities may cause the physical disturbance and destruction of heritage sites or remains within proximity of Project. There is a high probability of direct or collateral impact on three archaeological sites at Gergarub, namely QRS 177/15, 177/16 and 177/18, and a relatively low or medium probability of such impacts on the remaining fifteen sites (Kinahan, 2023). The nature of the impact is adverse, direct and irreversible due to the permanent loss or damage to valuable remains. Due to the importance and value of archaeological heritage in Namibia it is important that the proper procedures will be followed throughout the Gergarub project to minimise any potential damage to archaeological objects.

Mitigations highlighted in the archaeological assessment includes direct, site-specific actions such as mapping, systematic surface collection and excavation and removal in the case of sites discovered such as burials and graves, which should be led by the precautionary principle. The Archaeological heritage GIS database, along with mitigation measures outlined with the project EMP should essentially form part of site audits. It is highly recommended that the archaeological Chance Finds procedure should form part of the project EMP.

The magnitude of change is major due to the potentially severe damage to a heritage site within the ML 245 vicinity (Table 21). The sensitivity of receptor will be high due to the National extent of the potential impact. The overall significance is major, however, with mitigation measures, the impact will be moderate.

7.4.6.2 Potential damage and cultural violation during the excavation process

During the excavation of burial site QRS 177/18, potential damage, disturbance and disregard for cultural norms is a potential impact. The archaeologist responsible for the excavation, Dr John Kinahan, detailed the requirements and the procedure followed in the archaeological assessment report. It has been noted that although 91% complete, the human bones encountered were very poorly preserved, largely due to the weight of the large rocks used in filling the burial shaft and the fact that the bones were extensively leached and fragile. However, the bones were carefully extracted and securely packed for transport. The nature of the impact is adverse, direct and irreversible.

Before excavation occurred, a permit was issued by the National Heritage Council and an agreement was made with National Museum of Namibia to store the remains. During the excavation, the skeleton was removed, cleaned by use of dry brush and safely transported for analysis. The remains recovered from the site are housed in the National Museum of Namibia Archaeology Collection under accession number B4367. It is extremely unlikely that any damage was inflicted to the remains during the excavation practices.

The magnitude of change is moderate due to the removal of an archaeological site and the sensitivity of the receptor is high due to the national extent of the impact. It is highly unlikely that there was any damage, disturbance and violation of cultural traditions during excavation processes, therefore the overall significance of the impact is moderate.

7.4.6.3 Potential discovery of new cultural heritage sites and artifacts

During construction and operations, discovery of new cultural heritage sites, objects and artifacts may occur within the general mining area. Within recent decades more historical and archaeological remains have been discovered during mining operations such as the archaeological shipwreck during diamond operation near Oranjemund. In cases where heritage sites are discovered, the 'chance find procedure' will be used as implemented in the EMP. The nature of the impact is beneficial, direct and irreversible. Should any major discoveries be made, this may be substantial for both the Namibian cultural heritage and cultural tourism. Therefore, the magnitude of change is major, and the sensitivity of receptor will be high due to the National benefit associated with this impact.

7.4.6.4 Potential damage and disturbance to new cultural heritage discoveries and artifacts

During construction and operations, there is potential to unearth valuable heritage objects and artifacts. Should there be no awareness among employees or archaeological Chance Finds procedures in place, the valuable findings may be potentially damaged, disturbed or destroyed during mining activities. The nature of the impact will be adverse, direct, irreversible and permanent.

Mitigations are described in section 7.4.6.1 and in the Project EMP. The magnitude of change is major due to the severity of the damage to important archaeological artifacts. The sensitivity is high due to the national extent, should the impact occur. The overall significance is major, however, with mitigation measures, the impact will be moderate.

Table 21 - Heritage and cultural impacts

Activity	Receptor	Impact	Nature of Impact	Value & Sensitivity	Magnitude of change	Significance of impact
Construction and operational activities	Cultural heritage	Physical disturbance and destruction of sites or remains within proximity of Project surface works	Adverse Direct Irreversible High/major Permanent National Possible	High	Major	Major (9)
Excavation of burial site QRS 177/18	Cultural Heritage	Potential damage, disturbance and violation of cultural traditions during excavation of burial site QRS 177/18	Adverse Direct Irreversible High/major Permanent National Unlikely	High	Moderate	Moderate (6)
Construction and operational activities	Cultural heritage	Discovery of new cultural heritage sites and artifacts	Beneficial Direct Irreversible High/major Permanent National	High	Major	Beneficial Major (9)

Activity	Receptor	Impact	Nature of Impact	Value & Sensitivity	Magnitude of change	Significance of impact
			Possible			
Construction and operational activities	Cultural heritage	Potential damage and disturbance to new cultural heritage discoveries and artifacts	Adverse Direct Irreversible High/major Permanent National Possible	High	Major	Major (9)

7.4.7 SOCIAL IMPACTS

Mines and mining towns have a significant impact on the social fabric of a mining community, either being positive or negative. The degree of these impacts can vary depending on the size of the mine, and the size of the community associated with the mine. The town of Rosh Pinah already has two mines that contribute to the town, those two mines being Rosh Pinah Zinc Corporation (RPZC) and Skorpion Zinc (which is under care and maintenance), the addition of an additional mine will have further impacts on the town.

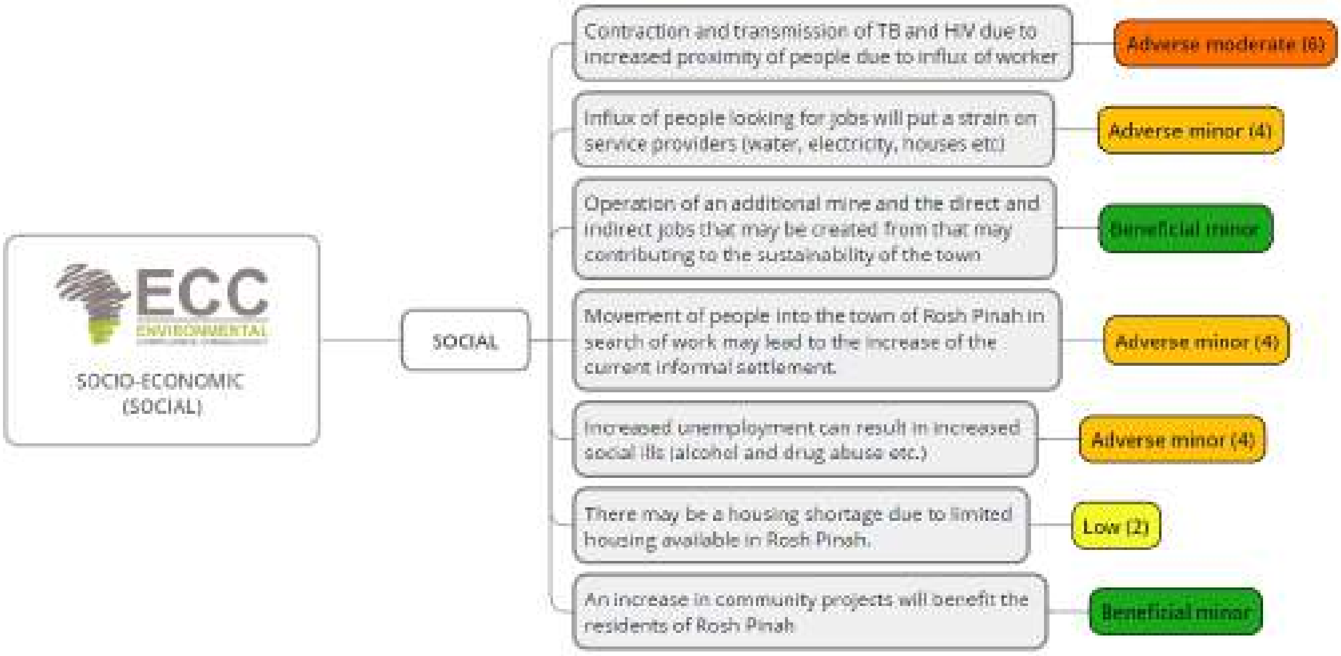


Figure 49 - Social impacts.

7.4.7.1 Impact of an influx of people into Rosh Pinah looking for work may increase the spread of communicable diseases.

New mines often attract an influx of people to areas in search of job opportunities. With the influx of people into the town for work they may not meet the requirements of the vacancies advertised by the mine, which may lead to increased unemployment rates in the town. The nature of this impact is adverse and indirect. The impact is partly reversible, while the magnitude of change is high. The duration of the impact is long-term, and the extent of the impact is regional. The probability of this impact is possible. Therefore, this impact has been rated adverse moderate.

7.4.7.2 Impact of an increased pressure placed on municipal services due to an increase in residents in Rosh Pinah.

Currently, water is supplied to the town by NamWater which is sourced from the Orange River and pumped to the town. Water provision for the town and the two mines is currently at full capacity, therefore adding additional pressure to supply water to the additional mine and employees residing in Rosh Pinah. Additionally, the new mine and additional residents residing in the town will put extra stress on the electricity that needs to be supplied to the town. There will need to be significant investment from either government or private investment to assist in upgrading and expanding municipal services to meet the increasing demand. The nature of this impact is adverse and indirect, the impact is reversible, and the magnitude of change is low. The duration of the impact is medium term while the extent of the impact is local. The probability of this impact occurring is likely. Therefore, this impact has been rated adverse minor.

7.4.7.3 Impact of the presence of the mine and associated investment and diversification of the economy will aid in the sustainability of the town of Rosh Pinah.

The presence of the new mine will attract investment to the Town of Rosh Pinah along with the infrastructure development and upgrades that will be required will result in a more diverse economy being developed in the town. The increased economic investment and infrastructure development will facilitate sustaining the sustainability and longevity of the town. However, the town will need to develop an economy that does not revolve around the mine to sustain the town long after mine closure and prevent an unemployment epidemic once the mine closes. The nature of this impact is adverse and indirect. The impact is reversible, and the magnitude of change is high, while the duration of the impact is medium-term, and the extent is local. The possibility of this impact occurring is likely to occur. Therefore, this impact has been rated beneficial minor.

7.4.7.4 Impact of an influx of job seekers may lead to an expansion of the current informal settlement in Rosh Pinah.

People often migrate to Rosh Pinah in hopes of being employed by the mine. If job seekers are unable to find jobs at either the mine or other businesses in the town, they may set up informal housing structures as can already be observed with the ever-growing Tutungeni informal settlement. Furthermore, family members are sent from different parts of Namibia to stay with family members residing in Tutungeni further exacerbating the problem and putting pressure on RoshSkor to provide municipal and health services and schools. The nature of this impact is adverse and indirect. The impact is partly reversible, and the magnitude of change is high. The duration of the impact is medium term while the extent of the impact is local. The possibility of this impact occurring is likely to occur. Therefore, the significance of this impact has been rated as adverse minor.

7.4.7.5 Impact of an increase in the migration of people to the town of Rosh Pinah along with growing unemployment rates can result in increased social ills.

The more people that move into Rosh Pinah may lead to more social tension, especially as an increase in people near each other may lead to an increase in social ills. Social tension may lead to increasing acts of violence such as robbery, house and business break-ins, an increase in interpersonal violent crimes, substance abuse, prostitution, and teenage pregnancies. This may lead to a deterioration of the social fabric of the community. The nature of this impact is adverse and indirect while being partly reversible. The magnitude of change of the impact is high, the duration of impact is long-term, and the extent is local. The possibility of this impact occurring is possible and the sensitivity of the impact is low. Therefore, the significance of this impact has been rated as adverse minor.

7.4.7.6 The impact of limited housing available in Rosh Pinah coupled with an increase of people moving into the town to settle and find jobs.

Only so many private erven are available for purchase from RoshSkor, which may mean that more housing will have to be built to provide for workers. However, there is a limit on how far the town can expand as the town cannot expand to the north and north fenced so to speak by a 100-year flood line (Saayman, Quzette, et al., 2015). This may create a housing shortage and crisis in Rosh Pinah and may further exacerbate the informal settlement predicament in Rosh Pinah. The nature of this impact is therefore adverse and indirect, while reversible. The magnitude of change of the impact is low, the duration short term and the extent is local. The possibility of the impact occurring is possible and the sensitivity of the impact is low. The significance of the impact has therefore been rated adverse low.

7.4.7.7 The impact of an increase in community projects in Rosh Pinah from CSR inputs from the Proponent.

Currently, RoshSkor facilitate various community Projects in the town of Rosh Pinah such as Hospitality training; Needlework classes; Tutungeni Centre for Hope for orphans and vulnerable children; School Principals training in Hardap Region; community garden and more. During the public engagement period, community projects were a big concern of the community and there was a request for more community Projects that would benefit the community e.g., VTC and a fire department. The Proponent will evaluate CSR projects as the project and community needs evolve. The nature of this impact is adverse and direct. The impact is reversible, and the magnitude of change is moderate. The duration of the impact is short term while the extent of the impact is local. The probability of this impact occurring is likely, while the sensitivity of the impact is low. Therefore, this impact has been rated as beneficial low.

7.4.7.8 The impact of an increased pressure on current already strained health care services due to an increase of residents in Rosh Pinah.

There are two clinics in Rosh Pinah, one being a private clinic, Sidadi day Clinic and the other a state-owned clinic. The equipment and the employment of medical professionals at these facilities are quite costly. Therefore, with an influx of additional people to the town would put additional pressure on an already strained system and resources. Currently, residents have to travel long distances when they require serious operations or require serious medical care, this puts many residents at risk should any serious medical emergencies ensue. The nature of this impact is adverse and indirect, the impact is reversible, and the magnitude of change is low. The duration of the impact is medium term while the extent of the impact is local. The probability of this impact occurring is likely. Therefore, this impact has been rated adverse minor.

7.4.7.9 The impact of an increase in the need for school facilities in the town due to an increase in the number of families with children residing in the town.

There are currently three schools in Rosh Pinah, two government schools namely Hoeksteen Combined School and Tsau//Khaeb Secondary School, a private school, Rosh Pinah Academy and a preschool – Stepping Stones Pre-Primary. The increase of people moving into the town with their families and the increasing births of children during the LoM will put more pressure on the town's current already over-capacitated schools to accommodate the growing school-going residents of the town. The nature of this impact is adverse and indirect, the impact is reversible, and the magnitude of change is low. The duration of the impact is medium term while the extent of the impact is local. The probability of this impact occurring is likely. Therefore, this impact has been rated adverse minor (Table 22).

Table 22 - Social Impacts

Activity	Receptor	Impact	Nature of Impact	Value & Sensitivity	Magnitude of change	Significance of impact
The influx of workers into Rosh Pinah	Community	Contraction and transmission of TB and HIV due to increased proximity of people due to influx of workers	Adverse Indirect Partly reversible High Long term Regional Possible	Medium	High	Moderate (6)
	Municipality	Influx of people looking for jobs will put a strain on service providers (water, electricity, houses, health facilities,	Adverse Indirect Reversible Low Medium Term Local Likely	Low	Low	Minor (3)

Activity	Receptor	Impact	Nature of Impact	Value & Sensitivity	Magnitude of change	Significance of impact
		schools etc)				
Increase in services being provided to the town	Community	Contributing to the sustainability of the town	Beneficial Indirect Reversible High Medium-term Local Likely	Low	High	Beneficial Minor
Influx of job seekers	Community	Movement of people into the town of Rosh Pinah in search of work may lead to the increase of the current informal settlement.	Adverse Indirect Partly reversible High Medium term Local Possible	Low	High	Minor (3)
	Community	Increased unemployment can result in increased social ills (alcohol and drug abuse etc.)	Adverse Indirect Partly reversible High Medium term Local Likely	Low	High	Minor (3)
	Community	A housing shortage due to limited housing available in Rosh Pinah.	Adverse Indirect Reversible Low Short term Local Possible	Low	Low	Low (2)
An increase in community projects	Community	Will benefit the residents and community of Rosh Pinah	Adverse Indirect Reversible Moderate	Low	Moderate	Beneficial Low

Activity	Receptor	Impact	Nature of Impact	Value & Sensitivity	Magnitude of change	Significance of impact
will benefit the residents of Rosh Pinah			Short term Local Possible			

7.4.8 OCCUPATIONAL HEALTH AND SAFETY IMPACTS

Major mining hazards associated with underground mining include but are not limited to underground fires, ground control failures, inrush, and subsidence. These hazards pose a unique risk that is specific to underground mining operations. While some elements of these risks can be mitigated through detailed planning often the management of these risks rely on strong operational management, safe working procedures and where possible the use of mechanical aids to reduce employee exposure. The potential social impacts associated with the Project were assessed and are further described below in Table 23.

Figure 50 - Impacts on social aspects

Table 23 - Occupational health and safety impacts

Activity	Receptor	Impact	Nature of Impact	Value & Sensitivity	Magnitude of change	Significance of change
Ground control	Employee Occupational Health and Safety	Injury to employees due to poor ground support or ground failure	Adverse Direct Partly Reversible High Medium Term Local	High	High	High (9)
Loud machinery	Employee	Hearing	Adverse	Moderate	Medium	Moderate (6)

Activity	Receptor	Impact	Nature of Impact	Value & Sensitivity	Magnitude of change	Significance of change
and blasting	Occupational Health and Safety	loss from loud equipment and blasting underground	Direct Irreversible High Long term On-site Possible			
Heat from the natural underground environment and mining equipment and activities	Employee Occupational Health and Safety	Dehydration/heat stress from extreme heat in underground working environment	Adverse Direct Reversible Minor Temporary On-site Possible	Low	Minor	Low (2)
Fire	Employee Occupational Health and Safety	Underground fire incident	Adverse Direct Irreversible High Long Term Local	High	High	High (9)
Mobile equipment	Employee Occupational Health and Safety	Collision of underground mining equipment causing injury to people	Adverse Direct Partly Reversible Moderate Short Term On-site	High	Moderate	Moderate (6)
Inrush and subsidence	Employee Occupational Health and Safety	Inrush or subsidence event within the underground mine causing injury and harm to people and project feasibility	Adverse Direct Irreversible Very High Long Term Regional	High	Very High	Major (12)

7.5 BIOPHYSICAL ENVIRONMENT

7.5.1 SOIL IMPACTS

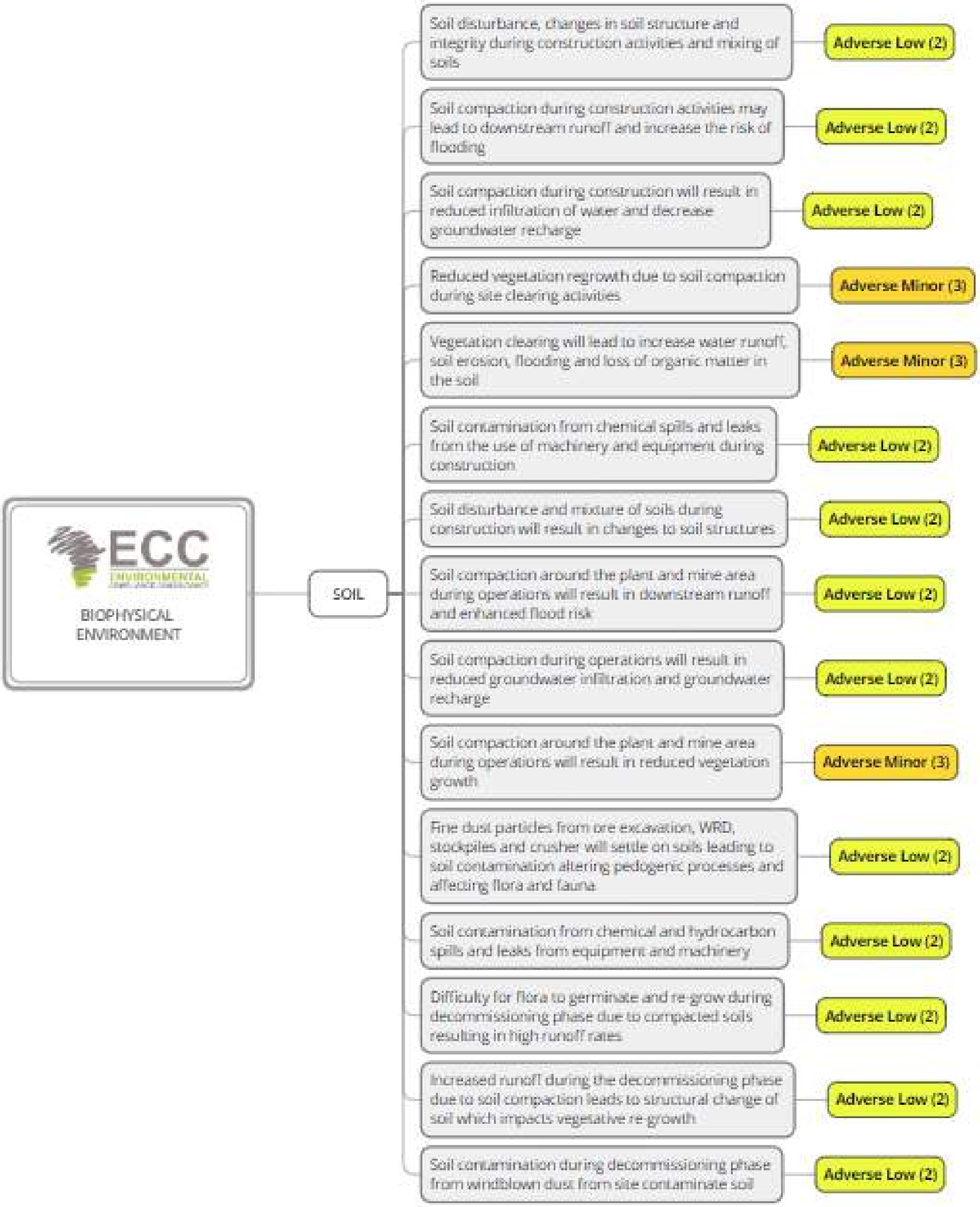


Figure 51 - Soil Impacts

7.5.1.1 *Activities during construction may cause soil disturbance, changes in soil structure and may lead to the mixing of soils which may lead to changes in soil structure and integrity.*

Construction activities significantly influence the soil, causing disturbances and modifications to its structure and integrity. The operation of heavy machinery induces compaction, leading to soil mixing during excavation and backfilling. This process alters the composition and drainage properties, resulting in a detrimental impact on soil quality. This impact is considered adverse and direct, but it is temporary and only persists during construction activities. The impact is localized on-site, reversible, and characterized by a low magnitude of change. The probability of occurrence is definite. Given the local nature of the impact and the receptor's capacity to accommodate change its sensitivity is low, the overall rating for this impact is considered adverse low.

7.5.1.2 *Construction activities may lead to soil compaction and may result in increased downstream runoff and enhanced flood risk.*

Construction activities can lead to soil compaction, reducing pore spaces between soil particles and diminishing natural permeability. This limits the soil's ability to absorb water, potentially causing increased downstream runoff. Compacted soil is less effective in retaining water during rainfall, leading to rapid surface runoff and an elevated risk of flooding in downstream areas near the construction site. This impact is considered adverse and direct, but it is temporary and only persists during construction activities. The impact is localized on-site, reversible, and characterized by a low magnitude of change. The probability of occurrence is definite. Given the local nature of the impact and the receptor's capacity to accommodate change, the sensitivity is low, the overall rating for this impact is considered adverse low.

7.5.1.3 *Construction activities may lead to soil compaction and result in reduced infiltration of groundwater recharge.*

Construction activities, often involving heavy machinery and the movement of materials, can lead to soil compaction, increasing soil density by eliminating air spaces between particles. This process has several negative effects on the soil and the environment, including reduced water infiltration, increased surface runoff leading to erosion and pollution, negatively impacting soil organisms and plant roots dependent on oxygen. This impact is considered adverse and direct, but it is temporary and only persists during construction activities. The impact is localized on-site, reversible, and characterized by a low magnitude of change. The probability of occurrence is definite. Given the local nature of the impact and the receptor's capacity to accommodate change makes its sensitivity low, the overall rating for this impact is considered adverse low.

7.5.1.4 *Removal of vegetation during construction may lead to reduced vegetation regrowth due to increased soil compaction.*

During construction, the removal of vegetation hinders plant regrowth due to increased soil compaction. Construction activities, particularly the use of heavy machinery, contribute to soil compaction by compressing the soil and reducing pore spaces. Loss of root systems that anchor the soil and facilitate aeration, making the soil more prone to compaction. The absence of protective vegetation cover exposes the soil to erosion, further compacting it and reducing its ability to absorb water and nutrients. The removal of vegetation also diminishes organic matter, essential for soil structure, and disrupts microbial activity, negatively impacting nutrient cycling. The absence of vegetation as a natural mulch removes a protective layer, making the soil more susceptible to compaction. Compacted soil presents challenges for seed germination, hindering the establishment of new vegetation. The long-term effects of soil compaction create a cycle that obstructs the natural regrowth of vegetation, as compacted soil becomes less conducive for plant roots to penetrate and establish themselves. This impact is considered adverse and direct, but it is temporary and only persists during construction activities. The impact is localized on-site, reversible, and characterized by a moderate magnitude of change. The probability of occurrence is likely. Given the local nature of the impact and the receptor's capacity to accommodate change is low, the overall rating for this impact is considered adverse minor.

7.5.1.5 Vegetation clearing during construction may lead to an increase in runoff, erosion, flooding, and loss of organic matter in the soil.

Vegetation plays a crucial role in ecological balance by absorbing rainwater and reducing surface runoff. Removal of vegetation results in increased runoff, potentially causing water pollution as it carries pollutants from construction sites. Additionally, the root systems of vegetation help stabilize soil and prevent erosion. Without this protection, soil becomes more vulnerable to erosion, leading to the loss of fertile topsoil and decreased land productivity. Increased runoff and soil erosion also elevate the risk of flooding, as vegetation acts as a natural buffer that absorbs and slows down water flow. Furthermore, the clearing of vegetation removes a vital source of organic matter for the soil, impacting fertility and structure. This loss can lead to decreased water retention capacity and heightened susceptibility to erosion. Finally, habitat loss due to vegetation clearing can contribute to a decline in biodiversity, with far-reaching effects on the entire ecosystem. This impact is considered adverse and indirect, but it is temporary and only persists during construction activities. The impact is localized on-site, reversible, and characterized by a moderate magnitude of change. The probability of occurrence is definite. Given the local nature of the impact and the receptor's capacity to accommodate change is low, the overall rating for this impact is considered adverse minor.

7.5.1.6 Chemical spills and leaks from equipment and machinery during construction may lead to soil contamination.

Chemical spills and leaks during construction can contaminate soil through pathways such as surface runoff, infiltration, direct contact with machinery, accumulation in sediments, vaporization, and wind transport. The impact depends on chemical types, quantities, soil characteristics, and local conditions. Spilled chemicals may be carried by runoff into soil and water bodies, while infiltration can lead to groundwater contamination. Machinery leaks can directly introduce contaminants, and wind can transport particles, depositing them in surrounding areas. Persistent chemicals, like POPs and heavy metals, may accumulate in the soil, causing long-term contamination. Soil contamination can disrupt ecosystems, affecting organisms, plants, and biodiversity. This impact is considered adverse and direct, but it is temporary and only persists during construction activities. The impact is localized on-site, reversible, and characterized by a low magnitude of change. The probability of occurrence is definite. Given the local nature of the impact and the receptor's capacity to accommodate change and sensitivity is low, the overall rating for this impact is considered adverse low.

7.5.1.7 During operation soil compaction around the plant or mine area may lead to increased downstream runoff and enhance the risk of flooding plant or underground mine area.

Soil compaction adversely impacts the hydrological cycle and elevates flood risks in plant or underground mine areas. This occurs through reduced pore spaces in compacted soil, hindering water infiltration and promoting surface runoff during precipitation or irrigation. The formation of impermeable compacted surface layers exacerbates this runoff effect, limiting the soil's water absorption capacity. The combination of reduced vegetation, increased runoff, and erosion heightens the risk of sedimentation in water bodies, decreasing channel capacity and raising flood probabilities. Altered water flow paths, faster surface runoff, and higher peak flows in rivers and streams can overwhelm natural drainage systems, contributing to flash floods. Compacted soil prolongs surface water flow, accumulating and moving downstream, further increasing flood risk. The diminished water storage capacity of compacted soil during heavy rainfall or snowmelt intensifies runoff, amplifying flooding dangers. Additionally, soil compaction alters subsurface drainage, redirecting water towards lower elevations, raising groundwater levels, and aggravating flood risks in low-lying areas. This impact is considered adverse and direct, but it is temporary and only persists during construction activities. The impact is localized on-site, reversible, and characterized by a low magnitude of change. The probability of occurrence is likely. Given the local nature of the impact and the receptor's capacity to accommodate change sensitivity is low, the overall rating for this impact is considered adverse low.

7.5.1.8 Soil compaction around the plant and mine area during operations may lead to reduced groundwater infiltration and recharge.

Soil compaction around plant and mine areas diminishes pore space crucial for water movement, causing reduced water-holding capacity. This leads to increased surface runoff, preventing water from infiltrating and recharging groundwater. Compaction forms impermeable layers, acting as barriers to downward water movement. It disrupts soil structure, transforming it into compacted layers that impede water flow. Additionally, compacted soil exhibits lower infiltration rates, resulting in decreased groundwater recharge. Compaction makes soil prone to erosion, reducing its permeability further. Continuous operations exacerbate compaction, diminishing the soil's ability to recover its natural structure over time. This impact is considered adverse and direct and is long term as the impact will last for the LoM. The impact is localized on-site, reversible, and characterized by a low magnitude of change. The probability of occurrence is definite. Given the local nature of the impact and the receptor's capacity to accommodate change sensitivity is low, the overall rating for this impact is considered adverse low.

7.5.1.9 Soil compaction may result in reduced vegetation re-growth.

Soil compaction impedes vegetation re-growth by limiting water infiltration, causing poor drainage and increased runoff. It restricts air flow, reducing oxygen levels critical for root growth and plant processes. Additionally, it hinders root penetration, resulting in shallow root systems and reduced access to nutrients and water. Soil compaction disrupts microbial activity, impacting nutrient cycling, and the lower porosity contributes to overall soil structure degradation, creating an unfavorable environment for plant growth. This impact is considered adverse and direct and is long term as the impact will last for the LoM. The impact is localized on-site, reversible, and characterized by a moderate magnitude of change. The probability of occurrence is likely. Given the local nature of the impact and the receptor's capacity to accommodate change sensitivity is low, the overall rating for this impact is considered adverse minor.

7.5.1.10 Soil contamination resulting from fine dust particles of ore and waste rock settled on soil may alter pedogenic process and adversely affect flora and fauna.

Soil contamination from fine dust particles in ore and waste rock deposition can adversely impact the environment and ecosystems. This contamination alters soil structure, causing compaction and reduced water infiltration. The dust may contain metals such as lead, cadmium, and arsenic, leaching into the soil and harming fertility. Changes in soil pH affect nutrient availability and heavy metal solubility. Plants may experience stunted growth and reduced yield. Fauna, including insects and worms, can accumulate contaminants, affecting animals higher up the food chain. Rainwater transport of dust can lead to water contamination, posing risks to aquatic ecosystems and human health. Fine dust particles contribute to soil erosion, disrupting water bodies and affecting water quality. This impact is considered adverse and direct and is medium term as the impact will last for the LoM. The impact is local, reversible, and characterized by a low magnitude of change. The probability of occurrence is likely. Given the local nature of the impact and the receptor's capacity to accommodate change sensitivity is low, the overall rating for this impact is considered adverse low.

7.5.1.11 Chemical and hydrocarbon spills and leaks from equipment and machinery during operation may lead to soil contamination.

Chemical spills and leaks during construction can contaminate soil through pathways such as surface runoff, infiltration, direct contact with machinery, accumulation in sediments, vaporization, and wind transport. The impact depends on chemical types, quantities, soil characteristics, and local conditions. Spilled chemicals may be carried by runoff into soil and water bodies, while infiltration can lead to groundwater contamination. Machinery leaks can directly introduce contaminants, and wind can transport particles, depositing them in surrounding areas. Persistent chemicals, like POPs and heavy metals, may accumulate in the soil, causing long-term contamination. Soil contamination can disrupt ecosystems, affecting organisms, plants, and biodiversity. This impact is considered adverse and indirect and is long term as the impact will last for the LoM. The impact is localized on-site, reversible, and characterized by a low magnitude of change. The probability of occurrence is likely. Given the local nature of the impact and the receptor's capacity to accommodate change sensitivity is low, the overall rating for this impact is considered adverse low.

7.5.1.12 After mine closure compacted soils may remain for many years making it difficult for other flora to germinate or grow and thus causes an increase in water runoff and erosion.

Mining activities will disturb the natural landscape, leaving exposed soils that are often compacted and lacking vegetation after closure. This compacted soil poses challenges for ecosystem recovery by reducing porosity and permeability, hindering water infiltration, and causing increased surface runoff. The diminished vegetation cover and compacted soil elevate the risk of erosion, leading to the loss of crucial topsoil for plant growth. The compacted soil also impedes seed germination and root penetration, hindering natural vegetation regeneration and the establishment of a diverse plant community. This difficulty for diverse plant species to thrive in compacted soils can result in a decline in biodiversity, affecting the entire ecosystem and the various animal species dependent on vegetation for habitat and food. Reclamation efforts are essential to mitigate these issues and restore the land to a condition that supports sustainable ecosystems. This impact is considered adverse and direct and is medium term, taking roughly 5 -15 years to recover. The impact is localized on-site, reversible, and characterized by a low magnitude of change. The probability of occurrence is likely. Given the local nature of the impact and the receptor's capacity to accommodate change sensitivity is low, the overall rating for this impact is considered adverse low.

7.5.1.13 After mine closure increased water runoff and changes in soil structure may result in difficulty for flora to germinate and revegetate the area.

Certain impacts mentioned above may still occur long after mine closure. The environment can still be impacted through altered water runoff, changes in soil structure, and disruptions to ecological succession. Increased surface runoff and erosion result from land disturbance during mining, affecting water bodies negatively. Soil compaction and contamination persist post-closure, hindering water penetration and plant growth. Challenges like the lack of organic matter and nutrient depletion impede seed germination and revegetation. Mining disrupts natural ecological succession processes, making it difficult for ecosystems to recover independently. Addressing these issues requires comprehensive mine closure plans and restoration strategies. This impact is considered adverse and direct and is medium term, taking roughly 5 -15 years to recover. The impact is localized on-site, reversible, and characterized by a low magnitude of change. The probability of occurrence is likely. Given the local nature of the impact and the receptor's capacity to accommodate change sensitivity is low, the overall rating for this impact is considered adverse low.

7.5.1.14 After mine closure windblown dust from the WRDs and TSF may result in soil contamination.

WRDs consist of rocks extracted during mining without economically viable mineral levels, and if left exposed after closure, wind can transport potentially harmful dust particles, including heavy metals. TSFs store waste slurry from ore processing, containing fine particles and chemicals. Poor TSF management after closure can lead to wind dispersal of fine particles, causing soil contamination. Wind-carried dust can settle on nearby soil, affecting ecosystems, vegetation, and potentially water quality if contaminants leach into water bodies. This impact is considered adverse and direct and is short term, taking roughly 5 years until rehabilitation of site takes place to recover. The impact is local, reversible, and characterized by a low magnitude of change. The probability of occurrence is likely. Given the local nature of the impact and the receptor's capacity to accommodate change sensitivity is low, the overall rating for this impact is considered adverse low (Table 24).

Table 24 - Impacts on soil

Activity	Receptor	Impact	Nature of impact	Value & Sensitivity	Magnitude of change	Significance of impact
Construction activities and mixing of soils	Soil	soil disturbance, changes in soil structure and integrity	Adverse Direct Temporary Onsite Reversible Low Definite	Low	Low	**Low (2)**
Construction activities	Soil	Soil compaction may lead to downstream runoff and increase the risk of flooding	Adverse Direct Temporary Onsite Reversible Low Definite	Low	Low	**Low (2)**
	Soil and Groundwater	Soil compaction will result in reduced infiltration of water and decrease groundwater recharge	Adverse Direct Temporary Onsite Reversible Definite Low	Low	Low	**Low (2)**
Site clearing during construction	Soil Vegetation (Flora)	Reduced vegetation regrowth due to soil compaction	Adverse Direct Temporary Onsite Reversible Likely Moderate	Low	Moderate	**Minor (3)**
Site clearing during construction	Soil	Vegetation clearing will lead to increase water runoff, soil erosion, flooding and loss of organic matter in the	Adverse Direct Temporary Onsite Reversible Definite Moderate	Low	Moderate	**Minor (3)**

Activity	Receptor	Impact	Nature of impact	Value & Sensitivity	Magnitude of change	Significance of impact
		soil				
Use of machinery and equipment during construction	Soil	Soil contamination from chemical spills and leaks	Adverse Direct Temporary Onsite Reversible Likely Low	Low	Low	**Low (2)**
Construction activities	Soil	Soil disturbance and mixture of soils will result in changes to soil structures	Adverse Direct Temporary Onsite Reversible Definite Low	Low	Low	**Low (2)**
Operational activities	Soil	Soil compaction around the plant and mine area will result in downstream runoff and enhanced flood risk	Adverse Direct Long term Onsite Definite Reversible Low	Low	Low	**Low (2)**
	Soil	Soil compaction will result in reduced groundwater infiltration and groundwater recharge	Adverse Direct Long term Onsite Definite Reversible Low	Low	Low	**Low (2)**
	Soil Vegetation (Flora)	Soil compaction around the plant and mine area will result in reduced vegetation growth	Adverse Direct Long term Onsite Likely Reversible Moderate	Low	Moderate	**Minor (3)**

Activity	Receptor	Impact	Nature of impact	Value & Sensitivity	Magnitude of change	Significance of impact
	Soil, Fauna and Flora	Fine dust particles from ore excavation, WRD, stockpiles and crusher will settle on soils leading to soil contamination altering pedogenic processes and affecting flora and fauna	Adverse Indirect Short term Local Definite Likely Reversible Low	Low	Low	**Low (2)**
	Soil	Soil contamination from chemical and hydrocarbon spills and leaks from equipment and machinery	Adverse Direct Medium term Onsite Likely Reversible Low	Low	Low	**Low (2)**
Decommissioning/ Mine closure	Soil	Difficulty for flora to germinate and re-grow due to compacted soils resulting in high runoff rates	Adverse Direct Medium term Onsite Likely Reversible Low	Low	Low	**Low (2)**
	Soil and vegetation (flora)	Increased runoff due to soil compaction leads to structural change of soil which impacts	Adverse Direct Medium term Onsite Likely Reversible Moderate	Low	Moderate	**Low (2)**

Activity	Receptor	Impact	Nature of impact	Value & Sensitivity	Magnitude of change	Significance of impact
		vegetative re-growth				
	Soil	Soil contamination from windblown dust from site contaminate soil	Adverse Indirect Short term Local Likely Reversible Low	Low	Low	**Low (2)**

7.5.2 SURFACE AND GROUNDWATER IMPACTS

Figure 52 - Impacts of construction and operation activities on drainage and hydrology

7.5.2.1 The impact of construction and operations of the Project to drainage and hydrology of the site

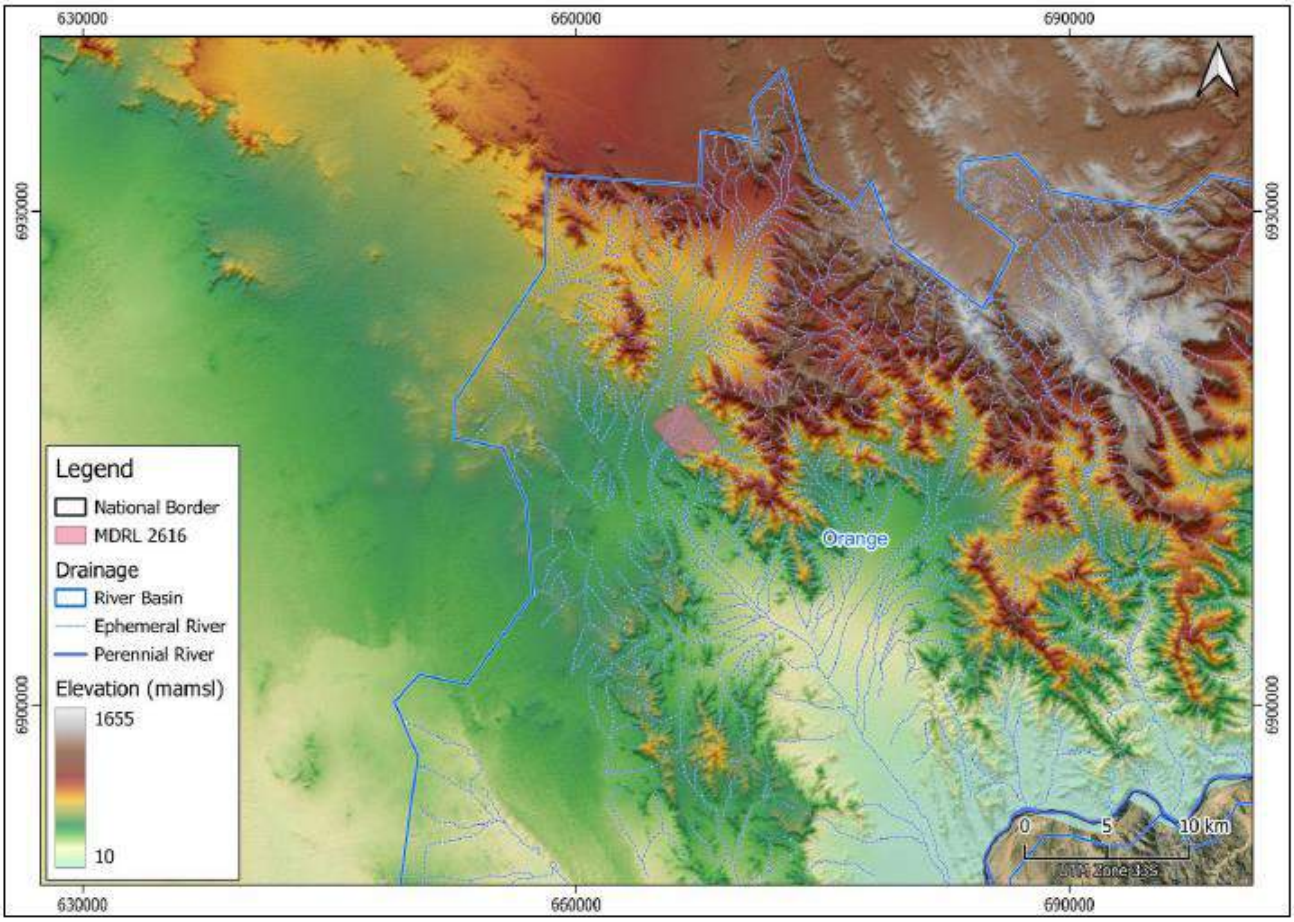


Figure 53 - Regional drainage map of the area (de Bruin et al., 2023)

7.5.2.1.1 The impact of diverting water away from the site causing a lag/reduction in downstream flow during construction and operation.

Figure 53 shows generalised drainage pattern of the region, including MDRL 2616, where numerous ephemeral water courses drain the site where various mining infrastructure will be constructed. Hydrologic (2023) notes many minor ephemeral rivers to the east of the mining licence (and the C13 road), originating in the highlands around the site. These ephemeral rivers only flow after significant rainfall events and lack running water throughout most of the year. To the west of the site (and the C13 road), the ephemeral rivers become larger in association with the containing catchment which collects rainfall and associated runoff from this catchment. These larger ephemeral rivers are positioned over the lower-lying valley of the containing catchment which runs from north to south. In considering the site's soil characteristics, crucial for infiltration and run-off characterisation, soils are classified as loam, loamy sand, and sandy loam. Land cover mapping identifies grassland, bare areas, and sparse vegetation across the site while in terms of vegetation, the site is considered to fall within the succulent Karoo biome. Hydrological flood modelling identified the need for diversion structures (see Figure 54) to avoid flooding from flow generated in the catchment east of the site and through the proposed position of the TSF wall (from east to west). Managing run-on (flooding) towards the site may entail diverting flow out of the natural water course and away from vital infrastructure. Diversion of surface water flow may result in a lag or reduction of flow further downstream and in adjoining water courses. Sediment distribution down stream of site may be altered, changing local drainage patterns, influencing spatial and temporal recharge of shallow alluvial aquifers (reduction in baseflow) and altering flow paths which may during intense rainfall events lead to localised flooding of previously dry areas and alter soil forming processes.

Modifications to flow patterns can have ecological implications, as downstream ecosystems may be accustomed to specific flow regimes. Such alterations can disrupt habitats, impact vegetation, and affect organisms reliant on a particular water flow. Neglecting the risk of flooding (particularly related to the TSF) may lead to mobilisation and redistribution of contaminant concentrations in intermittent flows, soils and baseflow. Soils are, however, highly permeable so this is not expected to carry additional sediment or contaminants into a major or perennial water course. As the surrounding environment is sparsely vegetated and no human communities or settlements are nearby, impacts of diverting run-on to site will pose limited to no risk to the environment or human health. As such the nature of this impact will be adverse and direct, while the duration of the impact during construction will be short term but long-term during operations. The extent of the impact however will be local, and partly reversible. The magnitude of change is moderate and the probability of this impact occurring is definite. The value and sensitivity of this impact is low and therefore the significance of this impact has been rated adverse moderate.

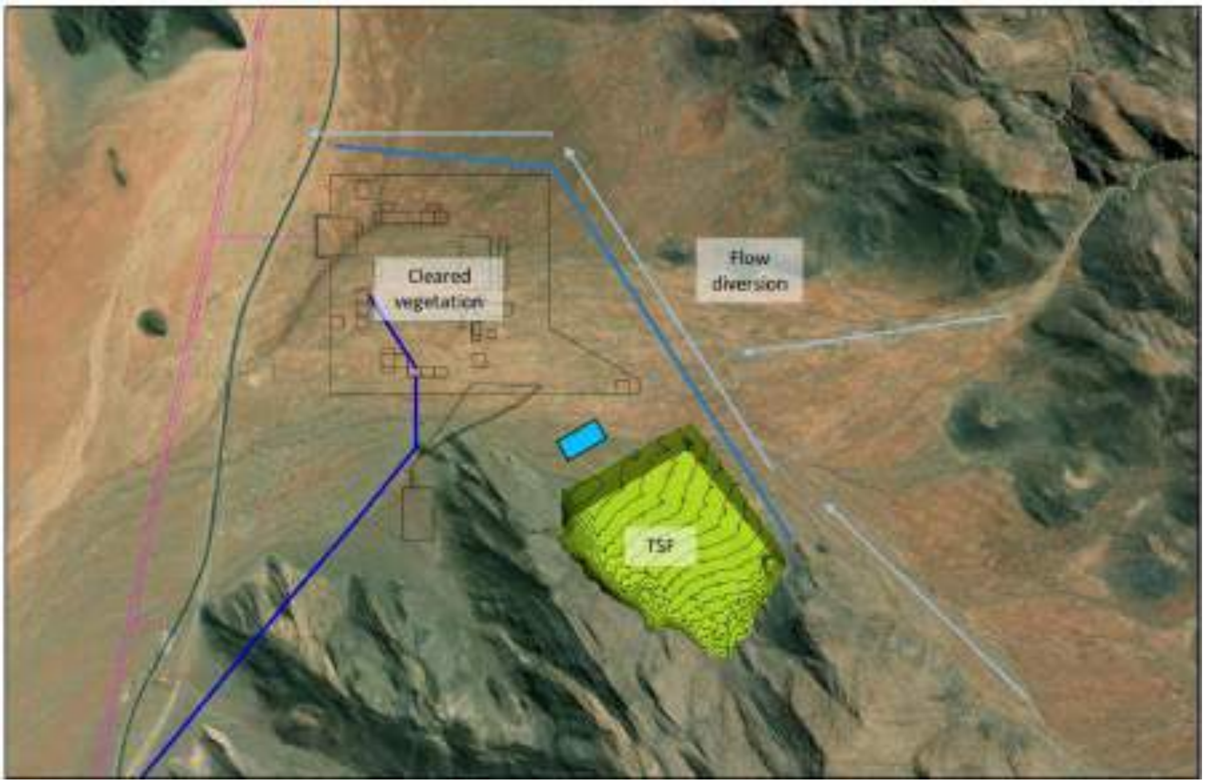


Figure 54 - Conceptual sketch of flow diversion required (de Bruin et al., 2023)

7.5.2.1.2 The impact of runoff generated on-site during construction and operation activities, contaminated with pollutants (such as hydrocarbons and metals) migrating downstream.

There are no perennial surface water bodies within and surrounding the mining licence. All rivers within this area are ephemeral and are unlikely to reach major water bodies such as the Orange River. The area is characterised by shallow soils, adding to the likelihood of compaction and creation of areas of impermeable to semi-impermeable soil during various construction and operation activities (e.g., ground preparation, land clearing). This, as well as the creation of impermeable surfaces (concrete or paving) may result in increased run-off of water from site (less infiltration) and concentration of flows into the environment. Unmanaged flow across impermeable and semi-impermeable surfaces has potential to mobilise various contaminants inherently present during construction and operation (hydrocarbons from refuelling of vehicles and machines, spills during hauling ore or gangue, heavy metal and sulphate liberation from exposed ore and gangue stockpiles or chemical spills from mineral processing areas) into the downstream environment (soil and shallow aquifer/river baseflow).

Over time these contaminants may accumulate in the shallow soils and contaminate the alluvial aquifer/river baseflow. Remobilisation (leaching and percolation) of contaminants in soils after rainfall events may also occur, creating an extended temporal input of contaminants to baseflow. This may lead to the deterioration of groundwater quality and soil health with subsequent impact to the health or prevalence of vegetation that are sustained by these soils and shallow groundwater. Since this ML is situated within the Succulent Karoo international biodiversity hotspot, and borders the Tsau //Khaeb National Park, this could pose a threat to the establishment and survival of ecologically sensitive flora. Although groundwater quality is predominantly Class D in the region, future land use (post closure) may be impacted upon if soils and groundwater are contaminated (e.g. groundwater treatment for agriculture or domestic use becomes less feasible). Adequate stormwater management plans and infrastructure will limit the impact, however, the nature of this impact will be adverse and direct, while the duration of the impact will be long term as it remains relevant during the construction and throughout the life of mine. The extent of the impact will be local, and partly reversible. The magnitude of change is moderate and the probability of this impact occurring is likely. The value and sensitivity of this impact is low and therefore the significance of this impact has been rated adverse minor.

7.5.2.1.3 The impact of possible TSF failure resulting in catastrophic flooding and contamination of downstream sediments (soil) and watercourses.

There are minor watercourses which ultimately contribute to flow (baseflow) in the Orange River ~30 km away from where the TSF will be situated. Should there be a catastrophic failure of the TSF, there will be a large amount of erosion coupled with sediment and contaminant (fines, metals, sulphates) redistribution/deposition throughout the water courses and adjacent environments. Any flow generated throughout the existing natural water courses (rainfall dependent) will become contaminated and promote further mobilisation of contaminants. It is unlikely that these contaminants will be transported in surface flows beyond the containing catchment (i.e. unlikely to reach the Orange River), however soils and shallow groundwater (base flow) and deeper groundwater will deteriorate in quality at varied rates each (elevated sulphates, acidity, bismuth, cadmium, uranium, lead, zinc). Since there are no local communities in the area and baseline groundwater is not fit for human consumption, any contamination to groundwater sources is unlikely to influence human health. The deterioration of baseflow quality and soil health will impact prevalence of vegetation that are sustained by these soils and shallow groundwater. Since this ML is situated within the Succulent Karoo international biodiversity hotspot, and borders the Tsau //Khaeb National Park, this could pose a threat to the establishment and survival of ecologically sensitive flora. Although groundwater quality is deemed Class C and Class D in the region, future land use (post closure) may be impacted upon if soils and groundwater are contaminated (e.g. groundwater treatment for agriculture or domestic use becomes unfeasible). Therefore, the nature of this impact will be adverse and direct, while the duration of the impact will be long term as it will last after the LoM. The extent of the impact is regional, and irreversible. The magnitude of change is high, however the probability of this impact occurring is unlikely. The value and sensitivity of this impact is high and therefore the significance of this impact has been rated adverse moderate.

7.5.2.1.4 The impact of a potential discharge or runoff of additional water from site which may increase flow to the downstream area during operation.

As all the natural surface water flow is ephemeral, increased water flow in water courses due to discharge from site e.g., stormwater and wastewater can lead to flooding in downstream areas during operation of the mine, especially if the natural drainage capacity is exceeded due to the creation of impermeable surfaces. Higher volumes and velocities of water flow can accelerate erosion along the banks of water courses, leading to increased sedimentation downstream and a change in drainage morphology. Faster water flows may transport contaminants, sediments, and nutrients from source areas (treatment plants, maturation ponds, stormwater ponds, return water dams) to downstream water courses more rapidly, allowing for less time to intervene. Proactive stormwater management, wastewater management and water storage options are thus necessary. Overtime contaminants may accumulate in the shallow soils downstream and infiltrate the alluvial aquifer, impacting the base flow water quality. This may lead to the deterioration of groundwater quality and soil health with knock on effects to the health or prevalence of vegetation that is sustained by the soils and groundwater. The nature of this impact will be adverse and direct, while the duration of the impact will be temporary. The extent of the impact is regional; however, the reversibility of the impact is reversible. The magnitude of change is moderate, and the probability of this impact occurring is possible. The value and sensitivity of this impact is low and therefore the significance of this impact has been rated adverse low.

7.5.2.1.5 The impact of contaminated runoff generated on site during operations making its way downstream, contaminating stream sediments (soil) and water courses.

During operations various wastewater is produced through ore excavation and ore processing. This water often contains various chemicals, contaminants, and heavy metals such as bismuth, cadmium, lead, uranium, zinc, cadmium and lead. If this water is not properly contained and discharged or treated it may run off into the natural environment. The runoff has the potential to mobilise contaminants and pollutants into surface water courses, soils or groundwater.

Overtime these contaminants may accumulate in these shallow soils and infiltrate both the shallow alluvial aquifer (base flow) and the deeper aquifer. Although soils are poorly developed and groundwater quality not fit for consumption, contamination of these may affect the health and prevalence of vegetation populations that are sustained by these soils and groundwater, posing a threat to the establishment and survival of ecologically sensitive flora. Therefore, the nature of this impact will be adverse and direct, while the duration of the impact will be medium term as impacts are likely to last after LoM but are recoverable. The extent of the impact is regional; however, the reversibility of the impact is partly reversible. The magnitude of change is moderate, and the probability of this impact occurring is possible. The value and sensitivity of this impact is low and therefore the significance of this impact has been rated adverse low.

7.5.2.1.6 The impact of contaminated runoff in distal areas where dust has settled on surface in upwind direction contaminating water courses.

There are no major surface water bodies in the area and all surface water courses are ephemeral rivers. During operations, dust and aerosols are mobilised during earthworks, excavations, crushing or stockpiling of ore or gangue. As wind direction is predominantly in a SSE or SSW direction, dust and aerosols from the site are unlikely to have any impact on any major surface watercourses. However, there could be changes in soil chemistry and water quality of seasonal flows from deposition of dust and aerosols blown from site to nearby dry watercourses. This could affect vegetation which reside along these water courses, affecting their establishment, growth, and viability. This may also impact recharge to shallow aquifer systems (reduction of recharge due to increased fine material clogging pore spaces or increased metal concentrations due to leaching of contaminated soils). Therefore, the nature of this impact will be adverse and direct, while the duration of the impact will be medium term as impacts are likely to last after LoM but are recoverable. The extent of the impact is regional; but is reversible. The magnitude of change is moderate, and the probability of this impact occurring is likely. The value and sensitivity of this impact is low and therefore the significance of this impact has been rated adverse low.

7.5.2.1.7 The impact of drainage never returning to normal as remaining structures and site alterations obstruct flow after decommissioning.

The presence of various infrastructure needed for operations that may remain onsite even after decommissioning, will obstruct, and disturb the natural flow of water in the area. This may result in a higher level of run-off of water, which also produces stronger flows of water. If the run-off is left uncontrolled it can lead to increased soil erosion, which in turn alters the flow path of run-off water and recharge mechanisms to groundwater. Therefore, the nature of this impact will be adverse and direct, and the duration of the impact is permanent as the impact will last after LoM. The extent of the impact, however, is only onsite but will be irreversible. The magnitude of change is moderate, and the probability of this impact occurring is definite. The value and sensitivity of this impact is low and therefore the significance of this impact has been rated adverse moderate.

7.5.2.1.8 The impact of persistent contaminants (ore, metals etc.) continuing as diffuse sources of pollution after decommissioning.

After decommissioning of the mine and associated infrastructure (TSF), contaminants (e.g., sulphates, metals) generated by these may continue to be released into the environment – underground mine works may flood and decant, or the tailings dam (if unlined) may generate a migrating leachate (at surface and sub surface). This would continue the contamination of river baseflow and potentially of seasonal surface flows with various compounds that may deteriorate the soil and groundwater quality over time. The long-term risk to this emanates from the continued input of contaminants from an undiminishing point source, allowing the accumulation and migration of these over time toward areas where surface and groundwater are more readily relied upon for domestic or agricultural use (nearer the Orange River for example). However, this area is characterised by low rainfall and groundwater movement is slow within geology which further provides a buffer to the likely contaminants generated from the mining operation. Future land use will likely be restricted based on prevailing soil and water quality conditions. The nature of this impact will be adverse and direct, and the duration of the impact will be long term as it will last after LoM and is irrecoverable. The extent of the impact is regional and is irreversible. The magnitude of change is moderate, and the probability of this impact occurring is Likely. The value and sensitivity of this impact is medium and therefore the significance of this impact has been rated adverse major.

Table 25 - Impact of construction and mining activities relating to drainage and hydrology on ML 245

Activity	Receptor	Impact	Nature of impact	Value & Sensitivity	Magnitude of change	Significance of impact
Altering / diverting the drainage systems on site during construction and operations	Surface water, ecosystem	Water flowing across the site will be diverted, causing a lag/change in flow to downstream areas	Adverse Direct Short term Local Partly reversible Moderate Definite	Low	Moderate	**Moderate (4)**
Contaminated runoff generated onsite flows to downstream fauna and flora during construction	Surface water, flora and fauna	Contaminated water courses	Adverse Direct Short term Local Partly reversible Moderate Likely	Low	Moderate	**Minor (3)**
TSF failure during operations	Flora, fauna, and surface water courses	TSF failure results in catastrophic flooding and contamination of downstream water courses	Adverse Direct Long term Regional Irreversible Very High Unlikely	High	High	**Moderate (6)**
Altering /	Surface	Potential	Adverse	Low	Moderate	**Low (2)**

Activity	Receptor	Impact	Nature of impact	Value & Sensitivity	Magnitude of change	Significance of impact
diverting the drainage systems on site during operations	water courses	discharge or runoff of additional water from site may increase flow to downstream area	Direct Temporary Regional Reversible Moderate Possible			
Mining operations	Surface water courses	Contaminated runoff generated on site during operations making its way downstream, contaminating stream sediments (soil) and water courses	Adverse Direct Medium term Regional Partly reversible Moderate Possible	Low	Low	**Low (1)**
	Surface water courses	Contaminated runoff in distal areas where dust has settled on surface in upwind direction, contaminating water courses	Adverse Direct Medium term Regional Reversible Low Likely	Low	Low	**Low (1)**
Altering or obstructing water flow during decommissioning	Surface water courses	Drainage never returning to normal as remaining structures	Adverse Direct Permanent On site Irreversibl	Medium	Moderate	**Moderate (6)**

Activity	Receptor	Impact	Nature of impact	Value & Sensitivity	Magnitude of change	Significance of impact
		and site alterations obstruct flow after decommissioning	e Moderate Definite			
Contaminated water courses after decommissioning	Surface water courses	Persistent contaminants (ore, metals etc.) continue as diffuse sources of pollution	Adverse Direct Long term Regional Moderate Likely	Medium	Moderate	**Major (8)**

Mitigation measures of impacts rated high:

Following the decommissioning process, there is a risk of water courses becoming contaminated due to the presence of persistent contaminants. These contaminants may continue to diffuse into groundwater sources, causing pollution. To address this issue, the following mitigation measures are recommended:

- Implementing a high-density polyethylene (HDPE) plastic liner at the base of the Tailings Storage Facility (TSF) to prevent contaminants from seeping into the local groundwater.
- Promptly addressing any contamination through effective techniques such as dilution, bioremediation, or chemical treatment.
- Undertaking the rehabilitation of the TSF after mine closure to restore its environmental integrity.

7.5.2.2 The impact of construction and operations of the Project to groundwater.

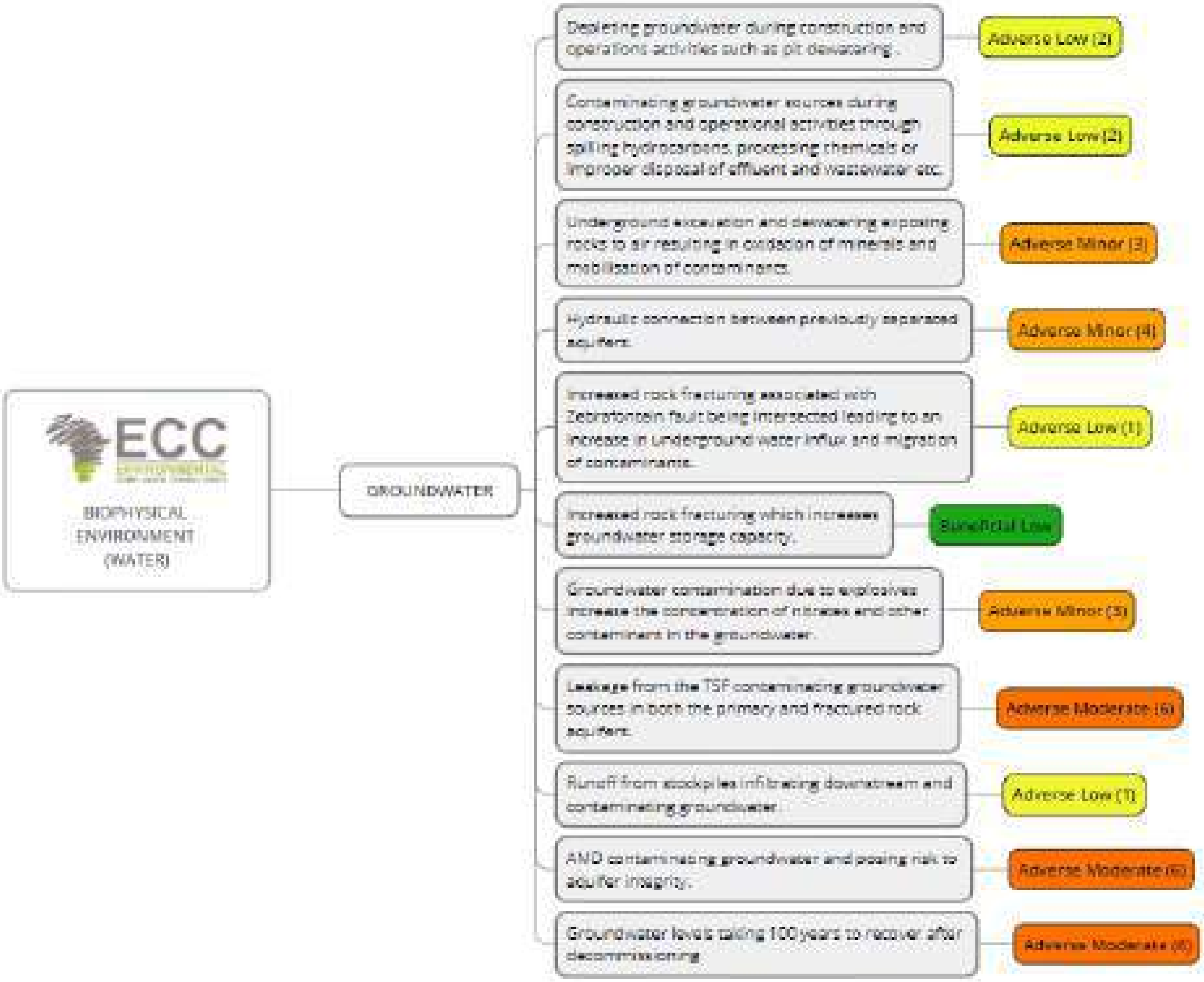


Figure 55 - Impacts on groundwater

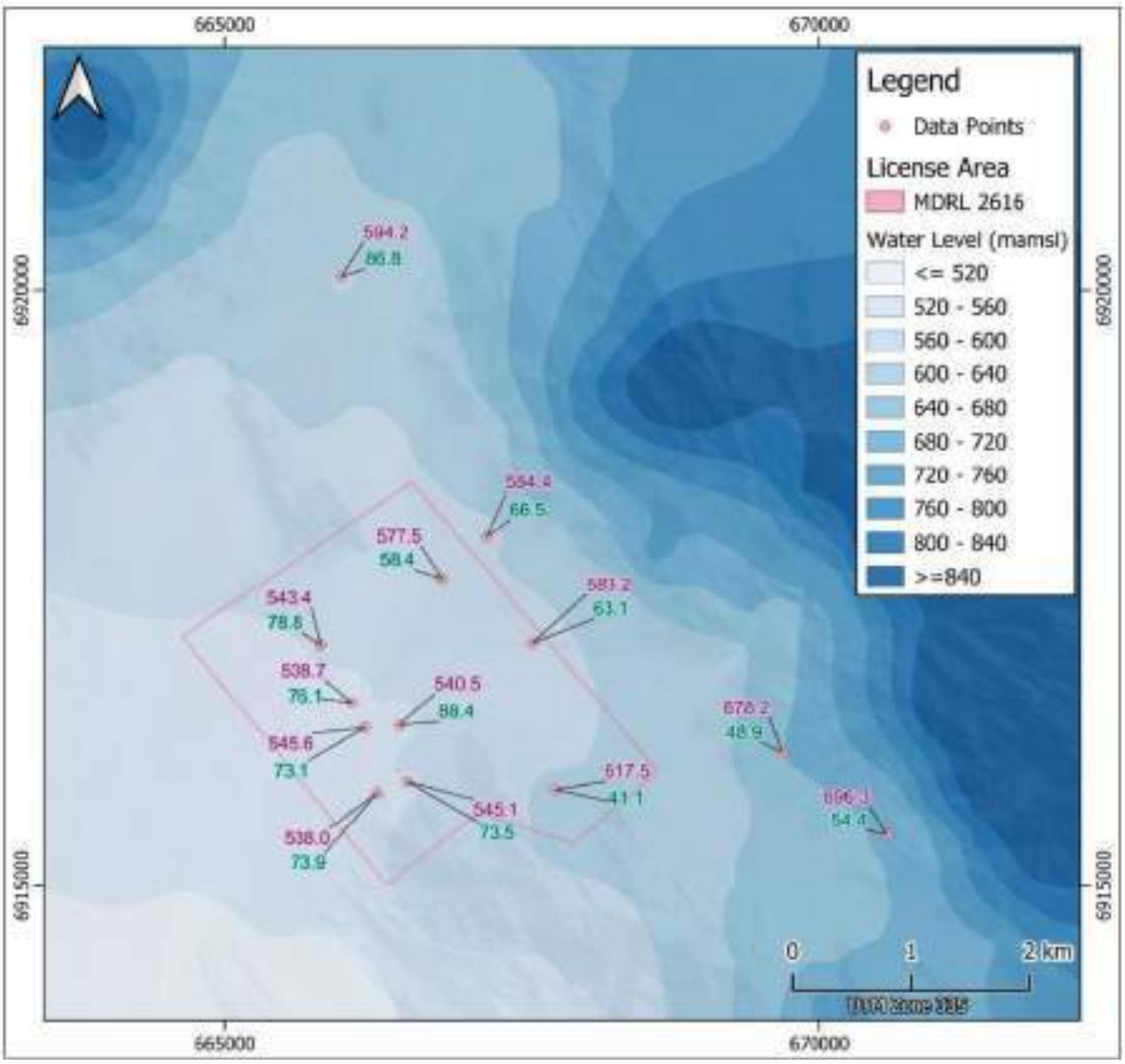


Figure 56 - Interpolated groundwater level map of the project area. The groundwater elevation (mamsl) is shown with the pink label, while the groundwater level (mbgl) is shown with light turquoise. Drainage lines were used as controls for interpolation (de Bruin et al., 2023)

7.5.2.2.1 The impact of depleting groundwater during construction and operations activities such as pit dewatering.

Groundwater levels (Figure 56) across most areas on the site are relatively deep occurring between 50 – 90 metres below ground level (mbgl) with flow toward the southwest (toward the Orange River). The shallow primary aquifer (predominantly linked to fluvial sediments) is anticipated to recharge the underlying, deeper aquifer. Groundwater from the deep secondary (fractured) aquifer is of poor quality (Class D) and the aquifer has low potential for groundwater abstraction further exacerbated by low recharge rates due to low rainfall in the region. Dewatering of the mine works may result in seepage from the upper aquifer leading to an increased or prolonged inflow of water to the mine and the eventual dewatering of both aquifer systems. This may also result in a reduction of baseflow in surface water courses and impact reaches of the water courses that harbour biodiversity. Overall lowering of the water table in the secondary aquifer system is unlikely to have adverse impacts as there are no other users reliant on the aquifer as a water source in the area. Recovery of water levels after mining is expected to be very slow, which may impact the future land use potential of the local area. The nature of this impact is adverse and direct, however it is temporary and reversible and will only affect the groundwater levels onsite, as not a lot of groundwater is required during construction. The magnitude of this impact will be moderate and the probability of this impact occurring is possible. The value and sensitivity of this impact is low and therefore the overall significance of the impact has been rated adverse low.

7.5.2.2.2 The impact of contaminating groundwater sources during construction and operational activities through spilling hydrocarbons, processing chemicals or improper disposal of effluent and wastewater etc.

Any runoff or discharge from site (runoff increased by creation of hard or impermeable surfaces and soil compaction) that potentially mobilises contaminants from spills, stockpiles etc. may carry these contaminants (metals, sulphates, hydrocarbons, or nutrients) into the shallow aquifer. Contamination of the shallow aquifer may lead to further contamination of the deeper underlying aquifer. It is however noted that groundwater levels in the secondary aquifer are deep, and that existing water quality is considered poor (Class D). The geology underlying the site may offer some buffer to various geochemical reactions that are likely to occur (reduction in acidity, sorption of metals and dispersion/diffusion of contaminant concentrations). As there are no identified groundwater dependent communities in the area and deep groundwater is not utilised by biodiversity, the nature of this impact is adverse and direct, temporary, and reversible. The magnitude of this impact will be moderate and the probability of this impact occurring is possible. The value and sensitivity of this impact is low and therefore the overall significance of the impact has been rated adverse low.

7.5.2.2.3 The impact of underground excavation and dewatering exposing rocks to air resulting in oxidation of minerals and mobilisation of contaminants.

Bismuth, cadmium, lead, uranium, and zinc are enriched in the rock material as geogenic sources and are readily associated with various sulphide minerals (e.g., pyrite). These compounds are most likely to be become enriched in groundwater as rocks are exposed to atmosphere (underground and on surface) and minerals are oxidised due to a lowering of the water table during dewatering. This process has the potential to alter groundwater chemistry significantly, particularly because pyrite oxidation yields more acidity compared to other sulphides. The oxidation of sulfide minerals is known to contribute to the occurrence of acid mine drainage (AMD), characterized by acidic water with heightened levels of metals. Furthermore, rock leachate tests indicate that aluminium, arsenic, beryllium, molybdenum, antimony, thallium, vanadium, and potassium are likely to surpass baseline concentrations. In the case of cadmium, copper, iron, manganese, tin, strontium, thorium, titanium, zinc, and zirconium, there are no groundwater baseline values for comparison, but their concentrations are expected to increase as well. The persistent effects of AMD pose challenges for the long-term remediation of groundwater. The aquifer contains buffering capacity against acidity from the minor dolomite and calcite minerals found outside of the ore zone. Additionally, the aquifers in the area exhibit relatively poor productivity compounded by low rainfall and recharge rates means that leachate generation and decant likelihood is considered low. Migration of contaminated groundwater is likely very slow with contamination plumes being neutralised over time due to geochemical reactions (buffering), sorption and diffusion/dispersity. No other groundwater users are identified in the area, limiting risk of this impact to human health and biodiversity. Future land use may however be adversely impacted if groundwater resources are needed. The nature of this impact is adverse and direct, and permanent as the impact will last after the LoM. The impact is partly reversible, and the extent of the impact is local. The magnitude of this impact will be moderate and the probability of this impact occurring is definite. The value and sensitivity of this impact is low and therefore the overall significance of the impact has been rated adverse minor.

7.5.2.2.4 The impact of hydraulic connection between previously separated aquifers.

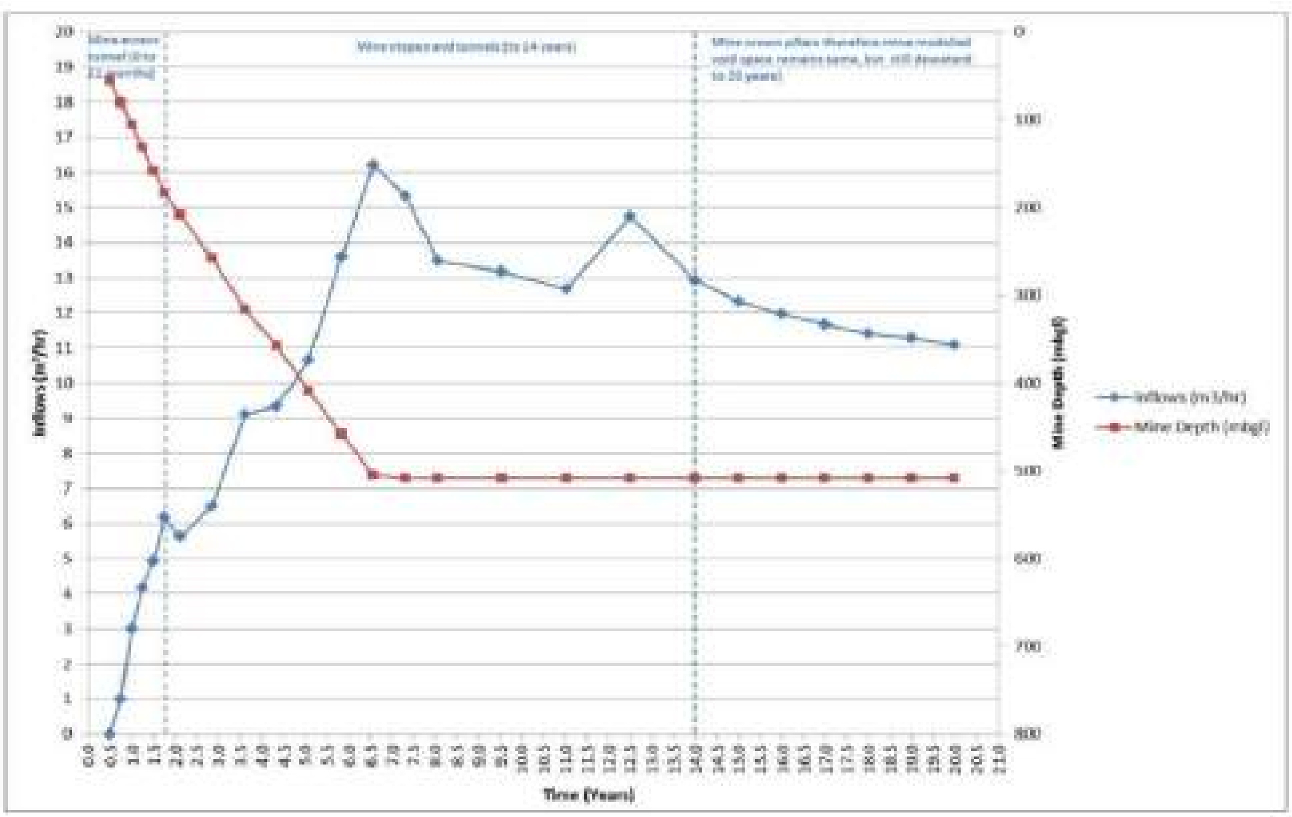
The Zebrafontein fault underlies the site and hosts the Spitskop and Koivib intrusives, each with different aquifer properties in terms of cooling rates and thickness. Swift cooling leads to increased porosity, and emplacement-induced fracturing can establish favourable aquifer conditions along the peripheries of the intrusions. Considering the above and widespread deformation of rock units, there's a possibility of interconnection between different aquifers. Blasting and mining activities may facilitate connections between aquifers, potentially creating a unified system. Contaminated water from one could cause contamination of adjoining or overlying systems. While this is true for contamination migration, mixing of different natural water qualities may occur. Nevertheless, groundwater in the area is unsuitable for human or livestock consumption Class D), and local agricultural processes do not utilise the groundwater, posing minimal risk to human well-being or local agricultural activities. Therefore, nature of this impact is adverse and direct, and permanent as the impact will last beyond the LoM. The impact is irreversible, and the extent is regional. The magnitude of this impact will be moderate, and the probability of occurrence is definite. The value and sensitivity of this impact is medium and therefore the overall significance of the impact has been rated adverse minor.

7.5.2.2.5 The impact of increased rock fracturing associated with Zebrafontein fault being intersected leading to an increase in underground water influx and migration of contaminants.

As explained in the point above, blasting and mining activities may facilitate connections between aquifers, potentially creating a unified system. This could lead to an increased influx rate of water in the underground mining environment. As per the numerical groundwater model conducted by SRK using MODFLOW for Gergarub, upon intersecting the groundwater level, the inflow may escalate progressively, starting at 0.3 l/s after nine months and reaching a peak of 1.6 l/s after 21 months. Subsequently, from the 21st month to the 14th year, the inflow continues to rise, reaching up to 8.0 l/s after 8 years, with the maximum mine depth approximately 500 mbgl. Following this period, the inflow experiences a swift increase to approximately 38 l/s upon intersecting the Zebrafontein Fault. Shown in the images below is the difference in rate of groundwater inflow when the Zebrafontein fault is or is not intersected (Figure 57). Fluctuations in inflow can be attributed to hydraulic property vectors, interlayer leakage, inflow from fault systems, and the response to the expanding drawdown zone encountering unforeseen boundaries. Over time, as the final mining depth is attained, the inflow gradually diminishes.

Intersection of the fault and highly fractured zones increases the rate at which contaminants move through the subsurface (following preferential flow paths). The contaminated groundwater may migrate more rapidly to areas of better groundwater quality, where groundwater is used. The low residence time in the aquifer diminishes the potential for natural neutralisation or buffering from the aquifer material.

The nature of this impact is adverse and direct, and long term as the impact will last after the activity has ceased after the LoM. The impact, however, is reversible, and the extent of the impact is local. The magnitude of this impact will be moderate and the probability of this impact occurring is possible. The value and sensitivity of this impact is medium and therefore the overall significance of the impact has been rated adverse low.



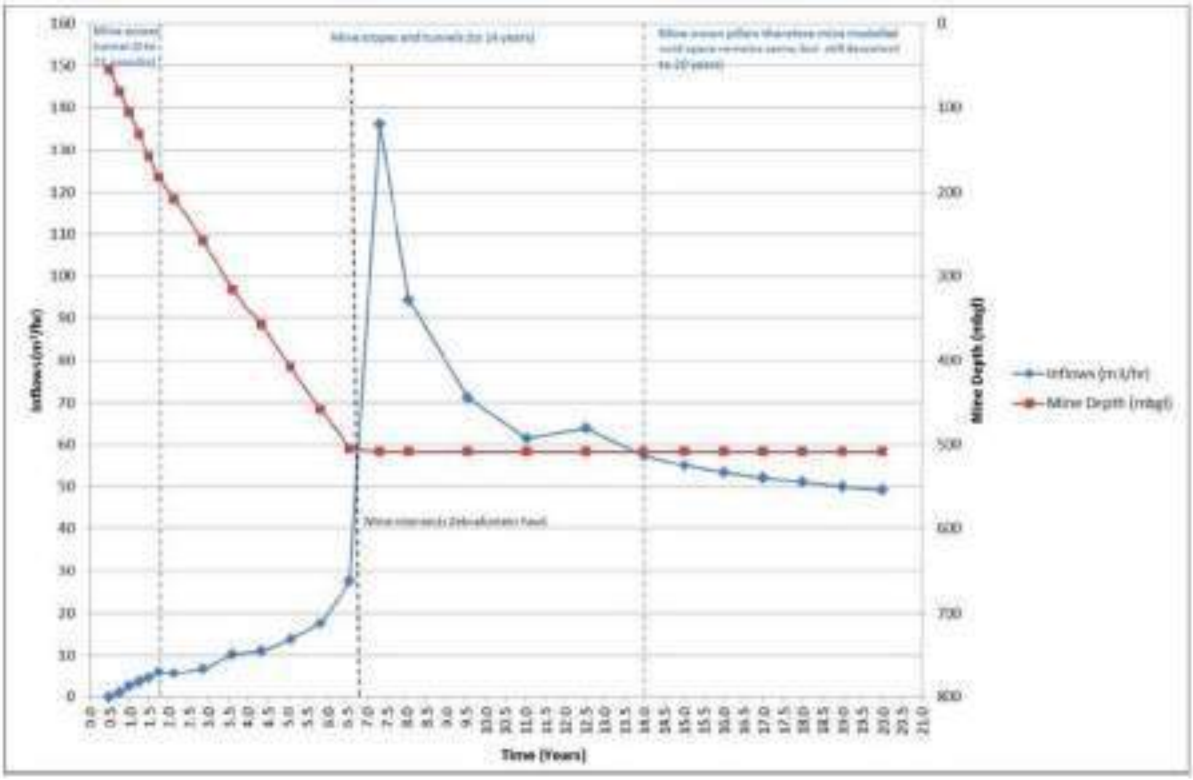


Figure 57 - Modelled mine inflows for Scenario 1, the Zebrafontein Valley Fault is not intersected (top) and Scenario 2, it is intersected (bottom) (Skorpion Mining Company, 2014b).

7.5.2.2.6 The impact of increased rock fracturing which increases groundwater storage capacity.

Blasting and mining of the underground overburden and aquitard may further fracture the Rosh Pinah formation. Fractured rocks, with their increased porosity and permeability, significantly boost groundwater storage capacity by creating additional pathways for water movement and storage in the subsurface. Therefore, blasting and mining may increase this areas groundwater potential and storage capacity. For this reason, the nature of this impact is beneficial and direct, and the duration of the impact is permanent as the impact will last beyond the LoM. The impact is irreversible, and the extent of the impact is local. The magnitude of this impact will be moderate and the probability of this impact occurring is definite. The value and sensitivity of this impact is low and therefore the overall significance of the impact has been rated beneficial low.

7.5.2.2.7 The impact of groundwater contamination due to explosives increase the concentration of nitrates and other contaminant in the groundwater.

Ammonium nitrate, commonly used in explosives, releases nitrogen compounds, including nitrates, when detonated. This decomposition leads to the release of nitrogen oxides and ammonia, elevating nitrate levels in groundwater (highly soluble). Nitrogen oxides can react with water to form nitric acid, further contributing to increased nitrate concentrations. Elevated nitrate levels pose environmental and health risks if they exceed established standards, and the groundwater is used for human or ecological use. The composition of explosives may introduce additional contaminants, such as heavy metals and organic compounds, exacerbating water quality concerns. The project will utilise 1,500 bags of ANFO (25 kg per bag) and 50 t of bulk emulsion. The water containing these residues is pumped from the mine face or mine heading into the mine water return system and is reused in the mining process. Therefore, it is expected that minimal volumes of such water would reach the groundwater causing contamination. Additionally, no other groundwater dependent communities were identified, lowering the impact to people, fauna, and flora. Therefore, nature of this impact is adverse and direct, and long term as the impact will last post LoM. The impact, however, is partly reversible, and the extent of the impact is local. The magnitude of this impact will be moderate and the probability of this impact occurring is definite. The value and sensitivity of this impact is medium and therefore the overall significance of the impact has been rated adverse minor.

7.5.2.2.8 The impact of the TSF leaking and contaminating groundwater sources in both the primary and fractured rock aquifers.

Surveys indicate that there is a potential fault beneath where the TSF is to be constructed, 15-50 m below the overburden. Additionally, the groundwater levels around the TSF are shallower than at other areas over the site at approximately 40 mbgl. Tests were carried and the outcome showed that unsaturated hydraulic conductivity, representing infiltration rates, varied between 6-15 m/day. Therefore, continual leakage or spills from the TSF could potentially saturate the subsurface and allow contamination plumes to infiltrate the groundwater. The relatively high infiltration rate, characteristic of unconsolidated alluvial sediments, suggests rapid water infiltration. However, due to scarce rainfall and extremely high evaporation, and low recharge rates (0.5 mm/a), leachate generation is expected to be managed with relative ease. Any water that does manage to infiltrate the overburden or primary aquifer is likely to accumulate at the contact with the underlying fractured bedrock, recharging the fractured aquifer at a slower rate (increased residence time) allowing for some geochemical reactions (buffering) and sorption of contaminants. However, should they choose to construct a lined TSF (HDPE-lined) this would reduce the risk of seepage from the TSF into the subsurface.

Three different scenarios were modelled and described by (de Bruin et al., 2023):

- Scenario A: Directing all tailings with approximately 25% moisture content to a lined Tailings Storage Facility (TSF) equipped with under-drainage. Water from this facility is pumped to a lined Return Water Dam (RWD) before undergoing reprocessing. Option 1A employs paste tailings, Option 1B utilizes thickened tailings, and Option 2 involves conventional tailings.
- Scenario B: A pyrite flotation cell is employed. Tailings rich in pyrite are directed to a lined TSF, while the remaining portion is sent to an unlined TSF. Water from the lined tailings is pumped to the RWD before undergoing reprocessing.
- Scenario C: Sending conventional tailings with a 25% moisture content to an unlined TSF surrounded by four manufactured walls.

It was found that the contaminant plume in the overburden spreads laterally with higher concentration upon reaching the bedrock aquifer. The zinc plume has a more limited reach compared to EC and sulphate plumes due to absorption effects. In Scenario B, initial zinc leakage potential is 20 mg/l, but the modelled concentration in the bedrock does not exceed 1 mg/l. Both Scenario A and B observe the contaminant plume reaching the mining area only after mine closure, with substantial groundwater level recovery anticipated by then. The plume's movement starts at about 3 m/year, slowing to approximately 1 m/year post-closure due to a reduced hydraulic gradient. In Scenario C, the contaminant plume moves faster at about 50 m/year along a fault into the mine before closure, slowing to 1 to 5 m/year beyond the mine area. After 100 years, the plume reaches the Zebrafontein Fault in the overburden, with concentrations remaining relatively low, comparable to background levels.

In the bedrock, the plume is not projected to reach the Zebrafontein Fault within the same timeframe. As mining and dewatering cease, groundwater levels recover, and the plume undergoes dilution and attenuation. It is crucial to seal potential rapid ingress pathways, such as existing boreholes around the TSF, using methods like grouting or bentonite. Tailings to be sent to the TSF will likely consist of elevated levels of major ions (SO_4, Ca, Mg, Na and K) and manganese, zinc, and lead but the presence of carbonate minerals may act as a buffer for acid generation, that could potentially seep through the TSF and lead to AMD. Additionally, it is imperative to note that groundwater quality around the where the TSF is to be constructed indicates poorer quality compared to the other groundwater samples taken on site. The samples taken around the area where the TSF is to be constructed mostly consisted of sodium-chloride and calcium-sulphate types and had a salty taste. The pH levels ranged from slightly acidic to slightly alkaline, measuring between 6.22 and 7.70. Additionally, the electrical conductivity (EC) varied from 163 to 900 mS/m. This is not to be confused for seepage from the tailings once operations commence.

Therefore, nature of this impact is adverse and direct, and long term as the impact will last post LoM. The impact, however, is partly reversible, and the extent of the impact is regional. The magnitude of this impact will be high, however the probability of this impact occurring is adopted as rare. The value and sensitivity of this impact is medium and therefore the overall significance of the impact has been rated adverse moderate.

7.5.2.2.9 The impact of runoff from stockpiles infiltrating downstream and contaminating groundwater.

The ROM and WRD stockpiles will most likely consist of minerals such as sphalerite, galena, tennantite, tetrahedrite, chalcopyrite, pyrite and bornite, should there be any significant rainfall events these minerals and the associated metals could be leached out of ROM stockpiles or WRDs. This would result in the leachate flowing overland and infiltrating the subsurface. However, the chances of these minerals penetrating and contaminating groundwater is low as the water table is significantly deep at 80mbgl and due to the fractures in the overburden and aquitard being the main point of entry into the aquifer. Additionally, the groundwater quality of this area is already poor (Category D) and not fit for human and livestock consumption and agricultural irrigation. Therefore, nature of this impact is adverse and direct, and the duration of the impact is temporary. The impact is partly reversible, and the extent of the impact is onsite. The magnitude of this impact will be low and the probability of this impact occurring is possible. The value and sensitivity of this impact is low and therefore the overall significance of the impact has been rated adverse low.

7.5.2.2.10 The impact of AMD contaminating groundwater and posing risk to aquifer integrity.

Pyrite, present in the orebody and overburden are known for its association with acid mine drainage and therefore pyrite-rich waste poses potential risks to groundwater quality. AMD significantly impacts groundwater quality by mobilising heavy metals like iron, aluminium, and manganese, commonly found in mineral deposits. Elevated concentrations of these metals pose substantial environmental risks as it significantly contaminates groundwater. However, carbonates in the host rock act as natural buffers against acidity. Should the carbonaceous material be fully utilised for buffering, portions of the aquifer will become dissolved – diminishing the buffering capacity for acid generated in future (should the source persist) and changing the storage properties of the aquifer. If massive portions of carbonaceous material are dissolved, aquifer integrity and collapse may occur. Therefore, nature of this impact is adverse and direct, and long term as the impact will last post LoM. The impact, however, is partly reversible, and the extent of the impact is local. The magnitude of this impact will be high and the probability of this impact occurring is possible. The value and sensitivity of this impact is medium and therefore the overall significance of the impact has been rated adverse moderate.

7.5.2.3 The impacts of groundwater levels taking 100 years to recover after decommissioning.

Should the Zebrafontein fault not be intersected, after mine closure, the drawdown zone will widen to a radius of about 700 meters ten years post-mining, as storage replenishes and the maximum drawdown depth decreases. Full recovery to pre-mining levels could take around 100 years post-closure, assuming average recharge conditions persist. Currently, with no utilization of groundwater for human consumption, agriculture, or industrial activities, the recovery is not anticipated to significantly inconvenience residents. However, if future residents decide to abstract water from the area, it will take 100 years for groundwater levels to return to pre-mining levels. Therefore, nature of this impact is adverse and direct, and long term as the impact will last post LoM. The impact, however, is reversible, and the extent of the impact is regional. The magnitude of this impact will be minor and the probability of this impact occurring is definite. The value and sensitivity of this impact is medium and therefore the overall significance of the impact has been rated adverse minor.

Table 26 - Impact of mining and construction activities on groundwater

Activity	Receptor	Impact	Nature of impact	Value & Sensitivity	Magnitude of change	Significance of impact
Groundwater for construction and operation activities	Groundwater	Depleted groundwater resources	Adverse Direct Temporary Onsite Reversible Moderate Possible	Low	Moderate	**Low (2)**
Refuelling stations, maintenance workshops, ore processing, hydrocarbon spillage etc.	Groundwater	Contaminating groundwater sources during construction and operational activities	Adverse Direct Temporary Onsite Reversible Moderate Possible	Low	Moderate	**Low (2)**
Underground excavation and dewatering	Groundwater	Rock is exposed to air resulting in oxidation of minerals and mobilising of contaminants	Adverse Direct Permanent Local Partly reversible Moderate Definite	Low	Moderate	**Minor (3)**
Operation activities	Groundwater	Hydraulic connection between previously separated aquifers	Adverse Direct Permanent Regional Irreversible Moderate Definite	Medium	Moderate	**Minor (4)**
Blasting	Groundwater	Increased rock fracturing leading to unstable subsurface conditions	Adverse Direct Long term Local Reversible Moderate Possible	Medium	Moderate	**Low (2**

Activity	Receptor	Impact	Nature of impact	Value & Sensitivity	Magnitude of change	Significance of impact
	Groundwater	Increased rock fracturing which increases groundwater storage capacity	Beneficial Direct Permanent Local Irreversible Moderate Definite	Low	Moderate	**Beneficial Low**
	Groundwater	Groundwater contamination from set explosives (nitrates and other contaminants)	Adverse Direct Long term Partly reversible Local Moderate Definite	Low	Moderate	**Minor (3)**
TSF operations results in leakage	Groundwater	TSF leaking will contaminate the groundwater in both primary and fractured rock aquifers	Adverse Direct Long term Regional Reversible High Unlikely	Medium	High	**Moderate (6)**
	Groundwater	Runoff from stockpiles infiltrate downstream and contaminate groundwater	Adverse Direct Temporary Onsite Partly reversible Low Possible	Low	Low	**Low (1)**
After decommissioning	Groundwater	Acid Mine Drainage contaminates groundwater and dissolves carbonate rocks.	Adverse Direct Partly reversible Long term Local High	Medium	High	**Moderate (6)**

Activity	Receptor	Impact	Nature of impact	Value & Sensitivity	Magnitude of change	Significance of impact
			Possible			
		Groundwater level recovery will take 100 years.	Adverse Direct Reversible Long term Regional High Definite	Medium	High	**Moderate (6)**

7.5.3 BIODIVERSITY IMPACTS: FLORA

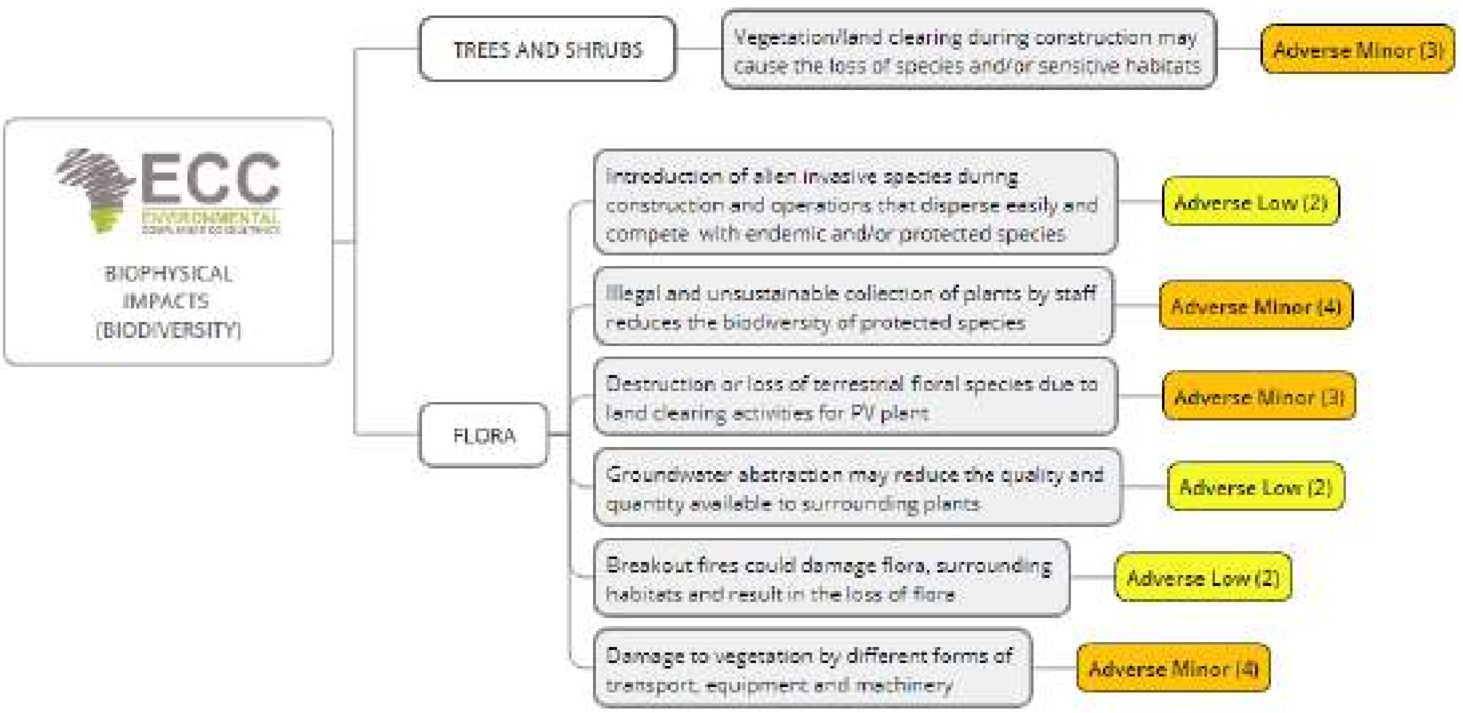


Figure 58 - Impacts on flora.

7.5.3.1 The impact of the removal and loss of sensitive flora species on biodiversity.

The impact of site clearing, and topsoil stockpiling are expected to be slightly damaging to the vegetation in the proposed site. Site clearing would involve loss of habitat and removal of species resulting in the reduction in the abundance of important species. According to the vegetation impact assessment conducted by Coleen Mannheimer (2014) species associated with areas that are highly to critically sensitive include the following: *Dracophilus dealbatus, Cheiridopsis robusta*, *Ruschia* spp., *Cephalophyllum ebracteatum*, *Aridaria noctiflora*, *Tylecodon reticulatus* and *Hoodia gordonii, Hartmanthus hallii*, *Aloe dichotoma*, *A. gariepensis*, *Pachypodium namaquanum*, *Crassula* spp. and *Conophytum* spp., as well as many other highly restricted-range species, such as *Sarcocaulon inerme* and *Zygophyllum* spp. The impact is adversely direct, partly reversible and over a medium term.

Mitigation should involve the avoidance of unnecessary loss and removal of sensitive or protected species. Identification of protected/endemic species should be identified prior to construction and operations to encourage replanting of endemic/protected species that are destroyed in the vicinity. The study highlighted the use of existing tracks and already disturbed areas for construction laydown. More mitigations are described in the operational environmental management plan (OEMP).

The magnitude of change after mitigation will be moderate due to the potential loss of individuals and modification of sensitive habitats. The sensitivity of the receptor is low because the target individuals that will be affected are on-site.

7.5.3.2 The impact of the introduction of alien invasive species on the biodiversity.

Possible introduction of alien invasive species could reduce endemic and/or protected species. An alien invasive species identified in the mountainous areas, koppies and footslopes in the vegetation study is *Dodonaea angustifolia* occurring in drainage lines near to the water pump station. The impact is adversely direct, partly reversible and over a medium term.

According to the vegetation study any alien, or non-native, species of flora that are already present in the project area, or any that might be introduced or spread by the project should be identified (Mannheimer, 2014). Internal weed and seed inspections should be completed prior to the use of equipment to minimise the spread of invasive species. The introduction of alien species for ornamental purposes should be avoided.

The magnitude of change after mitigation will be minor due to the minor modification to species composition. The sensitivity of the receptor is low due to the local extent.

7.5.3.3 The potential impacts of illegal collection of species on the biodiversity.

During the construction and operational phase of the project, various short-term as well as long-term contractors will be employed which may potentially lead to the illegal and unsustainable collection of plants by members of the staff, reducing the biodiversity of endemic and/or protected species. There has been reports of the *hoodia spp* illegally exported since the early 2000's in southern regions of Namibia (New Era, 2006). *Hoodia gordonii* is one of the species included as a species of concern in the vegetation impact assessment (Appendix F). The adverse impact is expected to be direct, irreversible and regional, as this would have implications on sensitive species in the region.

Mitigation should include educating all permanent staff and contractors about the illegal flora collection and consequences. The collection of plant material should be forbidden for any purpose except for relocation purposes. The magnitude of change will remain major due to possible loss of protected species populations while the sensitivity of the receptor is medium due to the regional implications.

7.5.3.4 The potential impacts of groundwater abstraction (Pit dewatering) on flora.

The Gergarub project area is a relatively dry environment and vegetation is expected to be well adapted to dry and unfavourable conditions, however the pristine nature of the area makes it difficult to foresee the outcomes. Groundwater abstractions may reduce the amount of water and affect the quality of water available for vegetation growth. The area is characterised by low groundwater supply, the abstraction of groundwater will then leave behind greater sulphate and calcium concentrations in the available groundwater (Gejl, Rygaard, Henriksen, Rasmussen, & Bjerg, 2019). This may cause an imbalance in nutrient uptake, affecting the root development of flora (Takahashi, 2019).

Mitigation measures include obtaining the necessary water abstraction licence, proper planning and mapping of boreholes that have greater volumes and quality of water. The groundwater study indicates boreholes that are safe in terms of volume and calcium, magnesium, sodium, and bromide. Refer to the OEMP For further mitigations discussed.

The magnitude of change is minor due to some measurable loss to an important component in the ecosystem, this however has an impact on a local scale which is why the sensitivity of the receptor is low.

7.5.3.5 The impact of transport activities, and the WRD and TSF construction on Flora

The transport of materials, waste rock dumps and TSF construction are expected to be slightly damaging to the vegetation in this area. Construction of facilities on the site would cause the destruction and modification of vegetation habitats, reducing species diversity. The impact is adverse, direct, partly reversible and likely to occur over the long-term depending on the Life of Mine (LoM).

Mitigation measures should include the increase of waste rock dump during backfill process. The design and development of the TSF and WRD should be done in collaboration with a restoration ecologist to ensure the re-establishment of vegetation over the long period. Rehabilitation strategies and plans should be established early in the project.

The magnitude of change after mitigation is minor because the TSF construction, transportation of materials and the WRD are expected to result in the minor loss or modification to the vegetation. The sensitivity of the receptors is between low because transportation will occur locally, and the construction of these facilities are on-site and therefore have impacts on populations on the study area.

7.5.3.6 Impacts of potential breakout fires on flora

The possibility of breakout fires or explosions through the handling of hazardous substances may cause local flora to be destroyed. Fires may result from the spontaneous heating of coal, friction from defective machines and equipment, electrical sparking, short circuits and poorly maintained explosives and detonators. The adverse impact is expected to be direct, irreversible, and temporary considering the duration of the specific impact (Table 27). However, these incidences are unlikely due to all the precautionary measures in place.

The extent of impact expected to be limited to the Project site. Mitigation includes good maintenance of equipment as well as proper storage units. Proactive approaches must be implemented in the OEMP.

The magnitude of change is expected to be negligible due to the minor loss and unlikelihood of the impact to occur after mitigation. The sensitivity of the receptor is low because it is likely that the impact will be maintained on-site of within a local scale.

Table 27 - Impacts on Flora

Activity	Receptor	Impact	Nature of impact	Value & Sensitivity	Magnitude of change	Significance of impact
Site clearing and topsoil stockpiling during construction.	Trees and shrubs	Vegetation/land clearing causes loss of species and sensitive habitats	Adverse Direct Partly reversible Medium term On-site Likely	Low	Moderate	Minor (3)
During construction and operation activities	Flora	Introduction of alien invasive species that disperse easily and compete heavily with endemic and/or protected species	Adverse Direct Partly reversible Long term Local Possible	Low	Minor	Low (2)
Employment, Procurement of contractors, good and services for underground mining method		Illegal and unsustainable collection of plants by staff reduces the biodiversity of protected species	Adverse Direct Partly reversible Permanent Regional Unlikely	Medium	Major	Minor (4)
Groundwater abstraction		Groundwater abstraction may	Adverse Direct	Low	Minor	Low (2)

Activity	Receptor	Impact	Nature of impact	Value & Sensitivity	Magnitude of change	Significance of impact
		reduce the quality and quantity available to surrounding plants.	Partly reversible Medium term On-site Possible			
Handling of hazardous substances including explosives		Breakout fires could damage flora, surrounding habitats and result in the loss of flora	Adverse Direct Irreversible Temporary On-site Unlikely	Low	Major	Low (2)
Transport of material, people, and equipment from surface to underground		Damage to vegetation by different forms of transport, equipment, and machinery	Adverse Direct Partly reversible Long term Regional Possible	Medium	Minor	Minor (4)

7.5.4 BIODIVERSITY IMPACTS: FAUNA

7.5.4.1 The impacts of the construction and operation of the Project on reptiles.

The reptile diversity on ML 245 is viewed as relatively moderate. There are approximately 51-60 different reptile species in the proposed site. However, 7 species were identified as sensitive during the fauna impact study carried out by John Irish (2014) with only 2 confirmed rated as high vulnerability. The species identified were the following: *Rhoptropella ocellata* (near threatened), *Homopus solus* (vulnerable), *Chamaeleo namaquensis* (least concern), *Karusasaurus polyzonus*, Cherian *angulate*, *Psammobates tentorius* and *Stigmochelys pardalis* (not evaluated) (Irish, 2014). The impacts to reptiles in the project area before mitigation during the project construction and operation phases are presented in Figure 59 for illustrative purpose only. In the fauna impact study, sensitive habitats were highlighted along with the potential impact associated with the habitat as seen in Table 28.

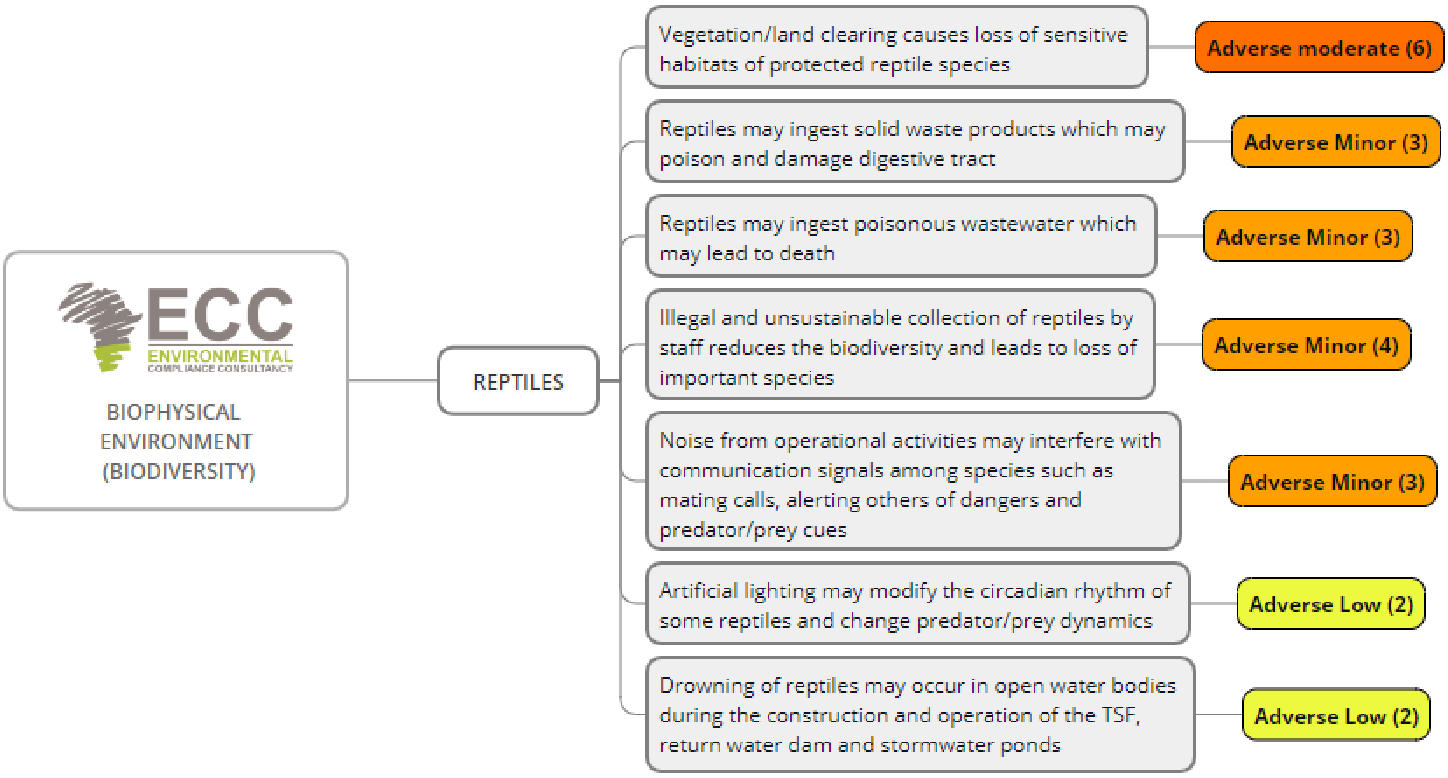


Figure 59 - Impacts on reptiles.

Table 28 - Habitat related sensitivities

Component/habitat	Sensitivity	Vulnerability	Potential Impact
Sandy gravelly plains	Above average diversity, average endemism and range-restrictedness.	Low; IFC Natural Habitat	Little or none: far outside direct development footprint.
Sandy gravelly plains	Average diversity and endemism, low range-restrictedness.	Medium; IFC Natural Habitat	Habitat destruction: the largest part of the development footprint is in this habitat.
Succulent plains	High diversity, high endemism, high range-restrictedness.	High; IFC Critical Habitat	Habitat destruction: part of the development footprint is in this habitat.
Mountains, hills and	High diversity,	High; IFC	Habitat destruction: part of the

Component/habitat	Sensitivity	Vulnerability	Potential Impact
footslopes	high endemism, high range-restrictedness.	Critical Habitat	tailings dump covers this habitat.
Windblown sand patches	Average diversity, high endemism, high range-restrictiveness.	Medium; IFC Critical Habitat	Little or none: far outside direct development footprint.
Natural water points	Ecological resource for vertebrates, aquatic habitat for invertebrates	High; IFC Critical Habitat	Habitat destruction through dewatering; focal points for poaching, illegal gathering, disturbance of game.

7.5.4.1.1 Impacts of site clearing and destruction of habitats on reptiles.

The impact of site clearing, and topsoil are not expected to be detrimental as is may result in the loss of habitat of some individuals in this area. The impact is adversely direct, partly reversible and will occur over a medium term.

As seen in Table 29, mitigations will involve the avoidance of critical habitats. In the fauna impact study, it was specified that ongoing attention on taxon level impacts is required. For vertebrates of concern this involves verification of occurrence and monitoring of population trends. The magnitude of change is minor due to the measurable change brought by the impact – migration of mammal species. The sensitivity of the receptor is low due to the impact occurring on-site and affecting individuals in the specific area. The table below depicts the overall summary of the reptile impact assessment.

7.5.4.1.2 Impacts of solid and effluent wastewater on reptiles.

Local reptiles may ingest solid waste often with sharp edges damaging their internal organs and/or wet industrial waste material which includes but is not limited to sludge and weak acids. However, due to the number of identified reptiles within the site is unlikely to have a detrimental impact the overall number of reptiles. The impact is adverse, direct, and irreversible.

Mitigation measures should include minimisation of waste, reuse of mining solid and liquid waste, regular disposal of waste to appropriate facilities especially when hazardous substances have been used. The magnitude of change is expected to be moderate due to the potential loss of sensitive reptile individuals. The sensitivity of the receptor is low due to the impact occurring on a local scale.

7.5.4.1.3 Impacts of illegal collection of important reptiles.

Illegal and unsustainable collection of reptiles by staff reduces the biodiversity and may lead to loss of important species. The Namaqua Chameleon (*Chamaeleo namaquensis*), CITES II protected species, are characterised as highly prized by collectors and it has been reported that these reptiles are illegally collected and exported. In 2018, several arrests were made due to the illegal collection of Karoo Girdled Lizard (*Karusasaurus polyzonus*), CITES II protected species, which are kept as pets by the Japanese (Information, 2019). The impact is adverse, direct and partly reversible as these species mentioned are least concern and will be able to recover.

Mitigation should include educating all staff members and contractors about the illegal reptile collection and consequences related to these illegal activities. Large sums in fines and imprisonment are a consequence for the collecting and reptiles without permits. The magnitude of change is major due to potential loss of protected species populations while the sensitivity of the receptor is medium due to the regional implications.

7.5.4.1.4 Impacts of noise and vibration from blasting activities on Reptiles.

Blasting and vibration activities during the development of the decline entrance may temporarily interfere with communications among species such as mating calls, alerting others of dangers and predator/prey cues. Essentially this may have an impact on the reproduction and survival rates of certain reptiles. However, this is a short-term impact and is unlikely to have detrimental effects on the reptiles present on ML 245. The impact is adverse, direct, and reversible.

Mitigation measures are described in the EMP. The magnitude of change is minor due to the minor changes to the behaviour of species and the sensitivity is low due to the local extent of the impact.

7.5.4.1.5 Impacts of artificial lighting on reptiles.

Power supply to the underground mining area is likely to attract reptiles to specific habitats, potentially increasing competition and changing predator/prey dynamics. Artificial light may affect the circadian rhythm of organisms. This impact is unlikely to be detrimental to reptiles due to the reversibility and medium-term nature of the impact.

The magnitude of change is minor due to potential measurable change to the behaviour of reptiles. The sensitivity of the receptor is low due to the impact occurring on-site and affecting individuals in the specific area.

7.5.4.1.6 Drowning of reptiles in artificial dams and the TSF.

Wastewater reservoirs featuring High-Density Polyethylene (HDPE) liners, like Permeable Reactive Barrier (PRB) dams, return water dams, and drainage systems, may present a hazard for reptiles and other wildlife. The smooth and slippery characteristics of HDPE liners are recognized for creating challenging surfaces, complicating the ability of reptiles to ascend from the water and elevating the risk of drowning occurrences. For this reason, the nature of this impact has been rated adverse and direct. The reversibility of this impact is irreversible, and the duration of this impact is medium term. The magnitude of change is moderate and the extent of the impact on site. While the probability of this impact occurring is likely. The sensitivity and value of this impact is low; therefore, this impact has been rated adverse minor.

Table 29 - Impacts of the Project on Reptiles

Activity	Receptor	Impact	Nature of impact	Value & Sensitivity	Magnitude of change	Significance of impact
Construction and operations of the underground mine and waste rock dump (WRD)	Reptiles	Vegetation/land clearing causes loss of sensitive habitats of protected reptile species	Adverse Direct Partly reversible Long term Regional Likely	Medium	Minor	Moderate (6)
Solid waste generation, collection, transport and disposal		Reptiles may ingest solid waste products which may poison and damage digestive tract	Adverse Direct Irreversible Long term Local Possible	Low	Moderate	Minor (3)
Human effluent wastewater generation, collection, transport and disposal		Reptiles may ingest poisonous wastewater which may lead to death	Adverse Direct Irreversible Long term Local Possible	Low	Moderate	Minor (3)
Employment, Procurement of contractors,		Illegal and unsustainable collection of reptiles by	Adverse Direct Partly reversible	Medium	Major	Minor (4)

Activity	Receptor	Impact	Nature of impact	Value & Sensitivity	Magnitude of change	Significance of impact
good and services for underground mining method		staff reduces the biodiversity and leads to loss of important species	Permanent Regional Unlikely			
Blasting and drilling activities during operations		Noise from operational activities may interfere with communication signals among species such as mating calls, alerting others of dangers and predator/prey cues	Adverse Direct Reversible Minor Short term Local Likely	Low	Minor	Minor (3)
Power supply to underground		Artificial lighting may modify the circadian rhythm of some reptiles and change predator/prey dynamics	Adverse Direct Reversible Long term On-site Likely	Low	Minor	Low (2)
Construction and operation of the TSF, return water dam and stormwater ponds		Drowning of reptiles in open water bodies	Adverse Direct Irreversible Medium term Moderate Onsite Likely	Low	Moderate	Low (2)

7.5.4.2 The impact of the construction and operations of the Project on amphibians.

The amphibian diversity is extremely low in the general project area with approximately 1- 3 species. During the fauna impact assessment carried out by John Irish (2014), no amphibian species were recorded. It has been determined that the proposed mining project is unlikely to impact amphibian diversity, abundance and composition and is therefore not assessed in this section.

7.5.4.3 The impact of the construction and operation of the Project on mammals.

The mammal species diversity in this area are low to moderate with approximately 46-60 species, of which 15 are carnivores. The fauna impact assessment conducted by John Irish (2014) identified 12 sensitive mammal species on ML 245, of which 10 are described as least concern. The species identified were the following: Panthera pardus and Hyaena brunnea (near threatened); *Papio Ursinus, Felis silvestris, Caracal caracal, Proteles cristata, Vulpes chama, Otocyon megalotis, Orycteropus afer, Raphicerus campestris, Sylvicapra grimmia and Oreotragus oreotragus* (least concern). The impacts to mammals in the project area before mitigation during the project construction and operation phases are presented in Figure 60 for illustrative purpose only. The summary of the mammal impacts is shown in Table 30.

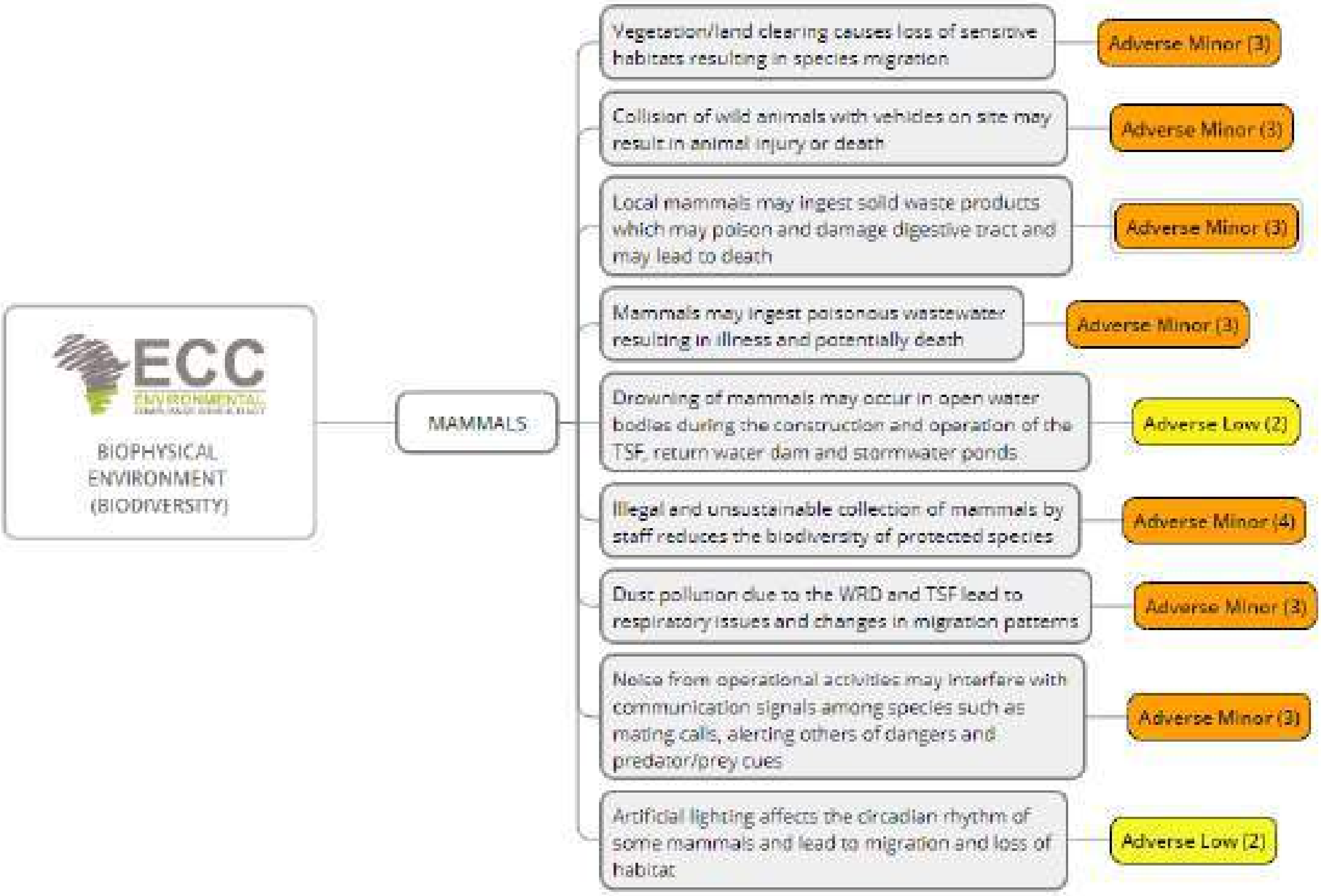


Figure 60 - Impacts of the Project on mammals.

7.5.4.3.1 Impacts of site clearing and destruction of habitats on mammals.

The impact of site clearing, and topsoil are not expected to be detrimental to local fauna as it would likely cause larger mammals to migrate to favourable areas with less disturbance and suitable habitats. This will also reduce the overall range size in which mammals can roam. The impact is adversely direct, partly reversible and will occur over a medium term.

The sensitive habitats described in Table 30 should be avoided, to prevent the destruction of critical habitats. Further mitigation measures are elaborated in the ESMP. The magnitude of change is minor due to the measurable change brought by the impact – migration of mammal species. The sensitivity of the receptor is low due to the impact occurring on-site and affecting individuals in the specific area.

7.5.4.3.2 Impacts of solid and effluent wastewater on mammals.

Mammals may ingest solid waste often with sharp edges damaging their digestive tract and internal organs and/or wet industrial waste material which may include sludge and weak acids. Animals are often attracted by brightly coloured materials, when ingested, it often blocks the digestive track preventing more food from being ingested (Lai, 2022). This causes starvation and possibly death. The impact is adverse, direct, and irreversible.

Mitigation measures should include minimisation of waste, reuse of mining solid and liquid waste, regular disposal of waste to appropriate facilities especially when hazardous substances have been used. The magnitude of change is moderate due to the potential death or severe injuries of sensitive large and small mammals. The sensitivity of the receptor is low due to the impact occurring on a local scale.

7.5.4.3.3 Drowning of reptiles in artificial dams and the TSF.

Wastewater reservoirs featuring High-Density Polyethylene (HDPE) liners, like Permeable Reactive Barrier (PRB) dams, return water dams, and drainage systems, may present a hazard for mammals. The smooth and slippery characteristics of HDPE liners are recognized for creating challenging surfaces, complicating the ability of reptiles to ascend from the water and elevating the risk of drowning occurrences. For this reason, the nature of this impact has been rated adverse and direct. The reversibility of this impact is irreversible, and the duration of this impact is medium term. The magnitude of change is moderate and the extent of the impact on site. While the probability of this occurring is likely, the sensitivity and value of this impact is low; therefore, this impact has been rated adverse minor.

7.5.4.3.4 Impacts of potential wildlife and vehicle collisions.

Wildlife-vehicle collisions are caused by the relationship and close interaction of human and wildlife as a result of invading each other's habitats (Pagany, 2020). According to the fauna impact assessment, the protected mammal species most prone to nocturnal vehicle collisions are *Hyaena brunnea*, R*oteles cristata*, *Vulpes chama, Otocyon megalotis* and *Orycteropus afer.* Increased collisions occurring on site may result in the injury or possible death of mammals. The impact is adverse, direct, irreversible and may lead to permanent injuries or loss of the species.

Mitigation may involve all vehicle activities to abide by the speed limits of maximum 30 km/h and using existing tracks and majority of trips should be during the day for the safety of the driver, passengers, and nocturnal animals. The magnitude of change is moderate due to the potential loss of important species such as the mammals mentioned in this section. The sensitivity of receptor is low due to the extent of the impact.

7.5.4.3.5 Impacts of illegal collection and trading of important mammal species.

Namibia has a rich wildlife and particularly has high mammal biodiversity and abundance. Leopards (Panthera pardus) are near threatened for various reasons including hunting activities for the illegal wildlife trade. Steenbok (Raphicerus campestris), NCO protected game, are also among the most frequent poached mammal species. Increased illegal collection and trade may lead to the loss of protected populations and impact the overall biodiversity and food web dynamics. Illegal collection and trading of mammal species is adverse, direct, and partly reversible.

Mitigation measures are explored in the ESMP. The magnitude of change is major due to the sizable impact on protected populations. The sensitivity of receptor is medium due to the regional scale of the impact.

7.5.4.3.6 Impact of dust generation on mammals during WRD and TSF construction.

Dust is often generated during construction of facilities especially waste rock dump (WRD) and tailings storage facility (TSF) construction, which in turn has a negative effect on mammals. It has been reported that dust particles irritate mammal respiratory tract and ultimately carry airborne bacteria and fungi to the lungs (Urso, Turgeon, Ribeiro, Smith, & Johnson, 2021). The impact is expected to be adverse, direct, and partly reversible.

Mitigations are described in depth within the ESMP. The magnitude of change is minor due to the measurable change this may cause to mammals on-site. The impact is likely to only effect the mammals on-site, therefore the sensitivity is low.

7.5.4.3.7 Impacts of noise and vibrations from blasting activities on mammals.

Noise and vibrations may interrupt communication signals among species such as mating calls, alerting others of dangers and predator/prey cues. Additionally, it may lead to confusion and potential hearing loss over the long term. The impact is adverse, direct, and reversible should the mine undergo closure.

Mitigation measures should include the shutting off equipment that are not in use and noise should be restricted to daytime and areas of activity. The magnitude of change is minor due to the minor inconvenience this may cause the surrounding mammal species and the sensitivity of receptor is low due to the local scale of the impact.

7.5.4.3.8 Impacts of artificial lighting on mammals.

Artificial lighting may impact mammals in various ways, it may lead to confusion and add to nocturnal collisions and deaths. It is expected that the artificial lights will likely deter large mammals and lead to the loss of their habitat as they move further from the light source. Long-term artificial light pollution may influence the circadian rhythm of small mammals potentially suppress melatonin production, which is required for various physiological functions in mammals. The negative impact is direct, reversible, and likely to occur throughout the construction and operations of the mine.

Alternative low intense lighting options should be taken into consideration at the project architectural design to limit lights to the mining site and operation area. More mitigations are explored in the EMP. The magnitude of change is minor as this impact will impact a few mammalian individuals. The sensitivity is low due to the impact only occurring on the actual operational site. The overall significance of the impact is low.

Table 30 - Impact of the Project on mammals

Activity	Receptor	Impact	Nature of impact	Value & Sensitivity	Magnitude of change	Significance of impact
Site clearing and topsoil stockpiling.	Mammals	Vegetation/land clearing causes loss of habitat resulting in species migration.	Adverse Direct Partly reversible Medium term On-site Likely	Low	Moderate	Minor (3)
		Collision of wild animals with vehicles on site may result in animal injury or death	Adverse Direct Irreversible Permanent On-site Possible	Low	Moderate	Minor (3)

Activity	Receptor	Impact	Nature of impact	Value & Sensitivity	Magnitude of change	Significance of impact
Solid waste generation, collection, transport and disposal		Local mammals may ingest solid waste products which may poison and damage digestive tract and may lead to death	Adverse Direct Irreversible Long term Local Possible	Low	Moderate	Minor (3)
Human effluent wastewater generation, collection, transport and disposal		Local mammals may ingest poisonous wastewater resulting in illness and potentially death	Adverse Direct Irreversible Long term Local Possible	Low	Moderate	Minor (3)
Construction and operation of the TSF, return water dam and stormwater ponds		Drowning of mammals in open water bodies	Adverse Direct Irreversible Medium term Moderate Onsite Likely	Low	Moderate	Low (2)
Employment, Procurement of contractors, good and services for underground mining method		Illegal and unsustainable collection of mammals by staff reduces the biodiversity of protected species	Adverse Direct Partly reversible Permanent Regional Unlikely	Medium	Major	Minor (4)
Waste Rock Dump (WRD)		Dust pollution due to the	Adverse Direct	Low	Minor	Minor (3)

Activity	Receptor	Impact	Nature of impact	Value & Sensitivity	Magnitude of change	Significance of impact
and Tailings Storage Facility (TSF) construction		WRD and TSF lead to respiratory issues and changes in migration patterns	Partly reversible Medium term On-site Likely			
Blasting and drilling activities during operations		Noise from operational activities may interfere with communication signals among species such as mating calls, alerting others of dangers and predator/prey cues	Adverse Direct Reversible Minor Short term Local Likely	Low	Minor	Minor (3)
Power supply to underground		Artificial lighting affects the circadian rhythm of some mammals and lead to migration and loss of habitat	Adverse Direct Reversible Long term On-site Likely	Low	Minor	Low (2)

7.5.4.4 The impact of the construction and operation of the Project on avifauna.

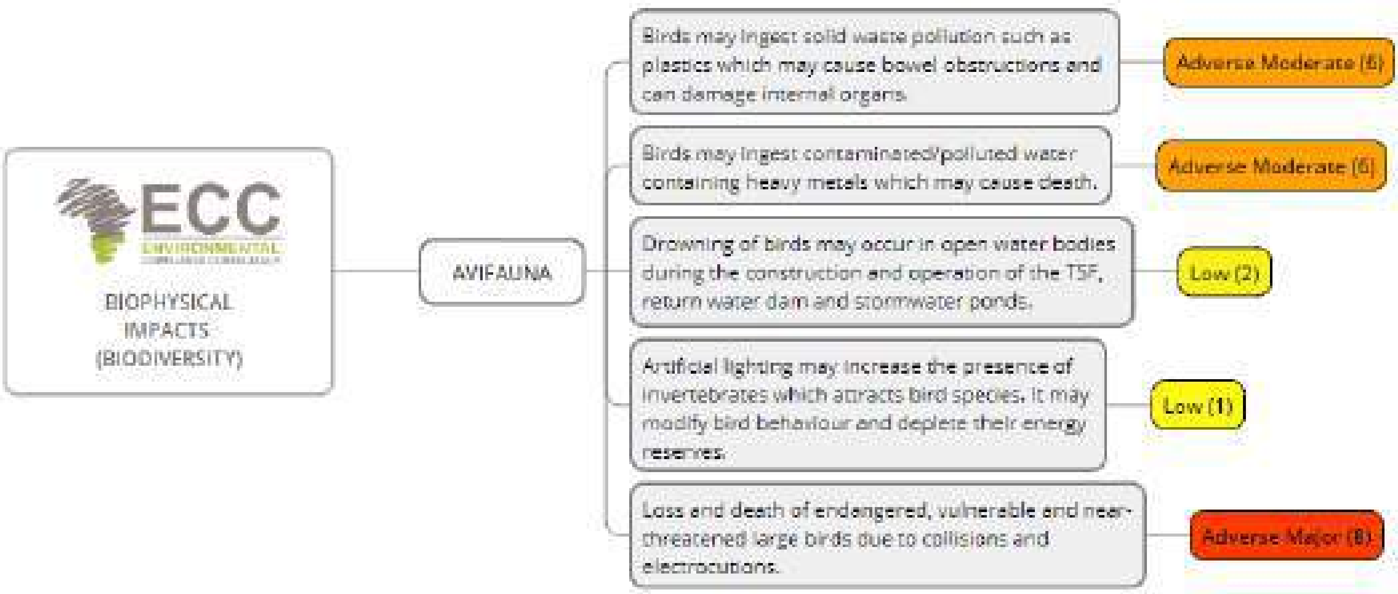


Figure 61 - Impact of the Project on avifauna

7.5.4.4.1 Solid waste and effluent wastewater generation, collection, transport, and disposal impact on avifauna.

The impacts of the underground mine on bird species are associated with activities that are focused on the ground such as disposal of solid and liquid wastes. Different bird species that occur in the area such as the Martial eagle (*Polemaetus bellicosus*), Lappet-faced vulture and Verreauxs' eagle that are particularly vulnerable to poison and drowning in local dams (Pellet, 2014). These may be attracted to waste rock dumps (WRDs) or tailings storage facilities (TSFs) whereby they ingest wet industrial waste material (sludge and weak acids) which may cause bowel obstructions, damaging internal organs could lead to possible injury or death. The adverse impact is expected to be direct, regional and will occur in the long term due to the LoM (approximately 15 years) (Table 31).

Mitigation measures should include minimisation of waste, reuse of mining solid and liquid waste, regular disposal of waste to appropriate facilities especially when hazardous substances have been used.

The magnitude of change after mitigation is expected to be moderate because individual will be impacted but entire population will not be at risk. The sensitivity of the receptor is medium because of the regional scale of the impact.

7.5.4.4.2 Artificial lighting impact on birds in the mining area.

The use of artificial lighting illuminate nocturnal environments and light pollution has only recently been identified as a potential impact on the behavioural and reproductive success of organisms (Davies, Bennie, & Gaston, 2012). Flying invertebrates may become increasingly attracted to artificial light during different times of the day which is likely to attract birds in search of prey. Light pollution may modify bird behaviour and deplete their energy reserves.

Birds are migratory and therefore the scale of these adverse impacts is expected to be regional. The adverse impacts are considered direct and long term for the duration of the mining activities. Mitigation measures should include awareness to staff members to reduce the amount and duration of artificial lighting. Avifauna monitoring programmes should be enforced especially regarding protected species and breeding sites. Light management measures include using low intensity lighting bulbs in the overall mine architectural design to limit light pollution.

The magnitude of change, should mitigation measures be applied, is expected to be negligible due minor alterations to the behaviour of birds. The sensitivity of the receptor will remain medium due to the birds being migratory, thus affecting bird species on a regional scale.

7.5.4.4.3 Avifauna may be attracted to open water bodies which may lead to drowning and the attraction of migratory or invasive bird species.

The existence of open water bodies is a magnet for avian species, particularly migratory birds. Birds may face the risk of drowning if they become entangled in aquatic flora or lack the strength to swim. These water bodies frequently serve as rest stops for migratory birds on their journeys, potentially heightening the chances of collisions with structures or nearby hazards. Open water bodies can also serve as conduits for the introduction of invasive species, either through water transfer or by offering an environment conducive to non-native species. This, in turn, has the potential to disturb local ecosystems and have adverse effects on native bird species. For this reason, the nature of this impact has been rated adverse and direct. The reversibility of this impact is irreversible, and the duration of this impact is medium term. The magnitude of change is moderate and the extent of the impact onsite. While the probability of this impact occurring is likely. The sensitivity and value of this impact is low; therefore, this impact has been rated adverse minor.

7.5.4.4.4 Avifauna may be subjected to powerline collisions and electrocutions.

A major impact on birds are powerline collisions and electrocutions which causes an alarming number of deaths. According to the bird impact assessment carried out by John Pellet (2014) endangered bird species common in the project area are the Ludwig's bustard, Martial eagle, Booted eagle and Black Harrier, while Secretary birds, Lappet-faced vultures are vulnerable. Approximately 47 000 Ludwig's bustards are killed in Southern Africa each year due to power lines, other large bird species killed at a high rate includes flamingos, storks, vultures, and Secretary birds (Pallett, Simmons, & Brown, 2022). Larger bustards have poor manoeuvrability making them more prone to collisions. Despite this, there are no accepted guidelines for mitigation of the issue in Namibia and South Africa.

Mitigations would include the use of bird deterrents that will prevent electrocutions and collisions may be visual such as flashing or blinking lights. The use of environmentally friendly, non-lethal and non-conductive plastic bird spikes are designed to fend off bird landings, protecting birds and preventing damage to powerlines. Bird-Flight Diverters were developed for overhead powerlines to increase the visibility with the use of round yellow wires, preventing collisions. The Bird impact assessment (Appendix F) assures that the current route of the proposed power line is the best possible option available as it is aligned close to the road which is likely to be avoided birds such as the Ludwig's bustard due to the increased traffic and noise.

The magnitude of change after mitigation is expected to be high due to the likelihood and long-term nature of the impacts and the sensitivity of the receptor is considered medium due to the regional/national scale at which the impact will occur. However, after mitigation the probability of the impact occurring is possible in certain circumstances.

Table 31 - Impacts on Avifauna

Activity	Receptor	Impact	Nature of impact	Value & Sensitivity	Magnitude of change	Significance of impact
Solid waste generation, collection, transport and disposal, TSF construction and operational phase	Avifauna	Birds may ingest solid waste pollution, including plastics which may poison and damage digestive tract and in severe cases lead to bird fatalities.	Adverse Direct Irreversible Long term Regional Possible	Medium	Moderate	Moderate (6)
Human effluent wastewater generation, collection, transport and disposal		Birds may ingest poisonous/ contaminated wastewater which may cause death	Adverse Direct Irreversible Long term Regional Possible	Medium	Moderate	Moderate (6)

Activity	Receptor	Impact	Nature of impact	Value & Sensitivity	Magnitude of change	Significance of impact
Construction and operation of the TSF, return water dam and stormwater ponds		Drowning of birds in open water bodies	Adverse Direct Irreversible Medium term Moderate Onsite Likely	Low	Moderate	Low (2)
Power supply to underground		Artificial lighting may increase the presence of invertebrates which attracts bird species. It may modify bird behaviour and deplete their energy reserves	Adverse Direct Reversible Long term Regional Possible	Medium	Minor	Minor (4)
		Increase in large bird collisions - increased electrocutions and death of birds, especially endangered, near-threatened and vulnerable birds	Adverse Direct Irreversible Long term Regional Likely	Medium	Major	Major (8)

7.5.4.5 Noise and vibrations associated with avifauna and fauna.

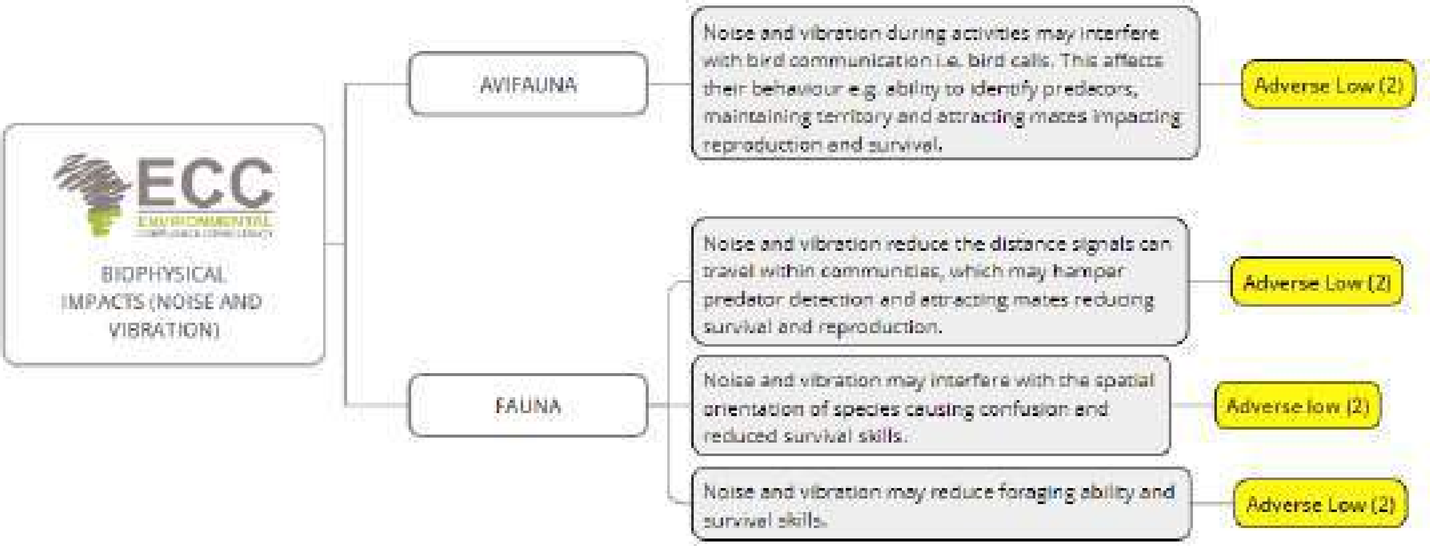


Figure 62 - Noise and vibration impacts on avifauna and fauna during the construction and operational phases

7.5.4.5.1 Impacts of noise and vibration on avifauna.

The impacts of blasting and other activities during the construction and development of the of the underground mine decline entrance will not be detrimental to local avian as it will lead changes or increased migration. Noise and vibrations may interrupt with communication among birds i.e., bird calls. This may affect their behaviour e.g., territory changes, identification of predators and courtship behaviour. The impact is adverse, direct, and reversible.

Mitigation may include restriction of excessive noise and to shut down equipment in between to minimise noise and vibrations as far as possible. It is also advised that activities be restricted during the day as to not disrupt or modify the life cycle of avifauna species.

The magnitude of change is minor due to the duration of impact, whilst the sensitivity of the receptor will be low because noise and vibrations associated with blasting activities will occur on-site.

7.5.4.5.2 Impacts of noise and vibration on fauna.

The impacts of blasting and other activities during the construction and operation phase of the underground mine are not expected to be detrimental to local fauna, as it would most likely lead to increased migration of larger species. Noise pollution may impact a variety of faunal functions and behaviours such as communication, spatial orientation, and foraging ability. The impact is likely to be reversible and over a short-term period.

Mitigation measures are highlighted in the section above and the EMP. The magnitude of change is minor due to the minor change and duration of the impact. The sensitivity of receptor will be low due to the local scale of the impact. The overall significance of the impact is low as seen in Table 32.

Table 32 - Impact of noise and vibration on fauna and avifauna

Activity	Receptor	Impact	Nature of impact	Value & Sensitivity	Magnitude of change	Significance of impact
Blasting during the underground decline development and other activities during the construction and operational phase	Avifauna	Noise and vibrations interfere with communication among birds i.e. bird calls. This affects their behaviour e.g. maintain territories, identify predators and attract mates impacting their reproduction and survival	Adverse Direct Reversible Short term Local Possible	Low	Minor	Low (2)
	Terrestrial ecology and biodiversity - fauna	Noice and vibration reduce the distance signals can travel within communities, which may hamper predator detection	Adverse Direct Reversible Short term Local Possible	Low	Minor	Low (2)
		Noise and vibration may interfere with spatial orientation of species	Adverse Direct Reversible Short term Local Possible	Low	Minor	Low (2)

Activity	Receptor	Impact	Nature of impact	Value & Sensitivity	Magnitude of change	Significance of impact
		causing confusion				
		Noise and vibration reduce foraging ability which impacts survival	Adverse Direct Reversible Short term Local Possibly	Low	Minor	Low (2)

7.6 FURTHER CONSIDERATION CUMULATIVE IMPACTS

The EIA regulations clearly state that cumulative impacts should be considered as part of the ESIA for a proposed project. Good practice requires that, as a minimum, cumulative impacts are assessed during the ESIA process. Cumulative impacts can arise when a single resource or receptor is affected by more than one impact from the proposed project. For example, sensitive receptors could be affected by noise from construction vehicles and dust from ground excavation during the construction stage. In isolation, the impacts of noise and dust may be insignificant, however, when combined, the impacts on the receptor (if present) may result in a significant impact.

Cumulative impacts may also arise because of the combination of two or more projects. A receptor could be impacted by similar types of impact from different developments, or a receptor. Cumulative impacts have a wide temporal and spatial scope and are not restricted to a local area nor need to happen at the same time. It is, therefore, crucial to identify a suitable study and assessment area, as well as a timeframe to assess. Cumulative impacts can also be vast and complicated; therefore, it is important to focus on the significant impacts.

The six-step rapid CIA process has been followed:

- Step 1: Scoping - determine spatial and temporal boundaries.
- Step 2: Scoping - identify valued environmental and social receptors and identify reasonably foreseeable developments.
- Step 3: Determine the present condition of valued environmental and social receptors (the baseline)
- Step 4: Assessment of cumulative impacts and evaluation of the significance of the cumulative impacts
- Step 5: Identification of mitigation measures to avoid or reduce cumulative impacts.

The cumulative impacts that may arise because of the project before mitigation are presented in Figure 63, for illustrative purposes only and are outlined in Table 33 and Table 34.

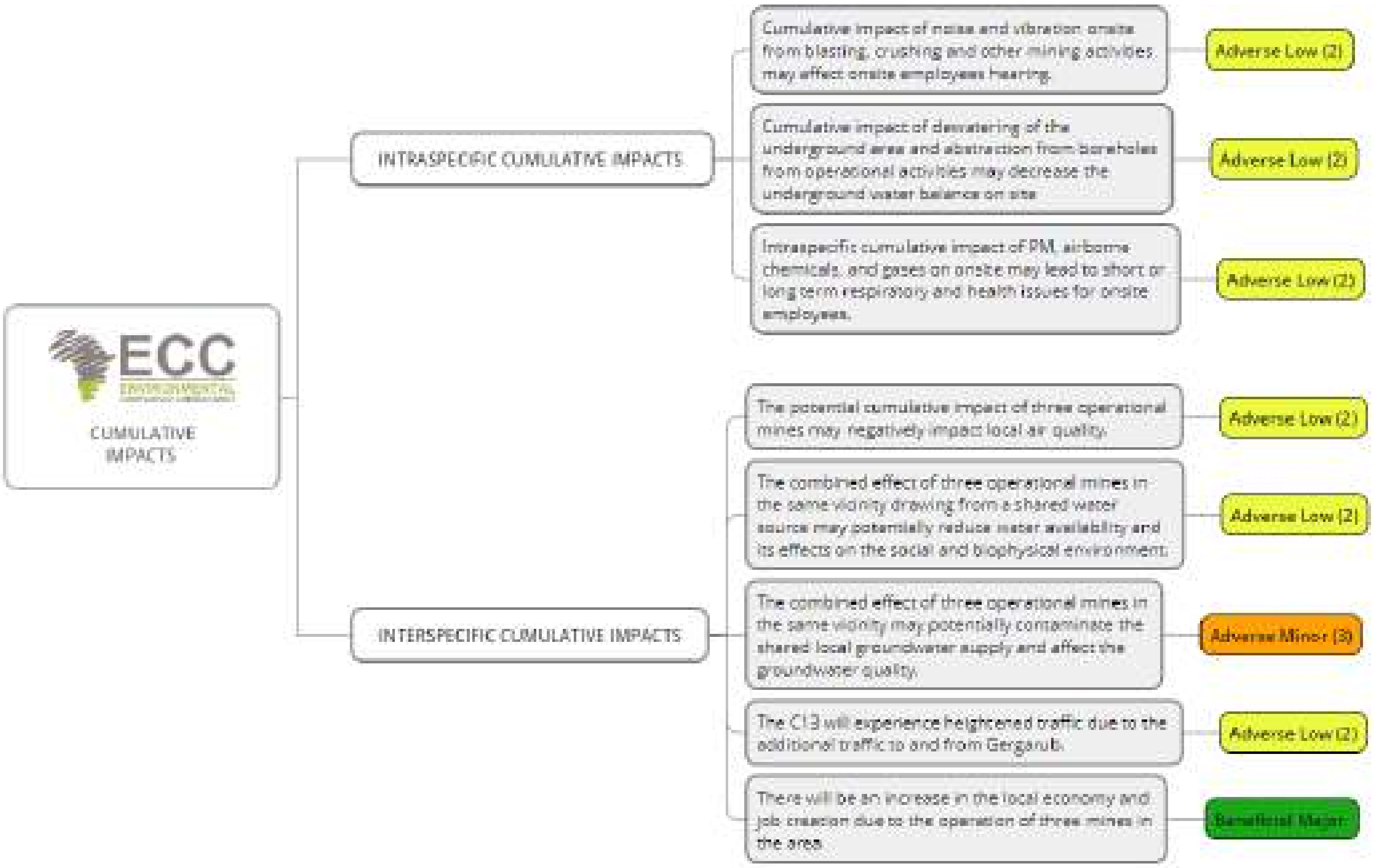


Figure 63 - Intraspecific and interspecific cumulative impacts.

7.6.1 INTRASPECIFIC CUMULATIVE IMPACTS

7.6.1.1 *Cumulative impact of noise and vibration on site from blasting, crushing and other mining activities may affect onsite employees hearing.*

Generate significant noise and vibration, which can disturb wildlife. Prolonged exposure to these disturbances can cause stress, affect communication, and alter behaviors within a population. Cumulative impacts may result in chronic stress levels that affect the overall health of employees on site. The nature of this impact is adverse and cumulative. The impact is reversible, and duration of the impact is short-term, lasting only during the LoM. The Scale of this impact is on site and the magnitude of the impact is low. The probability of this impact occurring is likely and the sensitivity of this impact is low. Therefore, this impact has been rated adverse low.

7.6.1.2 *Cumulative impact of dewatering of the underground area and abstraction from boreholes from operational activities may decrease the underground water balance on site.*

Mining activities may impact water flow and quality in the surrounding areas. Changes in hydrology can affect aquatic species, disrupting their habitats and potentially leading to cumulative impacts on population sizes and diversity. While underground dewatering and abstraction of water on site may adversely affect the availability and quality of water on site. While the potential for contamination of groundwater may also impede the availability and quality of water onsite. The nature of this impact is adverse and cumulative. The impact is reversible, and duration of the impact is short-term, lasting only during the LoM. The Scale of this impact is on site and the magnitude of the impact is low. The probability of this impact occurring is likely and the sensitivity of this impact is low. Therefore, this impact has been rated adversely low.

7.6.1.3 *Intraspecific cumulative impact of PM, airborne chemicals, and gases on onsite may lead to short or long term respiratory and health issues for onsite employees.*

The different mining activities such as blasting, excavating the underground area, crushing and hauling and other miscellaneous activities that produce windblown dust. This can impact the air quality on site and contribute to short-term discomfort to long-term health issues. The nature of this impact is adverse and cumulative. The impact is reversible, and duration of the impact is short-term, lasting only during the LoM. The Scale of this impact is on site and the magnitude of the impact is low. The probability of this impact occurring is likely and the sensitivity of this impact is low. Therefore, this impact has been rated adversely low.

7.6.2 INTERSPECIFIC CUMULATIVE IMPACTS

7.6.2.1 *The potential cumulative impact of three operational mines may negatively impact local air quality.*

Mining activities of ten produce a lot of airborne particulate matter such as PM_{10} and $PM_{2.5}$ and airborne chemical gases such as SO_2, NO_x, CO and VOC. These particles and chemicals can have detrimental effects of over air quality and respiratory health of nearby receptors. Additionally, dust and fugitive emissions can also impact local air quality. Furthermore, the operations of these three mines may contribute to the emission of greenhouse gases such as carbon dioxide (CO_2) and methane (CH_4). These gases can contribute to climate change and have broader environmental implications. The nature of this impact is adverse and cumulative. The impact is reversible, and duration of the impact is short-term, lasting only during the LoM. The Scale of this impact is local, and the magnitude of the impact is low. The probability of this impact occurring is likely and the sensitivity of this impact is low. Therefore, this impact has been rated adverse low.

7.6.2.2 *The combined effect of three operational mines in the same vicinity drawing from a shared water source may potentially reduce water availability and its effects on the social and biophysical environment.*

The combined extraction of groundwater by multiple mines may cause a depletion in available groundwater in the local area if the extraction rate is higher than the natural recharge rate. This may lead to disruption in the local water balance and availability. The extraction of water can impact local ecosystems that depend on the water source. Reduced water availability may harm aquatic habitats, affect plant life, and disrupt the overall balance of the ecosystem. This, in turn, can have cascading effects on the flora and fauna in the area. The increased demand for water by the mines may affect the local community's water supply. This can lead to water shortages for residential, agricultural, or other essential purposes, impacting the livelihoods and well-being of the local population. Competition for limited water resources can lead to conflicts among stakeholders, including the mining companies, local communities, and agricultural interests. This can escalate into legal disputes and social tensions. The nature of this impact is adverse and cumulative. The impact is reversible, and duration of the impact is short-term, lasting only during the LoM. The Scale of this impact is regional, and the magnitude of the impact is low. The probability of this impact occurring is likely and the sensitivity of this impact is low. Therefore, this impact has been rated adverse low.

7.6.2.3 The combined effect of three operational mines in the same vicinity may potentially contaminate the shared local groundwater supply and affect the groundwater quality.

The cumulative impact of three operational mines in the same vicinity may exacerbate the contamination risk. The interaction of pollutants from multiple sources can have a more pronounced effect on groundwater quality than individual impacts. The nature of this impact is adverse and cumulative. The impact is irreversible, and duration of the impact is long term, lasting throughout the LoM. The scale of this impact is regional, and the magnitude of the impact is low. The probability of this impact occurring is possible and the sensitivity of this impact is low. Therefore, this impact has been rated adverse minor.

7.6.2.4 The C13 will experience heightened traffic due to the additional traffic to and from Gergarub.

Increased mining traffic will worsen existing traffic congestion, causing delays and extending travel times for all road users. These delays can have widespread effects on businesses, commuters, and overall transportation system efficiency. The influx of heavy mining vehicles can accelerate road infrastructure deterioration, leading to higher maintenance costs and more frequent repairs. Congested roads are associated with increased accident rates, raising safety concerns, especially if the road wasn't designed for intense and frequent mining traffic. Efficient transportation is crucial for the mining industry and other businesses relying on the road, and delays can result in higher costs, impacting the region's economic sustainability. If the road is the primary route to the coast, congestion may have broader economic implications, affecting trade, logistics, and regional development strategies. The nature of this impact is adverse and cumulative. The impact is reversible, and duration of the impact is short-term, lasting only during the LoM. The Scale of this impact is local, and the magnitude of the impact is low. The probability of this impact occurring is likely and the sensitivity of this impact is low. Therefore, this impact has been rated adverse low.

7.6.2.5 There will be an increase in the local economy and job creation due to the operation of three mines in the area.

Mining operations require a diverse range of skilled and unskilled labor, from engineers and geologists to equipment operators and support staff. The establishment of three mines can lead to a significant increase in local employment opportunities, providing jobs for people with various skill sets and qualifications. The mining industry often stimulates the growth of ancillary businesses and services. Local businesses may emerge to provide goods and services needed by the mining operations, such as equipment maintenance, transportation, catering, and accommodation. The presence of multiple mines can contribute to economic diversification, reducing dependence on a single industry. This diversification can make the local economy more resilient to fluctuations in commodity prices and market conditions. The nature of this impact is beneficial and cumulative. The impact is reversible, and duration of the impact is medium-term, as they may last after the LoM. The Scale of this impact is regional, and the magnitude of the impact is high. The probability of this impact occurring is likely and the sensitivity of this impact is medium. Therefore, this impact has been rated beneficial major.

Table 33 - Intraspecific cumulative impacts of mining operations at Gergarub

Receptor	Impacts	Significance of impact	Impact management
Noise and vibration	**Activity:** Blasting, Crushing and overall operations. **Impact:** Blasting and vibration may affect the hearing of employees.	**Low (2)**	– Retrofit or upgrade equipment to reduce noise and vibration emissions. – Conduct regular training sessions to educate employees about the risks associated with noise and vibration and promote the use of personal protective equipment (PPE). – Provide and require the use of earplugs or earmuffs for employees working in high-noise area. – Implement a monitoring program to regularly assess noise and vibration levels across the mine site. – Ensure that all equipment is well-maintained to reduce the likelihood of excessive noise and vibration emissions.
Groundwater availability	**Activity:** Dewatering of the underground area and abstraction for daily operations. **Impact:** Decrease in the quantity of water available for operations.	**Low (2)**	– Regular water audits and monitoring by monitoring groundwater levels to ensure that mining activities do not negatively impact local aquifers. (Install monitoring systems to track water usage in different processes and areas of the mine). – Implement water recycling systems to treat and reuse water from processes like mineral processing, dust suppression, and vehicle washdown. – Use treated wastewater for non-potable purposes, such as dust control or irrigation. – Ensure compliance with permitting requirements and report water usage and conservation efforts as required. – Ensure compliance with permitting requirements and report water usage and conservation efforts as required. – Continuous engagement between the three mining operations.

Receptor	Impacts	Significance of impact	Impact management
Air quality	**Activity:** Construction of the mine and commencement of operations at the mine coupled with the mining operations at the other two mines in the nearby vicinity **Impact:** Increased dust in the air reducing the quality of the air in that area.	**Low (2)**	– Regular air quality monitoring. – Dust suppression measures (Applying chemical and water dust suppressants to roads and stockpiles can help to control dust). – Constructing physical barriers like berms or windbreaks to shield sensitive areas from prevailing winds. – Ensure that international air quality standards and best practices are adhered to.

Table 34 - Interspecific cumulative impacts of mining operations at Gergarub

Receptor	Impacts	Significance of impact	Impact management
Air quality	**Activity:** Construction of the mine and commencement of operations at the mine coupled with the mining operations at the other two mines in the nearby vicinity **Impact:** Increased dust in the air reducing the quality of the air in that area.	**Low (2)**	– Regular air quality monitoring. – Dust suppression measures (Applying chemical and water dust suppressants to roads and stockpiles can help to control dust) – Constructing physical barriers like berms or windbreaks to shield sensitive areas from prevailing winds. – Ensure that international air quality standards and best practices are adhered to. – Continuous engagement between the three mining operations
Groundwater availability	**Activity:** The additional use of the groundwater sources in the area. **Impact:** This may put extra pressure on the already stressed groundwater sources which may further exacerbate the scarce water available for operations.	**Low (2)**	– Regular water audits and monitoring by monitoring groundwater levels to ensure that mining activities do not negatively impact local aquifers. (Install monitoring systems to track water usage in different processes and areas of the mine). – Implement water recycling systems to treat and reuse water from processes like mineral processing, dust suppression, and vehicle washdown. – Use treated wastewater for non-potable purposes, such as dust control or irrigation. – Ensure compliance with permitting requirements and report water usage and conservation efforts as required. – Ensure compliance with permitting requirements and report water usage and conservation efforts as required. – Continuous engagement between the three mining operations.
Groundwater quality	**Activity:** Toxic chemicals from slurry produced from tailings and the dewatering of the	**Minor (3)**	– Ensure that international air quality standards and best practices are

Receptor	Impacts	Significance of impact	Impact management
	underground area. **Impact:** Potential increase of groundwater contamination from multiple mining activities in close proximity to one another.		adhered to. – Regular water audits and monitoring by monitoring groundwater quality to ensure that mining activities do not negatively impact local aquifers. – Continuous engagement between the three mining operations
Traffic (Road users and road quality)	**Activity:** Transport of people and goods to and from the site. **Impact:** Increased traffic and heavy loads on the C13 may cause an increase in traffic congestion, resulting in longer travel times, fuel wastage and increased emissions. There will be an increase in potholes, cracks, and surface degradation increasing the need for maintenance and repair of roads to keep them in a good condition.	**Low (2)**	– Implement a structured maintenance schedule to address wear and tear, including resurfacing, grading, and drainage improvements. – Continuous engagement between the three mining operations.
Employment, skills and the local economy	**Activity:** Job creation and investment in the local economy. **Impact:** Reducing unemployment and attracting investments in a community spur the formation of new businesses, cultivating an entrepreneurial environment and enhancing local economic diversity. The resulting growth in businesses and employment enlarges the local government's tax base, generating extra revenue for crucial public services like education, healthcare, and infrastructure. This contributes substantially to the comprehensive development of the	**Beneficial Major**	– Introduce focused training initiatives aimed at enhancing the skills of the local workforce, encompassing both technical mining expertise and soft skills. – Partner with nearby educational institutions to design specialized courses and certifications relevant to mining and its associated industries. – Establish apprenticeship and mentorship initiatives to facilitate the transfer of knowledge from seasoned professionals to the local workforce. – Invest in community development projects, including infrastructure, healthcare, and educational facilities, to enhance overall quality of life. – Advocate for mining companies to give preference to local suppliers for

Receptor	Impacts	Significance of impact	Impact management
	community. Moreover, the expansion of businesses involves investments in training programs, elevating the skills of the local workforce, boosting competitiveness, and attracting additional investments, ultimately fostering innovation.		goods and services, thereby fostering the growth of indigenous businesses. – Create mechanisms to assess and enhance the capacity of local businesses to meet the demands of the mining industry. – Collaborate with local and regional authorities to enhance infrastructure such as roads, power supply, and water facilities in support of mining operations. – Work in conjunction with mining companies to actively contribute to the development and upkeep of critical infrastructure in the town. – Promote the diversification of the local economy by encouraging the development of alternative industries, reducing reliance solely on mining. – Explore prospects in tourism, agriculture, or other sectors that can flourish in tandem with mining activities.

8 CONCLUSION

A complete and comprehensive Environmental and Social Impact Assessment (ESIA) has been undertaken for the Gergarub Mining Project. All aspects have been considered in the impact assessment. These aspects have been thoroughly investigated against planned mining activities. All contributions from the public participation have been considered and incorporated in the report for the decision making and impact assessment. All specialist input has been examined and the recommended mitigations have been included in the environmental and social management plan (ESMP).

The scoping phase of the ESIA described the receiving environment adequately. Alternatives were provided in terms of the method of mining, routings of the 66 kV powerline and tailings storage location which were further assessed in the ESIA report with the aid of specialist studies. However, the site layout might change as details are refined in which case an amendment to this assessment will be prepared.

Table 35 below summarises the impacts after mitigation. On a scale from 1 to 12, low to high, the beneficial (B) and negative (N) impact significance is stated. Some variation between the sub-sections of these aspects exists so the average significance is stated for some aspects.

Table 35 - Summary of the significance ratings after mitigations for the expected impacts (B = Beneficial impact; N = negative impact; scale of 1-12 from low to high)

Socioeconomic environment: economic		**Socioeconomic environment: social**		**Biophysical environment**	
Impacts on employment and job creation	B3	Impacts on air quality	N2	Impacts on soil	N2
Impacts on national and local economy	B6	Visual impacts	N2	Impacts on drainage and hydrology	N6
Mine closure impacts	N2	Traffic impacts	N6	Impacts on groundwater	N4
		Blast and vibration impacts	N2	Biodiversity – Flora	N2
		Noise impacts	N2	Biodiversity – Reptiles	N2
		Heritage and cultural impacts	N6	Biodiversity - mammals	N2
		Occupational health and safety impacts	N6	Biodiversity - Avifauna	N4

The ESIA report adequately outlines the process of impact assessment for Gergarub Mining Project and lists all the foreseeable outcomes and recommended mitigations to prevent or reduce the potential impacts. The ESMP includes the required monitoring of the project at all stages of the project. All stakeholders and registered interested and affected parties can now provide comments, if any, for a period of 14 days to ECC and this draft ESIA and ESMP report will be submitted to the competent authorities for their review.

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APPENDIX A – ENVIRONMENTAL AND SOCIAL MANAGEMENT PLAN

APPENDIX B – PUBLIC CONSULTATION DOCUMENT

APPENDIX C – SCOPING REPORT ADDENDUM REPORT

APPENDIX D – EAP CVS

APPENDIX E – SPECIES LIST

APPENDIX F – BIODIVERISTY STUDIES

APPENDIX G – HYDROLOGY IMPACT ASSESSMENT

APPENDIX H – AIR QUALITY IMPACT ASSESSMENT

APPENDIX I – NOISE IMPACT ASSESSMENT

APPENDIX J – BLAST AND VIBRATION IMPACT ASSESSMENT

APPENDIX K – TRAFFIC IMPACT ASSESSMENT

APPENDIX L – HERITAGE IMPACT ASSESSMENT

Submitted to: Gergarub Exploration and Mining (Pty) Ltd
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Namibia

ADDENDUM REPORT:

I&AP COMMENTS AND RESPONSES ON DRAFT SCOPING REPORT FOR THE GERGARUB PROJECT ON ML 245

PROJECT NUMBER:	ECC-99-425-REP-23-D
REPORT VERSION:	REV 01
DATE:	11 AUGUST 2023

Prepared by:

TITLE AND APPROVAL PAGE

Project Name:	I&AP Comments and Responses on draft scoping report for the Gergarub Project on ML 245
Client Company Name:	Gergarub Exploration and Mining (Pty) Ltd
Client Representatives:	Ms Sheron Kaviua
Ministry Reference:	APP-00785
Authors:	Monique Jarrett and Jessica Bezuidenhout
Status of Report:	Final for Government submission
Project Number:	ECC-99-425-REP-23-D
Date of issue:	11 August 2023
Review Period	NA

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ABBREVIATIONS

ABBREVIATIONS	DESCRIPTION
EAP	environmental assessment practitioner
ECC	Environmental Compliance Consultancy
EIA	environmental impact assessment
EMA	Environmental Management Act, No.7 of 2007
EMP	environmental management plan
ESIA	environmental and social impact assessment
I&APs	interested and affected parties
km	kilometre
m	metre
MEFT	Ministry of Environment, Forestry and Tourism
ML	mining licence
MLA	mining licence area
MME	Ministry of Mines and Energy

1 INTRODUCTION

1.1 PURPOSE OF THE COMMENTS CONSOLIDATION REPORT

This document has been compiled following the required period of review to be provided for public and registered interested and affected parties (I&APs) to have access to and opportunity to comment in writing on the draft scoping report for the proposed Gergarub Mine, //Kharas Region, Namibia (the Project) before submission to the Environmental Commissioner.

The draft scoping report was completed for the Project and undertaken in accordance with the requirements of the Environmental Management Act, 2007 (Act No. 7 of 2007) and the Environmental Impact Assessment Regulation, 2007 (No. 30 of 2011) gazetted under the Environmental Management Act (EMA), 2007 (Act No. 7 of 2007).

Environmental Compliance Consultancy (ECC) prepared the scoping report, which was provided to the public and registered I&APs for review for 14 days from 19th July 2023 -7th August 2023.

This document compiles all comments received during the public review period; presents the responses from ECC as the appointed environmental assessment practitioner (EAP) for the project, the Proponent and specialists engaged in the assessment.

2 SUMMARY OF COMMENTS FROM I&APS

2.1 INTRODUCTION

In accordance with the Regulations of the EMA 2007, on the 19th of July 2023, the scoping report was circulated electronically to all registered interested and affected parties (I&APs) and identified key stakeholders. Submissions received from 1 individual was collated in a separate "Comments and Responses" table that is presented in Table 1. Responses have been provided to all comments received.

2.2 KEY FEEDBACK ON ISSUES OF CONCERN

The scoping report was provided to all I&APs, identified stakeholders and made publicly available on ECC's website. This public review period is set out to solicit comments, and feedback, and allow genuine participation in the final phase of the ESIA process. Only one comment was received during the public review period. This I&AP requested that additional and continued community engagement occurs between the Proponent and the community of Rosh Pinah. Additionally, the I&AP requested the support of the Proponent to improve the livelihoods of the residents of the town of Rosh Pinah.

3 DRAFT SCOPING REPORT - COMMENTS AND RESPONSES

Table 1 – Comments and feedback from the scoping report public review period received from Thomas Johannes representing Rosh Pinah Community Youth Members:

Comment	EAP/Proponent Response
On behalf of rosh pinah community youth members we do appreciate to hear from you and due to the climate change things mite be changed and we demand feather communication/ public meeting. we have hope on you and don't forget to make Rosh pinah great again and home of all people.	Comment noted, the impact of this Project on the socioeconomic environment of Rosh Pinah will be assessed in further detail in the impact assessment. Community engagement during the assessment will be ongoing through various forms of communication and you are welcome to continue engagements with the proponent post the impact assessment process.

4 ACKNOWLEDGEMENTS

Through the ESIA process, the Proponent and ECC have endeavoured to provide a platform to hear and address all relevant comments put forward by I&APs. ECC would like to thank the I&APs and stakeholders for providing feedback during the scoping phase of the ESIA process. We acknowledge and appreciate the time required to review these documents and ECC genuinely appreciate the input provided by I&APS. The valuable feedback received during the scoping report phase of the ESIA process will ensure a robust impact assessment is submitted to the relevant authorities for a record of decision to be made. ECC acknowledges that constructive feedback results in an improved ESIA and a project that is understood by the community and I&APs.

SPECIES	ENDEMISM	PROTECTED	IUCN1	IUCN2
Galenia africana L.				
Galenia dregeana Fenzl ex Sond.				
Galenia meziana K.Müll.				
Galenia papulosa (Eckl. & Zeyh.) Sond.				
Galenia pruinosa Sond.				
Tetragonia arbuscula Fenzl				
Tetragonia decumbens Mill.				
Tetragonia reduplicata Welw. ex Oliv.				
Trianthema parvifolia E.Mey. ex Sond. var. parvifolia				
Hermbstaedtia glauca (J.C.Wendl.) Rchb. ex Steud.				
Ozoroa concolor (C.Presl ex Sond.) De Winter	Near endemic			
Rhus populifolia E.Mey. ex Sond.				
Chlorophytum viscosum Kunth				
Searsia populifolia (E.Mey. ex Sond.) Moffett	Near endemic			
Gethyllis namaquensis (Schönland) Oberm.	Near endemic			
Haemanthus pubescens L.f. subsp. arenicola Snijman				
Strumaria hardyana D.Müll.-Doblies & U.Müll.-Doblies	Endemic			
Blepharis furcata (L.f.) Pers.	Near endemic			
Monechma crassiusculum P.G.Mey.	Near endemic			
Monechma mollissimum (Nees) P.G.Mey.				
Pachypodium namaquanum (Wyley ex Harv.) Welw.		Protected	Near threatened	Near threatened
Carissa haematocarpa (Eckl.) A.DC.				
Quaqua acutiloba (N.E.Br.) Bruyns		Protected		
Microloma calycinum E.Mey.	Near endemic			
Stapeliopsis neronis Pillans				Vulnerable
Hoodia gordonii (Masson) Sweet ex Decne.		Protected		Near threatened
Asparagus capensis L. var. capensis				
Asparagus exuvialis Burch. forma exuvialis				

Asparagus graniticus (Oberm.) Fellingham & N.L.Mey.				
Asparagus juniperoides Engl.	Near endemic			
Asparagus retrofractus L.				
Aloe erinacea Hardy	Endemic	Protected	Endangered	Endangerd
Aloe gariepensis Pillans	Near endemic	Protected		
Aloe pearsonii Schönland	Near endemic	Protected		Near threatened
Bulbine capitata Poelln.				
Bulbine namaensis Schinz	Near endemic			
Bulbine rhopalophylla Dinter				
Trachyandra bulbinifolia (Dinter) Oberm.				
Trachyandra lanata (Dinter) Oberm.	Endemic			
Trachyandra muricata (L.f.) Kunth				
Asplenium cordatum (Thunb.) Sw.				
Heliophila cornuta Sond. var. squamata (Schltr.) Marais				
Heliophila deserticola Schltr. var. deserticola				
Heliophila eximia Marais				
Heliophila trifurca Burch. ex DC.	Near endemic			
Lepidium africanum (Burm.f.) DC. subsp. divaricatum (Aiton) Jonsell				
Wahlenbergia annularis A.DC.				
Wahlenbergia erophiloides Markgr.	Endemic			Near threatened
Wahlenbergia patula A.DC.				
Wahlenbergia subrosulata Brehmer				
Boscia albitrunca (Burch.) Gilg & Gilg-Ben.		Forestry protected		
Hexacyrtis dickiana Dinter	Near endemic			
Ornithoglossum parviflorum B.Nord. var. parviflorum				
Ornithoglossum vulgare B.Nord.				
Adromischus alstonii (Schönland & Baker f.) C.A.Sm.		Protected		
Adromischus marianiae (Marloth) A.Berger var. kubusensis (Uitewaal) Toelken		Protected		

Adromischus montium-klinghardtii (Dinter) A.Berger		Protected		
Cotyledon orbiculata L. var. orbiculata				
Crassula brevifolia Harv. subsp. brevifolia		Protected		
Crassula campestris (Eckl. & Zeyh.) Endl. ex Walp.		Protected		
Crassula cotyledonis Thunb.		Protected		
Crassula elegans Schönland & Baker f. subsp. elegans	Near endemic	Protected		
Crassula expansa Dryand. subsp. pyrifolia (Compton) Toelken		Protected		
Crassula fusca Herre		Protected		Near threatened
Crassula garibina Marloth & Schönland subsp. garibina		Protected		
Crassula macowaniana Schönland & Baker f.		Protected		Near threatened
Crassula muscosa L. var. muscosa		Protected		
Crassula nemorosa (Eckl. & Zeyh.) Endl. ex Walp.		Protected		
Crassula numaisensis Friedrich	Endemic	Protected		
Crassula oblanceolata Schönland & Baker f.		Protected		
Crassula pseudohemisphaerica Friedrich		Protected		
Crassula rupestris Thunb. subsp. commutata (Friedrich) Toelken		Protected		
Crassula subacaulis Schönland & Baker f. subsp. erosula (N.E.Br.) Toelken		Protected		
Crassula subaphylla (Eckl. & Zeyh.) Harv. var. subaphylla		Protected		
Crassula tenuipedicellata Schönland & Baker f.				
Crassula tomentosa Thunb. var. tomentosa		Protected		
Tylecodon bleckiae G.Will.				
Tylecodon buchholzianus (Schuldt & P.Stephan) Toelken subsp. buchholzianus				
Tylecodon hallii (Toelken) Toelken		Protected		
Tylecodon racemosus (Harv.) Toelken				

Tylecodon reticulatus (L.f.) Toelken subsp. phyllopodium Toelken				
Tylecodon wallichii (Harv.) Toelken subsp. ecklonianus (Harv.) Toelken				
Acanthosicyos horridus Welw. ex Hook.f.	Near endemic	Forestry protected		
Cucumella aspera (Cogn.) C.Jeffrey				
Dioscorea elephantipes (L'Hér) Engl.				
Diospyros ramulosa (E.Mey. ex A.DC.) De Winter				
Euclea asperrima Friedr.-Holzh.	Endemic			Near threatened
Euclea undulata Thunb.				
Clutia thunbergii Sond.				
Euphorbia cibdela N.E.Br.	Near endemic			
Euphorbia dregeana E.Mey. ex Boiss.	Near endemic			
Euphorbia ephedroides E.Mey. ex Boiss. var. ephedroides				
Euphorbia melanohydrata Nel subsp. melanohydrata	Near endemic			
Codon royenii L.				
Ehretia alba Retief & A.E.van Wyk				
Trichodesma africanum (L.) Lehm.				
Cysticapnos vesicaria (L.) Fedde				
Albuca cooperi Baker				
Albuca exuviata Baker				
Albuca longipes Baker				
Albuca setosa Jacq.				
Dipcadi brevifolium (Thunb.) Fourc.				
Drimia elata Jacq.				
Drimia exuviata (Jacq.) Jessop				
Lachenalia buchubergensis Dinter	Near endemic			
Lachenalia giessii W.F.Barker	Endemic			
Lachenalia nordenstamii W.F.Barker				
Namophila urotepala U.Müll.-Doblies & D.Müll.-Doblies	Endemic			
Ornithogalum glandulosum Oberm.	Near endemic			Near threatened

Ornithogalum puberulum Oberm. subsp. puberulum	Endemic			
Ornithogalum stapffii Schinz	Endemic			
Ornithogalum suaveolens Jacq.				
Ornithogalum unifolium Retz. var. unifolium				
Hydnora africana Thunb.				
Pollichia campestris Aiton				
Babiana namaquensis Baker				
Freesia viridis (Aiton) Goldblatt & J.C.Manning				
Lapeirousia barklyi Baker				
Lapeirousia dolomitica Dinter subsp. dolomitica	Near endemic			
Melasphaerula ramosa (L.) N.E.Br.				
Xenoscapa fistulosa (Spreng. ex Klatt) Goldblatt & J.C.Manning				
Ballota africana (L.) Benth.				
Stachys rugosa Aiton				
Kissenia capensis Endl.				
Cyphia dentariifolia C.Presl var. dentariifolia				
Tapinanthus oleifolius (J.C.Wendl.) Danser				
Nymania capensis (Thunb.) Lindb.				
Melianthus pectinatus Harv. subsp. gariepinus (Merxm. & Roessler) S.A.Tansley				
Antimima quarzitica (Dinter) H.E.K.Hartmann	Endemic	Protected		
Aridaria brevicarpa L.Bolus				
Aridaria noctiflora (L.) Schwantes subsp. straminea (Haw.) Gerbaulet		Protected		
Aridaria serotina L.Bolus				
Astridia alba (L.Bolus) L.Bolus				
Astridia hallii L.Bolus	Endemic	Protected		
Brownanthus neglectus S.M.Pierce & Gerbaulet				
Brownanthus pseudoschlichtianus S.M.Pierce & Gerbaulet				
Cephalophyllum confusum (Dinter) Dinter & Schwantes	Endemic	Protected		
Cephalophyllum herrei L.Bolus		Protected		Near threatened
Cheiridopsis caroli-schmidtii (Dinter & A.Berger) N.E.Br.	Endemic	Protected		

Cheiridopsis robusta (Haw.) N.E.Br.		Protected		
Conophytum pageae (N.E.Br.) N.E.Br.		Protected		
Dracophilus dealbatus (N.E.Br.) Walgate				
Drosanthemum luederitzii (Engl.) Schwantes				
Drosanthemum pauper (Dinter) Dinter & Schwantes	Endemic			
Eberlanzia clausa (Dinter) Schwantes	Endemic	Protected		Near threatened
Eberlanzia cyathiformis (L.Bolus) H.E.K.Hartmann		Protected		
Eberlanzia schneideriana (A.Berger) H.E.K. Hartmann	Near endemic	Protected		
Ebracteola derenbergiana (Dinter) Dinter & Schwantes	Near endemic	Protected		
Hereroa hesperantha (Dinter & A.Berger) Dinter & Schwantes	Near endemic	Protected		
Jordaaniella cuprea (L.Bolus) H.E.K.Hartmann		Protected		
Juttadinteria attenuata Walgate	Near endemic	Protected		
Juttadinteria deserticola (Marloth) Schwantes	Near endemic	Protected		
Leipoldtia weigangiana (Dinter) Dinter & Schwantes subsp. weigangiana	Near endemic			
Mesembryanthemum barklyi N.E.Br.	Near endemic			
Mesembryanthemum pellitum Friedrich				Near threatened
Phyllobolus oculatus (N.E.Br.) Gerbaulet	Near endemic			
Psammophora longifolia L.Bolus	Near endemic	Protected		
Psammophora modesta (Dinter & A.Berger) Dinter & Schwantes	Near endemic	Protected		
Psilocaulon articulatum (Thunb.) N.E.Br.				
Psilocaulon salicornioides (Pax) Schwantes	Near endemic			
Ruschia abbreviata L.Bolus	Near endemic			
Ruschia muelleri (L.Bolus) Schwantes				

Ruschia spinosa (L.) Dehn		Protected		
Ruschia tumidula (Haw.) Schwantes		Protected		
Stoeberia arborea van Jaarsv.		Protected		
Stoeberia beetzii (Dinter) Dinter & Schwantes	Near endemic	Protected		
Stoeberia frutescens (L.Bolus) van Jaarsv.		Protected		
Stoeberia gigas (Dinter) Dinter & Schwantes	Near endemic	Protected		
Hypertelis salsoloides (Burch.) Adamson var. salsoloides				
Limeum aethiopicum Burm.f. var. glabrum Moq.				
Pharnaceum brevicaule (DC.) Bartl.				
Montinia caryophyllacea Thunb.				
Ficus ilicina (Sond.) Miq.				
Grielum humifusum Thunb. var. parviflorum Harv.				
Ophioglossum polyphyllum A.Braun				
Oxalis beneprotecta Dinter ex R. Kunth				
Oxalis copiosa F.Bolus				
Oxalis laxicaulis R.Knuth	Endemic			
Oxalis obtusa Jacq.				
Oxalis pes-caprae L. var. pes-caprae				
Polygala mossii Exell	Near endemic			
Polygala teretifolia L.f.				
Ceraria fruticulosa H.Pearson & Stephens	Near endemic			
Ceraria namaquensis (Sond.) H.Pearson & Stephens	Near endemic			
Cheilanthes capensis (Thunb.) Sw.				
Cheilanthes deltoidea Kunze				
Cheilanthes kunzei Mett.				
Cheilanthes rawsonii (Pappe) Mett. ex Kuhn				
Ehrharta calycina Sm. var. angustifolia Kunth				
Ehrharta delicatula (Nees) Stapf				
Ehrharta triandra Nees ex Trin.				
Eragrostis brizantha Nees				
Fingerhuthia africana Lehm.				

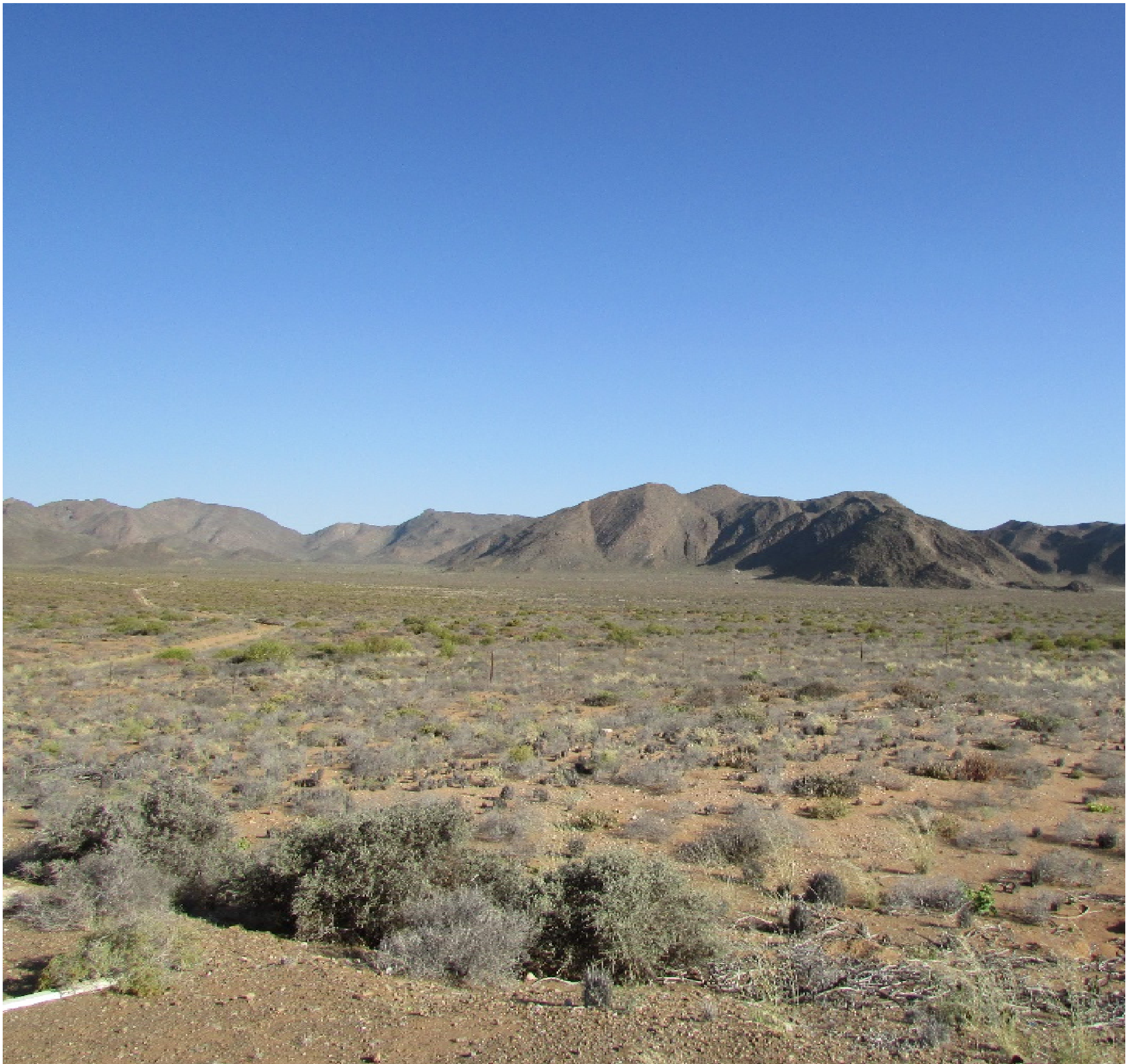
Karroochloa schismoides (Stapf ex Conert) Conert & Türpe				
Leucophrys mesocoma (Nees) Rendle				
Polypogon monspeliensis (L.) Desf.				
Schismus barbatus (Loefl. ex L.) Thell.				
Stipagrostis ciliata (Desf.) De Winter var. capensis (Trin. & Rupr.) De Winter				
Stipagrostis geminifolia Nees	Near endemic			
Stipagrostis obtusa (Delile) Nees				
Anthospermum dregei Sond. subsp. dregei				
Gaillonia crocyllis (Sond.) Thulin				
Galium tomentosum Thunb.				
Kohautia caespitosa Schnizl. subsp. brachyloba (Sond.) D.Mantell				
Gnidia suavissima Dinter				
Didymodoxa capensis (L.f.) Friis & Wilmot-Dear var. capensis				
Forsskaolea candida L.f.				
Chascanum namaquanum (Bolus ex H.Pearson) Moldenke				
Zygophyllum segmentatum Van Zyl				
Sisyndite spartea E.Mey. ex Sond.	Near endemic			
Tribulus cristatus C.Presl				
Zygophyllum applanatum Van Zyl	Endemic			Near threatened
Zygophyllum macrocarpon Retief				
Zygophyllum morgsana L.				Near threatened
Zygophyllum patenticaule Van Zyl				
Thesium lineatum L.f.				
Dodonaea angustifolia L.f.				
Pappea capensis Eckl. & Zeyh.				
Aptosimum tragacanthoides E.Mey. ex Benth.				
Diascia ausana Dinter				
Diascia minutiflora Hiern				
Dischisma spicatum (Thunb.) Choisy				

Hebenstretia namaquensis Roessler				
Jamesbrittenia fruticosa (Benth.) Hilliard				
Jamesbrittenia glutinosa (Benth.) Hilliard	Near endemic			
Jamesbrittenia ramosissima (Hiern) Hilliard				
Lyperia tristis (L.f.) Benth.				
Manulea androsacea E.Mey. ex Benth.	Near endemic			
Nemesia violiflora Roessler	Endemic			
Nemesia viscosa E.Mey. ex Benth.	Near endemic			
Peliostomum viscosum E.Mey. ex Benth.				
Phyllopodium namaense (Thell.) Hilliard	Near endemic			
Selago angustibractea Hilliard	Near endemic			
Lycium horridum Thunb.				
Hermannia amoena Dinter ex Friedr.-Holzh.				
Hermannia macra Schltr.				
Hermannia paucifolia Turcz.				
Hermannia stricta (E.Mey. ex Turcz.) Harv.				
Salsola armata C.A.Sm. ex Aellen				
Amellus nanus DC.				
Arctotis fastuosa Jacq.				
Arctotis frutescens Norl.	Endemic			
Berkheya canescens DC.				
Cotula tenella E.Mey. ex DC.				
Dicoma capensis Less.				
Didelta spinosa (L.f.) Aiton				
Eriocephalus ambiguus (DC.) M.A.N.Müll.				
Eriocephalus scariosus DC.	Near endemic			
Euryops namaquensis Schltr.				
Felicia microsperma DC.				
Foveolina dichotoma (DC.) Källersjö				
Gazania lichtensteinii Less.				
Gazania tenuifolia Less.				
Gorteria corymbosa DC.				
Helichrysum alsinoides DC.				

Helichrysum gariepinum DC.	Near endemic			
Helichrysum herniarioides DC.				
Helichrysum obtusum (S.Moore) Moeser				
Hirpicium echinus Less.				
Ifloga molluginoides (DC.) Hilliard				
Kleinia cephalophora Compton				
Kleinia pinguifolia DC.				
Lasiopogon glomerulatus (Harv.) Hilliard				
Lasiospermum brachyglossum DC.				
Nolletia gariepina (DC.) Mattf.				
Oncosiphon grandiflorum (Thunb.) Källersjö				
Oncosiphon suffruticosum (L.) Källersjö				
Osteospermum karrooicum (Bolus) Norl.				
Osteospermum polycephalum (DC.) Norl.				
Osteospermum sinuatum (DC.) Norl. var. sinuatum				
Othonna filicaulis Jacq.				
Othonna lasiocarpa (DC.) Sch.Bip.				
Pegolettia gariepina Anderb.	Near endemic			
Pentzia pinnatisecta Hutch.				
Pteronia lucilioides DC.	Near endemic			
Pteronia paniculata Thunb.				
Pteronia pomonae Merxm.	Endemic			
Senecio arenarius Thunb.				
Senecio cakilefolius DC.				
Senecio corymbiferus DC.				
Senecio flavus (Decne.) Sch.Bip.				
Senecio giessii Merxm.	Near endemic			
Tripteris breviradiata (Norl.) B.Nord.				
Tripteris crassifolia O.Hoffm.				
Tripteris karrooica Bolus				
Tripteris microcarpa Harv. subsp. microcarpa				
Tripteris polycephala DC.	Near endemic			
Tripteris sinuata DC. var. sinuata				

Troglophyton capillaceum (Thunb.) Hilliard & B.L.Burtt subsp. capillaceum				
Troglophyton parvulum (Harv.) Hilliard & B.L.Burtt				
Ursinia nana DC. subsp. nana				
Ursinia speciosa DC.				
Monsonia deserticola Dinter ex R.Knuth	Endemic			
Pelargonium antidysentericum (Eckl. & Zeyh.) Kostel. subsp. antidysentericum				
Pelargonium articulatum (Cav.) Willd.				
Pelargonium grandicalcaratum R.Knuth				
Pelargonium klinghardtense R.Knuth	Near endemic			
Pelargonium paniculatum Jacq.	Near endemic			
Pelargonium spinosum Willd.				
Pelargonium tenuicaule R.Knuth				
Pelargonium vinaceum E.M.Marais				
Pelargonium xerophyton Schltr. ex R.Knuth				
Sarcocaulon crassicaule Rehm				
Sarcocaulon flavescens Rehm				
Sarcocaulon inerme Rehm	Endemic			
Sarcocaulon patersonii (DC.) G.Don	Near endemic			
Indigofera pungens E.Mey.				
Lessertia benguellensis Baker f.				
Lessertia eremicola Dinter	Endemic			Near threatened
Lessertia falciformis DC.				
Lotononis pachycarpa Dinter ex B.-E.van Wyk	Endemic			
Lotononis rabenaviana Dinter & Harms				
Lotononis strigillosa (Merxm. & A.Schreib.) A.Schreib.	Near endemic			
Melolobium candicans (E.Mey.) Eckl. & Zeyh.				
Calobota halenbergensis (Merxm. & Schreib.) Boatwr. & B.-E. van Wyk				

Tylecodon paniculatus (L.f.) Toelken subsp. paniculatus				
Ferraria variabilis Goldblatt & J.C.Manning	Endemic			
Spiloxene etesionamibensis U.Müll.-Doblies, Mark.Ackermann, Weigend & D.Müll.-Doblies	Endemic			
Crotalaria giessii M.M.le Roux & B-E.Van Wyk	Endemic			
Gorteria parviligulata (Roessler) Stangb. & Anderb.				
Crassothonna cylindrica (Lam.) B.Nord.				
Crassothonna opima (Merxm.) B.Nord.	Near endemic			
Crassothonna protecta (Dinter) B.Nord.				
Desertia luteovirens Mart.-Azorín, M.Pinter & Wetschnig	Near endemic			
Aloidendron ramosissimum (Pillans) Klopper & Gideon F.Sm.	Near endemic	Protected	Vulnerable	
Aloidendron pillansii (L.Guthrie) Klopper & Gideon F.Sm.	Near endemic	Protected	Critically Endangered	Endangered
Crassothonna sparsiflora (S.Moore) B.Nord.	Near endemic			
Roepera cordifolia (L.f.) Beier & Thulin				
Roepera leptopetala (Sond.) Beier & Thulin				Near threatened
Tetraena applanata (Van Zyl) Beier & Thulin	Endemic			Near threatened
Tetraena longicapsularis (Schinz) Beier & Thulin	Near endemic			
Tetraena microcarpa (Licht. ex Cham.) Beier & Thulin	Near endemic			
Tetraena prismatocarpa (Sond.) Beier & Thulin				
Tetraena retrofracta (Thunb.) Beier & Thulin				
Arctotis namibiensis R.J.McKenzie & Mannheimer				
Roepera schreiberi (Merxm. & Giess) Beier & Thulin	Endemic			



Environmental and Social Impact Assessment (ESIA) for the proposed development of the Gergarub Mine

April 2015

Appendix E – Vegetation Impact Assessment

COPYRIGHT:	
PROJECT NAME	Gergarub Project
STAGE OF REPORT	Final for Feasibility Assessment
CLIENT	Skorpion Mining Company (Pty) Ltd
SPECIALIST CONSULTANT	Coleen Mannheimer
DATE OF RELEASE	Nov 2014
CONTRIBUTORS TO THE REPORT	Coleen Mannheimer
CONTACT	manfam@iafrica.com.na / 081 127 2820

DECLARATION

I hereby declare that I do:

(a) have knowledge of and experience in conducting specialist assessments, including knowledge of the Environmental Management Act (Act 7 of 2007)and the Regulations and Guidelines that have relevance to the proposed activity;

(b) perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant;

(c) comply with the abovementioned Act, its Regulations, Guidelines and other applicable laws.

I also declare that there is, to my knowledge, no information in my possession that reasonably has or may have the potential of influencing –

(i) any decision to be taken with respect to the application in terms of the Act and its Regulations; or

(ii) the objectivity of this report, plan or document prepared in terms of the Act and its Regulations.

Coleen Mannheimer

Botanist

EXECUTIVE SUMMARY

A proposed new mining project north of Rosh Pinah was assessed for potential impacts on the Namibian flora. It was found that damage to plants and habitats of conservation concern is potentially very high. However, there is also a very high potential for limitation and mitigation of that damage.

Potential impacts include loss of protected and range-restricted species and limited habitat (according to IFP guidelines - habitat of significant importance to endemic and/or restricted-range species) as well as illegal and unsustainable harvesting of protected plants and plant material for fuel.

The most important environmental goal in the context of this project should be to severely constrain impacts on the succulent plains and the mountainous habitats, particularly the south and south-west facing slopes and their deep gorges, foothills and footslopes. Careful planning of roads and placement of facilities, as well as strict track control, are of the essence. The uppermost part of slopes should not be impacted because that is where most plants of concern are located.

Slight adjustment of the location of some facilities is recommended. The road to the water reservoir is of high concern but no alternative road has been proposed here. It should, however, be taken under serious reconsideration.

Some plant rescue and relocation will be necessary, and these activities should be carefully and timeously planned and undertaken so that they are not rushed at the last minute. <u>However , it should not be done until it is known for certain that they will definitely be impacted.</u> Planning should include careful selection of relocation sites to favour previously damaged areas and suitable habitat, and should result in as 'natural' a dispersion of the plants as possible.

Collection of plants or plant material of any description should be forbidden.

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ABBREVIATIONS AND ACRONYMS

IFC	International Finance Corporation
NBRI	National Botanical Research Institute
SPMNDB	Specimen Database National Botanical Research Institute
TSF	Tailings Storage Facility
WIND	National Herbarium of Namibia in Windhoek

1 BACKGROUND

1.1 INTRODUCTION

A new zinc mine (Gergarub) is being considered in the Karas region just east of the existing Skorpion Zinc Mine, which lies north-west of Rosh Pinah. Following a reconnaissance sensitivity scoping exercise (Irish & Mannheimer, 2013) a specialist vegetation study was done to identify potential impacts on the Namibian flora of the proposed project and attendant infrastructure.

The greater area concerned falls into the northern section of the Succulent Karoo Biome, which is regarded as a global biodiversity hotspot (Myers et al 2000), and is thus important in global as well as regional and national terms. This makes only absolutely unavoidable damage acceptable. It is extremely sensitive in terms of near-endemic, endemic and protected plant and animal species, and widely recognised as an important area of both diversity and endemism (e.g. Van Wyk & Smith 2001, Barnard 1998, Hilliard 1994). Approximately 16% of the Namibian flora as a whole is thought to consist of endemic species (Craven & Vorster 2006), and over 30% of plants that occur in the Namibian section of the Desert Biome are believed to be endemic to that area. This is a remarkably high figure, with the areas of highest plant endemicity in the Namib being the Kaokoveld and the southern Namib, both regarded as major centres of endemicity in Namibia (Maggs et al. 1998). Furthermore, recent assessment by Burke and Mannheimer (2004) indicated that the Sperrgebiet, which lies very close to the study area and is thus very similar, carries nearly 25% of the plant species known to occur in Namibia. Many of these have a highly restricted distribution. Elevated areas, such as mountains and koppies, are known to harbour many plant species of conservation concern, making them sensitive to environmental disturbance, some more than others. Many of the species tend to congregate in small patches of suitable habitat, such as on moisture-gathering south-west-facing slopes that are in shade for part of the day, or on quartz or marble outcrops.

The section of this particular area that falls into the Sperrgebiet (i.e. just to the east of Skorpion) has been categorised by Burke (2006) as of High to Very High conservation importance. Flora studies for the Environmental Impact Assessment for the Skorpion Zinc Project found a high plant diversity in the area (over 220 species), with approximately 12% of those being Namibian endemic species, some of very restricted distribution.

1.2 SPECIALIST STUDY LEADER

Coleen Mannheimer.

1.3 TERMS OF REFERENCE

The objectives of the specialist vegetation study are to:

- By means of a field reconnaissance survey and review of relevant information, identify the plant species that occur or are thought to occur within the study area (Appendix A), with emphasis on those that are valuable from a biodiversity and/or ecological point of view.
- Identify habitats with sensitive vegetation (species that are endemic, protected, or otherwise of high conservation value) and explain the value of each habitat, including status according to IFC criteria.
- Identify any priority ecosystem services that might be affected by the project.
- Identify any alien, or non-native, species of flora that are already present in the project area, or any that might be introduced or spread by the project.
- Identify relevant national and international guidelines, protocols, legal and permit requirements (if any) to ensure compliance with such.
- Identify and assess the potential impacts on the flora resulting from the proposed project during construction and operational/maintenance phases, including cumulative impacts.
- Where appropriate outline methods to avoid and mitigate impacts.

1.4 METHODOLOGY

In order to assess impacts on vegetation and identify critical species and habitats the following process was followed:

- Review of known species occurrence in the general area of the proposed developments was undertaken. The Specimen Database National Botanical Research Institute (SPMNDB) and the Tree Atlas of Namibia Database were queried for data on one quarter-degree square, 2716 DC, a very well-collected square in Namibia. An annotated species list was generated from this information (Appendix A).
- Other existing relevant information was reviewed, including the studies mentioned in Section 1.1, the annotated species list and area conservation status.
- Fieldwork was done 18 to 20 September 2013. Preliminary zones that had been identified from satellite imagery were ground-truthed. Assessment of those zones was done by inspection on foot and by vehicle to identify species of conservation concern (i.e. Red Data species and those protected by Nature Conservation and Forestry legislation as well as restricted range

endemics) and where they are concentrated. Surveys were done using a modified floristic time-meander method (Goff et al 1982 in Alberta Native Plant Council 2012).

- Ø Each habitat was purposefully traversed on foot for a minimum of 30 minutes, and observations continued until no new species had been encountered for 10 consecutive minutes. In the habitat of highest sensitivity in the scoping study this resulted in approximately twelve hours of observations, and in the others approximately 2 hours each. Species observations from previous work done in the study area (Irish & Mannheimer 2013, Mannheimer 2013) were included in the inventory.
- Ø Preparation of report and finalisation of species inventory. Note that sensitivity and recovery potential may be different to that of Irish & Mannheimer (2013) because here they are scored for vegetation aspects only (see Section 4 below).

Plant vouchers will be deposited in WIND, the National Herbarium of Namibia in Windhoek.

Nomenclature and species conservation status largely follows Klaassen & Kwembeya 2013.

Red Data Status follows Klaassen & Kwembeya 2013 with the exception of species that have been regarded by the Red Data officer at the NBRI (S. Loots) since that publication.

1.5 ASSUMPTIONS AND LIMITATIONS

The last few rainy seasons in the study area have been poor and, although this fieldwork was delayed as far as possible to wait for winter rains, the area was still quite dry during the field period. A comprehensive baseline vegetation baseline in an area of such unpredictable and variable rainfall would require many years of fieldwork in different seasons. However, because the quarter-degree-square is well collected and I have considerable experience in the area, I believe that the information available is sufficient for the purpose of this assessment.

The Waste Stock Pile just south-east of the deposit appears very small for this type of project. It is my understanding that this is because much of the waste will be disposed of by back-filling, which is the ideal situation. This assessment assumes that this will be the case. If this should change then impacts will be very much more extensive.

Although translocation and monitoring protocols have been outlined, these sometimes have to be modified during the actual work in the field for unforeseeable reasons.

2 PROJECT DESCRIPTION

The proposed mining project, an underground mine, will lie mainly on the plains east of the existing Skorpion Mine. Although these plains are not a very sensitive habitat they do carry plant species that are protected and/or endemic, and they lie between footslope and mountain habitats that are highly sensitive. The presently proposed layout avoids the very sensitive areas to a large extent, but some minor adjustments to the layout could improve matters even further.

3 LEGAL AND REGULATORY REQUIREMENTS

3.1 ACTS AND ORDINANCES

Namibia's Constitution provides for the protection of the environment in Article 95(1), which says: "The State is obliged to ensure maintenance of ecosystems, essential ecological processes and biological diversity and utilisation of living natural resources on a sustainable basis for the benefit of Namibians both present and future".

Plant species are protected by various pieces of legislation in Namibia. These include the Nature Conservation Ordinance No. 4 of 1975 and amendments, which lists protected species, and the Forestry Act No. 12 of 2001, (as amended in 2005) which aims to conserve soil and water resources, maintain biological diversity, and use forest produce in a way which is compatible with the forest's primary role as the protector and enhancer of the natural environment.

Because the latter has no regulations as yet, the list of protected species from Forestry Act No. 72 of 1968 has been applied here. This list is commonly applied in Namibia as a precaution, including use by the Directorate of Forestry. A new list is pending, and is likely to include most of the same species with few exclusions, and will probably be expanded to include a number of additional species (G. Maggs-Kölling, at the time Deputy Director of Research, Directorate of Forestry, pers. comm.).

This Act also requires that any removal of any living tree, bush or shrub growing within 100 metres of a river, stream or watercourse to be done under the auspices of a permit issued by an appropriate official from the Directorate of Forestry. Details are available on their website.

The Environmental Management Act 7 of 2007 fixes principles for decision-making on issues affecting the environment.

3.2 NAMIBIAN COMMITMENT TO INTERNATIONAL STANDARDS AND/OR GUIDELINES

Namibia is a signatory to the Convention on Biodiversity, committing it to the preservation of species, particularly rare and endemic species, within its boundaries. As a signatory also to the Convention to Combat Desertification it is also bound to prevent excessive land degradation that may threaten livelihoods.

3.3 LOCAL, NATIONAL AND INTERNATIONAL POLICIES AND GUIDELINES

The proponents of the Gergarub Project have committed to adherence to the IFC Performance Standards and Guidelines promoting sustainable management and mitigation of impacts on biodiversity and ecosystem services (Performance Standard 6, IFC 2012). These aim to:

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

No protected areas are to be affected during this proposed project.

3.4 PERMIT REQUIREMENTS

A permit to remove and relocate protected plant species will be required. This can be obtained from the permit office of the Ministry of Environment and Tourism.

Contact person, permit office:

Mr. Matheus Iita

Email address: imatheus@met.na

Tel: 061-284 2832

4 THE RECEIVING ENVIRONMENT

The Gergarub study area is relatively "pristine", with only linear infrastructure such as a few roads/tracks and power lines and low level farming impacts existing, although exploration activities (albeit well-controlled) have already impacted on the stony-gravelly plain habitat. The area consists of plains interrupted by koppies and rocky outcrops and partly bordered by mountain slopes incised by several deep gorges. The deposit area is on Farm Spitzkop, which is well known to harbour high plant diversity, including many species of restricted distribution and conservation concern. Four major life zones were identified during this scoping, and they have been assessed for overall ecological sensitivity based on expected diversity, occurrence of species of conservation concern, extent of habitat and recovery potential (Table 1). The four main zones are mapped in Figure 1, and an orientation map is provided in Figure 2.

Table 1: Habitat sensitivity scoring

HABITAT	DIVERSITY	PRESENCE OF SPECIES	EXTENT OF HABITAT	RECOVERY POTENTIAL	TOTAL
Sandy-gravelly plains	2	3	1	1	7
Stony-gravelly plains	3	2	2	1	8
Succulent plains	1	1	4	3	9
Mountains, koppies, rocky outcrops and footslopes	4	4	3	4	15

Scoring: Diversity, species of concern 1 = lowest, 4 = highest, recovery potential 1 = highest, 4 = lowest; Extent of habitat: 1 = most extensive, 4 = most limited.

A detailed and annotated list of the 404 species listed for or observed in the study area during this assessment is provided in Appendix A, showing in which of the four habitats each species is expected, or known, to occur, and indicating the known Namibian distribution of species of concern.

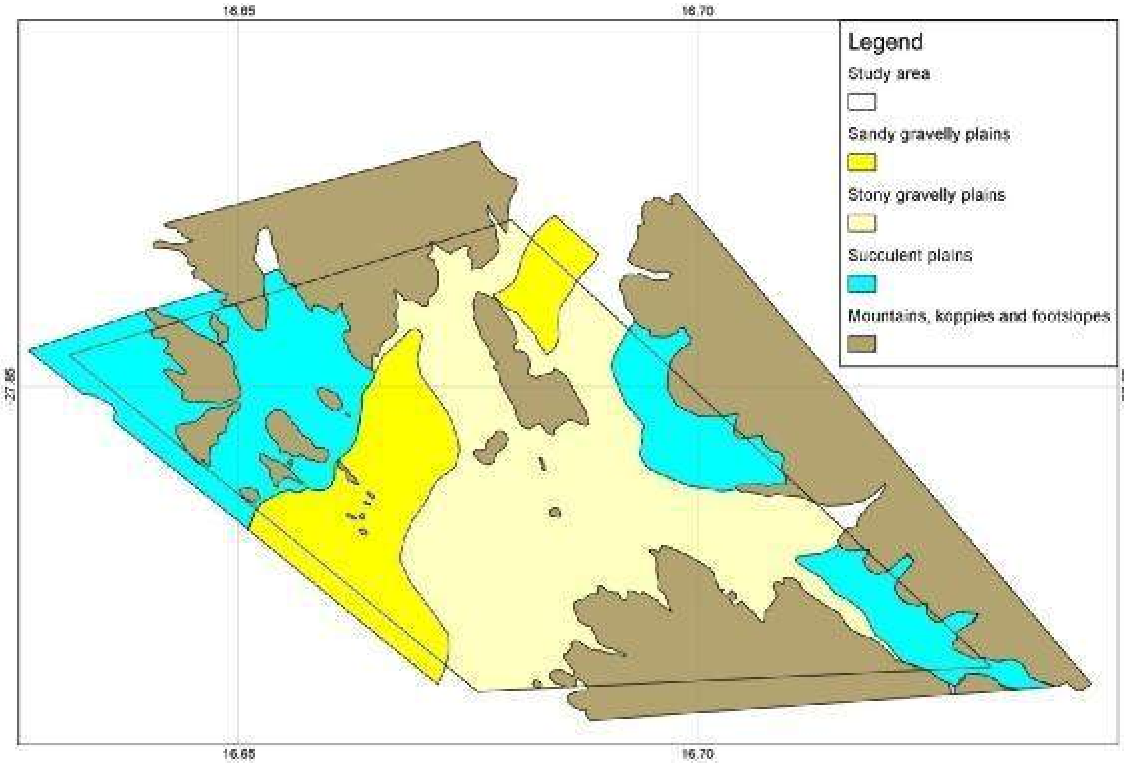

Figure 1: Life zones identified in the study area

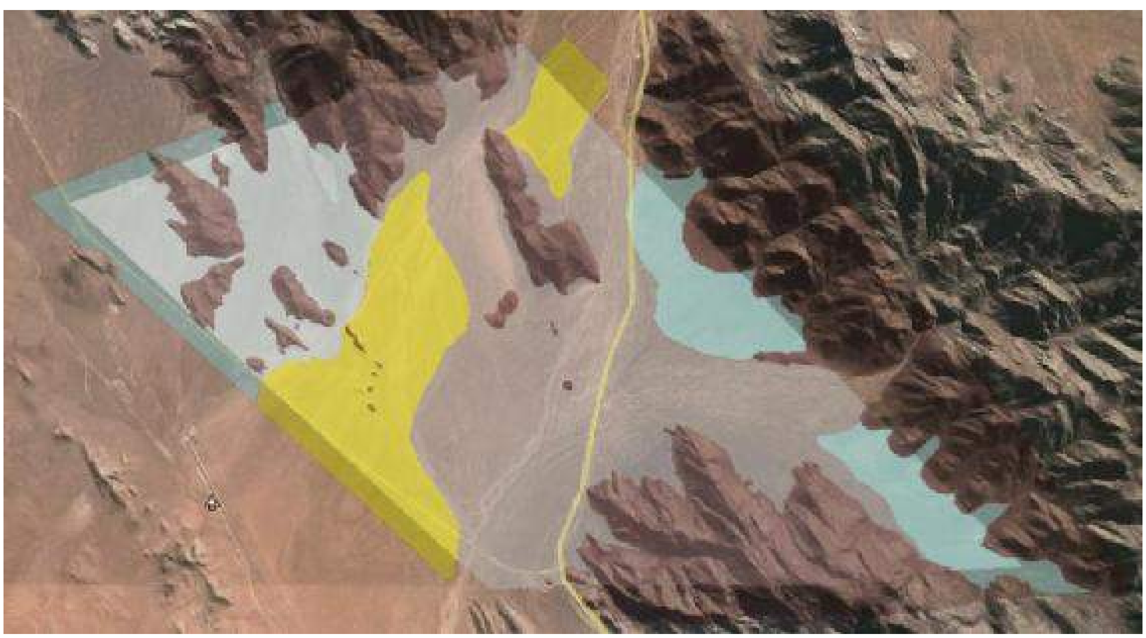
Figure 2: Life zones as in Figure 1, overlaid on Google Earth image for orientation.

For assessment and management purposes the plains may be divided into three zones. Note that these three zones have been based not only on plant occurrence, but taking other biota into consideration as well (Irish & Mannheimer 2013).

4.1 SANDY-GRAVELLY PLAINS

These red sand plains are characterised by dominance of Stipagrostis spp. and Brownanthus spp., with Tetragonia reduplicata, Asparagus capensis, Phyllobolus oculatus and Othonna cylindrica also common and Zygophyllum prismatocarpum, Sisyndite spartea, Searsia populifolia and Euphorbia dregeana defining the many shallow washes that cut through them. Despite being the zone of lowest sensitivity in the context of this project, these plains are known to harbour relatively high plant diversity, more obvious after rains when geophytes (lilies) and annual herbs and grasses are present. A number of range-restricted, endemic, near-endemic and protected species occur, including, but not limited to, Euphorbia melanohydrata, Dracophilus dealbatus, Cheiridopsis robusta, Mesembryanthemum pellitum, Hoodia gordonii and Ruschia spp..

Sensitivity: low to medium.

Recovery potential: medium to high.

4.2 STONEY-GRAVELLY PLAINS

These plains are set apart from the sandy-gravelly plains by the presence of coarse gravel and calcrete (easily visible on the surface), slightly more compacted substrate and by a slightly different complement of plant species, with low-growing *Zygophyllum* spp. (including endemic and range-restricted species) and succulents such as *Drosanthemum albens, Galenia pruinosa, Tetragonia reduplicata, Lampranthus hoerleinianus, Jordaaniella cuprea, Eberlanzia clausa* and *Cheiridopsis robusta* relatively more common. There is considerable overlap in plant species with the sandy-gravelly plains and the footslopes, with many of the species of concern in that zone present here too.

West of the drill camp and the track travelling past it there is an unusually dense concentration of *Hoodia gordonii*, a protected species.

Sensitivity: medium.

Recovery potential: medium.

4.3 SUCCULENT PLAINS

The structure of the mountains that semi-surround and 'cup' the valley wherein the exploration area lies is conducive to the 'gathering' of wind-borne moisture in the form of fog from the south-west. Similar plains lie to the south-west of the mountains in the west of the study site (although actual species composition is considerably different there). It is only in these situations that these unique succulent plains are found in Namibia. This makes them a highly restricted habitat.

The substrate in the succulent plains east of the main road (Figure 3) is a relatively stabilised, rocky, grey to red-brown sandy loam, often interspersed with weathered limestone rocks. Dominant plant species include *Brownanthus arenosus, Euphorbia chersina, E. cibdela, E. gummifera, E. dregeana* and *Ceraria fruticulosa*. A number of species of conservation concern are present, including, *inter alia*, *Dracophilus dealbatus, Cheiridopsis robusta, Ruschia* spp., *Cephalophyllum ebracteatum, Aridaria noctiflora, Tylecodon reticulatus* and *Hoodia gordonii*. The succulent plains west of the main road are composed of red sand far more stabilised than that in the sandy- and stony-gravelly plains. There species composition is somewhat different, as mentioned before, but still includes species of conservation concern, *inter alia, Jordaaniella cuprea, Cheiridopsis robusta, Dracophilus dealbatus, Pelargonium klinghardtense* and *Tylecodon reticulatus*. In small quartz areas that are scattered within this zone rarely-encountered species, such as *Psammophora longifolia* and *Zygophyllum schreiberianum*, were observed.

Sensitivity: high (Critical habitat according to IFP guidelines - habitat of significant importance to endemic and/or restricted-range species).

Recovery potential: low to medium.

Figure 3: Succulent plain north of the exploration area

4.4 MOUNTAINS, KOPPIES, ROCKY OUTCROPS AND FOOTSLOPES

The mountains, koppies and outcrops that are scattered in and around the study area collectively exhibit a relatively diverse structure and surface geology. They vary from quite gentle base slopes to quartz outcrops and steep, rocky schistose slopes incised by deep gullies, and provide high niche diversity by virtue of substrate, moisture and aspect variability. As a result they generally exhibit higher species diversity than the plains (Appendix A), and harbour a number of endemic, near-endemic, range-restricted and protected species, both on their slopes and on their footslopes. These include numerous protected species of high conservation concern and/or very restricted distribution including, *inter alia*, *Hartmanthus hallii, Aloe dichotoma, A. gariepensis, Pachypodium namaquanum, Crassula* spp. and *Conophytum* spp., as well as many other highly restricted-range species, such as *Sarcocaulon inerme, Dracophilus dealbatus, Cheiridopsis robusta* and *Zygophyllum* spp.. A number of these species show a tendency to congregate in small patches of suitable habitat on footslopes (pers. obs.), or near the tops of mountains and koppies, making the impact on them higher than on those species that are more randomly distributed. A good example of this is the protected 'halfmens' (*Pachypodium namaquanum*), which favours the moisture-collecting upper slopes of the koppies and mountains. Plant species diversity is generally higher on south and south-west facing slopes (Figure 4) than on north and north-east facing slopes, and the former also tend to harbour more species of conservation concern. The vulnerable Red Data species, *Stapeliopsis neronis* has been recorded on low mountain slopes on Farm Spitzkop, a farm that harbours an extremely high proportion of the species of conservation concern (Appendix A).

In the west of the study area there are a number of marble-limestone koppies and outcrops. These, to a large extent, harbour a different species complement, including *Crassula sladenii,* which is protected and has a highly restricted known distribution in Namibia (this quarter-degree square only), and also harbours several other highly restricted species.

Sensitivity: high to very high (Critical habitat according to IFP guidelines - habitat of significant importance to endemic and/or restricted-range species).

Recovery potential: very low

Figure 4: South-west facing slopes are highly diverse, with many species of conservation concern

4.5 EXISTING IMPACTS

4.5.1 Sandy-gravelly plains

These plains are already traversed by several linear facilities, including roads/tracks and power lines.

4.5.2 Stony-gravelly plains

These plains are already traversed by several linear facilities, including roads/tracks and power lines. Exploration activity, although clearly well-controlled has also already made some impact.

4.5.3 Succulent plains

This habitat has only a few farm tracks running through it.

4.5.4 Mountains, koppies, rocky outcrops and footslopes

In the study area this habitat is virtually pristine, with very little visible human impact.

Table 2: Habitat related sensitivities

ENVIRONMENTAL FEATURE	SENSITIVITY	VULNERABILITY	POTENTIAL IMPACT
Sandy- and Stony-gravelly plains	Central plains with grasses and low succulent shrubs dominating	Low to medium	Physical destruction of plant species of conservation concern, including cumulative impacts.
Succulent plains	Consolidated plains lying mainly south and south-west of mountains and koppies	High	Physical destruction of plant species of conservation concern, including cumulative impacts. Habitat loss.
Mountains, koppies, rocky outcrops and footslopes	Steep slopes and outcrops of varying geology	High	Physical destruction of plant species of conservation concern, including cumulative impacts. Habitat loss.

5 IMPACT ASSESSMENT

5.1 ASSESSMENT OF IMPACTS DURING THE CONSTRUCTION, OPERATIONAL AND DECOMMISSIONING PHASES OF THE PROJECT

Table 3: Impact assessment of the proposed project

POTENTIAL IMPACT	STATUS/ NATURE	EXTENT	DURATION	INTENSITY	PROBABILITY	DEGREE OF CONFIDENCE	SIGNIFICANCE		
							PRE-MITIGATION	MITIGATION/ ENHANCEMENT	POST-MITIGATION
CONSTRUCTION PHASE									
Loss of, or damage to populations or individuals of species of conservation concern due to direct destruction	Negative. Protected species will be damaged and destroyed, including some dense sub-populations	National, because some of these species have highly limited distributions	Long term	Medium	Definite	100%	Medium	Shift infrastructure as indicated in Appendix C. Undertake plant rescue and relocation as outlined in Appendix E.	Low to medium
Damage to limited habitats by vehicles and other heavy	Negative. Uncontrolled construction activity will	National	Long term.	Medium	Definite	100%	Medium	Educate contractors and machine/vehicle operators.	Low

POTENTIAL IMPACT	STATUS/ NATURE	EXTENT	DURATION	INTENSITY	PROBABILITY	DEGREE OF CONFIDENCE	SIGNIFICANCE		
							PRE-MITIGATION	MITIGATION/ ENHANCEMENT	POST-MITIGATION
machinery as well as mine facilities, including waste facilities	result in unnecessary collateral damage							Exercise strict track control. Mark tracks clearly prior to construction activity, sticking to routes that will be necessary during the operational phase as far as possible	
Illegal and unsustainable collection of plants by staff and visitors, either for ornamental purposes or for fuel	Negative	National	Long term to perma-nent	Medium	Probable	95%	High	Forbid any collection of plant material for any purpose whatsoever except rescue and relocation	Low
Increased	Negative. May	National	Short term	Medium	Uncertain	75%	Low		Low

POTENTIAL IMPACT	STATUS/ NATURE	EXTENT	DURATION	INTENSITY	PROBABILITY	DEGREE OF CONFIDENCE	SIGNIFICANCE		
							PRE-MITIGATION	MITIGATION/ ENHANCEMENT	POST-MITIGATION
morbidity and/or mortality of vegetation, affecting critical habitats or critical species	be caused by dust generated during construction								
OPERATIONAL PHASE									
Loss of, or damage to populations or individuals of species of conservation concern due to direct destruction	Negative. Additional sub-populations of protected species could be affected by uncontrolled extension of waste facilities	National, because some of these species have highly limited distributions	Long term	Medium	Uncertain	80%	Medium	Any additions to waste facilities must be minimized and carefully placed.	Low to medium
Damage to limited habitats by vehicles and other heavy	Negative. Uncontrolled operational activity could	National	Long term.	Low	Improbable	95%	Medium	Educate machine/vehicle operators. Exercise strict	Low

POTENTIAL IMPACT	STATUS/ NATURE	EXTENT	DURATION	INTENSITY	PROBABILITY	DEGREE OF CONFIDENCE	SIGNIFICANCE		
							PRE-MITIGATION	MITIGATION/ ENHANCEMENT	POST-MITIGATION
machinery as well as mine facilities, including waste facilities	result in unnecessary collateral damage							track control. Mark tracks clearly.	
Illegal and unsustainable collection of plants by staff and visitors, either for ornamental purposes or for fuel	Negative	National	Long term to perma-nent	Medium	Probable	95%	High	Forbid any collection of plant material for any purpose whatsoever except rescue and relocation	Low
Increased morbidity and/or mortality of vegetation, affecting critical habitats or	Negative. May be caused by dust deposition.	National	Long term	Medium	Uncertain	75%	High	Situate TSF out of the path of prevailing winds. Design and develop TSF in collaboration with restoration	Low to Medium

POTENTIAL IMPACT	STATUS/ NATURE	EXTENT	DURATION	INTENSITY	PROBABILITY	DEGREE OF CONFIDENCE	SIGNIFICANCE		
							PRE-MITIGATION	MITIGATION/ ENHANCEMENT	POST-MITIGATION
critical species								ecologist to promote re-establishment of vegetation over the longer term (e.g. organic form that echoes surrounding landshapes)	
DECOMMISSIONING PHASE									
Loss of, or damage to populations or individuals of species of conservation concern due to direct destruction	Negative. Protected species will be damaged and destroyed, including some dense sub-populations	National, because some of these species have highly limited distributions	Long term	Low	Improbable	95%	Medium	Control of contractors and subcontractors	Low
Damage to limited habitats	Negative. Uncontrolled	National	Long term.	Low	Probable	95%	Medium	Educate contractors and	Low

POTENTIAL IMPACT	STATUS/ NATURE	EXTENT	DURATION	INTENSITY	PROBABILITY	DEGREE OF CONFIDENCE	SIGNIFICANCE		
							PRE-MITIGATION	MITIGATION/ ENHANCEMENT	POST-MITIGATION
by vehicles and other heavy machinery as well as mine facilities, including waste facilities	deconstruction activity will result in unnecessary collateral damage							machine/vehicle operators. Exercise strict track control.	
Illegal and unsustainable collection of plants by staff and visitors, either for ornamental purposes or for fuel	Negative	National	Long term to perma-nent	Low	Probable	95%	Medium	Forbid any collection of plant material for any purpose whatsoever	Low
Increased morbidity and/or mortality of vegetation,	Negative. May be caused by dust from the TSF	National	Long term	Medium	Probable	75%	High	Design and develop TSF in collaboration with restoration	Low

POTENTIAL IMPACT	STATUS/ NATURE	EXTENT	DURATION	INTENSITY	PROBABILITY	DEGREE OF CONFIDENCE	SIGNIFICANCE		
							PRE-MITIGATION	MITIGATION/ ENHANCEMENT	POST-MITIGATION
affecting critical habitats or critical species								ecologist to promote re-establishment of vegetation	

5.2 DISCUSSION

Reservoir and attendant road

By far the highest impact on the highly sensitive south-west faces of the koppies and mountains is that of the water reservoir and its approach road in the south-west of the project area. The road in particular, as proposed at present, will definitely result in destruction of protected and restricted range species. This has been taken into consideration in the impact assessment below.

Aloe pillansii

During the sensitivity scoping exercise done for this area (Irish & Mannheimer, 2013), a small number of unusual tree aloes were observed on the north-eastern slopes just east of the exploration area. The possibility of these being *Aloe pillansii*, a highly range-restricted Red Data species was investigated during this study, and they were found to be *Aloe dichotoma,* which is also protected, but neither highly range-restricted nor a Red Data species.

Increased morbidity and mortality of vegetation due to dust deposition.

Although it is often brought up as a concern, very little published research from southern Africa appears to have been done on this topic. Effects on plants of dust include, inter alia, chemical changes to the soil surface, reduced water penetration of the soil, a reduction in photosynthesis due to less absorption of sunlight, abrasion of leaf surfaces and blocking of stomata, but it is uncertain whether the effects are permanent because plants may recover to an extent after rainfall. Farmer (1993) provided an overview of this issue.

Obviously, in areas such as the one in question where rainfall events are relatively few (or virtually none) per year, any plants affected would have to survive long periods of dust cover. In Namibia it is possible that dust blowing off of the mine dump near Rosh Pinah has caused the mortality of numerous Aloe pillansii trees lying above the mine downwind of the dump, but this phenomenon has never been investigated (pers. obs.).

This could be of concern on this site, even though it is likely to be very localised, due to the number of protected and restricted-range plant species on the south-west facing slopes downwind of the proposed facilities (the TSF in particular), and the high wind speeds prevalent in the area. Water constraints, would unlikely justify the probable undesirable increase in water consumption that would ensue if extensive control measures using water were instituted.

The most impact on plant morbidity and mortality may be expected to be felt downwind of the TSF even though it is sheltered by a ridge. Dust from the plant, which is not sheltered, is also of concern.

Due to very little empirical information being available on the effects of fine and toxic particulate deposition on plants in southern Africa, there is no way of telling what the effects might be here. However, observations at existing facilities in the area (at Rosh Pinah Mine, pers. obs.) make some monitoring of these effects a necessity.

It is thus presently not possible to usefully comment on the long-term effects of dust generated by mining activities on vegetation health with any confidence. If monitoring is undertaken, and methods are well designed then this mine may be able to shed some light on the issue.

5.3 MITIGATION

The following measures to avoid or reduce damage to sensitive areas and vegetation are recommended:

- As far as possible the succulent plains and the mountains, koppies and foothills habitat must be avoided, particularly south and south-west facing slopes. Where it is not possible to avoid slopes, such as in the proposed tailing storage facility east of the deposit, efforts should be made to keep the height of the facility below the level of the higher slopes where most of the *Aloe dichotoma* and *Pachypodium namaquanum*, as well as other protected species, such as *Conophytum* and *Crassula sladenii*, are found. Balance between the size of the footprint and damage to high slopes should be sought. Another factor to consider in this is that the steeper the slopes of the waste facility, the harder it will be to undertake restoration. Slopes of waste facilities should preferably not exceed 25°. Ideally the shape of the facility should not be a rigid square or rectangle because more organic shapes that echo the natural topography are far easier to rehabilitate.
- The footslopes of the mountains closest to the deposit, the proposed route of the reservoir road and the white quartz koppie within the proposed TSF harbour some very dense populations of protected succulents, mainly *Cheiridopsis robusta* and *Dracophilus dealbatus* but also *Crassula* spp. on the quartz and *Tylecodon paniculatus, Astridia* spp. and others on the route of the reservoir road. Appendix B and Appendix F show the approximate areas concerned. Firstly, as indicated in Appendix C, some of the infrastructure should be shifted if at all possible to avoid these concentrations. If at all possible, the reservoir road should be moved off of the south-west facing slope. In addition, rescue and relocation of protected succulents to previously damaged or otherwise suitable areas nearby and to the two Namibian botanic gardens (National Botanic Garden in Windhoek and Namib

Botanical Garden near Swakopmund) should be considered (see Appendix E). The curator of the National Botanic Garden in Windhoek has expressed an interest in collecting some of the succulents that will almost certainly be affected by the project. However, this would have to be done prior to construction and would have to be planned very carefully, in collaboration with the National Botanic Garden, so that the areas are selected beforehand to receive the plants. It is important to note that this would have to be done in a controlled way, and monitored for success to determine whether such interventions are worth the time and money required to undertake them. Obviously, plant removal and relocation should be undertaken for these populations only once it is certain that they will be affected by the planned facilities. The smaller plants can be removed by the National Botanic Garden (who would require some support to do this) and the large ones should be relocated in the close vicinity of Gergarub and Skorpion. I suggest they be put directly into suitable habitat rather than being kept in a nursery. This would, however, need to be done in a careful fashion to mimic natural distribution as far as possible so that plants are not placed very densely in a small area. Areas where the plants occur naturally (preferably ones that have previously been disturbed) should be selected for the translocation.

- Once infrastructure sites are fixed on the gravelly plains they should be physically inspected for the presence of *Euphorbia melanohydrata*. Any found should be carefully translocated because this species was heavily impacted by the Skorpion project.
- If at all possible the slopes and valley directly south-east of the deposit should be set aside as a 'nature reserve' or 'no-go' area (Appendix D). This would actually obviate the need for a very high number of *Cheiridopsis robusta* and *Dracophilus dealbatus* being translocated, and would prevent damage to quite dense populations of *Aloe dichotoma* (quiver tree, kokerboom) and *Aloe gariepensis,* as well as a number of *Pachypodium namaquanum* that are present on slopes on both sides of that area.
- Now, and in the future, all gorges containing natural water points should be regarded as strict 'no-go' areas.
- Strict track control must be applied during all phases of the project. Uncontrolled vehicle activity is of major concern. Careful pre-planning of construction and operational activities should be done to identify where tracks will be absolutely necessary for both construction and operation, overlapping these as far as possible. These should be clearly marked prior to construction activities beginning, together with construction laydown areas. The area used should be constrained as far as possible.

- Existing damaged areas should be used as far as possible for construction laydown.
- The population of *Hoodia gordonii* west of the drill camp should be avoided when the road is planned through that area. The present track does not impinge on it, and should be followed as closely as possible in any case because it is an existing line of damage.
- Collection of plants, or parts of plants (including seed and/or fuel wood) should be forbidden. Staff should be expressly forbidden to collect any plant material, dead or alive (including seed), for any purpose whatsoever (including mine office garden landscaping, with the exception of plants that have to be relocated in any case) and should be provided with fuel (preferably gas) for both heating and cooking.
- Construction and maintenance staff should be educated and informed of their environmental obligations. Meaningful penalties for damages should be stipulated. To prevent 'passing of the buck' the main contractor should be held responsible for all unnecessary damage due to non-compliance, whether caused by his/her company or by subcontractors.
- Fixed point photography, initiated prior to construction activities, could be utilised to assess compliance by contractors and he eventual success of mitigation and control of damage. An on-site environmental officer to monitor staff activities would make a substantial contribution to control of unacceptable practices.

5.4 MONITORING

If rescue and translocation of protected succulents is done as outlined in Appendix E, then the success of the work done should be monitored annually between August and October by means of carefully selected photopoints.

In addition, the condition of the succulent plain and the mountain slopes should be assessed annually by means of photopoint monitoring, also outlined in Appendix E. At least five photopoints should be established on the succulent plains and at least ten or more photopoints on the mountains and footslopes, particularly the south-west facing slopes to the north-east of the main mining area on both sides of the big gorge (i.e.: including those east of the TSF. Placement of these photopoints and annual assessment of the photographs should be supervised by a botanist or ecologist.

Before construction activities begin, permanent transects designed to quantitatively monitor vegetation condition on the succulent plain and mountain slopes should be established. These should assess relative cover, diversity and dominance of perennial species and should be revisited every year between August and October.

Serious consideration should be given to long-term monitoring of dust deposition and water infiltration rate and depth in the soils on the succulent plain and mountain slopes downwind of the proposed TSF, because there has been an apparent loss of *Aloe pillansii* and *Aloe dichotoma* on the slopes above Rosh Pinah Zinc Mine that may possibly be due to windblown fines deposition from the TSF south-west of Rosh Pinah. However, this has not been investigated, and it is thus not certain what the cause of the loss is. In addition, monitoring of photosynthetic activity by means of analysis of chlorophyll fluorescence is a more recent method that might be ideal, and the Gobabeb Research and Training Centre have the equipment and the expertise to apply it.

6 IDENTIFICATION OF KEY IMPACTS

Important impacts on vegetation that may be caused during construction and operation of the proposed project include all of those mentioned above i.e.:

- Loss of, or damage to, populations or individuals of species of conservation concern due to direct destruction
- Damage to and loss of limited habitats by vehicles and other heavy machinery as well as mine facilities, including waste facilities
- Long term dust deposition from the Tailings Storage Facility on species and habitats of concern
- Illegal and unsustainable collection of plants by staff and visitors, either for ornamental purposes or for fuel

7 CONCLUSIONS AND RECOMMENDATIONS

Although damage to plants and habitats of conservation concern by this proposed project is potentially very high, there is also a very high potential for limitation and mitigation.

In a project of this nature one of the most important mitigating actions is always control of unnecessary collateral damage. The degree to which this works depends greatly on the commitment of the company involved. If they are serious about conservation, then considerable success may be achieved in damage prevention, limitation, and mitigation.

The most important goal in the context of this project should be to severely constrain, control and monitor impacts on the succulent plains and the mountainous habitats, particularly the south and south-west facing slopes and their deep gorges.

Careful planning of activities as well as careful use and placement of tracks and roads during construction and operation, as well as avoidance of areas of known biological diversity and sensitivity can make a considerable contribution towards minimising cumulative disturbance to the area. <u>This aspect is often neglected because efforts in this regard sometimes start too late</u>. Track and road control at Skorpion has been notably successful, so experience gleaned there can, no doubt, be applied here.

Rescue and translocation, carefully and timeously planned and executed, will be an important aspect of mitigation for this project.

The apparent present practice of not monitoring dust deposition except where human habitation and fields may be affected should not be applied. Dust monitoring on the slopes and succulent plain downwind of the plant and the TSF should be undertaken.

Note that the shape of the TSF as planned at present is very unnatural, and will hamper rehabilitation at mine closure.

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APPENDIX A

Plant species list for Gergarub (2716DC)

Plant species list for Gergarub (2716DC)	Protected	Red Data	Sandy gravelly plains	Stony gravelly plains	Succulent plains	Mountains, koppies and footslopes	Annual (A) perennial (P)	Comments and red data status	Distribution in Namibia of endemic, near endemic, protected and Red Data species. Occurrence on or near site noted.
Acanthopsis disperma Nees						1	A		
Acrotome pallescens Benth.						1	P		
Adromischus alstonii (Schönland & Baker f.) C.A.Sm.	1					1	P		S Namib only, occurs on Farm Spitzkop
Adromischus marianiae (Marloth) A.Berger var. kubusensis (Uitewaal) Toelken	1					1	P		S Namib only, uncommon, occurs on Farm Spitzkop
Adromischus montium-klinghardtii (Dinter) A.Berger	1					1	P		S Namib only, seen in study area
Albuca cooperi Baker			1	1			P		
Albuca exuviata Baker						1	P		
Albuca longifolia Baker			1	1			P		
Albuca longipes Baker			1	1			P		
Aloe dichotoma Masson	1					1	P		Widespread, common, many seen in study area. Often illegally collected. Horticultural use. Previously used for arrow sheaths
Aloe gariepensis Pillans	1					1	P		Far S Namibia only, seen on higher slopes in study area. Often illegally collected. Horticultural potential
Aloe pearsonii Schönland						1	P		Far S Namib only, seen on higher ridges in study area. Horticultural potential

Plant species list for Gergarub (2716DC)	Protected	Red Data	Sandy gravelly plains	Stony gravelly plains	Succulent plains	Mountains, koppies and footslopes	Annual (A) perennial (P)	Comments and red data status	Distribution in Namibia of endemic, near endemic, protected and Red Data species. Occurrence on or near site noted.
Aloe pillansii L.Guthrie	1	1				1	**P**	**Endangered, but not seen in study area**	Far S Namib only, highly restricted extent of occurrence on high, fog collecting slopes mostly, not seen in study area, but definitely occurs on Farm Spitzkop. Horticultural potential
Aloe ramosissima Pillans						1	P		S Namib only, seen in study area. Often illegally collected. Horticultural potential
Amellus nanus DC.			1	1	1	1	A		
Anacampseros retusa Poelln. subsp. retusa var. retusa	1					1	P		S Namib only, occurs on Farm Spitzkop
Androcymbium exiguum Roessler subsp. vogelii (U.& D.Moell.-Doblies) U.& D.Moell.-Doblies						1	P		
Anthospermum dregei Sond. subsp. dregei						1	P		
Anticharis inflata Marloth & Engl.						1	A/P		Reasonably common and widespread, occurs on Farm Spitzkop
Antimima dolomitica (Dinter) H.E.K.Hartmann	1					1	P		S Namib only, occurs on Farm Spitzkop
Antimima quarzitica (Dinter) H.E.K.Hartmann	1					1	P		S Namib only, on high rocky ridges, occurs in study area
Aptosimum lineare Marloth & Engl. var. lineare			1	1		1	P		
Aptosimum viscosum Benth.					1	1	P		
Arctotis fastuosa Jacq.			1	1	1		A		

Plant species list for Gergarub (2716DC)	Protected	Red Data	Sandy gravelly plains	Stony gravelly plains	Succulent plains	Mountains, koppies and footslopes	Annual (A) perennial (P)	Comments and red data status	Distribution in Namibia of endemic, near endemic, protected and Red Data species. Occurrence on or near site noted.
Arctotis frutescens Norl.						1	P		Mountain slopes in vicinity of Rosh Pinah only, only few localities known, occurs on Farm Spitzkop
Aridaria brevicarpa L.Bolus			1	1		1	P		
Aridaria noctiflora (L.) Schwantes subsp. straminea (Haw.) Gerbaulet			1	1			P		
Aridaria serotina L.Bolus						1	P		
Asparagus asparagoides (L.) Druce						1	P		
Asparagus capensis L. var. capensis			1	1		1	P		
Asparagus exuvialis Burch. forma ecklonii (Baker) Fellingham & N.L.Mey.			1			1	P		
Asparagus graniticus (Oberm.) Fellingham & N.L.Mey.			1				P		
Asparagus juniperoides Engl.			1	1			P		Horticultural potential
Asparagus retrofractus L.			1	1			P		
Asplenium cordatum (Thunb.) Sw.						1	P		
Astridia alba (L.Bolus) L.Bolus						1	P		
Astridia hallii L.Bolus	1	1				1	**P**	**Rare**	Far S Namib only, mountain slopes only, occurs on Farm Spitzkop
Augea capensis Thunb.			1	1			A		
Ballota africana (L.) Benth.						1	P		
Berkheya canescens DC.						1	P		
Berkheya chamaepeuce (S.Moore) Roessler						1	P		
Berkheya spinosissima (Thunb.) Willd.						1	P		
Blepharis furcata (L.f.) Pers.				1	1	1	P		
Boophone disticha (L.f.) Herb.						1	P		Poisonous. Used medicinally and for arrow poison

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Boscia albitrunca (Burch.) Gilg & Gilg-Ben.	1		1	1		1	P		Common, widespread, occurs on Farm Spitzkop. Important as highly nutritious browse
Boscia foetida Schinz subsp. foetida					1		P		Important as highly nutritious browse
Brownanthus neglectus S.M.Pierce & Gerbaulet			1				P		
Brownanthus pseudoschlichtianus S.M.Pierce & Gerbaulet			1		1		P		
Brunsvigia bosmaniae F.M.Leight.					1	1	P		
Bulbine capitata Poelln.			1				P		
Bulbine longifolia Schinz			1				P		
Bulbine namaensis Schinz		1	1				**P**	**Rare**	S Namib only, seen in close vicinity at Skorpion. Horticultural potential
Bulbine rhopalophylla Dinter			1				P		Horticultural potential
Carissa haematocarpa (Eckl.) A.DC.						1	P		Horticultural potential
Cephalophyllum confusum (Dinter) Dinter & Schwantes						1	P		S Namib only, seen in close vicinity at Skorpion. Horticultural potential
Ceraria fruticulosa H.Pearson & Stephens					1	1	P		Reasonably widespread, as far N as Keetmanshoop, seen in study area
Ceraria namaquensis (Sond.) H.Pearson & Stephens						1	P		S Namibia only, seen in study area. Used in earlier times to produce cordage
Chascanum garipense E.Mey.						1	A/P		
Chascanum namaquanum (Bolus ex H.Pearson) Moldenke						1	P		
Cheilanthes capensis (Thunb.) Sw.						1	P		

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Cheilanthes deltoidea Kunze						1	P		
Cheilanthes kunzei Mett.						1	P		
Cheilanthes rawsonii (Pappe) Mett. ex Kuhn						1	P		
Cheiridopsis caroli-schmidtii (Dinter & A.Berger) N.E.Br.	1					1	P	Questionable ID, more probably C. robusta	S Namib only, very limited known occurrence, not seen in study area. Horticultural potential
Cheiridopsis robusta (Haw.) N.E.Br.	1		1	1	1	1	P		S Namib only, but reasonably common, seen in study area. Cumulative impacts of concern. Used in horticulture
Chlorophytum viscosum Kunth			1				P		
Cissampelos capensis L.f.						1	P		
Clutia thunbergii Sond.						1	P		
Codon royenii L.			1	1	1	1	A/P		
Conophytum taylorianum (Dinter & Schwantes) N.E.Br. subsp. ernianum (Loesch & Tischer) de Boer ex S.A.Hammer	1					1	P		S Namib only, common, seen in study area, but generally limited to higher slopes
Cotula tenella E.Mey. ex DC.						1	A		
Cotyledon orbiculata L. var. orbiculata						1	P		Widespread, seen in study area. Used in horticulture and medicinally
Crassula brevifolia Harv. subsp. brevifolia	1					1	P		S Namib only, seen in study area. Horticultural potential
Crassula campestris (Eckl. & Zeyh.) Endl. ex Walp.	1					1	A		S Namib only, occurs on Farm Spitzkop
Crassula columnaris Thunb. subsp. prolifera Friedrich	1					1	P		S Namib only, uncommon

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Crassula elegans Schönland & Baker f. subsp. elegans	1					1	P		S Namib only, common where it occurs
Crassula expansa Dryand. subsp. pyrifolia (Compton) Toelken	1					1	P		S Namib only, common where it occurs, seen in study area
Crassula fusca Herre	1					1	P		SW, only mountains near Orange River, seen in study area
Crassula garibina Marloth & Schönland subsp. garibina	1					1	P		Southern Namibia in mountains long the Orange as far east as Goodhouse, occurs on Farm Spitzkop
Crassula macowaniana Schönland & Baker f.	1					1	P		S Namib only, seen in study area. Horticultural potential
Crassula muscosa L. var. muscosa	1					1	P		Common in SW
Crassula muscosa L. var. obtusifolia (Harv.) G.D.Rowley						1	P		Common in SW, seen in study area
Crassula nemorosa (Eckl. & Zeyh.) Endl. ex Walp.		1				1	P	Rare	Annual, rarely seen, S Namib only, probably under-recorded, occurs on Farm Spitzkop
Crassula numaisensis Friedrich	1	1				1	A	Rare	Annual, rarely seen, S Namib only, extremely rare and restricted, occurs on Farm Spitzkop
Crassula oblanceolata Schönland & Baker f.	1					1	P		Annual, rarely seen, S Namib only, probably under-recorded, occurs on Farm Spitzkop
Crassula pallens Schönland & Baker f.	1					1	P		S Namib only
Crassula pseudohemisphaerica Friedrich	1					1	P		S Namib only, occurs on Farm Spitzkop

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Crassula rudolfii Schönland & Baker f.	1					1	P		S Namib only, occurs on Farm Spitzkop
Crassula rupestris Thunb. subsp. commutata (Friedrich) Toelken	1					1	P		S Namib only, occurs near Skorpion
Crassula sericea Schönland var. hottentotta (Marloth & Schönland) Toelken	1					1	P		S Namib only
Crassula sericea Schönland var. sericea	1					1	P		S Namib only, occurs on Farm Spitzkop
Crassula sladenii Schönland	1					1	P		S Namib only, very few localities known, seen in study area. Horticultural potential
Crassula subacaulis Schönland & Baker f. subsp. erosula (N.E.Br.) Toelken	1					1	P		S Namib only, occurs on Farm Spitzkop
Crassula subaphylla (Eckl. & Zeyh.) Harv. var. subaphylla	1				1	1	P		Reasonably widespread, occurs on Farm Spitzkop
Crassula tenuipedicellata Schönland & Baker f.						1	A		
Crassula tomentosa Thunb. var. tomentosa	1					1	P		S Namib only, occurs on Farm Spitzkop
Crotalaria meyeriana Steud.			1	1			A		Common, widespread
Cucumella aspera (Cogn.) C.Jeffrey						1	P		
Cyphia dentariifolia C.Presl var. dentariifolia						1	P		
Cysticapnos vesicaria (L.) Fedde						1	A		
Diascia ausana Dinter						1	A		S Namib only, but reasonably widespread, seen in study area
Diascia minutiflora Hiern						1	A		S Namib only, occurs on Farm Spitzkop

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Dicoma capensis Less.				1	1		P		
Didelta carnosa (L.f.) Aiton var. carnosa			1	1	1	1	A		Used in horticulture elsewhere
Didelta spinosa (L.f.) Aiton						1	P		
Didymodoxa capensis (L.f.) Friis & Wilmot-Dear var. capensis						1	A		
Dioscorea elephantipes (L'Hér.) Engl.						1	P		
Diospyros ramulosa (E.Mey. ex A.DC.) De Winter						1	P		
Dipcadi brevifolium (Thunb.) Fourc.			1				P		
Dipcadi gracillimum Baker			1	1			P		
Dischisma spicatum (Thunb.) Choisy			1	1			A		
Dodonaea angustifolia L.f.						1	P	Alien	Invasive in drainage lines, as may be seen near to water pump station south of Rosh Pinah. Not seen in study area
Dracophilus dealbatus (N.E.Br.) Walgate			1	1	1	1	P		S Namib only, but reasonably widespread, clumped distribution, common where it occurs, seen in study area in dense stands. Horticultural potential
Drimia elata Jacq.				1	1	1	P		
Drimia exuviata (Jacq.) Jessop				1		1	P		
Drimia filifolia (Jacq.) J.C.Manning & Goldblatt			1				P		
Drosanthemum albens L.Bolus				1	1	1	P		S Namib only, mainly the south-west of that area, common where it occurs. Horticultural potential
Drosanthemum pauper (Dinter) Dinter & Schwantes				1	1	1	P		S Namib only, common where it occurs, seen in study area

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Dyerophytum africanum (Lam.) Kuntze			1	1	1	1	P		
Eberlanzia clausa (Dinter) Schwantes	1		1	1	1		P		S Namib only, reasonably widespread
Eberlanzia cyathiformis (L.Bolus) H.E.K.Hartmann	1				1	1	P		
Eberlanzia schneideriana (A.Berger) H.E.K. Hartmann	1				1	1	P		S Namib only, reasonably widespread, common in study area
Ebracteola derenbergiana (Dinter) Dinter & Schwantes	1		1	1			P		S Namib mainly, clumped distribution, often common where it occurs, occurs at Skorpion. Horticultural potential
Ehretia alba Retief & A.E.van Wyk						1	P		
Ehrharta calycina Sm. var. angustifolia Kunth						1	P		
Ehrharta delicatula (Nees) Stapf						1	A		
Ehrharta triandra Nees ex Trin.						1	A		
Eragrostis brizantha Nees			1				A		
Eriocephalus ambiguus (DC.) M.A.N.Muell.				1			P		
Eriocephalus giessii M.A.N.Müll.						1	P		
Eriocephalus scariosus DC.						1	P		Widespread, seen in study area
Eriospermum roseum Schinz						1	P		
Euclea asperrima Friedr.-Holzh.						1	P		Disjunct distribution in vicinity of study area and at Naukluft, very few populations known, seen on limestone-marble koppies in west of study area
Euclea undulata Thunb.						1	P		

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Euphorbia cibdela N.E.Br.				1	1	1	P		S Namib only, reasonably widespread, quite common, seen in study area
Euphorbia dregeana E.Mey. ex Boiss.			1	1	1	1	P		S Namib only, reasonably widespread, quite common, seen in study area. Horticultural potential
Euphorbia ephedroides E.Mey. ex Boiss. var. ephedroides					1	1	P		
Euphorbia gummifera Boiss.			1	1	1	1	P		S Namib only, widespread, common, seen in study area
Euphorbia hamata (Haw.) Sweet						1	P		Horticultural potential
Euphorbia mauritanica L.						1	P		
Euphorbia melanohydrata Nel			1	1			P		S Namib only, limited distribution, concerns about cumulative impacts (many affected by Skorpion)
Euphorbia lignosa Marloth						1	P		Widespread, common, seen in study area
Euryops lateriflorus (L.f.) DC.						1	P		
Euryops namaquensis Schltr.						1	P		
Euryops namibensis (Merxm.) B.Nord.						1	P		S Namib only, reasonably common, only on rocky slopes, seen in study area
Felicia microsperma DC.			1				A		
Felicia hirsuta DC.						1	P		
Ferraria divaricata Sweet subsp. divaricata			1				P		

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Ferraria schaeferi Dinter			1				P		S Namib only, mainly sandy plains of SW, occurs on plains at Skorpion. Horticultural potential
Ficus ilicina (Sond.) Miq.						1	P		Fruit important for frugivorous birds
Fingerhuthia africana Lehm.						1	P		
Forsskaolea candida L.f.			1	1	1	1	P		Medicinal uses
Foveolina dichotoma (DC.) Källersjö			1	1	1	1	A		
Freesia viridis (Aiton) Goldblatt & J.C.Manning						1	P		
Gaillonia crocyllis (Sond.) Thulin				1		1	P		
Galenia africana L.			1	1			A/P		
Galenia dregeana Fenzl ex Sond.						1	P		
Galenia fruticosa (L.f.) Sond.				1	1		P		
Galenia meziana K.Muell.			1	1	1		P		
Galenia papulosa (Eckl. & Zeyh.) Sond.			1	1			A/P		
Galenia pruinosa Sond.			1	1	1	1	P		
Galium tomentosum Thunb.						1	P		
Gazania lichtensteinii Less.			1	1	1	1	A		Horticultural potential
Gazania tenuifolia Less.			1	1			A		
Gethyllis namaquensis (Schönland) Oberm.			1	1	1		P		Fruit edible, used to produce brandy and medicinally
Gnidia suavissima Dinter						1	P		
Gomphocarpus cancellatus (Burm.f.) Bruyns						1	P		
Gorteria corymbosa DC.			1		1		A		S Namibia, reasonably widespread, occurs on Farm Spitzkop. Horticultural potential

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Gorteria diffusa Thunb. subsp. parviligulata Roessler						1	A		
Grielum humifusum Thunb. var. parviflorum Harv.			1	1			A		
Gymnosporia szyszylowiczii (Kuntze) M.Jordaan							P		
Haemanthus pubescens L.f. subsp. arenicola Snijman			1				P		
Hartmanthus hallii (L.Bolus) S.A.Hammer	1					1	P	Highly restricted distribution and habitat	S Namib in vicinity of Rosh Pinah only, only known from few, highly localised populations, not seen in study area, but observed close by
Haworthia venosa (Lam.) Haw. subsp. tessellata (Haw.) M.B.Bayer							P		
Hebenstretia integrifolia L.			1	1	1	1	A		
Hebenstretia namaquensis Roessler			1				P		
Helichrysum alsinoides DC.				1			A		
Helichrysum gariepinum DC.			1	1			A		
Helichrysum herniarioides DC.				1			A		
Helichrysum obtusum (S.Moore) Moeser			1	1	1	1	A		
Heliophila cornuta Sond. var. squamata (Schltr.) Marais						1	P		
Heliophila crithmifolia Willd.						1	A		
Heliophila deserticola Schltr. var. deserticola			1	1	1	1	A		
Heliophila eximia Marais						1	A		
Heliophila trifurca Burch. ex DC.				1		1	A		S Namibia, reasonably common, occurs on Farm Spitzkop
Heliotropium tubulosum E.Mey. ex A.DC.			1	1			A		Horticultural potential

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Hereroa hesperantha (Dinter & A.Berger) Dinter & Schwantes	1			1		1	P		Reasonably widespread
Hermannia amoena Dinter ex Friedr.-Holzh.						1	P		
Hermannia disermifolia Jacq.						1	P		
Hermannia helianthemum K.Schum.						1	P		
Hermannia macra Schltr.			1	1			P		
Hermannia paucifolia Turcz.			1	1		1	P		
Hermannia pfeilii K.Schum.					1		P		Horticultural potential
Hermannia rautanenii Schinz ex K.Schum.							P		
Hermannia stricta (E.Mey. ex Turcz.) Harv.				1	1	1	P		Horticultural potential
Hermbstaedtia glauca (J.C.Wendl.) Rchb. ex Steud.				1		1	P		
Hirpicium echinus Less.			1	1	1		P		Horticultural potential
Holothrix villosa Lindl. var. condensata (Sond.) Immelman	1					1	P	Rarely seen	S Namib, very few localities, occurs on Farm Spitzkop
Hoodia gordonii (Masson) Sweet ex Decne.	1		1				P		Widespread, seen in study area. Used traditionally to quench hunger and thirst
Hypertelis salsoloides (Burch.) Adamson var. salsoloides				1	1		P		
Ifloga molluginoides (DC.) Hilliard			1	1			A		
Indigastrum argyroides (E.Mey.) Schrire			1	1	1	1	A		
Indigofera pungens E.Mey.			1	1	1	1	P		
Jamesbrittenia fruticosa (Benth.) Hilliard			1			1	P		
Jamesbrittenia glutinosa (Benth.) Hilliard						1	A/P?		Horticultural potential
Jamesbrittenia ramosissima (Hiern)						1	P		Horticultural potential

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Hilliard									
Jordaaniella cuprea (L.Bolus) H.E.K.Hartmann				1	1	1	P		Horticultural potential
Juttadinteria attenuata Walgate				1		1	P		S Namib only, restricted distribution, not seen in study area
Karroochloa schismoides (Stapf ex Conert) Conert & Türpe				1			A		
Kissenia capensis Endl.			1	1	1	1	P		
Kleinia cephalophora Compton						1	P		
Kleinia longiflora DC.					1	1	P		
Kohautia caespitosa Schnizl. subsp. brachyloba (Sond.) D.Mantell			1	1	1	1	P		
Lachenalia buchubergensis Dinter		1	1	1			P	Rare	S Namib only, few localities known, occurs on Farm Spitzkop
Lachenalia giessii W.F.Barker					1	1	P		S Namib only, few localities known, occurs on Farm Spitzkop. Horticultural potential
Lachenalia nordenstamii W.F.Barker		1				1	P	Rare	S Namib only, few localities known
Lampranthus hoerleinianus (Dinter) Friedrich			1		1		P		Horticultural potential
Lapeirousia barklyi Baker			1	1			P		Horticultural potential
Lapeirousia dolomitica Dinter subsp. dolomitica				1		1	P		S Namib only, reasonably widespread but few records
Lasiopogon glomerulatus (Harv.) Hilliard			1	1		1	A		
Lasiospermum brachyglossum DC.				1		1	A		Horticultural potential
Lebeckia halenbergensis Merxm. & A.Schreib.				1	1		P		
Ledebouria undulata (Jacq.) Jessop			1	1	1		P		

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Leipoldtia weigangiana (Dinter) Dinter & Schwantes subsp. weigangiana				1	1	1	P		S Namib only, mainly SW, reasonably common, known from Skorpion
Lepidium africanum (Burm.f.) DC. subsp. divaricatum (Aiton) Jonsell				1		1	P		
Lessertia benguellensis Baker f.				1			P		
Lessertia eremicola Dinter			1				A		S Namib only, reasonably widespread on sandy plains, known from Skorpion
Leucophrys mesocoma (Nees) Rendle			1	1	1	1	P		
Limeum aethiopicum Burm. var. glabrum Moq.						1	P		
Limeum fenestratum (Fenzl) Heimerl var. fenestratum			1				A		
Lotononis rabenaviana Dinter & Harms				1		1	A		
Lotononis strigillosa (Merxm. & A.Schreib.) A.Schreib.			1	1		1	A		S Namib only, reasonably common and widespread on sandy plains and in sandy gorges, occurs on Farm Spitzkop
Lycium bosciifolium Schinz				1		1	P		
Lycium cinereum Thunb.				1		1	P		
Lycium gariepense A.M.Venter						1	P		S Namibia only
Lycium pilifolium C.H.Wright						1	P		
Lyperia tristis (L.f.) Benth.			1	1			A		
Manulea androsacea E.Mey. ex Benth.			1	1			A		Widespread, known from Skorpion
Melasphaerula ramosa (L.) N.E.Br.						1	P		
Melianthus pectinatus Harv. subsp. gariepinus (Merxm. & Roessler) S.A.Tansley						1	P		

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Melolobium candicans (E.Mey.) Eckl. & Zeyh.			1	1			P		
Merxmuellera rangei (Pilg.) Conert				1			P		S Namib only, restricted to drainage lines
Mesembryanthemum barklyi N.E.Br.			1	1	1		A		
Mesembryanthemum pellitum Friedrich			1	1	1	1	A		S Namib only, restricted distribution but common in disturbed places around Rosh Pinah, seen in study area
Microloma armatum (Thunb.) Schltr. var. armatum			1				P		
Microloma calycinum E.Mey.						1	P		
Monechma crassiusculum P.G.Mey.			1	1			P		S Namib only, known from Skorpion
Monechma mollissimum (Nees) P.G.Mey.			1	1	1	1	P		
Monsonia deserticola Dinter ex R.Knuth				1			A		
Montinia caryophyllacea Thunb.						1	P		
Namaquanula bruce-bayeri D. Müll.-Doblies & U. Müll.-Doblies		1					**P**	**Vulnerable**	S Namib only, few localities known
Namophila urotepala U. Müll.-Doblies & D. Müll.-Doblies						1	P		S Namib only, rare, occurs on Farm Spitzkop
Nemesia fruticans (Thunb.) Benth.			1	1			A		Horticultural potential
Nemesia violiflora Roessler						1	A		S Namib only, mainly SW, seen in study area. Horticultural potential
Nemesia viscosa E.Mey. ex Benth.						1	A		S Namib only, seen in study area. Horticultural potential
Nolletia gariepina (DC.) Mattf.						1	P		
Nymania capensis (Thunb.) Lindb.				1		1	P		
Oncosiphon grandiflorum (Thunb.)			1	1	1		A		

Plant species list for Gergarub (2716DC)	Protected	Red Data	Sandy gravelly plains	Stony gravelly plains	Succulent plains	Mountains, koppies and footslopes	Annual (A) perennial (P)	Comments and red data status	Distribution in Namibia of endemic, near endemic, protected and Red Data species. Occurrence on or near site noted.
Källersjö									
Oncosiphon suffruticosum (L.) Källersjö				1			A		
Ophioglossum polyphyllum A.Braun			1	1	1	1	P		Leaf edible
Ornithogalum glandulosum Oberm.					1	1	P		S Namib only, few localities known, occurs on Farm Spitzkop
Ornithogalum puberulum Oberm. subsp. puberulum						1	P		S Namib only, few localities known, occurs on Farm Spitzkop
Ornithogalum stapffii Schinz						1	P		Widespread, occurs on Farm Spitzkop
Ornithogalum suaveolens Jacq.				1		1	P		
Ornithogalum subcoriaceum L.Bolus							P		
Ornithogalum unifolium Retz. var. unifolium			1			1	P		
Ornithoglossum parviflorum B.Nord. var. parviflorum						1	P		
Ornithoglossum pulchrum Snijman, B.Nord. & Mannheimer					1	1	P		S Namib only, few localities known, seen in study area
Ornithoglossum vulgare B.Nord.			1	1	1		P		
Osteospermum karrooicum (Bolus) Norl.			1	1			P		
Osteospermum pinnatum (Thunb.) Norl. var. pinnatum					1	1	A		
Othonna cylindrica (Lam.) DC.				1		1	P		Augea capensis Thunb.
Othonna filicaulis Jacq.						1	P		
Othonna lasiocarpa (DC.) Sch.Bip.					1	1	P		
Othonna opima Merxm.							P		S Namib only. Horticultural potential
Othonna protecta Dinter						1	P		
Othonna sparsiflora (S.Moore) B.Nord.			1				P		S Namib only, known from Skorpion

Plant species list for Gergarub (2716DC)	Protected	Red Data	Sandy gravelly plains	Stony gravelly plains	Succulent plains	Mountains, koppies and footslopes	Annual (A) perennial (P)	Comments and red data status	Distribution in Namibia of endemic, near endemic, protected and Red Data species. Occurrence on or near site noted.
Oxalis beneprotecta Dinter ex R.Knuth						1	P		
Oxalis copiosa F.Bolus						1	P		
Oxalis laxicaulis R.Knuth						1	P		S Namibia to Bethanie, occurs on Farm Spitzkop
Oxalis obtusa Jacq.						1	P		
Ozoroa concolor (C.Presl ex Sond.) De Winter						1	P		Horticultural potential
Ozoroa dispar (C.Presl) R.& A.Fern.						1	P		
Pachypodium namaquanum (Wyley ex Harv.) Welw.	1					1	P		S Namib only, cumulative impacts of concern, seen in study area. Often illegally collected
Pappea capensis Eckl. & Zeyh.				1		1	P		Fruit edible
Pegolettia gariepina Anderb.						1	P		S Namibia, seen in study area
Pelargonium antidysentericum (Eckl. & Zeyh.) Kostel. subsp. antidysentericum						1	P		
Pelargonium articulatum (Cav.) Willd.						1	P		
Pelargonium carnosum (L.) L'Hér.						1	P		
Pelargonium grandicalcaratum R.Knuth						1	P		
Pelargonium klinghardtense R.Knuth						1	P		S Namib only, uncommon, seen in study area
Pelargonium paniculatum Jacq.						1	P		S Namib only, uncommon, seen in study area
Pelargonium spinosum Willd.						1	P		Horticultural potential
Pelargonium tenuicaule R.Knuth						1	P		
Pelargonium xerophyton Schltr. ex R.Knuth						1	P		
Peliostomum viscosum E.Mey. ex Benth.						1	P		
Pentzia pinnatisecta Hutch.						1	P		

Plant species list for Gergarub (2716DC)	Protected	Red Data	Sandy gravelly plains	Stony gravelly plains	Succulent plains	Mountains, koppies and footslopes	Annual (A) perenial (P)	Comments and red data status	Distribution in Namibia of endemic, near endemic, protected and Red Data species. Occurrence on or near site noted.
Pergularia daemia (Forssk.) Chiov. var. leiocarpa (K.Schum.) H.Huber						1	P		
Pharnaceum brevicaule (DC.) Bartl.				1			P		
Phyllobolus oculatus (N.E.Br.) Gerbaulet			1	1	1		P		S Namib only, common, seen in study area
Phyllopodium hispidulum (Thell.) Hilliard			1	1			A		
Phyllopodium namaense (Thell.) Hilliard			1	1			A		S Namib only, common, occurs on Farm Spitzkop
Pollichia campestris Aiton						1	P		Used medicinally. Flower bracts edible
Polygala lasiosepala Levyns						1	P		
Polygala mossii Exell						1	P		
Polypogon monspeliensis (L.) Desf.						1	A	Naturalised species	
Psammophora longifolia L.Bolus	1			1	1		P		S Namib only, patchy distribution, seen in study area
Psammophora modesta (Dinter & A.Berger) Dinter & Schwantes	1		1	1			P		S Namib only, common
Psilocaulon salicornioides (Pax) Schwantes			1	1			P		Widespread, common, known from Skorpion
Pteronia cylindracea DC.						1	P		
Pteronia glabrata L.f.						1	P		
Pteronia lucilioides DC.						1	P		Widespread, common, seen in study area
Pteronia paniculata Thunb.						1	P		
Pteronia pomonae Merxm.				1		1	P		
Quaqua acutiloba (N.E.Br.) Bruyns	1					1	P		
Rhyssolobium dumosum E.Mey.						1	P		S Namib only, reasonably widespread, seen in study area

Plant species list for Gergarub (2716DC)	Protected	Red Data	Sandy gravelly plains	Stony gravelly plains	Succulent plains	Mountains, koppies and footslopes	Annual (A) perennial (P)	Comments and red data status	Distribution in Namibia of endemic, near endemic, protected and Red Data species. Occurrence on or near site noted.
Ruschia abbreviata L.Bolus						1	P		S Namib only, reasonably widespread, seen in study area
Ruschia muelleri (L.Bolus) Schwantes				1		1	P		Horticultural potential
Ruschia spinosa (L.) Dehn	1					1	P		Horticultural potential
Ruschia tumidula (Haw.) Schwantes	1					1	P		
Salsola armata C.A.Sm. ex Aellen						1	P		
Salsola zeyheri (Moq.) Bunge						1	P		
Sarcocaulon crassicaule Rehm				1		1	P		Horticultural potential
Sarcocaulon flavescens Rehm				1	1	1	P		
Sarcocaulon inerme Rehm				1	1	1	P		S Namib only, patchy distribution, seen in study area
Sarcocaulon patersonii (DC.) G.Don			1	1	1	1	P		Widespread, seen in study area
Sarcostemma viminale (L.) R.Br. subsp. viminale						1	P		
Searsia populifolia (E.Mey. ex Sond.) Moffett			1	1	1	1	P		S Namibia, common. Horticultural potential
Searsia undulata (Jacq.) T.S.Yi, A.J.Mill. & J.Wen						1	P		
Schismus barbatus (Loefl. ex L.) Thell.						1	A		
Selago angustibractea Hilliard						1	P		Widespread, occurs on Farm Spitzkop
Senecio arenarius Thunb.				1			A		
Senecio cakilefolius DC.			1				A		
Senecio flavus (Decne.) Sch.Bip.						1	A		
Senecio giessii Merxm.						1	A		S Namib only, reasonably common, seen in study area
Senecio maydae Merxm.						1	P		
Senecio pinguifolius (DC.) Sch.Bip.						1	P		
Senecio piptocoma O.Hoffm.						1	A		

Plant species list for Gergarub (2716DC)	Protected	Red Data	Sandy gravelly plains	Stony gravelly plains	Succulent plains	Mountains, koppies and footslopes	Annual (A) perennial (P)	Comments and red data status	Distribution in Namibia of endemic, near endemic, protected and Red Data species. Occurrence on or near site noted.
Senecio sarcoides C.Jeffrey						1	P		
Sisyndite spartea E.Mey. ex Sond.			1	1	1	1	P		S Namibia, common, widespread, seen in study area
Solanum burchellii Dunal						1	P		
Spiloxene scullyi (Baker) Garside						1	P		
Stachys rugosa Aiton						1	P		
Stapeliopsis neronis Pillans	1	1				1	**P**	**Vulnerable**	Extreme S Namib only, very few localities known, recorded on low mountain slopes on Farm Spitzkop
Stipagrostis ciliata (Desf.) De Winter var. capensis (Trin. & Rupr.) De Winter			1	1	1	1	P		
Stipagrostis geminifolia Nees			1	1		1	P		S Namib only, widespread, seen in study area
Stipagrostis obtusa (Delile) Nees			1	1			P		
Stoeberia beetzii (Dinter) Dinter & Schwantes	1		1	1			P		S Namib only, reasonably widespread
Stoeberia frutescens (L.) Van Jaarsv.	1				1	1	P		S Namib only
Stoeberia gigas (Dinter) Dinter & Schwantes	1					1	P		S Namib only, reasonably widespread, seen in study area
Strumaria hardyana D. Müll.-Doblies & U. Müll.-Doblies						1	P		S Namib only, very rarely seen, occurs on Farm Spitzkop
Sutherlandia frutescens (L.) R.Br.			1	1		1	P		Used medicinally
Tapinanthus oleifolius (J.C.Wendl.) Danser			1	1	1	1	P		
Tetragonia arbuscula Fenzl						1	P		
Tetragonia decumbens Mill.			1	1	1	1	P		
Tetragonia reduplicata Welw. ex Oliv.			1	1	1	1	P		
Thesium lacinulatum A.W.Hill						1	P		

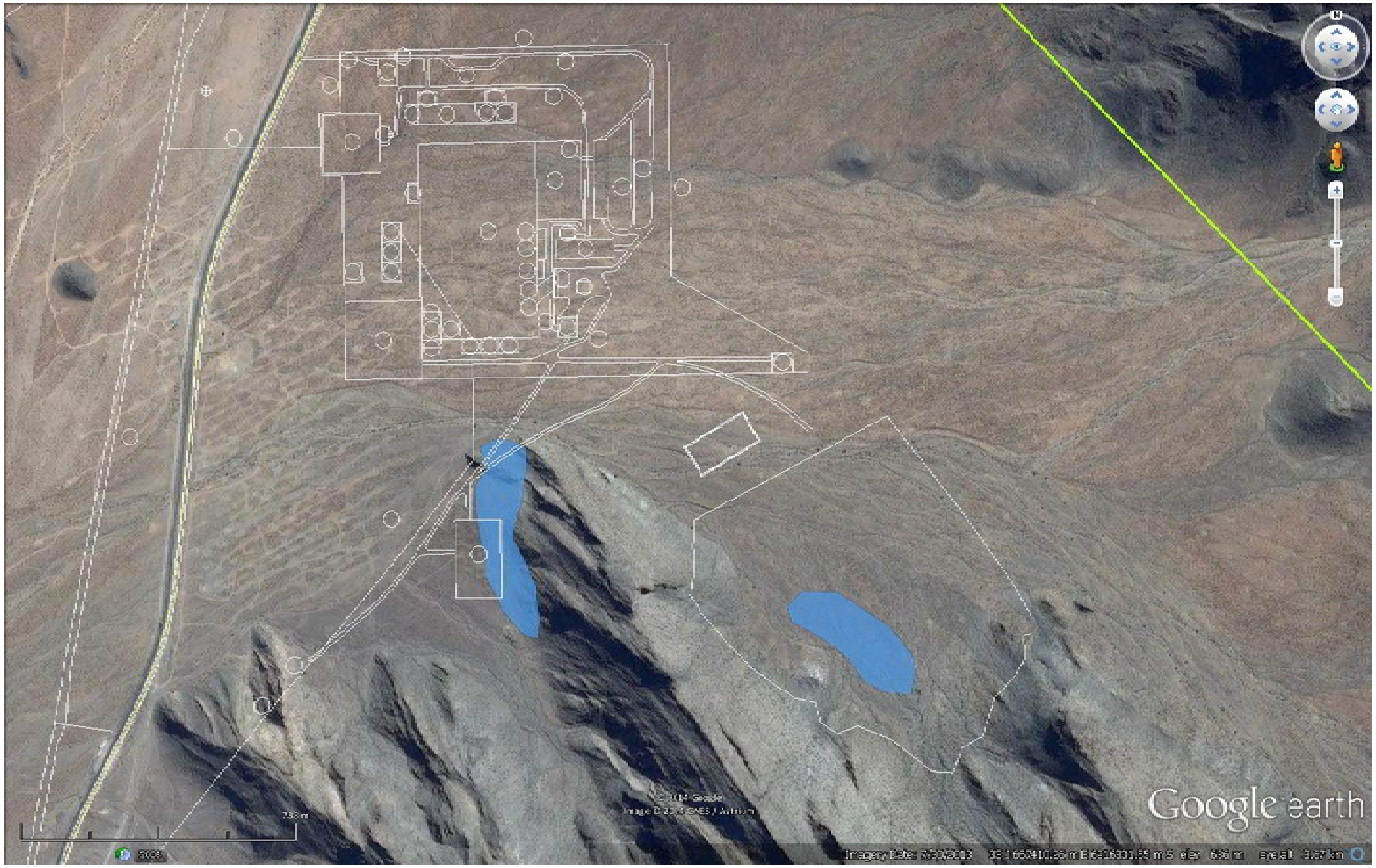
Plant species list for Gergarub (2716DC)	Protected	Red Data	Sandy gravelly plains	Stony gravelly plains	Succulent plains	Mountains, koppies and footslopes	Annual (A) perennial (P)	Comments and red data status	Distribution in Namibia of endemic, near endemic, protected and Red Data species. Occurrence on or near site noted.
Thesium lineatum L.f.						1	P		
Trachyandra bulbinifolia (Dinter) Oberm.			1	1	1		P		S Namibia, seen in study area
Trachyandra falcata (L.f.) Kunth					1		P		
Trachyandra lanata (Dinter) Oberm.			1	1			P		S Namib, reasonably common on sandy and gravelly plains
Trachyandra muricata (L.f.) Kunth			1	1		1	P		
Trianthema parvifolia E.Mey. ex Sond.			1	1	1		P		
Tribulus cristatus C.Presl						1	A		
Tripteris breviradiata (Norl.) B.Nord.							A		
Tripteris crassifolia O.Hoffm.				1			P		
Tripteris microcarpa Harv. subsp. microcarpa						1	A		
Tripteris polycephala DC.			1	1	1	1	A		S Namib only, common, seen in study area. Horticultural potential
Tripteris sinuata DC. var. sinuata				1			P		
Triraphis pumilio R.Br.						1	A		
Troglophyton capillaceum (Thunb.) Hilliard & B.L.Burtt subsp. capillaceum						1	A		
Troglophyton parvulum (Harv.) Hilliard & B.L.Burtt						1	A		
Tylecodon buchholzianus (Schuldt & P.Stephan) Toelken subsp. buchholzianus						1	P		S Namib only
Tylecodon hallii (Toelken) Toelken	1					1	P		S Namib only, limited distribution, seen in study area. Horticultural potential
Tylecodon paniculatus (L.f.) Toelken						1	P		Reasonably wide distribution, seen in study area. Used in horticulture

Plant species list for Gergarub (2716DC)	Protected	Red Data	Sandy gravelly plains	Stony gravelly plains	Succulent plains	Mountains, koppies and footslopes	Annual (A) perennial (P)	Comments and red data status	Distribution in Namibia of endemic, near endemic, protected and Red Data species. Occurrence on or near site noted.
Tylecodon racemosus (Harv.) Toelken		1				1	P	Rare	S Namib only, seen in study area
Tylecodon reticulatus (L.f.) Toelken subsp. phyllopodium Toelken					1	1	P		S Namib only, occurs on Farm Spitzkop
Tylecodon wallichii (Harv.) Toelken subsp. ecklonianus (Harv.) Toelken						1	P		S Namib to Aus, seen in study area
Ursinia nana DC. subsp. leptophylla Prassler			1	1			A		
Ursinia nana DC. subsp. nana			1	1			A		
Ursinia speciosa DC.			1	1			A		Horticultural potential
Wahlenbergia annularis A.DC.			1	1			A		
Wahlenbergia erophiloides Markgr.			1	1			A		S Namib only , reasonably wide distribution, occurs on Farm Spitzkop
Wahlenbergia patula A.DC.						1	A		
Wahlenbergia subrosulata Brehmer				1			A		
Whiteheadia bifolia (Jacq.) Baker						1	P		
Xenoscapa fistulosa (Spreng. ex Klatt) Goldblatt & J.C.Manning						1	P		
Zygophyllum applanatum Van Zyl				1		1	P		S Namib only, common where it occurs but occurrence patchy, occurs on Farm Spitzkop
Zygophyllum cordifolium L.f.				1	1	1	P		
Zygophyllum leptopetalum E.Mey. ex Sond.				1		1	P		
Zygophyllum longicapsulare Schinz				1	1	1	P		Widespread, common, seen in study area
Zygophyllum macrocarpon Retief						1	P		S Namib only, restricted distribution mainly in 2716DC mountain gorges, occurs on Farm Spitzkop

Plant species list for Gergarub (2716DC)	Protected	Red Data	Sandy gravelly plains	Stony gravelly plains	Succulent plains	Mountains, koppies and footslopes	Annual (A) perenial (P)	Comments and red data status	Distribution in Namibia of endemic, near endemic, protected and Red Data species. Occurrence on or near site noted.
Zygophyllum microcarpum Licht. ex Cham. & Schltdl.				1			P		Widespread, common, seen in study area
Zygophyllum morgsana L.						1	P		
Zygophyllum patenticaule Van Zyl ined.				1	1	1	P		S Namibia from Rosh Pinah to Ai-Ais, seen in study area
Zygophyllum prismatocarpum E.Mey. ex Sond.			1	1	1	1	P		S Namib, widespread, common, seen in study area
Zygophyllum pterocaule Van Zyl				1	1	1	P		S Namib only, highly restricted distribution, seen in study area
Zygophyllum retrofractum Thunb.			1	1	1		P		
Zygophyllum schreiberanum L.					1	1	P		S Namib only, highly restricted distribution, seen in study area
Zygophyllum simplex L.			1	1	1	1	A		
TOTAL	54	10	124	151	87	297			
Near-Endemic									
Endemic									
IUCN: E = Endangered; R = Rare; VU = Vulnerable									

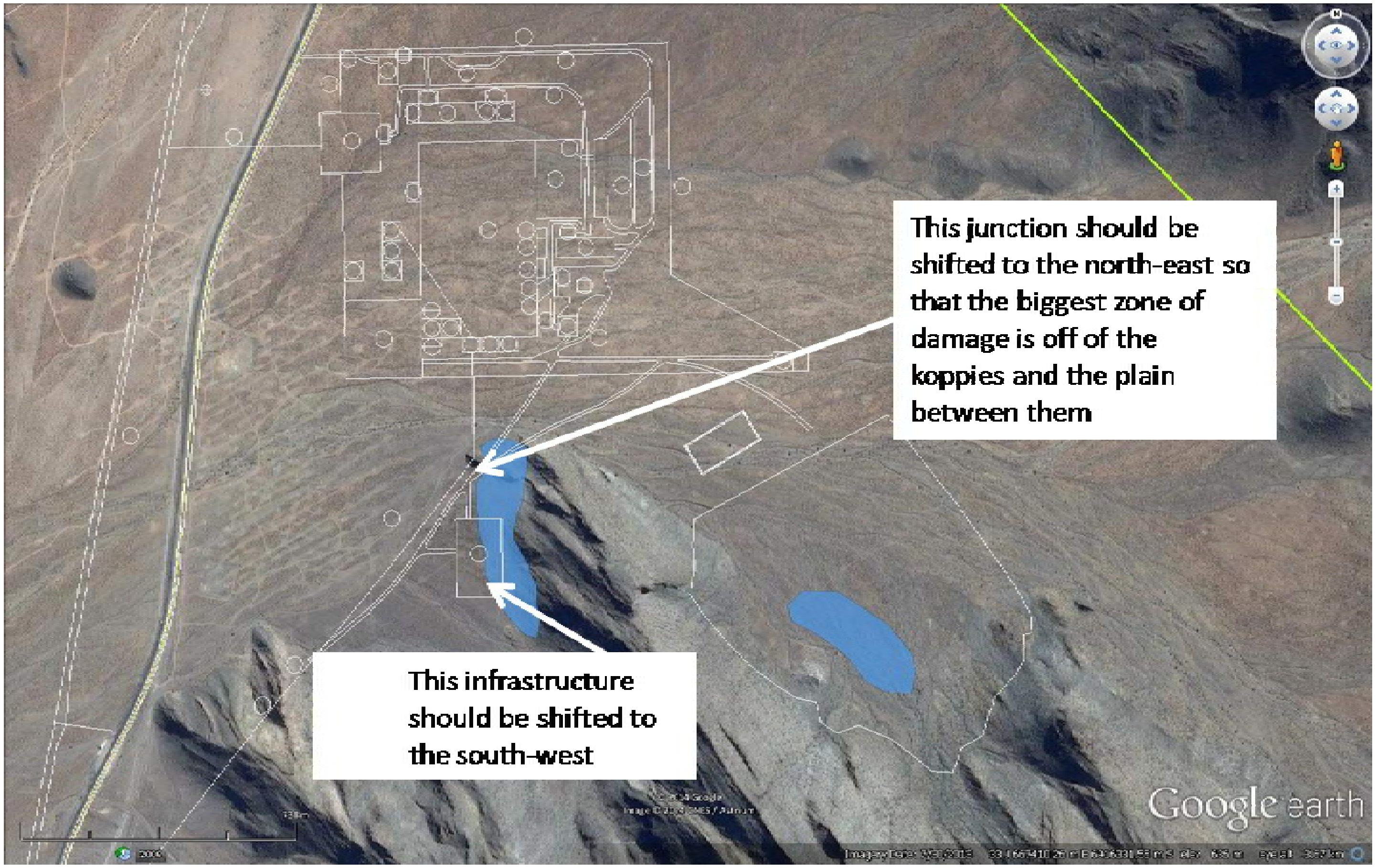
APPENDIX B

Two dense sub-populations of protected succulents that will be adversely affected or completely destroyed by the proposed infrastructure



APPENDIX C

Proposed shift of infrastructure to protect one of the two dense sub-populations of protected succulents that will be adversely affected or completely destroyed by the proposed infrastructure



APPENDIX D

Proposed “no-go” area or nature reserve

APPENDIX E

Translocation and monitoring protocols

1: Translocation, watering and monitoring protocol for *Dracophilus dealbatus* and *Cheiridopsis robusta* at Gergarub.

Background

Fieldwork has established that, *inter alia,* several dense sub-populations *of Dracophilus dealbatus* and *Cheiridopsis robusta* will almost certainly be destroyed by planned mine infrastructure at Gergarub (Mannheimer 2014). Construction of the reservoir road will also destroy considerable numbers of other protected and restricted range species. In order to mitigate the impact of the mine on these protected species it has been suggested that as many as possible of the individuals in the sub-populations in question be rescued and relocated on site, in the close vicinity (e.g. plains near Skorpion), to the National Botanic Garden in Windhoek , or to the new Namib Botanic Garden near Swakopmund. Plant relocation has been done successfully on several other exploration and mining license areas in the southern Namib, including Skorpion Zinc.

A permit for this work will be required from the Ministry of Environment and Tourism.

Methods

The work was must be undertaken before mine infrastructure development begins and should be done, or supervised, by persons experienced in this work. The best time to do it would be in June/July.

The plants should be carefully extracted by hand and transferred using manual methods.

Sites selection for relocation should be based on the following factors, listed below *in order of importance*:

- Suitable substrate, as indicated by the presence of the species in question
- Habitat resilience – whether one can plant the translocated individuals without compromising the habitat for the existing flora growing on the site
- Convenience for watering and monitoring

Sites for replanting should be carefully selected so as not to damage the plants already there and also to damage the habitat as little as possible.

The plants should be transplanted immediately, and should be watered in immediately after planting and then once every two weeks twice. One litre of water per plant should be applied each time, 500ml in the case of small plants.

Survival of the plants should be monitored annually in September for five years. Permanent quadrats within the replanting sites should be permanently marked by GPS and durable pegs so as to facilitate monitoring over several years. Within the marked quadrats, live plants of the target species should be counted every year. Photographic records at fixed points should be kept.

Results should be submitted to a recognised local journal, such as *Dinteria*, or made available on the net.

FORM A: Translocation record	
Date:	Locality:
UTM (GPS location)	
Number of plants translocated in total	
Species	Number planted
Monitoring quadrat 1	
Species	Number planted in quadrat
Year monitored (date)	Number alive % survival
Monitoring quadrat 2	
Species	Number planted in quadrat
Year monitored (date)	Number alive % survival

2: Photopoint monitoring of sensitive habitats and translocation quadrats at Gergarub.

Photo point monitoring is a cheap but effective monitoring technique that can be used by land managers who are not trained ecologists.

A photo point is a point from which a series of photographs is taken of a particular subject (ie a plant species/community/impact) to record any changes that are occurring.

In its simplest form it can involve taking a single photograph of a plant community once a year.

Photo point monitoring can be used to monitor change in a plant species or community or compliance with a particular management regime. It can also be used to illustrate the impact of changes that have been measured.

Photographs taken from a photo point can be very important in monitoring because they provide an accurate record of the changes that have occurred in the subject over time. As a result they can be powerful tools for showing that a significant change has or has not occurred.

Establishing photo points

Setting up a photo point needs careful consideration to make sure that you select the most appropriate site and set it up properly. You may need the advice of an ecologist/botanist at first.

Before setting up your photo point make sure that you select an area tree that stands out from the background so as to show changes clearly. Select the distance from the area so that you can take the photo from close enough to almost fill the frame of the camera but still showing some surrounds.

Set up a photo point as follows:

- Ø At the point from which you will take your photographs, cement a dropper into the ground so the top is 1.4–1.6 m above ground level. This dropper is referred to as the marker peg. It should be labelled with a numbered metal tag.
- Ø Hammer a metal peg into the ground 5–20 m from the marker peg along the direct line of sight between the marker peg and the plant species/community/impact being photographed. This peg is referred to as the sighter peg. The height of the sighter peg will depend on the subject being photographed but it should be tall enough to be seen easily from the marker peg throughout the monitoring project. The distance of the sighter peg from the marker peg may need to be adjusted if the ground is sloping. If

the ground slopes down from the marker peg to the sighter peg, the sighter peg may need to be closer. If the ground slopes up from the marker peg to the sighter peg, the sighter peg may need to be further away.

Using photo points

The main purpose of photo point monitoring is to provide a reliable and accurate record of the plant species/community/impact being monitored. However, it is all too easy to forget which photograph was taken from which photo point and when it was taken. This problem can be overcome by hanging a data board containing the relevant information on the sighter peg. The information will then appear on the photograph itself.

The following information should appear on the data board:

- location of the site (UTM of marker peg)
- number of the photo point
- photographer
- date
- time

When you take your photograph make sure that you:

- take the photograph from the marker peg
- focus over the sighter peg towards the tree you are monitoring to ensure you always take the same view
- use a camera lens of the same specification each time and always use the camera the same way (i.e. landscape or portrait, or both)
- take the photograph at as close to the same date and time of day as possible each time
- take least two photos each time (you could take two landscape and two portrait, for example)

Record the photo numbers on the data form (Form B).

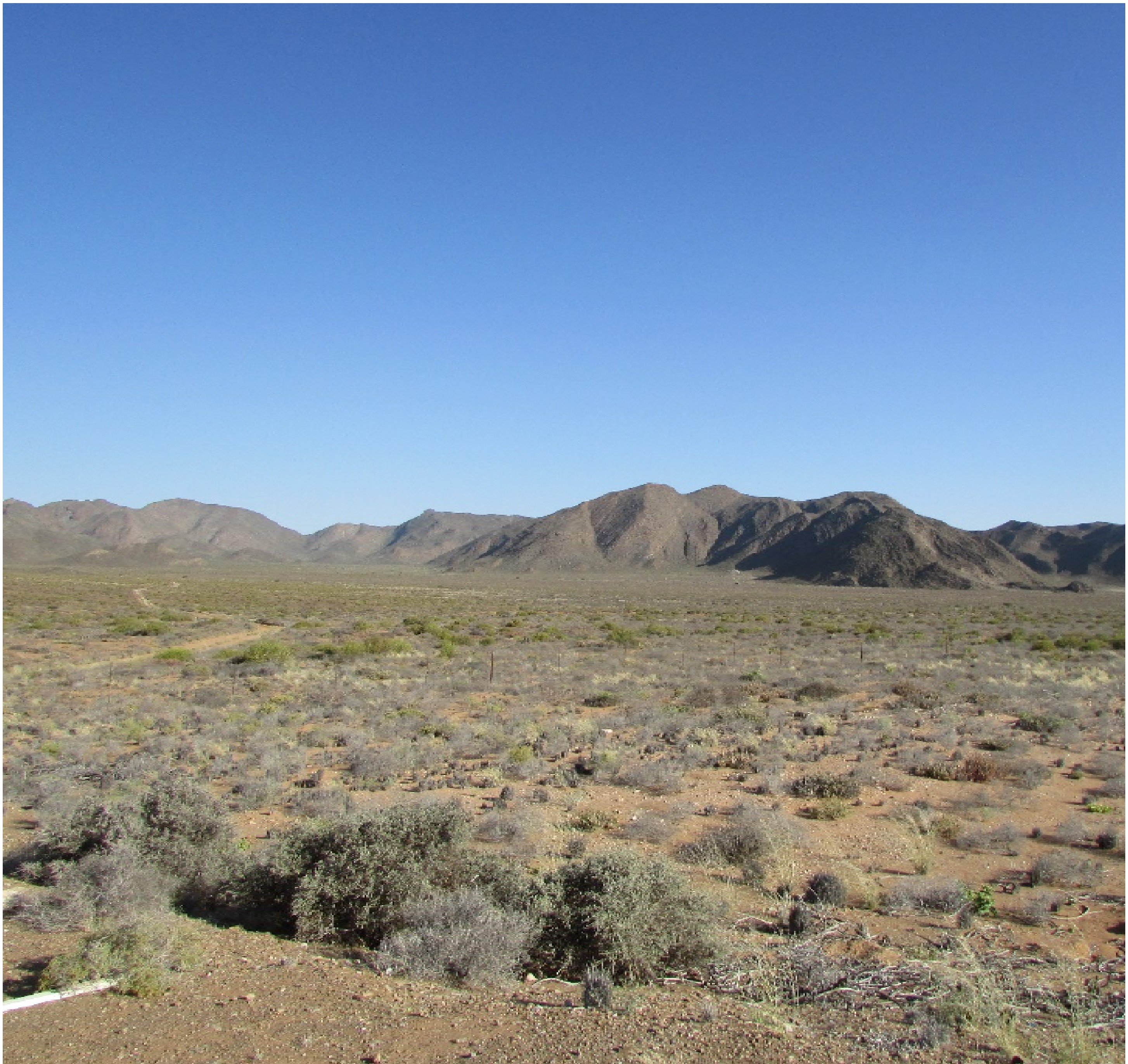
Save the photos on the computer using a specific name (e.g. Mountain slopes north east_2013 A).

BACK UP all your photographs every year. Keep the backup disks or drives in a safe place. Save them to DropBox (or some similar facility) as well.

FORM B: Photopoint record (UTM and locality only needed when point is first established)		
Date:		Locality description/Notes
Photopoint #		
Time:		
Person:		
Site:		
UTM marker peg	E	
	S	
UTM sighter peg	E	
	S	
Photograph numbers from camera		Photograph names in computer
		Backup location:
Paste best photo here		

APPENDIX F

South-west facing slope to be affected by reservoir road



Environmental and Social Impact Assessment (ESIA) for the proposed development of the Gergarub Mine

April 2015

Appendix F - Fauna Impact Assessment

COPYRIGHT:	
PROJECT NAME	Gergarub Project
STAGE OF REPORT	Final for Feasibility Assessment
CLIENT	Skorpion Mining Company (Pty) Ltd
SPECIALIST CONSULTANT	J. Irish representing Biodata Consultancy cc
DATE OF RELEASE	October 2014
CONTRIBUTORS TO THE REPORT	John Irish
CONTACT	biodata@biodiversity.org.na

DECLARATION

I hereby declare that I do:

(a) have knowledge of and experience in conducting specialist assessments, including knowledge of the Environmental Management Act (Act 7 of 2007)and the Regulations and Guidelines that have relevance to the proposed activity;

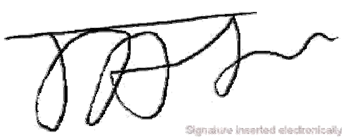
(b) perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant;

(c) comply with the abovementioned Act, its Regulations, Guidelines and other applicable laws.

I also declare that there is, to my knowledge, no information in my possession that reasonably has or may have the potential of influencing –

(i) any decision to be taken with respect to the application in terms of the Act and its Regulations; or

(ii) the objectivity of this report, plan or document prepared in terms of the Act and its Regulations.



John Irish, Ph.D.
Specialist Consultant

EXECUTIVE SUMMARY

The development is located in the Succulent Karoo Biome, an internationally recognised area of high biodiversity importance. Much of what occurs is endemic, occurring nowhere else in the world, and furthermore range-restricted, occurring only in very small (often < 100 km^2) parts of the broader region. The environment is therefore highly sensitive and highly vulnerable. Any particular infrastructure development could lead to the global extinction of endemic Namibian species, that are protected under both the Namibian Constitution and international conventions to which Namibia is signatory. The utmost care is therefore needed.

At a habitat level it has been possible to avoid directly destructive impacts on the most sensitive habitats in the area by restricting infrastructure footprints to relatively less sensitive (but still not unsensitive) areas. Population level impacts may be mitigated through a combination of water point monitoring, establishing of no-go areas and implementation of speed limits. Some taxon level impacts will need ongoing attention. For vertebrates of concern this involves verification of occurrence and monitoring of population trends. For invertebrates it involves taxonomic research and scientific description of undescribed species.

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GLOSSARY

Biodiversity	All living things on Earth
Biosystematic institutions	Traditionally natural history museums and herbaria; public bodies with the core business of providing taxonomic services, including the collection, storage and curation of study material
Conservation status	A measure of the extinction threat to a particular species. Categorisation is determined by standardised methods, maintained by IUCN. High conservation status and protected legal status often go together
Endemic	For animals, meaning they occur naturally only in a delimited area, usually used at the country level, as in 'Namibian endemic'
Habitat	A portion of the natural environment, with all living things in it, forming a functional ecological unit. Defined by the combination of physical characteristics peculiar to the habitat, and the variety of life forms adapted to it
Invertebrates	Smaller animals. Insects, Spiders, Scorpions, Centipedes and literally thousands of other groups, most of which have no common names. Invertebrates are often unnoticed and generally poorly known, but make up 99%+ of animal biodiversity
Range-restricted	For animals, an extreme form of endemism where they occur naturally in very small delimited areas only. Definitions of 'very small' differ, we have used a global range of less than 100 km^2 as an upper threshold here. At the lower end of the scale we have Namibian species with ranges measured in hectares
Succulent Karoo Biome	Biomes are natural areas at the subcontinent level. The Succulent Karoo is peculiar to north-western South Africa and south-western Namibia. It is characterised by a particular vegetation structure, in an area of very low rainfall, that falls in winter
Taxa	A group of unspecified generic animal(s). Singular: taxon
Taxonomy	The science of describing, naming and classifying living beings. A necessary first step for all more specialised biological studies
Vertebrate	Larger animals. Fish, Reptiles, Frogs, Birds, Mammals. Most noticeable and best known, but represent a tiny percentage of animal biodiversity

ABBREVIATIONS AND ACRONYMS

CITES	Convention on International Trade in Endangered Species
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
GBIF	Global Biodiversity Information Facility
IAP	Interested and Affected Party
IFC	International Finance Corporation
IUCN	International Union for the Conservation of Nature
NASA	National Aeronautics and Space Administration
NBD	Namibia Biodiversity Database
NCO	Nature Conservation Ordinance
SABIF	South African Biodiversity Information Facility
TOR	Terms of Reference

1 BACKGROUND

1.1 INTRODUCTION

The Gergarub Project is a proposed new zinc mine east of the existing Skorpion Zinc Mine in the Rosh Pinah area of south-western Namibia. Two documents of relevance precede this one. Irish & Mannheimer (2013) determined habitat diversity, habitat distribution and habitat sensitivity for the area. Irish (2013) included the faunal biodiversity study. This report draws on pertinent results of both, without repeating details.

1.2 SPECIALIST STUDY LEADER

Dr. J. Irish undertook the fauna study, with extensive background and experience of the Namibian fauna.

1.3 TERMS OF REFERENCE

Geographical scope: As per Gergarub EIA TOR dated 12 July 2012, map Section 3.1.

Developments to be assessed: Subsurface zinc mine, tailings storage facility and associated infrastructure.

Taxonomic scope: All fauna, general biodiversity. Plants excluded.

<u>Envisaged tasks and outputs</u>:

Desktop study: Do literature survey and database searches. Prepare draft lists of expected taxa. Identify potential taxa of concern and relevant legislation. Consider the high biodiversity importance of the Namibian Succulent Karoo Biome, but the fragmented nature of information on it.

Fieldwork in area to provide an environmental context within which confident extrapolations may be made from desktop results, essentially ground-truthing desktop work. Include a suitably wide surrounding area to accommodate ongoing changes to project details. Fieldwork will consist of observations and capture-identify-release surveying only; no destructive sampling will be done.

Refine prior desktop study based on fieldwork. Provide input to EIA process as needed.

1.4 METHODOLOGY

1.4.1 Study Area

The study area, and the habitats in it, are mapped in Figure 1 and Figure 2 below.

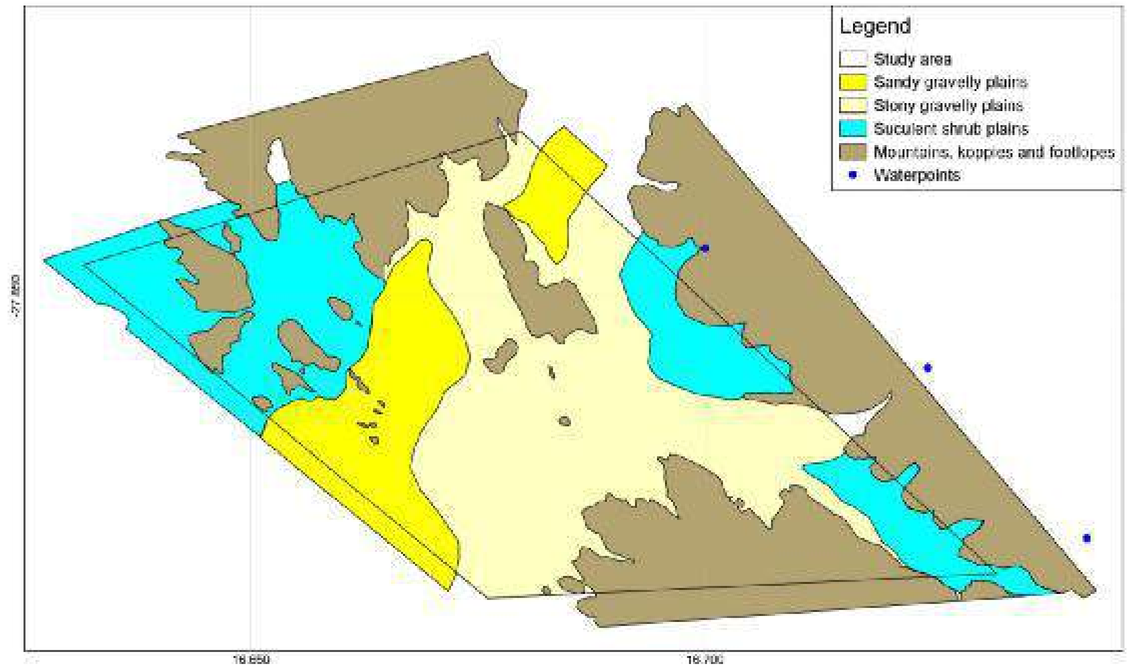

Figure 1: Study area and habitats in it, as delimited by Irish & Mannheimer (2013), and amended by Irish (2013).

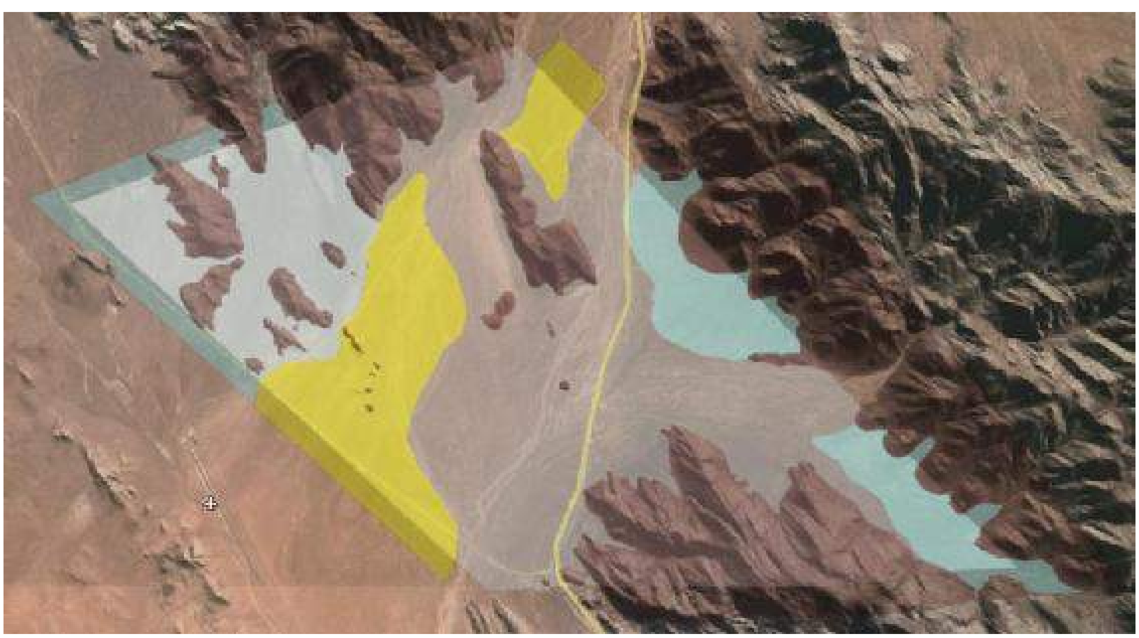

Figure 2: Habitats from Figure 1 overlain on satellite image, courtesy of NASA

1.4.2 Literature Survey

Available biodiversity data sources were accessed and inspected for prior faunal records from the study area and immediate surroundings, each according to the spatial resolution of the data. For coordinate based datasets, the coordinates of a rectangular bounding box surrounding the study area was used (Table 1). For quarter degree square based datasets, squares SE 2716Dc and 2716Dd were used. For place name based datasets all farm and other place names that appear on official topographical maps for both of the previous quarter degree squares were used.

Table 1: Coordinates of bounding box for study area, as used in data extraction

	LATITUDE	LONGITUDE
NORTHWESTERN CORNER	-27.75	16.5
SOUTHEASTERN CORNER	-28.1	16.9

The utilised datasets were:

- The Global Biodiversity Information Facility (GBIF 2013) provides online access to more than 416 million museum specimen records worldwide, including 439000 purportedly from Namibia (numbers valid as of 1 October 2013). Because of foreign data capturers unfamiliar with Namibian languages and geography, data requires extensive cleaning and evaluation before use; therefore doubtful or ambiguous records were not used here. The data is partially coordinate based.
- The South African Biodiversity Information Facility (SABIF 2013) provides online access to museum specimen records from South African museums, which includes Namibian records. It is separate from GBIF because it uses the incompatible quarter degree reference system. Doubtful records were excluded here, since the facility provides no simple method to access additional information that could have been used to verify them.
- The Namibia Biodiversity Database (NBD 2013) provides online access to summarised literature records for Namibian biota. It is coordinate based, and includes as a subset the online version of the Namibian component of the Bird Atlas of southern Africa (Harrison et al. 1997). The dataset clearly identifies doubtful records as such, and none were used here.
- A private collection of approximately 71 Gb of pdf files of taxonomic literature dealing with Namibian biodiversity was also accessed, using full text searches based on place names. Doubtful records that were incongruous considering the known distribution or habitat requirements of the taxa involved, and that could not be independently verified, were discarded.

Full results were listed in Table 6 in Irish (2013), with the above datasets or their components referenced in the 'Sources' column. Potential taxa of concern were extracted from the wider lists and are listed and discussed in Section 4.2 below.

1.4.3 Field Visit

The study area was investigated on 10 and 11 September 2013. One day was devoted to each of the portions west and east of the main road (C13) to Aus. The maximum available time was spent on foot in different parts of the area, representing all identified habitats. Observations were made of all fauna encountered, either in the flesh or indirectly through their tracks, dung, burrows, nests, calls or dead remains. Identifications were made visually, supplemented by photography for later verification where needed. No destructive sampling was done – all collecting was capture-release. Identification of invertebrates was done to the lowest possible level given the knowledge of the group, and within the magnification limits possible with a hand lens.

Some rain had fallen in the area prior to fieldwork, and conditions were sufficient to provide useful results, but not optimal. Unusually cold, windy and overcast weather on both days inhibited the activity of cold-blooded taxa like reptiles and invertebrates and they were probably under-recorded.

1.5 ASSUMPTIONS AND LIMITATIONS

The assumptions and limitations are those inherent to any biodiversity work in Namibia, and are not specific to Gergarub.

Since absence of prior work or specific information is the norm, we aim for the best possible data baseline by considering both literature records from comparable surrounding areas and observations made during fieldwork. We accept that fieldwork is time-limited and seasonally constrained, and we assume that our extrapolations give us an adequate baseline on which to evaluate the area. We accept that it cannot ever be complete given the general data deficiency in many groups.

Specific limitations to the current study is the fact that the main fieldwork happened to coincide with a winter cold front, and the low temperatures inhibited activity of most animals, especially cold-blooded ones like reptiles and invertebrates. They were probably underrepresented in observations as a result. While not ideal, results were nevertheless adequate for the purpose.

A general limitation is the taxonomic impediment caused by the lack of functioning biosystematic support institutions in Namibia. This inhibits our ability to identify unknown taxa, and effectively blocks taxonomic progress in many groups.

2 PROJECT DESCRIPTION

The entire project location falls into the northern section of the Succulent Karoo Biome, which is regarded as a global biodiversity hotspot (Myers et al 2000), and is thus important in global as well as regional and national terms. This makes only absolutely unavoidable damage acceptable. It is extremely sensitive in terms of near-endemic, endemic and protected plant and animal species, and widely recognised as an important area of high diversity and endemism for both plants (e.g. Van Wyk & Smith 2001) and animals (Pallett 1995; Barnard 1998). At least 15% of Namibian endemic insects are restricted to the Succulent Karoo Biome (Walmsley 2001).

Elevated areas, such as mountains and koppies, are particularly sensitive to environmental disturbance. The interaction between varied topography and a regional meteorology that is unique in southern Africa, combine to create an intricate mosaic of climatic refugia where relict species, some dating back to Gondwanan times, survive in tiny patches of suitable habitat. It follows that many of the taxa that occur here are endemic and have highly restricted distribution ranges. Almost none have ever had their conservation status formally evaluated, but if this were to be done, almost all would receive Critically Endangered ratings purely on limited range size.

It is therefore of extreme importance not to locate project infrastructure on sensitive habitats, where it could potentially destroy or decrease to unviable levels the entire global distribution of endemic range-restricted invertebrates, effectively causing their extinction. Irish & Mannheimer (2013) identified the mountains and hills as the most sensitive habitats in the project area, and no infrastructure footprints should be located on them at all. This has been achieved (see Figure 4).

3 LEGAL AND REGULATORY REQUIREMENTS

3.1 ACTS AND ORDINANCES

Namibian legislation pertinent to terrestrial biodiversity and applicable to the current project includes:

- Ø The Constitution of the Republic of Namibia. Article 95 commits Namibia to the maintenance of ecosystems, essential ecological processes and biological diversity.
- Ø Nature Conservation Ordinance 4 of 1975, including Nature Conservation General Amendment Act 1990 and Nature Conservation Amendment Act 5 of 1996, accords special status to defined taxa as per the following schedules:
  - Schedule 3: Specially Protected Game
  - Schedule 4: Protected Game
  - Schedule 5: Huntable Game
  - Schedule 6: Huntable Game Birds
  - Schedule 9: Protected Plants
- Ø The Forest Act 12 of 2001 provides for the protection and control of forest areas and their biodiversity. Section 22 deals with the protection of natural vegetation on any land which is not part of a surveyed erven in a local authority area, and specifically prohibits the cutting, destruction or removal of vegetation on sand dunes, or within 100 m of a watercourse, without a permit. Similarly, the clearance of more than 15 ha of woody vegetation per development also requires a permit.
- Ø Inland Fisheries Resources Act 1 of 2003 provides for the protection of aquatic ecosystems. Section 20 prohibits the erection or installation of any structure in a watercourse in the absence of consultation with the Minister.

3.2 NAMIBIAN COMMITMENT TO INTERNATIONAL STANDARDS AND/OR GUIDELINES

Legally binding international conventions to which Namibia is signatory include:

- Ø The Convention of Biological Diversity of 1992 provides for the conservation of biological diversity.
- Ø The Convention on International Trade in Endangered Species (CITES) of 1973 regulates trade in endangered species, through listing in appendices:
  - Appendix I includes species threatened with global extinction, and trade in these is subject to particularly strict regulations. It is only authorized under exceptional circumstances.
  - Appendix II includes species that are not necessarily now threatened with extinction, but may become so unless trade in them is strictly

regulated to avoid utilization incompatible with their survival. It also includes any other species for which trade needs to be regulated in order to effectively control trade in strict Appendix II species.

- Appendix III includes species where trade regulation to prevent exploitation is mainly needed on the individual country or regional level. Namibia currently has no CITES Appendix III species.

3.3 LOCAL, NATIONAL AND INTERNATIONAL POLICIES AND GUIDELINES

IFC (2012) Performance Standard 6 deals with Biodiversity Conservation and Sustainable Management of Living Natural Resources. The current impact assessment was therefore guided by the Standards and Principles laid down by IFC.

An overriding principle is the Mitigation Hierarchy (Performance Standard 1), with stated objectives (paragraph 6.7):

- Ø firstly, avoid impacts. 'As a matter of priority, the client should seek to avoid impacts on biodiversity and ecosystem services.'
- Ø secondly, if avoidance is not possible, minimize impacts (which includes abating, rectification, repair and restoration).
- Ø lastly, if residual impacts remain, compensate or offset for risks and impacts.

Different subsets of the Standards may be applicable to different areas, depending on whether the included habitats are classified as Modified, Natural or Critical (paragraph 6.9). The current pre-development project area represents Natural Habitat (paragraph 6.13), because it contains viable assemblages of plant and/or animal species of largely native origin, and human activity has not essentially modified the area's primary ecological functions and species composition. Mitigation for Natural Habitats should aim for '*no net loss of biodiversity*' (paragraph 6.15).

A subset of Natural Habitat may be classified as Critical Habitat if it meets the requirement of high biodiversity value, including being of importance to endangered, endemic or range-restricted taxa. For the current project, the habitats that were previously classified as being of High Sensitivity and High Vulnerability (Figure 4) for exactly the same reasons, may be considered Critical Habitat for IFC purposes. Mitigation measures for Critical Habitat should achieve '*no net reduction in the global and/or national/regional population of any Critically Endangered or Endangered species*' and include a '*robust, appropriately designed, and long-term biodiversity monitoring and evaluation program integrated into the client's management program*' (paragraph 6.17).

Projects may also impact Ecosystem Services (paragraph 6.24). While elements of services are involved in the current project, the affected area is relatively small in size when considered on an Ecosystem Service scale, and the potential impacts are relatively minor compared to habitat level impacts. Ecosystem Service impacts were therefore not considered separately here, and are considered to be adequately covered by proposed habitat level mitigation measures.

The above standards have been applied here as follows:

- Critical Habitat has been identified as such and represents those mapped as both Highly Sensitive and Highest Sensitivity in Figure 3.
- Impact avoidance to Critical Habitat has largely been achieved, as best illustrated by the final infrastructure footprint (Figure 4).
- While data deficiency disallows proving '*no net loss / reduction*', measures to address this deficiency have been suggested.
- Remedying data deficiency is to form part of the required monitoring and evaluation program for Critical Habitats.
- Because of data deficiency, the determination of required biodiversity offsets needs to be deferred. '*Like-for-like*' implies that both '*likes*' are adequately known to allow comparison. That is not the case here. Offsets will need to be defined once sufficient data has become available through the monitoring program, and should be one of the products of monitoring. The elsewhere suggested botanical set-aside/no-go area will of course benefit fauna in the area as well, but at this time that benefit cannot be adequately quantified.
- Habitat fragmentation is not addressed because no fragmentation of Critical Habitats has occurred.
- Habitat restoration is not addressed at this time, also because of data deficiency. It should be revisited in the context of the monitoring and evaluation program once sufficient data is available.

4 THE RECEIVING ENVIRONMENT

The environmental features of concern are a) habitats or life-zones (Table 2) and b) taxa (Table 3). Vulnerability of each was classified as Low, Medium or High, as follows, also taking into account IFC (2012) standards for Natural and Critical Habitats.

Table 2: Habitat vulnerability definitions

HABITAT VULNERABILITY RATING	CRITERIA
LOW	One or more of the following characteristics: • Includes few High Vulnerability taxa, few endemic or range-restricted taxa • The proportion of the global or regional extent of the habitat that will be impacted by the development is negligible • The habitat is simple, robust and tolerant of disruption, will self-heal with time or can be rehabilitated fairly easily
MEDIUM	Characteristics somewhere between those for Low and High habitat vulnerability
HIGH	One or more of the following characteristics: • Includes a high number or proportion of High Vulnerability taxa • Includes high numbers of endemic and range-restricted taxa • Habitat is unique in a global or regional context • Total extent of the habitat is small and a significant portion of it will be impacted by the development • Habitat is complex, highly sensitive to disruption, slow to heal, difficult or impossible to recreate artificially or rehabilitate

Table 3: Taxa vulnerability definitions

TAXA VULNERABILITY RATING	CRITERIA
LOW	One or more of the following characteristics: • Taxon is widespread, not endemic, and an insignificant proportion of its total range will be impacted by the

TAXA VULNERABILITY RATING	CRITERIA
	development. Global extinction is unlikely. • Taxon has neither Threatened conservation status, nor any other specially protected legal status. • Significant local population reduction or local extinction is unlikely
MEDIUM	Characteristics somewhere between those for Low and High taxon vulnerability
HIGH	One or more of the following characteristics: • The taxon is endemic to Namibia. • The taxon has a restricted range. • The development will impact a significant proportion of the taxon's range, reducing it to a non-viable size, rendering it globally extinct or increasing the likelihood of global extinction. • The taxon has a Threatened conservation status. Threatened is defined as the four IUCN status categories of Endangered, Critically Endangered, Vulnerable and Data Deficient, combined. • The taxon has legally protected status, whether CITES or NCO. • The development has the potential to significantly impact local populations, in a recurrent and ongoing fashion, causing population reductions and possible local extinction

4.1 HABITATS / LIFE ZONES

Six habitats (life zones) were described for the study area in Irish & Mannheimer (2013) and have been mapped in Figure 1 and Figure 2 above.

The faunal sensitivities of each were determined by Irish (2013), using the methodology described above. Resultant sensitivity ratings for each habitat are summarised in

Table 4 below, and depicted in an overall sensitivity map in Figure 3. The Succulent Plains and the Mountains and footslopes habitats are both rated as highly sensitive with High Vulnerability. Because of the special historical-biogeographical significance of the Mountains and footslopes habitat (refer Project description above), they were highlighted in Figure 3 as being of the Highest sensitivity and vulnerability. The other habitat with a high vulnerability rating, natural water points, was too small to map at the scale of Figure 3.

Table 4: Habitat related sensitivities

COMPONENT	SENSITIVITY	VULNERABILITY	POTENTIAL IMPACT
Sandy gravelly plains	Above average diversity, average endemism and range-restrictedness.	Low; IFC Natural Habitat	Little or none: far outside direct development footprint.
Stony gravelly plains	Average diversity and endemism, low range-restrictedness.	Medium; IFC Natural Habitat	Habitat destruction: the largest part of the development footprint is in this habitat.
Succulent plains	High diversity, high endemism, high range-restrictedness.	High, IFC Critical Habitat	Habitat destruction: part of the development footprint is in this habitat.
Mountains, hills and footslopes	High diversity, high endemism. High range-restrictedness.	High; IFC Critical Habitat	Habitat destruction: part of the tailings dump covers this habitat.
Windblown sand patches	Average diversity, high endemism, high range-restrictiveness.	Medium; IFC Critical Habitat	Little or none: far outside direct development footprint.
Natural water points	Ecological resource for vertebrates, aquatic habitat for invertebrates	High, IFC Critical Habitat	Habitat destruction through dewatering; focal points for poaching, illegal gathering, disturbance of game.

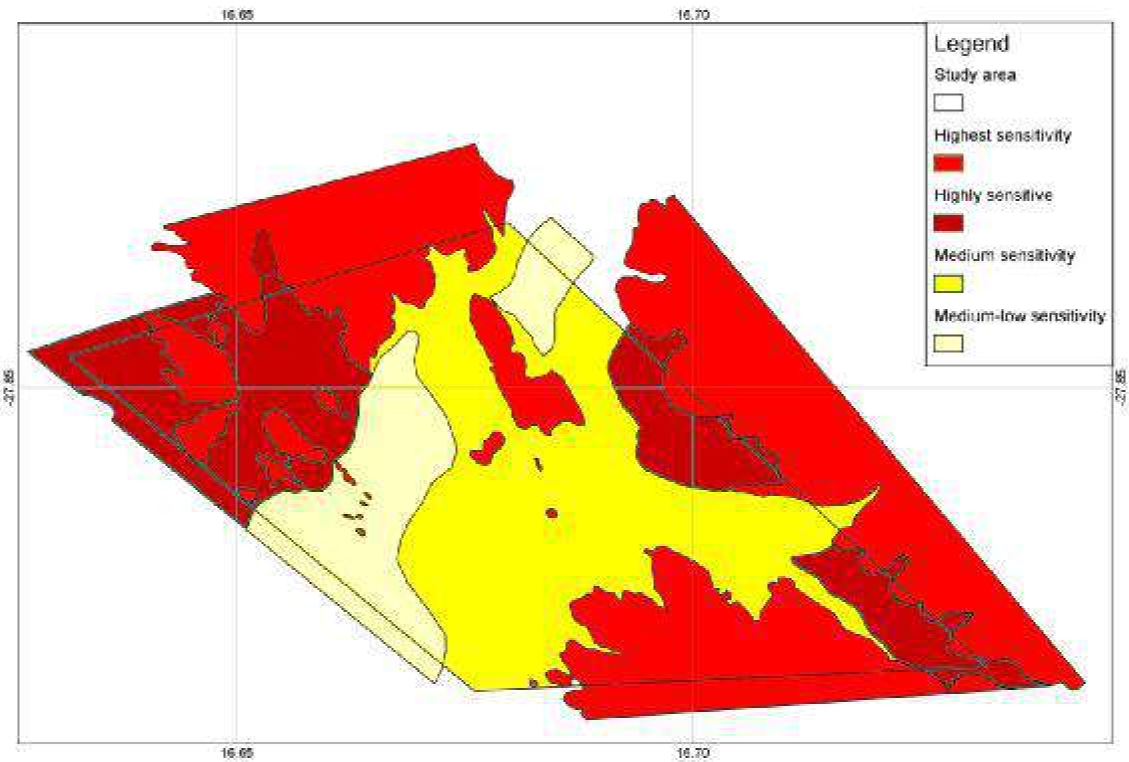

Figure 3: Habitat sensitivity map for study area

Only habitats with High vulnerability ratings have been carried forward into the impact assessment phase.

4.2 FAUNAL TAXA OF CONCERN

Irish (2013) recorded a minimum number of 537 animal taxa (identified species or taxonomically undifferentiated higher groupings) from the study area. Using the criteria for taxon vulnerability as listed above, 38 of them were then identified as being taxa of potential concern. They are listed in Table 5 below, where groups of related taxa with similar vulnerabilities have been treated together. CITES and NCO status are explained in section 3 (Legal and regulatory requirements) above.

Table 5: Taxon related sensitivities

COMPONENT	SENSITIVITY	VULNERABILITY	POTENTIAL IMPACT
Namaqua Chameleon, *Chamaeleo*	CITES II protected species, non-endemic, Least Concern	Low	Habitat loss, plains, but negligible part of range to be affected

COMPONENT	SENSITIVITY	VULNERABILITY	POTENTIAL IMPACT
namaquensis			
Karoo Girdled Lizard, *Karusasaurus polyzonus*	CITES II protected species, non-endemic, Not Evaluated	Low	Habitat loss, hills and mountains, but negligible part of range to be affected
Namaqua Day Gecko, *Rhoptropella ocellata*	CITES II protected species, non-endemic, Near Threatened	High	Habitat loss, hills and mountains, significant part of Namibian range to be affected
Nama Padloper, *Homopus solus*	CITES II protected species, NCO Protected Game, Range-restricted endemic, Vulnerable	High	Habitat loss, plains, rare and highly vulnerable species that was highlighted by IAPs
Angulate Tortoise, *Chersina angulata*, Tent Tortoise, *Psammobates tentorius*, and Leopard Tortoise, *Stigmochelys pardalis*	CITES II protected species, NCO Protected Game, non-endemic, Not Evaluated	Low	Habitat loss, plains, but negligible part of range to be affected
Black Stork, *Ciconia nigra*	CITES II protected species, NCO Protected Game, non-endemic, Least Concern	Low	Habitat loss, but not resident, not prime habitat, and negligible part of range to be affected
Fourteen different raptors (see Irish 2013)	CITES II protected species, NCO Protected Game, non-endemic, Least Concern	Medium	Population decimation through power line collisions: moderately susceptible. Habitat loss, but negligible part of range to be affected.
Black Harrier, *Circus maurus*, Secretary Bird,	CITES II protected species, NCO Protected Game, non-endemic,	Medium	Population decimation through power line collisions: moderately

COMPONENT	SENSITIVITY	VULNERABILITY	POTENTIAL IMPACT
Sagittarius serpentarius, and Martial Eagle, *Polemaetus bellicosus*	Near-Threatened		susceptible. Habitat loss, but negligible part of range to be affected.
Karoo Korhaan, *Eupodotis vigorsii*, and Ludwig's Bustard, *Neotis ludwigii*	CITES II protected species, NCO Protected Game, non-endemic, Least Concern (Karoo Korhaan), Endangered (Ludwig's Bustard)	High	Population decimation through power line collisions: highly susceptible, many fatalities. Habitat loss, but negligible part of range to be affected.
Barlow's Lark, *Calendulauda barlowi*	NCO Protected Game, range-restricted near-endemic, Least Concern	Low	Habitat loss, plains, but negligible part of range to be affected.
Spotted Eagle Owl, *Bubo africanus*, and Barn Owl, *Tyto alba*	CITES II protected species, NCO Protected Game, non-endemic, Least Concern	Low	Habitat loss, but negligible part of range to be affected.
Chacma Baboon, *Papio ursinus*	CITES II protected species, non-endemic, Least Concern	Low	Habitat loss, but negligible part of range to be affected.
African Wild Cat, *Felis silvestris*, and Caracal, *Caracal caracal*	CITES II protected species, non-endemic, Least Concern	Low	Habitat loss, but negligible part of range to be affected.
Leopard, *Panthera pardus*	CITES I protected species, NCO Protected Game, non-endemic, Near-threatened	Low	Habitat loss, mountains, but negligible part of range to be affected.
Brown Hyena, *Hyaena brunnea*	Non-endemic, Near-threatened	Medium	Prone to nocturnal vehicle collisions, habitat loss, but non-resident and negligible part of range to be affected.

COMPONENT	SENSITIVITY	VULNERABILITY	POTENTIAL IMPACT
Aardwolf, *Proteles cristata*, Cape Fox, *Vulpes chama* , Bat-eared Fox, *Otocyon megalotis*, and Aardvark, *Orycteropus afer*	NCO Protected Game, non-endemic, Least Concern	Medium	Prone to nocturnal vehicle collisions, habitat loss, but negligible part of range to be affected.
Steenbok, *Raphicerus campestris*, and Duiker, *Sylvicapra grimmia*	NCO Protected Game, non-endemic, Least Concern	Low	Habitat loss, plains, but negligible part of range to be affected.
Klipspringer, *Oreotragus oreotragus*	NCO Specially Protected Game, non-endemic, Least Concern	Low	Habitat loss, plains, but negligible part of range to be affected.

Although everything else we know about the Succulent Karoo Biome confirms that invertebrates are the most diverse occurring group, with the highest rates of endemism, greatest range-restriction and hence the highest sensitivity and highest vulnerability, all identified taxa of concern are vertebrates. This is not a true reflection of reality and can be related to general limitations regarding biodiversity studies in Namibia, as already alluded to above:

a. Namibian invertebrates suffer from data deficiency. Although especially endemic species enjoy general protection under article 96 of the Namibian Constitution, no specific legislative protection exists for any Namibian terrestrial invertebrate. Similarly, no endemic Namibian invertebrates have IUCN conservation ratings either. For two of the three main groups of criteria for taxa of concern, there is simply no data for them.
b. Information on endemism and occurrence is also lacking. Namibia's invertebrate biosystematic institution is non-functional. Unless it had been published, there is no way to determine whether prior work has been done in the study area, or what was collected. The identification of material collected during the baseline study (Irish 2013) similarly suffers from the lack of access to voucher collections.

The absence of invertebrates from the list of taxa of concern in therefore artificial. It is a known problem, and we have compensated for it by concentrating on habitats rather than species, in the usual belief that due consideration of a vulnerable habitat will necessarily also cover vulnerable species that inhabit that habitat, even if we do not know what all those species are in the case of some invertebrate groups.

For vertebrates, where more data is available, the conventional vulnerability assessment above was possible. Most taxa of potential concern ended up with low vulnerability ratings, because most are widespread, the project footprint represents a negligible portion of their overall range, individuals are relatively mobile, and the development is unlikely to have a significant negative impact on the overall species population.

Those that ended up having High vulnerability ratings are:

- Ø Namaqua Day Gecko, *Rhoptropella ocellata,* a protected species with Threatened status that will have a significant portion of the known Namibian range impacted by the proposed development.
- Ø Nama Padloper, *Homopus solus*, a protected tortoise species with Vulnerable status that is rare, range-restricted and endemic, and represents an issue that was specifically raised by IAPs.
- Ø Karoo Korhaan, *Eupodotis vigorsii*, and Ludwig's Bustard, *Neotis ludwigii,* protected bird species, one with Endangered conservation status, that are particularly susceptible to powerline collisions. Additional powerlines in the study area, erected to service the proposed development, will contribute to ongoing decimation of populations of these species.

A few taxa also had Medium Vulnerability ratings. They are:

- Ø A variety of raptors that are also susceptible to powerline collisions, though not so much as the Korhaan and Bustard above.
- Ø A number of nocturnal carnivores that are particularly prone to night-time vehicle collisions.

Only taxa with High or Medium vulnerability ratings have been carried forward into the impact assessment phase.

5 IMPACT ASSESSMENT

5.1 METHODOLOGY EMPLOYED FOR THE IMPACT ASSESSMENT

Only components that were rated as having Medium or High Vulnerability in the preceding section have been considered further here.

5.2 ASSESSMENT OF IMPACTS

The process of assessing the significance of each of the possible impacts is contained in Table 6.

Table 6: Impact assessment of the proposed project

POTENTIAL IMPACT	STATUS/ NATURE	EXTENT	DURATION	INTENSITY	PROBABILITY	DEGREE OF CONFIDENCE	SIGNIFICANCE		
							PRE-MITIGATION	MITIGATION/ ENHANCEMENT	POST-MITIGATION
CONSTRUCTION PHASE									
Mountain habitat destruction	Cumulative habitat loss in a high diversity, high endemism, high range-restricted, high sensitivity, low restorability habitat. Negative cost to Namibian nation, as custodians under Constitution.	Regional	Permanent	High	Definite	Certain	High	Impact avoidance as per IFC guidelines: Do not place infrastructure on or against mountains or hills; leave at least a 100 m gap between this habitat and the nearest infrastructure	-Low (footprints of reservoir, pipeline and access road remain)
Succulent plains habitat destruction	Cumulative habitat loss in a high diversity, high endemism, high range-	Regional	Permanent	High	Definite	Certain	High	-Do not locate infrastructure footprints on succulent plains	-Low (no direct footprint impact, but located in

POTENTIAL IMPACT	STATUS/ NATURE	EXTENT	DURATION	INTENSITY	PROBABILITY	DEGREE OF CONFIDENCE	SIGNIFICANCE		
							PRE-MITIGATION	MITIGATION/ ENHANCEMENT	POST-MITIGATION
	restricted, high sensitivity, low restorability habitat. Negative cost to Namibian nation, as custodians under Constitution.							habitat.	path of dominant wind and may be affected by fugitive dust)
Increased risk of extinction through range size reduction	Further reduction in range size of already range-restricted, endemic, threatened and/or protected species further reduces their viable range and hence	International	Permanent	High	Highly probable	Certain	High	Take responsibility for preserving taxa at risk by monitoring populations (vertebrates) or facilitating taxonomic research on data deficient taxa (invertebrates).	High (significance will probably be less after successful mitigation, but extent of reduction cannot be predicted. A High significance rating is

POTENTIAL IMPACT	STATUS/ NATURE	EXTENT	DURATION	INTENSITY	PROBABILITY	DEGREE OF CONFIDENCE	SIGNIFICANCE		
							PRE-MITIGATION	MITIGATION/ ENHANCEMENT	POST-MITIGATION
	potential for sustainable survival. Negative cost to global biosphere, accountable to Namibian nation as custodians under Constitution and Namibian Government as signatory of international conventions.								therefore retained as a precaution-nary measure).
OPERATIONAL PHASE									
Interference with ecological functioning, of natural water	Potential resource loss due to de-watering;	Local	Long-term	High	Probable	High confidence	Medium	Monitor yield of natural water points to ensure they remain	Low

POTENTIAL IMPACT	STATUS/ NATURE	EXTENT	DURATION	INTENSITY	PROBABILITY	DEGREE OF CONFIDENCE	SIGNIFICANCE		
							PRE-MITIGATION	MITIGATION/ ENHANCEMENT	POST-MITIGATION
points	disturbance of game and increase in poaching due to higher accessibility. Negative cost to local ecosystem functioning and ecological integrity.							productive Prohibit employee access to any part of the property outside the main development area, specifically the mountains. Enforce this by enclosing footprint with a security fence and penalising trespassers.	
Population reduction and possible extinction, of powerline collision-prone taxa	Bustards and birds of prey are especially prone to fatal powerline collisions, because of the placement and	Local	Long-term	Medium	Highly probable	Certain	High	All new power lines in bustard territory to be fitted with bird flight diverter devices e.g. flappers or spirals	Medium

POTENTIAL IMPACT	STATUS/ NATURE	EXTENT	DURATION	INTENSITY	PROBABILITY	DEGREE OF CONFIDENCE	SIGNIFICANCE		
							PRE-MITIGATION	MITIGATION/ ENHANCEMENT	POST-MITIGATION
	functioning of their eyes. In the case of Ludwig's Bustard this has already led to it being classified as Endangered. Negative cost to species populations and local ecosystem integrity, ultimately accountable to Namibian nation as above.								
Population reduction of nocturnal vehicle collision-prone taxa	Nocturnal mammals and owls are especially prone to night-time vehicle collisions	Local	Long-term	Medium	Highly probable	Certain	Medium	Establish night-time speed limits on all roads within the development area that lack	Low

POTENTIAL IMPACT	STATUS/ NATURE	EXTENT	DURATION	INTENSITY	PROBABILITY	DEGREE OF CONFIDENCE	SIGNIFICANCE		
							PRE-MITIGATION	MITIGATION/ ENHANCEMENT	POST-MITIGATION
	because of their instinctive reactions to imminent collision. Negative cost to species populations and local ecosystem integrity, ultimately accountable to Namibian nation as above.							roadside lighting. Recommended speed limit: 40 km/h.	

5.2.1 Assessment of Power Line Route

Information available as of 3 July 2014 is that electricity for the proposed development will be provided from the Obib substation, and that the supply line will run either in or parallel to existing servitudes: from the substation directly to the Skorpion Mine access road, next to that road as far as the T-junction with the Rosh-Pinah Aus road, then northwards next to the existing north-south NamPower line, branching off across from the proposed development's front gate, crossing the main road and then following the security fence southwards to the Gergarub substation.

The route completely avoids more sensitive habitats and there are no habitat-based concerns, but there are definite species and population based concerns. The route cuts diagonally across a wide valley between high mountains that represents a major flyway for birds. Bustards and raptors were identified above as the bird groups in the area that are particularly prone to power line collisions, with bustards being the most at risk. Studies in the Karoo region of South Africa have shown significant declines in bustard numbers as a result of power line collisions (Shaw 2013), resulting in the upgrading of Ludwig's Bustard's conservation status to Endangered. Data exists showing significant numbers of bustard deaths from power line collisions in the Rosh Pinah area as well (J. Pallett, pers. comm.)

Bird flight diverter devices have proven effective in reducing bustard strikes, and it is recommended that all new power lines in bustard territory be fitted with them (Shaw 2013). The rationale is that it is simpler and cheaper to fit these devices during construction, than to add them to a live wire at a later stage. In the current case, because the new line is localised near existing lines, fitting of devices to the new line will have the double benefit of also helping to partially and retroactively mitigate the impacts of the adjacent unmarked lines.

Both flappers and spirals are effective as bird diverters, but there is not yet enough information to determine which is more effective. It is therefore recommended that both flappers and spirals be installed along the entire length of the new power line. Current standards are to install diverters at 5 m intervals, alternating between wires, and alternating between flappers and spirals. However, this is a rapidly evolving field of study. Should more than six months elapse between this report and commencement of construction (i.e. later than January 2015), it is recommended that NamPower and J. Pallett be consulted at that time for the latest specifications See the specialist on Bird.

5.2.2 Assessment of Water Pipeline Route

As of 3 July 2014 no detailed route information is available, but it is known that water will come from the south, and that there will be a reservoir against the hillside to the southwest of the main development, with an access road to the reservoir. The need for elevating the reservoir is understood, as is the absence of alternative sites, but it will still be located in the highly sensitive Mountain and Hillslope habitat. The problem with similar development in ultra-sensitive habitats is usually that, although their actual footprint might be small, after construction they are left surrounded by a wide margin of largely unnecessarily destroyed habitat that may be larger than the footprint itself.

A similar situation should be avoided in the current case by careful planning and oversight of especially the operators of earthmoving equipment. A working area should be delimited with hazard tape before construction begins and should be adhered to. The road should be no wider than needed. The reservoir's apron should be no larger than needed. No clearing of vegetation should be done unless the ground is going to be paved or built on: the ideal at completion would be to have natural vegetation growing up to the edge of concrete, with no bare raw earth anywhere. The pipe line to the reservoir and the road to the reservoir should preferably be built next to each other so as to confine the damage to a single corridor. The shortest practical route should be chosen, again to limit damage.

5.2.3 Discussion

The following main areas of impact were identified:

- Ø Habitat destruction, specifically where the development footprint encroaches on highly sensitive habitats.
- Ø Potential population level impacts related to natural water points and taxa that are prone to power line and vehicle collisions.
- Ø Increased risk of extinction of range-restricted endemic taxa because of the destruction of these highly sensitive habitats.

5.2.4 Mitigation

a. Habitat destruction in high diversity, high endemism, high range-restricted areas cannot be mitigated, it can only be avoided. To aid in this a habitat classification a sensitivity assessment of the area was done at an early stage of the project (Irish & Mannheimer 2013). This clearly identified and mapped sensitive habitats, and recommended that infrastructure not be located on sensitive habitats. It also identified large tract of less sensitive habitat that were suitable for infrastructure placement. A subsequent faunal study in October 2013 (Irish 2013) confirmed the previous results and reiterated the recommendations. The final assessed infrastructure footprint (Figure 4) is almost entirely located on the Stony Gravelly Plains habitat, which is a habitat of medium sensitivity due to average diversity and endemism, low range-restrictedness and at least some restoration potential. Earlier iterations of the planned footprint encroached on two highly sensitive habitats: the Mountains and Hillslopes to the south and the Succulent Plains habitat to the northeast. With the current footprint, infrastructure is located on the relatively least sensitive habitat available, thereby meeting IFC's 'first avoidance' principle.

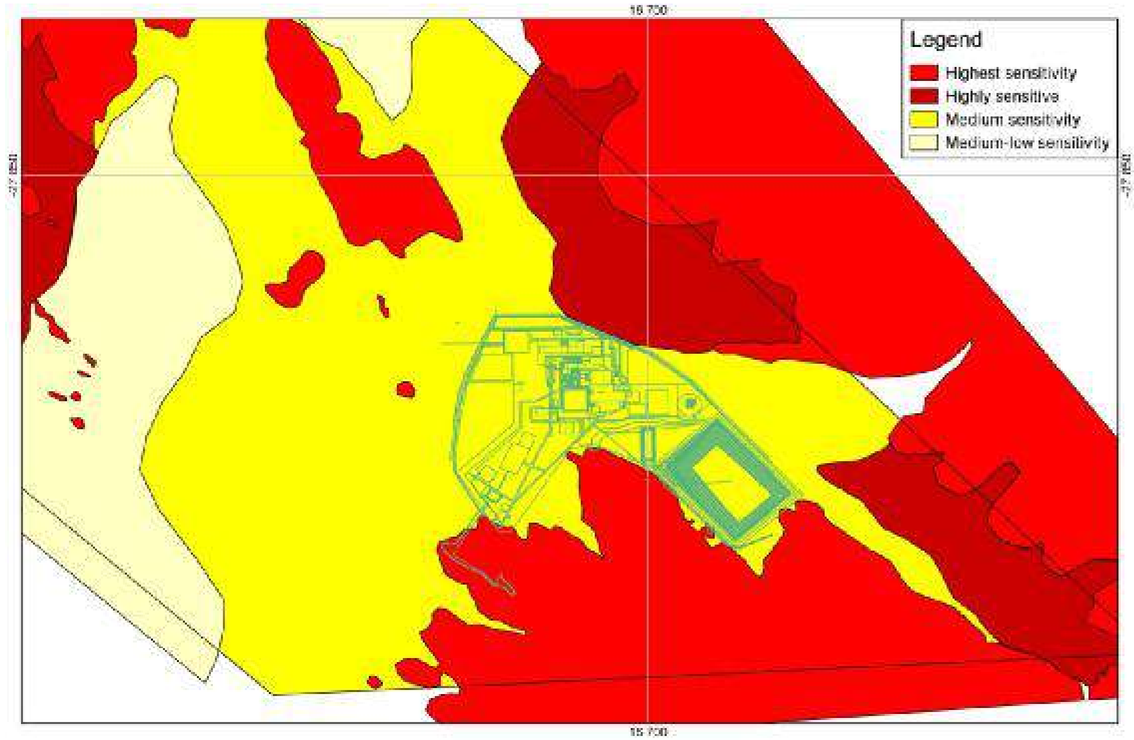

Figure 4: Final assessed development footprint, relative to habitat sensitivity

b. Mitigation of population level impacts are relatively simple in comparison. Natural water points (Figure 1) can be protected by making the entire area outside the strict infrastructure footprint a no-go area and enforcing it. Collision-prone birds are an issue that needs attention but it awaits completion of ongoing research. It has therefore been referred to the EMP for future attention. Collision-prone nocturnal animals may be mitigated by applying night-time speed limits.
c. Although the severity of habitat level impacts have been reduced by avoidance of the most sensitive habitats in the area, habitat level impacts have not been eliminated. Habitat will be permanently destroyed as a result of the development. It therefore becomes necessary to determine whether the IFC requirement of 'no nett biodiversity loss' will be met or not, but general data deficiency inhibits our ability to do this.
d. For vertebrates, where the taxa of concern are known, data deficiency can be mitigated by monitoring, refer next section. For invertebrates, the taxa of concern are problematic in that almost none are known by name from Gergarub specifically. Their occurrence there is extrapolated from what is known for their respective habitats and the region overall. The situation is unsatisfactory but not unique to Gergarub, and is the primary reason why

habitats rather than taxa are usually considered for invertebrates. Mitigation in this case then has to be taxonomical research to identify and describe the affected invertebrates of the Gergarub area, most of which have probably not been formally named scientifically yet. Taxonomic treatment will fix their data deficiency and provide the first tier of information from which sensible mitigatory measures can be developed. At the same time it will provide the information that is necessary for determining 'nett biodiversity loss'.

Taxonomic research and description of new taxa is a specialised and time-consuming process that may take many years. None of the potential avenues for mitigating this data deficiency are problem-free:

- Ø Namibian Government biosystematic service institutions, e.g. National Museum of Namibia, are not functional any more, lack capacity for doing the work and cannot even curate material collected by others.
- Ø Outsourcing to international experts is a short-term 'fix' that provides no long-term remedy for the root causes of the problem. The superficially excellent results of foreign 'experts' usually prove to lack depth and context on closer examination. Experience has shown that long-term hands-on contact with study organisms in their natural environment is needed to properly understand them, and neither hit-and-run collecting trips nor foreign museum material dating from colonial times provide this context. The most viable solution would be for the client to take responsibility, but it will be a major undertaking. It would involve the creation and management of a private natural history museum on site, and the training of full-time employment of taxonomists and supporting technical staff. The post-decommissioning fate of the facility and particularly its biological collections would also need to be addressed in advance.
- Ø The creation and management of a private natural history museum on site and the full-time employment of taxonomists and supporting technical staff is a major undertaking.

The solving of this dilemma lies beyond the current EIA. Something will need to be done, but it is not clear what can work. The problem is not unique to Gergarub.

5.2.5 Monitoring

Continuous monitoring and evaluation is an IFC requirement where Critical Habitats are involved, as is the case here. Monitoring might be expanded to include the long-term mitigation of data deficiency as discussed above.

a. Monitoring of *Homopus solus* and *Rhoptropella ocellata* populations. Two species of high conservation concern, of which one was specifically raised as an issue by an I&AP. Occurrence of both in the development area is likely but as yet unproven. A first phase of monitoring should therefore be to verify their occurrence or not, and determine their population sizes and distribution if present. Thereafter six-monthly (wet season, dry season) annual population counts by way of fixed transect counts should be done. Any significant downward population trends should be addressed in the context of the development's EMP.

b. Monitoring of Brown Hyena (and other nocturnal carnivore) populations. Residence of Brown Hyena populations in the area has not been confirmed and they seem to occur as vagrants only. However, they were raised as an issue by an I&AP. It is suggested that the Brown Hyena Research Project in Lüderitz be approached for guidance on how they would prefer the issue to be addressed.
c. The main natural water point in the kloof directly east of the main processing plant should be monitored for unnatural drops in water level that may be attributed to mine dewatering. This water point may then be used as a proxy for the other, less accessible, water points in the area. Water levels in the historical well should be measured four times per year, and the presence of open water in the waterfall spring should be verified. Any significant negative post-mining deviations from the starting condition should be addressed in the context of the development's EMP.

5.2.6 Summary

Impacts on sensitive habitats have been largely avoided by locating infrastructure on less sensitive areas. Some taxon level impacts need ongoing attention. For vertebrates of concern this involves verification of occurrence and monitoring of population trends. For invertebrates it involves taxonomic research and scientific description of undescribed species. Population level impacts can be mitigated through a combination of water point monitoring, establishing of no-go areas and implementation of speed limits.

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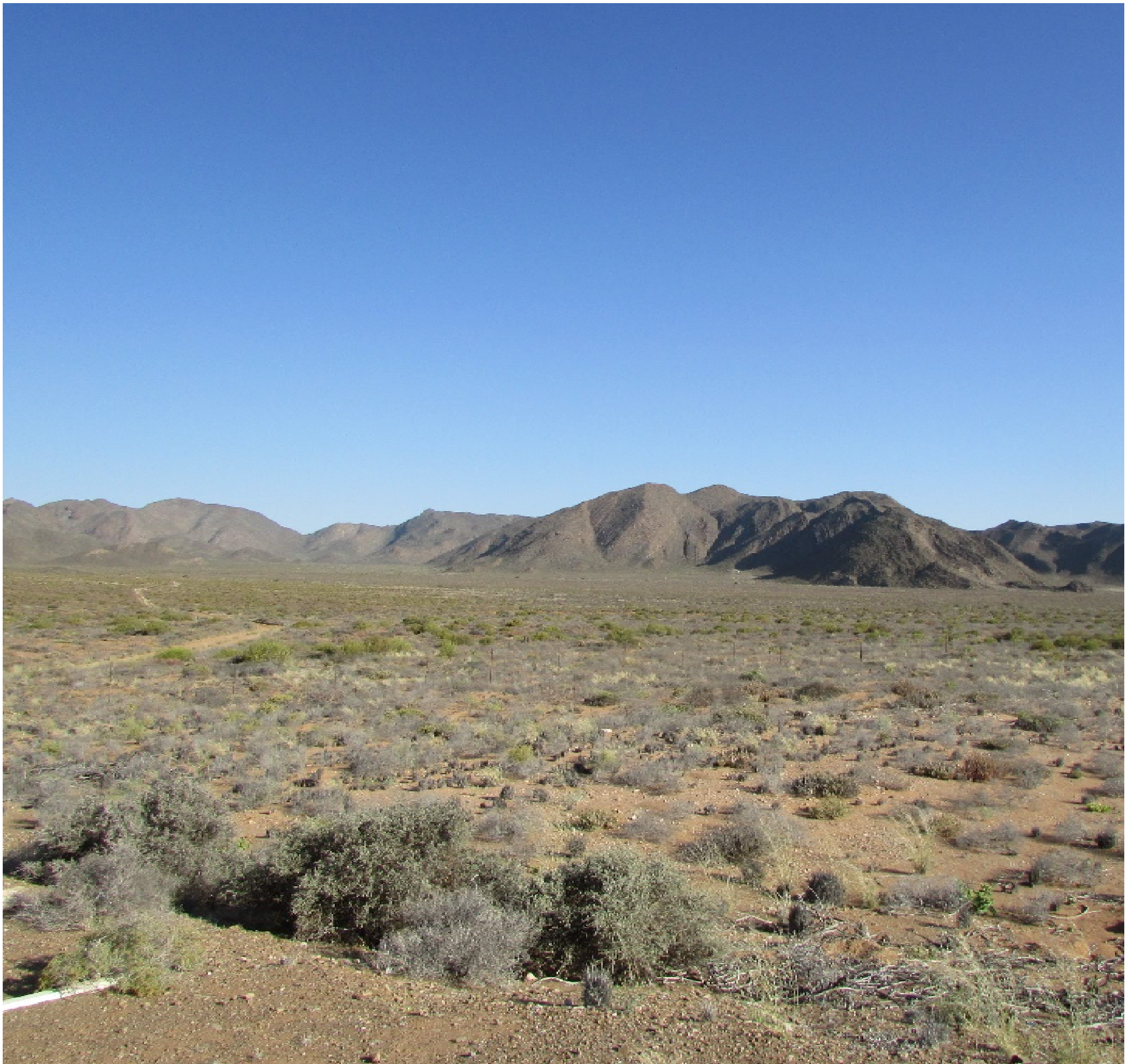

Environmental and Social Impact Assessment (ESIA) for the proposed development of the Gergarub Mine

April 2015

Appendix G – Bird Impact Assessment

COPYRIGHT:	
PROJECT NAME	Gergarub Project
STAGE OF REPORT	Final for Feasibility Assessment
CLIENT	Skorpion Mining Company (Pty) Ltd
SPECIALIST CONSULTANT	J. Pallett
DATE OF RELEASE	6 October 2014
CONTRIBUTORS TO THE REPORT	John Pallett
CONTACT	jpallett@afol.com.na

DECLARATION

I hereby declare that I do:

(a) have knowledge of and experience in conducting specialist assessments, including knowledge of the Environmental Management Act (Act 7 of 2007)and the Regulations and Guidelines that have relevance to the proposed activity;

(b) perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant;

(c) comply with the abovementioned Act, its Regulations, Guidelines and other applicable laws.

I also declare that there is, to my knowledge, no information in my possession that reasonably has or may have the potential of influencing –

(i) any decision to be taken with respect to the application in terms of the Act and its Regulations; or

(ii) the objectivity of this report, plan or document prepared in terms of the Act and its Regulations.

John Pallett

Specialist Consultant

EXECUTIVE SUMMARY

A short 66kV power line is proposed as part of the new Gergarub mine near Rosh Pinah. The line will put mainly Ludwig's bustards at risk, as this species is prone to colliding against power lines, and research on this topic has found evidence of them doing so on an identical kind of line running between Rosh Pinah and Luderitz. There is also the possibility of some raptors being killed on the line, both by collisions and electrocutions, but the risk is very much lower for these species, making this an insignificant impact.

Quantification of the impact of colliding bustards is difficult because numbers of bustards in this area fluctuates greatly over time. Using the little data that is available, the number of Ludwig's bustards that could be killed on the proposed line is about 30 to over 200 over the 20 year life of mine. While this is a relatively small loss for a bird whose population is over 100,000, there is substantial and ongoing loss of this species to power line collisions throughout south-western Africa, and all new lines being erected in bustard areas need to be marked to reduce the very high overall toll on this species.

Suggestions are made for mitigation of the predicted collisions by Ludwig's bustard. Firstly, it is concluded that the proposed route is the best option for line alignment. Secondly, the line should be supported on H-pole towers, rather than steel monopoles. Thirdly, devices should be fitted along the lines to increase their visibility. Double Loop Bird Flight Diverters (DLBFDs or 'spirals') should alternate with 'Viper' Bird Flappers, along the uppermost shield wires at 5m spacing. To enable comparison of the effectiveness of these devices, it is suggested that marked sections of the line alternate with unmarked sections, and that Gergarub mine management commit to regular (monthly), frequent and long-term monitoring of the whole line. This data-gathering should be closely coordinated with the NamPower – NNF Strategic Partnership, and the results fed into the national database of power line – wildlife conflicts. This will help to inform future bird mitigation efforts.

The estimated cost of the devices to be installed on the proposed line is about N$105,000.

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ABBREVIATIONS AND ACRONYMS

CITES	Convention on International Trade in Endangered Species
EIA	Environmental Impact Assessment
EIS	Environmental Information Service
EMP	Environmental Management Plan
GBIF	Global Biodiversity Information Facility
IAP	Interested and Affected Party
IFC	International Finance Corporation
IUCN	International Union for the Conservation of Nature
LB	Ludwig's bustard
NBD	Namibia Biodiversity Database
NCO	Nature Conservation Ordinance
OPGW	Optical Ground Wire
SABAP	Southern African Bird Atlas Project
SABIF	South African Biodiversity Information Facility
TOR	Terms of Reference

1 BACKGROUND

1.1 INTRODUCTION

The Gergarub Project is a proposed new zinc mine east of the existing Skorpion Zinc Mine in the Rosh Pinah area of southwestern Namibia. Fauna input to the EIA has been compiled by Irish (2014), building on preliminary habitat work by Irish and Mannheimer (2013). Arising from this work is the issue of the impact of power lines on birds, of which bustards are the most vulnerable. Clarification of this issue was needed.

1.2 SPECIALIST STUDY LEADER

I, John Pallett, gave this specialist input. I have been involved with the NamPower – Namibia Nature Foundation Strategic Partnership since 2012, on a project entitled 'Collisions of large birds with power lines in Namibia: significance and solutions'. The field work has included monitoring particular stretches of power lines in southern Namibia, to record collision mortalities, from July 2012 to October 2013. One of the lines that was investigated was the 66 kV line running from Rosh Pinah to Luderitz. I therefore have experience and data from a power line close to the proposed lines that will feed Gergarub. I also have expertise on power line conflicts from involvement in this issue with the Strategic Partnership since 2010.

1.3 TERMS OF REFERENCE

The specialist input is to address the risk that the power lines would pose to birds, and to explain and justify the suggested mitigations. Specifically, the following questions must be addressed:

a. Why are powerlines affecting birds?

b. Why are raptors and bustards specifically affected?

c. How many raptors/bustards in Namibia?

d. How many in this area?

e. How many can/will be affected by the line?

f. How does a 66kV line specifically affect such type of birds? (e.g. collision/electrocution)

g. What is a spiral or a flapper?

h. How do these devices mitigate the problem?

i. Which part of the line should be fitted with these devices, as it will be expensive to fit the whole 11 km of the line with them?

1.4 METHODOLOGY

1.4.1 Study Area

The project area is shown in Figure 1.

Figure 1: The project area. The proposed power line is shown in pink. The green (400 kV) and brown (66 kV) lines are existing.

1.4.2 Literature Survey

Information was drawn from

- A recent Ph.D thesis focused on the issue of power lines and bustards in the Karoo, South Africa (Shaw 2013)
- Data from field monitoring of the nearby 66 kV line between Luderitz and Rosh Pinah, undertaken in the past two years (Pallett, unpublished data).
- An unpublished but comprehensive book ‘Birds to watch – Red, rare and endemic species in Namibia’ in preparation by Simmons and Brown.
- Recommendations for the design of mitigation devices by the South African power utility, Eskom (2009).
- The expertise of people working on this conservation issue in Namibia and South Africa.

1.4.3 Field Visit

No field work was undertaken for this assessment.

1.5 ASSUMPTIONS AND LIMITATIONS

The problem of bird collisions against power lines has been known for many years (e.g. Bevanger 1994) but has received surprisingly little attention internationally. In southern Africa it has been the focus of research work only in the past 10 years or so, with research on the Namibian situation only in the last 5 years. The scale of the problem is still not fully recognised and solutions are still being investigated. There are no accepted guidelines for mitigation of the problem in Namibia or elsewhere in southern Africa, although Eskom has published some preliminary guidelines. The paucity of research and overall lack of well-proven mitigation procedures hampers any EIA work on this issue, both in the need to effectively reduce the negative impacts, at a reasonable cost.

2 PROJECT DESCRIPTION

The proposed Gergarub Mine will be located about 9 km southeast of Skorpion Mine, on the eastern side and immediately adjacent to the C13 main road from Rosh Pinah to Aus. Power lines associated with the town of Rosh Pinah and the Skorpion Mine exist in the area, as shown in Figure 1. The proposed additional line will start at Obib Substation and will run either in or parallel to existing servitudes:

- from the substation directly to the Skorpion Mine access road,
- next to that road south-eastwards to the T-junction with the C13 road from Rosh Pinah to Aus,
- northwards next to the existing north-south NamPower line, branching off at the proposed development's front gate, crossing the main road and then following the security fence southwards to the Gergarub substation.

The proposed power lines will run across open plains in a wide valley between high mountains. The proposed route follows existing tar roads for its entire length. For this reason, the route is deemed to be a suitable choice.

Two alternative routes were considered as shown in Figure 2 below. The first option considered the upgrading of the existing 66 kV line (black and white route below) rather than constructing a new line, but this option was disqualified because the upgrade would cause lengthy power outages within Rosh Pinah.

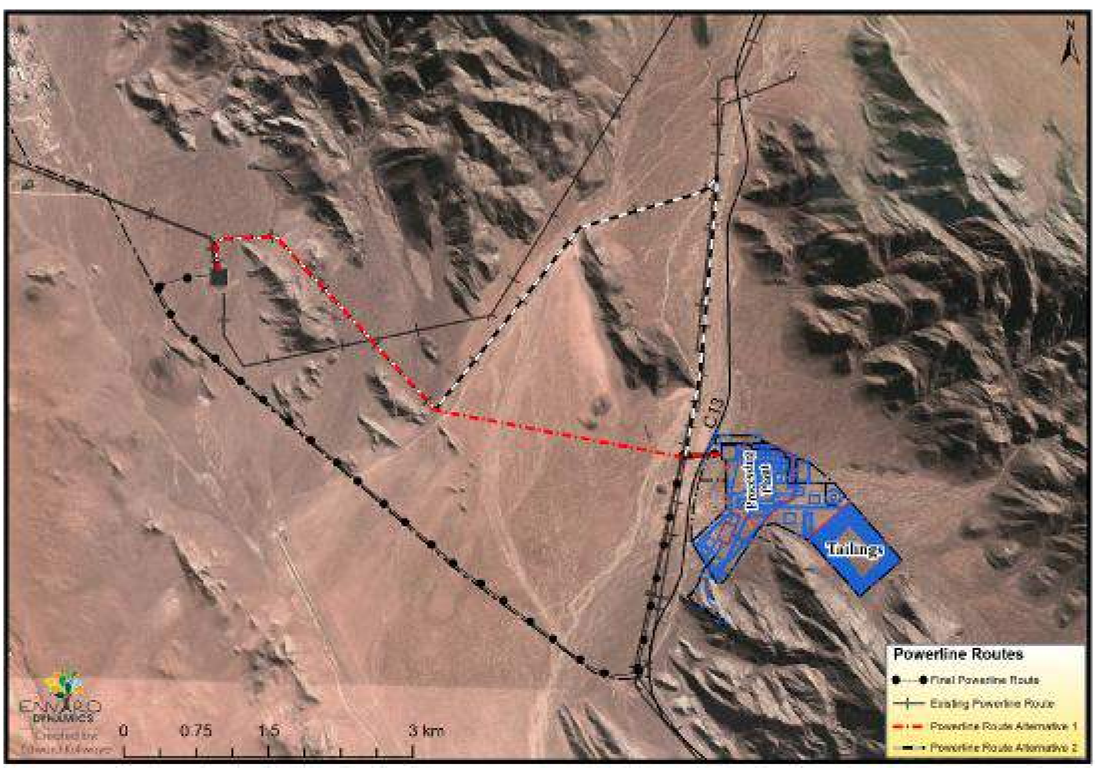

Figure 2: Alternative powerline routes that were considered

The second option is running parallel and close to the existing 66 kV line (shown in brown in Figure 1), and then crosses the plain to follow a more direct path to the Gergarub mine site as shown in red

This would be shorter but the plain is classified as Highly Sensitive (Irish and Mannheimer 2013) and so opening an access route across this plain was not recommended. Also, best practice when siting new power lines is to situate them close to roads, since bustards (the most vulnerable species in this area) tend to stay away from roads and traffic as they are very shy.

The towers supporting the conductors will be one of two alternative designs: an H-pole wooden structure, or a steel monopole. This assessment will consider both designs.

Figure 3: Wooden H-pole design.

Figure 4 Steel monopole design.

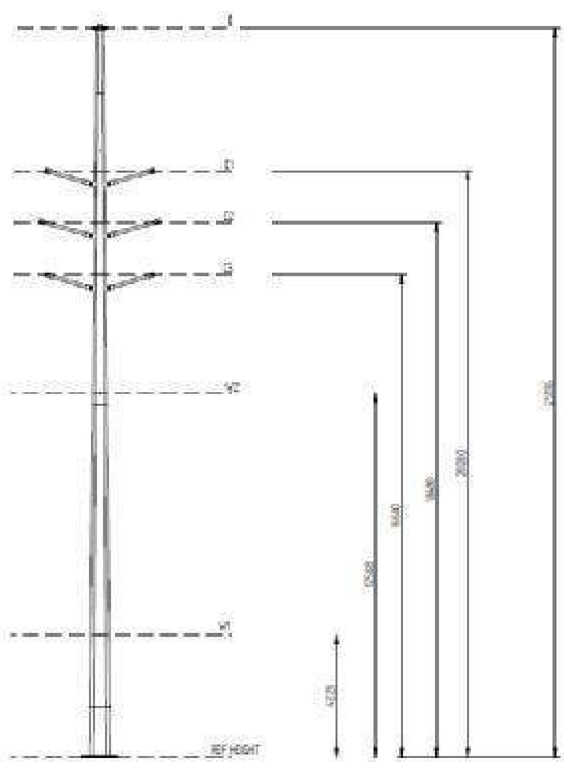

Figure 5: Technical specifications of the steel monopole design

The two pole designs are compared in Table 1.

Table 1: Pole design comparison

CRITERION	H-POLE	STEEL MONOPOLE
MAX HEIGHT OF TOWER	11.7 m	25.2 m
SHIELD WIRE	Present	Present
MAX HEIGHT OF SHIELD WIRE	11.7 m	25.2 m
ALIGNMENT OF CONDUCTORS	Horizontal	Vertically spaced over ~3.6 m
VERTICAL DISTANCE BETWEEN TOP AND BOTTOM WIRES	2.2 m	8.5 m
MINIMUM HEIGHT OF WIRES ABOVE GROUND	5.7 m	5.7 m
AVERAGE DISTANCE BETWEEN TOWERS	180 m	190 m

For birds, the main difference between the two designs is the vertical distance between the uppermost and lowest wires. This distance is almost four times greater on the steel monopole than on the H-pole design. This constitutes that much more of a ‘fence’ strung across the path of a bird in flight. Additionally, the steel monopole towers are also supported by 4 guy wires that do occasionally cause collisions.

3 LEGAL AND REGULATORY REQUIREMENTS

3.1 ACTS AND ORDINANCES

No additional laws and regulation over and above what Irish (2014) listed for fauna.

3.2 INTERNATIONAL STANDARDS AND/OR GUIDELINES

The Budapest Declaration on Bird Protection and Power Lines (Bern Convention 2011) does not carry any legal force in Namibia but its recommendations show the principles that European countries are adopting to minimise bird – power line conflicts. Relevant here is that the Declaration states that all new power lines and reconstructed sections should be safe for birds by design. In other words, mitigation measures to prevent bird mortalities should be installed on power lines at the time of their establishment.

3.3 LOCAL, NATIONAL AND INTERNATIONAL POLICIES AND GUIDELINES

Irish (2014) describes the IFC Performance Standard relevant to biodiversity. Its implications for preventing bird mortalities on power lines are:

- Avoid impacts. This can be achieved by judicious routing of power lines to avoid areas where birds are at risk, or to route the power lines where it causes the least risk to birds.
- If avoidance is not possible, minimize impacts. Even with route optimisation, the proposed lines will still impact bustards. Mitigatory devices on the lines must be considered.
- If residual impacts remain, compensate for risks and impacts. In this instance, monitoring of the power lines can serve to build up the information base that is needed for finding solutions to the bustard – power line problem.

4 THE RECEIVING ENVIRONMENT

4.1 HABITATS

The area between Skorpion Mine and the proposed Gergarub Mine is mostly open plains, described by Irish and Mannhemier (2013) as 'sandy gravelly plains and footslopes' and 'stony plains'. The plains fill the valleys between mountains and rocky koppies, which rise to over 1,000 m. The range of habitats within a radius of 50 km from the Skorpion-Gergarub area includes mostly mountainous terrain to the east, and open plains of the Sperrgebiet to the west. About 35 km to the southeast is the valley of the Orange River. While the power line is confined to the plains habitat, the proximity of the mountains means that mountain-habitat birds (such as booted eagle and Verreauxs' eagle) could also occur in the project area.

4.2 BIRDS OCCURRING IN THE AREA THAT ARE VULNERABLE TO POWER LINES

These habitats support a range of bird species, some of which are vulnerable to power lines through collisions and electrocutions. To identify the species at risk, the power lines and birds assessment tool on Namibia's Environmental Information Service (www.the-eis.com) was consulted. The quarter degree squares within a range of 50 km in all directions from the Skorpion-Gergarub area provide a list of nine non-threatened birds, and seven Red Data birds that could be impacted by power lines (Table 2). The quarter degree squares also list 19 wetland species that could occur in the Orange River area, but these are not considered in this assessment, as the birds from the river are unlikely to occur in the project area.

Table 2: Birds potentially impacted by the proposed Gergarub power lines

CATEGORY	BIRD SPECIES	STATUS IN NAMIBIA
NON-THREATENED BIRDS	Augur buzzard Steppe buzzard Jackal buzzard Pale chanting goshawk Lanner falcon Black-breasted snake-eagle Barn owl Spotted eagle owl Karoo korhaan	None of these species listed as threatened
RED DATA BIRDS	Ludwig's bustard	Endangered

CATEGORY	BIRD SPECIES	STATUS IN NAMIBIA
	Martial eagle	Endangered
	Booted eagle	Endangered
	Black Harrier	Endangered
	Secretary bird	Vulnerable
	Lappet-faced vulture	Vulnerable
	Kori bustard	Near-threatened
	Verreauxs' eagle	Near-threatened

The information below is drawn from Simmons & Brown (in prep.), unless referenced otherwise.

4.2.1 Ludwig's bustard (*Neotis ludwigii)*

This is a nomadic bird of arid, open habitat and is known to be common in the project area, although its occurrence is sporadic as it moves nomadically depending on food availability. It is classified as *Endangered* on account of its high mortality rate from collisions against power lines.

Ludwig's bustards are found only in the arid western areas of South Africa, Namibia and southern Angola. The total population of the species was estimated in 1989 as 56,000 – 81,000 birds (Allan 1994), but was recalculated subsequently to 97,000 birds, with a 95% Confidence Interval from 75,000 to 126,000 (Shaw 2013). This estimate was derived from road counts across their distribution range in South Africa, and extrapolated to include the Namibian range by reference to records from the Southern African Bird Atlas Project (SABAP).

A more recent revision of the population estimate arrived at a figure of 114,000, with the 95% Confidence Interval from 87,000 to 148,000 (Shaw 2013). Even though this number was higher than before, the 95% confidence range includes the higher end of the range of the early estimate. The conclusion from the SA work was that the population was showing no signs of decline, even though the known mortality rate on power lines was so high.

The high mortality rate that has been calculated, combined with the relatively small total population of the species, has resulted in Ludwig's bustard being classified as globally *Endangered* (Birdlife International 2012).

4.2.2 Martial eagle (*Polemaetus bellicosus*)

All large raptors in Namibia are vulnerable to two main factors: i) poisons, set intentionally to kill raptors or as a consequence of baiting against mammal predators, and ii) the declining availability of small wildlife prey. Drowning in farm reservoirs is also a frequent cause of mortalities, and the birds are vulnerable to collisions and electrocutions on power lines. Martial eagles are large birds, with a wing span up to 2.4 m (Hockey *et al.* 2005). This size is able to span the distance between two conductors on a 66 kV H-pole or kameraad design. Also, their habit of perching on towers, which provide a vantage over surrounding land, puts them at risk of causing a short-circuit when they defecate. The semi-liquid excrement is ejected in a long stream that can breach two lines of different phases. Even if that does not happen, gradual build-up of excrement on the insulators can cause these to fail after a long time.

Figure 6: A martial eagle injured by electrocution on a 66kV power line near Windhoek. This individual was treated and released. (Photo L.Komen)

It is estimated that there are less than 350 pairs of martial eagles in Namibia, and they are classified as *Endangered* in Namibia. The probability of their occurrence in the project area is low as they occur only rarely in hyper-arid habitat. Nevertheless, they are a possibility in the project area, especially young birds which tend to wander extensively, and especially when relatively higher rains have brought a flush of vegetation and a temporary abundance of prey such as hares. If and when they do occur, it will likely be young, inexperienced birds, so the power line needs protection to prevent a bird accidentally flying into the line.

4.2.3 Booted eagle

Two subspecies of booted eagle occur in Namibia, one that is a migrant from Europe (found in southern Africa only in summer), and the other which is resident and occurs throughout the year. It is likely that these separate populations are in fact full species. The resident sub-species is likely to occur in the project area, where it favours mountainous terrain with adjacent open plains in arid habitats.

Given that in Namibia there are probably less than 250 individuals and a maximum of about 20 breeding pairs (the southern African population is larger), it is classified as *Endangered* in this country. Its small overall population makes it vulnerable to fluctuations that could bring numbers dangerously low, possibly to local extinction.

4.2.4 Black harrier (*Circus maurus*)

Black harriers are seasonal visitors to Namibia, and prefer dry open grasslands and shrublands. This species is a possibility in the Gergarub area but nowhere in Namibia is it common so its presence will be rare at most. It is classified as *Endangered* in Namibia and is potentially vulnerable to colliding against power lines.

4.2.5 Secretary bird (*Sagittarius serpentarius*)

The secretary bird is classified as Vulnerable and is known to be a victim of power line collisions in Namibia. This bird needs open plains for foraging and isolated tall trees for breeding; conditions which occur in large areas of the eastern edge of the Namib. Movements of this species are poorly understood but its presence in the project area is possible. It is ranked as *Vulnerable* in Namibia and globally *Endangered* due to the small and declining population.

4.2.6 Lappet-faced vulture

Lappet-faced vultures occur at low density over most of Namibia, soaring over long distances to locate ungulate carcasses, their main food item. Poisons and drowning are their main threats in southern Africa, while persecution, disturbance at nesting sites, and collisions and electrocution on power lines are also a threat. The species is classified as *Vulnerable* in Namibia.

4.2.7 Verreauxs' eagle

This species is widespread across southern Africa and further afield in Africa, wherever there is broken, rocky, mountainous terrain. There is a relatively small population in Namibia, estimated at 500 to 1,000 breeding pairs, and these birds are threatened mainly by poisoning and drowning in farm dams. They are also vulnerable to electrocutions and collisions on power lines. Verreauxs' eagle may occur in the project area, and is classified as *Near Threatened* in Namibia.

4.2.8 Kori bustard

Kori bustards are large, mainly terrestrial birds which can fly strongly. The size of the Namibian population is not known but they are thinly scattered over open and tree savanna, and are quite common in southern Namibia but are unlikely to extend as far west as the project area (Allan 1997, Hockey *et al*. 2005). They are not listed as Namibian Red Data birds but are globally considered *Near-Threatened* due to the declining population, caused by power line mortalities, hunting and habitat degradation (BirdLiffe International 2013).

4.3 BACKGROUND TO BIRD – POWER LINE CONFLICTS

How do power lines affect birds? Birds come into conflict with power lines from two causes: electrocutions and collisions.

4.3.1 Electrocutions

Electrocutions on towers are caused when a bird breaches the space between two conductors, causing a short-circuit. Also, when birds defaecate, they eject a long stream of liquid which can cause a short-circuit between the conductors. Even if it does not, the faeces can gradually accumulate on the insulators and conductors, causing problems. Short-circuits are double trouble because they kill the bird, and cause the power line to fail. Birds that are vulnerable are those that like to perch on high structures with a clear view, such as eagles, vultures and other raptors.

4.3.2 Collisions

Large birds in flight have poor manoeuvrability, and may fly in conditions when the conductors are poorly visible, such as the half-light of dawn and dusk, or at night. Even in daylight, the wires are often invisible when viewed from above or against a rising slope. These factors explain the collisions of flamingos, which fly long distances at night and at a low level when there is wind turbulence. A number of flamingo mortalities have been recorded on power lines in southern Namibia, which likely occurred in such situations. Predator and scavenging birds are naturally quite alert when flying, but for instance when aiming for a prey item they are so focused that they are 'blind' to other things in the air. Mortalities of black-breasted snake-eagle, lappet-faced vulture, lanner falcon and crows, found along power lines in southern Namibia (Pallett, unpublished data), probably occurred in such situations.

The highest proportion of collision mortalities in southern Namibia are bustards, making up over 75% of all the birds killed on lines (Pallett, unpublished data). Kori bustard, the heaviest flying bird in the world, and Ludwig's bustard, which is not as large, are the two affected species in Namibia. Ludwig's bustard prefers open, relatively arid habitat, and kori more bushy and savanna-like conditions. The main victim recorded in the Rosh Pinah – Aus area is Ludwig's.

4.3.3 Why are bustards specifically affected?

4.3.3.1 Flying behaviour of Ludwig's bustards

Ludwig's bustards usually fly between roosting and feeding areas at dawn and dusk; daily journeys less than a few kilometres. They also undertake seasonal flights, moving between western areas of Succulent Karoo occupied in winter, and areas further inland in the Nama Karoo that are occupied in summer. The movements do not follow regular or fixed paths; rather, they are nomadic, in response to where rains have fallen and their main food, grasshoppers and other insects, are to be found. There is little regularity in these movements, and Ludwig's bustards have been recorded in the Rosh Pinah area in all four quarters of the year that was surveyed (July 2012 – October 2013).

Data from the Karoo and southern Namibia show that bustards have been caught against power lines of all heights, ranging from small distribution lines only 8 m high, to the highest 400 kV lines at 45 m. Relatively more bustards die against the higher capacity lines, but these lines are both higher as well as deeper in the array of wires that are strung from the highest to the lowest. Therefore the data does not reveal whether there is a 'favourite height' that they fly at, and it is impossible to accurately estimate the height of a flying bustard on the rare occasions when they are seen flying.

The Namibian power line monitoring work has compared the mortality rate on four different kinds of power lines: 400 kV, 220 kV, 132 kV and 66 kV. The results clearly show that the larger the power line, the more collisions. Collision rate is therefore directly correlated to one or more of the following factors:

- Ø The height of the conductors and shield wire;
- Ø The vertical distance of the array of conductors, from uppermost shield wire to the lowest wire;
- Ø The presence or absence of a shield wire.

4.3.3.2 Vision of bustards

Bustards are so vulnerable to collisions because they have very poor forward vision, and they often fly quite low. Raptors (e.g. eagles and hawks) have eyes set in the front of the head, and look forwards and all around when flying, as they are usually hunting or looking out for signs of danger. This gives them strong vision to the front. The eyes of bustards, on the other hand, are set on the sides of the head so there is little area of overlap of the fields of vision, giving them poor depth perception ahead. Also, while flying, bustards are mostly looking downwards, for other bustards or for suitability for foraging (Martin & Shaw 2010), and upwards to look out for aerial predators such as martial eagles. Consequently their forward vision is poor. My observations of bustard carcasses caught on conductors, and the data set of bustard collision mortalities (Shaw 2013, Pallett unpublished data) shows that they are wary enough to avoid towers but clearly do not see the conductors ahead of them, or if they do, they do not see them in time to be able to avoid them.

Most transmission power lines have an uppermost, thin 'shield wire' (also called the 'earth wire' or 'optical ground wire [OPGW]) to protect the line against lightning. It is thought that a high proportion of collisions occur against this wire, which is less visible than the main conductors. A bustard flying towards lines might see the conductors and try to lift above them, but then get caught by the shield wire that it had not seen.

4.3.4 Significance of the bustard collision problem

4.3.4.1 How many Ludwig's bustards die annually on power lines?

The only way to quantify the collision rate accurately is to routinely monitor particular sections of lines over an extended period. This was done on 400 kV lines in the Karoo over two years (Shaw 2013). Even with rigorous methods, the total offtake is difficult to calculate because some carcasses are never found. Factors that lead to under-estimation include:

- Removal of carcasses and dispersal of pieces of carcasses by scavengers such as jackals, hyenas, domestic dogs and people;
- Dispersal of carcass remnants by strong winds, and weathering and spattering of mud during heavy rains, so that the bones and feathers become less conspicuous;
- Carcasses being hidden behind rocks and bushes;
- Observers missing the evidence of a dead bird because of lapses of vigilance.

The power line work in the Karoo included various experiments to quantify these factors (Schutgens *et al.* 2013). After correcting for the identified factors, the collision rate was calculated to be one Ludwig's bustard per kilometre per year. Extrapolating this figure to the whole South African range of the species, it was estimated that the annual toll on Ludwig's bustards in South Africa is about 47,000 birds per year (Shaw 2013). This very high rate seems unsustainable.

In Namibia, monitoring along a 95 km length of the 66 kV power line between Luderitz and Rosh Pinah revealed 15 collisions of Ludwig's bustards over 12 months (Pallett, unpublished data). Most of these were found in the first 3 months of the monitoring, when food availability had attracted many bustards into the area. Averaged over the whole year, the mortality rate for this sample was 0.17 bustards / km / year.

An earlier 'once-off' investigation (2011) along a shorter section of the same line revealed 24 Ludwig's Bustards over a distance of 25 km (www.the-eis.com); this was recorded after it was noticed that bustards were abundant in the area. Although once-off monitoring does not allow a calculation of the collision rate, because one does not know the duration over which the carcasses accumulated, it is likely in the Sperrgebiet, where removal of carcass evidence by hyenas and strong winds is very effective, that these carcasses were not older than 6 months (possibly not older than 3 months). If this is the case, the mortality rate for this section would calculate to 2 - 4 bustards / km / year. These figures show that the mortality rate is extremely variable, and that although it is probably quite low for most of the time, there are short periods when the mortality rate can be very high.

4.3.4.2 How many bustards occur in Namibia, and in the project area?

It is impossible to state accurately how many Ludwig's bustards exist in Namibia, and even less possible to estimate the population in the Rosh Pinah – Skorpion – Gergarub area. Firstly, rigorous surveys in Namibia have not been done. Secondly, the number changes constantly, depending on food availability, and on how extensively the birds move. East-west movements are inferred from the absence or presence of birds in eastern and western areas (Allan 1997) and in South Africa this has been confirmed with radio-tracking of a few individuals (Shaw 2013). There could also be north-south movements, and mixing of the populations that are seen in Namibia and South Africa. This has only been confirmed once, with the observation of a Ludwig's bustard ringed in Rehoboth that was found in Kakamas, northern Cape, 10 years later (Heinrich pers. comm. 2013).

Despite this lack of information in Namibia, there has been some work on arriving at a population figure in South Africa. The LB population was estimated as 56,000 – 81,000 in 1988-89 (Allan 1994), an estimate which was revised to about 97,000 when the same data was re-worked in 2013. Censussing in 2011-2012 estimated the population as 114,000 (Shaw 2013). Although this number was slightly higher than the earlier estimate, the accuracy level of both surveys was low, and the confidence limits covered the range in the numbers. Surprisingly, there was no evidence of a decline in the population, even though the calculated mortality on power lines throughout South Africa may be as high as 42% of the population every year.

At present, the numbers do not make sense. We can say with certainty that 47,000 LBs die annually on power lines because this figure has been calculated from collision carcasses on power line surveys, and extrapolated over the entire South African range where LBs occur. At this rate of mortality, the species should be extinct by now! That it is not, proves that the population must be larger than estimated, and possibly that other factors are responsible, such as relatively higher mortality on age or sex classes which do not influence the reproduction rate. Possibly, there is greater movement between South Africa and Namibia than is currently realised, and the Namibian LB population supplements the South African birds. This problem is currently under investigation.

4.3.5 Solutions to the bustard collisions problem

Mitigation of collisions by bustards is very difficult. The obvious solution is to fix devices onto the conductors so that the lines become more visible and the birds avoid them. However this is not fully effective because of their poor forward vision. An experiment on a 400 kV line in SA showed that installation of spiral devices achieved some improvement in the collision rate, but not full prevention of collisions (Shaw 2013). Another bird that was suffering high mortalities along the particular line, blue crane, showed a much bigger improvement in collision rate with 'spirals'.

The experiment has not run for long enough to provide concrete results (Hoogstad pers. comm. 2014).

4.4 BIRDS OF CONCERN

The birds that are most vulnerable to the proposed power line are listed in Table 3 below.

Table 3: Bird sensitivities

COMPONENT	SENSITIVITY	VULNER-ABILITY	POTENTIAL IMPACT
Ludwig's Bustard	CITES II protected species, NCO Protected Game, non-endemic, Endangered	High	Population reduction through power line collisions: highly susceptible, many fatalities. Presence in project area fluctuates, occasionally numerous (after good rains).
Martial eagle Booted eagle Black Harrier	CITES II protected species, NCO Protected Game, non-endemic, Endangered.	Medium	Population reduction through power line electrocutions and collisions: moderately susceptible. Numbers in project area naturally low.
Secretary Bird Lappet-faced Vulture	CITES II protected species, NCO Protected Game, non-endemic, Vulnerable	Medium	Population reduction through power line collisions: moderately susceptible. Numbers in project area naturally low.
Verreauxs' eagle Kori bustard	CITES II protected species, NCO Protected Game, non-endemic, Near-Threatened	Medium	Population reduction through power line collisions: moderately susceptible. Numbers in project area naturally low.

Table 3 shows that the species of greatest concern, and most likely to be impacted, is Ludwig's bustard. The assessment and suggested mitigations below address this species. It should also be noted that any mitigations to make the line more visible to reduce bustard collisions, will have the same positive effect on the other species.

5 IMPACT ASSESSMENT

5.1 IMPACTS OF THE POWER LINE ON LARGE BIRDS THROUGH COLLISIONS

5.1.1 Description of the impact

The power line will potentially kill some large birds, mainly bustards, with Ludwig's bustard the most likely victim. Other species that might also be impacted are listed in Table 3, but these fatalities are likely to be in much smaller numbers. The mortality rate that was recorded on the Luderitz – Rosh Pinah 66 kV line close to the proposed Gergarub line, over one year of monitoring, was 15 Ludwig's bustards over a distance of 95.3 km (Pallett unpublished data). That calculates to 0.16 LB / km / year, which equates to 1.7 LBs annually over the 11 km distance of the proposed power line. Using the data from the once-off monitoring (www.the-eis.com), where the mortality rate was 2 – 4 bustards / km / year, the 11 km power line could kill 22 – 44 bustards in a year.

These numbers look small and even insignificant, but when they are added cumulatively to the hundreds of kilometres of other power lines that kill LBs every year, the total mortality is certainly a significant figure. It must also be noted that the monitoring definitely misses some birds, so these predictions are definitely lower than the real offtake. Assuming a life of mine of 20 years, at least 34 Ludwig's bustards will die on the power line, but if food availability is sporadically high the numbers could reach over 200 bustards.

The extent of the impact is local, as only birds that are in the area will be killed on the power line. The impact will also extend more widely, since these birds make up part of a larger population in South Africa, Namibia and Angola that is under threat. The cumulative impact of LB deaths extends nationally and internationally.

The duration of the impact is long-term, as the power line will be installed for the full life of the mine.

The probability of the impact is100% certain. Numbers of collision mortalities might rise and fall in different years, but it has been shown (Pallett unpublished data) that collision mortalities occur even when the birds are present in low densities.

The intensity of the impact is high, since Ludwig's bustard is classified as a Red Data species in the *Endangered* category.

The confidence of these predictions is high. There is background work in the project area to verify that collisions against this type of power line occur, which is consistent with other published and verified research in the Karoo.

The significance of the impact is rated as high.

5.1.2 Mitigation

5.1.2.1 Route of the proposed power line

The proposed route of the power line has both positive and negative aspects. On the positive side, it is aligned close to the road running from Skorpion Mine to the C13, and then close to the C13 itself. This follows a well-recognised principle, that linear infrastructures should be clumped together in a corridor rather than each following a separate alignment. This is also good for Ludwig's bustards, as they are naturally shy and are likely to fly higher over areas where there is vehicle traffic and noise, thus lifting them out of the danger zone. On the negative side, the route is slightly indirect and longer than necessary, thus being more likely to cause bustard collisions. However, the shorter, direct route crosses a sensitive habitat that was agreed in an earlier part of this EIA would not be disturbed (Irish & Mannheimer 2012). The present route is therefore the best option available.

5.1.2.2 Design of towers

Of the two kinds of towers suggested for this power line, the smaller H-pole structure is definitely the least harmful to bustards. This is because its conductors are aligned horizontally and the vertical distance between upper and lower wires is only about 2.2 m. The taller steel monopole towers create a vertical distance of about 8.5 m between the upper and lower wires, which acts as a much wider 'fence' into which bustards can collide.

Is it preferable to erect one line of 132 kV, that will supply all future likely demand, or to erect one 66 kV line now and possibly have to erect another parallel line in the future? From a bustard's perspective, probably the latter. This is because two lines in parallel are more visible, and likely to incur lower bustard mortalities, than one line on its own. Bustards are most likely to collide into power lines in the mid-span sections, i.e. away from the towers (Shaw 2013, Pallett unpublished data). They seem to be able to detect and avoid towers reasonably well. With two lines in parallel, the towers can be slightly offset from each other, making the distance between towers (as viewed by an approaching flying bustard) less, and therefore facilitating the bustard's avoidance action. It has been shown in the South African data set that two power lines in parallel incur relatively less bustard collisions than single lines.

In conclusion, it is preferable to erect this power line with the H-pole design, even if it means in future that another similar line will have to be added.

5.1.2.3 Making the wires more visible with bird diverters and bird flappers

Bird flight diverter devices have been shown to help in reducing bustard strikes, and it is recommended that all new power lines in bustard territory be fitted with them (Shaw 2013). The rationale is that it is simpler and cheaper to fit these devices during construction, than to add them to energized lines at a later stage. The recommendation here is that the proposed power line should be fitted with visibility devices, following the design and spacing guidelines given by Eskom (2009).

A major shortcoming in the southern African (and international) bustard – power line work is the lack of experimental data showing the effectiveness of anti-collision devices. This can only be done by including some 'control' sections in a marked line, to show what the collision rate is in the absence of any devices. I therefore suggest that only half of the proposed line gets fitted with bird flight diverters. Sections with roughly similar attributes should be split so that half of the section is fitted with diverters, and half not. Future monitoring of the collision rate along the full length of the line, for at least the next 5 – 10 years, and careful assessment of the data, is critical to implementing this mitigation.

Figure 7: Suggested layout of alternating marked and unmarked sections of the proposed power line. Sections a, c and e should be fitted with alternating spirals and flappers, while sections b, d and f should be left without any devices. The total distance to be fitted with devices is about 4.7 km.

Sections a and b represent experimental and control sections of approximately equal length across one habitat; sections c and d make up another pair, and sections e and f the last pair.

Both flappers and spirals are effective as bird diverters, but there is not enough information to determine which is more effective. It is therefore recommended that both flappers and spirals be installed along the new power line. Current standards are to install diverters at 5 m intervals, alternating between the two shield wires, and alternating between flappers and spirals.

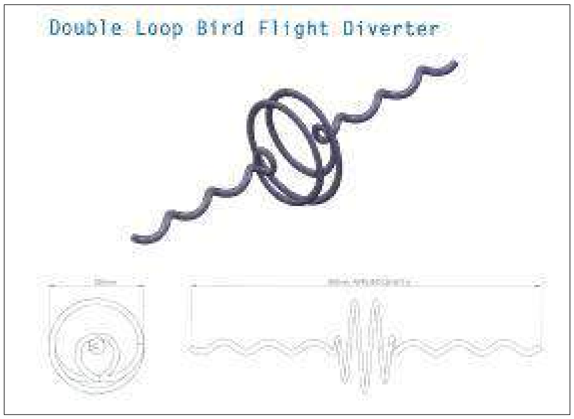

Figure 8: Graphics of the Double Loop Bird Flight Diverter (a 'spiral') and the Bird Flapper.

An experiment in the Karoo (Shaw 2013) showed that there is some improvement in the collision rate with a 10m interval between devices on any one shield wire, with the devices staggered so that an oncoming bird faces a device (spiral or flapper) every 5 m. This is the interval recommended by Eskom (2009), and is recommended here.

The spirals should be coloured either black or white for maximising contrast, and the two colours should alternate along the shield wires.

5.1.3 Cost of mitigation

The price quoted for bird flight diverters by Preformed Line Products (SA) is R138 per device. Fitted every 10 m, the price to mark 4.7 km is about N$ 65,000.

The price of the 'Viper' flapper manufactured by the same company is R84 each. Fitted every 10 m, the price to mark 4.7 km is about N$ 40,000.

The total price for the mitigation is therefore N$105,000. This excludes any reinforcement structures or reduced span length or other alteration to the overall design, that might be necessary to carry the extra weight and wind resistance of the devices.

5.1.4 Monitoring

The suggested mitigation is intentionally designed to compare the marked and unmarked sections of the power line. This requires thorough and regular monitoring of the power line. This involves driving under the line and searching for evidence of dead birds within a distance of about 30 m on either side of the line, about once per month. Such surveys were carried out every three months during the field work described above (Pallett 2014) but a higher frequency of monitoring is recommended here due to the likelihood of carcasses being scavenged and the strong winds which remove feathers that catch on the vegetation. A monitoring protocol can be provided, including a demonstration and assistance to get it started, when the power line is established.

This monitoring and long-term data-gathering should be closely coordinated with the NamPower – NNF Strategic Partnership. This will facilitate that the results get fed into the national database of power line – wildlife conflicts, which in turn helps to inform future bird mitigation efforts.

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Gergarub Mine

Hydrological and Hydrogeological Impact Assessment

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Gergarub Mine

Hydrological and Hydrogeological Impact Assessment

Version 1

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°C	-	degrees Celsius
a	-	annum
cf	-	Compared with
DWAF	-	Department of Water Affairs and Forestry
e.g.	-	For example
EC	-	Electrical conductivity
ECC	-	Environmental Compliance Consultancy
EMP	-	Environmental Management Plan
EPL	-	Exclusive Prospecting License
ESIA	-	Environmental and Social Impact Assessment
GIS	-	Geographic Information System
ha	-	Hectare
hr	-	hour
km	-	Kilometre
l/s	-	litres per second
LHOS	-	Long Hole Open Stoping
m	-	Metre
m/s	-	metres per second
m^3	-	meter cubed
m^3/h	-	metres cubed per hour
Ma	-	million years
mamsl	-	metres above mean sea level
mbgl	-	metres below ground level
MDRL	-	Mineral Deposit Retention License
mg/l	-	milligrams per litre
ML	-	Mining License
ML	-	megalitre
mm	-	Millimetre
mS/m	-	milli Siemens per metre
mV	-	millivolts
NW	-	Northwest
ORP	-	oxidation reduction potential
RPZM	-	Rosh Pinah Zinc Mine
SZM	-	Skorpion Zinc Mine
TSF	-	Tailings Storage Facility
TSF	-	Tailings Storage Facility
WL	-	water level

1. BACKGROUND

1.1. Introduction

Umvoto Africa (hereafter referred to as Umvoto) was appointed by Environmental Compliance Consultancy (hereafter referred to as ECC) to conduct a Hydrological and Hydrogeological Impact Assessment (hereafter referred to as the Impact Assessment) for the Gergarub Mine, a proposed underground base metals mine in the //Kharas region of Namibia, owned and to be operated by Gergarub Exploration and Mining (Pty) Ltd. The proposed mine has been granted a Mineral Deposit Retention License, MDRL 2616 (hereafter referred to as the site), which falls within the larger Exclusive Prospecting License, EPL 2616, and aims to exploit five ore zones containing zinc, lead, and silver deposits which lie between depths of ~100-500 metres (m). The application for a Mining License, ML 245, is pending.

Namibia is a water scarce country supporting that both groundwater and surface water resources need to be protected while maintaining a balance with economic function. The mine operations, if improperly conducted, carry potential to have adverse effects on water resources. Potential impacts from mining related activities need to be assessed so that actions for prevention, mitigation and management can be put in place. The mine will undertake water resource development and water use activities, as well as the use of hazardous and non-hazardous substances for mine operations.

1.2. Terms of Reference

The Scoping Report for the Gergarub Mining Project on ML 245 by ECC (Gergarub Exploration and Mining, 2023) revealed terms of reference for the assessment phase of the ESIA, including the various environmental components such as noise, air quality, traffic etc. The accepted terms of reference of the Hydrological and Hydrogeological Impact Assessment are as follows:

- Phase One – Gap Analysis
    - A review of relevant mining and water related legislation and other national documents to determine the legal requirements and national (Namibian) and international standards for an ESIA.
    - Review of all current and available data/information from previous studies to assess and evaluate the current and available data (as shown **Appendix A**).
    - A Gap Analysis Report to highlight shortfalls and request necessary data to complete the Impact Assessment (with the summary provided in **Appendix B**).
- Phase Two – Impact Assessment
    - A literature review conducted on existing and relevant publications and technical reports, and new data provided or collected.
    - A desktop assessment and analysis of all available datasets to characterise the physical and hydroclimatological setting of the site, including climate, topography, drainage, geology, and hydrogeology.
    - A 2-day long site visit to confirm the findings of the desktop assessment, identify boreholes and other groundwater users within the mining area and surrounds, and measure static groundwater levels.
    - Aquifer characterisation through analysis of collected and available geological and hydrogeological datasets and literature to understand the behaviour and characteristics of identified aquifers in the mine area.

- A hydrological flood assessment of the mine, carried out by reputable subcontractor Hydrologic (Pty) Ltd (provided as digital **Appendix C**).
- A conceptual model to inform potential interaction between groundwater and surface water resources and evaluate possible contamination plume evolution.
- Source-Pathway-Receptor identification and impact rating according to ECC's Impact Assessment Methodology, with recommendations for mitigation, control, or alternatives to be incorporated into the ESIA.

1.3. Literature Review

Several legislative and guideline documents of national scale have been reviewed to determine the legal requirements of a hydrological and hydrogeological specialist study for an ESIA. These requirements are important as they should be complied with to obtain an environmental clearance certificate for the proposed mine. Project specific documents were also reviewed, with the majority being from the feasibility phase of the project and from the previous 2015 ESIA (which was completed but an environmental clearance certificate was never awarded). This project-specific information proved useful and formed the basis of understanding for this Impact Assessment. Information and data gathered from these reports are updated and improved where possible, and any gaps in data and information noted were presented in a Gap Analysis Report. The documents reviewed are summarised in **Appendix A**. The findings of the Gap Analysis Report are summarised in **Appendix B**.

2. SITE DESCRIPTION

2.1. Locality

The Gergarub Mine (MDLR 2616) is located on the farm Spitskop 111 in the Oranjemund Constituency within the //Karas Region of southern Namibia (**Figure 2-1**). The proposed mine is ~12 km north-north-west (NNW) of Rosh Pinah town along the C13 road leading from Sendelingsdrif to Aus. Rosh Pinah relies heavily on the mining industry and has a population of ~7 000 people, half of which reside in informal settlements. Other notable mines in the area are the Skorpion Zinc Mine (SZM) ~9 km to the northwest (NW), and Rosh Pinah Zinc Mine (RPZM) ~12 km to the southeast (SE).

The area is surrounded by protected areas to the east, south and west. The northeastern edge of EPL 2616 shares its border with the Tsau //Khaeb Sperrgebiet National Park. The Sperrgebiet (meaning restricted area) is a biodiversity hotspot forming part of the Succulent Karoo biome with many endemic species. The /Ai-/Ais (meaning burning) Hotsprings Game Park is to the east and is home to the Fish River Canyon.

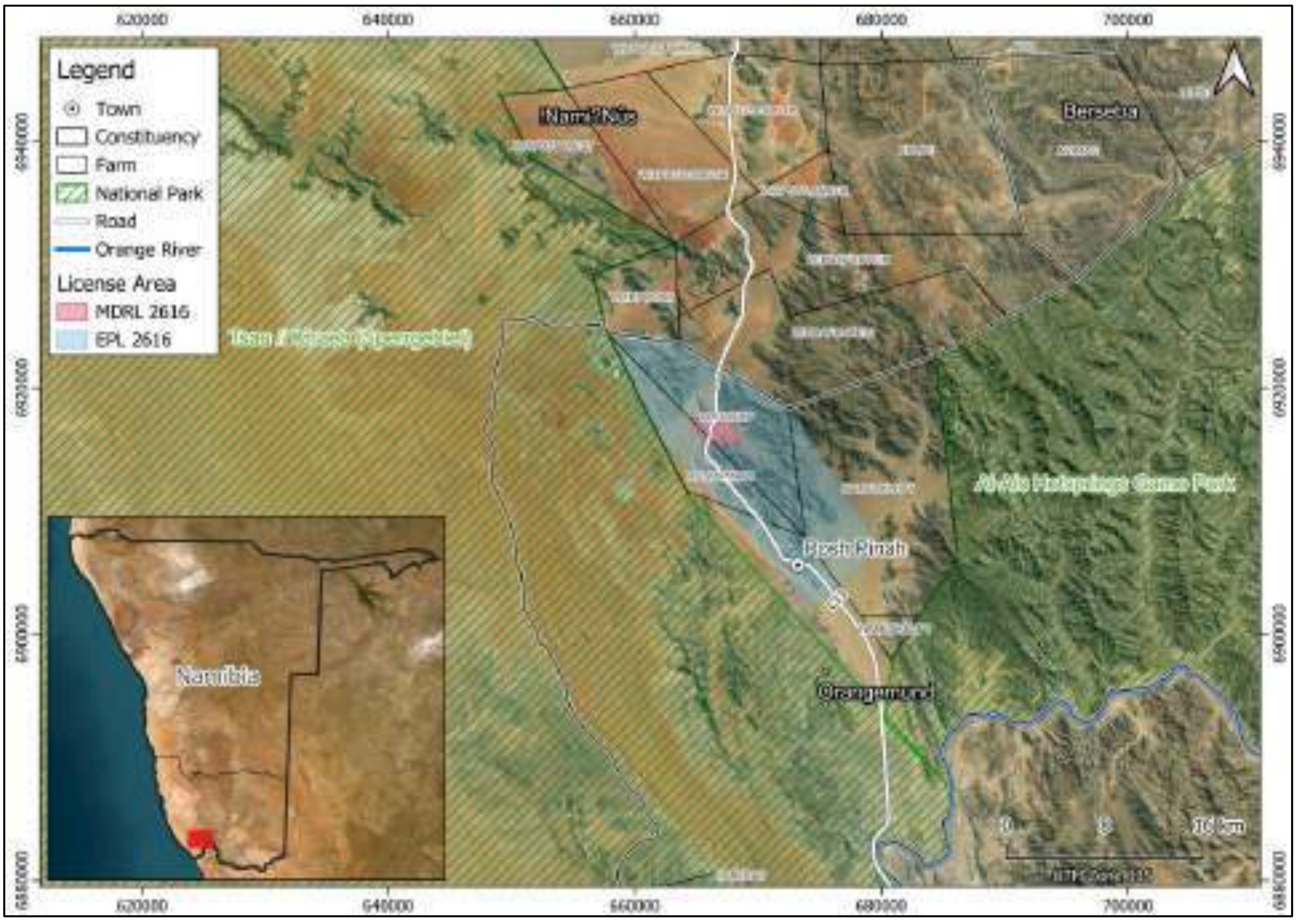

Figure 2-1 Locality map of the Gergarub Project MDLR 2616 within the EPL 2616.

2.2. Topography

The //Kharas terrain is rugged, comprising high mountainous areas (made up of relatively weathering-resistant rock) separated by valleys infilled with sediment to create plains of sand and gravel. West of the site are the dune fields of the Namib Desert west coast. The site (**Figure 2-2**) lies at the base of the Great Escarpment (red and white areas) where the low lying plains and dune fields (linear and barchan type dunes beginning ~7 km to the southwest), reaching elevations of ~300 metres above mean sea level (mamsl) in the mapped area, transform into the plateauing eastern highlands, reaching elevations up to ~1460 mamsl. The lowest lying areas are the Orange River ~30 km to the southeast reaching as low as ~10 mamsl.

Locally, the site is situated within the relatively flat and wide Zebrafontein Valley (named after the farm portions) originating ~20 km northeast of the site. The valley is surrounded by mountains to the east and south (reaching a maximum elevation of ~1360 mamsl to the east). There is an inselberg within the valley on the northern border of the site which protrudes ~120 m from the valley floor to an elevation of ~753 mamsl. The Zebrafontein Valley is infilled with sand, resulting in a relatively smooth topography across the site (as opposed to the adjacent rocky outcrops). Steeper areas on site are the foothills of the inselberg on the northern edge and the mountains on the southern edge. The site slopes southwards from the north with the lowest elevations (~600 mamsl) being present along the C13 road which crosscuts the site. On the site itself, slopes are gentle at ~10%, while the surrounding mountain slopes reach gradients ranging from ~30-50%.

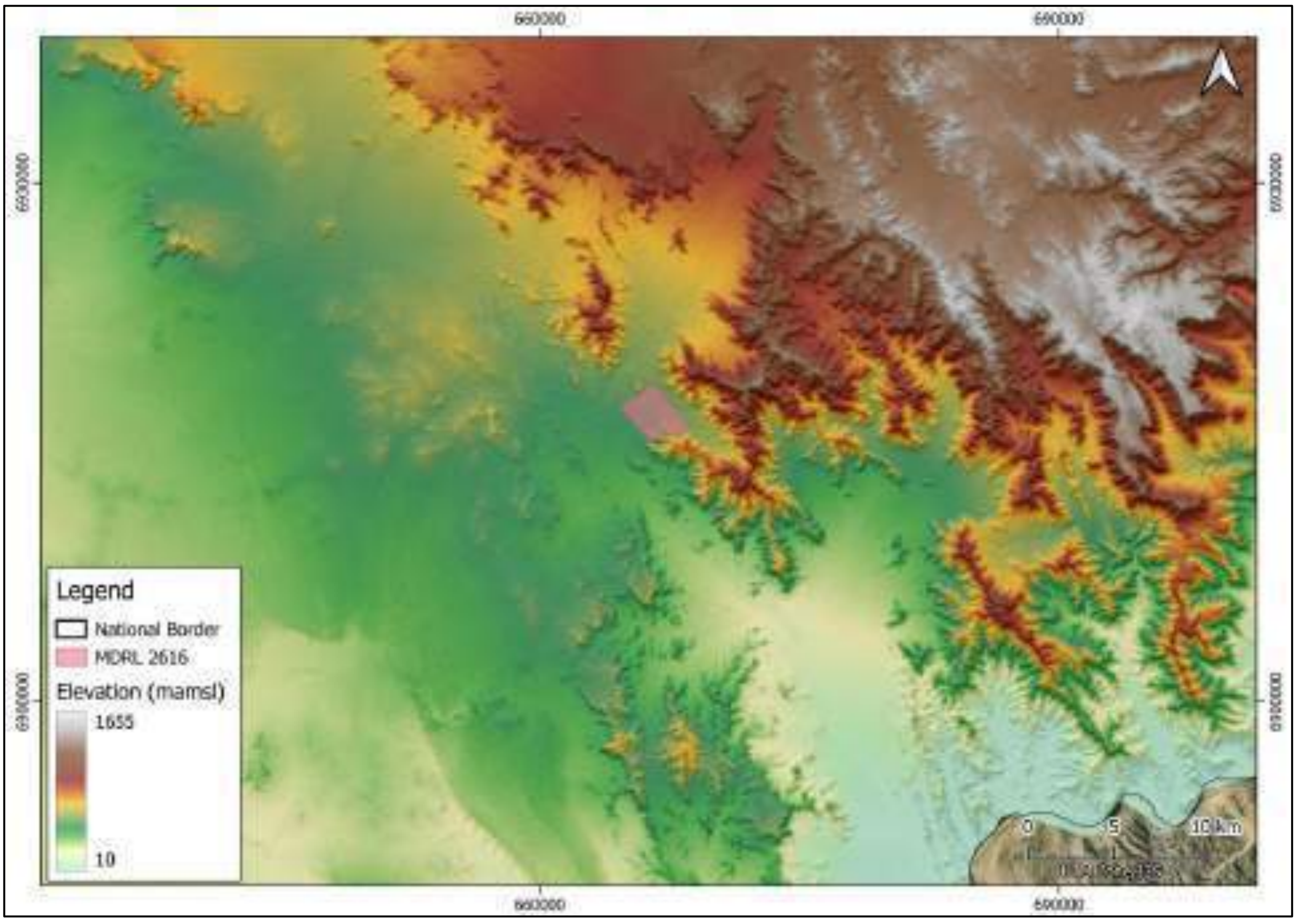

Figure 2-2 Topographic map of the Gergarub Project and surrounding area.

2.3. Climate

The area falls within the Namib dessert receiving less than 100 mm of precipitation per year. According to the Köppen-Geiger climate classification, the area is classified as a hot, arid dessert (BWh) with scattered, infrequent, and unpredictable rainfall restricted to the summer between October and February (Mendelsohn et al., 2002). A weather station at Rosh Pinah Zinc Mine (RPZM), ~12 km to the southeast, recorded precipitation data between 1994 and 2023, shown in **Figure 2-3**. An outlier occurred in 2005 with 212.9 mm of rainfall, while the average across the years is 45.7 mm/a. The years 2015-2019 show particularly low rainfall ranging from 7.7-11.0 mm/a. Most rainfall events are less than 3 mm, but occasional downpours and localised flooding can occur. The Flood Assessment (**Appendix C**) deals with this in more detail assessing rainfall intensities and frequencies.

Due to the cold Benguela Current in the Atlantic Ocean, fog is also a common occurrence. Average temperatures increase from the west coast eastwards. Daytime temperatures reach a maximum of more than 40°C with an average of 34°C occurring in February (summer), and nighttime minimum of below 0°C and an average of 7°C occurring in July (winter) (Metoblue.com). Prevailing winds are predominantly SSE to SSW (>45% frequency) and less frequently from the NNE. Wind speeds range from 6 m/s to 15 m/s (Gergarub Exploration and Mining, 2023). Average annual evaporation varies between 3 000-3200 mm which far exceeds the rainfall.

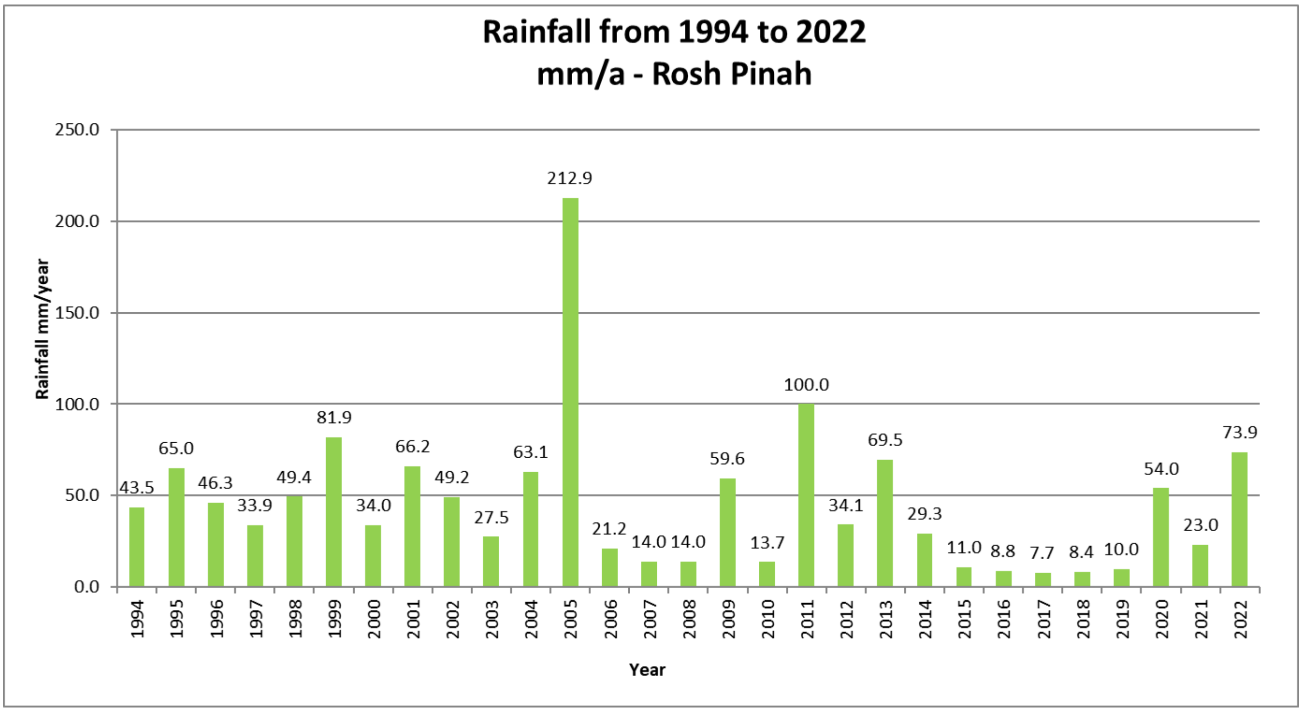

Figure 2-3 **Annual rainfall for the years 1994-2022 at RPZM.**

2.4. Hydrology

The site occurs in the Orange River West Catchment (**Figure 2-4**). The Orange River is the only major perennial river in the area, occurring ~30 km southeast of the site, also forming the border between South Africa and Namibia. There are no surface water bodies in the area and all non-perennial drainage leads southwards to the Orange River, which eventually drains westwards into the Atlantic Ocean. The Orange River is the main source of water for SZM, RPZM, and Rosh Pinah, and will also supply the Gergarub Zinc Mine through NamWater, the national supplier.

The area is drained by the Zebrafontein Catchment System to the northeast and the Trekpoort Catchment to the northwest, as well as a minor catchment to the west of the site (Skorpion Mining Company, 2014b). The Trekpoort Catchment does not seem to have any influence on the site (see **Appendix C**). The drainage pattern is dendritic with drainage lines originating at the steep hilltops draining to the flat open valleys where randomly braided channels are common. Drainage across the site is westwards to southwestwards (**Figure 2-4**), joining the main drainage line of the Zebrafontein Valley drainage system. The minor catchment occurring to the east of the site is of most significance as the runoff flows across the proposed mine site and proposed Tailings Storage Facility (TSF). Most of the runoff flowing through the area is channelled using culverts to the northern side of the C13 road away from the proposed Gergarub infrastructure. The construction of Gergarub Mine will alter this surface flow regime, particularly runoff from the mountains to the east and southeast. Due to the presence of relatively permeable soils, any surface water flows often drain away into the subsurface becoming baseflow rather than reaching the Orange River as surface runoff (Skorpion Mining Company, 2014c).

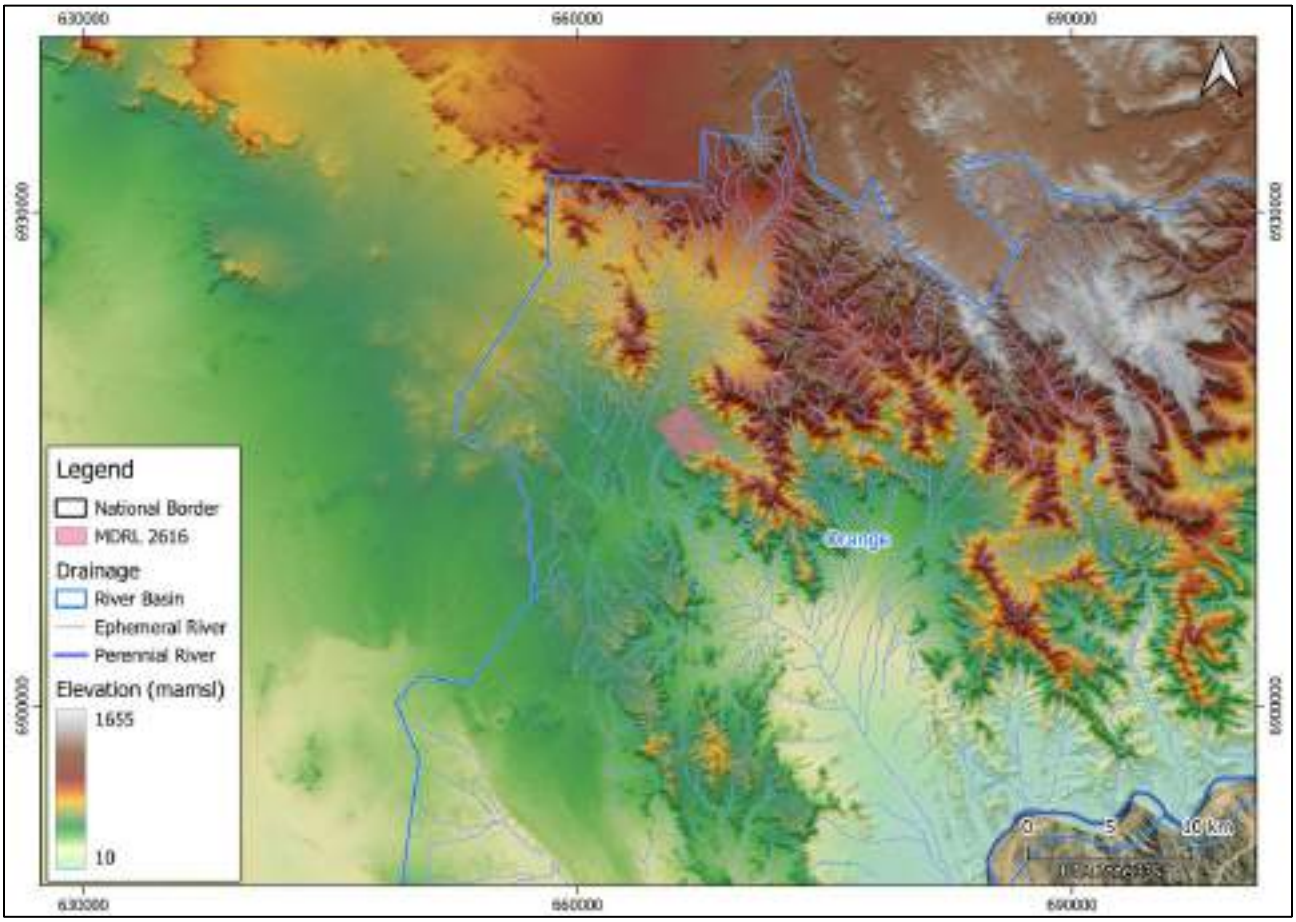

Figure 2-4 Regional drainage map of the area.

2.5. Soil

A soil classification map of the area, depicting only the dominant soil types, is shown in **Figure 2-5** (Atlas of Namibia Team, 2022) and described in **Table 2-1** (Driessen, et al., 2000). Soils harbour biodiversity that depends on water resources to survive. Soil can be the pathway medium for contaminated waters to have adverse impacts on the flora and fauna of the area which can affect entire ecosystems. The EPL license borders the Tsau ǁKhaeb (Sperrgebiet) National Park and forms part of the Succulent Karoo biome, which is regarded as a global biodiversity hotspot where only absolutely unavoidable damage is acceptable.

The site lies across three soil types, namely chromic arenosol (protocalcic), eutric fluvic cambisol (arenic), and skeletic lithic leptosol, in order of low to high elevation and steepness. The Zebrafontein Valley floor at the site is characterised by the protocalcic chromic arenosols implying that soils are developed in residual, shifting or recently deposited sands with early stages of carbonate formation processes. The lower Zebrafontein Valley drainage system south of the site comprises calcaric leptic fluvisol, indicating that these soils are stratified due to continuous fluvial input (i.e., sediments carried by runoff from higher reaches to the lower catchment area) and are relatively shallow with later stages of carbonate formation.

Table 2-1 Dominant soil types and associated definitions (Atlas of Namibia Team, 2022 and Driessen, et al., 2000)

Code	Dominant Soil Type	Definitions
caleFLar	Calcaric Leptic Fluvisol (Arenic)	Calcaric: calcareous at least between 20-50 cm depth. Leptic: having continuous hard rock between 20-100 cm depth. Fluvisol: having a thickness of 25 cm or more with fluvic soil material (stratified by fluvial input) within 50 cm depth. Arenic: loamy fine sand or coarser texture in the upper 50 cm.
crARqc	Chromic Arenosol (Protocalcic)	Chromic: having a subsurface horizon with a Munsell hue of 7.5YR, and a moist chroma of more than 4 or a moist hue redder than 7.5YR. Arenosol: loamy sand or coarser texture to a depth of 100 cm, or to an plinthic or petroplinthic (cemented by iron), or salic (salts) horizon, and having less than 35% volume of rock or other coarse fragments within 100 cm depth. Protocalcic: early stages of carbonate precipitation.
euflCMar	Eutric Fluvic Cambisol (Arenic)	Eutric: having a base saturation of 50% or more between 20-100 cm. Fluvic: having fluvic soil material within 100 cm of the surface. Cambisol: a plinthic or petroplinthic (cemented by iron), or salic (salts) diagnostic horizon between 50-100 cm depth. Arenic: see above.
prARay	Protic Arenosol (Aeolic)	Protic: having very little soil horizon development. Arenosol: see above. Aeolic: derived from windblown processes.
skliLP	Skeletic Lithic Leptosol	Skeletic: having 40-90% weight gravel or other coarse fragments. Lithic: having continuous hard rock within 10 cm depth. Leptosol: continuous hard rock within 25 cm and a yermic (desert pavement) diagnostic horizon.
TC	Technosol	Technosol: containing anthropogenic artefacts and natural pedogenic processes have been disrupted

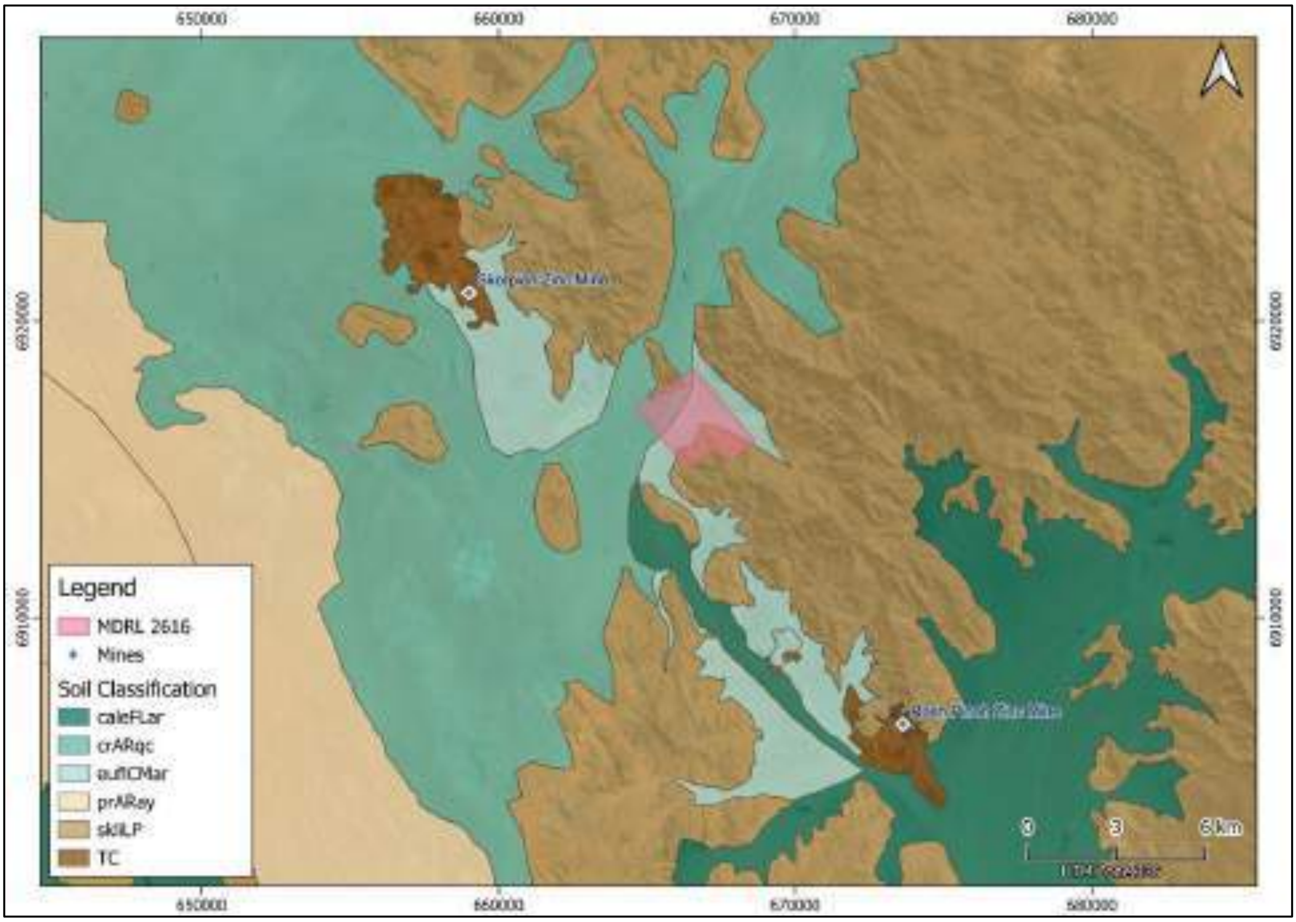

Figure 2-5 **Soil classification map showing the dominant soil types in the area (Atlas of Namibia Team, 2022)**

Cambisol means a young soil with only the beginning signs of soil formation being evident. The eutric fluvic cambisol (arenic), as seen in the smaller catchment to the southeast of the site and other foothill areas, are young and shallow, but have fluvial input from runoff originating from the higher mountainous areas. In the higher lying areas above these foothills, the skeletic lithic leptosol is present. Leptosol are soils in elevated, rugged topography which are shallow and overly hard rock, as is expected in the mountainous areas. The dune fields to the west of the site are classed as aeolic protic arenosols as these are young windblown sediments with little to no evidence of soil horizons.

Of most interest is the presence of technosols around RPZM and SZM. Technosols are anthropogenic in origin where natural soil processes have been completely disrupted by industry or burial, such as agriculture or waste disposal. Technosols show presence of anthropogenic artefacts. The mining in the area has led to the formation of technosols, and it is certain that soils surrounding Gergarub Mine will be altered to technosols as a result of the operations.

2.6. Mine Description

Gergarub Exploration and Mining (2023) provides a detailed summary of the project including orebody description, mining method and equipment, mine haulage and design, metallurgy and processing, support infrastructure and services. The conceptual mine layout is shown in **Figure 2-6**. Note this is conceptual and, although it may not be the final design, it includes relevant components sufficient for the Impact Assessment. The mine infrastructure lies within a drainage line and respective alluvial/talus fan deposits, and any drainage coming across the site will need to be diverted. The TSF is cornered between two spurs on a relatively shallow overburden. The decline portal is located on Rosh Pinah Formation outcrop, and it is assumed that no quaternary sediment overburden is expected to be intercepted by the underground infrastructure. It is unclear if any road diversions will be undertaken.

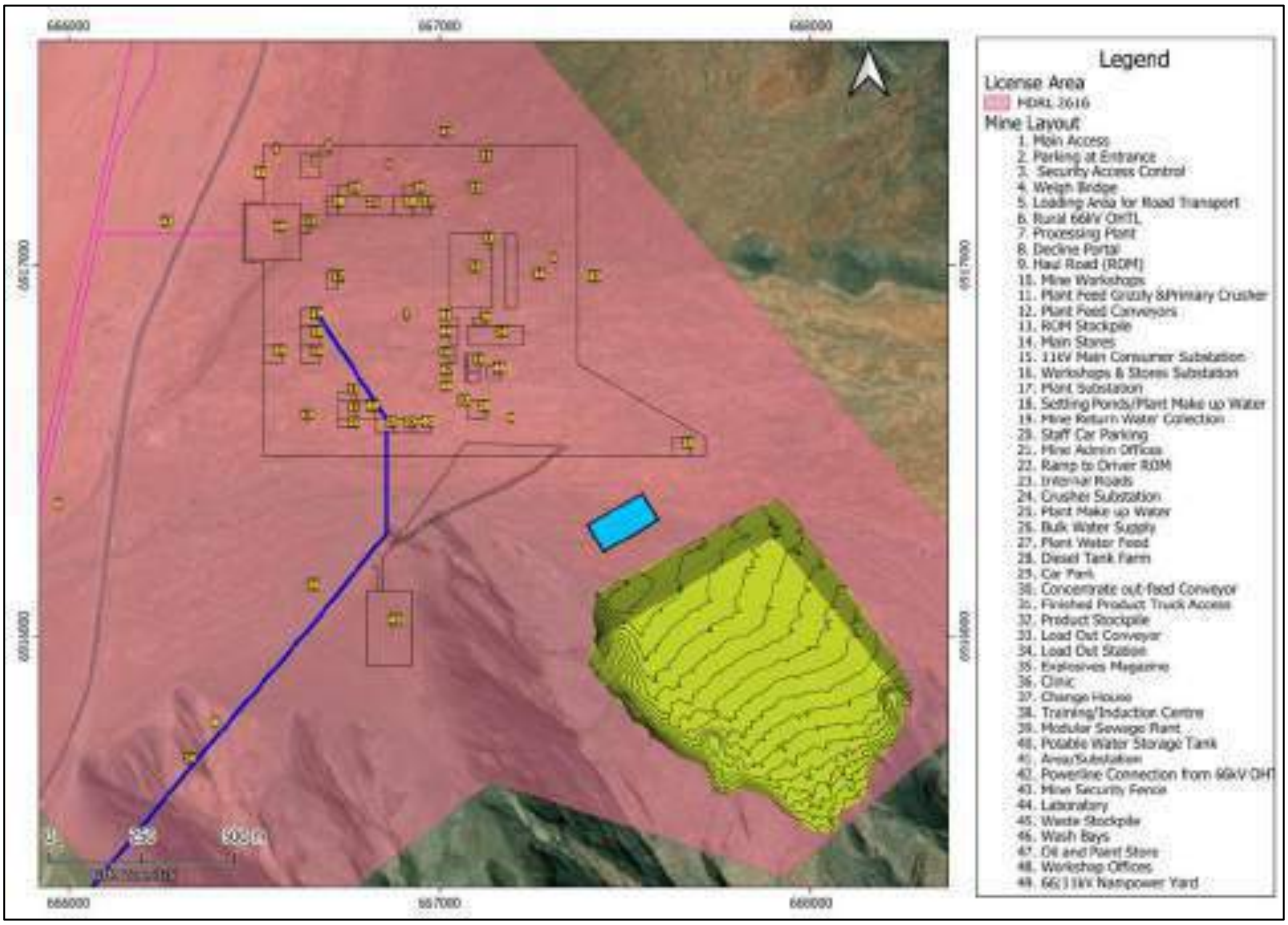

Figure 2-6 **Conceptual mine layout provided as a DWG file shown as a georeferenced shapefile to offer spatial reference. Numbered items are provided in the legend and the TSF is shown in yellow while the return water dam (RWD) is shown in blue.**

Mining Method and Equipment

The deposits will be mined with a long hole open stope (LHOS) with paste backfill technique supplemented with drift and fill mining. Mining will progress from the centre to the extents of each mining level and the stopes will be mined and backfilled in an overhand (bottom-up) extraction sequence. The proposed method including backfill has the advantage of producing higher ore volumes, improved ground stability (local and regional) and mining recovery, and reduced dilution and tailings production. Paste backfill material will be produced on site at a backfill plant from dewatered tailings combined with a cement binder and water to achieve a desired density. Bulk cement will be stored in a steel silo.

It is planned that the most efficient dewatering system will be underground main and temporary sumps and a staged pumping system with rising main infrastructure extending as the mine progresses deeper. The total maximum expected groundwater inflow to the mine is ~38 l/s at the end of the mine life (SRK, 2014). The excess water pumped from dewatering sumps will be stored in holding ponds and tanks to be used for dust suppression and plant make up water. Water is planned to be 100% recycled with in-mine and surface run-off controls to be in place.

The ventilation system is designed to dilute or remove airborne dust, diesel emissions and explosive gases and maintain safe temperature levels. Drilling, blasting, loading and hauling operations will also be undertaken. Blasting will be done with nitrate based or emulsion explosives and stored in separate facilities with capacity for 1 500 bags (20 kg each) of ammonium nitrate-fuel oil (ANFO) and 50 tonnes of bulk emulsion, and there will also be some underground explosive storage. Loading, hauling, and other operations require mobile vehicles and equipment, usually operating on diesel. The primary (and preliminary) planned diesel fleet consists of 27 units, including 3 development drills; 2 production drills; 4 trucks; 5 loaders; and 13 ancillary equipment. A tertiary support equipment fleet such as light delivery vehicles, maintenance vehicles and buses etc. will also be used.

Other Mining Activities and Infrastructure

Roads, dumps, and stockpiles will be constructed in initial phases of the mine. Ore stockpiles will be placed near the primary crusher. Haul trucks will dump waste rock which will be pushed down and levelled by bulldozer which can lead to dump failure, heavy erosion, loss of fines, visual and air quality impacts. The waste rock will also be used to construct run of mine pads and tailings storage dam walls.

Metallurgy and Processing

A concentrator with capacity of 1 million tonnes per annum (Mpta) capacity is planned for Gergarub Mine. Ore will go through lead and zinc flotation circuits to produce concentrate grades of 51.2% and 58.2%, respectively. The concentrates are pumped to high rate thickeners and filtered, with filtrate being recovered for re-use in the plant and waste being pumped to tailings storage facility (TSF).

Administrative Buildings

Administrative buildings and associated infrastructure are necessary for the proposed mine to function and provide working space for management, geological and engineering services, and other operations. The mine will require the following, each of which may have their own potential impacts and contaminant sources:

- An administration and management building; human resources; security control; and a health; safety and environment building, each with sanitary facilities and expected mine traffic of ~640 people over 24 hours.
- A large change house for mine employees.
- Training facilities to upskill workers and facilitate induction protocols.

- Core sheds for storing drill cores and data.
- A variety of workshops (such as electrical, communication, and transport) for maintenance and operations.
- Warehouses and store facilities for consumables and chemicals.
- Fuel storage (82 000 litre and 23 000 litre units) and a refuelling station.
- Surface storage facility with capacity of 1 500 bags (20 kg each) of ammonium nitrate-fuel oil (ANFO) and 50 tonnes of bulk emulsion, and additional smaller underground explosives storage facility.
- Steel silo for bulk cement storage to be used in paste backfill production.

Water Supply

Water will primarily be sourced from NamWater, and once water requirements have been finalised an application will be made. Preliminary water balance modelling indicated a total water requirement of 134 m^3/hour (37.2 l/s) supplied from the Orange River some ~30 km to the south. It is understood that dewatered groundwater will also be used in addition to river water.

Waste

The project will produce waste rock, tailings, domestic waste, and hazardous waste during operations. Waste rock will be used underground in stope voids or will be deposited on the surface waste rock stockpile. Some will also be used to construct the run of mine pad (roads). Tailings produced will be disposed in a tailings storage facility (TSF), however, the original TSF design (SRK, 2014) as shown in **Figure 2-6**, did not consider the use of tailings in backfill production.

Gergarub Exploration and Mining (2023) states that a dedicated waste management facility will need to be constructed on site to manage the various types of waste produced. Waste will be sorted on site, stored appropriately to avoid contamination of the environment, and either recycled, reused, or disposed of appropriately. Hazardous wastes include fuels, chemicals, lubricating oils, hydraulic and brake fluid, paints, solvents, acids, detergents, resins, brine, solids from sewage, and sludge. Effluent treatment facilities will be installed to treat sewage and grey water generated as part of the project, and any surface runoff available will be used and recycled. Some types of wastes expected are summarised in **Table 2-2**.

Rehabilitation Plan

Currently, no rehabilitation plan exists for the Gergarub Project. Outcomes of this Impact Assessment may be incorporated in the rehabilitation plan to minimise potential contamination after mine closure.

Table 2-2 Waste types, storage and use expected to be generated as part of the Gergarub Project (ECC, 2023). These are potential sources of environmental water contamination.

Waste type	Waste types	Storage facility	End use
Non-hazardous solid waste (non-mineralised)	Wooden crates, pallets, cable drums, scrap metal, general domestic waste such as food and packaging.	Dust bins in relevant work areas will be provided for different waste types. A waste management contractor will remove dust bins regularly to a dedicated waste handling and storage area.	Waste will be sorted further at a dedicated waste handling and storage area on site. Recyclable waste will be sent to a reputable recycling company. Some items may be distributed directly to the community if possible. The remainder of the waste will be transported by the waste management contractor to a permitted landfill facility which may be constructed on site for example within the WRD.
	Building rubble and waste concrete	Designated rubble collection points will be determined to which contractors will take rubble and concrete.	The waste management contractor will regularly remove the waste from the designated collection points to the footprint of the waste rock dump.
Hazardous contaminated solid waste (nonmineralised).	Treated timber crates, printer cartridges, batteries, fluorescent bulbs, paint, solvents, tar, empty hazardous material containers etc.	Hazardous waste will be separated at source and stored in designated containers in bunded work areas. The waste management contractor will remove these drums regularly to a dedicated waste handling and storage area.	Hazardous waste will be disposed of at the permitted hazardous disposal site (for example in Walvis Bay) by the waste management contractor.
	Hydrocarbons (oils, grease)	Used oil and grease will be stored in drums in bunded areas at key points in work areas. The waste management contractor will remove these drums regularly to a dedicated waste handling and storage area. The yard will have a dedicated used oil storage area which will include a concrete slab, proper bunding and an oil sump. The appointed bulk fuel supplier will collect used oil for recycling.	Used oil will be sent to a reputable recycling company for recycling.
	Sewage	Sewage treatment will be required	May be reused as greywater for dust suppression

Waste type	Waste types	Storage facility	End use
Laboratory waste	Mineral samples, mineral assay samples, chemical fluids, glass, gloves, and general laboratory waste samples	Mineral waste samples that are not required to be kept will be disposed of at the tailing storage facility and at an approved mineral disposal landfill. A mineral waste management contractor will remove the waste on a regular basis to a waste handling and storage area.	Hazardous laboratory waste will be collected regularly and transported to a hazardous disposal treatment facility (for example in Walvis Bay). Non- hazardous waste will be disposed of at an appropriate landfill which may be on site.
Medical waste	Syringes, material with blood stains, bandages, etc.	Medical waste will be stored in sealed containers. A waste management contractor will remove these drums regularly to a dedicated waste handling and storage area.	Medical waste will be transported by the waste management contractor to a permitted medical waste treatment facility.

2.7. Geology

2.7.1. Regional Geology

The geology described here is taken from the Geology of Area 2716 Ai-Ais Explanation Sheet (Geological Survey of Namibia, 2019), and R. Miller's Geology of Namibia Vol. 1 and Vol. 2 (2008). Southwestern Namibia is largely made up of rocks of the Namaqua-Natal Metamorphic Province and the Gariep Belt, the former extending southwards into northwestern South Africa and then eastwards across South Africa. The province is comprised of a series of orogenic belts (mountains ranges), formed by multiple orogenies throughout the Earth's history, that are now eroded. The main orogenic events being the Namaqua Orogeny (construction of Rodina) occurring ~1200 million years (Ma) ago and the Gariep Orogeny occurring ~545 Ma. The Gariep Belt, also occurring in southwestern Namibia, is a smaller part of the later Pan-African/Brasiliano Orogeny (construction of the Gondwana continent). The relevant metamorphic divisions are shown in **Figure 2-7**, with the geology and stratigraphy shown in **Figure 2-8** and **Table 2-3**, respectively, as discussed below.

The Namaqua-Natal Metamorphic Province can be subdivided into various subprovinces defined by major shear zones or changes in deformation or metamorphic grade, of which the Richtersveld Subprovince occurs in the area. The Richtersveld Subprovince is characterised by the low to medium metamorphic grade Sperrgebiet Domian, Vioolsdrif Domain (occurring in the area), and Pella Domain (**Figure 2-7**).

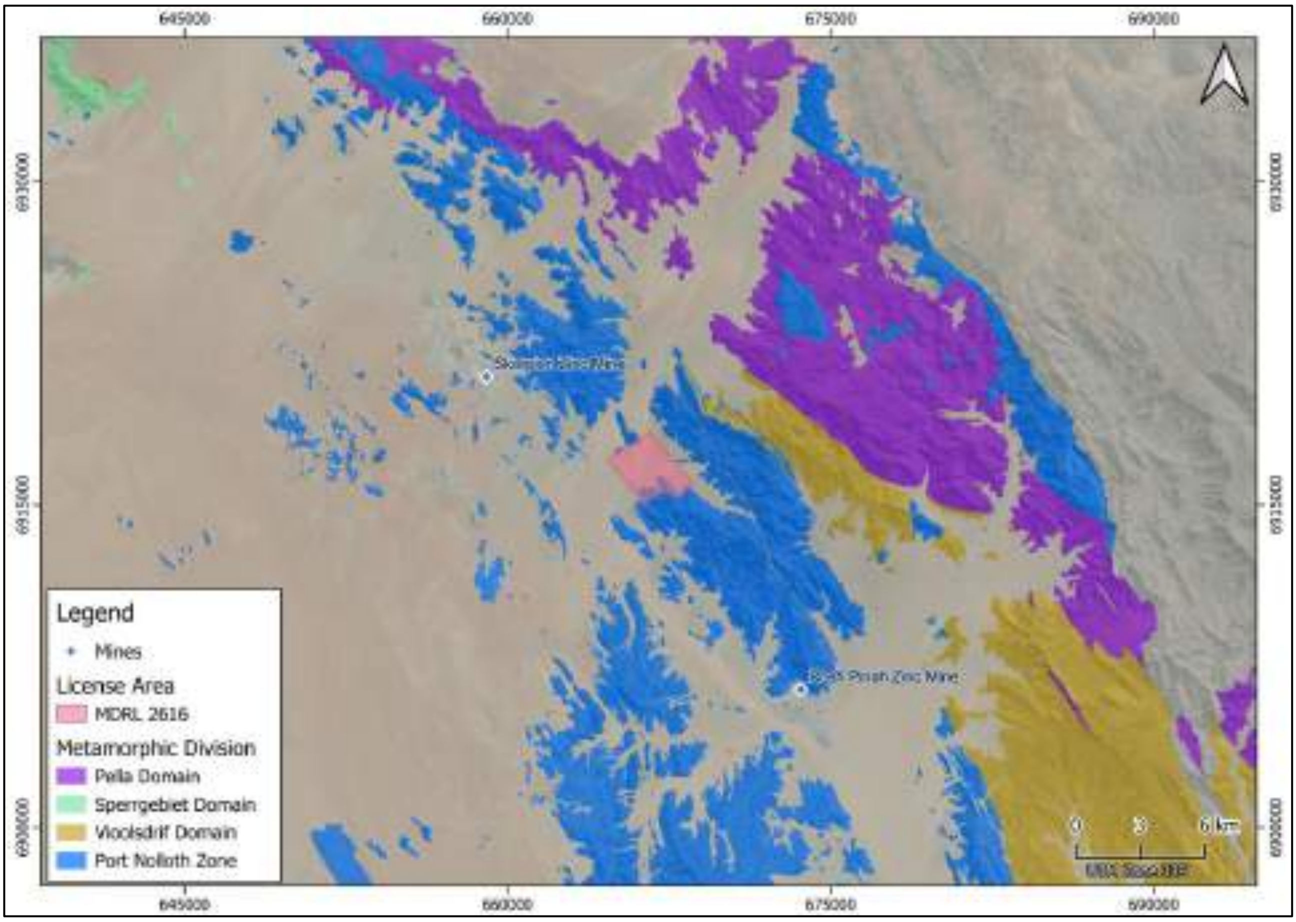

Figure 2-7 **Map depicting the regional metamorphic divisions which are related to particular metamorphic grade and orogenic events.**

The oldest rocks of the area are the foliated schists and gneisses of the Nudavib Complex, which are ~2000 Ma old metasedimentary and metavolcanic deposits, outcropping ~15 km north of the site. These were previously thought to be tectonised equivalents of the Orange River Group, but recent zircon dating has shown that they are older. Also outcropping to the north are the migmatites and orthogneisses of the Sperrgebiet Arc (Sperrgebiet Domain), and the schists and quartzites of the Aurus Group, forming the Aurus Mountains. The ~1910-1865 Ma Orange River Group volcanic and plutonic rocks were intruded by the ultramafic to felsic Vioolsdrif Intrusive Suite, making up the Vioolsdrif Domain, both of which outcrop ~10 km west and ~2.5 km east of the site, respectively. These intrusives include the Garseep Granodiorite and the Harisberg Granite. These rocks were deposited prior to any tectonic activity and were first deformed by the Orange River Orogeny occurring ~1900 Ma. The other domains (Pella and Sperrgebiet) occur outside of the study area and are not discussed. The Vioolsdrif domain rocks underwent relatively low grade metamorphism during the Namaqua Orogeny.

Following the Namaqua Orogeny (Namaqua-Natal Metamorphic Province), a series of intrusions occurred. These are the pre-continental-breakup Richtersveld Intrusive Suite, the syn-rift mafic Gannakouriep Suite, and the pre-orogenic Spitskop Complex and Koivib Amphibolite Suite, with only the latter two occurring in the area. The Spitskop Complex is a ~770 Ma old succession of felsic/rhyolitic lava, agglomerate, lapilli tuff and ash flow deposits, as well as some granitic intrusions, and is closely associated with the Rosh Pinah Formation of the Port Nolloth Group. The volcanic centre (directly to the east of the site) is located on the same farm Spitskop 111 after which it is named. These pinkish volcanic units, outcropping in the mountains east of the site, display feldspar phenocrysts (large crystals) in a quartz biotite matrix with minor pyrite, pyrrhotite, sphalerite, marcasite, magnetite, and graphite. The mafic Koivib Amphibolite Suite, consisting of basalts and gabbros, is closely associated with the Hilda Subgroup of the Port Nolloth Group. These mafic intrusives are tightly folded and recrystallised, and outcrop largely to the north and northwest of the site but also to the south and southeast.

Concurrent with these intrusives are the rocks of the low metamorphic grade Gariep Belt, i.e., the Gariep Supergroup. The Port Nolloth Group (i.e., Port Nolloth Zone) is dominant in the area (**Figure 2-7**) and consists of metasedimentary rocks with minor volcanics and intrusions. Within the Numees Thrust Subzone, where the site occurs, are the Rosh Pinah, Pickelhaube, Wallekraal, and Dabie River formations (Hilda Subgroup), the isolated Numees Formation, and the Daberas Formation (Holgat Subgroup). Only the Rosh Pinah and Pickelhaube formations occur on the site, along with the Spitskop Complex and Koivib Amphibolite Suite. The Hilda Subgroup is a succession of sandstones, shales and carbonate rocks deposited in a shallow marine environment within a rift graben. Overlying is the Numees Formation glacial diamictites, minor shale and greywacke, outcropping to the south along the hanging wall of the Numees Thrust (which extends through the site area). The Daberas Formation of the Holgat Subgroup overlies the Numees Formation to the south and east of Rosh Pinah and consists of carbonate rocks metamorphosed into low-grade marbles, with minor arenitic and siltstone/pelite units, representing deeper marine deposition.

The next depositional phases led to the formation of the Nama Group. Most of the Great Escarpment occurring eastwards of the site consists of Nama Group sandstones, shales and shallow marine carbonates, however, they are not discussed as the outcrops occur far from the site. Overlying the Port Nolloth Group on site is the Namib Group spanning in age from ~3 Ma to present. The Sossus Sand Formation makes up the mobile aeolian dunes of southwestern Namibia and can be seen in the distance to the west of site. The dunes are predominantly longitudinal in a NW-SE to N-S direction, while barchanoid dunes do occur locally. Unconsolidated quaternary deposits also occur constituting river alluvium and talus fans in the vicinity of drainage lines, gravels separating river braids, and a mix of sand, gravel, scree, and calcrete in all other areas (Geological Survey of Namibia, 2019).

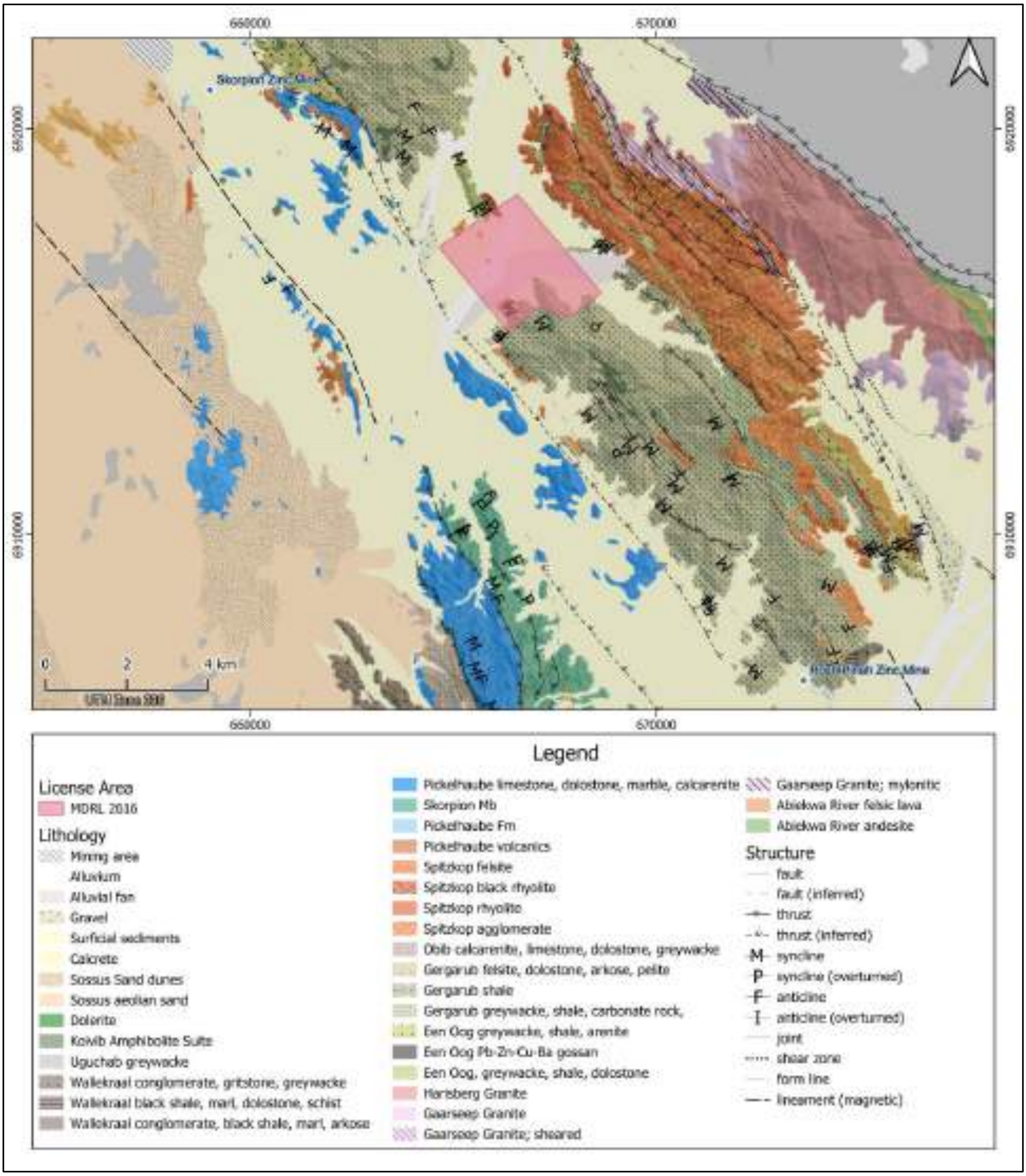

Figure 2-8 **1:250 000 2716 Ais-Ais geological map of the area, showing rocks and quaternary deposits within the Vioolsdrif Domain and Port Nolloth Zone. The greyed out area in the top right corner is outside of these domains.**

Table 2-3 Stratigraphy of the regional area, with grey highlighted formations being present on site (adapted from Geological Survey of Namibia, 2019).

Stratigraphy of the Site Area					
Age (Ma)	**Supergroup**	**Group**	**Subgroup**	**Formation**	**Intrusive**
~0-3	-	-	-	Quaternary Deposits (Alluvium/Talus fan/Gravel/Sand/Calcrete)	-
	-	Namib Group		Sossus Sand	
~200	-				Karoo Dolerite Dyke
~545	Gariep Orogeny				
~635	Gariep Supergroup (Gariep Belt)	Port Nolloth Group (Port Nolloth Zone)	Holgat (Numees Thrust Zone)	Debaras Formation	-
~716			-	Numees Formation (Numees Thrust Zone)	
~740-770			Hilda (Numees Thrust Zone)	Dabie River Formation	
				Wallekraal Formation	
				Pickelhaube Formation	
				Rosh Pinah Formation	Spitskop Complex / Koivib Amphibolite Suite
~1200	Namaqua Orogeny				
~1850	Orange River Orogeny				
~1900	Pretectonic Units (Richtersveld Subprovince)	Orange River (Vioolsdrif Domain)	De Hoop	Kuams River	Vioolsdrif Intrusive Suite
				Abiekwa River	
~2000		Aurus			-
		Sperrgebiet Arc (Sperrgebiet Domain)			Wasserkuppe Suite / Roter Kamm Granite
		Nudavib Complex			

2.7.2. Local Geology

The geology local to the site is dominated by the Rosh Pinah Formation, along with the Spitskop Complex and Koivib Amphibolite Suite. The Spitskop Complex and Koivib Amphibolite Suite outcrop within the valley directly to the east of the site. The Spitskop felsics have the volcanic centre here, reaching a thickness of up to 15 km. These volcanics are interfingered with the Rosh Pinah Formation and occur as black (due to presence of graphite) rhyolite on the inselberg within the Zebrafontein Valley (**Figure 2-10**) adjacent to the Een Oog Member (Rosh Pinah Formation). In the mountains to the east and a small wedge on the southern portion of the site, the Spitskop Complex outcrops as typical pink rhyolite, agglomerate, and tuff (**Figure 2-11**). The Koivib Amphibolite Suite is testament to the bimodal nature of the Rosh Pinah magmatic episode. These mafic intrusions are between ~5-120 m thick, outcrop in the mountain to the south of the site within the Gergarub Member (Rosh Pinah Formation) and are likely to be intersected during underground mine construction.

The Rosh Pinah Formation exceeds ~850 m in thickness in the area and is the host formation of the zinc-lead ore zones, consisting of the Een Oog, Gergarub, and Obib Members (the latter not occurring locally). The large inselberg in the valley comprises mostly of the Een Oog Member greywackes, shales and dolostones (**Figure 2-10**). Ore zones occur within the minor clastic and carbonate rocks as opposed to the dominant volcanic and volcanosedimentary units. The Gergarub Member, on the other hand, is dominated by a succession of clastic rocks. The ~130 m thick member consists of upward fining greywackes, conglomerates, with minor carbonates schist, coarse wackestone, argillite and arkose, and forms most of the Rosh Pinah Mountain outcrops to the south of the site (**Figure 2-12**). The rocks of the Rosh Pinah Formation have undergone intense deformation and there are a series of synclines and overturned synclines occurring on site (**Figure 2-13**). Drilling on site is conducted at angles of 60-70° to accommodate for the intensely folded nature of the formations. While the Rosh Pinah ore deposit is sediment hosted and the Skorpion deposit mainly hosted in volcanic rocks, the Gergarub ore deposit is hosted in both the clastic and volcanic rocks. The common Zn-Pb-Ag minerals include sphalerite, galena, tennantite, tetrahedrite, chalcopyrite, and bornite. Pyrite is a common mineral as well which is known to cause acid mine drainage issues that can impact the groundwater quality (Geological Survey of Namibia, 2019). **Figure 2-9** shows a 3D rendition of the ore zones that were discovered below the ~60-100 m of alluvial cover, extending to depths of ~500 m with a similar lateral extent. The geometry is complex due to the tectonic deformation and alteration that the rock has undergone, and the deposits dip at angles of 26-45° (Gergarub Exploration and Mining, 2023).

Rock outcrops are limited to the mountains as most of the lower lying area has been covered by unconsolidated Quaternary deposits. An alluvial/talus fan crosscuts the site in a general east to west direction, originating from the valley shown in **Figure 2-11**. The main Zebrafontein Catchment drainage lines are comprised of alluvium transported from the northeast to the southwest. The rest of the valley is covered by a mixture of sand, gravel, scree, and in some areas calcrete (Geological Survey of Namibia, 2019). These deposits are up to ~100 m thick on site, upon which the surface mining infrastructure will be constructed.

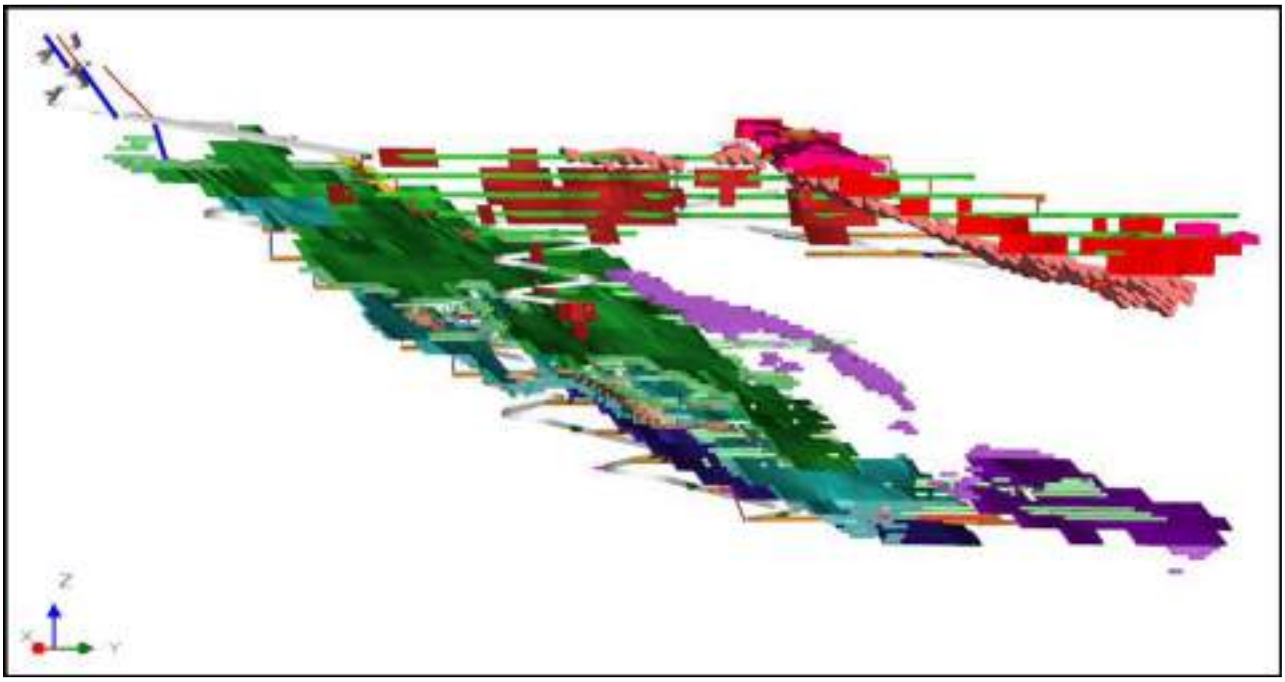

Figure 2-9 Modelled ore bodies of the Gergarub deposit (Gergarub Exploration and Mining, 2023).

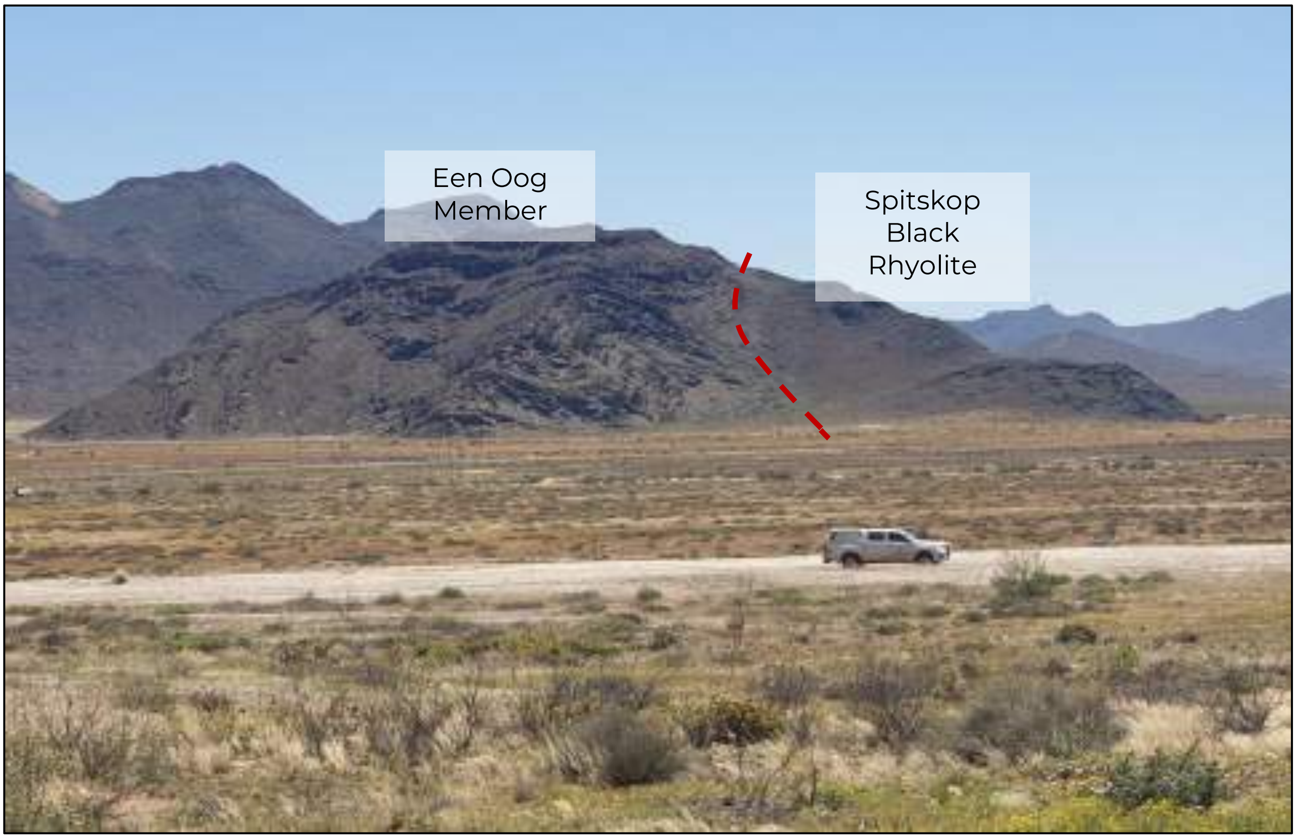

Figure 2-10 Outcrops of the large inselberg in the Zebrafontein Valley

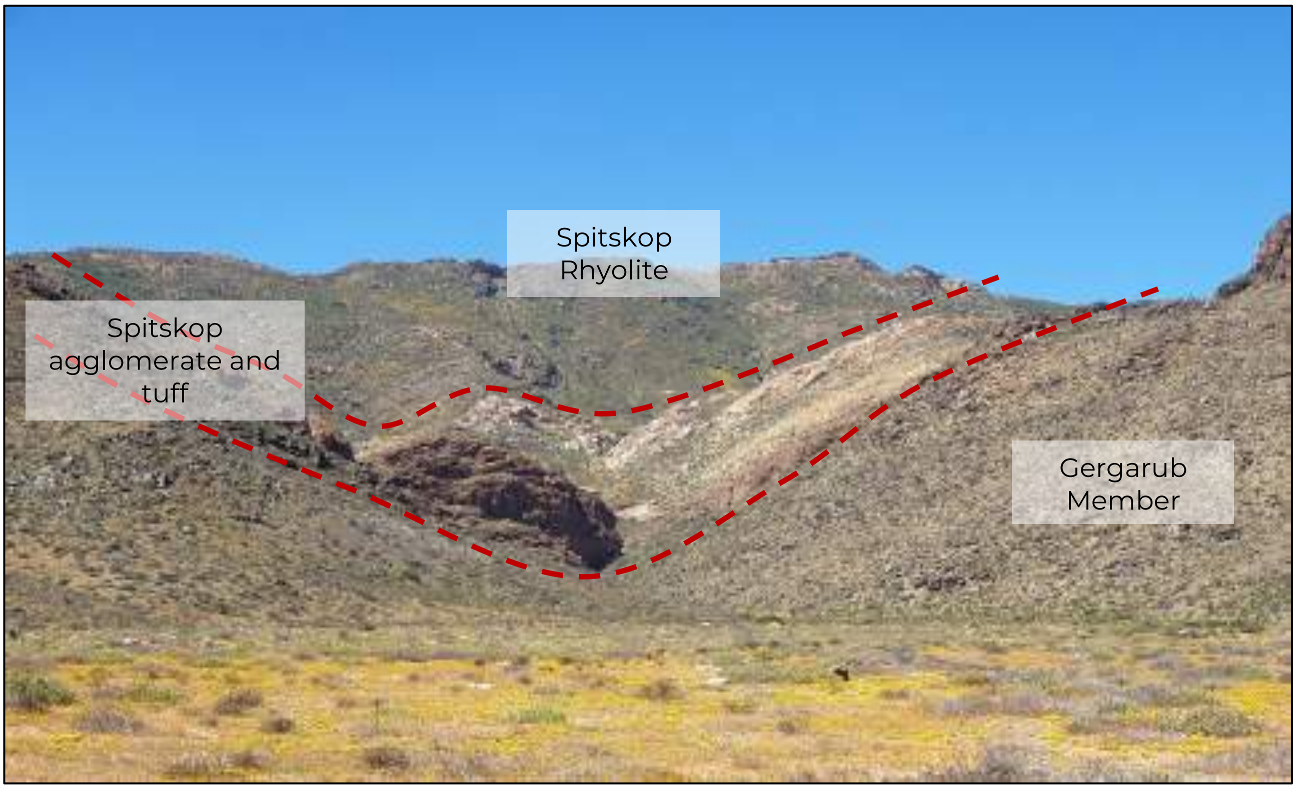

Figure 2-11 Outcrops of the large, incised valley to the northeast of the site

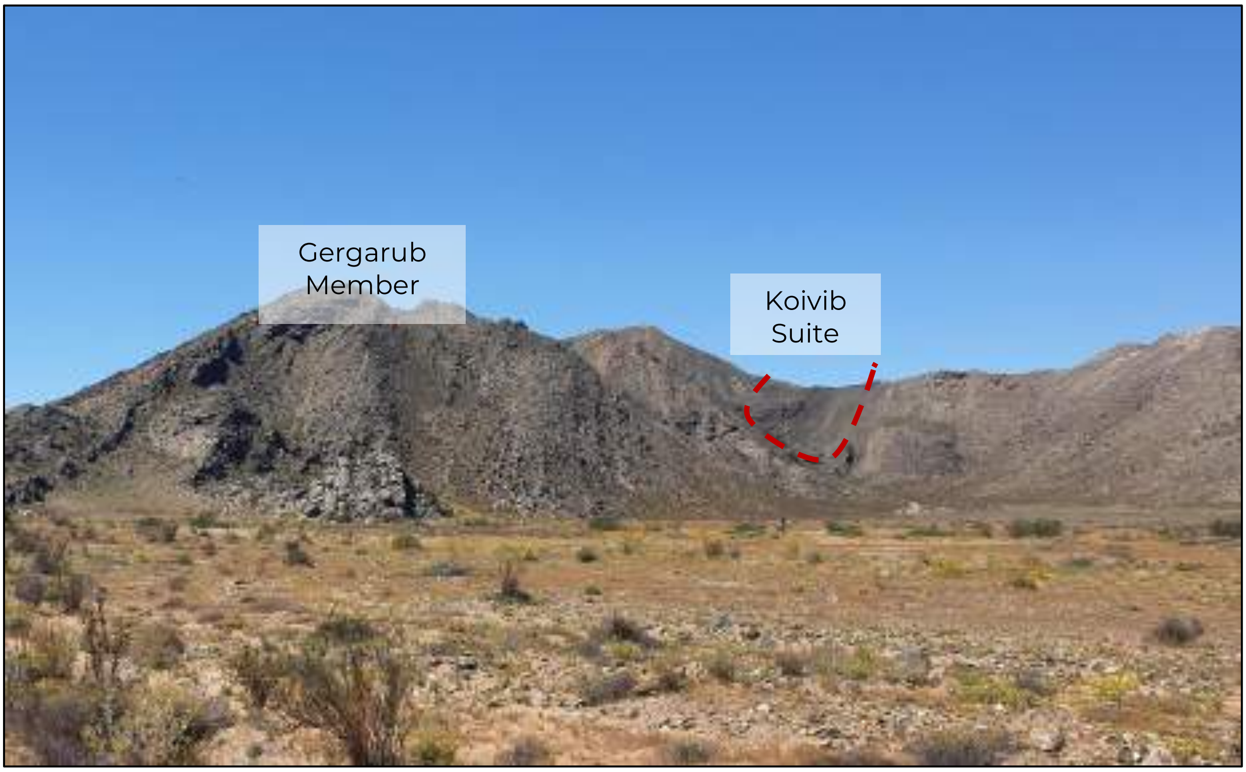

Figure 2-12 Outcrops to the south of the site (Rosh Pinah Mountains)

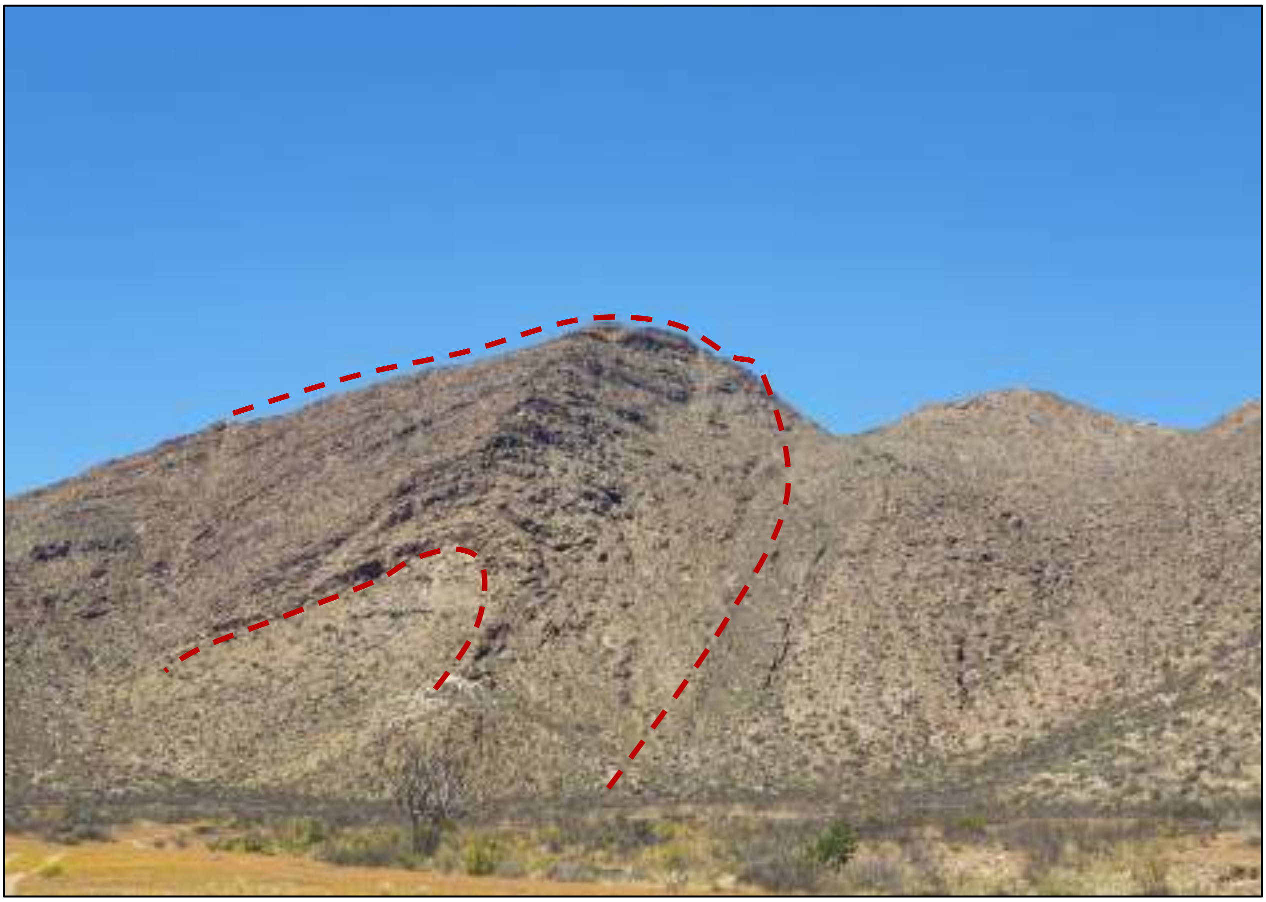

Figure 2-13 An overturned syncline on the southeastern edge of the site near the proposed TSF.

2.8. Hydrogeology

Namibia is arid with very high temperatures and low rainfall, hence, there are no prominent aquifers in the area and literature-based descriptions of the hydrostratigraphy are lacking. The Atlas of Namibia (**Figure 2-14**) shows hard rock (secondary) aquifer types with very low and limited potential, to generally low and locally moderate potential in the area. These aquifers are dependent on the presence of fractures and faults within the deformed and metamorphosed rocks. The Quaternary overburden is not shown as an aquifer in **Figure 2-14**, however, it is likely to act as an unconfined, primary, intergranular aquifer with varying thickness and saturation. Extensive hydrogeological investigations were conducted by SRK consulting (Skorpion Mining Company, 2014b), including geophysics, drilling, aquifer testing, and groundwater quality, and isotope analysis, which forms the basis for hydrogeological understanding. A site visit and hydrocensus was also conducted in October 2023 to improve hydrogeological understanding and obtain updated and spatially representative groundwater levels to produce a groundwater level map.

Figure 2-14 Aquifer type and potential map for the Gergarub Area taken from the Atlas of Namibia (2022).

2.8.1. Hydrocensus

An initial hydrocensus was conducted in April 2013 by SRK (Skorpion Mining Company, 2014b) which included measurements of groundwater levels and groundwater quality sampling. A second hydrocensus was undertaken by Umvoto in October 2023, which consisted of a site walkover and groundwater level measurements. Two basic water quality measurements were also taken at two pumping boreholes on site. The borehole locations visited on both occasions are shown in **Figure 2-15**, the results of each are shown in **Table 2-4** and **Table 2-5**.

The 2013 hydrocensus recorded borehole information as far as ~20 km away from the site (Süd Witputz boreholes). One water level of ~9.94 mbgl was recorded here but is far away on different geological and aquifer system and is likely not representative. An old but dry shallow hand dug well was found in the kloof to the east of the site as well. It was stated that adjacent property owners use groundwater to supply livestock, however, no livestock was seen in the recent hydrocensus and the residents of the homestead to the north reported that water is received from Skorpion Mine (via NamWater supply). It is suggested that, should any impacts arise to surrounding properties, Gergarub Mine should offer the same.

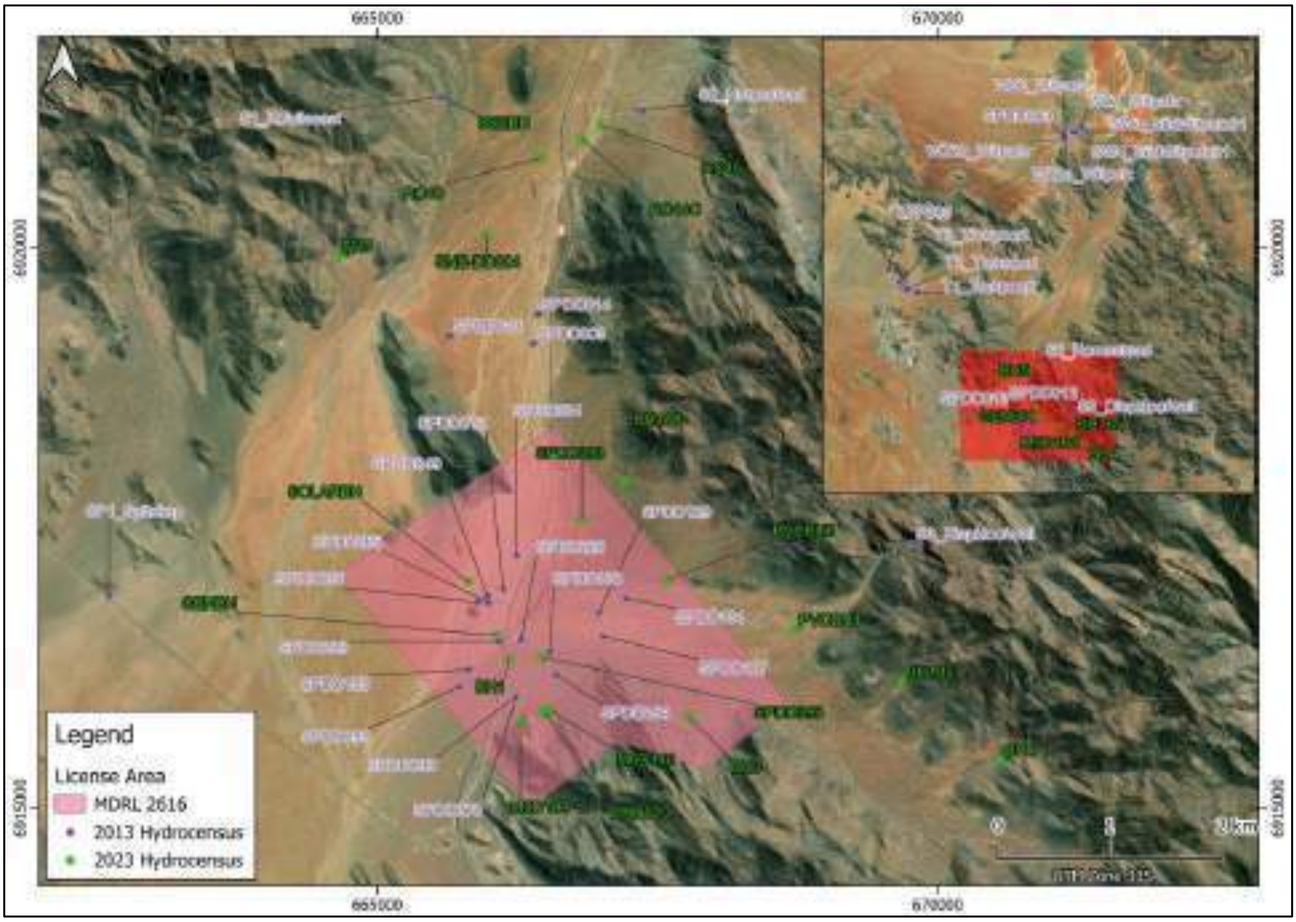

Figure 2-15 Map showing the locations visited during the 2013 and 2023 hydrocensus.

Most of the groundwater levels of the 2013 hydrocensus were concentrated central to the site. The 2023 hydrocensus provided a wider spatial distribution of water levels to understand the flow of groundwater across the site. Note that many boreholes are drilled at angles of ~60-70° and measured groundwater levels were corrected to represent true depths (which many lead to some inaccuracy). It was also found that two boreholes were being pumped (**Figure 2-16**), i.e., Solar BH and Gen (generator) BH, for water used in drilling on site. It was reported by drillers that these boreholes are being pumped at ~3.5 m^3/h (~1.0 l/s) each for most of the day, and that Solar BH only shows ~0.3 m of drawdown, implying it is in a relatively transmissive area. Solar BH is believed to be GB-GH-BH1 and shows an average transmissivity of ~19.5 m^2/day according to test pumping results (Skorpion Mining Company, 2014b). Basic water quality of EC, pH and Temperature, was measured using a handheld probe at both of these boreholes with values of 304.5 mS/m, 6.7 pH, and 36.0°C, and 422.1 mS/m, 6.36 pH, and 54.5°C for Solar BH and Gen BH, respectively. The high temperature is due to the pipe heating in the sun, while pH is slightly alkali and EC is just above typical drinking water standards although the water was salty to the taste. Gen BH is believed to be GB-GH-BH3.

Figure 2-16 SolarBH (left) and GenBH (right) being pumped at ~3.5 m^3/h for use in drilling on site.

Table 2-4 Results of the hydrocensus conducted in 2013 by SRK Consulting (directly from Skorpion Mining Company, 2014b). WL means water level and ORP means oxidation reduction potential (in milliVolts).

Borehole ID	Latitude	Longitude	WL (mbgl)	pH	EC (mS/m)	Temperature (°C)	ORP (mV)	Colour, Odor, Sediment	Comment
S2_Homestead	-27.82323	16.69929	71.36	7.25	302	25.7	46	Clear, no, no	Wind pump not equipped
S3_Diepkloofwell	-27.85776	16.72426	3.21	7.44	554	26.7	39	Clear, no, no	Dug well.
S1_Koivilseast	-27.82236	16.68110	-	-	-	-	-	-	Cannot sample or measure WL.
SP1_Spitskop	-27.86286	16.65159	-	-	-	-	-	-	Not a BH (booster mono pump) wind pump inoperable.
T1_Trekpoort	-27.78239	16.61408	-	-	-	-	-	-	Cannot measure WL or CHEM. Previous Pump pipes were 69 m deep.
T2_Trekpoort	-27.7806	16.60685	-	-	-	-	-	-	Abandoned BH.
T3_Trekpoort	-27.77586	16.60207	-	-	-	-	-	-	No BH.
ZFP005	-27.76813	16.59437	-	-	-	-	-	-	Blocked. Approximate coordinates. Co-ordinates not measured during hydrocensus.
SW5_ SüdWitputz31	-27.68150	16.71600	9.94	7.04	802	23.3	49	Clear, no, no	Not surveyed in previous hydrocensus
SW3_SüdWitputz31	-27.68100	16.72115	-	6.84	278	29.2	32	Clear, no, no	Cannot measure WL at wind pump.
SW3_SüdWitputz31	-27.68100	16.72115	-	-	-	-	-	-	Could not measure WL. Solar pump.
SW4_SüdWitputz31	-27.68100	16.72163	-	7.11	150	23.8	52	Clear, no, no	Equipped with solar pump. Cannot measure WL.
WZ1_Witputz	-27.67790	16.72752	-	6.82	702	27.5	85	Clear, no, no	Equipped with wind pump. Cannot measure WL.
WZ2_Witputz	-27.68321	16.71534	-	-	-	-	-	-	Collapsed.
WZ2a_Witputz	-27.68484	16.71573	-	-	-	-	-	-	Equipped with solar pump. Cannot measure WL.
WZ2b_Witputz	-27.68560	16.71567	-	-	-	-	-	-	Equipped with solar pump. Cannot measure WL.
SPDD003	-27.68430	16.71573	84.44	7	288	24.6	-160	Dark grey, organic, yes	Dip meter filled with mud.
SPDD004	-27.85917	16.68847	82.87	6.8	213	26.6	-332	Grey, rotten	-

Borehole ID	Latitude	Longitude	WL (mbgl)	pH	EC (mS/m)	Temperature (°C)	ORP (mV)	Colour, Odor, Sediment	Comment
								egg, yes	
SPDD005	-27.86299	16.68503	83.94	6.59	212	29.2	-43	Dark grey, organic, no	-
SPDD009	-27.84209	16.68967	-	6.41	182	25.1	-153.8	Grey, slight odor, yes	Bailed sample.
SPDD012	-27.86187	16.68727	-	-	-	-	-	-	Welded closed.
SPDD013	-27.84159	16.68206	-	6.05	310	20.5	52.3	Black, organic, yes	Bailed sample.
SPDD014	-27.83974	16.69008	-	-	-	-	-	-	Covered with sand.
SPDD049	-27.86253	16.68590	-	-	-	-	-	-	Blocked at 4.87 mbc.
SPDD093	-27.86979	16.68347	-	-	-	-	-	-	Unable to measure WL or chemistry - BH filled with drilling lubricants
SPDD099	-27.87051	16.68863	81.61	6.78	384	27.1	-142	Dark grey, rotten egg, yes	-
SPDD100	-27.86694	16.69162	-	-	-	-	-	-	BH buried - Site Rehabilitated.
SPDD127	-27.8656	16.69642	-	-	-	-	-	-	Bailer gets stuck, cannot sample.
SPDD129	-27.86371	16.69598	-	-	-	-	-	-	Sand and mud in BH, cannot sample.
SPDD134	-27.86249	16.69842	-	-	-	-	-	-	Blocked at 62.29 m.
SPDD154	-27.86873	16.69219	-	-	-	-	-	-	BH buried - Site Rehabilitated.
SPDD159	-27.86841	16.68432	-	-	-	-	-	-	Welded closed.
SPDD228	-27.86595	16.68897	86.9	-	-	-	-	-	BH filled with ECOLUBE - cannot sample.
SPDD265	-27.86302	16.68600	-	-	-	-	-	-	Blocked at 38.68 mbc.
SPDD278	-27.87052	16.68862	-	-	-	-	-	-	BH buried - Site Rehabilitated.
SPDD289	-27.86613	16.68701	79.83	7.01	390	26.7	-120	Dark grey, Yes, yes	-

Table 2-5 Results of the hydrocensus undertaken by Umvoto in October 2023.

Borehole ID	Latitude	Longitude	Elevation (mamsl)	Borehole Depth (m)	Water Level (mbgl)	Water Level (mamsl)	Comment
SPDD395	-27.867322	16.690875	628.98	178.00	88.44	540.55	-
BH1	-27.867534	16.687921	618.74	-	73.14	545.60	-
M9D120	-27.871776	16.691184	620.96	51.00	-	-	Measured dry at 51.00 mbgl, likely due to collapse or obstructions.
M6D146	-27.871560	16.691636	618.57		73.50	545.07	-
BH3	-27.872018	16.704234	658.69	-	41.15	617.54	-
M9D104	-27.872473	16.689014	611.96	-	73.93	538.03	-
BH188	-27.852906	16.698072	650.89	-	66.46	584.43	-
SPDD393	-27.856159	16.694352	635.90	800.00	58.41	577.49	-
PVCBH1	-27.864823	16.713753	677.52	36.85	-	-	Measured dry at 36.85 mbgl, likely due to collapse or obstructions.
BH185	-27.868955	16.723564	727.15	60.00	48.94	678.21	
BH4	-27.875089	16.732623	750.64	-	54.38	696.26	
PVCBH2	-27.860974	16.702120	646.34	-	63.13	583.21	
SOLARBH (GB-GH-BH1)	-27.861322	16.684109	622.25	-	78.85	543.40	BH pumped at ~3.5 m^3/h (~1.0 l/s). EC = 304.5 mS/m; pH = 6.7, Temp =36.0°C
GENBH (GB-GH-BH3)	-27.865649	16.686802	614.83	-	76.13	538.70	BH pumped at ~3.5 m^3/h (~1.0 l/s). EC = 422.1 mS/m; pH = 6.36, Temp = 54.5°C
BH5	-27.835283	16.672197	671.69	-	-	-	Shallow obstruction in BH
BEEBH	-27.822345	16.681167	701.65	-	-	-	Not accessible due to beehive.
RC40	-27.827119	16.690253	697.94	-	-	-	Shallow obstruction in BH.
SNE-DD004	-27.833385	16.685400	681.03	602.65	86.84	594.18	-
RC45	-27.824431	16.695548	707.35	63.60	-	-	Measured dry at 63.6 mbgl, likely due to collapse or obstructions.
RC44	-27.825491	16.693859	702.61	-	-	-	Shallow obstruction in BH.

2.8.2. Aquifer Characterisation

Electrical Resistivity Tomography (ERT) geophysical surveying was conducted across the area, with investigative depths up to ~75 m. The findings confirm that overburden thickness is generally deepest towards the centre of the site and decreases towards the mountain areas but is locally undulating. The presence of the Zebrafontein Fault was seen and confirmed with several drill logs. Surveys at the TSF site indicated a potential fault beneath 15-50 m of overburden (Skorpion Mining Company, 2014b).

While some confidence is provided in the depth to bedrock, i.e., the overburden thickness, the depths and characterisation of the underlying units of Rosh Pinah Formation are not well known. Therefore, interception depths of various units, which may have differing aquifer characteristics, is not understood. Care must be taken with regards to water inflows when intercepting good aquifer units during mine construction. It may be likely that the coarser clastic sediments (conglomerates, arkose, and greywacke) of the upper Gergarub Member may act as higher yielding aquifer units, particularly in fractured zones. The carbonate schist units are expected to be slightly poorer aquifers due to foliation, but presence of fractures may make for good aquifer properties. Wackestone and argillite is expected to act as aquitard/aquiclude units (with low transmissivity) and may provide confining conditions that separate aquifer units if not severely fractured/faulted. The same is true for the greywackes and shales of the lower Een Oog Member at depth, while the dolostone units may act as karst aquifers with high transmissivity if dissolution has taken place and cavities have formed. Evidence of this may be found in core drill logs (which were not provided for this study). The aquifer properties of the Spitskop and Koivib intrusives can be highly variable depending on cooling rate and thickness. Rapid cooling provides increased porosity, and fracturing caused during emplacement can also lead to good aquifer conditions on the intrusive body peripheries. With the intense deformation that all rock units have undergone, it is possible that they are all connected and form one or two larger aquifers (as supported by groundwater levels).

Seven percussion boreholes were drilled (**Table 2-6**) and the logs confirm overburden thicknesses of ~12 - 108 m, with the underlying units dominated by mudstones, greywackes, and arkoses. Only one instance of rhyolite was recorded in GB-GH-BH02. It is noted that these borehole depths range from ~103-330 mbgl, hence, no data is available for depths greater than ~330 mbgl. GB-GH-BH4 and GB-GH-BH5 are the only boreholes drilled into the overburden. These two boreholes had maximum abstraction yields of 1.5 and 2.1 l/s, respectively, with transmissivities of 1-3 m^2/day. The transmissivities of boreholes within the fractured bedrock ranged from <1-17 m^2/day, indicating variable degrees of fracturing. Storage values are relatively low, with the fractured aquifer ranging from 0.0002-0.0036, and the intergranular aquifer range from 0.02-0.06. Packer test results showed hydraulic conductivities of fracture zones being ~1.4 m/day. GB-GH-BH1 (Solar BH) and GB-GH-BH3 (Gen BH), being 147 m and 166 m deep, are being pumped at ~3.5 m^3/hr (1.0 l/s) for use in drilling on site.

Surface infiltration tests using double ring infiltrometers and mini disk tension infiltrometers were also conducted, which provides insight into potential recharge mechanisms. The infiltration rates (unsaturated hydraulic conductivity) ranged from 6-15 m/day and show Kostiakov predicted infiltration rates of 5-7 m/day over long periods of saturation. This is important for the TSF facility as continuous leakage/spills could cause saturation of the subsurface and infiltration of contamination plumes to the groundwater. This relatively high infiltration rate, as expected with unconsolidated alluvial sediments, also implies that water will infiltrate rapidly. However, rainfall is scarce and evaporation is extremely high, leading to low recharge rates of up to 0.5 mm/a (Skorpion Mining Company, 2014b). Any water that does manage to infiltrate the overburden primary aquifer will likely pool on the contact with underlying fractured bedrock and recharge the fractured aquifer at a slower rate. However, inter-aquifer connectivity needs to be investigated and confirmed. There is potential that dewatering the lower fractured aquifer will result in downward leakage from the upper intergranular aquifer, leading to increased and/or sustained inflows, as well as inevitably dewatering both aquifers.

Table 2-6 **Details of the seven boreholes drilled as part of the site investigations (Skorpion Mining Company, 2014b).**

Borehole ID	Latitude	Longitude	Overburden Depth (mbgl)	Final Depth (mbgl)	Water Strikes (mbgl)	Blow Yield (l/s)	Rest Water Level (mbgl)	7 inch' Steel Casing Depth
GB-GH-BH1	-27.86123	16.68416	33	147	84, 144	10	84.99	60 m solid
GB-GH-BH2	-27.86633	16.68922	102	330	102, 130, 171	0.21	84.27	103 m solid
GB-GH-BH3	-27.86565	16.68682	45	166	119	4.9	80.05	80 m solid
GB-GH-BH4	-27.86775	16.68833	100	103	100	0.077	80.64	96.6 m solid; 6 m slotted
GB-GH-BH5	-27.86675	16.69053	106	111	94	0.31	83.61	93 m solid; 18 slotted
GB-GH-BH6	-27.87002	16.70316	17	150	65	1.8	49.95	45 m solid
GB-GH-BH7	-27.86934	16.70272	14	250	52	-	58.4	30 m solid

2.8.3. Groundwater Levels and Flow

The regional groundwater flow is towards the Orange River along the Zebrafontein Valley and Rosh Pinah Valley, with a spring existing near Sendelingsdrif (~30 km away) at the Orange River (Skorpion Mining Company, 2014b). The area is dry, with groundwater levels being relatively deep (~50-90 mbgl) and little to no evidence of spring occurrence or surface water bodies seen near site, hence groundwater-surface water interaction is likely not a concern. The groundwater levels recorded in the 2023 hydrocensus provide a good spatial distribution at site and have been interpolated to derive the groundwater level map (**Figure 2-17**). Drainage lines were used as controls for the interpolation.

Groundwater levels follow the general topography and are highest within the mountainous areas, particularly towards the east, decreasing towards the valley plains. Flow is directed southwest across the site along the Zebrafontein Valley, where it will eventually flow southwards to the Orange River. In the centre of the site, groundwater levels are ~73-89 mbgl offering a thicker vadose (unsaturated) zone which offers natural mitigation through attenuation to groundwater contamination. However, at the location of the TSF, groundwater levels are far shallower at ~41 mbgl, reducing the advantage of natural protection.

It is noted that groundwater levels have been corrected for true depth due to borehole inclinations of 65°, under the assumption that the boreholes are drilled at angles of 60-70° (as reported by drillers on site). Without knowing the drilling details this is only an estimation, and the groundwater levels may be slightly inaccurate. The construction and lithologies intercepted by the boreholes are also not known, so there is uncertainty as to which aquifer units the water levels represent. For the purpose of interpretation, it is assumed that all aquifer units (overburden and underlying fractured bedrock) are hydraulically connected. This is not an unreasonable assumption with the intense deformation that the rocks have undergone and is supported by no existing outliers.

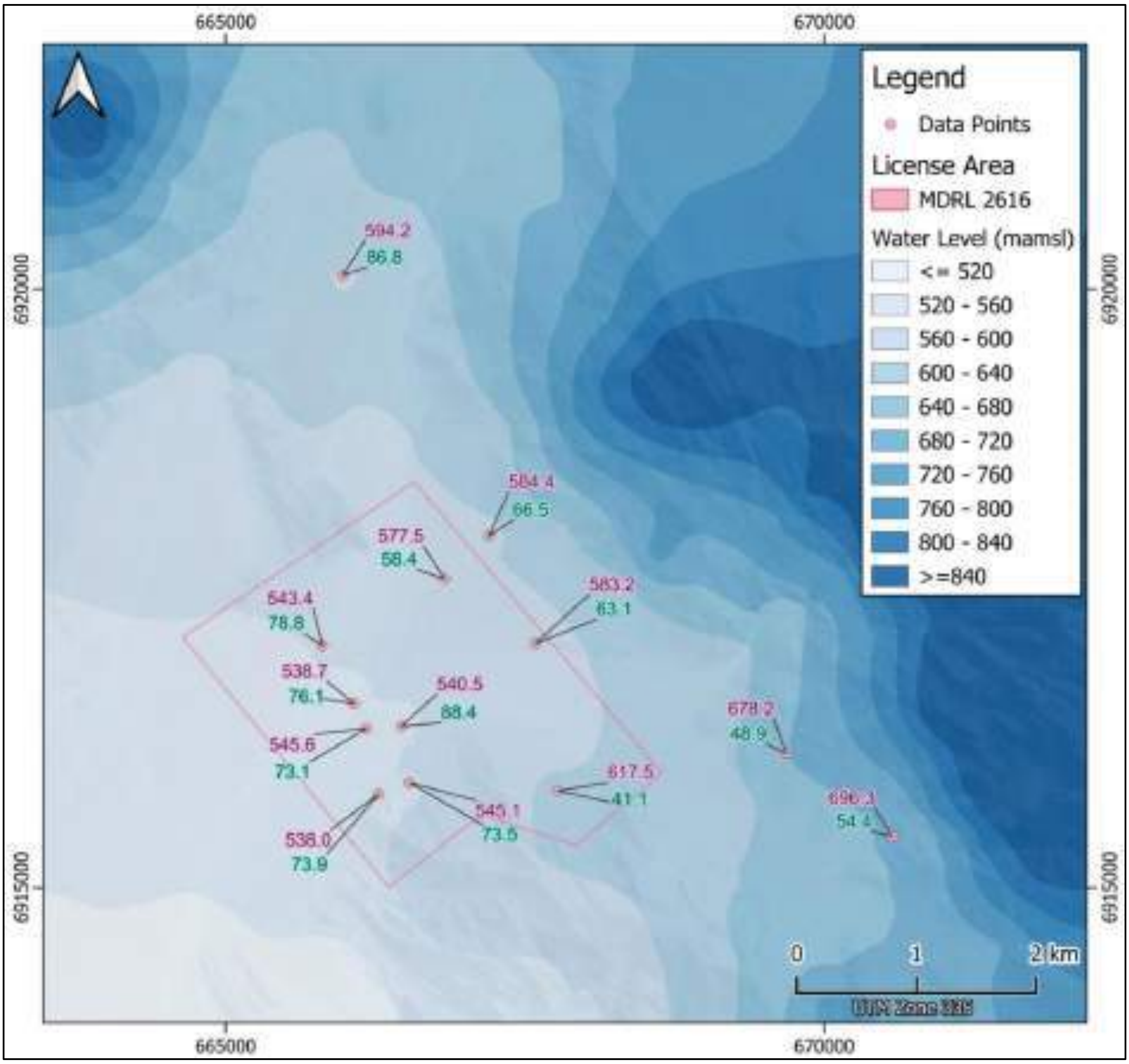

Figure 2-17 **Interpolated groundwater level map of the project area. The groundwater elevation (mamsl) is shown with the pink label, while the groundwater level (mbgl) is shown with light turquoise. Drainage lines were used as controls for interpolation.**

2.8.4. Hydrochemistry

The Atlas of Namibia (2022) water quality map (**Figure 2-18**) shows water quality in the area grouped as Class B and Class D. The former implies water is safe for farms and small communities while the latter means water is not suitable for animal or human consumption. Hydrochemical results (**Appendix C**) of samples taken during the hydrocensus in 2013 (Skorpion Mining Company, 2014b) are classified as Class B, apart from GB-GH-BH6 and GB-GH-BH7 which are classified as Class D. These two boreholes are at the proposed TSF site, indicating existing poor quality baseline values. The groundwater is mostly of sodium-chloride and calcium-sulphate type waters and was salty to the taste. pH was slightly acidic to slightly alkali (6.22-7.70) and EC, ranging from 163-900 mS/m, is noted to be lower along the river channels which is consistent with newly recharged waters as opposed to older fossil waters. The EC and pH values are consistent with measurements taken by Umvoto in October 2023. Iron, manganese, and calcium in the groundwater may pose infrastructural issues (corrosion and scaling). It must be noted that the hydrochemistry of GB-GH-BH7 and

GB-GH-BH6, located at the TSF site, is of poorer quality compared to the other samples. This observation is poorly understood and warrants further investigation. Isotope results showed that groundwater age varies from sub modern (prior to 1950s) to modern (5-10 years) (Skorpion Mining Company, 2014b).

A rock elemental abundance analysis showed that bismuth, cadmium, lead, uranium, and zinc are enriched in the rock material as geogenic sources, with cadmium and lead mostly present in the rhyolite and greywackes and uranium in carbonaceous mudstones (Skorpion Mining Company, 2014d). These contaminants are most likely to be become enriched in groundwater as rocks are exposed to atmosphere (underground and on surface) and minerals are oxidised.

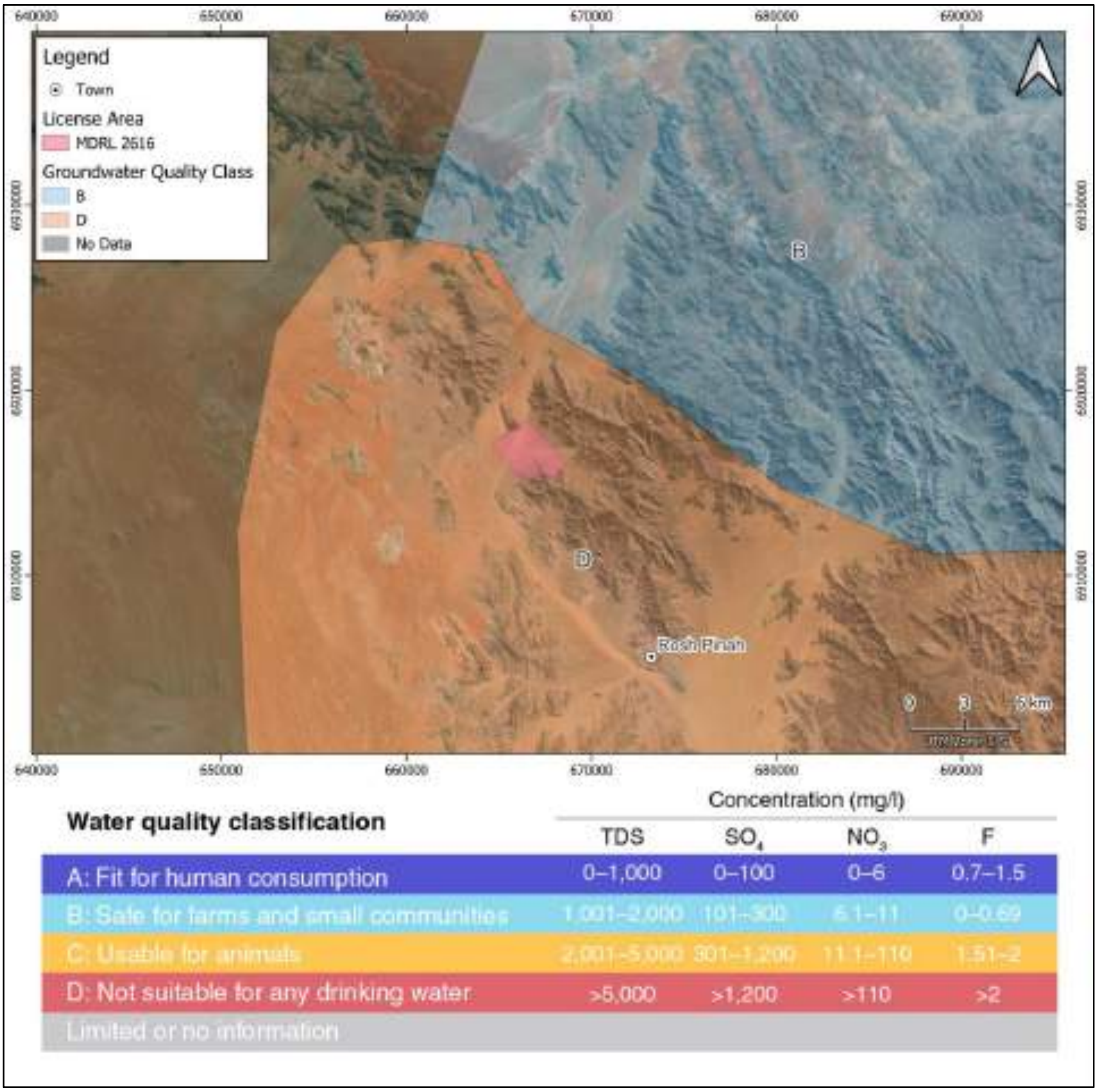

Figure 2-18 Water quality map taken from the Atlas of Namibia (2022).

The construction and operation of the mine (further summarised in **Section 2.8**) is expected to have impacts on groundwater quality, with baseline values for certain hydrochemical parameters shown in **Table 2-7** (Skorpion Mining Company, 2014d). Acid mine drainage caused by common sulphide minerals will have detrimental impacts on surrounding water quality. Pyrite oxidation produces the most acidity, more than other sulphides of covellite, chalcocite, sphalerite, and galena, for example, and the only acid buffering capacity is offered by the minor dolomite and calcite minerals present outside of the ore zone. Addition of cement to the stope backfill material will also increase neutralisation potential. Rock leachate tests show that aluminium, arsenic, beryllium, molybdenum, antimony, thallium, vanadium, and potassium will likely exceed baseline concentrations while cadmium, copper, iron, manganese, tin, strontium, thorium, titanium, zinc, and zirconium have no groundwater baseline values for comparison (but will likely increase as well). However, due to the relatively poor productivity of the aquifers, low rainfall and recharge in the area, leachate generation potential is considered low, aiding in reducing impact severity (Skorpion Mining Company, 2014d).

The recovered ore will be crushed and milled and concentrate extracted, while the pyrite-rich waste disposed to the TSF. Dynamic Tailings reactions were recorded for a period of 40 weeks, although only 15 weeks of results have been provided. The results indicate that pH is neutral to slightly alkali and alkalinity remained relatively constant at 36-77 mg/l for the 15 weeks, confirming the presence of carbonate minerals that act as buffering capacity for acid generation. This aids in reducing the severity of impacts to water quality. Elevated major ions (SO_4, Ca, Mg, Na and K) and manganese, zinc, and lead are present for the first three weeks after which it decreases rapidly; this is attributed to initial flushing of weathered rock material (Skorpion Mining Company, 2014d).

Table 2-7 Average Baseline Groundwater Quality for certain metals/metalloids in the Gergarub Project area (Skorpion Mining Company, 2014d).

Metal/Metalloids	Average Baseline (mg/l)
Al	0.09
As	0.0048
Ba	0.42
Be	0.16
Bi	<0.0006
Cd	0.01
Co	0.01
Cr	0.01
Hg	<0.002
Mo	0.01
Ni	0.02
P	0.31
Pb	0.01
Sb	<0.003
Se	<0.003
Si	14.37
Tl	<0.003
U	<0.005
V	0.003
Ca	120
K	21
Mg	43
Na	265

2.8.5. Conceptual Model

Through the description of the various site components, a conceptual understanding of the natural environment is developed, which allows for prediction and evaluation of the potential impacts of the proposed mine on the environment. SRK (Skorpion Mining Company, 2014b) described a detailed conceptual model (**Figure 2-19**) which informed the numerical model. The same is summarised here, with improvements made where applicable.

As **Section 2.4** and **Section 2.7** showed, the mining infrastructure on surface will be built in the middle of an alluvial fan which forms part of the Zebrafontein Valley drainage system. Although rainfall is limited, any surface flows that occur will need to be diverted around the site (**Figure 2-20**) which has impacts on the natural drainage systems, including lags in flow or inundation of areas previously remaining dry. The diversion will need to be engineered to accommodate both the 1:50 year and 1:100 year flood lines, as per the Flood Assessment (**Appendix C**). The site visit revealed a relatively vegetated site, and clearing of vegetation to make way for mine infrastructure may have effects on runoff and infiltration (with recharge already being low at 0.5 mm/a). **Section 2.5** showed that natural soils are likely to be altered into technosols surrounding the mine as with SZM and RPZM.

The overburden is ~100 m thick in the centre of the site with groundwater levels occurring at ~80 mbgl. At the TSF site, groundwater levels are shallower at ~40-50 mbgl offering less natural mitigation of potential TSF contamination. Potential leakage may infiltrate the subsurface and reach the groundwater at rates of 5-7 m/day. Contamination (and other natural groundwater recharge) will infiltrate and pool on the contact with underlying fractured bedrock and recharge the fractured aquifer at a slower rate. Dewatering the mine in the lower fractured aquifer may result in downward leakage from the upper intergranular aquifer, resulting in increased and/or sustained inflows, as well as inevitable dewatering of both aquifers. The connection between the two aquifers is poorly understood but is assumed to be represented in the numerical model.

While some confidence is provided in the depth to bedrock, i.e., overburden thickness, the depths and characterisation of the underlying units of Rosh Pinah Formation are not well known. The underground mine workings will intercept the Rosh Pinah Formation sedimentary and volcanosedimentary deposits with interfingered intrusives of the Spitskop Complex and Koivib Suite. The transmissivity of the fractured bedrock ranged from <1-17 m^2/day, indicating variable degrees of fracturing which may affect mine inflow and dewatering rates and volumes. Depths of individual aquifer and aquitard units and the degree of hydraulic connection is unknown, but the mine may create connection between aquifers resulting in mixing of different water qualities.

Water quality at the TSF is poorer than in other areas which warrants further investigation and care must be taken in the future to avoid mistaking this for TSF leakage. Low rainfall and recharge in the area means that leachate generation is considered low. Baseline values for various chemical parameters have been provided and bismuth, cadmium, lead, uranium, and zinc are expected to become enriched in the groundwater. The mine voids will expose minerals to oxidative conditions which will mobilise contaminants and lead to potential acid mine drainage. Carbonate minerals are present to provide some buffering capacity. Underground explosives will also impact groundwater quality (increase in nitrates).

Groundwater flows towards the west and southwest eventually ending up in the Orange River ~30 km away. This is sufficiently far, and groundwater movement is sufficiently slow to have minimal risk on the important water resource. Additionally, no groundwater users were found in the area with the local homestead and Rosh Pinah receiving water from the Orange River via NamWater. Although some deterioration in groundwater quality is expected, impact severity is low as there are no groundwater dependent users or ecosystems, and the groundwater quality is already of relatively poor quality.

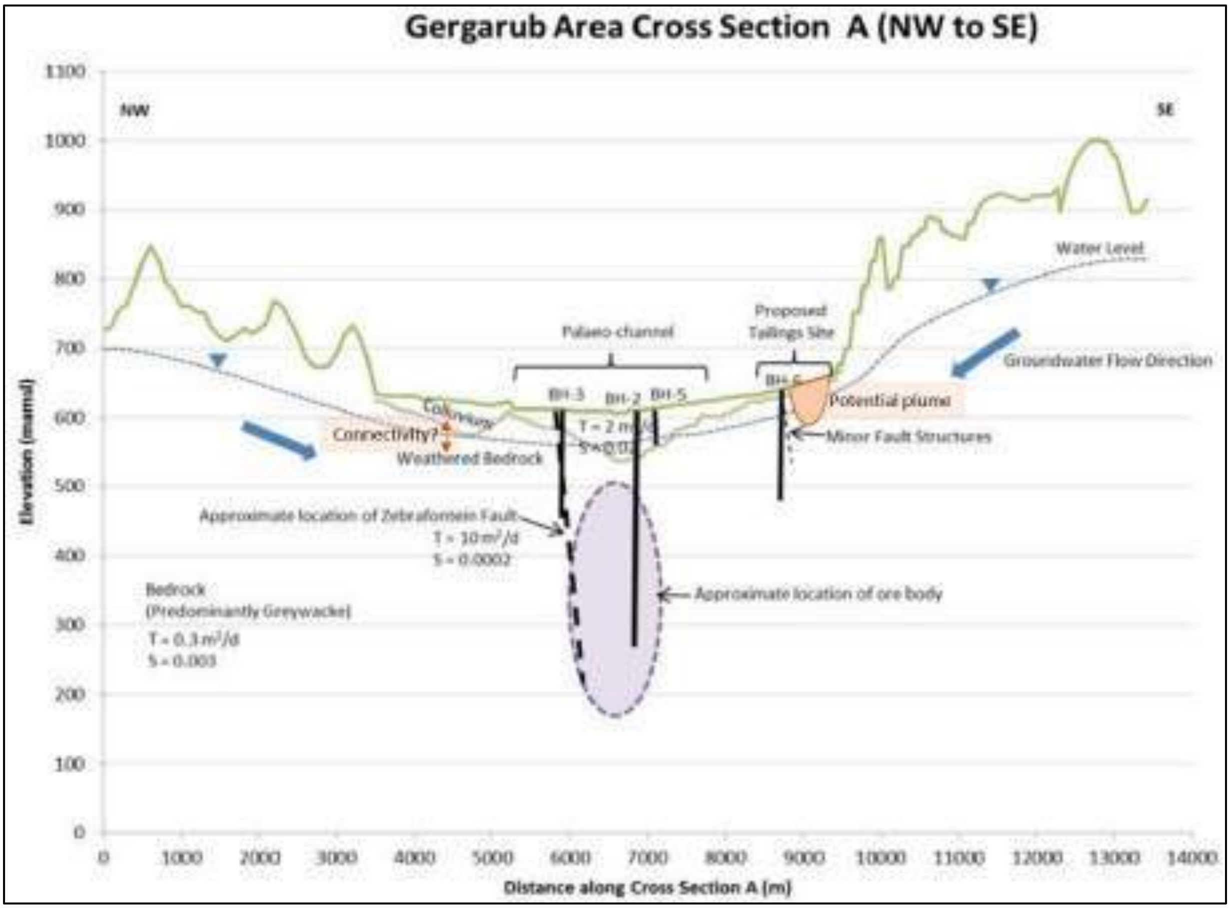

Figure 2-19 **Conceptual model of the Gergarub Mine developed by SRK (Skorpion Mining Company, 2014b)**

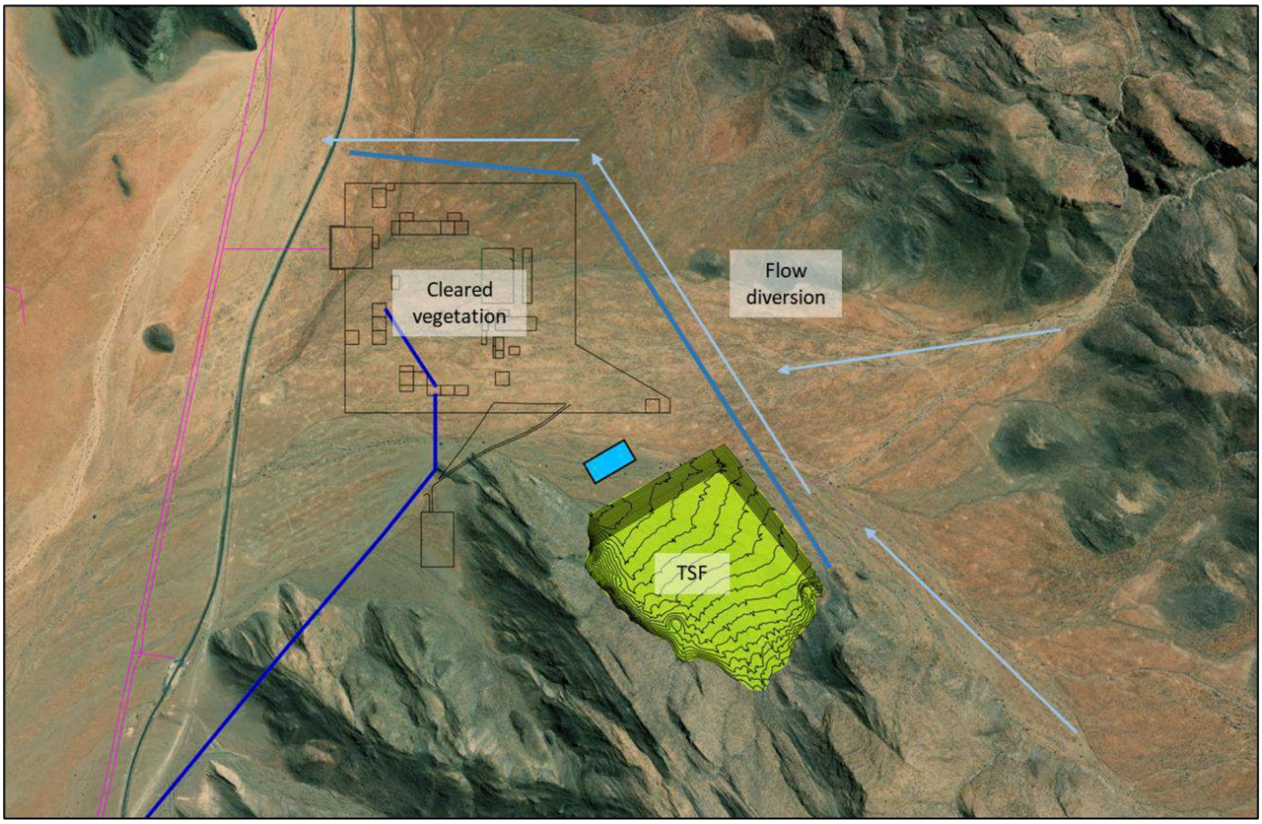

Figure 2-20 **Conceptual sketch of flow diversion required.**

2.8.6. Numerical Model

2.8.6.1. Mine Inflows

SRK (Skorpion Mining Company, 2014b) developed a numerical groundwater model of the area using MODFLOW to assess the impacts of the mine on groundwater in terms of inflow/dewatering and potential contamination plume evolution. Two dewatering scenarios were simulated, one where the Zebrafontein Fault is not intercepted by the mine (Scenario 1), and one where it is intercepted (Scenario 2) as there is uncertainty in the lateral and vertical extent of the fault. The results of both scenarios are shown in **Figure 2-21**, **Table 2-8**, and are discussed below. The mine inflows are linked to three distinct phases of the modelled mining plans:

a) 0 to 21 months when access tunnel is constructed,

b) 21 months to 14 years during mining of tunnels and stopes, and

c) 14 years to 20 years with no change in modelled mine plans, but dewatering continues to allow for mining of crown pillars.

The model shows it may take ~100 years following mine closure for groundwater levels to recover.

<u>Scenario 1</u>

- There is no groundwater inflow for about nine months of mining, until the groundwater table is reached at ~80 mbgl (although in the area of the decline shaft and TSF it may be shallower).
- Once the groundwater level is intersected, inflows may increase with depth from 0.3 l/s after nine months up to a maximum of 1.7 l/s after 21 months.
- From 21 months to 14 years, inflow increases up to 4.5 l/s after 6.5 years with a maximum mine depth ~500 mbgl. Thereafter, inflow slowly decrease as the mine extends laterally. Variations in inflow may be due to different vectors of hydraulic properties, leakage between layers, inflow from the unexpected fault systems, and response to the expanding drawdown zone reaching unexpected boundaries.
- Due to low conductivities, drawdown is very steep and the radius of influence relatively small but will continue to extend in a mostly radial fashion (due to simplifying assumption of isotropy) over the life of mine. Model outputs show radius of influence will be:
    - ~1 800 m radius after 5 years,
    - ~3 000 m after 14 years
    - ~3 500 m after 20 years
    - ~4 500 m 10 years after mine closure as storage is replenished.
- Following mine closure, the drawdown zone continues to expand in width to a radius of approximately 700 m after 10 years post mining, as storage is replenished, and the maximum depth of drawdown decreases.
- The nearest private boreholes at S1 (Koivilseast) and S2 (Homestead) are unaffected by the drawdown zone from mining in Scenario 1.
- The groundwater model shows that following mine closure, it could take approximately 100 years for the full recovery of groundwater levels back to pre-mining levels, assuming average recharge conditions persist.

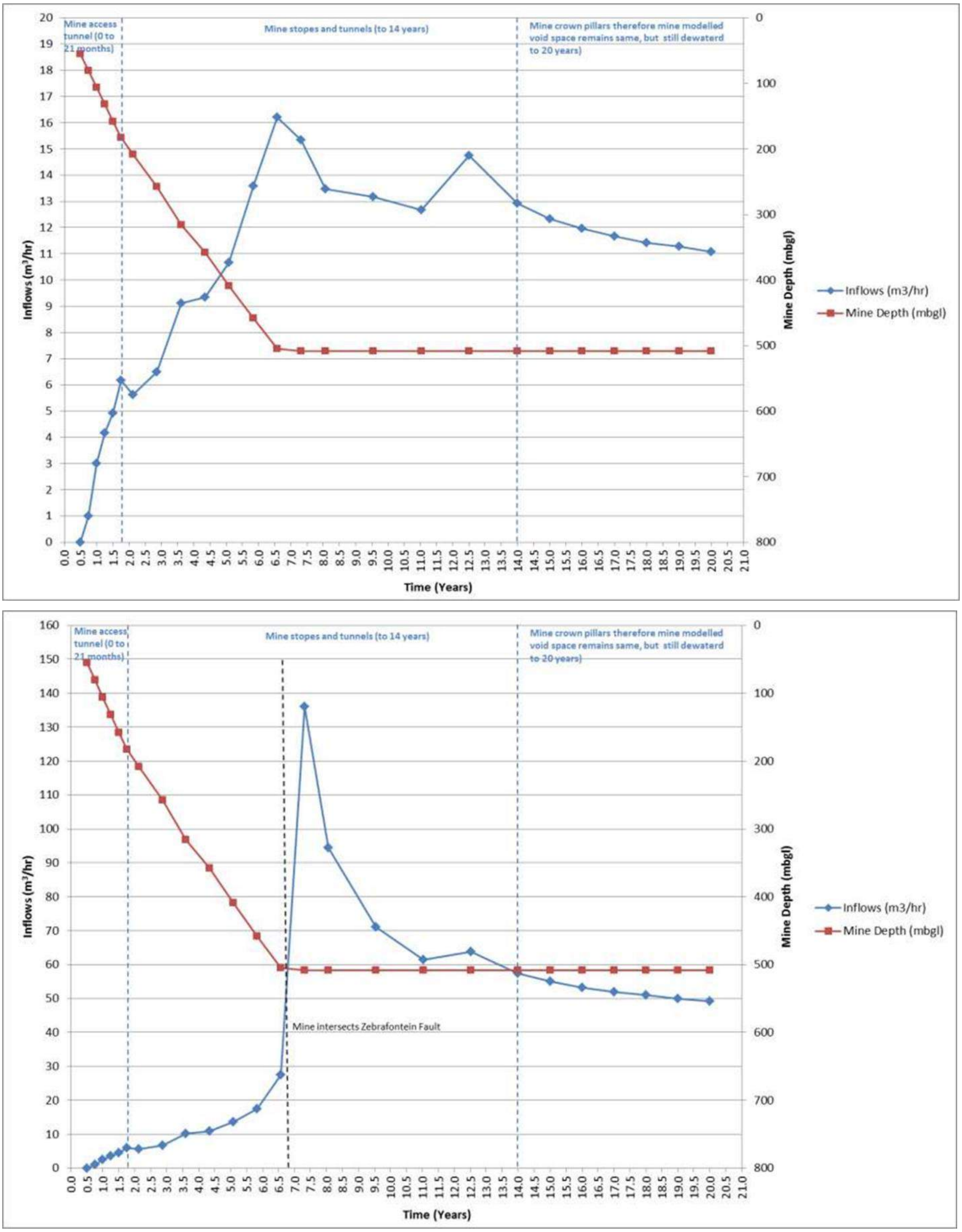

Figure 2-21 **Modelled mine inflows for Scenario 1, the Zebrafontein Valley Fault is not intersected (top) and Scenario 2, it is intersected (bottom) (Skorpion Mining Company, 2014b).**

Table 2-8 Modelled mine inflows for Scenario 1 and Scenario 2. Grey cells indicate when the fault is intercepted (Skorpion Mining Company, 2014b). Units of ML represent million litres.

Time (years)	Scenario 1 (Fault not Intercepted)					Scenario 2 (Fault Intercepted)				
	Inflow (l/s)	Inflows (m^3/hr)	Inflows (m^3/day)	Volume over time (ML)	Cumulative Volume (ML)	Inflow (l/s)	Inflows (m^3/hr)	Inflows (m^3/day)	Volume over time (ML)	Cumulative Volume (ML)
0.5	0	0	0	0	0	0	0	0	0	0
0.75	0.3	1	24	7	7	0.3	1	25	7	7
1	0.8	3	72	26	33	0.7	3	61	22	29
1.25	1.2	4	100	46	78	1	4	87	40	69
1.5	1.4	5	118	65	143	1.2	4	107	59	127
1.75	1.7	6	148	94	237	1.6	6	141	90	217
2.12	1.6	6	135	104	342	1.6	6	134	104	321
2.86	1.8	7	156	163	505	1.9	7	162	169	490
3.61	2.5	9	219	288	793	2.8	10	242	318	809
4.35	2.6	9	224	355	1149	3	11	263	417	1226
5.09	3	11	256	476	1624	3.8	14	328	609	1836
5.83	3.8	14	326	694	2318	4.8	17	419	892	2728
6.58	4.5	16	389	934	3252	7.6	27	659	1582	4309
7.32	4.3	15	368	983	4235	37.8	136	3266	8723	13033
8.06	3.7	13	323	950	5185	26.2	94	2267	6670	19702
9.55	3.7	13	316	1101	6286	19.7	71	1706	5944	25646
11.03	3.5	13	304	1224	7510	17.1	61	1475	5938	31584
12.52	4.1	15	354	1617	9127	17.7	64	1529	6984	38569
14	3.6	13	310	1584	10711	15.9	57	1377	7036	45605
15	3.4	12	296	1621	12332	15.3	55	1320	7227	52832
16	3.3	12	287	1676	14008	14.8	53	1279	7471	60303
17	3.2	12	280	1738	15746	14.4	52	1247	7739	68042
18	3.2	11	274	1800	17546	14.2	51	1224	8043	76085
19	3.1	11	271	1781	19327	13.9	50	1200	7885	83970
20	3.1	11	266	1845	21172	13.7	49	1181	8193	92162

Scenario 2:

- There is no groundwater inflow for approximately nine months of mining, until the groundwater table is reached at ~80 mbgl (although in the area of the decline shaft and TSF it may be shallower).
- Once the groundwater level is intersected, inflow may increase with depth from 0.3 l/s after nine months up to a maximum of 1.6 l/s after 21 months.
- From 21 months to 14 years, inflow increases up to 8.0 l/s after 8 years with a maximum mine depth ~500 mbgl. Thereafter, the inflow increases rapidly to ~38 l/s when the Zebrafontein Fault is intersected. Variations in inflow may be due to vectors of hydraulic properties, leakage between layers, inflow from fault systems, and response to the expanding drawdown zone intersecting unexpected boundaries.
- Inflow starts to decrease over time as final mining depth is reached.
- The initial expansion of drawdown is radial, and after ~5 years it elongates slightly and extends along the Zebrafontein Valley Fault zone.
- Due to low conductivities, drawdown is very steep and the radius of influence relatively small but will continue to extend in mostly radial fashion (due to simplifying assumption of isotropy) over the life of mine. Model outputs show radius of influence will be:
    - ~2 200 m after 5 years,
    - ~5 200 m after 14 years
    - ~6 000 m after 20 years
    - ~7 000 m 10 years after mine closure as storage is replenished.
- The nearest private boreholes further up the Zebrafontein valley at S1_Koivilseast and S2_Homestead (**Table 2-4**) are modelled as showing 5 to 10 m drawdown after 14 years, and 10 to 15 m drawdown after 20 years of mining (which contradicts the above bullet point as these private boreholes are ~4 km away). No users were noted in the area at the time of writing.

2.8.6.2. Contaminant Transport

Several contaminant transport scenarios were run to assess potential leakage from the TSF, with the important conceptual notes being tailings leakage infiltrating into the subsurface, subsequent groundwater mounding in the quaternary deposits and on the bedrock aquifer, the hydraulic connection (leakage) between the two aquifers, and the slow dissipation of the plume following termination of the leak/source. EC, sulphate, and pH are modelled as indicator elements. Infiltration/percolation rates are assumed to be ~5 m/day for overburden and ~0.16 m/day for the bedrock aquifer, and advection is assumed as the dominant transport mechanism with diffusion, dispersion and sorption being minor influencing factors depending on the modelled element. Modelled times were up to 100 years from start of mining.

Three overarching scenarios with sub-options are (Skorpion Mining Company, 2014b):

- Scenario A – all tailings (~25% moisture content) are sent to a lined TSF with under-drainage, from where water is pumped to a lined Return Water Dam (RWD) before being sent for reprocessing. Option 1A entails paste tailings, Option 1B entails thickened tailings, and Option 2 entails conventional tailings.
- Scenario B – this option includes the use of a pyrite flotation cell. Pyrite rich tailings are sent to a lined TSF, and the remainder is sent to an unlined TSF. Water is pumped from the lined tailings to the RWD before being sent for re-processing.
- Scenario C – conventional tailings (with 25% moisture content) are sent to an unlined TSF that it is surrounded by four manufactured walls.

The main findings of the model results are:

- The contaminant plume in the overburden extends laterally on contact with the bedrock aquifer and is of higher concentration.
- The zinc plume does not travel as far as the EC and sulphate plumes due to the effect of sorption.
- In Scenario B, the potential leakage of initial zinc concentration is 20 mg/l, however, the modelled concentration in bedrock does not exceed 1 mg/l.
- In Scenario A and B, the contaminant plume only reaches the mining area after time of mine closure and the groundwater levels will have largely recovered. The plume moves at a rate of ~3 m/year which will decrease to ~1 m/year after mine closure (due to decrease in hydraulic gradient).
- In Scenario C, the contaminant plume extends northwest along a modelled fault into the mine before closure, moving at a rate of ~ 50 m/year. Beyond the mine area movement is slower at ~1 to 5 m/year. The plume reaches the Zebrafontein Fault in the overburden after 100 years, but the concentrations are relatively low, comparable with background levels. The plume in the bedrock is not shown to reach the Zebrafontein Fault within 100 years.
- As mining and dewatering stops, groundwater levels recover and the plume undergoes dilution and attenuation.
- It is important to seal off (with grouting or bentonite) any potential pathways for rapid ingress such as existing boreholes below and surrounding the TSF.

3. IMPACT ASSESSMENT

Impact assessments are important tools for decision-making ensuring that all potential consequences of project activities are thoroughly understood and effectively managed. An impact is considered as a deviation from the baseline conditions on site. Identification and evaluation of potential impacts and appropriate mitigation measures is crucial to the process. Various anticipated impacts on soil, drainage (hydrology) and groundwater throughout the mining and ore processing operations are discussed, including construction phase, operational phase, and decommissioning phase. The methodology presented by the ECC Impact Predication and Evaluation Methodology (**Appendix D**), adapted from the 2008 Draft Procedures and Guidelines for Environmental Impact Assessment and Environmental Management Plan (EMP), is followed. Definitions of key terms and criteria used to evaluate impacts are:

- Source – the point, location, or activity that generates an impact.
- Pathway – the route or course through which impacts can migrate or propagate from a source to potentially affected receptors or receptors of concern.
- Receptor – a resource, individual or group residing in close proximity to an impact source, potentially exposed to the effects of project activities.
- Baseline environment – the existing environmental conditions and characteristics of a study area before any proposed project, activity, or development is implemented.
- Nature – whether the impact positively (beneficial) or negatively (adversely) changes the baseline environment.
- Type – impacts can be direct (direct interaction between the activity and the receptor), indirect (a secondary activity related to the project which causes an impact and may occur at a later date or wider area), or cumulative (impacts that are result of another impact).
- Reversibility – refers to the permanence of the impact i.e., will the impact be reversible (reversible and recoverable in the future), partly reversible (only some of the impact can be reversed whilst some remains), or will the impact be irreversible (and therefore permanent).
- Duration – the time over which the impact will be felt, i.e., will it be temporary (less than 1 year), short term (1 – 5 years), medium term (5 – 15 years), long term (more than 15 years until after decommissioning of the project) or permanent.
- Magnitude – the degree of loss or change of a resource’s quality, integrity, characteristics, features and/or elements etc., as described as very high (unknown), high (major), moderate and low (minor).
- Extent – the area affected by the impact, i.e., whether it is onsite (within the boundaries of the project site), local (within the local area and impacts the local community), regional (impacts to a receptor), national (impacts a receptor that is nationally important) or international (impacts a receptor that is internationally important).
- Probability – likelihood of an impact occurring and exerting influence as described as improbable (rare), low probability (unlikely), medium probability (possible), high probability (likely) and definite (almost certain).
- Sensitivity –degree to which an impact has the capacity to change or accommodate change, as described by low, medium, and high.
- Significance – degree to which impacts are expected to influence decision-making processes taking into consideration sensitivity and magnitude of change thresholds and as described by low- beneficial, low – negative, minor, moderate, and major sensitivity.
- Mitigation – action taken with the intention of either minimising or preventing exposure, or the probability of exposure to impacts.

To assess the overall impact, based on significance and sensitivity, a score is established. This is done by multiplying the ratings of each (low, medium, high for sensitivity and low, minor, moderate, major, for significance) to obtain an overall score with larger values being worse than lower values. **Table 3-1** shows this in detail.

Table 3-1 Scoring matrix for assessing the sensitivity and significance of impacts.

		Significance			
		Low (1)	Minor (2)	Moderate (3)	Major (4)
Sensitivity	High (3)	Minor (3)	Moderate (6)	Major (9)	Major (12)
	Medium (2)	Low (2)	Minor (4)	Moderate (6)	Major (8)
	Low (1)	Low (1)	Low (2)	Minor (3)	Moderate (4)

3.1. Soil

Main impacts relating to soil include soil compaction, vegetation clearing, changes in soil chemistry as well as soil pollution. These are shown in **Table 3-2** with the applied Impact Assessment methodology.

Construction activities may result in the following:

- Soil compaction which increases downstream runoff, enhances flood risks, reduces groundwater infiltration and recharge and causes adverse biodiversity effects.
- Vegetation clearing which leads to increased runoff, erosion, flooding and loss of soil organic matter.
- Soil contamination from accidental chemical spills, and leaks of hazardous materials like fuel, oil and other hydrocarbons.
- Changes in soil chemistry and structure adversely affecting biodiversity and water infiltration.

Operational activities may result in the following:

- Soil compaction which increases downstream runoff and flood risks, reduces groundwater infiltration and recharge and causes adverse biodiversity effects.
- Soil contamination occurs in immediate vicinity and larger downwind area due to fine dust particles of ore and waste rock.
- Soil contamination from accidental chemical spills, and leaks of hazardous materials like fuel, oil and other hydrocarbons.

Decommissioning activities may result in the following:

- Soil compaction persists increasing runoff and making it difficult for flora to be reintroduced.
- Changes in soil chemistry and structure adversely affecting biodiversity and water infiltration.
- Soil contamination by windblown and entrained dust.

Table 3-2 Impact assessment of various activities relating to soil.

Impact	Pathway/ Receptor/Result	Nature of Impact	Type of Impact	Duration	Extent	Probability	Magnitude of Change	Reversibility	Confidence	Sensitivity	Significance	Scoring	Mitigation
Construction Phase													
Soil Compaction	Increased downstream runoff and enhanced flood risk	Adverse	Direct	Short term	Onsite	Almost certain	Low	Reversible	High	Low	Low	Low	• Scarification of compacted soil. • Flow dissipation measures to reduce velocity of runoff.
	Reduced infiltration and groundwater recharge	Adverse	Direct	Short term	Onsite	Almost certain	Low	Reversible	High	Low	Low	Low	
	Reduced vegetation growth (including potentially rare and endemic species)	Adverse	Direct	Short term	Onsite	Likely	Moderate	Reversible	Moderate	Medium	Moderate	Moderate	
Vegetation Clearing	Increased runoff, erosion, flooding, and loss of organic matter	Adverse	Direct	Short term	Onsite	Almost certain	Moderate	Reversible	Moderate	Medium	Minor	Minor	• Implement erosion control measures such as terracing, erosion control blankets and matting. • Clear vegetation in a manner that encourages plant regrowth, such as stem cutting where possible. • Divert water away from unvegetated areas. • Replant vegetation as part of rehabilitation interventions.
Soil Contamination	Chemical spills and leaks from equipment and machinery.	Adverse	Direct	Temporary	Onsite	Likely	Low	Reversible	High	Low	Low	Low	• Excavate and remove contaminated soil and replace with uncontaminated soil. • Utilise drip trays where possible to prevent leaks from reaching soil. • Store fuel and chemicals in bunded areas and do regular inventory checks.
Changes in soil structure/ integrity	Construction activities can cause soil disturbance, changes in soil structure and mixing of soils	Adverse	Direct	Short term	Onsite	Almost certain	Low	Reversible	High	Low	Low	Low	• Ensure removed/ disturbed soil is replaced and returned to previous state as far as possible. • Conduct regular soil quality monitoring.
Operational Phase													
Soil compaction around the plant/mine area	Increased downstream runoff and enhanced flood risk	Adverse	Direct	Long term	Onsite	Almost certain	Low	Reversible	Moderate	Low	Low	Low	• Undertake scarification of compacted soil. • Implement erosion control measures to prevent further soil compaction due to water runoff.
	Reduced groundwater infiltration and recharge	Adverse	Direct	Long term	Onsite	Almost certain	Low	Reversible	Moderate	Low	Low	Low	• Undertake scarification of compacted soil. • Implement erosion control measures to prevent further soil compaction due to water runoff.
	Reduced vegetation growth of potentially rare and endemic species	Adverse	Direct	Long term	Onsite	Likely	Moderate	Reversible	Moderate	Medium	Moderate	Moderate	• Undertake scarification of compacted soil. • Implement erosion control measures to prevent further soil compaction due to water runoff.

Impact	Pathway/ Receptor/Result	Nature of Impact	Type of Impact	Duration	Extent	Probability	Magnitude of Change	Reversibility	Confidence	Sensitivity	Significance	Scoring	Mitigation
Soil Contamination	Fine dust particles of ore and waste rock settle on soils, altering pedogenic processes, and adversely affecting flora and fauna.	Adverse	Indirect	Short term	Local	Likely	Low	Reversible	Moderate	Low	Minor	Low	• Employ dust control measures throughout site. • Increase watering to supress dust on roadways.
	Chemical and hydrocarbon spills and leaks from equipment and machinery.	Adverse	Direct	Medium term	Onsite	Likely	Low	Reversible	High	Low	Minor	Low	• Remediate contaminated soils using appropriate techniques, such as excavation and removal, soil washing, bioremediation, or chemical treatment. • Store in bunded areas and carry out regular inventory checks
Decommissioning Phase													
Compacted soil remains	Compacted soils remain for many years making it difficult for flora to be reintroduced and grow and causing runoff to be higher.	Adverse	Direct	Short term	Onsite	Likely	Low	Reversible	High	Medium	Low	Low	• Employ soil compaction remediation techniques that include scarification, deep ripping, subsoiling, etc.
Soil structure and characteristics are altered	Increased runoff, soil structure is changed/ disturbed and flora struggle to be reintroduced.	Adverse	Direct	Medium term	Onsite	Likely	Moderate	Reversible	Moderate	Low	Low	Low	• Ensure removed/ disturbed soil is replaced and returned to previous state as far as possible. • Conduct regular soil quality monitoring.
Soil contamination by windblown and entrained dust	Windblown dust from the site contaminates soil	Adverse	Indirect	Short term	Onsite	Likely	Low	Reversible	Moderate	Low	Minor	Low	• Employ dust control measures. • Increase watering to supress dust on roadways.

3.2. Drainage

Main impacts include altered drainage regimes and flow rates, surface water contamination and in rare cases catastrophic flooding should TSF failure occur. The impacts are shown in **Table 3-3** with the applied Impact Assessment methodology.

Construction activities may result in the following:

- Altered drainage regimes causing water flowing across the site to be diverted, and subsequently causing a lag in flow to downstream.
- Downstream water contamination via contaminated runoff generated onsite from accidental chemical spills, and leaks of hazardous materials like fuel, oil and other hydrocarbons.
- Flow changes to the local and wider area as it will be necessary to divert several intermittent streams that cross the proposed site during its construction to mitigate flooding risks.

Operational activities may result in the following:

- Tailings Storage Facility (TSF) failure resulting in catastrophic flooding and contamination of downstream water courses.
- Altered drainage regimes as water flowing from upgradient side will be diverted, causing a lag in flow to downstream and potential discharge or runoff of additional water from site may increase flow to downstream area.
- Downstream water contamination via contaminated runoff generated onsite and distal areas where dust has settled on surface in upwind direction.
- Flow changes in local and regional catchments due to the diversion which will prevent any upstream water from flowing through the site and a delay in the flow rate downstream.
- Contamination risks due to ore and/or concentrate entering the local and downstream environment through surface water flow especially during rain events.

Decommissioning activities may result in the following:

- Drainage never returns to normal as remaining structures obstruct flow.
- Persistent contaminants and dust continue as diffuse sources of pollution to downstream.
- Contamination through pollution generated from removal of storage facilities and through exposed minerals which continue to oxidise and mobilise contaminants.

Table 3-3 Impact assessment of various activities relating to drainage and hydrology.

Impact	Pathway/ Receptor/Result	Nature of Impact	Type of Impact	Duration	Extent	Probability	Magnitude of Change	Reversibility	Confidence	Sensitivity	Significance	Scoring	Mitigation
Construction Phase													
Altered drainage regime	Water flowing across the site will be diverted, causing a lag/change in flow to downstream areas	Adverse	Direct	Short term	Regional	Almost certain	Moderate	Partly Reversible	High	Low	Minor	Low	• Drainage regime to be restored as per a post mining rehabilitation plan. • Ensure stream diversions accommodate and encourage natural water flow regimes as far as possible.
Contaminated water courses	Contaminated runoff generated onsite flows to downstream fauna and flora.	Adverse	Direct	Temporary to short term	Regional	Likely	Moderate	Partly Reversible	High	Low	Minor	Low	• Implement a stormwater management program to separate dirty and clean water.
Operational Phase													
TSF failure	TSF failure results in catastrophic flooding and contamination of downstream water courses	Adverse	Direct	Long Term	Regional	Rare	Very high	Irreversible	Moderate	Medium	Major	Major	• Establish early warning systems for wall stability, water levels, seepage, and dam deformation.
Altered drainage regime	Water flowing from upgradient side is diverted, causing lag in flow to downstream	Adverse	Direct	Long term	Regional	Almost certain	Moderate	Reversible	High	Low	Minor	Low	• Ensure stream diversions accommodate and encourage natural water flow regimes as far as possible. • Monitor flow rates and changes.
	Potential discharge or runoff of additional water from site may increase flow to downstream area	Adverse	Direct	Temporary	Regional	Possible	Moderate	Reversible	Moderate	Low	Low	Low	• Ensure drainage channels can withstand increased flow. • Implement effective stormwater management program
Contaminated water courses	Contaminated runoff generated onsite makes its way downstream	Adverse	Direct	Temporary to Medium term	Regional	Possible	Moderate	Partly Reversible	Moderate	Low	Minor	Low	• Implement effective stormwater management program. • Ensure early warning systems are in place
	Contaminated runoff in distal areas where dust has settled on surface in upwind direction	Adverse	Indirect	Medium term	Regional	Likely	Low	Reversible	Moderate	Low	Minor	Low	• Implement dust suppression techniques, such as water spraying, dust suppressant chemicals, etc at dust generation points like crushing and drilling sites and along overhaul roads.
	Runoff of mineralised waste causing contamination of stream sediments	Adverse	Direct	Short term	Onsite	Possible	Low	Irreviersble	Moderate	Low	Low	Low	• Construct sedimentation/settling ponds to allow suspended solids to settle.
Decommissioning Phase													
Flow changes in regional catchments	A slight delay in the flow rate of water reaching the downstream environment due to the diversion.	Adverse	Direct	Long Term	Regional	Almost certain	Low	Partly Reversible	Moderate	Low	Minor	Low	• Create diversion in manner that reduces lag time.
Altered/ obstructed water flow	Drainage never returns to normal as remaining structures and site alterations obstruct flow.	Adverse	Direct	Permanent	On site	Almost certain	Moderate	Irreversible	High	Medium	Moderate	Moderate	• Remove all structures and rehabilitate site to (near) natural state

Impact	Pathway/ Receptor/Result	Nature of Impact	Type of Impact	Duration	Extent	Probability	Magnitude of Change	Reversibility	Confidence	Sensitivity	Significance	Scoring	Mitigation
Contaminated water courses	Persistent contaminants (ore, metals etc.) continue as diffuse sources of pollution	Adverse	Direct	Medium term	Regional	Likely	Moderate	Partly Reversible	Moderate	Low	Moderate	Minor	• Remediate contamination using appropriate techniques, dilution, bioremediation, or chemical treatment. • Remove pollutants from site following mine closure and dispose of correctly.

3.3. Groundwater

Main impacts include depleted groundwater resources, groundwater contamination and acid mine drainage. The impacts as per the applied Impact Assessment methodology are shown in **Table 3-4**.

Construction activities may result in the following:

- Groundwater overabstraction for construction use may cause water resources to become depleted as recharge is low.
- Groundwater contamination from spills and leaks of chemicals and hydrocarbons from refuelling and servicing construction vehicles and equipment and other onsite activities.

Operational activities may result in the following:

- Mine dewatering will lower the water table and deplete groundwater resources and potentially affect other groundwater users, expose rock to air resulting in oxidation of minerals and mobilising of contaminants.
- Mixing of water quality when various aquifers previously separated become connected resulting in mixing and potential deterioration of water qualities.
- Blasting can increase fracturing in rock, increase groundwater storage capacity, cause breaching of confining layers and loss of artesian conditions, and groundwater contamination.
- TSF and pipeline leakages may contaminate the groundwater in both primary and fractured rock aquifers.
- Groundwater contamination through leaching of ore and waste rock stockpile waters, spills from chemical storage and refuelling and servicing equipment and windblown contaminated dust.
- Erosion of mineralised waste drainage causing concentrations of metals in stream sediments. Degradation of surface and groundwater quality because of the oxidation and dissolution of metal-bearing minerals from zinc processing.
- Acid Mine Drainage can occur when sulphides oxidize during the process of mine dewatering.

Decommissioning activities may result in the following:

- Groundwater levels from mine dewatering will take about 100 years to recover to normal levels.
- Acid mine leachate and mineral leachate from ore and waste rock stockpiles contaminate groundwater and as dewatering ceases and water levels increase, contamination is anticipated as oxidized materials and spilled chemicals come into contact with the air and water.
- Contaminant plumes continue to migrate within the subsurface and groundwater.

Table 3-4 Impact assessment of various activities relating to groundwater.

Impact	Pathway/ Receptor/Result	Nature of Impact	Type of Impact	Duration	Extent	Probability	Magnitude of Change	Reversibility	Confidence	Sensitivity	Significance	Score	Mitigation
Construction Phase													
Depleted groundwater resources	Groundwater may be used for construction activities.	Adverse	Direct	Short term	Onsite	Possible	Moderate	Reversible	High	Low	Low	Low	• Utilise groundwater sustainably.
Groundwater Contamination	Chemical and hydrocarbon spills and leaks from construction activities, refuelling stations, maintenance workshops etc.	Adverse	Direct	Temporary to short term	Onsite	Possible	Moderate	Reversible	High	Low	Minor	Low	• Hazardous materials must be managed within designated spill containment/bunded systems. • Oil spill kits should be available. • Conduct routine inspections and maintenance of structures, equipment, and storage areas. • Regular service of vehicles in designated repair bays. • Refuelling of vehicles only in designated areas.
Operational Phase													
Mine dewatering	Groundwater resources is depleted, and other users affected	Adverse	Direct	Long term	Local	Almost certain	High	Partly Reversible	High	Low	Moderate	Minor	• Provide alternative water supply to affected users.
	Rock is exposed to air resulting in oxidation of minerals and mobilising of contaminants	Adverse	Direct	Long term	Local	Almost certain	Moderate	Permanent	Medium	Low	Moderate	Minor	• None
Deterioration in water quality	Previously separate aquifers become connected resulting in mixing of water qualities (if not already connected)	Adverse	Direct	Short term	Regional	Possible	Moderate	Irreversible	Medium	Low	Minor	Low	• Backfill/seal to restore confining layers.
Blasting	Increased rock fracturing leading to unstable subsurface conditions	Adverse	Direct	Long term	Local	Possible	Moderate	Reversible	High	Medium	Low	Low	• Backfill with cement. • Install blasting mats, barriers, or cushions made of materials like rubber or straw to dampen the shockwave and reduce the impact on surrounding rock.
	Increased rock fracturing which increases groundwater storage capacity	Beneficial	Direct	Permanent	Local	Almost certain	Moderate	Reversible	High	Low	Low	Low	• None
	Breaching of confining layers and loss of artesian conditions	Adverse	Direct	Long term	Local	Possible	Moderate	Partly Reversible	Medium	Medium	Low	Low	• Backfill/seal to restore confining layers.

Impact	Pathway/ Receptor/Result	Nature of Impact	Type of Impact	Duration	Extent	Probability	Magnitude of Change	Reversibility	Confidence	Sensitivity	Significance	Score	Mitigation
	Groundwater contamination from set explosives (nitrates and other contaminants)	Adverse	Direct	Long term	Local	Almost certain	Moderate	Partly Reversible	High	Low	Minor	Low	• None
TSF leakage	TSF leaking will contaminate the groundwater in both primary and fractured rock aquifers	Adverse	Direct	Long term	Regional	Rare	High	Reversible	High	Medium	Moderate	Moderate	• Ensure the installation of appropriate liners to prevent leaks. • Implement early warning systems.
Leakage of ore, waste rock stockpiles, and chemical storage	Leakage of ore, waste rock stockpiles, and chemical storage may seep into and contaminate groundwater	Adverse	Direct	Temporary to long term	Onsite	Possible	Moderate	Partly Reversible	High	Low	Minor	Low	• Store materials on an appropriate liner or bunded area to contain and control leachate/leakages. • Minimise contact of substances with water through appropriate storage and stormwater management plans.
	Runoff from stockpiles infiltrate downstream	Adverse	Direct	Temporary	Onsite	Possible	Low	Partly Reversible	High	Low	Low	Low	
Groundwater Contamination	Chemical and hydrocarbon spills from refuelling and servicing equipment	Adverse	Direct	Medium term	Onsite	Possible	Moderate	Reversible	High	Low	Minor	Low	• Oil spill kits should be available to contain emergency spills of hydrocarbons. • Service and refuel vehicles in designated bays. • Store in bunded areas and carry out regular inventory checks.
	Windblown contaminated dust seep into the groundwater	Adverse	Indirect	Medium term	Local	Possible	Moderate	Partly Reversible	Moderate	Low	Minor	Low	• Employ dust control measures throughout site.
Acid Mine Drainage	Acid Mine Drainage contaminates groundwater and dissolves carbonate rocks.	Adverse	Direct	Long term	Local	Possible	High	Partly Reversible	Moderate	Medium	Moderate	Moderate	• Minimise acid generating potential where possible. • Contain and neutralise materials where possible
Decommissioning Phase													
Groundwater level recovery	Water levels will take 100 years to recover to normal levels	Adverse	Direct	Long term	Regional	Almost certain	High	Reversible	High	Medium	Moderate	Moderate	• Implement recharge enhancing or managed aquifer recharge practices. • Adjust the pumping rates of boreholes and dewatering systems to minimise the impact on water levels. • Implement artificial recharge techniques, such as infiltration basins or more boreholes. Regular monitoring of water levels.
Groundwater contamination	Acid mine/mineral leachate from ore and waste rock stockpiles contaminate groundwater	Adverse	Direct	Medium term	Local	Likely	Moderate	Partly Reversible	Moderate`	Low	Minor	Low	• Rehabilitation efforts should be aimed at ensuring groundwater contamination does not continue in the future, i.e., remove tailings and waste rock etc.

Impact	Pathway/ Receptor/Result	Nature of Impact	Type of Impact	Duration	Extent	Probability	Magnitude of Change	Reversibility	Confidence	Sensitivity	Significance	Score	Mitigation
	Rising water levels mobilise oxidised contaminants in host rock	Adverse	Direct	Medium term	Local	Almost certain	Moderate	Permanent	Medium	Low	Minor	Low	• Backfill applicable areas with cement to decrease exposed rock surfaces.

4. CONCLUSION AND RECOMMENDATIONS

The natural environment and site characteristics at the Gergarub Project proposed base metals mine have been described, and a hydrological and hydrogeological impact assessment has been undertaken for construction, operational and decommissioning phases of the mine's lifetime. Impacts on soil are low to moderate, with soil impacts influencing drainage (runoff), groundwater (recharge) and biodiversity. It is recommended that offsets be found for vegetation, and flow reduction measures be implemented to reduce runoff and increase infiltration where possible.

Impacts to drainage/hydrological systems may be more significant as water courses are diverted to make way for mine infrastructure as the infrastructure occurs within the 1:100 year flood line. This diversion and building infrastructure means drainage will never again return to its current state. An impact of major severity, but rare probability, is TSF failure which may cause disastrous flooding and contamination of water courses.

Due to the underground nature of the mine, potential impacts on groundwater are many and dewatering of aquifers and groundwater contamination are obvious impacts. Dewatering will lower regional groundwater levels, although the severity thereof is low as no groundwater dependent users or ecosystems were identified. If impacts on surrounding users do occur, it is suggested that Gergarub Mine offer alternative water supply as SZM does to the local homestead. Only one impact is rated as beneficial whereby underground blasting may increase porosity and storage of the aquifer units. Groundwater contamination by various means (TSF leakage, acid mine drainage etc.) is the other major impact, however, due to the low water levels and no groundwater dependent users or ecosystems being present, the scores are low to moderate.

It is recommended that the Gergarub Project be given environmental authorisation as the economic benefits outweigh potential environmental impacts, and that the mine implement prevention and mitigation measures for the various impacts through adherence with Environmental Management Plans and Stormwater Management Plans. It is also recommended that:

- A monitoring network be established, and routine (quarterly to bi-annual) groundwater quality monitoring is conducted to increase the confidence of baseline values prior to mine construction and investigate the presence of poorer quality water at the TSF site. This can be continued into the mine operations to assess likelihood of potential contamination.
- Routine groundwater level monitoring be undertaken to improve understanding of groundwater flow direction and seasonal changes. This can be continued into the mine operational phase to assess the effects of dewatering.
- The monitoring network should include upgradient and downgradient boreholes in both the primary and secondary aquifers, and boreholes proximal to the TSF. This will aid in understanding the connectivity between the two aquifers and monitor potential contamination plumes emanating from the TSF. Locations can be confirmed once mine layout is confirmed.
- Understanding of connectivity between aquifer units and aquitard/aquiclude units be improved to assess potential mixing of different quality groundwaters. Confidence in the location, vertical extent, and hydraulic properties of the Zebrafontein Valley Fault must be improved through exploration and monitoring to avoid unexpected high mine inflows and increased risk.
- The numerical model should be updated as monitoring continues, and additional data is available. Updates must be regular and throughout the life of mine to evaluate uncertainties and potential impacts.
- Cumulative impacts of RPZM, Gergarub Mine, and SZM have not been considered in the current numerical model and in this impact assessment. It is recommended that the cumulative impacts are modelled and evaluated prior to mine construction.
- Improved elevation data (Lidar) be sourced, and the flood assessment updated prior to

construction of the mine. The current data is not of high confidence, increasing risk to mine infrastructure.

- A weather station be installed to measure hydroclimatic data and improve understanding of water balance components such as rainfall, evapotranspiration, and recharge.
- A mine rehabilitation plan be drawn up and implemented to reduce the impacts of the decommissioning phase of the mine. Monitoring of water levels and water quality should continue beyond the life of mine.

5. REFERENCES

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Appendix A – Literature Review

Document	Summary
National and Legislative Documents	
The Water Act, 1956.	Although this Act is outdated, it remains relevant as the Water Resources Management Act (No. 11 of 2013) has been billed but not promulgated. The Water Act thoroughly addresses issues related to water pollution and protection of water quality, ensuring that mining activities do not significantly degrade water resources through the processes undertaken and waste produced. The Act aims to control certain activities utilising water resources within designated areas, however, has separate controls for groundwater and surface water.
Soil Conservation Act, No. 76 of 1969.	The Soil Conservation Act aims to enact laws for the conservation and protection of soil and vegetation and prevention of soil erosion. Soil is a vital component of the hydrogeological cycle, and the the protection of water sources is also covered. Mining may disturb and contaminate existing soils or create new soil as waste rock brought to surface is weathered. It also addresses matters incidental to these objectives.
Hazardous Substances Ordinance, No. 14 of 1974	This legislation is designed to regulate substances that have the potential to cause harm, injury, illness, or even death to human beings due to their toxic, corrosive, irritant, strongly sensitising, or flammable properties. Mining waste and processing chemicals can be of a hazardous nature to the receiving environment. The Act proposes to categorise these substances into different groups based on the level of danger they pose. It further seeks to control, and prohibit where necessary, the importation, manufacturing, sale, use, disposal or dumping of such hazardous substances.
Minerals (Prospecting and Mining) Act, No. 33 of 1992.	This legislation aims to establish regulations, guidelines, and licensing procedures for conducting exploration, prospecting, and mining activities in Namibia, as well as the proper disposal of mineral and mineral waste, which is of importance for the Impact Assessment. It groups different minerals into classes, and grants authority for exercising control over these mineral resources. The Act also addresses related incidental matters that may arise during these licensed activities.
Namibia's Environmental Assessment Policy for Sustainable Development and Environmental Conservation, 1995.	This policy aims to integrate environmental considerations into decision-making processes, promote sustainable development practices, and conserve natural resources for present and future generations. The policy emphasises the use of EIAs for to assess and mitigate potential environmental impacts, encourages public participation in decision-making, supports biodiversity conservation, focuses on pollution control, and outlines roles and responsibilities of stakeholders in implementing environmental management measures. Overall, the policy aims to ensure that development activities, such as the Gergarub Mine, are environmentally conscious for the preservation of unique ecosystems.
General Environmental Guidelines for the Mining (Onshore and Offshore) Sector in Namibia, 2000	These guidelines are designed to assist mining developers in preparing Environmental Assessments (EAs) at both project specific and strategic levels, serving as the foundation for EMPs. The guidelines present checklists of major activities for onshore and offshore mining, along with corresponding impacts and common mitigation measures. Some discretion is necessary to distinguish operational activities from mitigation measures, and the checklists broad to account for the environmental diversity in Namibia. The checklists are based on reviews of previous EAs, however,

Document	Summary
	they are not exhaustive and project specific knowledge should applied.
Environmental Management Act, 2007.	The purpose of the Environmental Management Act is to promote the use of natural resources in a manner which can be managed sustainably through the establishment of specific principles. It outlines certain activities, such as mining, that may not be undertaken without environmental authorisation and provides a guide on how to obtain this authorisation, such as ESIAs. The principles are used for decision making on matters which affect the environment. The Act speaks to. Where activities have significant effects on the environment, the Act provides processes to follow for environmental assessment, control, management, and environmental incidents, as well as the establishment of a Sustainable Development Advisory Council, an Environmental Commissioner, and subsequent officers.
Draft Procedures and Guidelines for Environmental Impact Assessment and Environmental Management, No. 1 of 2008.	This document serves as a guideline for the procedure of conducting EIAs and Environmental Management Plans (EMP). It offers a comprehensive list of tasks from the initial project proposal to conducting baseline studies, carrying out preliminary and detailed assessments (with this Impact Assessment being part of the detailed assessment phase), and implementing EMPs which aim to mitigate and manage the identified risks and impacts of the EIA. It also outlines the monitoring and reporting process of the associated activities.
Integrated Water Resources Management Plan for Namibia, 2010.	Integrated Water Resources Management (IWRM) considers all water uses together, factoring in their impacts on each other and aligning with social, economic, and environmental objectives. It involves participatory decision-making, allowing diverse user groups to influence water resource strategies effectively. IWRM ensures sustainable development, allocation, and monitoring of water resources. The mining industry makes up a large percentage of water use, and so understanding the IWRM and its implication for mining is important.
Environmental Impact Assessment Regulations, No. 30 of 2011.	This Government Gazette provides a schedule of regulations to aid an applicant in preparing an Environmental Impact Assessment (EIA) for environmental authorisation for an activity listed in the Act above. The list of regulations is intended to guide the applicant through all stages of the EIA and includes, but is not limited to, listed activities, environmental clearance certificates, scoping, lists of competent authorities, reporting, decision-making, public consultation, appeals, record-keeping, and fees.
International Finance Corporation (IFC) - Policy and Performance Standards, 2012.	The IFC, a member of the World Bank Group, offers investment, advisory and asset management services to private sectors in developing countries. The IFC Performance Standards outlines sustainability principles and guidance on identifying risks and impacts as well as mitigation and management thereof. Performance Standard 1, 3 4 and 6 are of most importance and pertain to Assessment and Management of Environmental and Social Risks and Impacts, Resource Efficiency and Pollution Prevention, Community Health, Safety, and Security, and Biodiversity Conservation and Sustainable Management of Living Natural Resources, respectively.
Water Resources Management Act, No. 11 of 2013.	The Act establishes provisions for the effective management, protection, development, use, and conservation of water resources in Namibia. The act governs the allocation and use of water, including the process for obtaining water rights and permits for activities such as mining and protects against overabstraction and pollution of water resources. It includes regulations for monitoring and compliance of water uses, pollution control, management practices and addresses incidental matters. This applies to surface and groundwater resources as a whole, rather than two separate resources (as in the Water Act, 1956). Compliance with this act is essential for mining companies to operate legally

Document	Summary
	and sustainably to ensure the protection and preservation of water as a scarce resource in Namibia.
NamWater Integrated Annual Report, 2020/21.	This report aims to share information with stakeholders about the bulk water supply in Namibia, from which Gergarub Mine will draw water supply. The organisation adopts an integrated approach for corporate reporting, which provides insights into NamWater's resources, business relationships, risks, and its contribution to the environment to create long-term value. Embracing holistic thinking, NamWater seeks to continually enhance its implementation of integrated reporting as set out by the guidelines of the International Integrated Reporting Framework.
Environmental Principles for Mining in Namibia - A Best Practice Guide (n.d)	This Best Practice Guide was developed by ECC in collaboration with key stakeholders, including the Chamber of Mines, the Namibian Chamber of Environment, the Namibian Government, and members of the Namibian mining industry. Mining is significant in the country's social and economic development, and the guide emphasises responsible and sustainable practices in line with the National Development Plan. The guide outlines leading practices in all aspects of the mining life cycle, including construction, mining and processing, closure and rehabilitation. By applying these leading practices in the Impact Assessment, Gergarub Mine can actively contribute to sustainable development, maintain positive relationships with regulators and communities, and uphold sound environmental and social principles.
Environmental Compliance Consultancy Impact Predication and Evaluation Methodology, n.d.	This document, produced by ECC, outlines a sound methodology to identify, predict and evaluate the impacts of an activity which may arise during the EIA process. The methodology applies the source-pathway-receptor approach to risk assessments and rating index for sensitivity and significance of impacts. The methods are based on the principles upheld by the IFC, the Nambian Draft Procedures and Guidelines for EIA and EMP, and Environmental Principles for Mining in Namibia, a Best Practice Guide., and will be applied in the Impact Assessment.
Project Specific Documents	
Skorpion Sulphides and Gergarub Concept Study Report, 2010.	The concept study report is a comprehensive document that evaluates all aspects of the project to assess the feasibility of the mine. It covers the social, environmental, and economic viability of the project, offering an overview of its implementation, estimated financial parameters, key risks and important considerations The exploration results, mining methods and mineral resource estimation and classification are discussed in detail, and the report provides recommendations for the mine's development based on the findings and analysis.
Gergarub Zinc Deposit Feasibility Study: Geochemical Assessment, 2014.	This report presents the results of the geochemical characterisation of the waste rock and tailings. The assessment provides insight into the geochemistry, leachability potential, mineralogy, and acid generation potential, which are important in understanding potential risks and impacts to water resources. Recommendations to minimise the impacts of the waste were discussed, however, the report does not address potential geochemical impacts from other mining processes, such as the return water dam, aging pond, backfilling hydrolyzation, settling pond, dirty water dam, sewage treatment, and run-of-mine stockpiles
Tailings Feasibility report, 2014.	The Tailing feasibility report prepared by SRK details the design of the tailings dam and its components for the proposed Gergarub Mine. Geochemical tests confirmed that the tailings are acid-generating, necessitating a geosynthetic liner barrier to prevent groundwater contamination. The most economical and water-efficient conventional tailings deposition method was chosen after a trade-off study. The dam's height and slope were

Document	Summary
	determined based on the rate of rise, and the drainage system manages process water effectively. The design ensures compliance with environmental regulations, economic viability, and efficient water management for the Gergarub Mine and will be used in the ESIA.
Gergarub Zinc Deposit Feasibility Study: Geohydrological Assessment, 2014.	The Geohydrological Assessment was completed by SRK which looks at the risk of groundwater contamination at the mine and the proposed tailings storage facility (TSF) through numerical modeling. However, the planned lining of the TSF and effective facility management should minimise the contamination risk to an insignificant level. Any potential contamination would likely be confined to the immediate vicinity of the site. The study shows results of a hydrocensus and identifies no known receptors that may be impacted by groundwater contamination, but to ensure ongoing assessment monitoring of the drawdown zone and groundwater quality is recommended.
Gergarub Feasibility Study: Integrated Hydrological and Road Infrastructure Assessment, 2014.	This assessment by SRK speaks to stormwater management systems and the need to address flooding risks for the proposed plant, and pollution prevention through control of contaminated stormwater runoff. Integration of road and stormwater design is essential to ensure hard-surfaced roads for transporting material, and proper conveyance of stormwater to the aging and settling ponds to avoid contamination of the surrounding environment, hence transport routes and methods can also be considered as an impact. To mitigate risks, a tailings flow failure protection berm is included in the designs for the proposed tailings facility, preventing negative environmental impacts in case of failure. By addressing stormwater and tailings management, the project aims to safeguard human life and the environment while operating in an arid area with occasional significant rainfall events.
Draft Scoping Report for the Environmental and Social Impact Assessment for The Proposed Development of the Gergarub Mine, 2014.	The purpose of the scoping report was to identify the key issues for investigation and assigned specialist studies, such as the Surface water and Groundwater Impact Assessments. The document contains a project description, a summary of the project's environmental regulatory framework, an overview of the socio-economic and bio-physical environment, details of the public consultation as well as, a list of identified key issues with a preliminary risk assessment, this document will provide us with a helpful insight into the issues of concern raised by the Rosh Pinah community during the public participation process.
Environmental and Social Impact Assessment (ESIA) for the Proposed Development of the Gergarub Mine, Appendix C - Surface Water Impact Assessment, 2015.	The surface water impact assessment was conducted by SRK as part of the previous ESIA and includes road design as this has an impact on surface water flow regimes. The report mentions dust as a high impact factor as well as tailings storage and tailings storage failure and highlights the need for separate clean and contaminated stormwater management systems. Surface water modeling and a comprehensive project water balance including many components of the mine was undertaken. However, it does not address potential surface water groundwater interactions.
Environmental and Social Impact Assessment (ESIA) for the Proposed Development of the Gergarub Mine, Appendix D - Groundwater Impact Assessment, 2015.	The groundwater impact assessment was conducted by Geo Pollution Technology as part of the previous ESIA, which shows the impacts of the mine on the soil and groundwater. The report incorporates much includes a groundwater modeling for mine dewatering and contaminant transport from potential tailings leakage, as well as soil contamination from waste rock and the impacts of acid mine drainage. It also addresses other contaminants that may arise during the processing and handling of ore, which could affect the groundwater during the mining process. The report discusses the impacts, mitigation, and management of these effects over the lifecycle of the mine.
Scoping Report and EMP for Gergarub	The Scoping Report was prepared for the Gergarub Mine in 2019 and covers all aspects required for the new and

Document	Summary
Exploration and Mining, 2019.	updated ESIA scoping process. The report addresses the impacts that exploration activities will have on the environment and speaks to the current environmental state of the area. It offers mitigation and management measures for impacts of exploration activities, with additional measures which are helpful in preparing the ESIA. This Impact Assessment falls under this EIA.
Scoping report for the Gergarub Mining Projecton ML 245, //Kharas Region, Namibia, 2023.	This Scoping Report is more comprehensive than above and covers a lot of detail regarding the mining process and equipment. The outcomes are separate terms of references for various specialist studies that are required for the ESIA.

Appendix B – Gap Analysis

Following the information assessment, the gaps identified are summarised below. If the data/information cannot be provided, the alternative source will be used and the consequence to the final output is described. A rating of the consequence is also provided as low, moderate, or high.

Component	Gap Identified	Alternative Source	Consequence to Output	Rating
Mining Method	Gergarub Strategy Optimisation Study for Gergarub Mining and Exploration (AMC Consultants, 2022), Technical Report of the Gergarub Deposit, Namibia (Rosh Pina Mine and Skorpion Zinc Mine, 2022) and Rosh Pinah Expansion "RP2.0" NI 43-101 Feasibility Study (AMC, 2021).	Summary provided in Scoping report for the Gergarub Mining Project on ML 245 will be used.	Mining components and related impacts to water environments not included in Impact Assessment.	Moderate
Mine Layout	Confirm drawings are current: • 100_Rev_0.pdf and 200_Rev_0.pdf (plant and haul roads layout plans)	It is assumed that these are the current design plans	Discontinuity in the ESIA, irrelevant hydrologic outputs and misrepresentative Impact Assessment.	Moderate
TSF Design	TSF design and capacity remain as the original study (SRK, 2014) however, did not consider using tailings for backfill material.	The design as is provided design will be used as is.	Insufficient assessment of impacts.	Moderate
	Confirm the following are current: • 003Proposed TSF shape and location_TAILINGS.dwg • 006REVB_Pyrite flotation_TAILINGS.dwg • TAILINGS DWG.dwg • 301_Rev_0 .pdf (tailings flow Failure Protection Berm plans).	Assumed that these are current.	Important impacts not identified or considered in the Impact Assessment	Low

Component	Gap Identified	Alternative Source	Consequence to Output	Rating
Rehabilitation Plan	No rehabilitation plan is available.	It is assumed that no rehabilitation plan is available.	Higher rated impacts without mitigation/rehabilitation.	Low
Climate	Annual datasets of daily rainfall	Daily rainfall from 1953-1973 (20 years) at Alexander Bay South African Weather Station. Alternatively, modelled data from Meteoblue.com sourced at additional cost.	increased uncertainty in the flood assessment model.	High
Terrain/ Elevation	Lidar/DSM data/spot heights.	Combination of ALOS and SRTM 30 m.	Increased uncertainty (and error margin) in the flood assessment model.	High
Drainage	Catchment boundaries for the Zebrafontein and Trekpoort catchments	A GIS-based drainage and catchment analysis will be undertaken to delineate these sub catchments and drainage lines using ALOS/SRTM 30 m (or improved elevation data provided).	Inaccurate representation of drainage and surface flow directions.	Low
	Drainage lines at finer scale (1:250 000 or better)			
Geology	Geological maps at finer scale	Literature and 1:250 000 geological shapefiles from the Geological Survey of Namibia.	Errors in aquifer characterisation and loss of important features in the conceptual model.	Moderate
	Overburden thickness shapefiles	Drill logs (point source data) will be used to infer depth to bedrock.	Incorrect impact ratings for contamination transport.	Moderate
	Drill logs of core boreholes drilled during concept and feasibility phases	7 borehole logs provided will inform the conceptual model.	The geological and hydrogeological detail and certainty of the conceptual model reduced.	Low to Moderate
Borehole Information	Surface elevations (surveyed) of boreholes	Handheld GPS elevations will be used or calculated using the best available DEM.	misrepresentative piezometric maps and groundwater flow paths.	Low
Water Levels	Additional water level data • Data from the 2007 hydrocensus • Final water levels of the core boreholes after drilling.	The 16 available water levels and additional water levels obtained during a site visit.	Uncertainty in piezometric maps increased and temporal variations in water levels unknown. Impacts understanding recharge patterns/mechanisms, contamination transport.	High

Component	Gap Identified	Alternative Source	Consequence to Output	Rating
Hydrochemistry	No water quality result for cyanide, ammonia, chlorine, typical faecal coli., phenolic compounds, fats, oil and grease, detergents, surfactants, and tensides	Water quality data provided will be used as is.	Missing parameters will have no groundwater baseline values. Sulphate, sulphide, cyanide, ammonia and ammonium are particularly important as they are common mining contaminants.	Moderate
	No groundwater baseline value for sulphate, sulphide, cyanide, ammonia, ammonium, cadmium, copper, iron, manganese, tin, strontium, thorium, titanium, zinc, and zirconium are present.	None.		Moderate to High
Geochemistry	Data for 40 week-long leachate tests.	Data and conclusions drawn from the first 15 weeks will be used.	Long term impacts overlooked.	Moderate to High
	No geochemistry data for return water dam, aging pond, backfilling hydrolyzation process, settling pond, and dirty water dam.	Geochemistry of the ore rock, waste rock and tailings as provided will be used to assess potential contaminants.	Omission of potential contaminants and impacts.	Low
Water Users	Estimated abstraction volumes by other users.	Volumes will be obtained during a site visit and hydrocensus, or assumptions will be made based on literature.	Groundwater misrepresentative and cumulative impacts on aquifer and other users not assessed.	Moderate

Appendix B – Flooding Assessment

Report (No. UVO-004) provided as digital appendix.

GERGARUB MINE

FLOODING ASSESSMENT

Project No. UVO-004

Draft

October, 2023

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Appendix C – Water Quality

Parameters	Unit	SPDD005	SPDD0058-MIN	SPDD009	SPDD013	SPDD108	SPDD166	SPDD271	NAMWATER Guideline Values			
		18/04/2013	20/04/2013	19/04/2013	19/04/2013	20/04/2013	20/04/2013	20/04/2013	A	B	C	D*
Electrical Conductivity @25C	mS/m	198.4	170.9	173.7	275.9	177.5	213.2	400.7	150	300	400	>400
Calcium Hardness Dissolved as $CaCO_3$	mg/l	331.3	250.0	291.0	283.0	242.0	342.5	422.8	300	650	1300	>1300
Chloride	mg/l	396.5	332.5	281.3	745.2	360.8	417.3	939.6	250	600	1200	>1200
Fluoride	mg/l	0.6	1.1	1.1	<0.3	1.2	0.4	<0.3	1.5	2	3	>3
Sulphate	mg/l	138.61	228.63	336.21	33.71	58.29	14.16	48.65	200	600	1200	>1200
Dissolved Copper	mg/l	0.078	<0.007	<0.007	0.091	<0.007	0.088	0.010	0.5	1	2	>2
Nitrate as NO_3	mg/l	0.8	0.8	0.8	0.4	0.6	0.8	0.6	10	20	40	>40
Nitrite as NO_2	mg/l	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	-	-	-	-
Total Dissolved Iron	mg/l	1.809	0.472	0.453	65.400	0.389	1.615	1.297	0.1	1	2	>2
Dissolved Manganese	mg/l	0.312	1.702	1.041	3.200	0.628	2.980	0.434	0.05	1	2	>2
Dissolved Zinc	mg/l	0.516	0.069	0.123	0.222	0.014	0.535	0.115	1	5	10	>10
pH	pH units	7.40	7.16	6.77	6.22	7.30	6.96	7.56	6.0-9.0	5.5-9.5	4.0-11.0	>11.0
Dissolved Aluminum	mg/l	0.041	0.032	0.066	0.259	<0.02	0.057	0.133	0.15	0.50	1	>1
Dissolved Antimony	mg/l	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.05	0.1	0.2	>0.2
Dissolved Arsenic	mg/l	0.0048	<0.0025	<0.0025	<0.0025	<0.0025	<0.0025	<0.0025	0.10	0.3	0.6	>0.6
Dissolved Barium	mg/l	0.072	0.123	0.079	0.207	0.259	0.194	0.255	0.50	1	2	>2

Parameters	Unit	SPDD005	SPDD0058-MIN	SPDD009	SPDD013	SPDD108	SPDD166	SPDD271	NAMWATER Guideline Values			
		18/04/2013	20/04/2013	19/04/2013	19/04/2013	20/04/2013	20/04/2013	20/04/2013	A	B	C	D*
Dissolved Beryllium	mg/l	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.002	0.01	0.01	>0.01
Dissolved Boron	mg/l	0.344	0.208	0.240	0.792	0.257	0.389	0.949	0.50	2	4	>4
Dissolved Cadmium	mg/l	0.0011	<0.0005	<0.0005	0.0143	<0.0005	0.001	<0.0005	0.01	0.02	0.04	>0.04
Dissolved Calcium	mg/l	132.5	100.0	116.4	113.2	96.8	137.0	169.1	150	200	400	>400
Total Dissolved Chromium	mg/l	<0.0015	<0.0015	<0.0015	0.012	<0.0015	0.0021	0.0023	0.10	0.2	0.4	>0.4
Dissolved Cobalt	mg/l	<0.002	<0.002	<0.002	0.008	<0.002	0.003	<0.002	0.25	0.5	1	>1
Dissolved Lead	mg/l	0.008	0.008	<0.005	0.013	<0.005	0.022	0.008	0.05	0.1	0.2	>0.2
Dissolved Magnesium	mg/l	44.4	33.5	39.9	44.5	35.3	49.0	70.3	70	100	200	>200
Dissolved Mercury	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.005	0.01	0.02	>0.02
Dissolved Molybdenum	mg/l	<0.002	0.003	<0.002	0.016	<0.002	0.004	0.003	0.05	0.1	0.2	>0.2
Dissolved Nickel	mg/l	0.015	0.008	0.013	0.036	0.003	0.029	0.015	0.25	0.5	1	>1
Dissolved Phosphorus	mg/l	0.488	0.105	0.122	0.375	0.092	0.948	0.248	-	-	-	-
Dissolved Potassium	mg/l	15.3	8.7	11.2	41.5	14.6	23.3	46.2	200	400	800	>800
Dissolved Selenium	mg/l	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.02	0.05	0.1	>0.1
Dissolved Silicon	mg/l	9.01	13.44	12.05	23.31	14.04	18.53	11.28	-	-	-	-
Dissolved Sodium	mg/l	195.8	199.6	182.7	367.5	229.5	196.9	550.4	100	400	800	>800
Dissolved Thallium	mg/l	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.005	0.01	0.02	>0.02
Dissolved Uranium	mg/l	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	1.00	4	8	>8
Dissolved Vanadium	mg/l	<0.0015	<0.0015	<0.0015	0.0044	<0.0015	<0.0015	0.0025	0.25	0.5	1	>1
Bromide	mg/l	0.95	0.67	0.93	1.39	0.92	1.14	0.94	1.00	3	6	>6

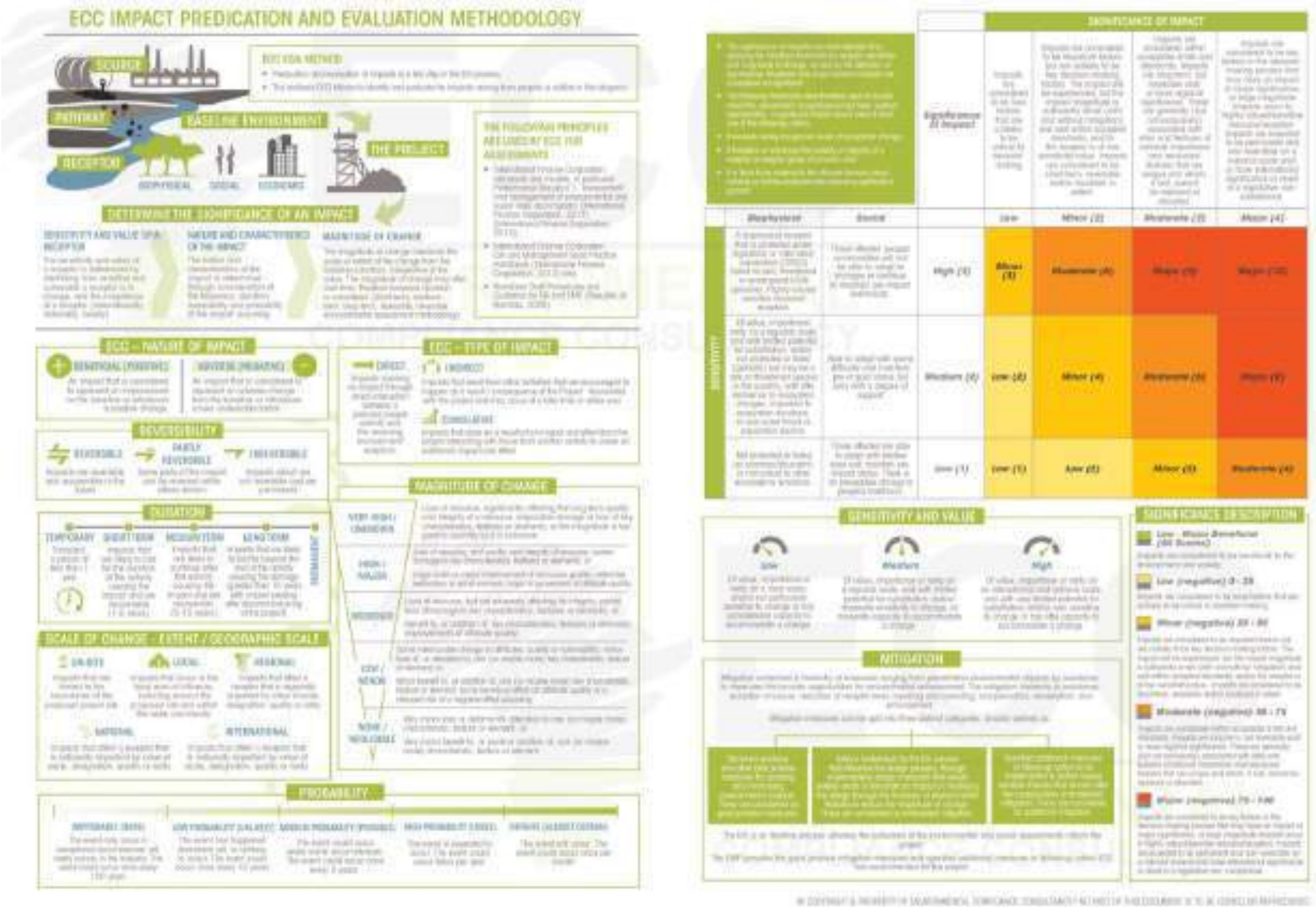
Parameters	Unit	SPDD005	SPDD0058-MIN	SPDD009	SPDD013	SPDD108	SPDD166	SPDD271	NAMWATER Guideline Values			
		18/04/2013	20/04/2013	19/04/2013	19/04/2013	20/04/2013	20/04/2013	20/04/2013	A	B	C	D*
Ortho Phosphate as PO_4	mg/l	<0.06	<0.06	<0.06	1.21	<0.06	<0.06	<0.06	-	-	-	-
Hexavalent Chromium	mg/l	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	-	-	-	-
Total Alkalinity as $CaCO_3$	mg/l	358	144	142	292	356	536	530	-	-	-	-
Sulfide	mg/l	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	-	-	-	-
COD (Settled)	mg/l	88	17	8	570	91	187	289	-	-	-	-
Dissolved Organic Carbon	mg/l	25	5	4	156	25	52	83	-	-	-	-
Total Dissolved Solids	mg/l	1330	1030	1142	2020	1105	1404	2638	-	-	-	-
Total Suspended Solids	mg/l	280	272	106	1199	653	487	225	-	-	-	-
pH of Calcium Carbonate Saturation	mg/l	6.92	7.70	7.52	7.22	7.10	6.82	6.8	-	-	-	-

Parameters	Units	GB-GH-BH1	GB-GH-BH2	GB-GH-BH3	GB-GH-BH4	GB-GH-BH5	GB-GH-BH6	GB-GH-BH7	NAMWATER guidelines			
		23/11/2013	06/11/2013	28/10/2013	15/11/2013	11/11/2013	01/12/2013	03/12/2013	A	B	C	D*
Electrical Conductivity @25C	mS/m	257.8	169.6	241.1	155.0	163.3	880.5	900.3	150	300	400	400
Chloride	mg/l	522.0	348.0	502.2	292.3	290.6	2670.8	2795.7	250	600	1200	1200
Fluoride	mg/l	0.8	1.2	0.8	1.8	1.6	0.5	0.5	1.5	2	3	3
Sulphate	mg/l	236.20	116.62	298.22	203.54	208.25	1529.14	1802.25	200	600	1200	1200
Dissolved Copper	mg/l	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.5	1	2	2
Nitrate as NO_3	mg/l	0.2	9.7	0.7	2.4	3.2	<0.2	10.3	10	20	40	40
Nitrite as NO_2	mg/l	<0.02	0.05	<0.02	<0.02	<0.02	<0.02	<0.02	-	-	-	-
Total Dissolved Iron	mg/l	0.177	1.202	1.518	0.216	0.286	12.610	0.007	0.1	1	2	2

Parameters	Units	GB-GH-BH1	GB-GH-BH2	GB-GH-BH3	GB-GH-BH4	GB-GH-BH5	GB-GH-BH6	GB-GH-BH7	NAMWATER guidelines			
		23/11/2013	06/11/2013	28/10/2013	15/11/2013	11/11/2013	01/12/2013	03/12/2013	A	B	C	D*
Dissolved Manganese	mg/l	0.269	0.191	0.440	0.064	0.013	2.449	0.013	0.05	1	2	2
Dissolved Zinc	mg/l	0.0244	0.0173	0.0246	0.0216	0.0246	0.0536	0.1712	1	5	10	10
pH	pH units	7.47	7.65	7.23	7.70	7.51	6.74	7.11	6.0-9.0	5.5-9.5	4.0-11.0	4.0-11.0
Dissolved Aluminium	mg/l	<0.0015	0.0058	0.0019	<0.0015	<0.0015	0.0036	<0.0015	0.15	0.5	1	1
Dissolved Antimony	mg/l	<0.002	0.006	<0.002	<0.002	<0.002	<0.002	<0.002	0.05	0.1	0.2	0.2
Dissolved Arsenic	mg/l	<0.0009	0.0009	0.0050	0.0015	<0.0009	0.0104	0.0058	0.1	0.3	0.6	0.6
Dissolved Barium	mg/l	0.0299	0.3860	0.0278	0.0289	0.0366	0.0166	0.0037	0.5	1	2	2
Dissolved Beryllium	mg/l	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.002	0.005	0.01	0.01
Dissolved Boron	mg/l	0.463	0.376	0.348	0.190	0.203	1.227	1.075	0.5	2	4	4
Dissolved Cadmium	mg/l	<0.00003	0.00022	0.00014	<0.00003	<0.00003	0.00076	0.00034	0.01	0.02	0.04	0.04
Dissolved Calcium	mg/l	141.1	78.2	161.6	83.2	76.8	928.2	1162.0	150	200	400	400
Total Dissolved Chromium	mg/l	<0.0002	<0.0002	<0.0002	<0.0002	0.0007	<0.0002	<0.0002	0.1	0.2	0.4	0.4
Dissolved Cobalt	mg/l	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.25	0.5	1	1
Dissolved Lead	mg/l	0.0015	0.0050	0.0076	0.0006	0.0068	0.0057	0.0076	0.05	0.1	0.2	0.2
Dissolved Magnesium	mg/l	54.6	21.6	59.1	28.8	27.4	271.0	303.1	70	100	200	200
Dissolved Mercury	mg/l	<0.0005	<0.0005	0.0042	<0.0005	<0.0005	<0.0005	<0.0005	0.005	0.01	0.02	0.02
Dissolved Molybdenum	mg/l	<0.0002	0.0031	0.0019	0.0027	0.0042	0.0006	0.0026	0.05	0.1	0.2	0.2
Dissolved Nickel	mg/l	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	0.0013	0.0025	0.25	0.5	1	1
Dissolved Phosphorus	mg/l	0.0136	0.0109	0.0147	0.0015	<0.0007	0.0075	0.0083	-	-	-	-
Dissolved Potassium	mg/l	13.6	11.3	14.0	7.4	6.7	53.5	59.2	200	400	800	800

Parameters	Units	GB-GH-BH1	GB-GH-BH2	GB-GH-BH3	GB-GH-BH4	GB-GH-BH5	GB-GH-BH6	GB-GH-BH7	NAMWATER guidelines			
		23/11/2013	06/11/2013	28/10/2013	15/11/2013	11/11/2013	01/12/2013	03/12/2013	A	B	C	D*
Dissolved Selenium	mg/l	<0.0012	<0.0012	<0.0012	<0.0012	<0.0012	<0.0012	0.0466	0.02	0.05	0.1	0.1
Dissolved Silicon	mg/l	11.620	7.715	9.252	12.150	9.480	12.670	14.170	-	-	-	-
Dissolved Sodium	mg/l	574.3	246.0	262.8	210.3	172.1	1122.0	1068.0	100	400	800	800
Dissolved Thallium	mg/l	<0.0009	<0.0009	<0.0009	<0.0009	<0.0009	<0.0009	<0.0009	0.005	0.01	0.02	0.02
Dissolved Uranium	mg/l	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	1	4	8	8
Dissolved Vanadium	mg/l	<0.0006	0.0019	0.0006	0.0020	0.0067	0.0015	0.0010	0.25	0.5	1	1
Bromide	mg/l	1.50	1.08	1.47	1.06	0.91	5.97	6.85	1	3	6	6
Ortho Phosphate as PO_4	mg/l	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	-	-	-	-
Hexavalent Chromium	mg/l	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.009	-	-	-	-
Total Alkalinity as $CaCO_3$	mg/l	320	172	236	108	116	244	420	-	-	-	-
COD (Settled)	mg/l	84	42	53	7	17	75	61	-	-	-	-

Appendix D – Impact Predication And Evaluation Methodology



Air Quality Impact Assessment for the Gergarub Project near Rosh Pinah in Namibia

Project done for **Environmental Compliance Consultancy (ECC)**

Report No: 23ECC01 | **Date: October** 2023

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Report Details

Report Title	Air Quality Impact Assessment for the Gergarub Project near Rosh Pinah in Namibia
Client	Environmental Compliance Consultancy (ECC)
Report Number	23ECC01
Report Version	Rev 1
Date	27 October 2023
Prepared by	Marilize Steyn MEng Environmental Engineering (University of Pretoria)
Reviewed by	Hanlie Liebenberg-Enslin, PhD (University of Johannesburg)
Notice	Airshed Planning Professionals (Pty) Ltd is a consulting company located in Midrand, South Africa, specialising in all aspects of air quality, ranging from nearby neighbourhood concerns to regional air pollution impacts as well as noise impact assessments. The company originated in 1990 as Environmental Management Services, which amalgamated with its sister company, Matrix Environmental Consultants, in 2003.
Declaration	Airshed is an independent consulting firm with no interest in the project other than to fulfil the contract between the client and the consultant for delivery of specialised services as stipulated in the terms of reference.
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Revision Record

Version	Date	Report Status	Summary Description of Revision(s)
Rev 1	27 October 2023	Draft report	Submitted to client for review

Abbreviations

ADMS	Atmospheric Dispersion Modelling System
AQG	Air Quality Guidelines
AQIA	Air Quality Impact Assessment
AQMP	Air Quality Management Plan
AQO	Air Quality Objectives
AQSRs	Air Quality Sensitive Receptors
ASTM	American Society for Testing and Materials standard method
CERC	Cambridge Environmental Research Consultants
CO	carbon monoxide
CO_2	carbon dioxide
EC	European Community
EGL	Effective Grinding Length
EHS	Environmental, Health and Safety
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency
FEL	front-end-loaders
GHG	greenhouse gas
GIIP	Good International Industry Practice
GLCs	ground level concentrations
HSE	UK Health and Safety Executive
IFC	International Finance Corporation
IT	interim target
LMo	Obukhov length
LOM	life of mine
NAAQS	National Ambient Air Quality Standards (South Africa)
NDCR	National Dust Control Regulations (South Africa)
NOx	oxides of nitrogen
NPI	Australian National Pollutant Inventory
PM	Particulate Matter
PM_{10}	Particulate matter with an aerodynamic diameter of less than 2.5 µm (thoracic particles)
$PM_{2.5}$	Particulate matter with an aerodynamic diameter of less than 10 µm (respirable particles)
Project	Gergarub project
PSD	particle size distribution
ROM	Run-of-Mine
SA	South African
SEA	Strategic Environmental Assessment
SEMP	Strategic Environmental Management Plan
SEPA	Scottish Environmental Protection Agency
SO_2	sulfur dioxide
TSF	tailings storage facility
TSP	Total Suspended Particulates
UK	United Kingdom
US	United States
VKT/day	vehicle kilometres travelled per day
WBG	World Bank Group

WHO	World Health Organisation
WRDs	waste rock dumps
TSF	tailings disposal facility

Units

°C	Degree Celsius
Gg CO_2-eq	Greenhouse gas carbon dioxide equivalent
K	Kelvin
km	kilometre
kPa	kilo pascal
m	metres
mm	millimetre
mg/m²/day	milligram per metre squared per day
mtpa	million tons per annum
t	ton
tpa	tons per annum
tpm	tons per month
µg/m³	microgram per cubic metre
%	percent

Glossary

Air pollution: means any change in the composition of the air caused by smoke, soot, dust (including fly ash), cinders, solid particles of any kind, gases, fumes, aerosols and odorous substances.

Atmospheric emission: means any emission or entrainment process emanating from a point, non-point or mobile sources that result in air pollution.

Averaging period: This implies a period of time over which an average value is determined.

Dust: Solid materials suspended in the atmosphere in the form of small irregular particles, many of which are microscopic in size.

Frequency of Exceedance: A frequency (number/time) related to a limit value representing the tolerated exceedance of that limit value, i.e. if exceedances of limit value are within the tolerances, then there is still compliance with the standard.

Particulate Matter (PM): These comprise a mixture of organic and inorganic substances, ranging in size and shape and can be divided into coarse and fine particulate matter. The former is called Total Suspended Particulates (TSP), whilst PM_{10} and $PM_{2.5}$ fall in the finer fraction referred to as Inhalable particulate matter.

TSP: Total suspended particulates refer to all airborne particles and may have particle sizes as large as 150 µm, depending on the ability of the air to carry such particles. Generally, suspended particles larger than 75 to 100 micrometre (µm) do not travel far and deposit close to the source of emission.

PM_{10}: Thoracic particulate matter is that fraction of inhalable coarse particulate matter that can penetrate the head airways and enter the airways of the lung. PM_{10} consists of particles with a mean aerodynamic diameter of 10 µm or smaller, and deposit efficiently along the airways. Particles larger than a mean size of 10 µm are generally not inhalable into the lungs. These PM_{10} particles are typically found near roadways and dusty industries.

$PM_{2.5}$: Respirable particulate fraction is that fraction of inhaled airborne particles that can penetrate beyond the terminal bronchioles into the gas-exchange region of the lungs. Also known as fine particulate matter, it consists of particles with a mean aerodynamic diameter equal to or less than 2.5 µm ($PM_{2.5}$) that can be inhaled deeply into the lungs. These particles can be directly emitted from sources such as forest fires, or they can form when gases emitted from power plants, industries and automobiles react in the air.

Point sources: are discrete, stationary, identifiable sources of emissions that release pollutants to the atmosphere (International Finance Corporation (IFC), 2007).

Vehicle entrainment: This is the lifting and dropping of particles by the rolling wheels leaving the road surface exposed to strong air current in turbulent shear with the surface. The turbulent wake behind the vehicle continues to act on the road surface after the vehicle has passed.

Executive Summary

Gergarub Mining and Exploration (Pty) Ltd owns the Gergarub Project, a joint venture agreement between Vedanta Zinc International (51 %), via its Namibian subsidiary Skorpion Zinc Mine, and Rosh Pinah Zinc Corporation, or Rosh Pinah (49 %) (JV). The proposed Gergarub Project will be an underground mine using the long hole open stoping (LHOS) and Drift and Fill (DAF) with a backfill mining method. Additionally, LHOS will be supplemented with Drift and Fill (DAF) mining which will be used to mine the orebody extremities and maximize the overall recovery of the Mineral Resource. Airshed Planning Professionals (Pty) Ltd (Airshed) was appointed by Environmental Compliance Consultancy (ECC) to conduct an air quality impact assessment study as part of the Project Environmental Impact Assessment (EIA).

The main objective of the investigation was to quantify the potential air quality impacts resulting from the proposed activities on the surrounding environment and human health. As part of the air quality assessment, a good understanding of the regional climate and local dispersion potential of the site is necessary and subsequently an understanding of existing sources of air pollution in the region and the current and potential future activities resulting in air quality related impacts.

The scope of work (SoW) included the review of technical information and legislative context relevant to Namibia. A baseline assessment was required to get an understanding of the receiving environment, looking at existing sources of air pollution and the status of air quality within the region, as well as sensitive receptors in the form of human settlements. Modelled meteorological data for a thee year period (1 January 2020 to 31 December 2022) was used to determine the dispersion potential of the site, which influences the spreading and removal of air pollution. To determine the potential impacts from the proposed mining operations, an emissions inventory had to be established accounting for all sources of air pollution associated with the mining activities (underground mining, and processing operations). Emissions were based on the process description and mine layout plan as provided. The ADMS dispersion model was used to simulate the expected impacts from these emission sources, with the simulated particulate matter ground level concentrations (GLCs) and dustfall rates screened against the applicable air quality objectives (AQOs) to determine the significance of the proposed project on the receiving environment. Once the significance of these impacts has been established, the main contributing sources could be identified, and mitigation measures defined to ensure reduced impacts from these activities.

Baseline Characterisation

The main findings from the baseline assessment can be summarised as follows:

- The Project is located to the North of Rosh Pinah in the Kharas region in the South of Namibia.
- The project site is located in a hilly area that could impact the wind flow at the site.
- There are no villages or homesteads near the project, with the closest buildings located towards the southern side of the side boundary.
- On-site weather data was not available for the site and the assessment utilised modelled weather data. The predominant wind direction was southwest to westerly, with an increase in easterly winds during winter.
- Maximum, minimum, and mean temperatures were given as 1.5°C, 19.6°C and 41.1°C respectively from the modelled weather data for the period 1 January 2020 to 31 December 2022.
- Modelled MeteoBlue annual rainfall for 2020, 2021 and 2022 was 31.7, 38.9 and 34.1 mm respectively, with the highest monthly rainfall in January 2021 (25.7 mm).
- The main pollutant of concern in the region is particulate matter (TSP; PM_{10} and $PM_{2.5}$) resulting from vehicle entrainment on the roads (paved, unpaved and treated surfaces), windblown dust, and mining and exploration

activities. Gaseous pollutants such as SO_2, NOx, CO and CO_2 would result from vehicles and combustion sources, but these are expected to be at low concentrations due to the few sources in the region.

- Sources of atmospheric emissions in the vicinity of the proposed Project include:
    - Windblown dust: Windblown particulates from natural exposed surfaces, mine waste facilities, and product stockpiles can result in significant dust emissions with high particulate concentrations near the source locations, potentially affecting both the environment and human health. Windblown dust from natural exposed surfaces in and at the Project is only likely to result in particulate matter emissions under high wind speed conditions (>10 m/s), and since recorded wind speeds did not exceed 10 m/s, this source is likely to be of low significance.
    - Mines and Exploration operations: Mines in proximity to the proposed Project are Skorpion Zinc Mine located northwest of the site, approximately 10 km from the site and the Rosh Pinah Mine located approximately 15 km from the site.
    - Vehicle entrainment on paved and unpaved roads.
    - Regional transport of pollutants: regional-scale transport of mineral dust and ozone (due to vegetation burning) from the north of Namibia is a significant contributing source to background PM concentrations.

Impact Assessment

The findings from the impact assessment can be summarised as follows:

Construction normally comprises a series of different operations including land clearing, topsoil removal, road grading, material loading and hauling, stockpiling, grading, bulldozing, compaction, etc., with particulate matter the main pollutants of concern from these activities. The extent of dust emissions would vary substantially from day to day depending on the level of activity, the specific operations, and the prevailing meteorological conditions, and how close these activities are to AQSRs. Due to the intermittent nature of construction operations, the emissions are expected to have a varying impact depending on the level of activity. With mitigation measures in place these impacts are expected to be low.

Operational Phase:

- Emissions quantified for the proposed Project were restricted to fugitive releases (non-point releases) and point source emissions from the ventilation shaft with particulates the main pollutant of concern. Gaseous emissions (i.e. SO_2, NOx, CO and VOCs) will primarily result from diesel combustion, both from mobile and stationary sources.
- Both unmitigated and mitigated scenarios were modelled. Mitigation was applied was based on design mitigation measures provided, which included the following:
    - Surface haul roads: water sprays combined with chemical suppressant on resulting in 75% CE;
    - Materials handling (loading and unloading ROM and waste rock): water sprays at tip points resulting in 50% CE; and
    - Crushing and screening of ROM (primary; secondary and tertiary): resulting in 50% CE from water sprays to keep ore wet.
- Dispersion modelling results indicate no off-site exceedances of the AQOs for $PM_{2.5}$, PM_{10} and dustfall. The air quality impacts can be reduced by applying mitigation measures.
- Cumulative air quality impacts could not be assessed since no background PM_{10} and $PM_{2.5}$ data are available. The localised PM_{10} and $PM_{2.5}$ impacts from the proposed Project modelling results indicate the potential for low regional cumulative impacts, and only high cumulative impacts in the immediate vicinity of the mine. Off-site impacts are likely to be managed with proper mitigation measures in place.

Closure operations are likely to include demolishing existing structures, scraping and moving surface material to cover the remaining exposed surfaces (WRDs and TSF) and contouring of the surface areas. The impacts are expected to be similar to that of construction operations – potentially small but harmful impacts at nearby receptors, depending on the level of activity but low impacts with mitigation measures in place. **Post-closure** operations, likely to include vegetation cover maintenance, would result in very low air quality related impacts.

Conclusion

The proposed Project is likely to result in increased $PM_{2.5}$ and PM_{10} ground level concentrations in the immediate vicinity of the mine and impacts can be reduced by applying appropriate mitigation measures. The dispersion modelling results indicate that the AQOs were not exceeded off-site. Dustfall rates are likely to be low throughout the life of mine, with gaseous concentrations (SO_2, NO_2 and CO) also expected to result in low air quality impacts.

It is the specialist's opinion that the proposed project could be authorised provided strict enforcement of mitigation measures and the tracking of the effectiveness of these measures to ensure the lowest possible off-site impacts.

Recommendations

Based on the findings from the air quality impact assessment for the Project following recommendations are included:

- Construction and closure phases:
    - Air quality impacts during construction would be reduced through basic control measures such as limiting the speed of haul trucks; limit unnecessary travelling of vehicles on untreated roads; and applying dust-a-side on regularly travelled, unpaved sections.
    - When haul trucks need to use public roads, the vehicles need to be cleaned of all mud and the material transported must be covered to minimise windblown dust.
- Operational phases:
    - For the control of vehicle entrained dust a control efficiency (CE) of 90% on unpaved surface roads through the application of chemical surfactants is recommended.
    - In controlling dust from crushing and screening operations, it is recommended that water sprays be applied to keep the ore wet, to achieve a control efficiency of up to 50%.
    - Mitigation of materials transfer points should be done using water sprays at the tip points. This should result in a 50% control efficiency. Regular clean-up at loading points is recommended.
    - In controlling emissions from the TSF it is recommended that the TSF slope be clad progressively during operation using waste rock. It is further recommended that a dust suppressing polymer is sprayed on the TSF surface following tailings placement.
- Air Quality Monitoring:
    - It is recommended that a dustfall monitoring network be established around the site boundary. The dustfall units must be maintained and the monthly dustfall results used as indicators to tract the effectiveness of the applied mitigation measures. Dustfall collection should follow the ASTM method.
    - It is further recommended that the dustfall monitoring network be supplemented by periodic ambient PM_{10} and $PM2_{.5}$ monitoring to determine whether the Air Quality Objectives are being met.

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1 INTRODUCTION

Gergarub Mining and Exploration (Pty) Ltd owns the Gergarub project (Project), a joint venture agreement between Vedanta Zinc International (51 %), via its Namibian subsidiary Skorpion Zinc Mine, and Rosh Pinah Zinc Corporation, or Rosh Pinah (49 %) (JV). The proposed Gergarub Project will be an underground mine using the long hole open stoping (LHOS) and Drift and Fill (DAF) with a backfill mining method. Additionally, LHOS will be supplemented with Drift and Fill (DAF) mining which will be used to mine the orebody extremities and maximize the overall recovery of the Mineral Resource. The proposed Project area is located in the Oranjemund Constituency, 15km north of the town of Rosh Pinah in the Karas Region in southern Namibia. The overall scale of mining envisaged for the Project is a medium-sized mine with an ore production of 1 Mtpa.

An air quality assessment is required as part of the Environmental Impact Assessment (EIA) for the Project. Airshed Planning Professionals (Pty) Ltd was appointed by Environmental Compliance Consultancy (ECC) to undertake an air quality impact assessment for the proposed Project. The main objective of the investigation is to quantify the potential impacts resulting from the proposed activities on the surrounding environment and human health. As part of the air quality assessment, a good understanding of the regional climate and local dispersion potential of the site is necessary and subsequently an understanding of existing sources of air pollution in the region.

The investigation followed the methodology required for a specialist impact assessment report.

1.1 Terms of Work

The baseline assessment includes a study of the receiving environment by referring to:

- A study of legal requirements pertaining to air quality – applicable international legal guidelines and limits and dust control regulations.
- Desktop review of all available project and associated data, including meteorological data, previous air quality assessments, EIAs and technical air quality data and modelled results.
- A study of atmospheric dispersion potential by referring to available on-site weather records for a period of at least one year (required for dispersion modelling) or modelled weather data where on-site data is not available, land use and topography data.
    - Details on the physical environment i.e. meteorology (atmospheric dispersion potential), land use and topography.
    - Identification of existing air pollution sources (other mines; industries; commercial operations, etc.).
    - Identification of air quality sensitive receptors (AQSRs), including any nearby residential dwellings and proposed receptors (temporary or permanent workers accommodation site(s)) in the vicinity of the mine.
    - Any freely available ambient air quality data, specifically Particulate Matter (PM).
- An impact assessment, including:
    - Identify all current sources of air pollution in the area (other mines; wildfires; domestic fuel burning; etc.).
    - The compilation of a comprehensive emissions inventory including the identification and quantification of all emissions associated with the proposed mining (open pit, hauling and processing operations).
    - Atmospheric dispersion modelling to simulate ambient air pollutant concentrations and dustfall rates from the project activities.
    - The screening of simulated ambient pollutant concentration levels and dust fallout against ambient air quality guidelines and standards.
- Assessment of the potential air quality impacts on human health and the environment.
- The identification and recommendation of suitable mitigation measures and monitoring requirements.

- The preparation of a comprehensive specialist air quality impact assessment (AQIA) report.

1.2 Project Description

The proposed Project area is located in the Oranjemund Constituency, 15 km north of the town of Rosh Pinah in the Karas Region in southern Namibia. The Project location is provided in Figure 1.

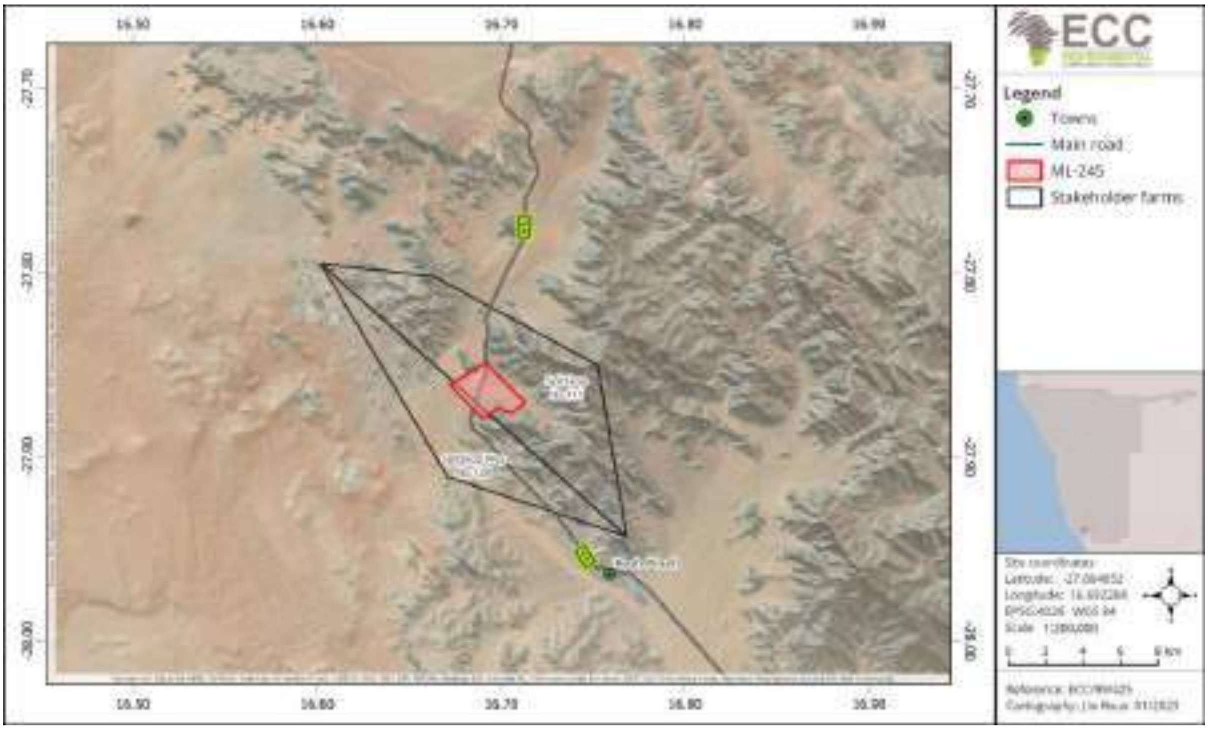

Figure 1: Gergarub Project Location

The proposed Gergarub Project will be an underground mine and ore will be transported to surface for processing at the processing plant. The processing plant at the proposed Project includes several processes (NPI, 2011), which are illustrated in Figure 2 and described as follows:

- The metallurgical performance projections for the concentrator indicate an approximate average recovery of 91.1% for zinc, 74.1% for lead, and 51.6% for silver.
- The average zinc concentrate will be 51.2% and the lead concentrate grade will be 58.2%.
- The milling circuit will consist of a SAG mill operating at throughput of 132.5 tph. The SAG mill will be a 6.1 m x 2.36 m Effective Grinding Length (EGL) with 1.8 MW motor and open grate discharge operating in closed circuit with primary and secondary cyclones to produce a combined feed slurry at a P80 particle size of 90 µm to the flotation circuit.
- The lead flotation circuit is of conventional design inclusive of a rougher, scavenger, and a cleaner flotation circuit with regrind. The circuit will have an effective capacity of 0.75 m^3/t/h and a required flotation volume of approximately 99 m^3.
- The zinc flotation circuit will have a capacity of 2.6 m^3/t/h and a required flotation volume of approximately 343 m^3. This will generate an overall residence time of the order of 60 minutes for flotation.
- Lead and zinc concentrates will be pumped to individual high-rate thickeners and the underflows filtered in Larox plate diaphragm filters. Filtrate is recovered to process water storage for re-use in the plant. Zinc circuit tailings stream is pumped to a high-rate thickener, water is recovered to the process water storage and thickener underflow pumped to an above ground tailings storage facility. A portion of the tailings will be processed further and utilised as backfill for the underground mine.

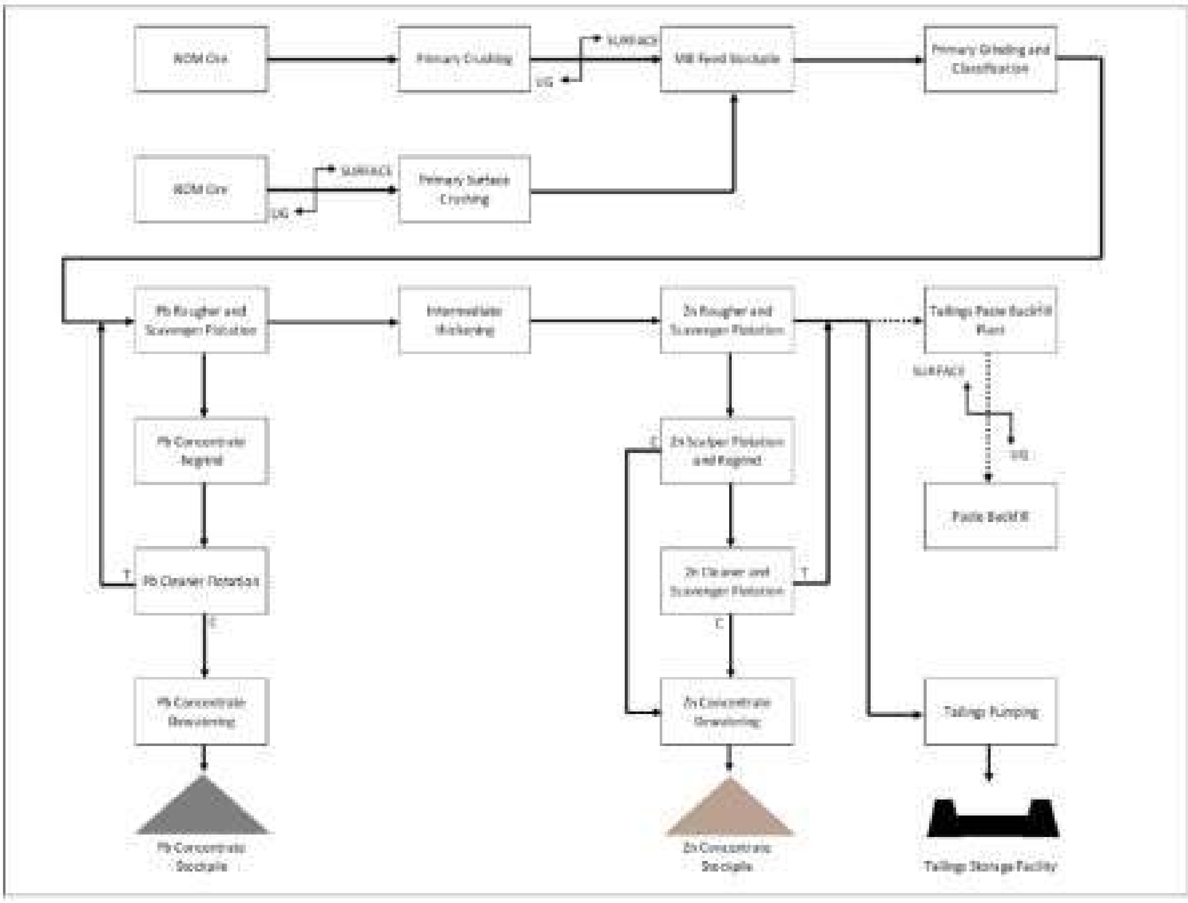

Figure 2: Gergarub Project Process Plant Flowsheet

With the focus of this assessment on air quality impacts from the proposed mining operations on the surrounding environment, the subsequent discussion is intended to provide an indication of the likely source activities associated with the different phases of the mine, and intended to guide planning around the monitoring network (i.e. which pollutants to focus on). Air pollution associated with opencast mining activities include air emissions emitted during the construction-, operational-, closure- and post-closure phases.

The construction phase will include the establishment of required mining infrastructure and associated facilities such as workshops, maintenance areas, stores, wash bays, lay-down areas, batch plant, fuel handling and storage area, offices, change houses, etc. Activities that would result in air pollution during the construction phase are listed Table 1.

Table 1: Construction activities resulting in air pollution

Activity	Associated pollutants
Handling and storage area for construction materials (paints, solvents, oils, grease) and waste	Particulate matter (PM)[(a)] and fumes (Volatile Organic Compounds [VOCs])
Power and water supply infrastructure	Sulfur dioxide (SO_2); oxides of nitrogen (NOx); carbon monoxide (CO); carbon dioxide (CO_2)[(b)]; particulate matter (PM)
Clearing and other earth moving activities	Mostly PM, gaseous emissions from earth moving equipment (SO_2; NOx; CO; CO_2)
Stockpiling topsoil and sub-soil	Mostly PM, gaseous emissions from front-end-loaders (FEL) (SO_2; NOx; CO; CO_2)
Foundation excavations	Mostly PM, gaseous emissions from excavators (SO_2; NOx; CO; CO_2)

Activity	Associated pollutants
Opening and backfill of material (specific grade) from borrow pits	Mostly PM, gaseous emissions from trucks and equipment (SO_2; NOx; CO; CO_2)
Establishing access roads (scraping and grading)	Mostly PM, gaseous emissions from trucks and equipment (SO_2; NOx; CO; CO_2)
Digging of foundations and trenches	Mostly PM, gaseous emissions from diggers (SO_2; NOx; CO; CO_2)
Delivery of materials – storage and handling of material such as sand, rock, cement, chemical additives, etc.	Mostly PM, gaseous emissions from trucks (SO_2; NOx; CO; CO_2)
General building/construction activities including, amongst others: mixing of concrete; operation of construction vehicles and machinery; refuelling of machinery; civil, mechanical and electrical works; painting; grinding; welding; etc	Mostly PM, gaseous emissions from construction vehicles and machinery (SO_2; NOx; CO; CO_2)

Notes: [a] Particulate matter (PM) comprises a mixture of organic and inorganic substances, ranging in size and shape and can be divided into coarse and fine particulate matter. Total Suspended Particulates (TSP) represents the coarse fraction >10μm, with particulate matter with an aerodynamic diameter of less than 10μm (PM_{10}) and particulate matter with an aerodynamic diameter of less than 2.5μm ($PM_{2.5}$) falling into the finer inhalable fraction. TSP is associated with dust fallout (nuisance dust) whereas PM_{10} and $PM_{2.5}$ are considered a health concern.

[b] CO_2 is a greenhouse gas (GHG).

Activities at the Project during Operation are likely to result in pollutants to air are listed in Table 2.

Table 2: Operational activities resulting in air pollution

Activity		Associated pollutants
Haulage of materials (ore and waste rock)		PM from road surfaces and windblown dust from trucks, gaseous emissions from truck exhaust (PM, SO_2; NOx; CO; CO_2)
Waste rock dump(s) (WRDs)		PM from tipping and windblown dust, gaseous emissions from truck exhaust (PM, SO_2; NOx; CO; CO_2)
Tailings Storage Facility (TSF)		
Ore Stockpiles		
Processing Plant	Crushing and Screening	PM
	Loading from Stockpiles	Mostly PM, gaseous emissions from machinery (PM, SO_2; NOx; CO; CO_2)

Closure and post-closure activities typically include rehabilitation of the site infrastructure – demolition of infrastructure and vegetation of WRDs and TSF. These activities mainly result in PM emissions with gaseous emissions from equipment and trucks.

1.3 Project Approach and Methodology

The approach to, and methodology followed in the completion of tasks completed as part of the scope of work are provided in Table 3.

An information requirements list was sent to ECC at the onset of the project. In response to the request, the following information was supplied:

- Layout maps;
- Process descriptions.

Documentation reviewed included the following:

- Scoping Report for the Gergarub Mining Project on ML 245, //Kharas Region, Namibia, Environmental Compliance Consultancy, 11 August 2023

- Gergarub Zinc project Stage 1 Concept Mine Plan, A&B Global Mining, 1 July 2022
- Scorpion Zinc Ventillation Study for Gergarub Project, BBE Consulting, 13 August 2014
- Measured Meteorological Data from RPZC Station

Table 3: Project Approach and Methodology

Task	Activity	Description	Report Section
Legal Review	A study of legal requirements pertaining to air quality in Namibia – ambient air quality standards and guidelines; dust control regulations and emission limits and guidelines.	Namibian Atmospheric Pollution Prevention Ordinance (No. 11 of 1976) International air quality criteria referenced, include: • World Health Organisation (WHO); • World Bank Group (WBG); • International Finance Corporation (IFC); and • South Africa (SA) air quality legislation.	Section 2
Baseline Assessment	Physical environmental parameters that influence the dispersion of pollutants in the atmosphere include: • terrain, • land cover, and • meteorology.	Modelled (Meteoblue) meteorological data from January 2020 to December 2022 was used for the assessment.	Section 3.2
	Identification of existing air pollution sources (other mines; agriculture; industries; etc.).	Likely sources of potential air quality pollution include but are not limited to mining and quarry operations, biomass burning and wildfires and vehicle emissions.	Section 3.1
	Identification of air quality-sensitive receptors, including any nearby residential dwellings and proposed receptors (temporary or permanent workers accommodation site(s)) near the mine.	A map of all the potential air quality sensitive receptors (AQSRs) are provided.	Section 3.1
Impact Assessment	The compilation of an emissions inventory incl. the identification and quantification of all emissions associated with the proposed mining operations (open pit mine and processing plant).	Construction operations will include the development of the mining infrastructure. Pollutants quantified are limited to particulate matter (TSP, PM_{10} and $PM_{2.5}$) and gaseous emissions (SO_2, NO_2 and CO). Use is made of process descriptions, mining rates and infrastructure maps to quantify activity emissions through the application of emissions factors and emission equations as published by the United States Environmental Protection Agency (US EPA) and Australian National Pollutant Inventory (NPI).	Section 4.1
	Atmospheric dispersion simulations of all pollutants (PM_{10}, $PM_{2.5}$ and dust fallout) for the operations reflecting highest daily and annual average concentrations due to routine emissions from the mining operations.	Use was made of the ADMS 5 model (Atmospheric Dispersion Modelling System) developed by the Cambridge Environmental Research Consultants (CERC). This model simulates a wide range of buoyant and passive releases to the atmosphere either individually or in combination. It has been the subject of several inter-model comparisons (CERC, 2004), one conclusion of which is that it tends	Section 4.2

		provide conservative values under unstable atmospheric conditions in that, in comparison to the older regulatory models, it predicts higher concentrations close to the source. The ADMS model was chosen specifically for its capability of modelling flow over complex topography, to account for the local topographical features in the project region.	
	Dispersion modelling results and compliance evaluation for the different scenarios of the Operational phase. Construction, Closure and Decommissioning phases are assessed qualitatively.	Compliance is assessed by comparing modelled ambient PM ($PM_{2.5}$ and PM_{10}) concentrations and dustfall rates to the relevant national and international ambient air quality standards and dustfall regulations.	Section 4.3
	Air quality impact assessment	The impact significance is evaluated against the adopted Air Quality Objectives (AQO).	Section 5
	The identification of air quality management and mitigation measures based on the findings of the compliance and impact assessment.	Practical mitigation and optimisation measures that can be implemented effectively to reduce or enhance the significance of impacts were identified.	Section 6

1.4 Assumptions, Exclusions and Limitations

The main assumptions, exclusions and limitations are summarised below:

- Meteorological and Ambient Data:
  - Modelled meteorological data for the period January 2020 to December 2022 was used for the assessment as measured data with adequate data availability was not available for the site.
- Emissions:
  - The quantification of sources of emission was restricted to the Project activities only. Although other background sources were identified, such as emissions from roads and other mines and quarries, these could not be quantified and did not form part of the scope of work.
  - Emissions were based on the process description and mine layout plan as provided. An ore throughput rate of 1 Mta was utilised to quantify emissions.
  - Since it is a proposed mine, no site-specific particle size fraction data for the various sources were available. The wind erosion emissions were assumed to be continuous, which could potentially lead to an overestimation of the impacts.
  - Routine emissions for the proposed operations were simulated.
- Impact Assessment:
  - Impacts due to the operational phase were assessed quantitatively, whilst the construction, closure and decommissioning phases were assessed qualitatively due to the limited information available.
  - The impact assessment was limited to airborne particulate (including TSP, PM_{10} and $PM_{2.5}$). Gaseous emissions from vehicle exhaust were quantified, but not modelled since impacts from these sources are usually localized and unlikely to exceed health screening limits outside the proposed mining right area.
  - There will always be some degree of uncertainty in any geophysical model, but it is desirable to structure the model in such a way to minimize the total error. A model represents the most likely outcome of an ensemble of experimental results. The total uncertainty can be thought of as the sum of three components: the uncertainty due to errors in the model physics; the uncertainty due to data errors; and the uncertainty due to stochastic processes (turbulence) in the atmosphere. Nevertheless, dispersion modelling is generally accepted as a necessary and valuable tool in air quality management.

2 LEGAL OVERVIEW

Air quality guidelines and standards are fundamental to effective air quality management, providing the link between the source of atmospheric emissions and the user of that air at the downstream receptor site. Air quality guidelines and standards are based on benchmark concentrations that normally indicate safe daily exposure levels for the majority of the population, including the very young and the elderly, throughout an individual's lifetime. Benchmark concentrations could therefore be based on health effects, such as SO_2 or carcinogenic consequences, such as benzene.

Air quality guidelines and standards are normally given for specific averaging or exposure periods and are evaluated as the observed air concentration expressed as a fraction of a benchmark concentration. A standard, as opposed to a benchmark concentration only, is a set of instructions which include a limit value and may contain a set of conditions to meet this limit value. Standards are normally associated with a legal requirement as implemented by the country's relevant authority; however, organisations such as the World Bank Group (WBG) International Finance Corporation (IFC) and private companies also issue standards for internal compliance. The benchmark concentrations issued by the World Health Organisation (WHO), on the other hand, are not standards, but rather guidelines that may be considered for use as limit values in standards.

A common condition included in a standard is the allowable frequency of exceedances of the limit value. The frequency of exceedances recognises the potential for unexpected meteorological conditions coupled with emission variations that may result in outlier air concentrations and would normally be based on a percentile, typically the 99^{th} percentile.

Standards are normally issued for criteria pollutants, i.e. those most commonly emitted by industry including SO_2, NO_2, CO, PM_{10} and $PM_{2.5}$, but may also include secondary pollutants such as O_3. Some countries include other pollutants, specifically when these are considered to be problematic emissions.

In addition to ambient air quality standards or guidelines, emission limits aim to control the amount of pollution from a point source[1]. Emissions to air should be avoided or controlled according to Good International Industry Practice (GIIP) applicable to the specific industry sector (IFC, 2007a).

Namibia does not have air quality guidelines or limits and reference is usually made to international ambient air quality guidelines and standards. The WHO is widely referenced, as well as countries in the region who have air quality standards. As part of the Air Quality Management Plan (AQMP) developed for the Strategic Environmental Management Plan (SEMP) update, ambient guidelines for PM_{10} and $PM_{2.5}$ were determined to provide the necessary performance indicators for mines and industries within the Erongo Region. These guidelines are regarded applicable to the all mining operations in Namibia since these guidelines were adopted as Air Quality Objectives in the Best Practice Guide for the Mining Sector in Namibia (see Section 2.1.1).

2.1 Namibian Legislation

The Atmospheric Pollution Prevention Ordinance (No. 11 of 1976) deals with the following:

Part I	:	Appointment and powers of officers;
Part II	:	Control of noxious or offensive gases;
Part III	:	Atmospheric pollution by smoke;
Part IV	:	Dust control;
Part V	:	Pollution of the atmosphere by gases emitted by vehicles;
Part IV	:	General provisions; and

[1] Point sources are discrete, stationary, identifiable sources of emissions that release pollutants to the atmosphere (IFC, 2007).

Schedule 2: Scheduled processes.

The Ordinance does not include any ambient air standards with which to comply, but opacity guidelines for smoke are provided under Part III. It is implied that the Director[2] provides air quality guidelines for consideration during the issuing of Registration Certificates, where Registration Certificates may be issued for "Scheduled Processes" which are processes resulting in noxious or offensive gases and typically pertain to point source emissions. To our knowledge no Registration Certificates have been issued in Namibia. However, an Environmental Clearance Certificate is required for any activity entailing a scheduled process as referred to in the Atmospheric Pollution Prevention Ordinance, 1976.

Also, the Ordinance defines a range of pollutants as noxious and offensive gases, but no ambient air quality guidelines or standards or emission limits are provided for Namibia.

Part II of the Ordinance pertains to the regulation of noxious or offensive gases. The Executive Committee may declare any area a *controlled area* for the purpose of this Ordinance by notice in the Official Gazette. Any scheduled process carried out in a *controlled area* must have a current registration certificate authorising that person to carry on that process in or on that premises.

The published Public and Environmental Health Act 1 of 2015 provides "a framework for a structured uniform public and environmental health system in Namibia; and to provide for incidental matters". The act identifies health nuisances, such as chimneys sending out smoke in quantities that can be offensive, injurious, or dangerous to health and liable to be dealt with.

2.1.1 Best Practice Guide for the Mining Sector in Namibia

A Best Practice Guide for the Mining Sector in Namibia was published in July 2020 (NCE, 2020). The document serves as a guiding framework during all mining phases to effectively assess aspects such as environmental and social impacts.

The report lists air quality as an environmental risk. It provides examples of sources and activities that would result in particulate and gaseous emissions and gives guidance on management and control of these source activities. Aspects relevant to the Project can be summarised as follows:

- Section 3 provides requirements for Baseline Studies where air quality is listed as one of the most important aspects where background conditions of dust, gaseous and nuisance emissions and in some cases fumes and odours are required. Dust and gaseous emissions require immediate monitoring, as well as the establishment of a network of meteorological measuring points. Dust requires the monitoring of particulate matter (PM), in PM_{10}–format, but the monitoring program may require simultaneous measurement of TSP or $PM_{2.5}$ as well.
- Applicable ambient air quality guidelines are listed in Section 3 of the report. It states that Namibia does not have ambient air quality standards or guidelines and references published by the WBG, the WHO, and the European Community (EC). The South African (SA) National Ambient Air Quality Standards (NAAQS) are also referenced.
- Recommendations in Section 3 include: Dust Management Plans for all operational sites (mines, exploration sites and quarries); annual reporting of dust fall levels and PM_{10} concentrations to the authorities; dust suppression at construction sites (as well as annual reporting on dust mitigation measures); update and improvement of the current emissions inventory; establishing a monitoring regime to enhance source apportionment of PM concentrations and sodium content; and continuation with PM_{10} and meteorological monitoring.

[2] *Director* means the Director of Health Services of the Administration, and, where applicable, includes any person who, in terms of any authority granted to him under section 2(2) or (3) of the Ordinance.

- Section 4 indicates that once mines are operational, an air quality management plan is essential for dealing with issues that can potentially have an adverse impact on operations. In addition to dust, an air quality plan needs to incorporate the management of emissions (release of pollutants and particulates) and fumes as well. All mines must, as a minimum requirement of an air quality management plan, manage dust.
- Requirements for air quality monitoring during the operational phase is provided.
- The report further provides guidance on closure and maintenance where management and monitoring of erosion is one of the essential aspects.

2.2 International Criteria

Typically, when no local ambient air quality criteria exist, or are in the process of being developed, international criteria are referenced. This serves to provide an indication of the severity of the potential impacts from proposed activities. The most widely referenced international air quality criteria are those published by the WBG, the WHO, and the European Community (EC). The South African (SA) National Ambient Air Quality Standards (NAAQS) are also referenced since it is regarded representative indicators for Namibia due to the similar environmental and socio-economic characteristics between the two countries.

2.2.1 WHO Air Quality Guidelines

Air Quality Guidelines (AQGs) were published by the WHO in 1987 and revised in 1997. Since the completion of the second edition of the AQGs for Europe, which included new research from low-and middle-income countries where air pollution levels are at their highest, the WHO has undertaken to review the accumulated scientific evidence and to consider its implications for its AQGs. The result of this work is documented in *'Air Quality Guidelines – Global Update 2005'* in the form of revised guideline values for selected criteria air pollutants, which are applicable across all WHO regions (WHO, 2005).

Given that air pollution levels in developing countries frequently far exceed the recommended WHO AQGs, interim target (IT) levels were included in the update. These are more lenient than the WHO AQGs with the purpose to promote steady progress towards meeting the WHO AQGs (WHO, 2005). There are two or three interim targets depending on the pollutant, starting at WHO interim target-1 (IT-1) as the most lenient and IT-2 or IT-3 as more stringent targets before reaching the AQGs. The SA NAAQS are, for instance, in line with IT-1 for SO_2 and IT-3 for PM_{10} and $PM_{2.5}$. It should be noted that the WHO permits a frequency of exceedance of 1% per year (4 days per year) for 24-hour average PM_{10} and $PM_{2.5}$ concentrations. In the absence of interim targets for NO_2, reference is made to the AQG value. These are provided in Table 4 for pollutants considered in this study.

2.2.2 SA National Ambient Air Quality Standards

NAAQSs for SA were determined based on international best practice for SO_2, NO_2, $PM_{2.5}$, PM_{10}, O_3, CO, Pb and benzene. These standards were published in the Government Gazette on 24 of December 2009 and included a margin of tolerance (i.e. frequency of exceedance) and with implementation timelines linked to it. SA NAAQSs for $PM_{2.5}$ were published on 29 July 2012. As mentioned previously, SA NAAQS closely follow WHO interim targets, which are targets for developing countries, for $PM_{2.5}$, PM_{10} and SO_2. The SA NAAQS for ambient NO_2 concentrations is equivalent to the WHO AQG. SA NAAQSs referred to in this study are also given in Table 4.

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Table 4: International assessment criteria for criteria pollutants

Pollutant	Averaging Period	WHO Guideline Value ($\mu g/m^3$)	South Africa NAAQS ($\mu g/m^3$)
Sulfhur Dioxide (SO_2)	1-year	-	50
	24-hour	125 (IT1) 50 (IT2) (a) 20 (guideline)	125 (b)
	1-hour	-	350 (c)
	10-minute	500 (guideline)	500 (d)
Nitrogen Dioxide (NO_2)	1-year	40 (guideline)	40
	1-hour	200 (guideline)	200 (c)
Particulate Matter (PM_{10})	1-year	70 (IT1) 50 (IT2) 30 (IT3) 20 (guideline)	40 (e) (b)
	24-hour	150 (IT1) 100 (IT2) 75 (IT3) 50 (guideline)	75 (e)
Particulate Matter ($PM_{2.5}$)	1-year	35 (IT1) 25 (IT2) 15 (IT3) 10 (guideline)	25 (f) 20 (g) 15 (h)
	24-hour	75 (IT1) 50 (IT2) 37.5 (IT3) 25 (guideline)	65 (f) 40 (g) 25 (h)

Notes:

(a) Intermediate goal based on controlling motor vehicle emissions; industrial emissions and/or emissions from power production. This would be a reasonable and feasible goal to be achieved within a few years for some developing countries and lead to significant health improvement.
(b) 4 permissible frequencies of exceedance per year
(c) 88 permissible frequencies of exceedance per year
(d) 526 permissible frequencies of exceedance per year
(e) Applicable from 1 January 2015.
(f) Applicable immediately to 31 December 2015.
(g) Applicable 1 January 2016 to 31 December 2029.
(h) Applicable 1 January 2030.

2.2.3 Dustfall Limits

Air quality standards are not defined by all countries for dust deposition, although some countries may make reference to annual average dust fall thresholds above which a 'loss of amenity' may occur. In the southern African context, widespread dust deposition impacts occur as a result of windblown dust from mine tailings and natural sources, from mining operations and other fugitive dust sources.

South Africa has published the National Dust Control Regulations (NDCR) on the 1st of November 2013 (Government Gazette No. 36974). The purpose of the regulations is to prescribe general measures for the control of dust in all areas including residential and light commercial areas. Similarly, Botswana published dust deposition evaluation criteria (BOS 498:2013). According to these limits, an enterprise may submit a request to the authorities to operate within the Band 3 (action band) for a limited period, providing that this is essential in terms of the practical operation of the enterprise (for example the final removal of a tailings deposit) and provided that the best available control technology is applied for the duration. No margin of tolerance will be granted for operations that result in dustfall rates in the Band 4 (alert band). This four-band scale is presented in Table 5.

Table 5: Bands of dustfall rates

Band Number	Band Description	30 Day Average Dustfall Rate (mg/m^2-day)	Comment
1	Residential	Dustfall rate < 600	Permissible for residential and light commercial
2	Industrial	600 < Dustfall rate < 1 200	Permissible for heavy commercial and industrial
3	Action	1 200 < Dustfall rate < 2 400	Requires investigation and remediation if two sequential months lie in this band, or more than three occur in a year.
4	Alert	2 400 < Dustfall rate	Immediate action and remediation required following the first exceedance. Incident report to be submitted to relevant authority.

2.3 International Conventions

The technical reference documents published in the IFC Environmental, Health and Safety (EHS) Guidelines provide general and industry specific examples of Good International Industry Practice (GIIP). The General EHS Guidelines are designed to be used together with the relevant Industry Sector EHS Guidelines (IFC, 2007).

The IFC EHS Guidelines provide a general approach to air quality management for a facility, including the following:

- Identifying possible risks and hazards associated with the project as early on as possible and understanding the magnitude of the risks, based on:
    - the nature of the project activities; and,
    - the potential consequences to workers, communities, or the environment if these hazards are not adequately managed or controlled.
- Preparing project- or activity-specific plans and procedures incorporating technical recommendations relevant to the project or facility;
- Prioritising the risk management strategies with the objective of achieving an overall reduction of risk to human health and the environment, focusing on the prevention of irreversible and / or significant impacts;
- When impact avoidance is not feasible, implementing engineering and management controls to reduce or minimise the possibility and magnitude of undesired consequence; and,

- Continuously improving performance through a combination of ongoing monitoring of facility performance and effective accountability.

Significant impacts to air quality should be prevented or minimised by ensuring that:

- Emissions to air do not result in pollutant concentrations exceeding the relevant ambient air quality guidelines or standards. These guidelines or standards can be national guidelines or standards or in their absence WHO AQGs or any other international recognised sources.
- Emissions do not contribute significantly to the relevant ambient air quality guidelines or standards. It is recommended that 25% of the applicable air quality standards are allowed to enable future development in a given airshed. Thus, any new development should not result in ground level concentrations exceeding 25% of the guideline value.
- The EHS recognises the use of dispersion models to assess potential ground level concentrations. The models used should be internationally recognised or comparable.

2.3.1 Degraded Airsheds or Ecological Sensitive Areas

The IFC provides further guidance on projects located in degraded airsheds (IFC, 2007), i.e. areas where the national/ WHO/ other recognised international Air Quality Guidelines are significantly exceeded or where the project is located next to areas regarded as ecological sensitive such as national parks. The Project is not located in an ecologically sensitive area, and the airshed is not regarded to be degraded.

2.3.2 Fugitive Source Emissions

According to the IFC (IFC, 2007), fugitive source emissions refer to emissions that are distributed spatially over a wide area and confined to a specific discharge point. These sources have the potential to result in more significant ground level impacts per unit release than point sources. It is therefore necessary to assess this through ambient quality assessment and monitoring practices.

2.4 Recommended Guidelines and Objectives

The IFC references the WHO guidelines but indicates that any other internationally recognized criteria can be used such as the United States (US) Environmental Protection agency (EPA) or the EC. It was, however, found that merely adopting the WHO guidelines would result in exceedances of these guidelines in many areas due to the arid environment in the country, and specifically in Namibia. The WHO states that these AQG and interim targets should be used to guide standard-setting processes and should aim to achieve the lowest concentrations possible in the context of local constraints, capabilities, and public health priorities. These guidelines are also aimed at urban environments within developed countries (WHO, 2005). For this reason, the South African NAAQS are also referenced since these were developed after a thorough review of all international criteria and selected based on the socio, economic and ecological conditions of the country.

In the absence of guidelines on ambient air concentrations for Namibia, reference is made to the Air Quality Objectives (AQO) recommended as part of the SEMP AQMP (Liebenberg-Enslin, et al., 2019). These objectives are based on the WHO interim targets and SA NAAQS (Table 4). The criteria were selected on the following basis:

- The WHO IT3 was selected for particulates since these limits are in line with the SA NAAQSs, and the latter are regarded feasible limits for the arid environment of Namibia.
- Even though $PM_{2.5}$ emissions are mainly associated with combustion sources and mainly a concern in urban environments, it is regarded good practice to include as health screening criteria given the acute adverse health

effects associated with this fine fraction. Also, studies found that desert dust with an aerodynamic diameter 2.5 µm cause premature mortality.

- For SO_2, there is no IT3, and the IT2 was selected since the WHO states: “This would be a reasonable and feasible goal for some developing countries (it could be achieved within a few years) which would lead to significant health improvements that, in turn, would justify further improvements (such as aiming for the AQG value)”.
- The WHO provides no interim targets for NOx. The AQGs are in line with the SA NAAQSs and therefore regarded as achievable limits.
- The Botswana and South African criteria for dust fallout are the same and with limited international criteria for dust fallout, these were regarded applicable.

The proposed Air Quality Objectives (AQOs) as set out in Table 6 are intended to be used as indicators during the impact assessment.

Table 6: Proposed Air Quality Objectives for the Project

Pollutant	Averaging Period	Criteria	Reference
NO_2	1-hour average (µg/m³)	200[(a)]	WHO AQG & EC & SA NAAQS
	Annual average (µg/m³)	40	WHO AQG & EC & SA NAAQS
SO_2	1-hour average (µg/m³)	350[(a)]	EC Limit & SA NAAQS (no WHO guideline)
	24-hour average (µg/m³)	50[(b)]	WHO IT2 (seen as a per 40% of the SA and EC limits)
	Annual average (µg/m³)	50	SA NAAQS (no WHO guideline)
Particulate matter (PM_{10})	24-hour average (µg/m³)	75[(b)]	WHO IT3 & SA NAAQS (as per SEMP AQMP)
	Annual average (µg/m³)	40	SA NAAQS (as per SEMP AQMP)
Particulate matter ($PM_{2.5}$)	24-hour average (µg/m³)	37.5[(b)]	WHO IT3 (as per SEMP AQMP)
	Annual average (µg/m³)	15	WHO IT3 & SA NAAQS (as per SEMP AQMP)
Dustfall	30-day average (mg/m²/day)	600[(c)]	SA NDCR & Botswana residential limit
		1 200[(c)]	SA NDCR & Botswana industrial limit
		2 400	Botswana Alert Threshold

Notes: [(a)] Not to be exceeded more than 88 hours per year (SA)

[(b)] Not to be exceeded more than 4 times per year (SA)

[(c)] Not to be exceeded more than 3 times per year or 2 consecutive months

3 Description of the Baseline Environment

3.1 Site Description and Sensitive Receptors

Air Quality Sensitive (AQSRs) primarily relate to where people reside and all structures in the vicinity of the mine was included as sensitive receptors. All identified AQSRs are shown in Figure 3 providing the spatial context for the closest AQSRs. These will be included as sensitive receptors during the air quality impact assessment.

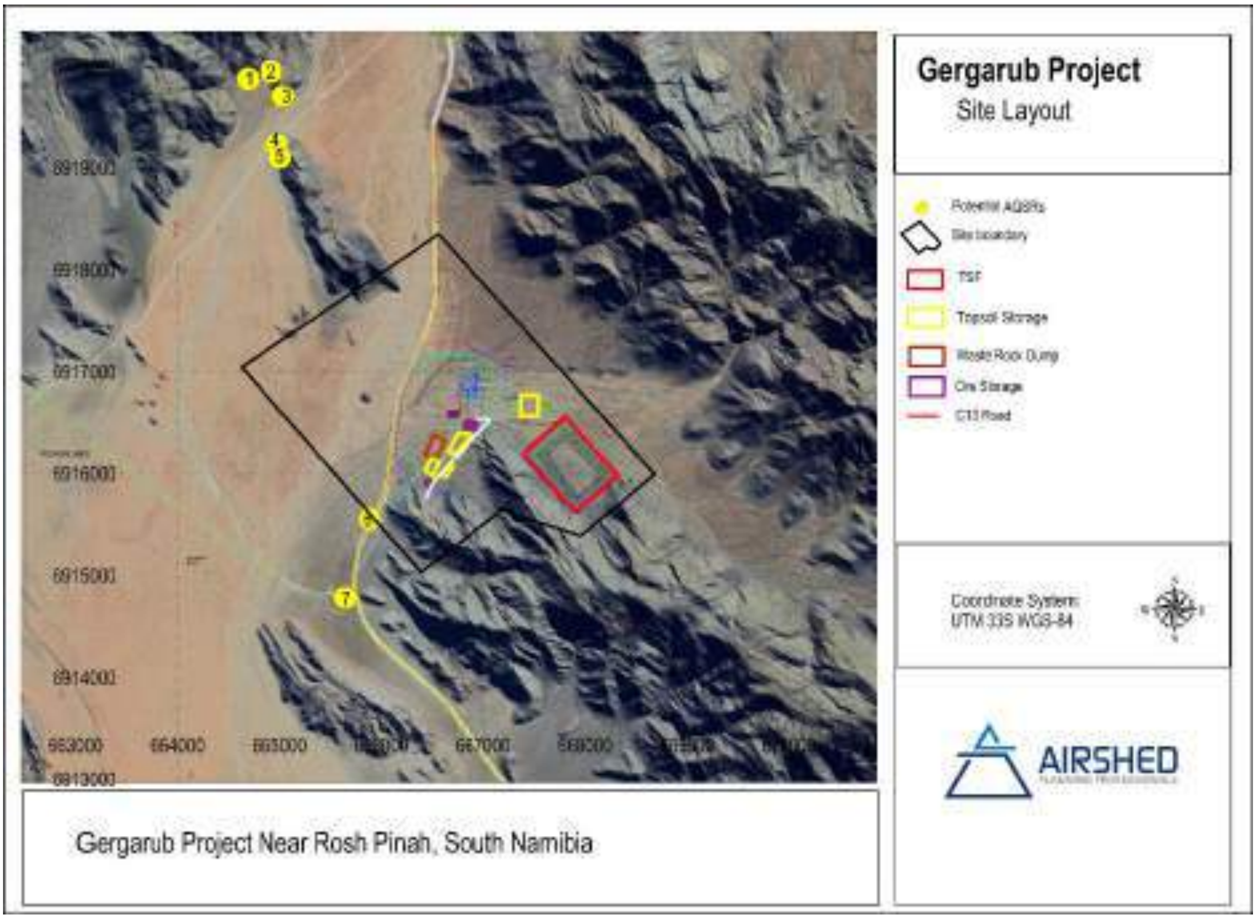


Figure 3: Gergarub Project layout and identified air quality sensitive receptors

Main (national) roads in close proximity to the Project are the C13 to the west of the site. The topography of the Project site is shown in Figure 4. As can be seen from the topographical map, the site is located in an area with complex topography that may influence the wind field. Hilly areas can be seen towards the north, northwest and south of the site.

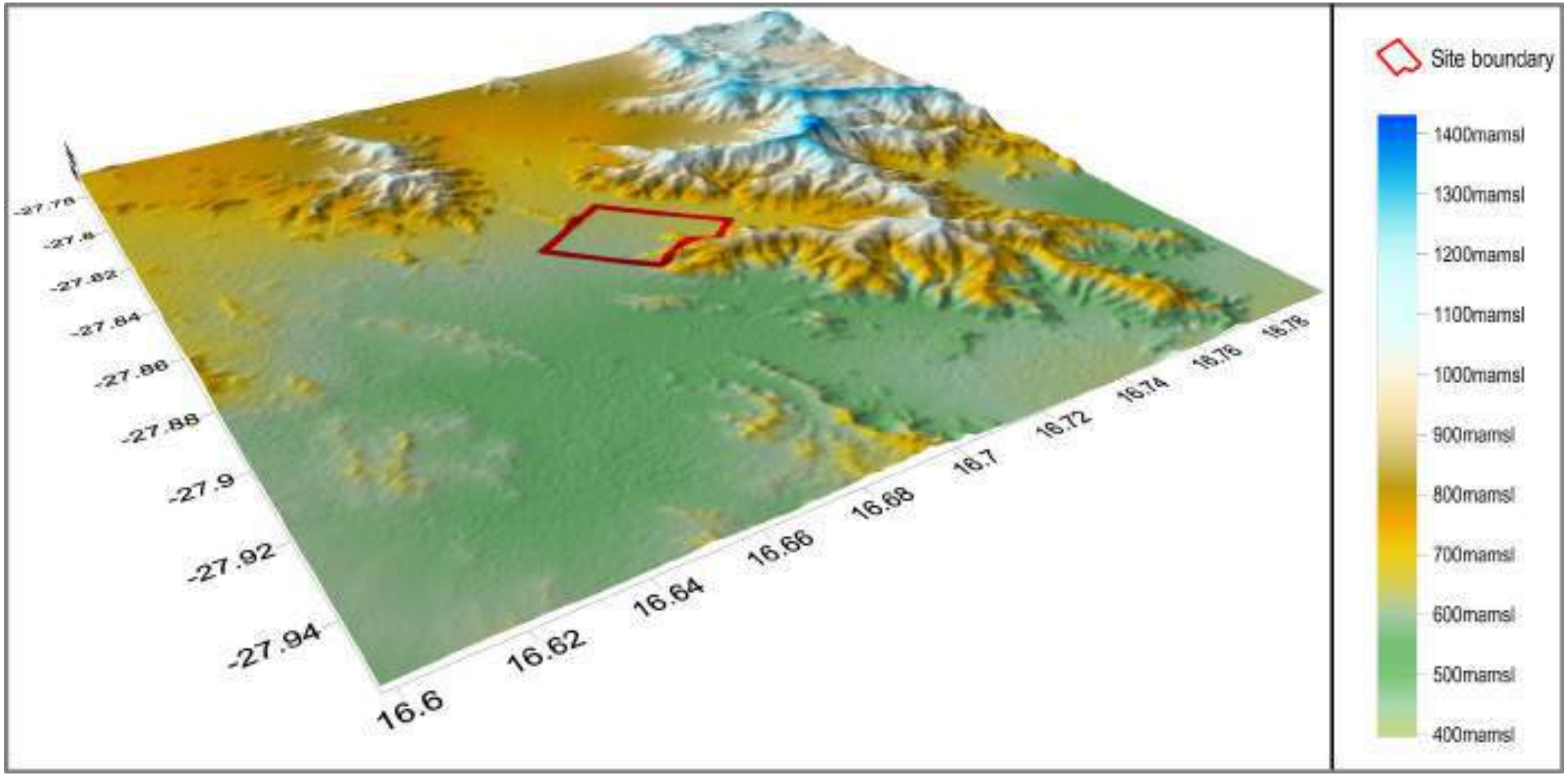


Figure 4: Topography of the proposed Gergarub Project

3.2 Atmospheric Dispersion Potential

Meteorological mechanisms govern the dispersion, transformation and eventual removal of pollutants from the atmosphere. The extent to which pollution will accumulate or disperse in the atmosphere is dependent on the degree of thermal and mechanical turbulence within the earth's boundary layer. Dispersion comprises vertical and horizontal components of motion. The stability of the atmosphere and the depth of the surface-mixing layer define the vertical component. The horizontal dispersion of pollution in the boundary layer is primarily a function of the wind field. The wind speed determines both the distance of downwind transport and the rate of dilution as a result of plume 'stretching'. The generation of mechanical turbulence is similarly a function of the wind speed, in combination with the surface roughness. Pollution concentration levels therefore fluctuate in response to changes in atmospheric stability, to concurrent variations in the mixing depth, and to shifts in the wind field.

A description of the wind field, temperature, precipitation, and atmospheric stability is provided in the following section. Modelled meteorological data obtained from Meteoblue[3] for Rosh Pinah was utilised which include wind speed (km/hr), wind direction (degrees), temperature (°C), humidity (%), barometric pressure (Pa) and rainfall (mm).

3.2.1 Surface Wind Field

The wind direction, and the variability in wind direction, determines the general path that air pollutants will follow, and the extent of crosswind spreading. Wind roses comprise 16 spokes, which represent the directions from which winds blew during the period. The colours used in the wind roses below, reflect the different categories of wind speeds; the red area, for example, representing winds higher than 6 m/s. The dotted circles provide information regarding the frequency of occurrence of wind speed and direction categories. The frequency with which calms occurred refers to periods during which the wind speed was below 1 m/s.

Period, daytime and night-time wind roses for the study area, based on the modelled meteorological data for three year period: 1 January 2020 to 31 December 2022 are depicted in Figure 5, with seasonal wind roses for the same period shown in Figure 6.

The wind field is dominated by winds from the southwest, with less frequent flow from the east and south-southeast and almost no airflow from the north. This is reflective of the topography at Rosh Pinah but should be noted that it differs at the Project site. The highest winds speed modelled during the 1 January 2020 to 31 December 2022 period was 9.8 m/s.

[3] https://www.meteoblue.com/en/weather/week/rosh-pinah_namibia_7116015

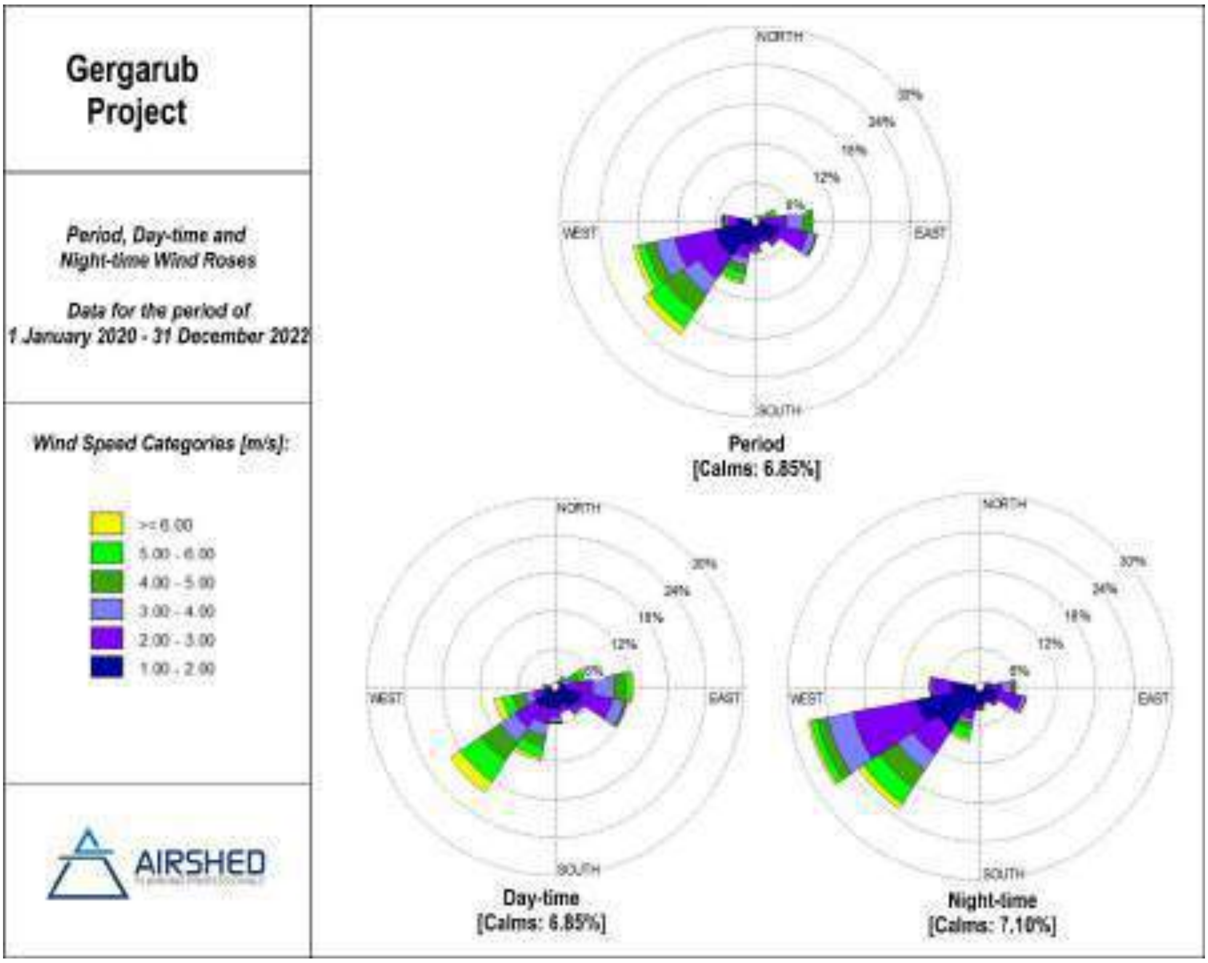


Figure 5: Period, day- and night-time wind roses based on modelled weather data (1 January 2020 to 31 December 2022)

Seasonal variation in the wind field is shown in Figure 6. During summer, autumn and spring, the wind field is dominated by winds from the southwest, with winds from the easterly sector increasing during winter.

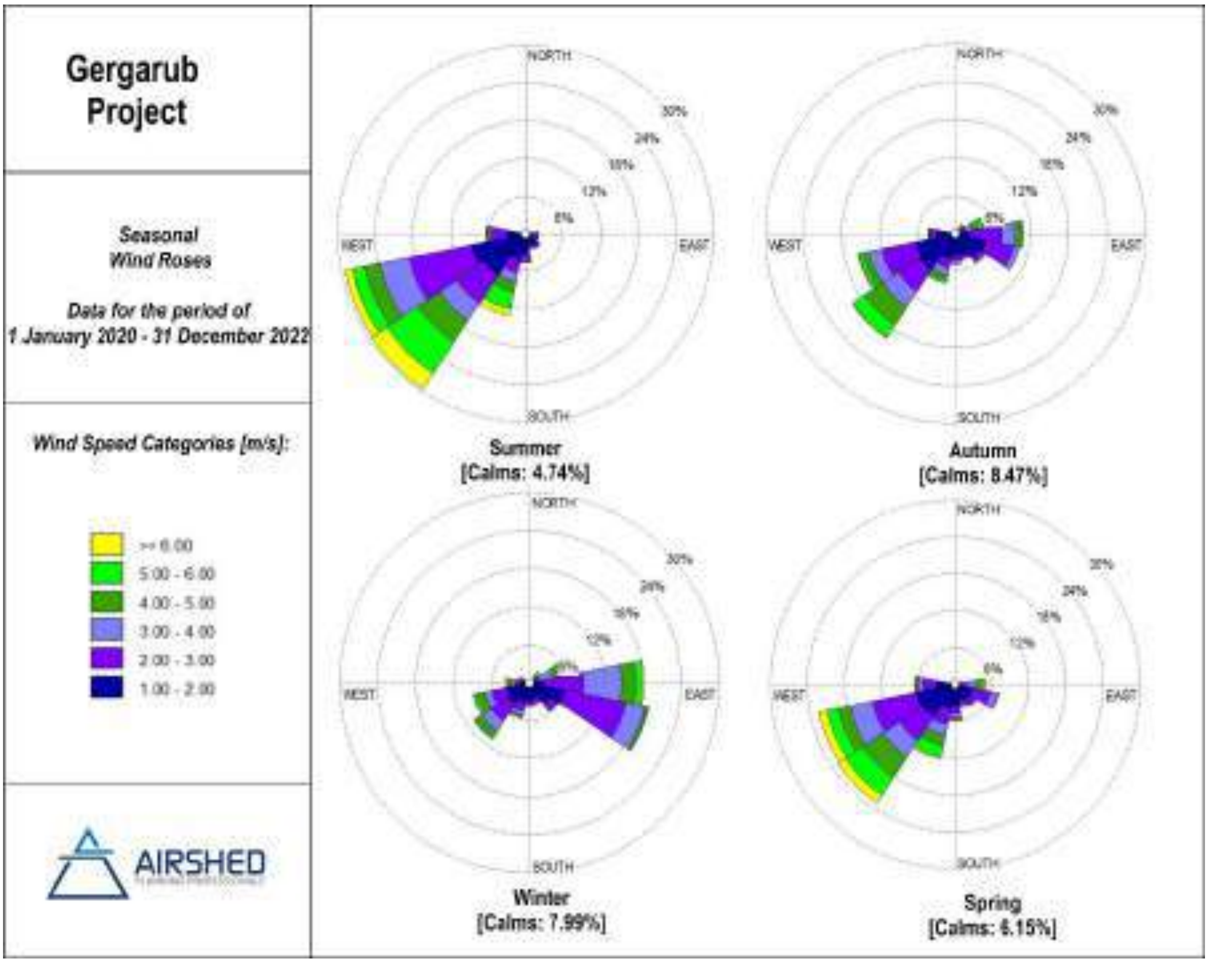


Figure 6: Seasonal wind roses based on modelled weather data (1 January 2020 to 31 December 2022)

According to the Beaufort wind force scale (https://www.metoffice.gov.uk/guide/weather/marine/beaufort-scale), wind speeds between 6-8 m/s equate to a moderate breeze, with wind speeds between 14-17 m/s near gale force winds. Based on the modelled data for the period 1 January 2020 to 31 December 2022, with a maximum wind speed of 9.8 m/s. The average wind speed over the period was 2.6 m/s. Calm conditions (wind speeds <1 m/s) occurred for 6.8% of the time (Figure 7). The likelihood for wind erosion to occur from open and exposed surfaces, with loose fine material, but taking into account that the natural surfaces are crusted, was estimated when the wind speed exceeds 10 m/s (Liebenberg-Enslin, et al., 2019). During the period assessed, there were no occurrences of wind speeds exceeding 10 m/s and wind erosion from natural surfaces is not likely to occur.

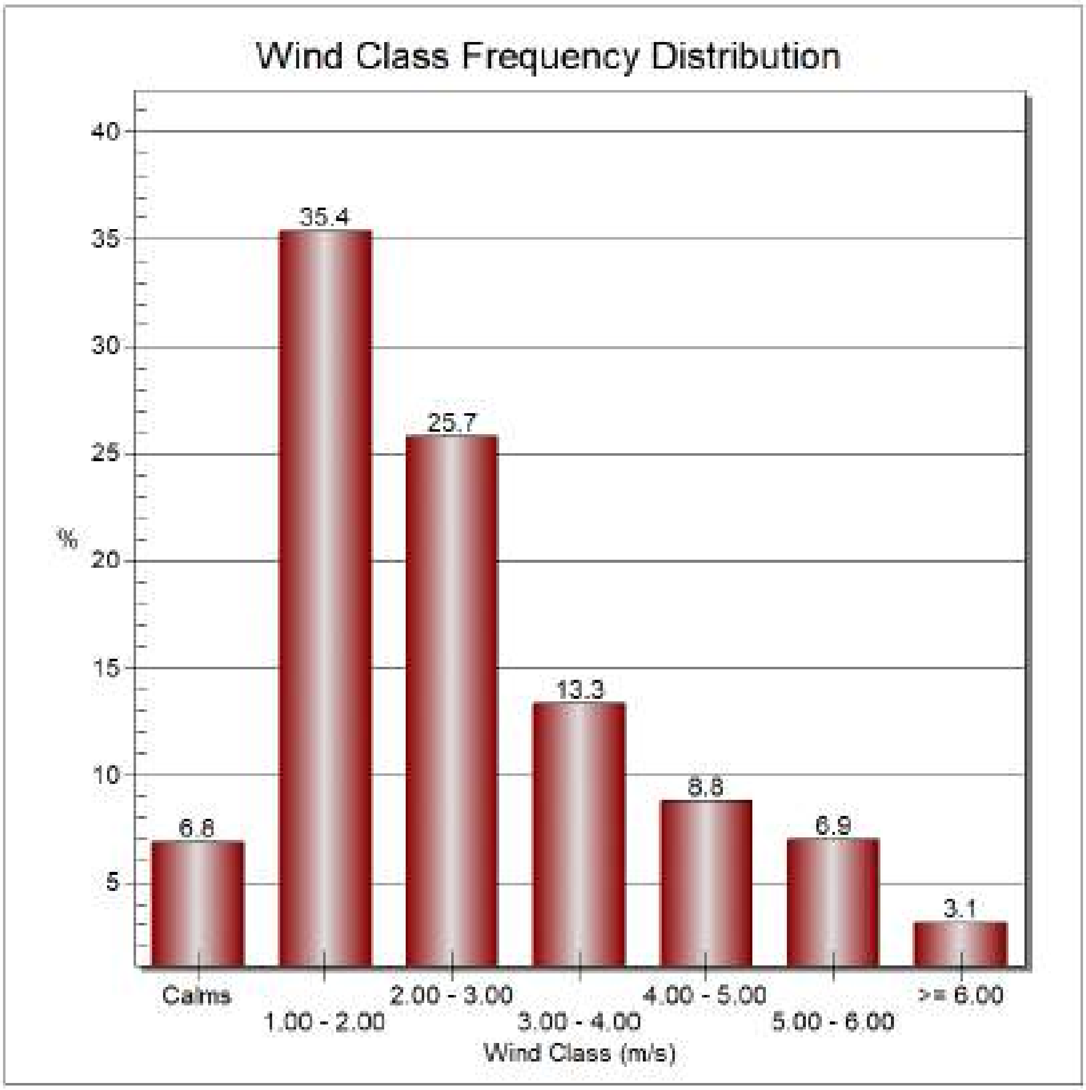


Figure 7: Wind speed categories based on modelled meteorological data (1 January 2020 to 31 December 2022)

3.2.2 Temperature

Air temperature is important, both for determining the effect of plume buoyancy (the larger the temperature difference between the plume and the ambient air, the higher the plume can rise), and determining the development of the mixing and inversion layers.

Minimum, average, and maximum temperatures for the study area are given as 1.5°C, 19.6°C and 41.1°C respectively, based on modelled weather data for the period January 2020 to December 2022 (Figure 8).

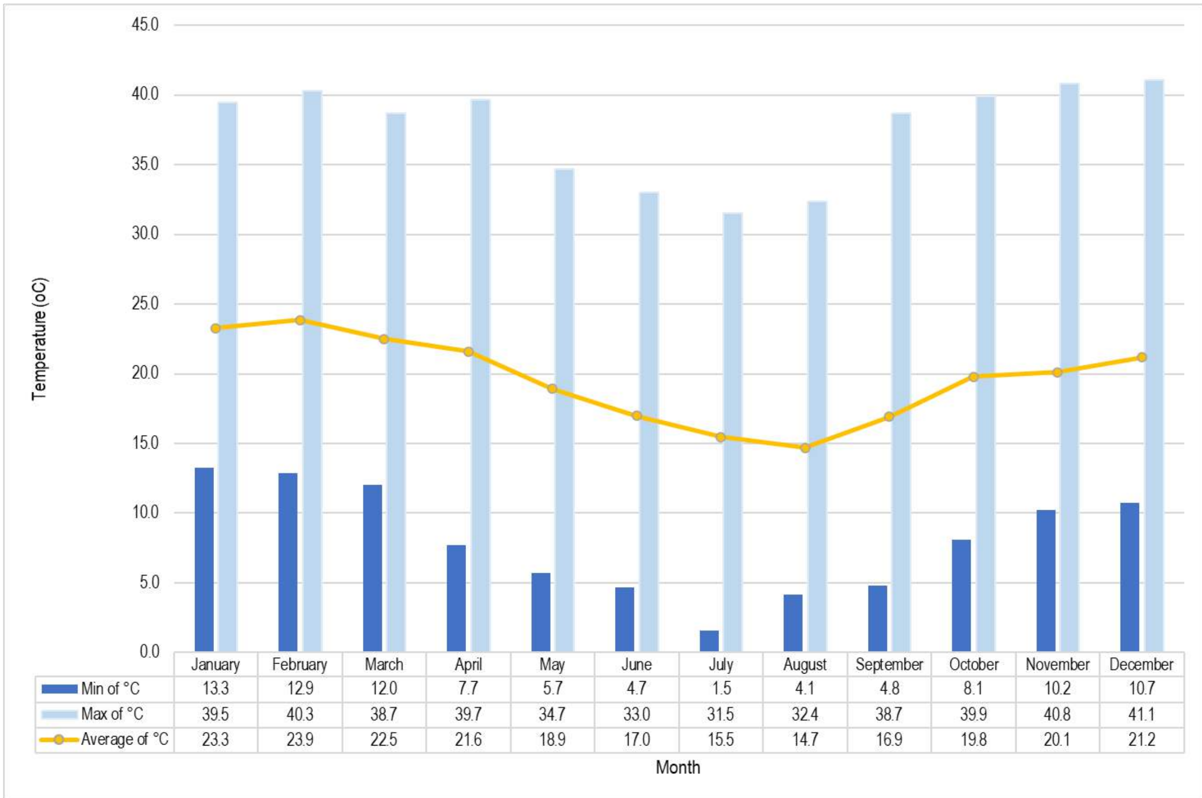
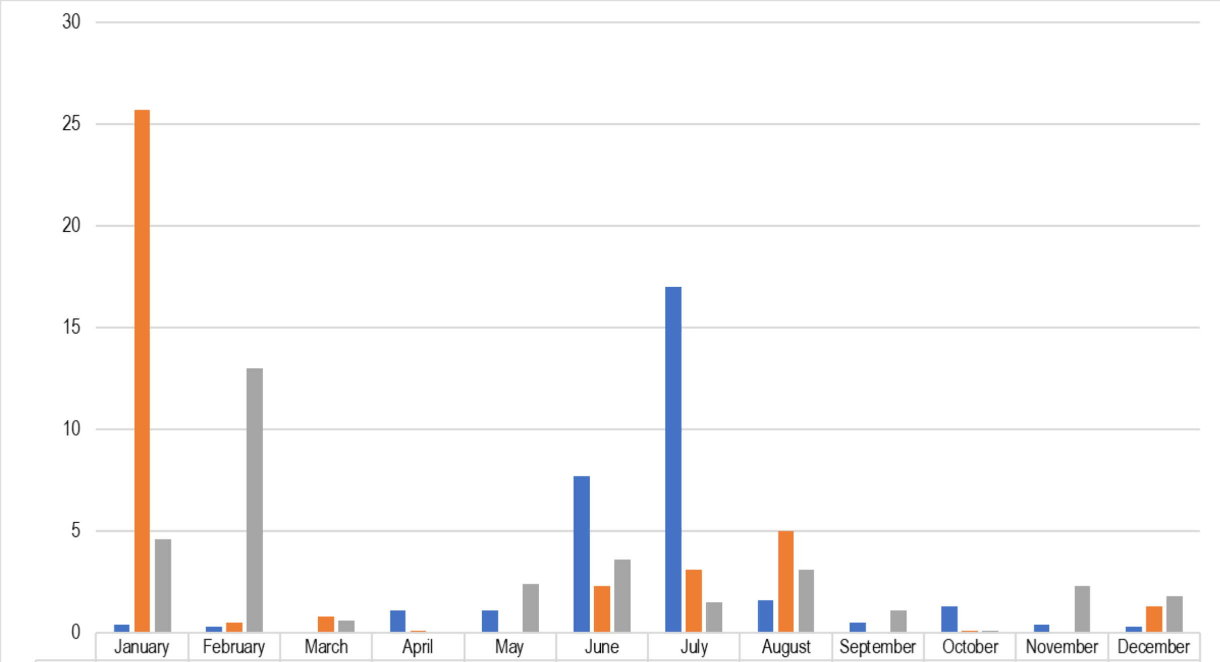


Figure 8: Daily minimum, average, and maximum temperatures based on modelled meteorological data (1 January 2020 to 31 December 2022)

3.2.3 Precipitation

Precipitation is important to air pollution studies since it represents an effective removal mechanism for atmospheric pollutants and inhibits dust generation potentials. Monthly average rainfall figures obtained from the modelled data are illustrated in Figure 9. Modelled annual rainfall for 2020, 2021 and 2022 was 31.7, 38.9 and 34.1 mm respectively, with the highest monthly rainfall in January 2021 (25.7 mm).



	January	February	March	April	May	June	July	August	September	October	November	December
2020	0.4	0.3	0	1.1	1.1	7.7	17	1.6	0.5	1.3	0.4	0.3
2021	25.7	0.5	0.8	0.1	0	2.3	3.1	5	0	0.1	0	1.3
2022	4.6	13	0.6	0	2.4	3.6	1.5	3.1	1.1	0.1	2.3	1.8

Figure 9: Average rainfall based on modelled meteorological data (1 January 2020 to 31 December 2022)

3.2.4 Atmospheric Stability

The new generation air dispersion models differ from the models traditionally used in several aspects, the most important of which are the description of atmospheric stability as a continuum rather than discrete classes. The atmospheric boundary layer properties are therefore described by two parameters: the boundary layer depth and the Obukhov length, rather than in terms of the single parameter Pasquill Class. The Obukhov length (LMo) provides a measure of the importance of buoyancy generated by the heating of the ground and mechanical mixing generated by the frictional effect of the earth's surface. Physically, it can be thought of as representing the depth of the boundary layer within which mechanical mixing is the dominant form of turbulence generation (CERC, 2004).

The atmospheric boundary layer constitutes the first few hundred metres of the atmosphere. During the daytime, the atmospheric boundary layer is characterised by thermal turbulence due to the heating of the earth's surface and the predominance of an unstable layer. In unstable conditions, ground level pollution is readily dispersed thereby reducing ground level concentrations. Elevated emissions, however, such as those released from a chimney, are returned more readily to ground level, leading to higher ground level concentrations.

Night times are characterised by weak vertical mixing and the predominance of a stable layer. These conditions are normally associated with low wind speeds and less dilution potential. During windy and/or cloudy conditions, the atmosphere is normally neutral (which causes sound scattering in the presence of mechanical turbulence). For low level releases, the highest ground level concentrations would occur during weak wind speeds and stable (night-time) atmospheric conditions.

Atmospheric stability is frequently categorised into one of six stability classes – these are briefly described in Table 7 with the percentage time each class occurred during the 12 months. For low level releases, such as mining operations, the highest ground level concentrations would occur during weak wind speeds and stable (night-time) atmospheric conditions (Category E), which relates to on average 7% of the time at the proposed Project site. However, windblown dust is likely to occur under high winds (neutral conditions – Category D) which accounted for 5% of the time, on average. Stack releases, such as from the power generators and smelter stacks, unstable conditions (Category C – 22%) can result in very high concentrations of poorly diluted emissions close to the stack. Neutral conditions disperse the plume equally in both the vertical and horizontal planes and the plume shape is referred to as coning. Stable conditions (Category E) prevent the plume from mixing vertically, although it can still spread horizontally and is called fanning (Tiwary & Colls, 2010).

Table 7: Atmospheric stability classes: Frequency of occurrence for the period 1 January 2020 to 31 December 2022

Designation	Stability Class	Atmospheric Condition	Frequency of occurrence
A	Very unstable	calm wind, clear skies, hot daytime conditions	0.3%
B	Moderately unstable	clear skies, daytime conditions	0.7%
C	Unstable	moderate wind, slightly overcast daytime conditions	7.7%
D	Neutral	high winds or cloudy days and nights	74.9%
E	Stable	moderate wind, slightly overcast night-time conditions	13.2%
F	Very stable	low winds, clear skies, cold night-time conditions	3.2%

3.3 Current Ambient Air Quality

3.3.1 Existing Sources of Atmospheric Emissions in the Area

The Project falls within the Kharas Region in South Namibia. The main air pollution sources within the region include current mining and quarry operations, exploration activities, public roads (paved and unpaved), natural exposed areas prone to wind erosion and marine aerosols (sea salts and organic matter originating from the Atlantic Ocean).

The main pollutant of concern would be particulate matter (TSP; PM_{10} and $PM_{2.5}$) resulting from vehicle entrainment on the roads (paved, unpaved, and treated surfaces), windblown dust, and mining and exploration activities. Gaseous pollutants such as SO_2, NOx, CO and CO_2 would result from vehicles and combustion sources, but these are expected to be at low concentrations due to the few combustion sources in the region.

3.3.1.1 Vehicle entrainment from roads

Particulate emissions from roads occur when the force of the wheels on the road surface grinds the surface material into finer particles which are then lifted by the rolling wheels and kept in suspension due to the turbulent wake behind the vehicle (U.S. EPA, 2011). Dust emissions from paved and unpaved roads varies linearly with the volume of traffic. In addition, a number of parameters influence the surface condition of a particular road, such as average vehicle speed, mean vehicle weight, silt content of road material, and road surface moisture, and these will thus impact on dust emissions (U.S. EPA, 2006).

The national road to the west (C13) of the Project is a paved road connecting Oranjemund in the South to Luderitz and Keetmanshoop. The settlement of Rosh Pinah is accessed from the C13 road. These sources are more likely to affect receptors close to the roads.

3.3.1.2 Windblown dust

Windblown particulates from natural exposed surfaces, mine waste facilities, and product stockpiles can result in significant dust emissions with high particulate concentrations near the source locations, potentially affecting both the environment and human health.

Wind erosion is a complex process, including three different phases of particle entrainment, transport, and deposition. For wind erosion to occur, the wind speed needs to exceed a certain threshold, called the friction velocity. This relates to gravity and the inter-particle cohesion that resists removal. Surface properties such as soil texture, soil moisture and vegetation cover influence the removal potential. For a natural environment such as gravel plains, the threshold friction velocity was estimated to be 10 m/s and above due to the crusting effect of the soil surface. This may be similar for the arid environment where the Project is located.

Wind speeds from the modelled weather data exceeded 10 m/s for 0% of the time over the three years of data analysed. Windblown dust from natural exposed surfaces at and around the Project is regarded to be an insignificant source of particulate matter.

3.3.1.3 Mines and Exploration operations

Pollutants typically emitted from mining and quarrying activities are particulates, with smaller quantities associated with vehicle exhaust emissions. Mining and quarrying activities, especially open-cast mining methods, as well as exploration activities, emit pollutants near ground-level over (potentially) large areas. Source activities resulting in significant dust emissions include: drilling and blasting; materials handling (loading, unloading, and tipping); crushing and screening; windblown dust (from the sources as described above); access roads; and plant stack emissions.

Mines in proximity to the proposed Project are Skorpion Zinc Mine located northwest of the site, approximately 10 km from the site and the Rosh Pinah Mine located approximately 15 km from the site.

3.3.1.4 Regional transportation of pollutants

Another source of air pollution is aerosols as a result of regional-scale transport of mineral dust and ozone (due to vegetation burning) from the north of Namibia (http://www.fao.org/docrep/005/x9751e/x9751e06.htm). Biomass burning is an incomplete combustion process (Cachier, 1992), with carbon monoxide, methane and nitrogen dioxide gasses being emitted. Approximately 40% of the nitrogen in biomass is emitted as nitrogen, 10% is left in the ashes, and it may be assumed that 20% of the nitrogen is emitted as higher molecular weight nitrogen compounds (Held, et al., 1996). The visibility of the smoke plumes is attributed to the aerosol (particulate matter) content. Formenti et al., (2018) attributed the recording of black carbon at Henties Bay to contributions from biomass burning and even from the SA highveld's coal fired power stations.

Evaporation of sea spray are also sources of airborne particles, whereas pollen grains, mould spores and plant and insect parts all contribute to the atmospheric particulate load. Marine aerosols may include sea salt as well as organic matter (O'Dowd and De Leew, 2007). Sea salt is a major atmospheric aerosol component on a global scale, with a significant impact on PM concentrations (O'Dowd and De Leew, 2007; Athanasopoulou et al., 2008; Kelly et al., 2010; Karaguliun et al., 2015). Aside from the primary contribution from sea salt, recent interest is on its role in chemical reactions (with gaseous emission) and on climate change (O'Dowd and De Leew, 2007; Kelly *et al.*, 2010). One of the findings from the SEMP AQMP was the contribution from the ocean (westerly sector) to PM_{10} concentrations at Swakopmund and Walvis Bay. The contribution from sea salts in the PM_{10} filters was confirmed through chemical analyses (Liebenberg-Enslin, et al., 2019). How far these sea salts can be transported inland is not known.

3.3.2 Existing Ambient Air Pollutant Concentrations in the Project Area

There is no ambient PM (PM_{10} and $PM_{2.5}$) monitoring network or dustfall monitoring being conducted at the site.

4 IMPACT ASSESSMENT

The emissions inventory, dispersion modelling and results are discussed in Section 4.1, 4.2 and Section 4.3 respectively.

4.1 Atmospheric Emissions

4.1.1 Construction Phase

Construction normally comprises a series of different operations including land clearing, topsoil removal, material loading and hauling, stockpiling, grading, bulldozing, compaction, etc. Most of the infrastructure such as surface haul roads and stockpiles required for the Life of Mine (LOM) will be constructed during the first year of mining. WRDs will progress over time with haul trucks tipping the waste on the top elevation of the dumps with the dozers pushing the waste material down. These actions will cause the WRDs to progress horizontally over time. ROM pad stockpiles will be constructed in close vicinity to the primary crusher tipping point in order to minimise the reclamation costs.

The main pollutant of concern from construction operations is particulate matter, including PM_{10}, $PM_{2.5}$ and TSP. PM_{10} and $PM_{2.5}$ concentrations are associated with potential health impacts due to the size of the particulates being small enough to be inhaled. Nuisance effects are caused by the TSP fraction (20 µm to 75 µm in diameter) resulting in soiling of materials and visibility reductions. This could in effect also have financial implications due to the requirement for more cleaning materials.

All operations associated with the construction phase are listed in Table 1. Each of the operations has their own duration and potential for dust generation. It is therefore often necessary to estimate area wide construction emissions, without regard to the actual plans of any individual construction process. Quantified construction emissions are usually lower than operational phase emissions and due to their temporary nature and duration, and the likelihood that these activities will not occur concurrently at all portions of the site; dispersion simulation was not undertaken for construction emissions.

The US EPA documents emission factors which aim to provide a general rule-of-thumb as to the magnitude of emissions which may be anticipated from construction operations (US EPA, 2006). The quantity of dust emissions is assumed to be proportional to the area of land being worked and the level of construction activity. The approximate emission factors for general construction activity operations are given as:

E = 2.69 Mg/hectare/month of activity (269 g/m^2/month)

The PM_{10} fraction is given as ~39% of the US EPA total suspended particulate factor. These emission factors are most applicable to construction operations with (i) medium activity levels, (ii) moderate silt contents, and (iii) semiarid climates. The emission factor for TSP considers 42 hours of work per week of construction activity. Test data were not sufficient to derive the specific dependence of dust emissions on correction parameters, and because the above emission factor is referenced to TSP, use of this factor to estimate PM_{10} emissions will result in conservatively high estimates. Also, because derivation of the factor assumes that construction activity occurs 30 days per month, the above estimate is somewhat conservatively high for TSP as well.

Areas assumed to be cleared of vegetation for infrastructure development and mining preparation are listed in Table 8. Assuming all areas to be developed simultaneously, the resulting emission estimates are 4 869 tpa for TSP, 1 889 tpa for PM_{10} and 950 tpa for $PM_{2.5}$.

Table 8: Construction areas

Mining Area	Area (m²)	Area (ha)
Processing Plant Area and Ore storage	720 097	72
Surface road construction, WRD, Topsoil dumps, Ore storage	377 439	38
TSF	410 920	41
Total	**1 508 456**	**151**

4.1.2 Operational Phase

Quantification of emissions from the proposed Project are restricted to fugitive releases (non-point releases) as listed in Table 2 and point source emissions from the ventilation shaft. Particulates are the main pollutant of concern from mining operations. Gaseous emissions (i.e. SO_2, NO_x, CO and VOCs) will primarily result from diesel combustion, both from mobile and stationary sources. Gaseous emissions were not quantified as information on expected diesel consumption was not available at the time of the study.

Ore production is estimated at 1 million tons per annum (mtpa), realising a total production of 23.8 million tons over the life of mine (LOM).

Wins erosion can occur from the WRD, Topsoil piles as the TSF. Wind erosion is a complex process, including three different phases of particle entrainment, transport, and deposition. It is primarily influenced by atmospheric conditions (e.g. wind, precipitation and temperature), soil properties (e.g. soil texture, composition and aggregation), land-surface characteristics (e.g. topography, moisture, aerodynamic roughness length, vegetation and non-erodible elements) and land-use practice (e.g. farming, grazing and mining). For wind erosion to occur, the wind speed needs to exceed a certain threshold, called the threshold velocity. This relates to gravity and the inter-particle cohesion that cause the individual particles to resist removal. Thus, for particles to become airborne, the wind shear at the surface must exceed the gravitational and cohesive forces acting upon them, called the threshold friction velocity (Shao, 2008). The particle size distribution of the tailings, waste and topsoil was not available and wind erosion was assumed to occur continuously, which could overpredict the wind erosion impacts.

The emission equations used to quantify emissions from the proposed activities are shown in Table 9. Both unmitigated and mitigated activities were assessed. The estimated control efficiencies as obtained from literature (NPI, 2012) for the various mining activities are given in Table 10.

A summary of estimated particulate emissions from the proposed Project operations is provided in Table 11.

Table 9: Emission equations used to quantify fugitive dust emissions from the proposed Project

<table>
<tr><th>Activity</th><th>Emission Equation/Emission Factor</th><th>Source</th><th>Information assumed/provided</th></tr>
<tr>
<td>Materials handling</td>
<td>$$E = 0.0016\frac{(U/2.2)^{1.3}}{(M/2)^{1.4}}$$
Where,
E = Emission factor (kg dust / t transferred)
U = Mean wind speed (m/s)
M = Material moisture content (%)

The $PM_{2.5}$, PM_{10} and TSP fraction of the emission factor is 5.3%, 35% and 74% respectively.</td>
<td>US-EPA AP42 Section 13.2.4 (US EPA, 2006)</td>
<td>The moisture content of materials are as follows:
Ore: 3% (assumed)
Waste: 3% (assumed)
The respective throughput of materials during the operational phase was calculated as:
<table>
<tr><th>Area</th><th>Ore (tpa)</th><th>Waste (tpa)</th></tr>
<tr><td>Ore Stockpile 1</td><td>1 000 000</td><td></td></tr>
<tr><td>Ore Stockpile 2</td><td>1 000 000</td><td></td></tr>
<tr><td>Ore Stockpile 3</td><td>1 000 000</td><td></td></tr>
<tr><td>WRD</td><td></td><td>5 210 000</td></tr>
</table>
Operational hours: 8 694 hours per year (362.25 days, 24 hours per day)
Average wind speed of 2.55 m/s, from on-site weather data (period 1 January 2018 to 1 December 2022).</td>
</tr>
<tr>
<td>Front-end-loader (FEL)</td>
<td>Emission factors
<table>
<tr><th>TSP</th><th>PM_{10}</th><th>$PM_{2.5}$ (a)</th><th>Unit</th></tr>
<tr><td>0.47</td><td>0.026</td><td>0.004</td><td>kg/tonne</td></tr>
</table>
Notes: (a) Fraction assumed to be the same fraction as for Materials Handling</td>
<td>NPI Section: Mining (NPI, 2012)</td>
<td>The location of operation and handling rates are:
<table>
<tr><th>Description</th><th>Handling rate (tph)</th></tr>
<tr><td>FEL - ore on largest ore storage pile</td><td>115</td></tr>
</table>
No split between ore stockpiles was provided, it was assumed that ore is loaded at largest stockpile are close to the crusher.</td>
</tr>
<tr>
<td>Vehicle entrainment on unpaved surfaces (mine roads)</td>
<td>$$E = k\left(\frac{s}{12}\right)^{a}\left(\frac{W}{3}\right)^{b} \cdot 281.9$$
Where,
E = particulate emission factor in grams per vehicle km travelled (g/VKT)
k = basic emission factor for particle size range and units of interest
s = road surface silt content (%)
W = average weight (tonnes) of the vehicles travelling the road

The particle size multiplier (k) is given as 0.15 for $PM_{2.5}$ and 1.5 for PM_{10}, and as 4.9 for TSP</td>
<td>US-EPA AP42 Section 13.2.2 (U.S. EPA, 2006)</td>
<td>Truck/ vehicle information:
<table>
<tr><th rowspan="2">Information</th><th rowspan="2">Unit</th><th>Trucks</th></tr>
<tr><th>B45D</th></tr>
<tr><td>No. of Trucks</td><td></td><td>4</td></tr>
<tr><td>Onsite truck Payload</td><td>ton</td><td>41</td></tr>
<tr><td>Empty weight</td><td>ton</td><td>33</td></tr>
<tr><td>Full weight on road (a)</td><td>ton</td><td>74</td></tr>
<tr><td>Average speed (b)</td><td>km/hr</td><td>40</td></tr>
</table>
Notes: (a) assumed
(b) assumed

Vehicle kilometre travelled (VKT) were calculated from road lengths, truck capacities and the number of trips required for transporting materials.</td>
</tr>
</table>

<table>
<tr><th>Activity</th><th>Emission Equation/Emission Factor</th><th>Source</th><th>Information assumed/provided</th></tr>
<tr><td></td><td>The empirical constant (a) is given as 0.9 for $PM_{2.5}$ and PM_{10}, and 4.9 for TSP

The empirical constant (b) is given as 0.45 for $PM_{2.5}$, PM_{10} and TSP</td><td></td><td>
<table>
<tr><th rowspan="2">Road Description</th><th rowspan="2">Material</th><th rowspan="2">Length (m)</th><th colspan="2">Trips/hour</th><th rowspan="2">VKT/hour</th></tr>
<tr><th>Haul Truck Full</th><th>Haul Truck Empty</th></tr>
<tr><td>Road from incline to ore stockpile</td><td>Ore</td><td>1104.11</td><td>2.81</td><td>2.81</td><td>6.19</td></tr>
</table>
Hours of operation: 24 hours (three 8-hour shifts hrs per day), 7 days per week

Silt content (USEPA mean silt loading for Iron and Steel Production):
• Surface haul roads: 6%
Layout of the roads was based on technical drawings received</td></tr>
<tr><td>Vehicle entrainment on paved surfaces (access roads)</td><td>$$EF = k \cdot (sL)^{0.91} \cdot (W)^{1.02}$$
Where
EF is the emission factor in g/vehicle kilometre travelled (VKT)
k is the particle size multiplier (k_{TSP} – 3.23, k_{PM10} – 0.62, $k_{PM2.5}$ – 0.15)
sL is the road surface material silt loading in g/m²
W is the average weight vehicles in tonnes</td><td>US-EPA AP42 Section 13.2.1 (U.S. EPA, 2011)</td><td>Transport activities include the transport of consumables, product, and staff on the:
• C13 tarred road connecting the mine to Rosh Pinah
Truck/ vehicle information:
<table>
<tr><th rowspan="2">Information</th><th rowspan="2">Unit</th><th>Staff Transport</th></tr>
<tr><th>Busses</th></tr>
<tr><td>No. of Busses</td><td></td><td>1</td></tr>
<tr><td>Onsite truck Payload</td><td>ton</td><td>12.8</td></tr>
<tr><td>Full weight [(b)]</td><td>ton</td><td>3.6</td></tr>
<tr><td>Average weight on road [(a)]</td><td>ton</td><td>16.3</td></tr>
<tr><td>Operational Hours</td><td>hours/year</td><td>4 500</td></tr>
</table>
Notes: [(a)] assumed 50 seater bus.
[(b)] assumed 50 people at 70 kg each
The road surface silt loading:
• Access road: 7 g/m² (Baseline Value for public roads)
<table>
<tr><th>Road Description</th><th>Length (m)</th><th>Trips/hour</th><th>VKT/hour</th></tr>
<tr><td>Public paved road (C13)</td><td>5 698.37</td><td>2</td><td>11.4</td></tr>
</table></td></tr>
<tr><td>Crushing and screening</td><td>Emission factors
<table>
<tr><th>Crushing</th><th>TSP</th><th>PM_{10}</th><th>$PM_{2.5}$[(a)]</th><th>Unit</th></tr>
<tr><td>Primary</td><td>0.2</td><td>0.02</td><td>0.01</td><td>kg/tonne</td></tr>
</table></td><td>NPI Section: Mining (NPI, 2012)</td><td>The throughput of the ROM material was provided as 1 000 000 tpa for all operational years.

Hours of operation were given as 24 hrs per day, 7 days per week.</td></tr>
</table>

<table>
<tr><th>Activity</th><th>Emission Equation/Emission Factor</th><th>Source</th><th>Information assumed/provided</th></tr>
<tr><td></td><td>Notes: (a) Fraction of $PM_{2.5}$ taken from US-EPA crushed stone emission factor ratio for tertiary crushing.

Where,</td><td></td><td>ROM moisture: 3%

Primary crushing assumed to be located near ROM pad.</td></tr>
<tr><td>Wind Erosion</td><td>Emission factors
<table>
<tr><th>Wind erosion</th><th>TSP</th><th>PM_{10}</th><th>$PM_{2.5}$(a)</th><th>Unit</th></tr>
<tr><td>Primary</td><td>0.4</td><td>0.2</td><td>0.1</td><td>kg/ha/h</td></tr>
</table>
Notes: (a) Fraction of $PM_{2.5}$ assumed to be 50% of PM_{10}.</td><td>NPI Section: Mining (NPI, 2012)</td><td>Layout of WRD, TSF and Topsoil stockpiles was provided, with moisture content and particle density assumed:
<table>
<tr><th>Dump/ Stockpile</th><th>Area (m²)</th><th>Moisture content (%)</th></tr>
<tr><td>TSF</td><td>410 920</td><td>3</td></tr>
<tr><td>WRD</td><td>24 130</td><td>3</td></tr>
<tr><td>Topsoil 1</td><td>37 398</td><td>3</td></tr>
<tr><td>Topsoil 2</td><td>18 973</td><td>3</td></tr>
<tr><td>Topsoil 3</td><td>12 540</td><td>3</td></tr>
<tr><td>Topsoil 4</td><td>4 772</td><td>3</td></tr>
</table>
Notes: (a) average assumed between ore and waste.

Emissions were assumed to be continuous as a worst case scenario, included for hours where the threshold friction velocity (u^*) was not exceeded.</td></tr>
<tr><td>Shaft Emissions</td><td>Occupational exposure limits
PM_{10} = 10 mg/m³
$PM_{2.5}$ = 5 mg/m³
SO_2 = 5 mg/m³
NO_2 = 5 mg/m³
CO = 35 mg/m³</td><td>ACGIH TLVs 1996 – Occupational Guidelines</td><td>Parameters provided by the client:
- Diameter: 5.5 m
- Exit velocity: 20 m/s
Assumed:
- Height: 10 m</td></tr>
</table>

Table 10: Estimated control efficiencies provided for mitigation measures applied to various mining operations (NPI, 2012)

Operation/Activity	Control method and emission reduction
Unpaved surface haul roads	75% CE for water sprays with chemical suppressants
Paved public road	No control
Materials handling (loading and unloading)	50% CE for water sprays
FEL	50% CE for water sprays
Crushing and screening	50% CE for water sprays keeping ore wet
Windblown dust from WRDs and TSF	60% CE for the cladding of the TSF

Note: CE is Control Efficiency

Table 11: Scenario 1 – Calculated emission rates from unmitigated and mitigated mining operations

Activity/ Area of operation	Unmitigated			Mitigated		
	$PM_{2.5}$ (tpa)	PM_{10} (tpa)	TSP (tpa)	$PM_{2.5}$ (tpa)	PM_{10} (tpa)	TSP (tpa)
Materials Handling	0.48	3.16	6.68	0.24	1.58	3.34
Crushing & Screening	10.00	20.00	200.00	5.00	10.00	100.00
Unpaved Roads	4.38	43.76	191.20	1.09	10.94	47.80
Paved Roads	0.18	0.77	4.05	0.18	0.77	4.05
FEL	3.94	26.00	470.00	1.97	13.00	235.00
WE (WRDs & SP)	44.57	89.13	178.26	22.97	45.93	91.87
Total	**63.54**	**182.83**	**1 050.19**	**31.46**	**82.23**	**482.06**

4.1.3 Closure and Decommissioning Phase

It is assumed that all the operations will have ceased by the closure phase of the project. The potential for impacts during this phase will depend on the extent of rehabilitation efforts during closure. Aspects and activities associated with the closure phase of the proposed operations are listed in Table 12. Simulations of the closure and decommissioning phases were not included in the current study due to its temporary impacting nature.

Table 12: Activities and aspects identified for the closure and decommissioning phase

Impact	Source	Activity
PM emissions	WRDs, TSF, Stockpiles and mine pits	Dust generated during rehabilitation activities
PM emissions	Plant and infrastructure	Demolition of the process plant and infrastructure
Gas emissions	Vehicles	Tailpipe emissions from vehicles utilised during the closure phase

4.2 Atmospheric Dispersion Modelling

The impact assessment of the project's operations on the environment is discussed in this section. To assess impact on human health and the environment the following important aspects need to be considered:

- The criteria against which impacts are assessed (Section 2.5);
- The potential of the atmosphere to disperse and dilute pollutants emitted by the project (Section 3.2); and
- The AQSRs in the vicinity of the proposed mine (Section 3.1).

The impact of proposed operations on the atmospheric environment was determined through the simulation of ambient pollutant concentrations. Dispersion models simulate ambient pollutant concentrations as a function of source configurations, emission strengths and meteorological characteristics, thus providing a useful tool to ascertain the spatial and temporal patterns in the ground level concentrations arising from the emissions of various sources. Increasing reliance has been placed on concentration estimates from models as the primary basis for environmental and health impact assessments, risk assessments and emission control requirements. It is therefore important to carefully select a dispersion model for the purpose.

4.2.1 Dispersion Model Selection

For the purpose of the current study, it was decided to use the Atmospheric Dispersion Modelling System (ADMS) developed by the Cambridge Environmental Research Consultants (CERC). CERC was established in 1986, with the aim of making use of new developments in environmental research from Cambridge University and elsewhere for practical purposes. CERC's leading position in environment software development and associated consultancy has been achieved by encapsulating advanced scientific research into a number of computer models which include ADMS 5. This model simulates a wide range of buoyant and passive releases to the atmosphere either individually or in combination. It has been the subject of a number of inter-model comparisons (CERC, 2004), one conclusion of which is that it tends provide conservative values under unstable atmospheric conditions in that it predicts higher concentrations than the older models close to the source.

ADMS 5 is a new generation air dispersion model which differs from the regulatory models traditionally used in a number of aspects, the most important of which are the description of atmospheric stability as a continuum rather than discrete classes (the atmospheric boundary layer properties are described by two parameters; the boundary layer depth and the Monin-Obukhov length, rather than in terms of the single parameter Pasquill Class) and in allowing more realistic asymmetric plume behaviour under unstable atmospheric conditions. Dispersion under convective meteorological conditions uses a skewed Gaussian concentration distribution (shown by validation studies to be a better representation than a symmetric Gaussian expression).

ADMS 5 is currently used in many countries worldwide and users of the model include Environmental Agencies in the UK and Wales, the Scottish Environmental Protection Agency (SEPA) and regulatory authorities including the UK Health and Safety Executive (HSE). Concentration and deposition distributions for various averaging periods may be calculated. It has generally been found that the accuracy of off-the-shelf dispersion models improve with increased averaging periods. The accurate prediction of instantaneous peaks is the most difficult and are normally performed with more complicated dispersion models specifically fine-tuned and validated for the location. For the purposes of this report, the shortest time period modelled is one hour.

4.2.2 Meteorological Requirements

Modelled hourly meteorological data for the 1 January 2020 to 31 December 2020 was utilised for the dispersion simulations.

4.2.3 Source Data Requirements

ADMS 5 model is able to model point, jet, area, line and volume sources. Sources were modelled as follows:

- Paved and unpaved roads – modelled as area sources;
- Wind erosion – modelled as area sources;
- Materials handling and crushing and screening – modelled area sources;
- Ventilation shaft – modelled as a point source

4.2.4 Modelling Domain

The dispersion of pollutants expected to arise from proposed activities was modelled for an area covering 8 km (east-west) by 8 km (north-south). The area was divided into a grid matrix with a resolution of 100 m by 100 m, with the project located centrally. ADMS 5 calculates ground-level (1.5 m above ground level) concentrations and dustfall rates at each grid and discrete receptor point. All AQSRs shown in Figure 3 were included in the model.

4.3 Dispersion Modelling Results

Dispersion modelling was undertaken to determine the 99th percentile daily and annual average ground level concentrations (GLCs). Averaging periods were selected to facilitate the comparison of predicted pollutant concentrations to relevant ambient air quality and inhalation health criteria as well as dustfall regulations.

Pollutants with the potential to result in human health impacts which are assessed in this study include $PM_{2.5}$ and PM_{10}. Dustfall is assessed for its nuisance potential. Results are primarily provided in form of isopleths to present areas of exceedance of assessment criteria. Ground level concentration or dustfall isopleths presented in this section depict interpolated values from the concentrations simulated by ADMS for each of the receptor grid points specified.

It should also be noted that ambient air quality criteria apply to areas where the Occupational Health and Safety regulations do not apply, thus outside the property or lease area. Ambient air quality criteria are therefore not occupational health indicators but applicable to areas where the general public has access i.e. off-site.

4.3.1 Unmitigated Scenario

4.3.1.1 PM_{10}

The simulated ground level concentrations of daily and annual average PM_{10} for unmitigated operations are provided in Figure 10 and Figure 11 respectively. The modelled results indicate that the AQOs are not exceeded off-site.

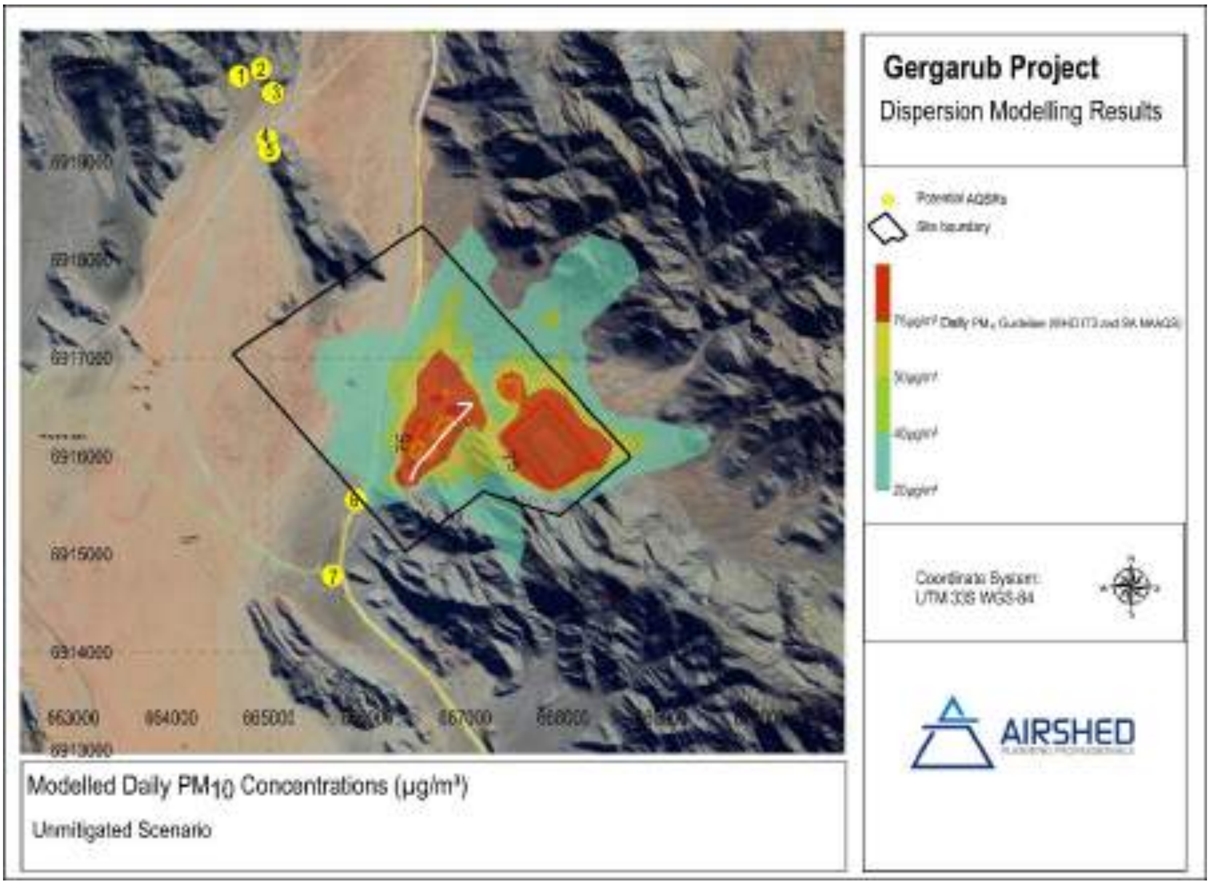


Figure 10: Modelled ground level concentrations of daily PM_{10} AQO for unmitigated operations

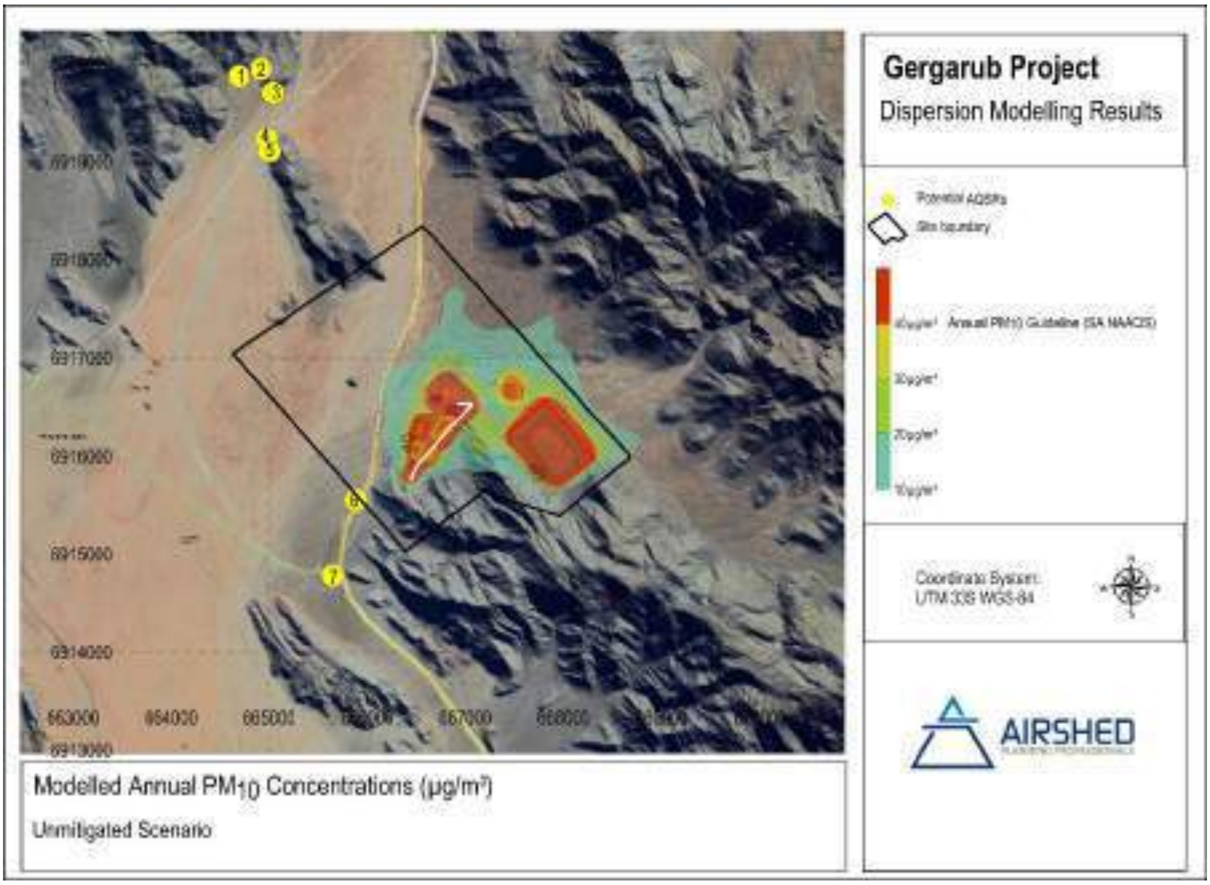


Figure 11: Modelled ground level concentrations of annual PM_{10} AQO for unmitigated operations

4.3.1.2 $PM_{2.5}$

The simulated ground level concentrations of daily and annual average $PM_{2.5}$ for unmitigated and mitigated operations are provided in Figure 17 and Figure 18.

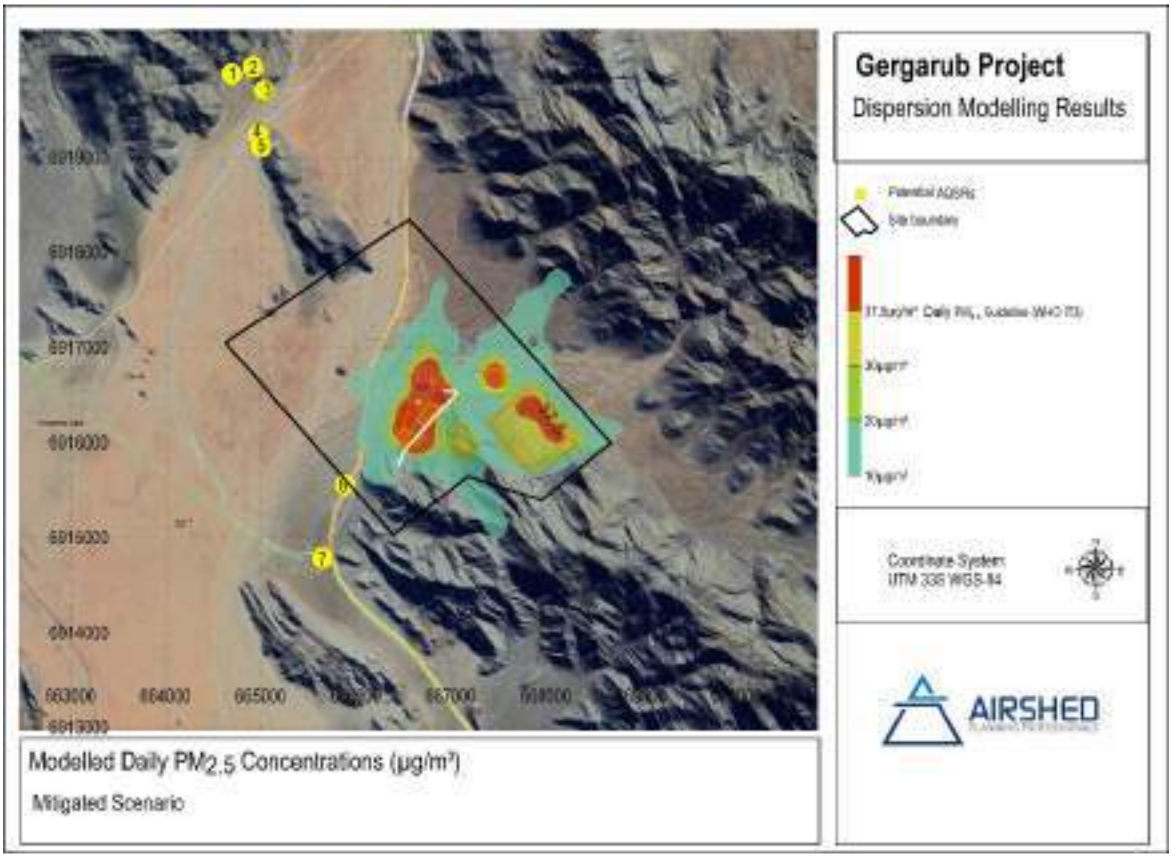


Figure 12: Modelled ground level concentrations of daily $PM_{2.5}$ AQO for unmitigated operations

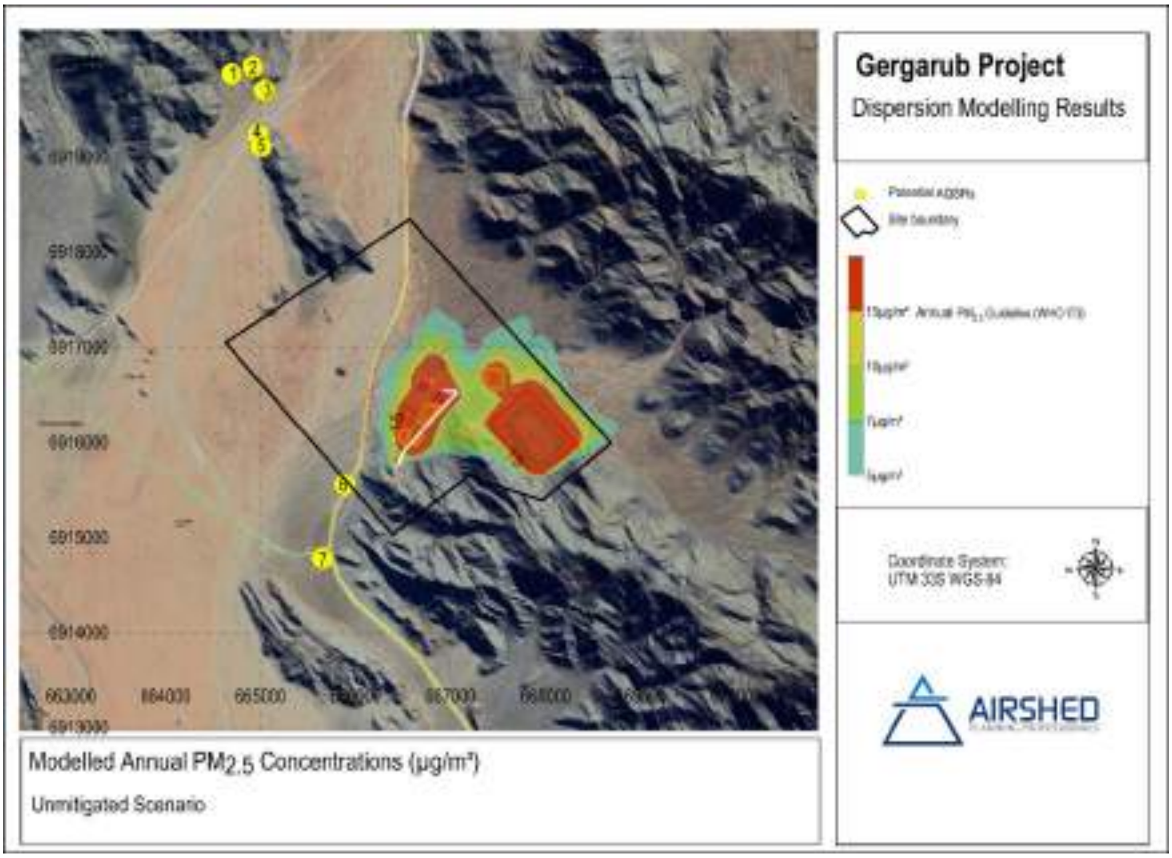


Figure 13: Modelled ground level concentrations of annual $PM_{2.5}$ AQO for unmitigated operations

4.3.1.3 *Dust Fallout*

The simulated maximum daily dustfall rates for unmitigated and mitigated activities are provided in Figure 14. Maximum daily dustfall rates, for both unmitigated and mitigated activities, do not exceed the AQO (SA NDCR residential limit of 600 mg/m²/day) at any of the AQSRs or outside the site boundary.

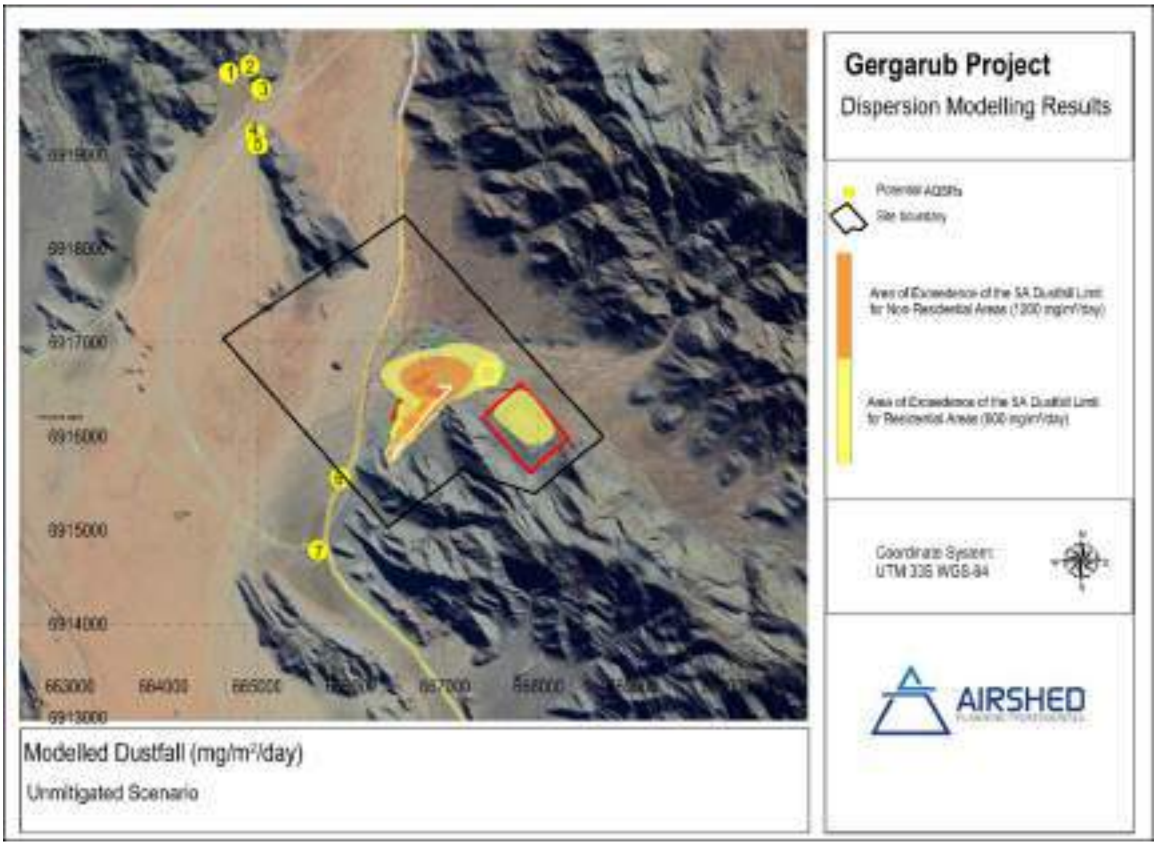


Figure 14: Modelled dustfall values for unmitigated operations

4.3.2 Mitigated Scenario

4.3.2.1 *PM_{10}*

The simulated ground level concentrations of daily and annual average PM_{10} for mitigated operations are provided in Figure 15 and Figure 16 respectively. The modelled results indicate that the AQOs are not exceeded off-site.

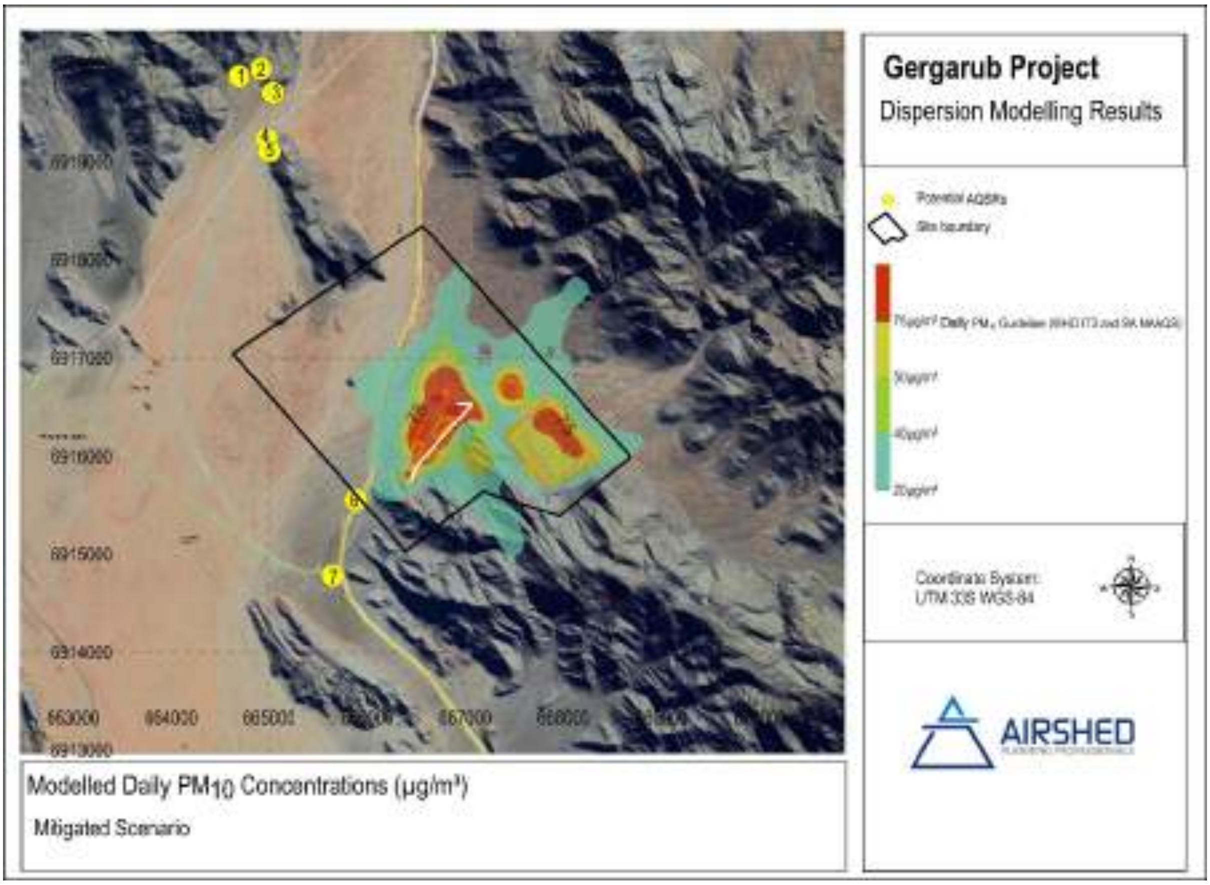


Figure 15: Modelled ground level concentrations of daily PM_{10} AQO for mitigated operations

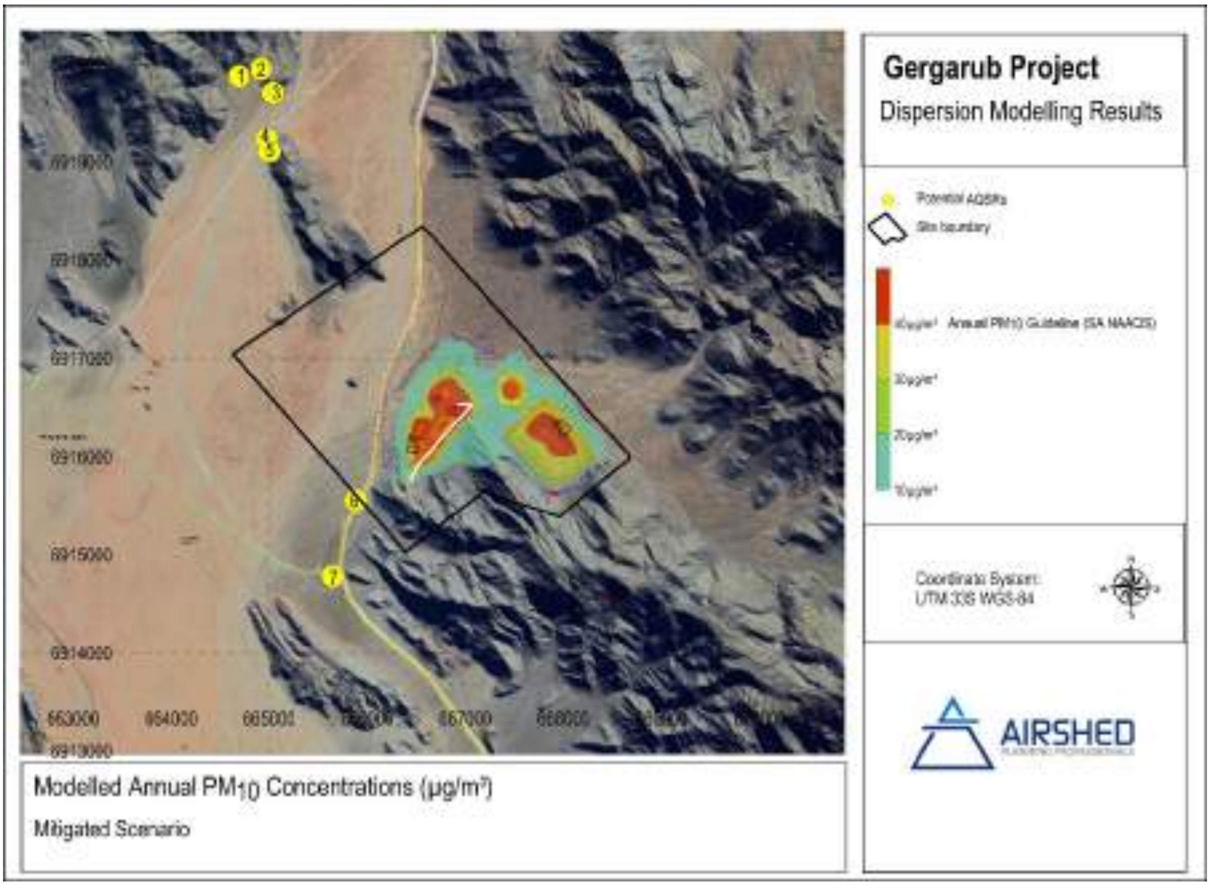


Figure 16: Modelled ground level concentrations of annual PM_{10} AQO for mitigated operations

4.3.2.2 *$PM_{2.5}$*

The simulated ground level concentrations of daily and annual average $PM_{2.5}$ for unmitigated and mitigated operations are provided in Figure 17 and Figure 18 respectively. The modelled results indicate that the AQOs are not exceeded off-site.

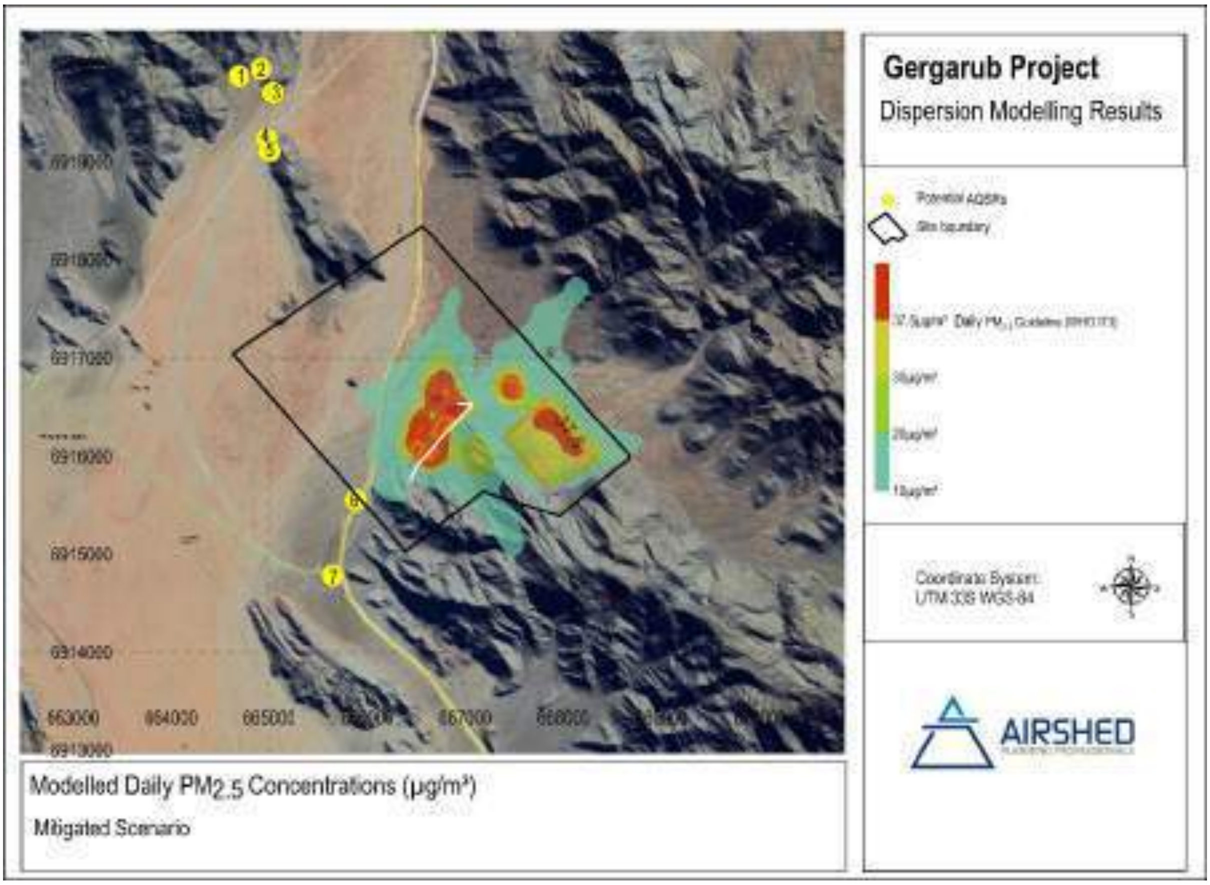


Figure 17: Modelled ground level concentrations of daily $PM_{2.5}$ AQO for mitigated operations

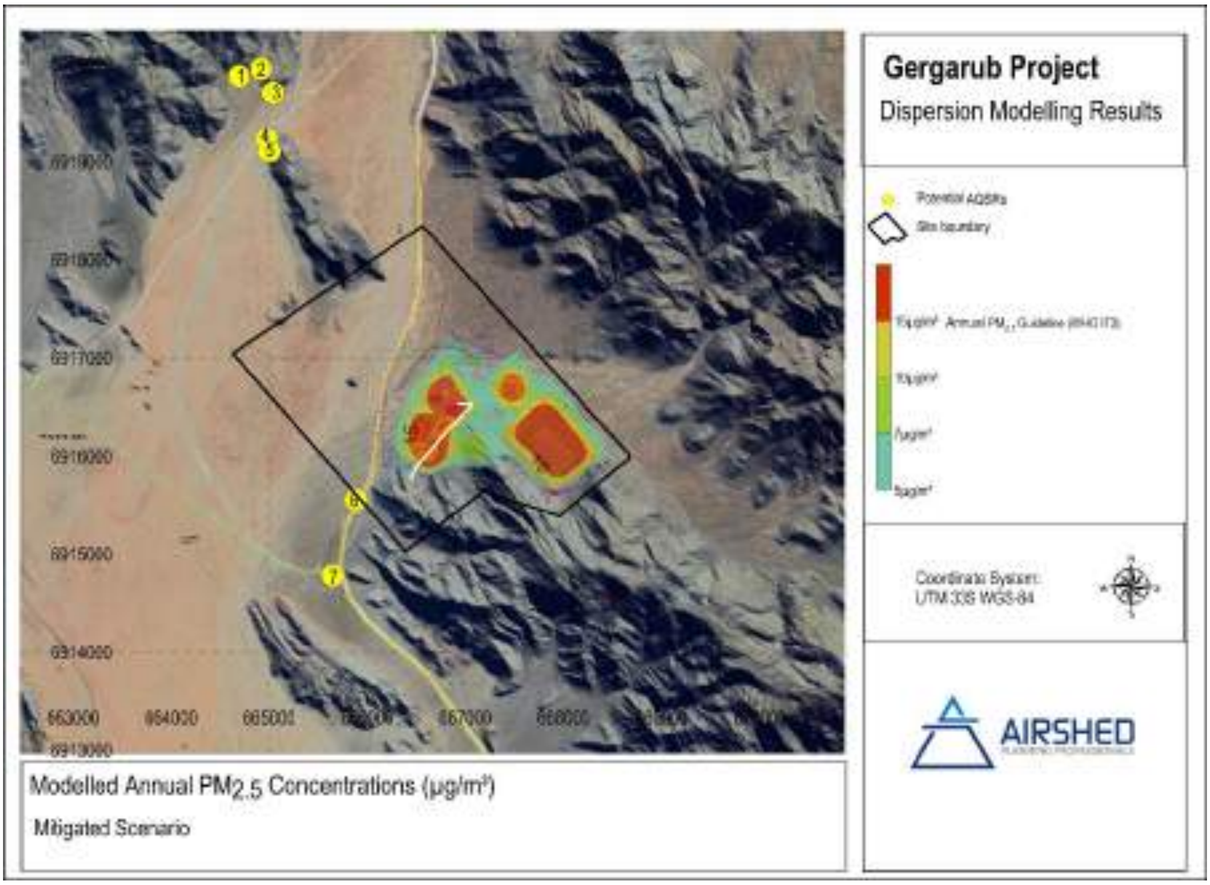


Figure 18: Modelled ground level concentrations of annual $PM_{2.5}$ AQO for mitigated operations

4.3.2.3 Dust Fallout

The simulated maximum daily dustfall rates for mitigated and unmitigated activities are provided in Figure 18. Maximum daily dustfall rates, for both unmitigated and mitigated activities, are within the AQO (SA NDCR residential limit of 600 mg/m²/day) at all of the AQSRs and outside the site boundary.

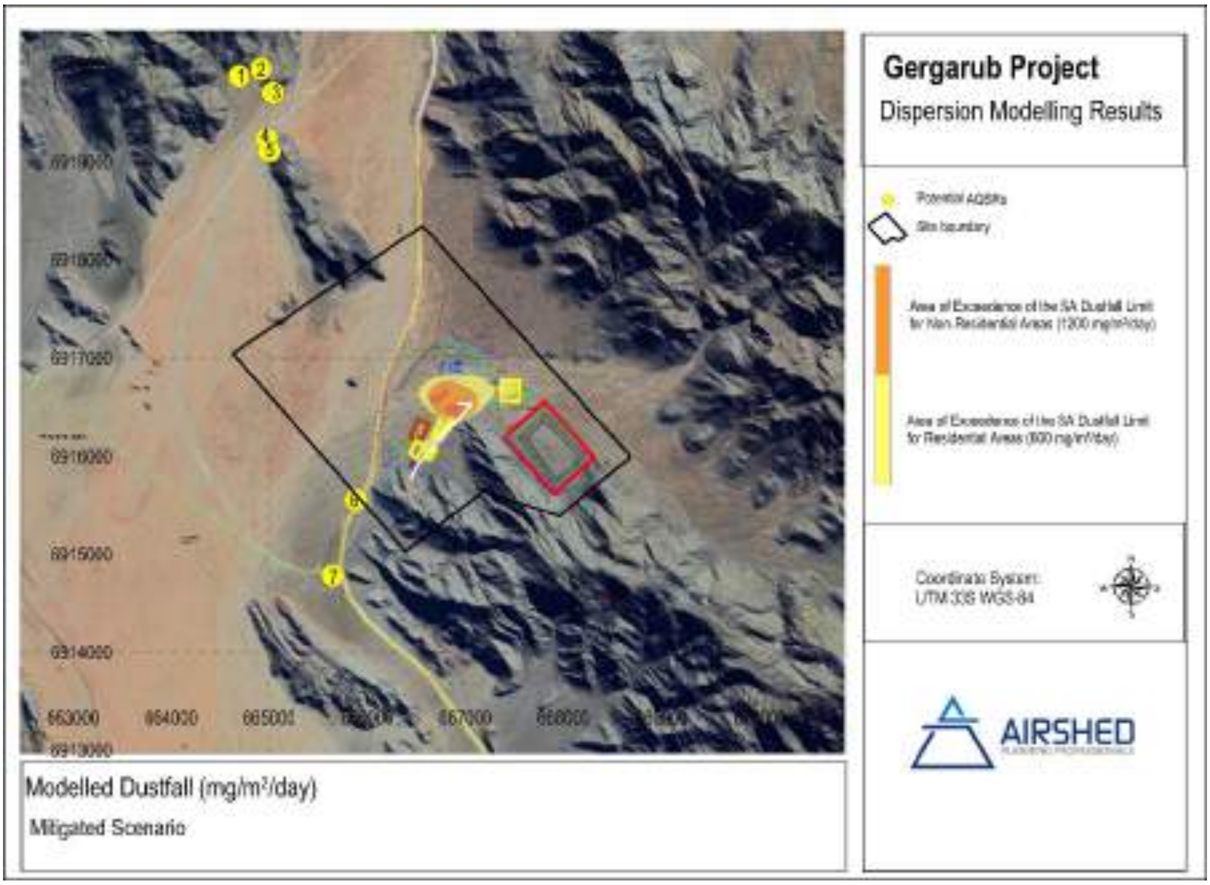


Figure 19: Modelled dustfall values for mitigated operations

5 AIR QUALITY MANAGEMENT MEASURES

In the light of potentially high impacts from the proposed mining operations, specifically from PM_{10} and $PM_{2.5}$ concentrations, it is recommended that the project proponent commit to adequate air quality management planning throughout the life of the proposed project. An air quality management plan provides options on the control of particulate matter at the main sources, while the monitoring network is designed to track the effectiveness of the mitigation measures.

Based on the findings of the impact assessment, the following mitigation, management, and monitoring recommendations are proposed following a hierarchy of: **Avoidance > Minimisation > Rehabilitation > Offset**.

5.1 Proposed Mitigation and Management Measures

5.1.1 Proposed Mitigation Measures and/or Target Control Efficiencies

The main sources resulting in PM emissions and impacts from the proposed Project was wind erosion from the TSF, WRD and Topsoil storage followed by crushing and screening activities and vehicle entrainment on unpaved roads.

Mitigation measures used for the mitigation scenarios were provided to include the following:

5.1.1.1 Construction and closure phase:

- Air quality impacts during construction would be minimised through basic control measures such as limiting the speed of haul trucks; limit unnecessary travelling of vehicles on untreated roads; reducing the area of construction where it is close to receptors; and to apply water sprays on regularly travelled, unpaved sections.
- During closure and post-closure, the open exposed areas prone to wind erosion should be either covered with surface material and rehabilitated (vegetated or compacted) to ensure the surfaces form a hard crust and/or gladded with waste rock.

5.1.1.2 Operational phases (the control efficiencies are from NPI, 2012):

In order to minimise off-site impacts the following mitigation measures are recommended:

- For the control of vehicle entrained dust the following is recommended to use chemical suppressants such as *dust-a-side* to ensure a control efficiency of 90%, as indicated by literature to be achievable. The application frequency of the chemical suppressants would depend on the road conditions which in turn is affected by traffic and climate. The road conditions should therefore be closely monitored to determine the frequency of the application to ensure minimal dust generation from the unpaved road surfaces.
- In minimising dust from crushing and screening operations, water sprays to keep the ore wet should ensure a 50% CE, whereas windbreaks around the crushers could achieve 30%. According to literature hooding with cyclones would achieve 65% CE, whereas scrubbers will achieve 75% and fabric filters would result in 83% CE. Enclosure or underground crushing would result in up to 100% CE.
- Minimising dust from materials transfer points, excluding the dried concentrate, could be done using water sprays at the tip points. This should result in a 50% CE.
- In minimising windblown dust from stockpile areas, water sprays should be used to keep surface material moist. A mitigation efficiency of 50% is anticipated.
- Cladding of the TSF is recommended to reduce wind erosion.

5.1.2 Performance Indicators

Key performance indicators against which progress of implemented mitigation and management measures may be assessed, form the basis for all effective environmental management practices. In the definition of key performance indicators careful attention is usually paid to ensure that progress towards their achievement is measurable, and that the targets set are achievable given available technology and experience.

Performance indicators are usually selected to reflect both the source of the emission directly (source monitoring) and the impact on the receiving environment (ambient air quality monitoring). Ensuring that no visible evidence of windblown dust exists represents an example of a source-based indicator, whereas maintaining off-site dustfall levels, at the identified AQSRs, to below 600 mg/m²-day represents an impact- or receptor-based performance indicator.

Except for vehicle/equipment emission testing, source monitoring at mining activities can be challenging due to the fugitive and wind-dependant nature of particulate emissions. The focus is therefore rather on receptor-based performance indicators i.e. compliance with ambient air quality standards and dustfall regulations.

5.1.3 Ambient Air Quality Monitoring

Ambient air quality monitoring can serve to meet various objectives, such as:

- Compliance monitoring;
- Validate dispersion model results;
- Use as input for health risk assessment;
- Assist in source apportionment;
- Temporal and spatial trend analysis;
- Source quantification; and,
- Tracking progress made by control measures.

It is recommended that a dustfall monitoring network be established around the site boundary. The dustfall units must be maintained and the monthly dustfall results used as indicators to tract the effectiveness of the applied mitigation measures. Dustfall collection should follow the ASTM method.

The dustfall monitoring network should follow the American Society for Testing and Materials standard method for collection and analysis of dustfall (ASTM D1739-98). The ASTM method covers the procedure of collection of dustfall and its measurement and employs a simple device consisting of a cylindrical container exposed for one calendar month (30 ±2 days). The method provides for a dry bucket, which is advisable in the dry environment.

It is recommended that the dustfall monitoring network be supplemented by periodic ambient PM_{10} and $PM2_{.5}$ monitoring to determine whether the Air Quality Objectives are being met.

5.1.4 Periodic Inspections and Audits

Periodic inspections and external audits are essential for progress measurement, evaluation and reporting purposes. It is recommended that site inspections and progress reporting be undertaken at regular intervals (at least quarterly), with annual environmental audits being conducted. Annual environmental audits should be continued at least until closure. Results from site inspections and monitoring efforts should be combined to determine progress against source- and receptor-based performance indicators. Progress should be reported to all interested and affected parties, including authorities and persons affected by pollution.

The criteria to be taken into account in the inspections and audits must be made transparent by way of minimum requirement checklists included in the management plan. Corrective action or the implementation of contingency measures must be proposed to the stakeholder forum in the event that progress towards targets is indicated by the quarterly/annual reviews to be unsatisfactory.

5.1.5 Liaison Strategy for Communication with I&APs

Stakeholder forums provide possibly the most effective mechanisms for information dissemination and consultation. Management plans should stipulate specific intervals at which forums will be held and provide information on how people will be notified of such meetings. Given the close proximity of the mine to residential housing units, it is recommended that such meetings be scheduled and held at least on a bi-annual basis. A complaints register must be kept at all times.

5.1.6 Financial Provision

The budget should provide a clear indication of the capital and annual maintenance costs associated with dust control measures, dust monitoring plans and rehabilitation. It may be necessary to make assumptions about the duration of aftercare prior to obtaining closure. This assumption must be made explicit so that the financial plan can be assessed within this framework. Costs related to inspections, audits, environmental reporting and Interested and Affected Parties liaison should also be indicated where applicable. Provision should also be made for capital and running costs associated with dust control contingency measures and for security measures. The financial plan should be audited by an independent consultant, with reviews conducted on an annual basis.

6 FINDINGS AND RECOMMENDATIONS

A quantitative air quality impact assessment was conducted for the operational phase activities of the proposed Project. Construction, closure, and post-closure activities were assessed qualitatively. The assessment included an estimation of atmospheric emissions, the simulation of pollutant concentrations and determination of the significance of impacts. The main concern is the potential air quality impacts from the proposed Project on the receiving environment and human health.

6.1 Main Findings

6.1.1 Baseline Assessment

The main findings from the baseline assessment can be summarised as follows:

- The Project is located to the North of Rosh Pinah in the Kharas region in the South of Namibia.
- The project site is located in a hilly area that could impact the wind flow at the site.
- There are no villages or homesteads near the project, with the closest buildings located towards the southern side of the side boundary.
- On-site weather data was not available for the site and the assessment utilised modelled weather data. The predominant wind direction was southwest to westerly, with an increase in easterly winds during winter.
- Maximum, minimum, and mean temperatures were given as 1.5°C, 19.6°C and 41.1°C respectively from the modelled weather data for the period 1 January 2020 to 31 December 2022.
- Modelled annual rainfall for 2020, 2021 and 2022 was 31.7, 38.9 and 34.1 mm respectively, with the highest monthly rainfall in January 2021 (25.7 mm).
- The main pollutant of concern in the region is particulate matter (TSP; PM_{10} and $PM_{2.5}$) resulting from vehicle entrainment on the roads (paved, unpaved and treated surfaces), windblown dust, and mining and exploration activities. Gaseous pollutants such as SO_2, NOx, CO and CO_2 would result from vehicles and combustion sources, but these are expected to be at low concentrations due to the few sources in the region.
- Sources of atmospheric emissions in the vicinity of the proposed Project include:
  - Windblown dust: Windblown particulates from natural exposed surfaces, mine waste facilities, and product stockpiles can result in significant dust emissions with high particulate concentrations near the source locations, potentially affecting both the environment and human health. Windblown dust from natural exposed surfaces in and at the Project is only likely to result in particulate matter emissions under high wind speed conditions (>10 m/s), and since recorded wind speeds did not exceed 10 m/s, this source is likely to be of low significance.
  - Mines and Exploration operations: Mines in proximity to the proposed Project are Skorpion Zinc Mine located northwest of the site, approximately 10 km from the site and the Rosh Pinah Mine located approximately 15 km from the site.
  - Vehicle entrainment on paved and unpaved roads
  - Regional transport of pollutants: regional-scale transport of mineral dust and ozone (due to vegetation burning) from the north of Namibia is a significant contributing source to background PM concentrations.

6.1.2 Impact Assessment

The findings from the impact assessment can be summarised as follows:

Construction normally comprises a series of different operations including land clearing, topsoil removal, road grading, material loading and hauling, stockpiling, grading, bulldozing, compaction, etc., with particulate matter the main pollutants of concern from these activities. The extent of dust emissions would vary substantially from day to day depending on the level of activity, the specific operations, and the prevailing meteorological conditions, and how close these activities are to AQSRs. Due to the intermittent nature of construction operations, the emissions are expected to have a varying impact depending on the level of activity. With mitigation measures in place these impacts are expected to be low.

Operational Phase:

- Emissions quantified for the proposed Project were restricted to fugitive releases (non-point releases) and point source emissions from the ventilation shaft with particulates the main pollutant of concern. Gaseous emissions (i.e. SO_2, NOx, CO and VOCs) will primarily result from diesel combustion, both from mobile and stationary sources.
- Topography was included in the dispersion model to account for the site-specific topography that will influence the dispersion results.
- Both unmitigated and mitigated scenarios were modelled. Mitigation was applied was based on design mitigation measures provided, which included the following:
    - Surface haul roads: water sprays combined with chemical suppressant on resulting in 75% CE;
    - Materials handling (loading and unloading ROM and waste rock): water sprays at tip points resulting in 50% CE; and
    - Crushing and screening of ROM (primary; secondary and tertiary): resulting in 50% CE from water sprays to keep ore wet.
- Dispersion modelling results indicate no off-site exceedances of the AQOs for $PM_{2.5}$, PM_{10} and dustfall. The air quality impacts can be reduced by applying mitigation measures.
- Cumulative air quality impacts could not be assessed since no background PM_{10} and $PM_{2.5}$ data are available. The localised PM_{10} and $PM_{2.5}$ impacts from the proposed Project modelling results indicate the potential for low regional cumulative impacts, and only high cumulative impacts in the immediate vicinity of the mine. Off-site impacts are likely to be managed with proper mitigation measures in place.

Closure operations are likely to include demolishing existing structures, scraping and moving surface material to cover the remaining exposed surfaces (WRDs and TSF) and contouring of the surface areas. The impacts are expected to be similar to that of construction operations – potentially small but harmful impacts at nearby receptors, depending on the level of activity but low impacts with mitigation measures in place. **Post-closure** operations, likely to include vegetation cover maintenance, would result in very low air quality related impacts.

6.2 Conclusion

The proposed Project is likely to result in increased $PM_{2.5}$ and PM_{10} ground level in the immediate vicinity of the mine and impacts can be reduced by applying appropriate mitigation measures. The dispersion modelling results indicate that the AQOs were not exceeded off-site. Dustfall rates are likely to be low throughout the life of mine, with gaseous concentrations (SO_2, NO_2 and CO) also expected to result in low air quality impacts.

It is the specialist's opinion that the proposed project could be authorised provided strict enforcement of mitigation measures and the tracking of the effectiveness of these measures to ensure the lowest possible off-site impacts.

6.3 Recommendations

Based on the findings from the air quality impact assessment for the Project following recommendations are included:

- Construction and closure phases:
  - Air quality impacts during construction would be reduced through basic control measures such as limiting the speed of haul trucks; limit unnecessary travelling of vehicles on untreated roads; and applying dust-a-side on regularly travelled, unpaved sections.
  - When haul trucks need to use public roads, the vehicles need to be cleaned of all mud and the material transported must be covered to minimise windblown dust.
- Operational phases:
  - For the control of vehicle entrained dust a control efficiency (CE) of 90% on unpaved surface roads through the application of chemical surfactants is recommended.
  - In controlling dust from crushing and screening operations, it is recommended that water sprays be applied to keep the ore wet, to achieve a control efficiency of up to 50%.
  - Mitigation of materials transfer points should be done using water sprays at the tip points. This should result in a 50% control efficiency. Regular clean-up at loading points is recommended.
  - In controlling emissions from the TSF it is recommended that the TSF slope be clad progressively during operation using waste rock. It is further recommended that a dust suppressing polymer is sprayed on the TSF surface following tailings placement.
- Air Quality Monitoring:
  - It is recommended that a dustfall monitoring network be established around the site boundary. The dustfall units must be maintained and the monthly dustfall results used as indicators to tract the effectiveness of the applied mitigation measures. Dustfall collection should follow the ASTM method.
  - It is further recommended that the dustfall monitoring network be supplemented by periodic ambient PM_{10} and $PM2_{.5}$ monitoring to determine whether the Air Quality Objectives are being met.

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8 APPENDIX A – SPECIALIST CURRICULUM VITAE

CURRICULUM VITAE	HANLIE LIEBENBERG-ENSLIN

FULL CURRICULUM VITAE

Name of Firm	Airshed Planning Professionals (Pty) Ltd
Name of Staff	Hanlie Liebenberg-Enslin
Profession	Managing Director / Air Quality Scientist
Date of Birth	09 January 1971
Years with Firm/ entity	21 years
Nationalities	South African

MEMBERSHIP OF PROFESSIONAL SOCIETIES

- International Union of Air Pollution Prevention and Environmental Protection Associations (IUAPPA) – President 2010–2013, Board member 2013-present
- Member of the National Association for Clean Air (NACA) - President 2008-2010, NACA Council member 2010 –2014

KEY QUALIFICATIONS

Hanlie Liebenberg-Enslin started her professional career in Air Quality Management in 2000 when she joined Environmental Management Services (EMS) after completing her Master's Degree at the University of Johannesburg (then Rand Afrikaans University) in the same field. She is one of the founding members of Airshed Planning Professionals in 2003 where she has worked as a company Director until May 2013 when she was appointed as Managing Director. She has extensive experience on the various components of air quality management including emissions quantification for a range of source types, simulations using a range of dispersion models, impacts assessment and health risk screening assessments. She has worked all over Africa and has an inclusive knowledge base of international legislation and requirements pertaining to air quality.

She has developed technical and specialist skills in various modelling packages including the industrial source complex models (ISCST3 and SCREEN3), EPA Regulatory Models (AERMOD and AERMET), UK Gaussian plume model (ADMS), EPA Regulatory puff based model (CALPUFF and CALMET), puff based HAWK model and line based models such as CALINE. Her experience with emission models includes Tanks 4.0 (for the quantification of tank emissions) and GasSim (for the quantification of landfill emissions).

Having worked on projects throughout Africa (i.e. South Africa, Mozambique, Botswana, Namibia, Malawi, Kenya, Mali, Democratic Republic of Congo, Tanzania, Madagascar, Guinea and Mauritania) Hanlie has developed a broad experience base. She has a good understanding of the laws and regulations associated with ambient air quality and emission limits in South Africa and various other African countries, as well as the World Bank Guidelines, European Community Limits and World Health Organisation.

Being an avid student, she received her PhD in 2014, specialising in Aeolian dust transport. Hanlie is also actively involved in the National Association for Clean Air and is their representative at the International Union of Air Pollution Prevention and Environmental Protection Associations.

RELEVANT EXPERIENCE

Air Quality Management Plans and Strategies

Vaal Triangle Airshed Priority Area Draft Second Generation Air Quality Management Plan (AQMP)(Aug 2017 – Jun 2020); Advanced Air Quality Management for the Strategic Environmental Management Plan for the Uranium and Other Industries in the Erongo Region (May 2016 – Feb 2019); City of Johannesburg AQMP (2016-2019); Air Quality Monitoring and Management for the Al Madinah Al Munawarah Development Authority (MDA) in Saudi Arabia (2016-2017). Provincial Air Quality Management Plan for the Limpopo Province (March 2013); Mauritius Road Development Agency Proposed Road Decongestion Programme (July 2013); Transport Air Quality Management Plan for the Gauteng Province (February 2012); Gauteng Green Strategy (2011); Air Quality and Radiation Assessment for the Erongo Region Namibia as part of a Strategic Environmental Assessment (June, 2010); Vaal Triangle Airshed Priority Area AQMP (March, 2009); Gauteng Provincial AQMP (January 2009); North West Province AQMP (2008); City of Tshwane AQMP (April 2006); North West Environment Outlook 2008 (December 2007); Ambient Monitoring Network for the North West Province (February 2007); Spatial Development Framework Review for the City of uMhlathuze (August 2006); Ambient Particulate Pollution Management System (Anglo Platinum Rustenburg).

Hanlie has also been the Project Director on all the listed Air Quality Management plan developments.

Mining and Ore Handling

Hanlie has undertaken numerous air quality impact assessments and management plans for coal, platinum, uranium, copper, cobalt, chromium, fluorspar, bauxite and mineral sands mines. These include air quality impact assessments for: Namibia – Husab Uranium Mine, Trekkopje Uranium Mine; Bannerman Uranium Project; Langer Heinrich Uranium Mine, Valencia Uranium Mine, Rössing Uranium Mine; and B2Gold Otjikoto Gold Mine. South Africa – Sishen Iron Ore Mine; Tshipi Borwa Manganese Mine; Mamatwan Manganese Mine; Kolomela Iron Ore Mine; Thabazimbi Iron ore Mine; UKM Manganese Mine; Everest Platinum Mine; Impala Platinum Mine; Anglo Platinum Mines; Abglo Gold Ashanti MWS, Vaal River and West Wits complexes, Harmony Gold, Glencore Coal Mines, South32 and Anglo Coal; Tselentis Coal mine (Breyeton); Lime Quarries (De Hoek, Dwaalboom, Slurry); Beesting Colliery (Ogies); Anglo Coal Opencast Coal Mine (Heidelberg); Klippan Colliery (Belfast); Beesting Colliery (Ogies); Xstrata Coal Tweefontein Mine (Witbank); Xstrata Coal Spitskop Mine (Hendrina); Middelburg Colliery (Middelburg); Klipspruit Project (Ogies); Rustenburg Platinum Mine (Rustenburg); Impala Platinum (Rustenburg); Buffelsfontein Gold Mine (Stilfontein); Kroondal Platinum Mine (Kroondal); Lonmin Platinum Mine (Mooinooi); Rhovan Vanadium (Brits); Macauvlei Colliery (Vereeniging); Voorspoed Gold Mine (Kroonstad); Pilanesberg Platinum Mine (Pilanesberg); Kao Diamond Mine (Lesotho); Modder East Gold Mine (Brakpan); Modderfontein Mines (Brakpan); Zimbiwa Crusher Plant (Brakpan); RBM Zulti South Titanium mining (Richards Bay); Premier Diamond Mine (Cullinan). Botswana – Jwaneng Diamond Mine and Debswana Mining Company. Zimbabwe – Murowa Diamond Mine. Other mining projects include Sadiola Gold Mine (Mali); North Mara Gold Mine (Tanzania); Bulyanhulu North Mara Gold Mine (Tanzania).

Metal Recovery

Air quality impact assessments have been carried out for Smelterco Operations (Kitwe, Zimbia); Waterval Smelter (Amplats, Rustenburg); Hernic Ferrochroime Smelter (Brits); Rhovan Ferrovanadium (Brits); Impala Platinum (Rustenburg); Impala Platinum (Springs); Transvaal Ferrochrome (now IFM, Mooinooi), Lonmin Platinum (Mooinooi); Xstrata Ferrochrome Project Lion (Steelpoort); ArcelorMittal South Africa (Vandebijlpark, Vereeniging, Pretoria, Newcastle, Saldanha); Hexavalent Chrome Xstrata (Rustenburg); Portland Cement Plant (DeHoek, Slurry, Dwaalboom, Hercules, Port Eelizabeth); Vantech Plant (Steelpoort); Bulyanhulu Gold Smelter (Tanzania), Sadiola Gold Recovery Plant (Mali); RBM Smelter Complex (Richards Bay); Chibuto Heavy Minerals Smelter (Mozambique); Moma Heavy Minerals Smelter (Mozambique); Boguchansky Aluminium Plant (Russia); Xstrata Chrome CMI Plant (Lydenburg); SCAW Metals (Germiston).

Chemical Industry

Comprehensive air quality impact assessments have been completed for AECI (Pty) Ltd Operations (Modderfontein); Kynoch Fertilizer (Potchefstroom), Foskor (Richards Bay) and Omnia (Rustenburg).

Petrochemical Industry

Numerous air quality impact assessments have been completed for SASOL operations (Sasolburg); Sapref Refinery (Durban); Health risk assessment of Island View Tank Farm (Durban Harbour).

Pulp and Paper Industry

Air quality studies have been undertaken or the expansion of Mondi Richards Bay, Multi-Boiler Project for Mondi Merebank (Durban), impact assessments for Sappi Stanger, Sappi Enstra (Springs), Sappi Ngodwana (Nelspruit) and Pulp United (Richards Bay).

Power Generation

Air quality impact assessments have been completed for numerous Eskom coal fired power station studies including the Coal 3 Power Project near Lephalale, Komati Power Station and Lethabo Power Stations. In addition to Eskom's coal fired power stations, projects have been completed for the proposed Mmamabula Energy Project (Botswana); Morupule Power Plant (Botswana), NamPower Erongo Power Project (Namibia), NamPower Van Eck Power Station (Namibia) and NamPower Biomass Power Plant (Namibia).

Apart from Eskom projects, heavy fuel oil power station assessments have also been completed in Kenya (Rabai Power Station) and Namibia (Arandis Power Plant).

Green energy projects included several Solar Photovoltaic Projects (Mulilo and Enertrag South Africa (Pty) Ltd) and assessing potential particulate matter impacts from Wind Farms near the South African Large Telescope (SALT)

Waste Disposal

Air quality impact assessments, including odour and carcinogenic and non-carcinogenic pollutants were undertaken for the proposed Coega Waste Disposal Facility (Port Elizabeth); Boitshepi Waste Disposal Site (Vanderbijlpak); Umdloti Waste Water Treatment Plant (Durban).

Cement Manufacturing

Impact assessments for ambient air quality have been completed for the PPC Cement Alternative Fuels Project (which included the assessment of the cement manufacturing plants in the North West Province, Gauteng and Western).

Vehicle emissions

Transport Air quality Management Plan for the Gauteng Department of Roads and Transport (Feb 2012); Platinum Highway (N1 to Zeerust); Gauteng Development Zone (Johannesburg); Gauteng Department of Roads and Transport (Transport Air Quality Management Plan); Mauritius Road Development Agency (Proposed Road Decongestion Programme); South African Petroleum Industry Association (Impact Urban Air Quality).

Government and International Strategy Projects

Hanlie in one of the Lead Authors of Section 1.1: Africa's Development: Challenges, Drivers and key objectives, of the United Nations Environment Programme (UNEP), Climate and Clean Air Coalition (CCAC) and Stockholm Environment Institute (SEI) coordinated 'Integrated Assessment of Air Pollution and Climate Change for Africa Report. She was also the Terminal Reviewer of the UNEP/UNDA project "Air quality data for health and environment policies in Africa and the Asia-Pacific region"

(May 2020). Hanlie was also the project Director on the APPA Registration Certificate Review Project for Department of Environmental Affairs (DEA); Green Strategy for Gauteng (2011).

EDUCATION

Ph.D Geography	University of Johannesburg, RSA (2014) Title: *A functional dependence analysis of wind erosion modelling system parameters to determine a practical approach for wind erosion assessments*
M.Sc Geography and Environmental Management	University of Johannesburg, RSA (1999) Title: *Air Pollution Population Exposure Evaluation in the Vaal Triangle using GIS*
B.Sc Hons. Geography	University of Johannesburg, RSA (1995) GIS & Environmental Management
B.Sc Geography and Geology	University of Johannesburg, RSA (1994) Geography and Geology

ADDITIONAL COURSES AND ACADEMIC REVIEWS

External Examiner (February 2021)	PhD Candidate: Ms NM Walton Aerosol source apportionment in southern Africa Faculty of Natural and Agricultural Sciences, North-West University
External Examiner (May 2018)	MSc Candidate: Ms A Quta Characterisation of Particulate Matter and Some Pollutant Gasses in the City of Tshwane Department of Environmental Sciences, University of South Africa
External Examiner (December 2017)	MSc Candidate: Ms B Wernecke Ambient and Indoor Particulate Matter Concentrations on the Mpumalanga Highveld Faculty of Natural and Agricultural Sciences, North-West University
External Examiner (January 2016)	MSc Candidate: Ms M Grobler Evaluating the costs and benefits associated with the reduction in SO_2 emissions from Industrial activities on the Highveld of South Africa Department of Chemical Engineering, University of Pretoria
External Examiner (August 2014)	MSc Candidate: Ms Seneca Naidoo Quantification of emissions generated from domestic fuel burning activities from townships in Johannesburg Faculty of Science, University of the Witwatersrand
Air Quality Law– Lecturer (2012 - 2016)	Environmental Law course: Centre of Environmental Management.
Air Quality law for Mining – Lecturer (2014)	Environmental Law course: Centre of Environmental Management.
Air Quality Management – Lecturer (2006 -2012)	Air Quality Management Short Course: NACA and University of Johannesburg, University of Pretoria and University of the North-West.

ESRI SA (1999)	ARCINFO course at GIMS: Introduction to ARCINFO 7 course
ESRI SA (1998)	ARCVIEW course at GIMS: Advanced ARCVIEW 3.1 course

COUNTRIES OF WORK EXPERIENCE

South Africa, Mozambique, Botswana, Namibia, Malawi, Mauritius, Kenya, Mali, Zimbabwe, Democratic Republic of Congo, Tanzania, Zambia, Madagascar, Guinea, Russia, Mauritania, Morocco, and Saudi Arabia.

EMPLOYMENT RECORD

March 2003 - Present

Airshed Planning Professionals (Pty) Ltd, Managing Director and Principal Air Quality Scientist, Midrand, South Africa.

January 2000 – February 2003

Environmental Management Services CC, Senior Air Quality Scientist.

May 1998 – December 1999

Independent Broadcasting Authority (IBA), GIS Analyst and Demographer.

February 1997 – April 1998

GIS Business Solutions (PQ Africa), GIS Analyst

January 1996 – December 1996

Annegarn Environmental Research (AER), Student Researcher

LANGUAGES

	Speak	Read	Write
English	Excellent	Excellent	Excellent
Afrikaans	Excellent	Excellent	Excellent

CONFERENCE AND WORKSHOP PRESENTATIONS AND PAPERS

- Dust and radon levels on the west coast of Namibia – What did we learn? Hanlie Liebenberg-Enslin, Detlof von Oertzen, and Norwel Mwananawa. Atmospheric Pollution Research, 2020. https://doi.org/10.17159/caj/2020/30/1.8467
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CERTIFICATION

I, the undersigned, certify that to the best of my knowledge and belief, these data correctly describe me, my qualifications, and my experience.

AIRSHED

21 July 2021

Full name of staff member: Hanlie Liebenberg-Enslin

9 APPENDIX B – DECLARATION OF INDEPENDENCE

I, Hanlie Liebenberg-Enslin, as the appointed independent air quality specialist for the proposed Project, hereby declare that I:

- acted as the independent specialist in this Environmental Impact Assessment;
- performed the work relating to the application in an objective manner;
- regard the information contained in this report as it relates to my specialist input/study to be true and correct,
- do not have and will not have any financial interest in the undertaking of the activity, other than remuneration for work performed in terms of the Air Quality Impact Assessment;
- declare that there are no circumstances that may compromise my objectivity in performing such work;
- have expertise in conducting the specialist report relevant to this application;
- have no, and will not engage in, conflicting interests in the undertaking of the activity;
- have no vested interest in the proposed activity proceeding;
- undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing the decision of the competent authority; and
- all the particulars furnished by us in this specialist input/study are true and correct.

Signature of the specialist:

Name of Specialists: Hanlie Liebenberg-Enslin

Date: 18 September 2023

Environmental Noise Impact Assessment for the Proposed Gergarub Zinc Project Near Rosh Pinah in Namibia

Project done for **Environmental Compliance Consultancy**

Report compiled by:
Reneé von Gruenewaldt

Report No: 23ECC04GN | **Date:** October 2023

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Report Details

Report Title	Environmental Noise Impact Assessment for the Proposed Gergarub Zinc Project Near Rosh Pinah in Namibia
Client	Environmental Compliance Consultancy
Report Number	23ECC04GN
Report Version	Rev 1
Date	October 2023
Prepared by	Renee von Gruenewaldt, (Pr. Sci. Nat.), MSc (University of Pretoria)
Fieldwork conducted by	Jeffrey Moletsane, BSc (University of Pretoria), MSc (China)
Reviewed by	Gillian Petzer (Pr. Eng), BEng (Chem) (University of Pretoria)
Notice	Airshed Planning Professionals (Pty) Ltd is a consulting company located in Midrand, South Africa, specialising in all aspects of air quality and noise impacts, ranging from nearby neighbourhood concerns to regional impact assessments. The company originated in 1990 as Environmental Management Services, which amalgamated with its sister company, Matrix Environmental Consultants, in 2003.
Declaration	Airshed is an independent consulting firm with no interest in the project other than to fulfil the contract between the client and the consultant for delivery of specialised services as stipulated in the terms of reference.
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Revision Record

Version	Date	Comments
Rev 0	October 2023	For internal review
Rev 1	October 2023	For client review

Glossary and Abbreviations

Airshed	Airshed Planning Professionals (Pty) Ltd
BSI	British Standards Institution
dB	Descriptor that is used to indicate 10 times a logarithmic ratio of quantities that have the same units, in this case sound pressure.
dBA	Descriptor that is used to indicate 10 times a logarithmic ratio of quantities that have the same units, in this case sound pressure that has been A-weighted to simulate human hearing.
ECC	Environmental Compliance Consultancy
EHS	Environmental Health and Safety Standards
Hz	Frequency in Hertz
IEC	International Electrotechnical Commission
IFC	International Finance Corporation
ISO	International Standards Organisation
K1	Noise propagation correction for geometrical divergence
K2	Noise propagation correction for atmospheric absorption
K3	Noise propagation correction for the effect of ground surface;
K4	Noise propagation correction for reflection from surfaces
K5	Noise propagation correction for screening by obstacles
km	kilometer
L_{Aeq} (T)	The A-weighted equivalent sound pressure level, where T indicates the time over which the noise is averaged (calculated or measured) (in dBA)
L_{AIeq} (T)	The impulse corrected A-weighted equivalent sound pressure level, where T indicates the time over which the noise is averaged (calculated or measured) (in dBA)
L_{A90}	The A-weighted 90% statistical noise level, i.e., the noise level that is exceeded during 90% of the measurement period. It is a very useful descriptor which provides an indication of what the L_{Aeq} could have been in the absence of noisy single events and is considered representative of background noise levels (L_{A90}) (in dBA)
L_{AFmax}	The A-weighted maximum sound pressure level recorded during the measurement period
L_{AFmin}	The A-weighted minimum sound pressure level recorded during the measurement period
L_P	Sound pressure level (in dB)
Ltd	Limited
L_W	Sound Power Level (in dB)
m	meter
mamsl	Meters above mean sea level
MDRL	Minerals Deposit Retention Licence
m/s	Meters per second
NACA	National Association for Clean Air
NSRs	Noise sensitive receptors
p	Pressure in Pa
Pa	Pressure in Pascal

μPa	Pressure in micro-pascal
p_{ref}	Reference pressure, 20 μPa
Pty	Proprietary
SABS	South African Bureau of Standards
SACNASP	South African Council for Natural Scientific Professions
SANS	South African National Standards
SLM	Sound Level Meter
STRM	Shuttle Radar Topography Mission
USGS	United States Geological Survey
%	Percentage
°C	Degrees Celsius

Executive Summary

Airshed Planning Professionals (Pty) Ltd (Airshed) was commissioned by Environmental Compliance Consultancy (ECC) to undertake an environmental noise impact assessment for the Gergarub Zinc Project near Rosh Pinah in Namibia (hereafter referred to as the project).

The main objective of the noise specialist study was to determine the potential impact on the acoustic environment and noise sensitive receptors (NSRs) as a result of the proposed project and to recommend suitable management and mitigation measures.

To meet the above objective, the following tasks were included in the Scope of Work:

1. A review of available technical project information.
2. A review of the legal requirements and applicable environmental noise guidelines.
3. A study of the receiving (baseline) acoustic environment, including:
    a. The identification of NSRs from available maps and field observations;
    b. A study of environmental noise attenuation potential by referring to available weather records, land use and topography data sources; and
    c. Determining representative baseline noise levels through the analysis of sampled environmental noise levels obtained from surveys conducted for the site.
4. An impact assessment, including:
    a. The establishment of a source inventory for proposed activities.
    b. Noise propagation simulations to determine environmental noise levels as a result of the project.
    c. The screening of simulated noise levels against environmental noise criteria.
5. The identification and recommendation of suitable mitigation measures and monitoring requirements.
6. The preparation of a comprehensive specialist noise impact assessment report.

In the assessment of simulated noise levels, reference was made to the International Finance Corporation (IFC) noise level guidelines for industrial receptors (70 dBA for day- and night-time conditions).

The baseline acoustic environment was described in terms of the location of NSRs, the ability of the environment to attenuate noise over long distances, as well as existing background and baseline noise levels. The baseline noise levels were measured at six sites and were co-located with potential NSRs.

Noise emissions from mobile and non-mobile equipment were estimated using L_W predictions for industrial machinery (Bruce & Moritz, 1998), where L_W estimates are a function of the power rating of the equipment engine. Crushing and milling noise source L_W's for the project was obtained from a database for similar operations. Values from the database are based on source measurements carried out in accordance with the procedures specified in South African National Standards (SANS) 10103.

The source inventory, local meteorological conditions and information on local land use were used to populate the noise propagation model (CadnaA, ISO 9613).

Based on the findings of the assessment, IFC guidelines for off-site industrial NSRs were not exceeded. It is therefore the specialist's opinion that the project may be authorised.

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1 Introduction

Gergarub Exploration and Mining Company (Pty) Ltd is considering developing the Gergarub Zinc-Lead Project in Namibia with an objective of achieving 150,000 tonnes per year of metal-in-concentrate over the life of mine.

The Gergarub Project (hereafter referred to as the project) comprises the Minerals Deposit Retention Licence 2616 (MDRL 2616) which is located in southern Namibia, about 15 km north-northwest of Rosh Pinah town and 10 km east-southeast of Skorpion Zinc Mine. Gergarub is situated on the farm Spitskop 111, along the C13 road between Rosh Pinah and Aus, within the Karas Region, Oranjemund Constituency in Namibia as shown in Figure 1-1. The closest town to the deposit is Rosh Pinah, an un-proclaimed mining town the economy of which mainly revolves around the two nearby mines, Skorpion Zinc Mine and Rosh Pinah Zinc Mine.

Airshed Planning Professionals (Pty) Ltd (Airshed) was commissioned by Environmental Compliance Consultancy (ECC) to undertake an environmental noise impact assessment for the project.

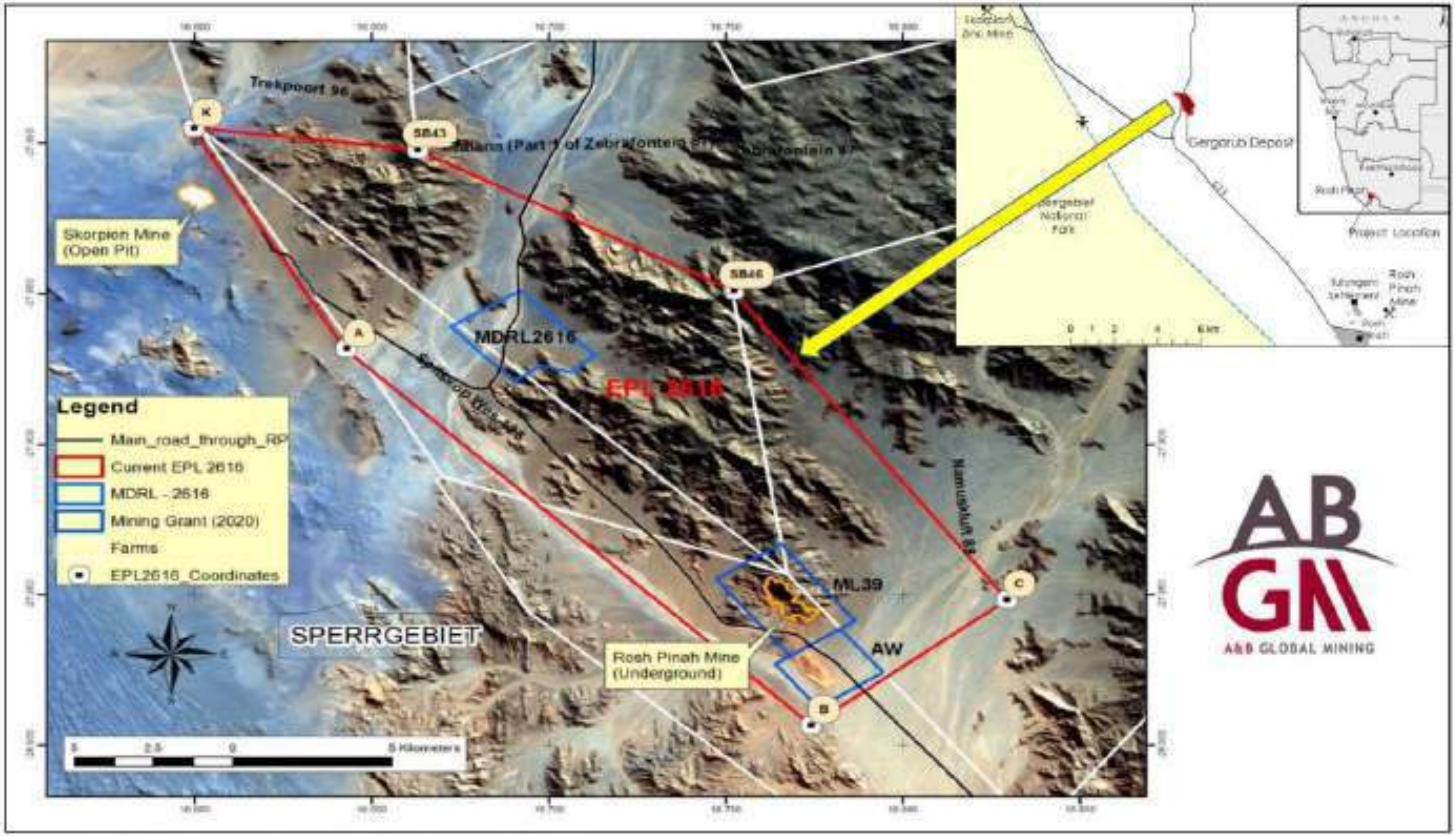
1.1 Study Objective

The main objective of the noise specialist study was to determine the potential impact on the acoustic environment and noise sensitive receptors (NSRs) as a result of the operations at the project site and to recommend suitable management and mitigation measures.

1.2 Scope of Work

To meet the above objective, the following tasks were included in the Scope of Work (SoW):

1. A review of available technical project information.
2. Review of the legal requirements and applicable environmental noise guidelines (if applicable).
3. Study of the receiving (baseline) noise environment based on:
    a. The identification of NSRs.
    b. Analysis of sampled baseline noise levels.
    c. Analysis of topographical data for the area.
4. The quantification and assessment of noise impacts, including:
    a. The establishment of a source inventory for proposed activities.
    b. Noise propagation simulations to determine environmental noise levels as a result of the project activities.
    c. The screening of simulated noise levels against environmental noise criteria.
5. The recommendations of suitable mitigation measures and monitoring requirements (if applicable).
6. The preparation of a comprehensive specialist noise impact assessment report.



Adapted from Enviro Dynamics 2014 & Speiser Environmental, 2019

Figure 1-1: Location of the Gergarub Project

1.3 Specialist Details

1.3.1 Specialist Details

Airshed is an independent consulting firm with no interest in the project other than to fulfil the contract between the client and the consultant for delivery of specialised services as stipulated in the terms of reference.

1.3.2 Competency Profile of Specialist

Reneé von Gruenewaldt is a Registered Professional Natural Scientist (Registration Number 400304/07) with the South African Council for Natural Scientific Professions (SACNASP) and a member of the National Association for Clean Air (NACA).

Following the completion of her bachelor's degree in atmospheric sciences in 2000 and honours degree (with distinction) with specialisation in Environmental Analysis and Management in 2001 at the University of Pretoria, her experience in air pollution started when she joined Environmental Management Services (now Airshed Planning Professionals) in 2002. Reneé von Gruenewaldt later completed her master's degree (with distinction) in Meteorology at the University of Pretoria in 2009.

Reneé von Gruenewaldt became a partner of Airshed Planning Professionals in September 2006. Airshed Planning Professionals is a technical and scientific consultancy providing scientific, engineering, and strategic impact assessments and management services and policy support to assist clients in addressing a wide variety of air pollution and environmental noise related assessments.

She has experience on the various components of environmental noise assessments from 2015 to present. Her project experience range over various countries in Africa, providing her with an inclusive knowledge base of international legislation and requirements pertaining to noise impacts.

A comprehensive curriculum vitae of Reneé von Gruenewaldt is provided in Appendix A.

1.4 Description of Activities from a Noise Perspective

Sources of noise at the project site will include the following:

- Ore and waste handling (loading, unloading) on waste dumps and crusher/plant area;
- Haul truck traffic;
- Diesel mobile equipment use (including reverse warnings); and,
- Ore processing activities such as crushing, screening and milling.

Whereas ore processing activities generate noise fairly constantly; ore and waste handling, transport activities and operating diesel mobile equipment generate noise that is intermittent and highly variable spatially.

The biggest determinant of noise impacts from operations will be the spatial distribution of noise sources and to a lesser extent mining rates and fleet size due to the non-linear cumulative nature of sound pressure levels (see Section 1.5.3).

1.5 Background to Environmental Noise and the Assessment Thereof

Before more details regarding the approach and methodology adopted in the assessment is given, the reader is provided with some background, definitions and conventions used in the measurement, calculation, and assessment of environmental noise.

Noise is generally defined as unwanted sound transmitted through a compressible medium such as air. Sound in turn, is defined as any pressure variation that the ear can detect. Human response to noise is complex and highly variable as it is subjective rather than objective.

A direct application of linear scales (in pascal (Pa)) to the measurement and calculation of sound pressure leads to large and unwieldy numbers. As the ear responds logarithmically rather than linearly to stimuli, it is more practical to express acoustic parameters as a logarithmic ratio of the measured value to a reference value. This logarithmic ratio is called a decibel or dB. The advantage of using dB can be clearly seen in Figure 1-2. Here, the linear scale with its large numbers is converted into a manageable scale from 0 dB at the threshold of hearing (20 micro-pascals (µPa)) to 130 dB at the threshold of pain (~100 Pa) (Brüel & Kjær Sound & Vibration Measurement A/S, 2000).

As explained, noise is reported in dB. "dB" is the descriptor that is used to indicate 10 times a logarithmic ratio of quantities that have the same units, in this case sound pressure. The relationship between sound pressure and sound pressure level is illustrated in this equation.

$$L_p = 20 \cdot \log_{10}\left(\frac{p}{p_{ref}}\right)$$

Where:

L_p *is the sound pressure level in dB;*
p *is the actual sound pressure in Pa; and*
p_{ref} *is the reference sound pressure (p_{ref} in air is 20 µPa).*

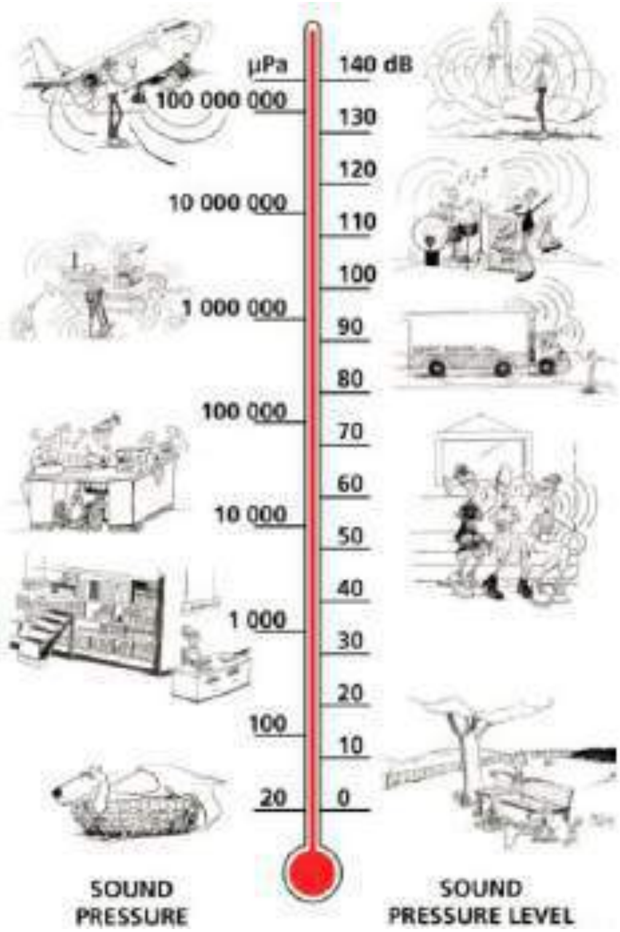


Figure 1-2: The decibel scale and typical noise levels (Brüel & Kjær Sound & Vibration Measurement A/S, 2000)

1.5.1 Perception of Sound

Sound has already been defined as any pressure variation that can be detected by the human ear. The number of pressure variations per second is referred to as the frequency of sound and is measured in hertz (Hz). The hearing frequency of a young, healthy person ranges between 20 Hz and 20 000 Hz.

In terms of L_P, audible sound ranges from the threshold of hearing at 0 dB to the pain threshold of 130 dB and above. Even though an increase 6 dB represents a doubling in sound pressure, an increase of 8 to 10 dB is required before the sound subjectively appears to be significantly louder. Similarly, the smallest perceptible change is about 1 dB (Brüel & Kjær Sound & Vibration Measurement A/S, 2000).

1.5.2 Frequency Weighting

Since human hearing is not equally sensitive to all frequencies, a 'filter' has been developed to simulate human hearing. The 'A-weighting' filter simulates the human hearing characteristic, which is less sensitive to sounds at low frequencies than at high frequencies (Figure 1-3). "dBA" is the descriptor that is used to indicate 10 times a logarithmic ratio of quantities that have the same units (in this case sound pressure) and have been A-weighted.

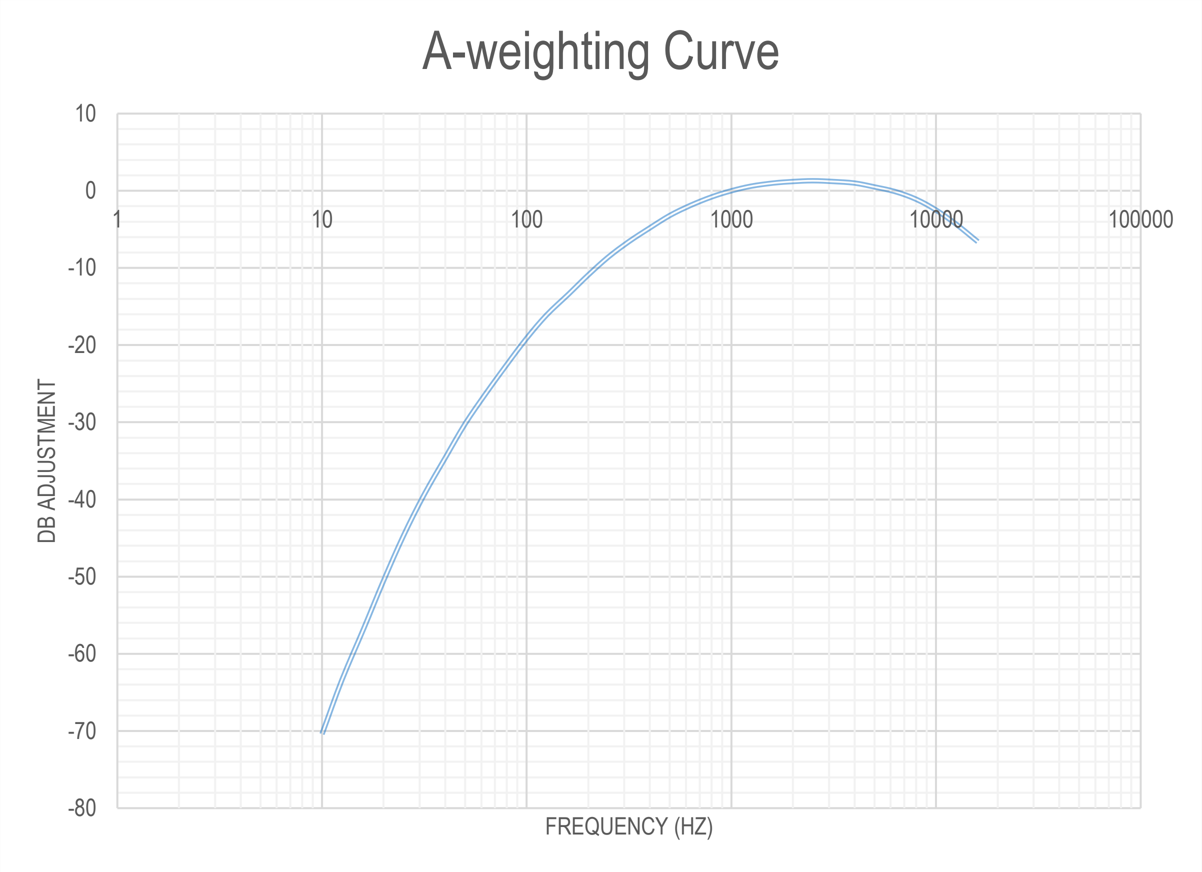


Figure 1-3: A-weighting curve

1.5.3 Adding Sound Pressure Levels

Since sound pressure levels are logarithmic values, the sound pressure levels as a result of two or more sources cannot simply be added together. To obtain the combined sound pressure level of a combination of sources such as those at an industrial plant, individual sound pressure levels must be converted to their linear values and added using:

$$L_{p\_combined} = 10 \cdot \log\left(10^{\frac{L_{p1}}{10}} + 10^{\frac{L_{p2}}{10}} + 10^{\frac{L_{p3}}{10}} + \cdots 10^{\frac{L_{pi}}{10}}\right)$$

This implies that if the difference between the sound pressure levels of two sources is nil the combined sound pressure level is 3 dB more than the sound pressure level of one source alone. Similarly, if the difference between the sound pressure levels of two sources is more than 10 dB, the contribution of the quietest source can be disregarded (Brüel & Kjær Sound & Vibration Measurement A/S, 2000).

1.5.4 Environmental Noise Propagation

Many factors affect the propagation of noise from source to receiver. The most important of these are:

- The type of source and its sound power (L_W);
- The distance between the source and the receiver;
- Atmospheric conditions (wind speed and direction, temperature and temperature gradient, humidity etc.);
- Obstacles such as barriers or buildings between the source and receiver;
- Ground absorption; and
- Reflections.

To arrive at a representative result from either measurement or calculation, all these factors must be taken into account (Brüel & Kjær Sound & Vibration Measurement A/S, 2000).

1.5.5 Environmental Noise Indices

In assessing environmental noise either by measurement or calculation, reference is made to the following indices:

- **L_{Aeq} (T)** – The A-weighted equivalent sound pressure level, where T indicates the time over which the noise is averaged (calculated or measured).
- **L_{AIeq} (T)** – The impulse corrected A-weighted equivalent sound pressure level, where T indicates the time over which the noise is averaged (calculated or measured). In the South African Bureau of Standards' (SABS) South African National Standard (SANS) 10103 of 2008 for *'The measurement and rating of environmental noise with respect to annoyance and to speech communication'* prescribes the sampling of L_{AIeq} (T).
- **L_{A90}** – The A-weighted 90% statistical noise level, i.e., the noise level that is exceeded during 90% of the measurement period. It is a very useful descriptor which provides an indication of what the L_{Aeq} could have been in the absence of noisy single events and is considered representative of background noise levels.
- **L_{AFmax}** – The maximum A-weighted noise level measured with the fast time weighting. It's the highest level of noise that occurred during a sampling period.
- **L_{AFmin}** – The minimum A-weighted noise level measured with the fast time weighting. It's the lowest level of noise that occurred during a sampling period.

1.6 Approach and Methodology

The assessment included a study of the legal requirements pertaining to environmental noise impacts, a study of the physical environment of the area surrounding the project and the analyses of existing noise levels in the area. The impact assessment focused on the estimation of sound power levels (L_W's) (noise 'emissions') and sound pressure levels (L_P's) (noise impacts) associated with the operational phase. The findings of the assessment components informed recommendations of management measures, including mitigation and monitoring. Individual aspects of the noise impact assessment methodology are discussed in more detail below.

1.6.1 Information Review

An information requirements list was sent to ECC at the onset of the project. In response to the request, the following information was supplied:

- Georeferenced project layout;
- Process description; and,
- Mining information with specification on the ventilation needs.

1.6.2 Review of Assessment Criteria

In the absence of local guidelines and standards, this study refers to noise level guidelines published by the International Finance Corporation (IFC) in their '*General Environmental, Health, and Safety (EHS) Guidelines'* (IFC, 2007).

1.6.3 Study of the Receiving Environment

NSRs generally include private residences, community buildings such as schools, hospitals and any publicly accessible areas.

The ability of the environment to attenuate noise as it travels through the air was studied by considering land use and terrain.

Readily available terrain data was obtained from the United States Geological Survey (USGS) web site (https://earthexplorer.usgs.gov/) accessed in October 2023. A study was made of Shuttle Radar Topography Mission (STRM) 1 arc-sec data.

1.6.4 Noise Survey

The extent of noise impacts as a result of an intruding noise depends largely on existing noise levels in an area. Higher ambient noise levels will result in less noticeable noise impacts and a smaller impact area. The opposite also holds true. Increases in noise will be more noticeable in areas with low ambient noise levels. The data from a baseline noise survey conducted on the 2nd and 3rd October 2023 was studied to determine current noise levels within the area.

The survey methodology, which closely followed guidance provided by the IFC (2007) and SANS 10103 (2008), is summarised below:

- The survey was conducted by a trained Airshed specialist and accompanied by an ECC staff member.
- Sampling was carried out using a Type 1 sound level meter (SLM) that meet all appropriate International Electrotechnical Commission (IEC) standards and is subject to calibration by an accredited laboratory (Appendix C). Equipment details are included in Table 1-1.

- The acoustic sensitivity of the SLM was tested with a portable acoustic calibrator before and after each sampling session.
- Samples representative and sufficient for statistical analysis were taken with the use of the portable SLM capable of logging data continuously over the sampling time period.
- L_{AIeq} (T), L_{Aeq} (T); L_{AFmax}; L_{AFmin}; L_{90} and octave frequency spectra were recorded.
- The SLM was located approximately 1.5 m above the ground and no closer than 3 m to any reflecting surface.
- SANS 10103 states that one must ensure (as far as possible) that the measurements are not affected by the residual noise and extraneous influences, e.g., wind, electrical interference and any other non-acoustic interference, and that the instrument is operated under the conditions specified by the manufacturer.
- A detailed log and record were kept. Records included site details, weather conditions during sampling and observations made regarding the acoustic environment of each site.

Table 1-1: Sound level meter details

Equipment	Serial Number	Purpose	Last Calibration Date
Svantek 977 sound level meter	S/N 36183	Noise sampling	14 March 2023
Svantek 7052E ½" microphone	S/N 78692		
Svantek SV 12L ½" pre-amplifier	S/N 40659		
SVANTEK SV33 Class 1 Acoustic Calibrator	S/N 43170	Testing of the acoustic sensitivity before and after each daily sampling session.	14 March 2023
Kestrel 4000 Pocket Weather Tracker	S/N 559432	Determining wind speed, temperature and humidity during sampling.	Not Applicable

1.6.5 Source Inventory

To determine the change in noise impacts associated with the project, a source inventory had to be developed. Information on the sources were provided in conceptual mining documents and ventilation studies. L_W's for these noise sources were calculated using predictive equations for industrial machinery as per the Handbook of Acoustics, Chapter 69, by Bruce and Moritz (1998).

Milling and crushing noise source L_W's for operations at the project plant was obtained from a database for similar operations. Values from the database are based on source measurements carried out in accordance with the procedures specified in SANS 10103.

Estimates of road traffic were made given mining rates and assumed vehicle speeds and road conditions.

1.6.6 Noise Propagation Simulations

1.6.6.1 ISO 9613

The propagation of noise from proposed activities was simulated with the DataKustic CadnaA software. Use was made of the International Organisation for Standardization's (ISO) 9613 module for outdoor noise propagation from industrial noise sources.

ISO 9613 specifies an engineering method for calculating the attenuation of sound during propagation to predict the levels of environmental noise at a distance from a variety of sources. The method predicts the equivalent continuous A-weighted sound pressure level under meteorological conditions favourable to propagation from sources of known sound emission. These conditions are for downwind propagation or, equivalently, propagation under a well-developed moderate ground-based temperature inversion, such as commonly occurs at night.

The method also predicts an average A-weighted sound pressure level. The average A-weighted sound pressure level encompasses levels for a wide variety of meteorological conditions. The method specified in ISO 9613 consists specifically of octave-band algorithms (with nominal mid-band frequencies from 63 Hz to 8 kHz) for calculating the attenuation of sound which originates from a point sound source, or an assembly of point sources. The source (or sources) may be moving or stationary. Specific terms are provided in the algorithms for the following physical effects: geometrical divergence, atmospheric absorption, ground surface effects, reflection and obstacles. A basic representation of the model is given in the equation below:

$$L_P = L_W - \sum [K_1, K_2, K_3, K_4, K_5, K_6]$$

Where;

L_P *is the sound pressure level at the receiver;*

L_W *is the sound power level of the source;*

K_1 *is the correction for geometrical divergence;*

K_2 *is the correction for atmospheric absorption;*

K_3 *is the correction for the effect of ground surface;*

K_4 *is the correction for reflection from surfaces; and*

K_5 *is the correction for screening by obstacles.*

This method is applicable in practice to a great variety of noise sources and environments. It is applicable, directly or indirectly, to most situations concerning road or rail traffic, industrial noise sources, construction activities, and many other ground-based noise sources.

To apply the method of ISO 9613, several parameters need to be known with respect to the geometry of the source and of the environment, the ground surface characteristics, and the source strength in terms of octave-band sound power levels for directions relevant to the propagation.

1.6.6.2 Simulation Domain

If the dimensions of a noise source are small compared with the distance to the listener, it is called a point source. All sources were quantified as point sources or areas/lines represented by point sources. The sound energy from a point source spreads out spherically, so that the sound pressure level is the same for all points at the same distance from the source and decreases by 6 dB per doubling of distance. This holds true until ground and air attenuation noticeably affect the level. The impact of an intruding industrial noise on the environment will therefore rarely extend over more than 5 km from the source and is therefore always considered "local" in extent.

The propagation of noise was calculated over an area of 8.4 km east-west by 7.4 km north-south and encompasses the project. The area was divided into a grid matrix with a 20 m resolution. NSRs and survey locations were included as discrete receptors. The model was set to calculate L_P's at each grid and discrete receptor point at a height of 1.5 m above ground level.

1.6.7 Presentation of Results

Results are presented in tabular and isopleth form. An isopleth is a line on a map connecting points at which a given variable (in this case sound pressure, L_P) has a specified constant value. This is analogous to contour lines on a map showing terrain elevation. In the assessment of environmental noise, isopleths present lines of constant noise level as a function of distance.

Simulated noise levels were assessed according to guidelines published by the IFC.

1.6.8 Recommendations of Management and Mitigation

The findings of the noise specialist study informed the recommendation of suitable noise management and mitigation measures.

1.7 Management of Uncertainties

The following limitations and assumptions should be noted:

- Estimates of road traffic were made with the provided material throughputs and haul truck capacities. The vehicle speeds and road conditions were assumed. Trucks were assumed to travel at 40 km/h on site.
- The mitigating effect of pit walls, buildings, and infrastructure acting as acoustic barriers were not taken into account providing a conservative assessment of the noise impacts off-site.
- Given the topographical features within the study area, it is expected that the site will be influenced by topographically induced flow patterns. As no on-site meteorological data was available, and the closest meteorological stations (i.e., at Skorpion Zinc Mine and Rosh Pinah) are not likely to represent the local flow field at the project site, the attenuation modelling was conservatively undertaken assuming equal distribution of wind in all directions to assess the maximum noise impact from the project in all directions.

- The quantification of sources of noise was limited to the operational phase of the project. Construction and closure phase activities are expected to be similar or less significant. Noise impacts will cease post-closure.
- All activities were assumed to be 24 hours per day, 7 days per week.
- Although other existing sources of noise within the area were identified, such sources were not quantified but were taken into account during the survey.
- Blast vibration and noise did not form part of the scope of work of this assessment.
- The environmental noise assessment focuses on the evaluation of impacts for humans.
- The baseline noise levels as surveyed in October 2023 were assumed to be representative of current baseline noise levels.

2 Legal Requirements and Noise Level Guidelines

The IFC best practice guidelines were adopted in the absence of Namibian legislation.

2.1 International Finance Corporation Guidelines on Environmental Noise

The IFC General Environmental Health and Safety Guidelines on noise address impacts of noise beyond the property boundary of the facility under consideration and provides noise level guidelines.

The IFC states that noise impacts **should not exceed the levels presented in Table 2-1**, or result in a maximum **increase above background levels of 3 dBA** at the nearest receptor location off-site (IFC, 2007). For a person with average hearing acuity an increase of less than 3 dBA in the general ambient noise level is not detectable. Δ = 3 dBA is, therefore, a useful significance indicator for a noise impact.

It is further important to note that the IFC noise level guidelines for residential, institutional and educational receptors correspond with the SANS 10103 guidelines for urban districts.

Table 2-1: IFC noise level guidelines

Area	One Hour L_{Aeq} (dBA) 07:00 to 22:00	One Hour L_{Aeq} (dBA) 22:00 to 07:00
Industrial receptors	70	70
Residential, institutional and educational receptors	55	45

3 Description of the Receiving Environment

This chapter provides details of the receiving acoustic environment which is described in terms of:

- Local NSRs;
- The local environmental noise propagation and attenuation potential; and
- Current noise levels and the existing acoustic climate.

3.1 Noise Sensitive Receptors

Noise sensitive receptors generally include places of residence and areas where members of the public may be affected by noise generated by mining, processing and transport activities.

Potential noise sensitive receptors within the study area include industrial sites (Figure 3-1), with the closest residential area (Rosh Pinah) ~12 km southeast of the project. The description of the potential NSRs is provided in Table 3-1.

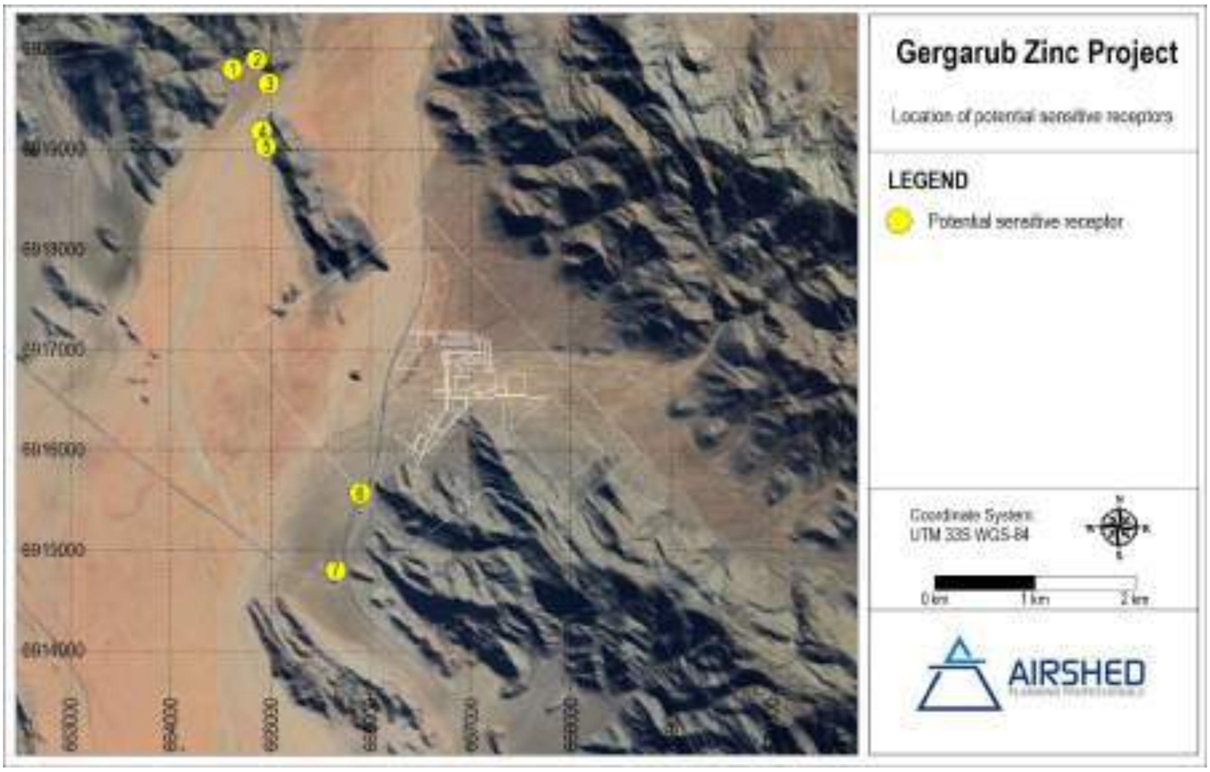


Figure 3-1: Potential noise sensitive receptors within the study area

Table 3-1: Description of noise sensitive receptors within the study area

Receptor	Description	Industrial/ Residential
1	Building structure	Appears to be industrial
2	Building structure	Appears to be industrial
3	Building structure	Appears to be industrial
4	Old storage facility for scrap metals	Industrial
5	Old storage facility for scrap metals	Industrial
6	Road authority building (where trucks stop for inspection)	Industrial
7	Skorpion Zinc mine gate	Industrial

3.2 Environmental Noise Propagation and Attenuation potential

3.2.1 Atmospheric Absorption and Meteorology

Atmospheric absorption and meteorological conditions have already been mentioned with regards to their role in the propagation on noise from a source to receiver (Section 1.5.4). The main meteorological parameters affecting the propagation of noise include wind speed, wind direction and temperature. These along with other parameters such as relative humidity, air pressure, solar radiation and cloud cover affect the stability of the atmosphere and the ability of the atmosphere to absorb sound energy.

Wind speed increases with altitude. This results in the 'bending' of the path of sound to 'focus' it on the downwind side and creating a 'shadow' on the upwind side of the source. Depending on the wind speed, the downwind level may increase by a few dB but the upwind level can drop by more than 20 dB (Brüel & Kjær Sound & Vibration Measurement A/S, 2000). It should be noted that at wind speeds of more than 5 m/s, ambient noise levels are mostly dominated by wind generated noise.

Temperature gradients in the atmosphere create effects that are uniform in all directions from a source. On a sunny day with no wind, temperature decreases with altitude and creates a 'shadowing' effect for sounds. On a clear night, temperatures may increase with altitude thereby 'focusing' sound on the ground surface. Noise impacts are therefore generally more notable during the night (Figure 3-2). An average temperature of 20°C and relative humidity of 54%, as obtained from Meteoblue data for the period January 2018 to October 2023, was used in the attenuation modelling.

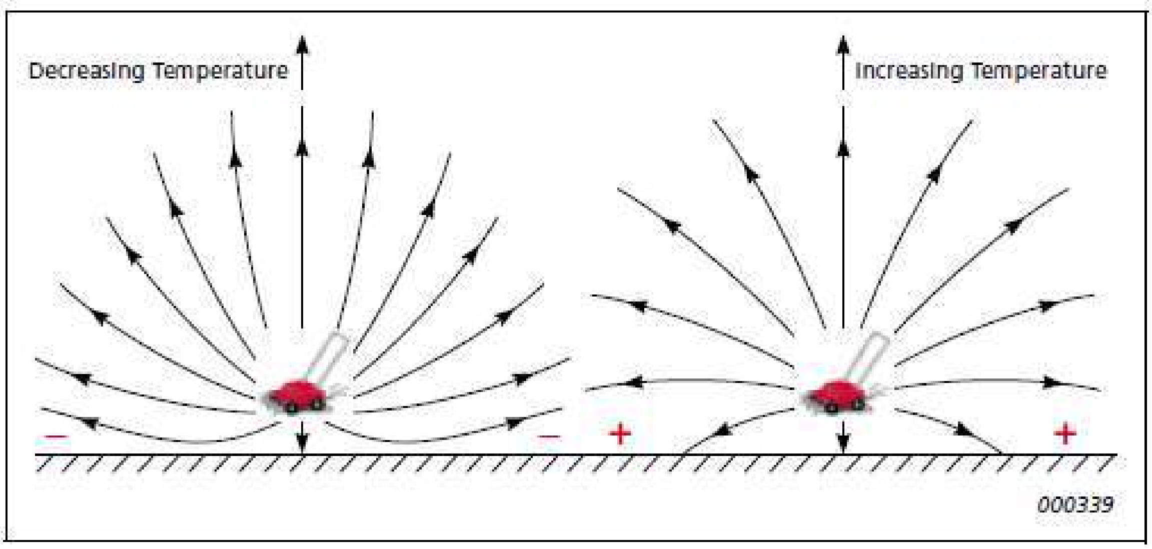


Figure 3-2: Bending the path of sound during typical day time conditions (image provided on the left) and night-time conditions (image provided on the right)

3.2.2 Terrain, Ground Absorption and Reflection

Noise reduction caused by a barrier (i.e. natural terrain, installed acoustic barrier, building) feature depends on two factors namely: the path difference of a sound wave as it travels over the barrier compared with direct transmission to the receiver and the frequency content of the noise (Brüel & Kjær Sound & Vibration Measurement A/S, 2000). Readily available terrain data was obtained from the USGS web site (https://earthexplorer.usgs.gov/) accessed in October 2023. A study was made of STRM 1 arc-sec data (Figure 3-3).

Sound reflected by the ground interferes with the directly propagated sound. The effect of the ground is different for acoustically hard (e.g., concrete or water), soft (e.g., grass, trees or vegetation) and mixed surfaces. Ground attenuation is often calculated in frequency bands to take into account the frequency content of the noise source and the type of ground between the source and the receiver (Brüel & Kjær Sound & Vibration Measurement A/S, 2000). Based on observations, ground cover was found to be acoustically mixed.

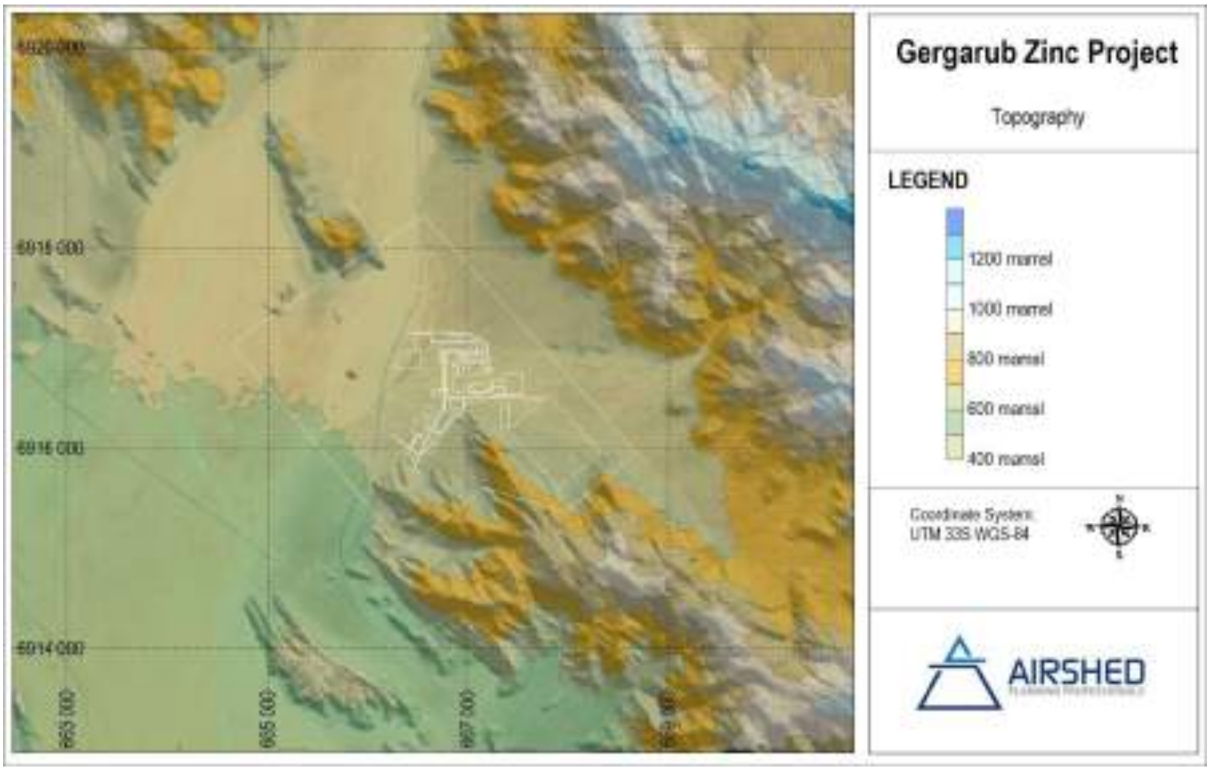


Figure 3-3: Topography for the study area

3.3 Survey Results

Survey sites were selected after careful consideration of future activities, accessibility, potential noise sensitive receptors, and safety restrictions. A total of six survey sites were selected. The location of the noise survey sites is provided in **Error! Reference source not found.**. Photographs of the sites are included in Appendix E.

Survey results for the campaign undertaken on the 2nd and 3rd of October 2023 are summarised in Table 3-2 and for comparison purposes, visually presented in Figure 3-5 (day-time results) and Figure 3-6 (night-time results).

For detailed time-series, frequency spectra and statistical results, the reader is referred to Appendix D.

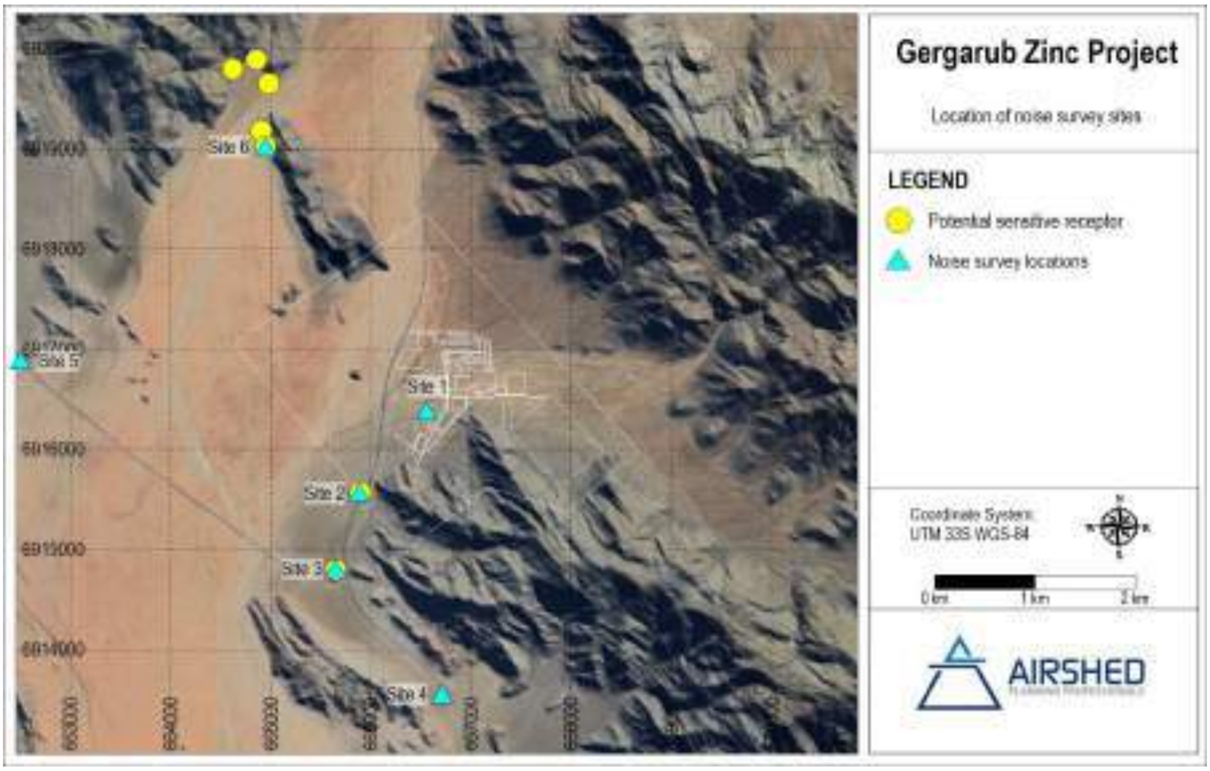


Figure 3-4: Location of the noise survey sites for the survey conducted on the 2nd and 3rd of October 2023

Table 3-2: Project baseline environmental noise survey results summary

Sampling point	Visual and acoustic observations	General weather conditions	Time of day	Start date and time	Duration	L_{AFmax} (dBA)	L_{AFmin} (dBA)	L_{Aleq} (dBA)	L_{A90} (dBA)	L_{Aeq} (dBA)[(a)]
Site 1	Survey site located ~400 m from C13 road within a drilling area (no activities were taking place during measurements). Noise sources include birds and vehicle traffic.	Winds of 3.8 m/s (SW); 36°C; 17% humidity; no cloud cover	Day	2023/10/02 12:00	00:21:02	56.8	23.4	57.5	26.3	35.9
		Winds of 0.6 m/s (N); 19°C; 59% humidity; no cloud cover	Night	2023/10/02 23:19	00:20:33	62.8	17.8	66.8	20.0	35.3
Site 2	Survey site was at the road authority building (where trucks stop for inspection) located ~10 m from C13 road. Noise sources include birds and vehicle traffic.	Winds of 4.3 m/s (SW); 34°C; 15% humidity; no cloud cover	Day	2023/10/02 11:08	00:19:56	80.2	27.1	65.2	31.6	58.5
		Winds of 1.1 m/s (N); 18°C; 60% humidity; no cloud cover	Night	2023/10/02 23:53	00:20:36	55.0	20.1	51.3	21.5	31.5
Site 3	Survey site was located at the Skorpion Zinc mine gate. Noise sources include birds, insects and vehicle traffic.	Winds of 3.8 m/s (SW); 27°C; 33% humidity; no cloud cover	Day	2023/10/02 10:30	00:20:23	71.0	30.6	52.4	35.0	48.0
		No wind; 21°C; 58% humidity; no cloud cover	Night	2023/10/03 00:22	00:20:56	69.3	22.2	50.5	23.5	49.3
Site 4	Survey site was located in an open area with stoney surfaces and shrubs. Noise sources include birds, insects and vehicle traffic.	Winds of 1 m/s (SW); 24°C; 39% humidity; no cloud cover	Day	2023/10/02 08:51	00:20:43	82.2	23.0	51.0	26.4	56.7
		Winds of 0.5 m/s (N); 19°C; 59% humidity; no cloud cover	Night	2023/10/03 00:52	00:20:25	84.7	19.8	55.1	21.8	56.1
Site 5	Survey site was located in an open area with airstrip to the west and ~150 m from the main mine road. Noise sources include birds and insects.	Winds of 4 m/s (SW); 35°C; 20% humidity; no cloud cover	Day	2023/10/02 12:57	00:21:00	63.5	24.5	53.4	27.9	40.5
		No wind; 20°C; 45% humidity; no cloud cover	Night	2023/10/02 22:01	00:21:33	61.0	27.4	52.1	30.1	37.7
Site 6	Survey site was located in an open area near an old storage facility for scrap metals. Noise sources include birds.	Winds of 4 m/s (SW); 39°C; 12% humidity; no cloud cover	Day	2023/10/02 13:45	00:20:59	56.3	22.6	56.5	24.5	36.5
		No wind; 29°C; 53% humidity; no cloud cover	Night	2023/10/02 22:36	00:20:43	58.0	17.8	51.1	19.7	25.4

(a) LAeq is used to assess incremental increase due to project activities.

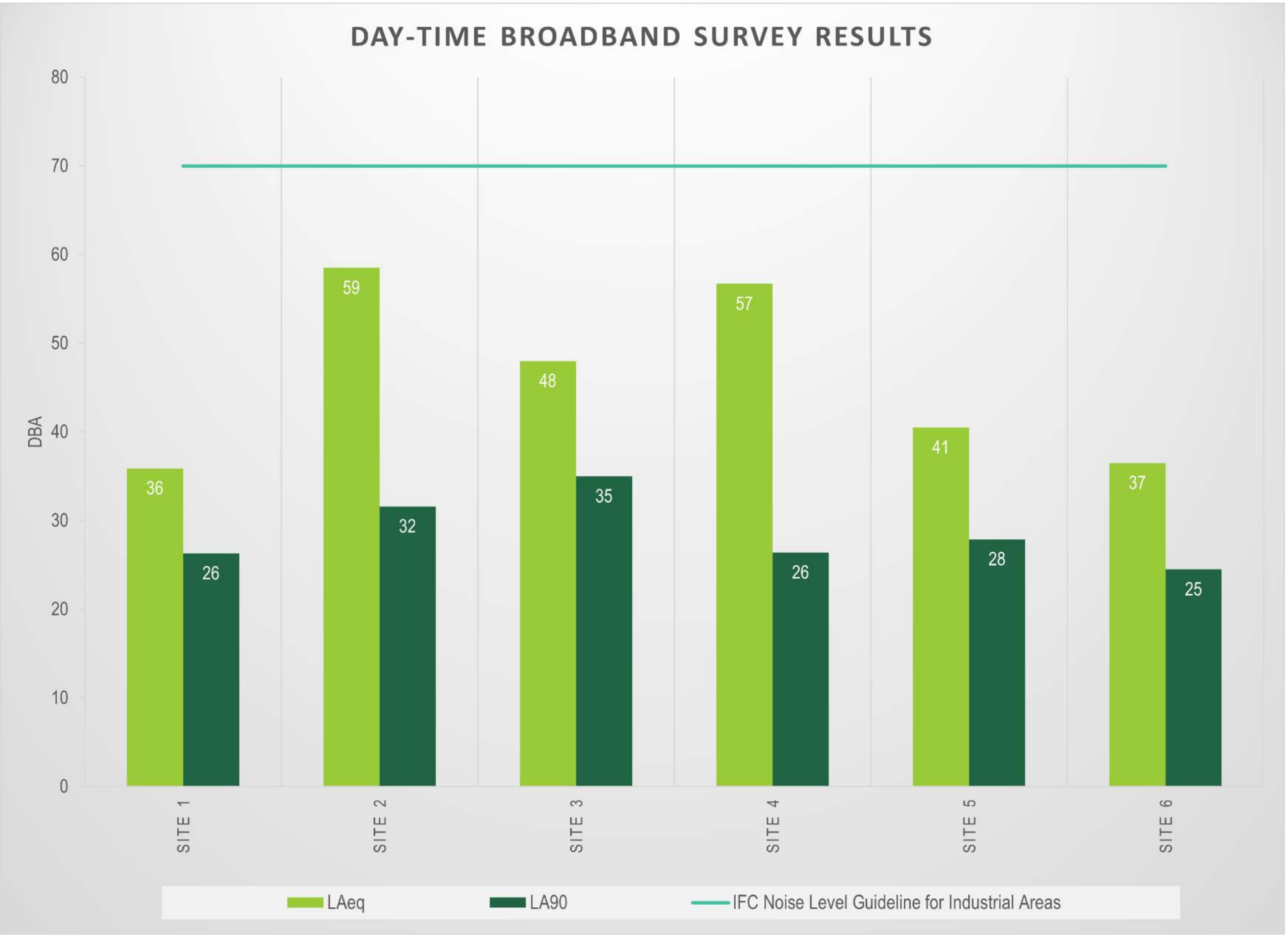


Figure 3-5: Day-time broadband survey results

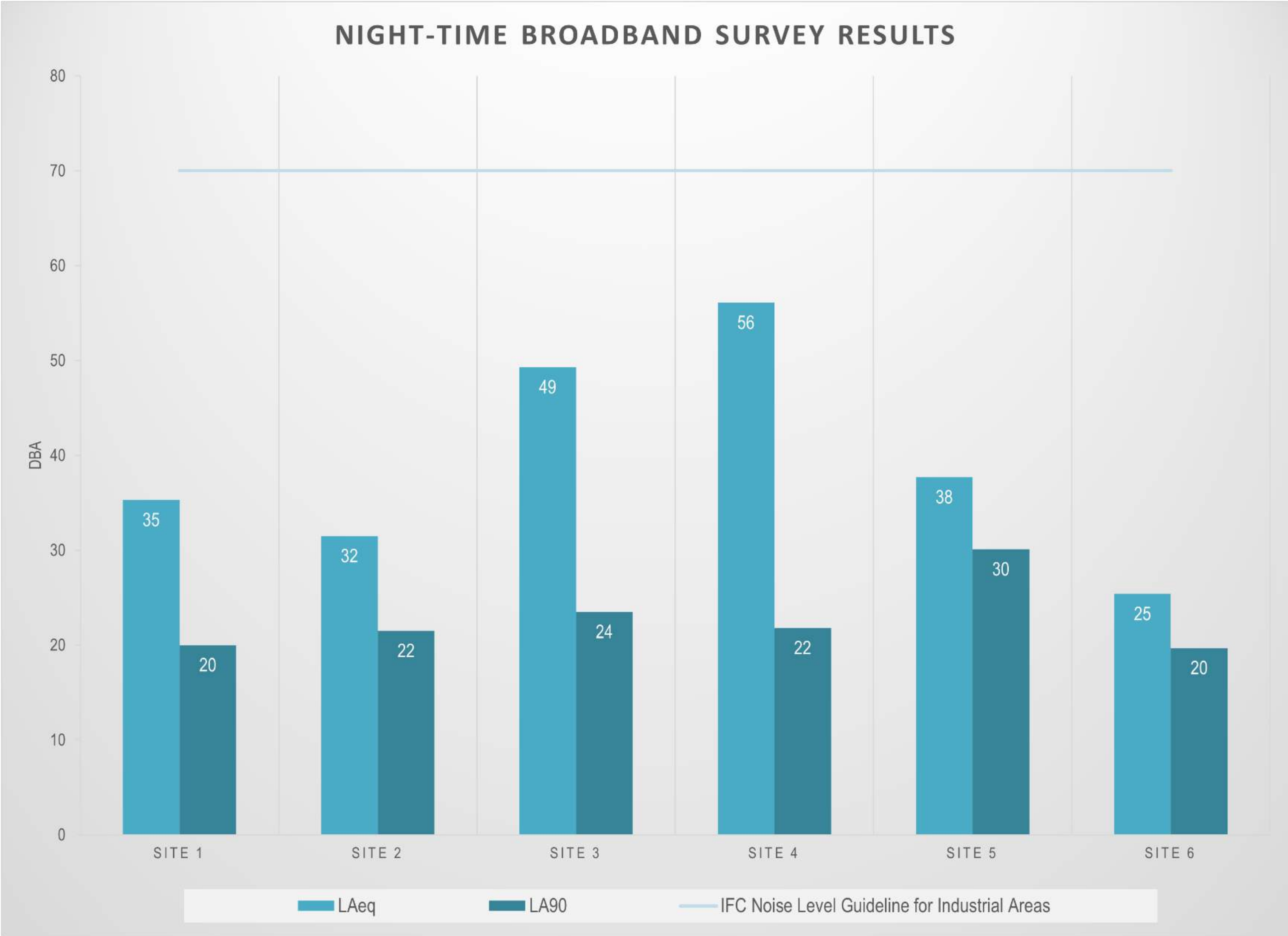


Figure 3-6: Night-time broadband survey results

4 Impact Assessment

The noise source inventory, noise propagation modelling and results are discussed in Section 4.1 and Section 4.2 respectively.

4.1 Noise Sources and Sound Power Levels

Haul truck traffic movement was calculated using the mining rates and truck capacities (Table 4-1). The attenuation modelling of this source was undertaken assuming a speed of 40 km/hr.

The vent parameters used in this assessment is provided in Table 4-2.

Octave band frequency spectra L_W's for the project noise sources are included in Table 4-3. The frequency spectra were determined for the source term (total dBA) based on measured databases for similar equipment or from calculations.

The reader is reminded of the non-linearity in the addition of L_W's. If the difference between the sound power levels of two sources is nil the combined sound power level is 3 dB more than the sound pressure level of one source alone. Similarly, if the difference between the sound power levels of two sources is more than 10 dB, the contribution of the quietest source can be disregarded (Brüel & Kjær Sound & Vibration Measurement A/S, 2000). Therefore, although some sources of noise could not be quantified (e.g., light vehicle movements, etc.), the incremental contributions of such sources are expected to be minimal given that the majority of sources are considered in the source inventory.

Table 4-1: Truck trips calculated for the assessment

Production (tpm)	Truck capacity (t)	Trips per month	Trips per day	Trips per hour
75000	41	1829.27	60.98	2.54

Table 4-2: Vent parameters used for the assessment

Area	Velocity (m/s)	Diameter (m)	Height (m)[(a)]
Upcast shaft	20	5.5	10
Downcast Shaft	18	5	5

(a) Assumed based on drawing provided

Table 4-3: Octave band frequency spectra L_W's for the project

Plant Section	Equipment	Type	L_W octave band frequency spectra (dB)								L_W (dB)	L_{WA} (dBA)	Source
			63	125	250	500	1000	2000	4000	8000			
Fan Station (main fan)	Axial Fan (1)	L_W	123.1	124.1	125.1	125.1	125.1	123.1	119.1	118.1	132.5	129.8	L_W Predictions (Bruce & Moritz, 1998)
	Fan Motor (1)	L_W	90	92	93	93	96	96	88	81	101.8	100.6	L_W Predictions (Bruce & Moritz, 1998)
	Axial Fan (2)	L_W	123.1	124.1	125.1	125.1	125.1	123.1	119.1	118.1	132.5	129.8	L_W Predictions (Bruce & Moritz, 1998)
	Fan Motor (2)	L_W	90	92	93	93	96	96	88	81	101.8	100.6	L_W Predictions (Bruce & Moritz, 1998)
Secondary Ventilation	Fan (1)	L_W	98.1	100.1	99.1	98.1	98.1	94.1	90.1	83.1	106.2	102.0	L_W Predictions (Bruce & Moritz, 1998)
	Fan (2)	L_W	98.1	100.1	99.1	98.1	98.1	94.1	90.1	83.1	106.2	102.0	L_W Predictions (Bruce & Moritz, 1998)
	Fan Motor (1)	L_W	81.1	84.1	86.1	89.1	89.1	88.1	83.1	75.1	95.2	93.8	L_W Predictions (Bruce & Moritz, 1998)
	Fan Motor (2)	L_W	81.1	84.1	86.1	89.1	89.1	88.1	83.1	75.1	95.2	93.8	L_W Predictions (Bruce & Moritz, 1998)
Trucks	B45D	L_W	113.7	118.7	121.7	116.7	114.7	111.7	105.7	99.7	125.4	120.0	L_W Predictions (Bruce & Moritz, 1998)
ROM Pad	Primary Crusher	L_W	121	122	120	120	117	113	106		127.6	121.7	L_W Database
Plant	SAG Mill	L_W	118	117	118	114	111	108	100		123.5	116.5	L_W Database
	SAG Mill Motor	L_W	90	92	93	93	96	96	88	81	101.8	100.6	L_W Predictions (Bruce & Moritz, 1998)
	Ball Mill	L_W	107	108	109	107	106	101	97		114.9	110.0	L_W Database
Pumps	Tailings Pump	L_W	94.8	95.8	96.8	98.8	98.8	101.8	98.8	94.8	107.2	106.4	L_W Predictions (Bruce & Moritz, 1998)

4.2 Noise Propagation and Simulated Noise Levels

The propagation of noise generated during the operational phase was calculated with CadnaA in accordance with ISO 9613. Meteorological and site-specific acoustic parameters as discussed in Section 3.2 along with source data discussed in 4.1, were applied in the model.

Table 4-4 provides a summary of simulated noise levels for the project at NSRs. Results for the project operations are presented in isopleth form (Figure 4-1 and Figure 4-2). It should be noted that as no site-specific wind field was included in the attenuation modelling, the noise impacts due to project activities for day- and night-time will be the same.

Table 4-4: Summary of simulated noise levels (provided as dBA) for proposed project operations at NSR within the study area

NSR	Industrial / residential	Project[(a)]		Baseline[(b)]		Increase above baseline for project operations	
		Day	Night	Day	Night	Day	Night
1	Residential	0.0	0.0	36.5	25.4	0.0	0.0
2	Residential	0.0	0.0	36.5	25.4	0.0	0.0
3	Residential	0.0	0.0	36.5	25.4	0.0	0.0
4	Residential	0.0	0.0	36.5	25.4	0.0	0.0
5	Residential	0.0	0.0	36.5	25.4	0.0	0.0
6	Residential	44.6	44.6	58.5	31.5	0.2	13.3
7	Residential	36.3	36.3	48.0	49.3	0.3	0.2

Notes:

(a) Exceedance of day- and night-time IFC guideline is provided in bold (guideline for industrial receptors is 70 dBA for day- and night-time).

(b) Baseline noise levels taken from the closest survey sites

Noise levels due to project operations are predicted to be within the day- and night-time IFC noise guideline of 70 dBA at all off-site industrial receptors.

For a person with average hearing acuity an increase of less than 3 dBA in the general ambient noise level is not detectable. If we assume that the measured noise levels for survey Site 2 is representative of baseline conditions, the increase in noise levels above the baseline for proposed project operations is more than 3 dBA at the NSR6 (road authority building) for night-time conditions.

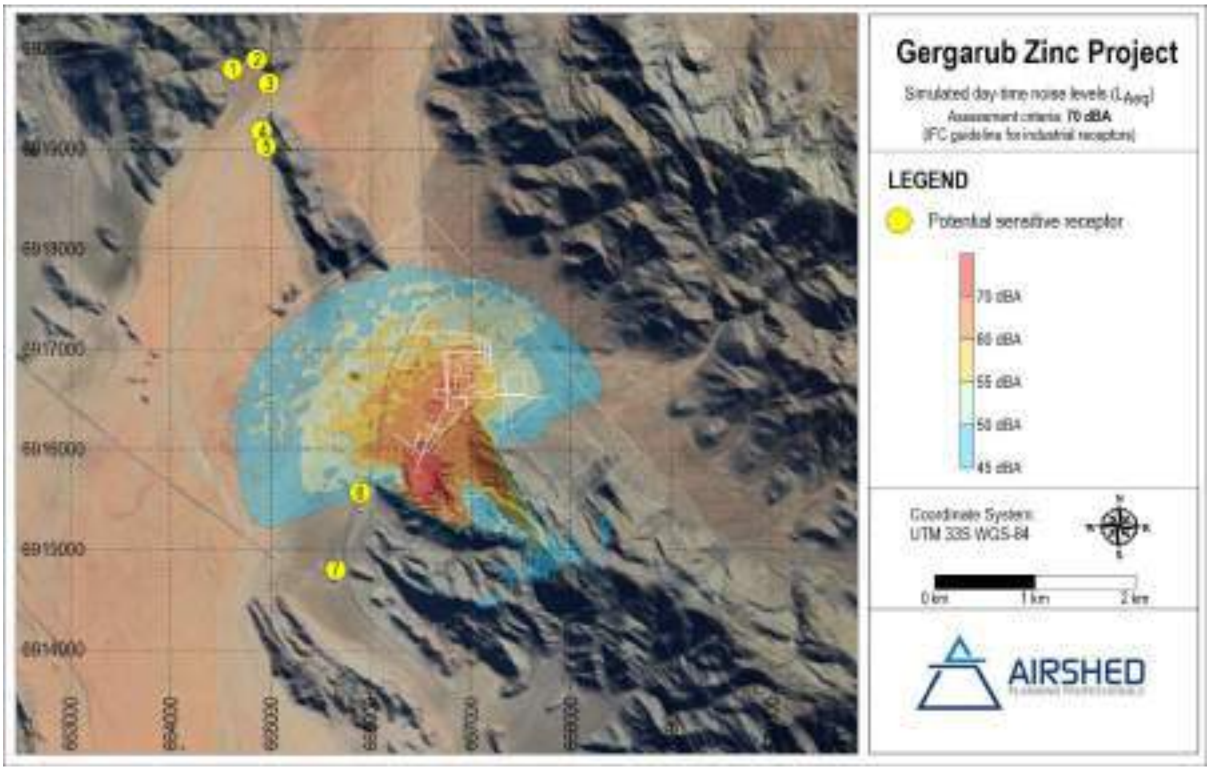


Figure 4-1: Simulated day-time noise levels for the project operational activities

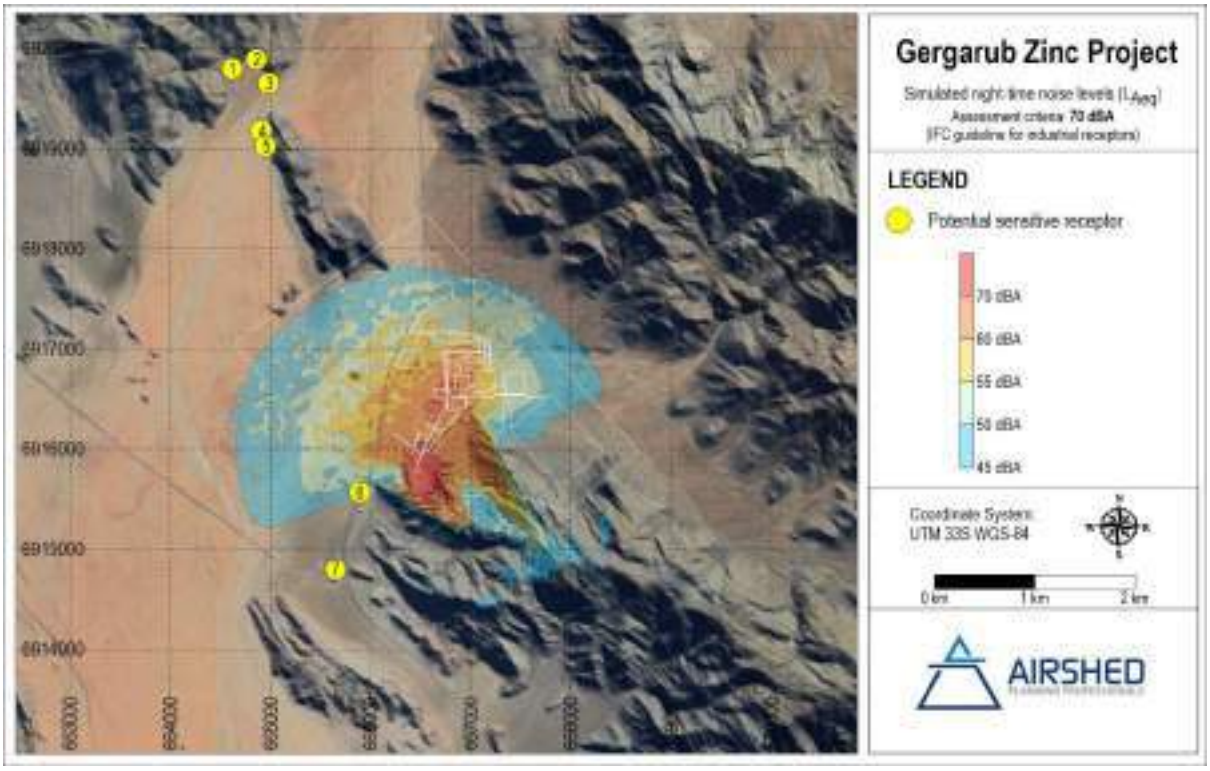


Figure 4-2: Simulated night-time noise levels for the project operational activities

5 Management Measures

In the quantification of noise emissions and simulation of noise levels as a result of the project, it was found that environmental noise evaluation criteria for industrial receptors is not exceeded due to proposed project operations.

The measures discussed in this section are measures typically applicable to industrial sites and are considered good practice by the IFC (2007) and British Standards Institution (BSI) (2014).

It should be noted that not all mitigation measures are to be implemented, but should the need arise the mitigation measures as discussed in this section can be considered.

5.1 Controlling Noise at the Source

5.1.1 General Good Practice Measures

Good engineering and operational practices will reduce levels of annoyance. For general activities, the following good engineering practice **should** be applied to **all project phases**:

- All diesel-powered equipment and plant vehicles should be kept at a **high level of maintenance**. This should particularly include the regular inspection and, if necessary, replacement of intake and exhaust silencers. Any change in the noise emission characteristics of equipment should serve as trigger for withdrawing it for maintenance.
- In managing noise specifically related to vehicle traffic, efforts **should** be directed at:
  - Minimising individual vehicle engine, transmission, and body noise/vibration. This is achieved through the implementation of an equipment maintenance program.
  - Maintain road surfaces regularly to repair potholes etc.
  - Keep all roads well maintained and avoid steep inclines or declines to reduce acceleration/brake noise.
  - Avoid unnecessary equipment idling at all times.
  - Minimising the need for trucks/equipment to reverse. This will reduce the frequency at which disturbing but necessary reverse warnings will occur. Alternatives to the traditional reverse ‘beeper’ alarm such as a ‘self-adjusting’ or ‘smart’ alarm could be considered. These alarms include a mechanism to detect the local noise level and automatically adjust the output of the alarm is so that it is 5 to 10 dB above the noise level near the moving equipment.
- Where possible, other non-routine noisy activities such as construction, decommissioning, start-up and maintenance, should be limited to day-time hours.
- A noise complaints register must be kept.

5.1.2 Specifications and Equipment Design

Equipment can be reviewed to ensure the quietest available technology is used. Where equipment with lower sound power levels is selected, vendors/contractors should be required to guarantee optimised equipment design noise levels.

5.1.3 Enclosures

As far as is practically possible, source of significant noise should be enclosed. The extent of enclosure will depend on the nature of the machine and their ventilation requirements. Pumps are examples of such equipment.

It should be noted that the effectiveness of partial enclosures and screens can be reduced if used incorrectly, e.g., noise should be directed into a partial enclosure and not out of it, there should not be any reflecting surfaces such as parked vehicles opposite the open end of a noise enclosure.

5.1.4 Use and Siting of Equipment and Noise Sources

Recommendations on use and siting of equipment is as follows:

a) Machines used intermittently should be shut down between work periods or throttled down to a minimum and not left running unnecessarily. This will reduce noise and conserve energy.
b) Plants or equipment from which noise generated is known to be particularly directional, should be orientated so that the noise is directed away from NSRs.
c) Acoustic covers of engines should be kept closed when in use or idling.
d) Doors to pump houses should be kept closed at all times.
e) Construction materials such as beams should be lowered and not dropped.

5.1.5 Maintenance

Regular and effective maintenance of equipment and plants are essential to noise control. Increases in equipment noise are often indicative of eminent mechanical failure. Also, sound reducing equipment/materials can lose effectiveness before failure and can be identified by visual inspection.

Noise generated by vibrating machinery and equipment with vibrating parts can be reduced through the use of vibration isolation mountings or proper balancing. Noise generated by friction in conveyor rollers, trolley etc. can be reduced by sufficient lubrication.

5.1 Monitoring

Given the nature of NSRs within the area and that IFC guidelines are not predicted to be exceeded off-site, routine noise monitoring is not recommended.

In the event, however, that noise related complaints are received short term ambient noise measurements should be conducted as part of investigating the complaints. The results of the measurements should be used to inform any follow up interventions. The investigation of complaints should include an investigation into equipment or machinery that likely result or resulted in noise levels annoying to the community. This could be achieved with source noise measurements.

The following procedure should be adopted for all noise surveys:

- Any surveys should be designed and conducted by a **trained specialist**.
- Sampling should be carried out using a **Type 1** SLM that meets all appropriate IEC standards and is subject to **annual calibration** by an accredited laboratory.
- The **acoustic sensitivity of the SLM should be tested** with a portable acoustic calibrator before and after each sampling session.
- Samples sufficient for statistical analysis should be taken with the use of portable SLM's capable of logging data continuously over the time period. Samples representative of the day- and night-time acoustic environment should be taken.
- The following acoustic indices should be recoded and reported: L_{Aeq} (T), statistical noise level $L_{A90,}$ L_{AFmin} and $L_{AFmax,}$ octave band or 3rd octave band frequency spectra.
- The SLM should be located approximately 1.5 m above the ground and no closer than 3 m to any reflecting surface.
- Efforts should be made to ensure that measurements are not affected by the residual noise and extraneous influences, e.g., wind, electrical interference and any other non-acoustic interference, and that the instrument is operated under the conditions specified by the manufacturer. It is good practice to avoid conducting measurements when the wind speed is more than 5 m/s, while it is raining or when the ground is wet.
- A detailed log and record should be kept. Records should include site details, weather conditions during sampling and observations made regarding the acoustic environment of each site.

6 Conclusion

Based on the findings of the assessment, it is the specialist's opinion that the project may be authorised.

7 References

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Appendix A – Specialist Curriculum Vitae

CURRICULUM VITAE | **RENEÉ VON GRUENEWALDT**

FULL CURRICULUM VITAE

Name of Firm	Airshed Planning Professionals (Pty) Ltd
Name of Staff	Reneé von Gruenewaldt (nee Thomas)
Profession	Air Quality and Environmental Noise Scientist
Position	Principal consultant
Date of Birth	13 May 1978
Years with Firm	Since January 2002
Nationalities	South African

MEMBERSHIP OF PROFESSIONAL SOCIETIES

- Registered Professional Natural Scientist (Registration Number 400304/07) with the South African Council for Natural Scientific Professions (SACNASP)
- Member of the National Association for Clean Air (NACA)

KEY QUALIFICATIONS

Reneé von Gruenewaldt (Air Quality Scientist): Reneé joined Airshed Planning Professionals (Pty) Ltd (previously known as Environmental Management Services cc) in 2002. She has, as a Specialist, attained over twenty (20) years of experience in the Earth and Natural Sciences sector in the field of Air Quality and nine (9) years of experience in the field of environmental noise assessments. As an environmental practitioner, she has provided solutions to both large-scale and smaller projects within the mining, minerals, and process industries.

She has developed technical and specialist skills in various air quality modelling packages including the AMS/EPA Regulatory Models (AERMOD and AERMET), UK Gaussian plume model (ADMS), EPA Regulatory puff-based model (CALPUFF and CALMET), puff-based HAWK model and line-based models, Lagrangian GRAL model. Her experience with air emission models includes Tanks 4.0 (for the quantification of tank emissions), WATER9 (for the quantification of wastewater treatment works) and GasSim (for the quantification of landfill emissions). Noise propagation modelling proficiency includes CONCAWE, South African National Standards (SANS 10210) for calculating and predicting road traffic noise and CadnaA for propagation of industrial, road and rail noise sources.

Having worked on projects throughout Africa (i.e., South Africa, Mozambique, Malawi, Kenya, Angola, Democratic Republic of Congo, Namibia, Madagascar and Egypt for Air Quality Impact Assessments and Mozambique, Namibia, Botswana, Kenya, Ghana, Suriname and Afghanistan for Environmental Noise Impact Assessments) Reneé has developed a broad experience base. She has a good understanding of the laws and regulations associated with ambient air quality and emission limits in South Africa and various other African countries, as well as the World Bank Guidelines, European Community Limits and World Health Organisation.

RELEVANT EXPERIENCE (AIR QUALITY)

Mining and Ore Handling

Reneé has undertaken numerous air quality impact assessments and management plans for coal, platinum, uranium, copper, cobalt, chromium, fluorspar, bauxite, manganese and mineral sands mines. These include: compilation of emissions databases for Landau and New Vaal coal collieries (SA), impact assessments and management plans for numerous mines over Mpumalanga (viz. Schoonoord, Belfast, Goedgevonden, Mbila, Evander South, Driefontein, Hartogshoop, Belfast, New Largo, Geluk, etc.), Mmamabula Coal Colliery (Botswana), Moatize Coal Colliery (Mozambique), Revuboe Coal Colliery (Mozambique), Toliera Sands Heavy Minerals Mine and Processing (Madagascar), Corridor Sands Heavy Minerals Mine monitoring assessment, El Burullus Heavy Minerals Mine and processing (Egypt), Namakwa Sands Heavy Minerals Mine (SA), Tenke Copper Mine and Processing Plant (DRC), Rössing Uranium (Namibia), Lonmin platinum mines including operations at Marikana, Baobab, Dwaalkop and Doornvlei (SA), Impala Platinum (SA), Pilannesburg Platinum (SA), Aquarius Platinum, Hoogland Platinum Mine (SA), Tamboti PGM Mine (SA), Sari Gunay Gold Mine (Iran), chrome mines in the Steelpoort Valley (SA), Mecklenburg Chrome Mine (SA), Naboom Chrome Mine (SA), Kinsenda Copper Mine (DRC), Kassinga Mine (Angola) and Nokeng Flourspar Mine (SA), etc.

Mining monitoring reviews have also been undertaken for Optimum Colliery's operations near Hendrina Power Station and Impunzi Coal Colliery with a detailed management plan undertaken for Morupule (Botswana) and Glencor (previously known as Xstrata Coal South Africa).

Air quality assessments have also been undertaken for mechanical appliances including the Durban Coal Terminal and Nacala Port (Mozambique) as well as rail transport assessments including BHP-Billiton Bauxite transport (Suriname), Nacala Rail Corridor (Mozambique and Malawi), Kusile Rail (SA) and WCL Rail (Liberia).

Metal Recovery

Air quality impact assessments have been carried out for Highveld Steel, Scaw Metals, Lonmin's Marikana Smelter operations, Saldanha Steel, Tata Steel, Afro Asia Steel and Exxaro's Manganese Pilot Plant Smelter (Pretoria).

Chemical Industry

Comprehensive air quality impact assessments have been completed for NCP (including Chloorkop Expansion Project, Contaminated soils recovery, C3 Project and the 200T Receiver Project), Revertex Chemicals (Durban), Stoppani Chromium Chemicals, Foskor (Richards Bay), Straits Chemicals (Coega), Tenke Acid Plant (DRC), and Omnia (Sasolburg).

Petrochemical Industry

Numerous air quality impact assessments have been completed for Sasol (including the postponement/exemption application for Synfuels, Infrachem, Natref, MIBK2 Project, Wax Project, GTL Project, re-commissioning of boilers at Sasol Sasolburg and Ekandustria), Engen Emission Inventory Functional Specification (Durban), Sapref refinery (Durban), Sasol (at Elrode) and Island View (in Durban) tanks quantification, Petro SA and Chevron (including the postponement/exemption application).

Pulp and Paper Industry

Air quality studies have been undertaken or the expansion of Mondi Richards Bay, Multi-Boiler Project for Mondi Merebank (Durban), impact assessments for Sappi Stanger, Sappi Enstra (Springs), Sappi Ngodwana (Nelspruit) and Pulp United (Richards Bay).

Power Generation

Air quality impact assessments have been completed for numerous Eskom coal fired power station studies including the ash expansion projects at Kusile, Kendal, Hendrina, Kriel and Arnot; Fabric Filter Plants at Komati, Grootvlei, Tutuka, Lethabo and Kriel Power Stations; the proposed Kusile, Medupi (including the impact assessment for the Flue Gas Desulphurization) and Vaal South Power Stations. Reneé was also involved and the cumulative assessment of the existing and return to service Eskom power stations assessment and the optimization of Eskom's ambient air quality monitoring network over the Highveld.

In addition to Eskom's coal fired power stations, various Eskom nuclear power supply projects have been completed including the air quality assessment of Pebble Bed Modular Reactor and nuclear plants at Duynefontein, Bantamsklip and Thyspunt.

Apart from Eskom projects, power station assessments have also been completed in Kenya (Rabai Power Station) and Namibia (Paratus Power Plant).

Waste Disposal

Air quality impact assessments, including odour and carcinogenic and non-carcinogenic pollutants were undertaken for the Waste Water Treatment Works in Magaliesburg, proposed Waterval Landfill (near Rustenburg), Tutuka Landfill, Mogale General Waste Landfill (adjacent to the Leipardsvlei Landfill), Cape Winelands District Municipality Landfill, the Tsoeneng Landfill (Lesotho) and the FG Landfill (near the Midstream Estate). Air quality impact assessments have also been completed for the BCL incinerator (Cape Town), the Ergo Rubber Incinerator and the Ecorevert Pyrolysis Plant.

Cement Manufacturing

Impact assessments for ambient air quality have been completed for the Holcim Alternative Fuels Project (which included the assessment of the cement manufacturing plants at Ulco and Dudfield as well as a proposed blending platform in Roodepoort).

Management Plans

Reneé undertook the quantification of the baseline air quality for the first declared Vaal Triangle Airshed Priority Area. This included the establishment of a comprehensive air pollution emissions inventory, atmospheric dispersion modelling, focusing on impact area "hotspots" and quantifying emission reduction strategies. The management plan was published in 2009 (Government Gazette 32263).

Reneé has also been involved in the Provincial Air Quality Management Plan for the Limpopo Province.

RELEVANT EXPERIENCE (NOISE)

Mining

Reneé has undertaken numerous environmental noise assessments for mining operations. These include environmental noise impact assessments including baseline noise surveys for numerous coal, platinum, manganese, tin and zinc mines. Projects include, but are not limited to, Balama (Mozambique), Masama Coal (Botswana), Lodestone (Namibia), Osino (Namibia), Kurmuk (Ethiopia), Gamsberg (SA), Prieska (SA), Kolomela (SA), Heuningkranz (SA), Syferfontein (SA), South 32 (SA), Mamatwan (SA), Alexander (SA) and Marula Platinum Mine (SA), etc.

Power Generation

Environmental noise assessments have been completed for numerous Eskom coal fired power station studies in SA including the Kriel Fabric Filter Plant, Kendal ash facility, Medupi ash facility. Apart from Eskom projects, power plant assessments have also been completed in Botswana (Morupule), Kenya (Or Power geothermal power plants), Suriname (EBS power plant) and SA (Richards Bay combined cycle power plant).

Process Operations

Environmental noise assessments have been undertaken for various process operations including waste disposal facilities (Bon Accord in Gauteng), bottling and drink facilities (Imali and Isanti Project in Gauteng) and Smelter (Gamsberg in Northern Cape).

Transport

An environmental noise assessment was completed for the Obetsebi road expansion and flyover project in Ghana, the Scorpion Zinc Mine transport route in Namibia and the Sisian-Kajaran (North-South Corridor) Road Project in Armenia.

Gas Pipelines

An environmental noise assessment was completed for the Sheberghan gas pipeline in Afghanistan.

Baseline Noise Surveys

Baseline noise surveys have been undertaken for numerous mining and process operation activities (including Raumix quarries, Kolomela and Sibanye Stillwater Platinum Mines (SA)) in support of onsite Environmental Management Programmes.

OTHER EXPERIENCE (2001)

Research for B.Sc Honours degree was part of the "Highveld Boundary Layer Wind" research group and was based on the identification of faulty data from the Majuba Sodar. The project was THRIP funded and was a joint venture with the University of Pretoria, Eskom and Sasol (2001).

Curriculum Vitae: Reneé von Gruenewaldt 4

EDUCATION

M.Sc Earth Sciences	University of Pretoria, RSA, Cum Laude (2009) Title: *An Air Quality Baseline Assessment for the Vaal Airshed in South Africa*
B.Sc Hons. Earth Sciences	University of Pretoria, RSA, Cum Laude (2001) Environmental Management and Impact Assessments
B.Sc Earth Sciences	University of Pretoria, RSA, (2000) Atmospheric Sciences: Meteorology

ADDITIONAL COURSES

CALMET/CALPUFF	Presented by the University of Johannesburg, RSA (March 2008)
Air Quality Management	Presented by the University of Johannesburg, RSA (March 2006)
ARCINFO	GIMS, Course: Introduction to ARCINFO 7 (2001)

COUNTRIES OF WORK EXPERIENCE

South Africa, Mozambique, Botswana, Ghana, Suriname, Afghanistan, Malawi, Liberia, Kenya, Angola, Democratic Republic of Congo, Ethiopia, Afghanistan, Lesotho, Namibia, Madagascar, Egypt, Suriname and Iran.

EMPLOYMENT RECORD

January 2002 - Present

Airshed Planning Professionals (Pty) Ltd, (previously known as Environmental Management Services cc until March 2003), Principal Air Quality and Environmental Noise Scientist, Midrand, South Africa.

2001

University of Pretoria, Demi for the Geography and Geoinformatics department and a research assistant for the Atmospheric Science department, Pretoria, South Africa.

Department of Environmental Affairs and Tourism, assisted in the editing of the Agenda 21 document for the world summit (July 2001), Pretoria, South Africa.

1999 - 2000

The South African Weather Services, vacation work in the research department, Pretoria, South Africa.

CONFERENCE AND WORKSHOP PRESENTATIONS AND PAPERS

- Understanding the Synoptic Systems that lead to Strong Easterly Wind Conditions and High Particulate Matter Concentrations on The West Coast of Namibia, H Liebenberg-Enslin, R von Gruenewaldt, H Rauntenbach and L Burger. National Association for Clean Air (NACA) conference, October 2017.
- Topographical Effects on Predicted Ground Level Concentrations using AERMOD, R.G. von Gruenewaldt. National Association for Clean Air (NACA) conference, October 2011.
- Emission Factor Performance Assessment for Blasting Operations, R.G. von Gruenewaldt. National Association for Clean Air (NACA) conference, October 2009.
- Vaal Triangle Priority Area Air Quality Management Plan – Baseline Characterisation, R.G. Thomas, H Liebenberg-Enslin, N Walton and M van Nierop. National Association for Clean Air (NACA) conference, October 2007.
- A High-Resolution Diagnostic Wind Field Model for Mesoscale Air Pollution Forecasting, R.G. Thomas, L.W. Burger, and H Rautenbach. National Association for Clean Air (NACA) conference, September 2005.
- Emissions Based Management Tool for Mining Operations, R.G. Thomas and L.W. Burger. National Association for Clean Air (NACA) conference, October 2004.
- An Investigation into the Accuracy of the Majuba Sodar Mixing Layer Heights, R.G. Thomas. Highveld Boundary Layer Wind Conference, November 2002.

LANGUAGES

	Speak	Read	Write
English	Excellent	Excellent	Excellent
Afrikaans	Fair	Fair	Fair

CERTIFICATION

I, the undersigned, certify that to the best of my knowledge and belief, these data correctly describe me, my qualifications, and my experience.

______________________	14/07/2023
Signature of staff member	Date (Day / Month / Year)

Full name of staff member: Reneé Georgeinna von Gruenewaldt

Appendix B – Declaration of Independence

DECLARATION OF INDEPENDENCE - PRACTITIONER

Name of Practitioner: Reneé von Gruenewaldt
Name of Registration Body: South African Council for Natural Scientific Professions
Professional Registration No.: 400304/07

Declaration of independence and accuracy of information provided:
Environmental Noise Impact Assessment for the Proposed Gergarub Zinc Project Near Rosh Pinah in Namibia.

I, René von Gruenewaldt, declare that I am independent of the applicant. I have the necessary expertise to conduct the assessments required for the report and will perform the work relating the application in an objective manner, even if this results in views and findings that are not favourable to the applicant. I will disclose to the applicant and the air quality officer all material information in my possession that reasonably has or may have the potential of influencing any decision to be taken with respect to the application by the air quality officer. The additional information provided in this atmospheric impact report is, to the best of my knowledge, in all respects factually true and correct. I am aware that the supply of false or misleading information to an air quality officer is a criminal offence in terms of section 51(1)(g) of this Act.

Signed at Pretoria on this 20th of October 2023

SIGNATURE
Principal Noise Scientist
CAPACITY OF SIGNATORY

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Calibration Laboratory
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M AND N ACOUSTIC SERVICES (Pty) Ltd
Co. Reg. No. [illegible] VAT NO. [illegible] BEE Status: Level 4
P.O. Box 61713, Pierre van Ryneveld, 0045

No. 15, [illegible] Avenue
Pierre van Ryneveld, 0045

Tel: 012 689-2007 / 076 [illegible] • Fax: [illegible] 4650
E-mail: admin@mnacoustics.co.za
Website: www.mnacoustics.co.za

CERTIFICATE OF CALIBRATION

CERTIFICATE NUMBER	*2023-AS-0353*
ORGANISATION	*AIRSHED PLANNING PROFFESSIONALS (PTY) LTD*
ORGANISATION ADRESS	*P.O. BOX 5260, HALFWAY HOUSE, 1685*
CALIBRATION OF	*SOUND & VIBRATION ANALYZER complete with built-in ⅓-OCTAVE/OCTAVE FILTER, ½" PRE-AMPLIFIER and ½" MICROPHONE*
MANUFACTURERS	*SVANTEK and ACO*
MODEL NUMBERS	*SVAN 977, SV 12L and 7052E*
SERIAL NUMBERS	*36183, 40659 and 78692*
DATE OF CALIBRATION	*14 - 15 MARCH 2023*
RECOMMENDED DUE DATE	*MARCH 2024*
PAGE NUMBER	*PAGE 1 OF 6*

This certificate is issued in accordance with the conditions of approval granted by the South African National Accreditation System (SANAS). This Certificate may not be reproduced without the written approval of SANAS and M and N Acoustic Services.

The measurement results recorded in this certificate were correct at the time of calibration.
The subsequent accuracy will depend on factors such as care, handling, frequency of use and the number of different users. It is recommended that re-calibration should be performed at an interval, which will ensure that the instrument remains within the desired limits and/or manufacturer's specifications.

The South African National Accreditation System (SANAS) is member of the International Laboratory Accreditation Cooperation (ILAC) Mutual Recognition Arrangement (MRA).
This arrangement allows for mutual recognition of technical test and calibration data by member accreditation bodies worldwide. For more information on the arrangement please consult www.ilac.org

Calibrated by Calibration Technician:	*N.J. BLIGNAUT*	*Clause 3.1, 3.2 & 3.3*
Calibrated/Supervised by Calibration Technician:	*W.S SIBANYONI*	*Clause 3.1 - 3.4*
Authorized/Checked by SANAS Technical Signatory:	*M. NAUDE*	***Date of Issue:*** ***15 MARCH 2023***

Director: Marianka Naude

1. PROCEDURE

The Integrating Sound Level Meter was calibrated according to procedure 10[illegible] and to the IEC 61672-3:2006 specifications as well as the manufacturer's specifica[illegible]

The ½" Microphone was calibrated according to procedure 1002/P/002 and 1002/P/011 as well as the manufacturer's specifications.

The ⅓-Octave/Octave Filter was calibrated according to procedure 1002/P/008 and to the IEC 61260 specification as well as the manufacturer's specifications.

2. MEASURING EQUIPMENT

JFW	50BR-022	50 Ohm Step Attenuator	7051581438
Keysight	33522A	Function Generator	MY 50000462
Major Tech	MT 669	Environmental Logger	150828456
Keysight	34461A	Digital Multimeter	MY 53223917
Agilent	34461A	Digital Multimeter	MY 53205694
G.R.A.S	42 AP	Piston Phone	256092
B&K	2829	4-Ch Microphone Power Supply	2329283
G.R.A.S	26 AJ	½" Pre-Amplifier	188476
G.R.A.S	40 AQ	½" Microphone	160816
B&K	4226	Multi-Functional Calibrator	2912645
Greysinger	80 CL	Data Logger	02304030/1/2
G.R.A.S	42 AG	Multi-Frequency Calibrator	279025
Gems	PD6000-6RO	Pressure Sensor	1606-0204475

Calibrations performed by this laboratory are in terms of standards, the accuracies of which are traceable to national measuring standards as maintained by NMISA.

Calibrated by Calibration Technician:	*N.J. BLIGNAUT*	*Clause 3.1, 3.2 & 3.5*
Calibrated/Supervised by Calibration Technician:	*W.S SIBANYONI*	*Clause 3.1 - 3.4*
Authorized/Checked by SANAS Technical Signatory:	*M. NAUDE*	*Date of Issue: 15 MARCH 2023*

3. RESULTS - ACCORDING TO THE IEC 61672-3: 2006:

3.1 The following parameters of the Integrating Sound Level Meter were calibrated

Parameter	Specification	Uncertainty of Measurement in dB
Calibration Check Frequency at 114,0 dB at 1 000 Hz at Nominal Range: High	IEC 61672-3: Clause 9	± 0,3
Self-Generated Noise: A-Weighted with Microphone 23,7 dB A-Weighted Electrical 18,7 dB C-Weighted Electrical 19,2 dB Z-Weighted Electrical 23,7 dB B-Weighted Electrical 21,4 dB	IEC 61672-3: Clause 10	-------
Level Linearity at 8 000 Hz Nominal Range: High Reference Level at 114,0 dB: (69,4 dB to 149,0 dB)	IEC 61672-3: Clause: 14	± 0,3
Level Range Control at 1 000 Hz Reference Level at 114,0 dB Nominal Range: High Low Range	IEC 61672-3: Clause: 15	± 0,3
Frequency and Time Weightings at 1 000 Hz at 114,0 dB	IEC 61672-3: Clause 13	± 0,3
Tone Burst Response (Max. Fast, Max. Slow, LA_{eq} and SEL)	IEC 61672-3: Clause 16	± 0,3

Calibrated by Calibration Technician:	*N.J. BLIGNAUT*	*Clause 3.1, 3.2 & 3.3*
Calibrated/Supervised by Calibration Technician:	*W.S SIBANYONI*	*Clause 3.1 - 3.4*
Authorized/Checked by SANAS Technical Signatory:	*M. NAUDE*	*Date of Issue:* *15 MARCH 2023*

Parameter	Specification	Uncertainty of Measurement in dB
A-Weighting Network (31,5 to 20 000) Hz	IEC 61672-3: Clause 12	± 0,3
C-Weighting Network (31,5 to 20 000) Hz	IEC 61672-3: Clause 12	± 0,3
Z- Weighting Network (31,5 to 20 000) Hz	IEC 61672-3: Clause 12	± 0,3
B- Weighting Network (31,5 to 20 000) Hz	IEC 61672-3: Clause 12	± 0,3
Peak, C Low Peak Range	IEC 61672-3: Clause 17	± 0,3

Conclusion: The Integrating Sound Level Meter complied with the above-specified clauses of the IEC 61672-3:2006 specifications, recommended tests and requirements according to ARP 0109:2014, **Class 1.**

3.2 The following parameters of the built-in ⅓-Octave/Octave Filter were calibrated:

Octave Frequency Response (31,5 to 16 000) Hz	IEC 61260: Sections 4.7 & 5.6
⅓-Octave Frequency response (25 to 20 000) Hz	IEC 61260: Sections 4.7 & 5.6

The uncertainty of measurement was estimated as follows: ± 0,3 dB

Conclusion: The built-in Octave Filter complied with the above-specified clauses of the IEC 61260 specification, **Class 1.**

Calibrated by Calibration Technician:	*N.J. BLIGNAUT*	*Clause 3.1, 3.2 & 3.3*
Calibrated/Supervised by Calibration Technician:	*W.S SIBANYONI*	*Clause 3.1 - 3.4*
Authorized/Checked by SANAS Technical Signatory:	*M. NAUDE*	*Date of Issue: 15 MARCH 2023*

3.3 The following parameters of the ½" Microph... were ...ted and the results were corrected to the ambient condition of 1 013,25 mBar

Output Sensitivity at 250 Hz at 94,0 dB was found to be: -2... ...6 mV/Pa
Frequency Response (31,5 to 16 000) Hz

The uncertainty of measurements was estimated as follows:

Conclusion: The parameters measured for the ½" Microphone, complied w... the manufacturer's specification.

3.4 The ½" Microphone was calibrated Electroacoustic according to Clause 12 of IEC 61672-3: 2006 complete with Integrating Sound Level Meter and Svantek SV 12L ½" Pre-amplifier Serial No: 40659, free-field corrections were taken into consideration and the results were corrected to the ambient condition of 1 013,25 mBar:

FREQUENCY (Hz)	CALCULATED EXPECTED VALUE (dB)	MEASURED VALUE (dB)	DEVIATION (dB)	UoM (dB)
1 000 (Ref)	114,0	114,0	0,0	± 0,3
31,5	111,2	111,3	+ 0,1	± 0,3
63	113,4	113,4	0,0	± 0,3
125	113,9	114,0	+ 0,1	± 0,3
250	114,0	114,1	+ 0,1	± 0,3
500	114,0	114,1	+ 0,1	± 0,3
1 000	114,0	114,0	0,0	± 0,3
2 000	113,6	113,7	+ 0,1	± 0,3
4 000	113,2	112,9	- 0,3	± 0,3
8 000	106,7	107,4	+ 0,7	± 0,3
12 500	100,9	101,7	+ 0,8	± 0,3
16 000	96,4	97,4	+ 1,0	± 0,3

Calibrated by Calibration Technician:	*N.J. BLIGNAUT*	*Clause 3.1, 3.2 & 3.3*
Calibrated/Supervised by Calibration Technician:	*W.S SIBANYONI*	*Clause 3.1 - 3.4*
Authorized/Checked by SANAS Technical Signatory:	*M. NAUDE*	*Date of Issue: 15 MARCH 2023*

Director: Marianka Naudé - marianka@mnacoustics.co.za

4. REMARKS

4.1 The reported expanded uncertainties of measurements are based on a standard uncertainty multiplied by a coverage factor of $k = 2$, providing a level of confidence of approximately 95,45%, the uncertainties of measurements have been estimated in accordance with the principles defined in the GUM (Guide to Uncertainty of Measurement) ISO, Geneva, 1993

4.2 The environmental conditions during calibration of items in section 3 were:
Temperature: (23 ± 2) °C
Relative Humidity: (50 ± 15) %RH

4.3 Calibration labels bearing cal date, due date (if requested), certificate number and serial number have been affixed to the instrument.

4.4 The above statement of conformance is based on the measurement values obtained, extended by the estimated uncertainty of measurement, being within the appropriate specification limits.

4.5 The above specified Sound & Vibration Analyser and ½" Microphone must be used as a unit. The ½" Microphone's frequency range determines the useful frequency range of the instrument vice versa.

4.6 The result on this Certificate relates only to the items and parameters calibrated.

4.7 Abbreviation:
UoM = Uncertainty of Measurement

------------SECTION 4.7 THE END OF CERTIFICATE-----------

Calibrated by Calibration Technician:	*N.J. BLIGNAUT*	*Clause 3.1, 3.2 & 3.3*
Calibrated/Supervised by Calibration Technician:	*W.S SIBANYONI*	*Clause 3.1 - 3.4*
Authorized/Checked by SANAS Technical Signatory:	*M. NAUDÉ*	*Date of Issue: 15 MARCH 2023*

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BEE Status: Level 4
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No. 15, Mustang Avenue
Pierre van Ryneveld, 0045

Tel: 012 689-2007 / 076 [illegible] • Fax: [illegible]
E-mail: admin@mnacoustics.co.za
Website: www.mnacoustics.co.za

CERTIFICATE OF CONFORMANCE

CERTIFICATE NUMBER	2023-AS-0347
ORGANISATION	AIRSHED PLANNING PROFFESSIONALS (PTY) LTD
ORGANISATION ADDRESS	P.O. BOX 5260, HALFWAY HOUSE, 1685
CALIBRATION OF	ACOUSTIC CALIBRATOR
MANUFACTURER	SVANTEK
MODEL NUMBER	SV 33
SERIAL NUMBER	43170
DATE OF CALIBRATION	14 MARCH 2023
RECOMMENDED DUE DATE	MARCH 2024
PAGE NUMBER	PAGE 1 OF 3

This certificate is issued in accordance with the conditions of approval granted by the South African National Accreditation System (SANAS). This Certificate may not be reproduced without the written approval of SANAS and M and N Acoustic Services.

Calibrations performed by this laboratory are in terms of standards, the accuracies of which are traceable to national measuring standards as maintained by NMISA.

The measurement results recorded in this certificate were correct at the time of calibration. The subsequent accuracy will depend on factors such as care, handling, frequency of use and the number of different users. It is recommended that re-calibration should be performed at an interval, which will ensure that the instrument remains within the desired limits and/or manufacturer's specifications.

The South African National Accreditation System (SANAS) is member of the International Laboratory Accreditation Cooperation (ILAC) Mutual Recognition Arrangement (MRA). This arrangement allows for mutual recognition of technical test and calibration data by member accreditation bodies worldwide. For more information on the arrangement please consult www.ilac.org

Calibrated by:	Authorised/Checked by:	Date of Issue:
W.S. SIBANYONI (CALIBRATION TECHNICIAN)	M. NAUDÉ (SANAS TECHNICAL SIGNATORY)	15 MARCH 2023

Director: Marianka Naudé

1. PROCEDURE

The UUT was calibrated according to the procedures 1002/P/001 and also to the IEC 60942:1997 specifications for Sound Level Calibrators as well as the manufacturer's specifications.

2. MEASURING EQUIPMENT

Keysight	34461A	Digital Multimeter	MY 53224004
Greysinger	80 CL	Environmental Logger	02304030/1/2
G.R.A.S	42 AP	Piston Phone	256092
G.R.A.S	26 AJ	½" Pre-Amplifier	188476
B&K	2829	4-Ch Microphone Power Supply	2329283
G.R.A.S	40 AQ	½" Microphone	160816
Leader	LDM-170	Distortion Meter	0100240
Svantek	SV 35	Acoustic Calibrator	58106
LG	FC-7015	Universal Counter	00022701
Agilent	34461A	Digital Multimeter	MY 53205694
G.R.A.S	42 AG	Multi-Frequency Calibrator	279025

3. RESULTS

3.1 The following parameters of the Calibrator were calibrated:

Output Level	IEC 60942: Section 5.2.3
Output Frequency	IEC 60942: Section 5.3.3
Selective Distortion	IEC 60942: Section A.4.9

The Calibrator output level was found to be 114,1 dB at 1 000,03 Hz.
No adjustment was made.

These results were corrected to the ambient condition of 1 013,25 Pa.

Conclusion: The Calibrator complied with the above-specified clauses of the IEC 60942:1997 specifications, recommended tests, and requirements according to ARP 0109:2014, **Class 1**.

Calibrated by:	Authorised/Checked by:
W.S. SIBANYONI (CALIBRATION TECHNICIAN)	M. NAUDE (SANAS TECHNICAL SIGNATORY)

Director: Marianka Naudé - marianka@mnacoustics.co.za

4. REMARKS

4.1 The reported expanded uncertainties of measurements are based on a standard uncertainty multiplied by a coverage factor of $k = 2$, providing a level of confidence of approximately 95,45%, the uncertainties of measurements have been estimated in accordance with the principles defined in the GUM (Guide to Uncertainty of Measurement) ISO, Geneva, 1993.

4.2 The environmental conditions were:

Temperature:	(23 ± 2) °C
Relative Humidity:	(50 ± 15) %RH

4.3 Calibration labels bearing calibration date, due date (if requested), certificate number and serial number have been affixed to the instrument.

4.4 The above statement of conformance is based on the measurement values obtained, extended by the estimated uncertainty of measurement, being within the appropriate specification limits.

4.5 The uncertainty of measurements was estimated as follows:

Sound Pressure Level:	± 0,13 dB
Frequency:	± 0,1 Hz
Distortion:	± 0,2 %

4.6 The result on this Certificate relates only to the items and parameters calibrated.

------------SECTION 4.6 THE END OF CERTIFICATE-----------

Calibrated by:	*Authorized/Checked by:*
W.S. SIBANYONI *(CALIBRATION TECHNICIAN)*	*M. NAUDE* *(SANAS TECHNICAL SIGNATORY)*

Appendix D – Time-series, Statistical, and Frequency Spectrum Results

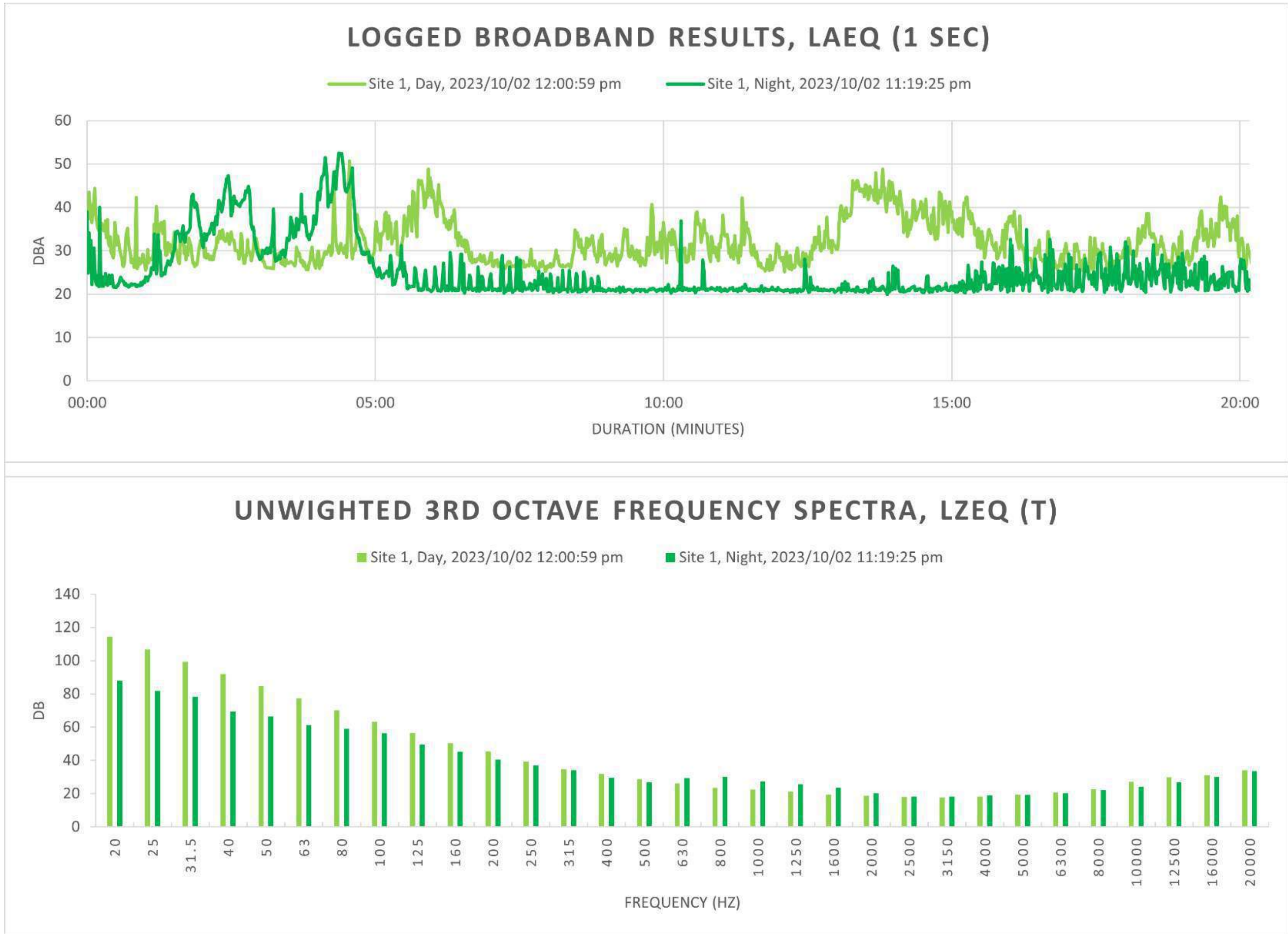


Figure D-1: Detailed day-time survey results for Site 1

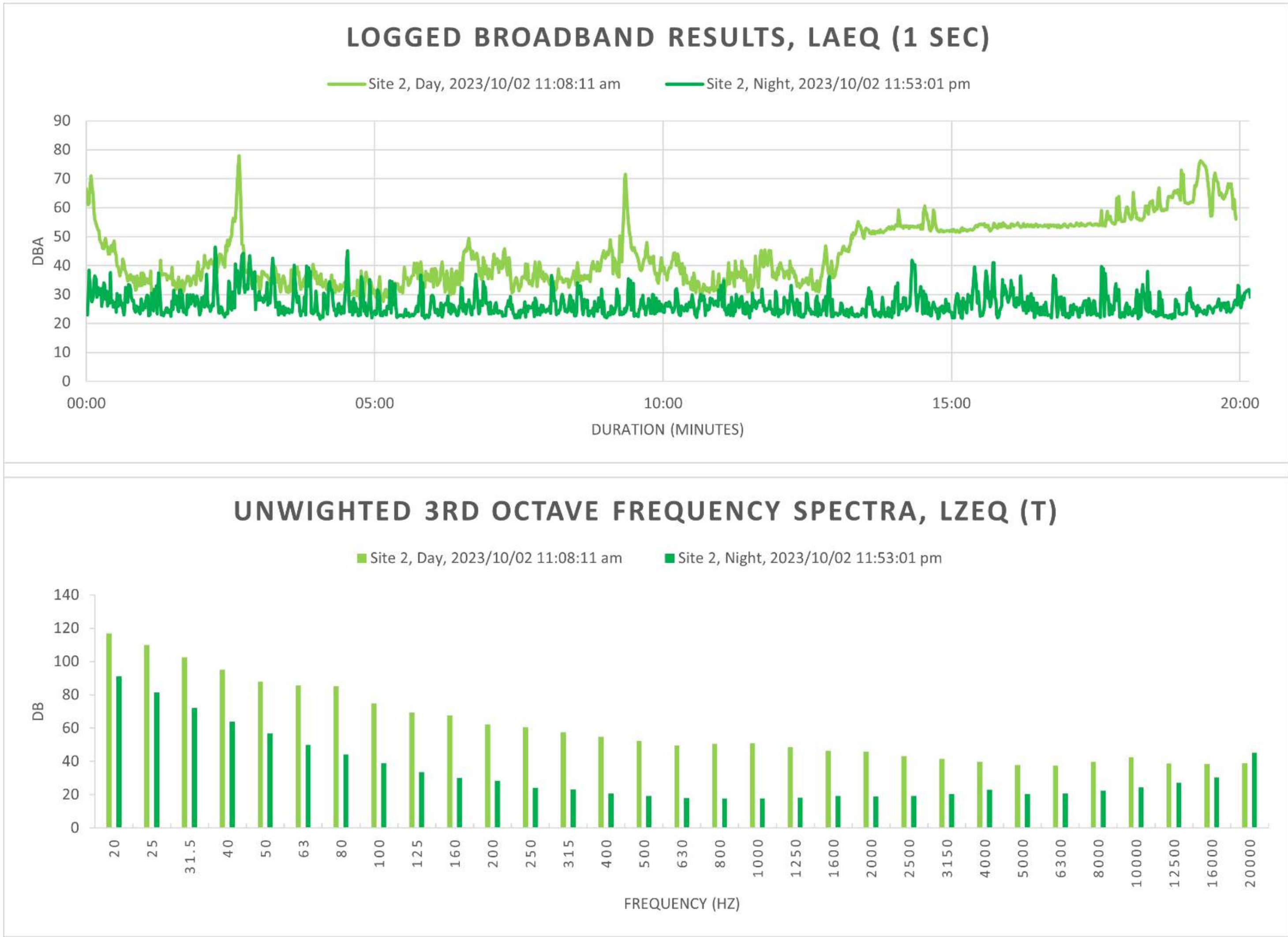


Figure D-2: Detailed day-time survey results for Site 2

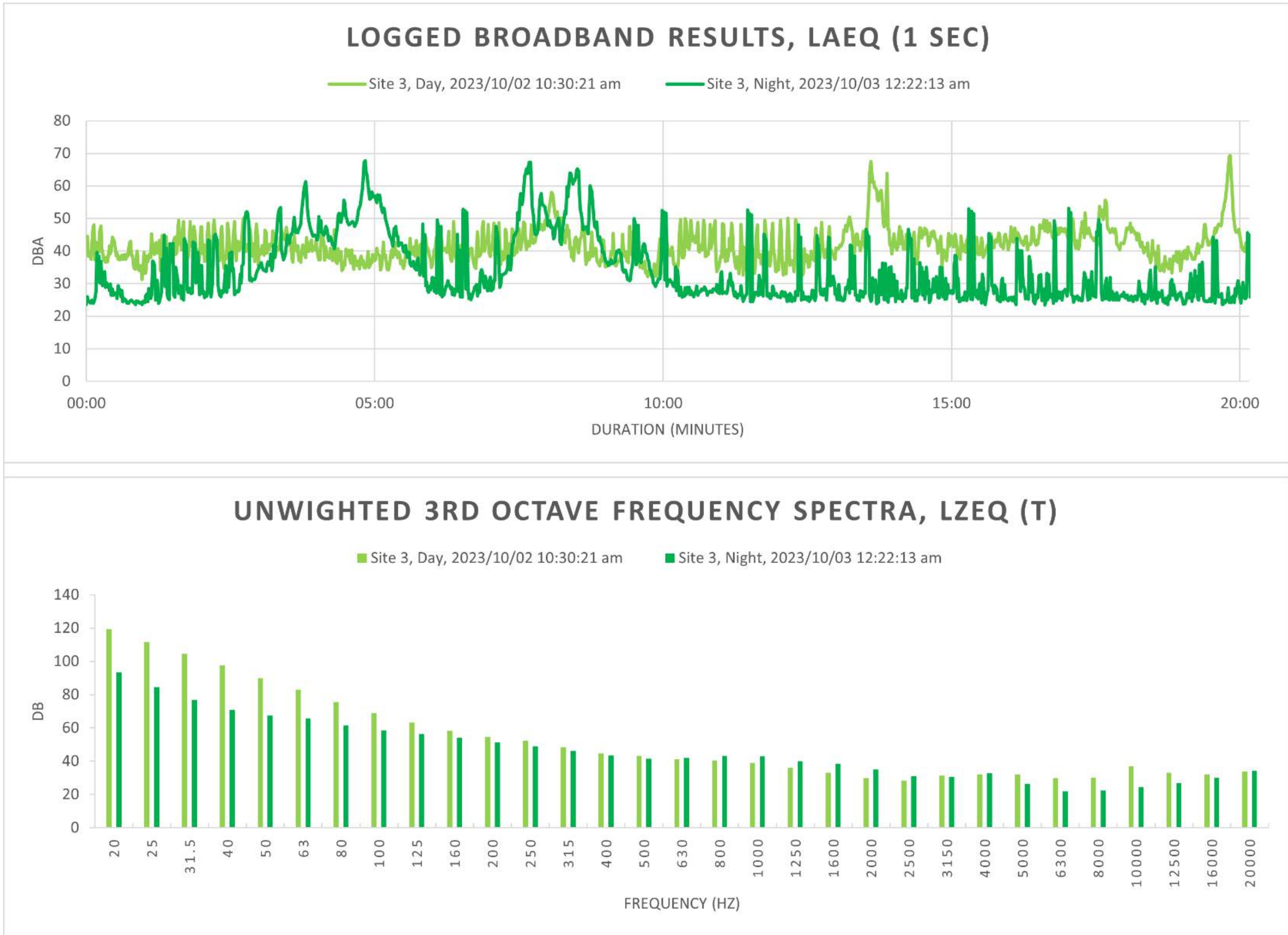


Figure D-3: Detailed day-time survey results for Site 3

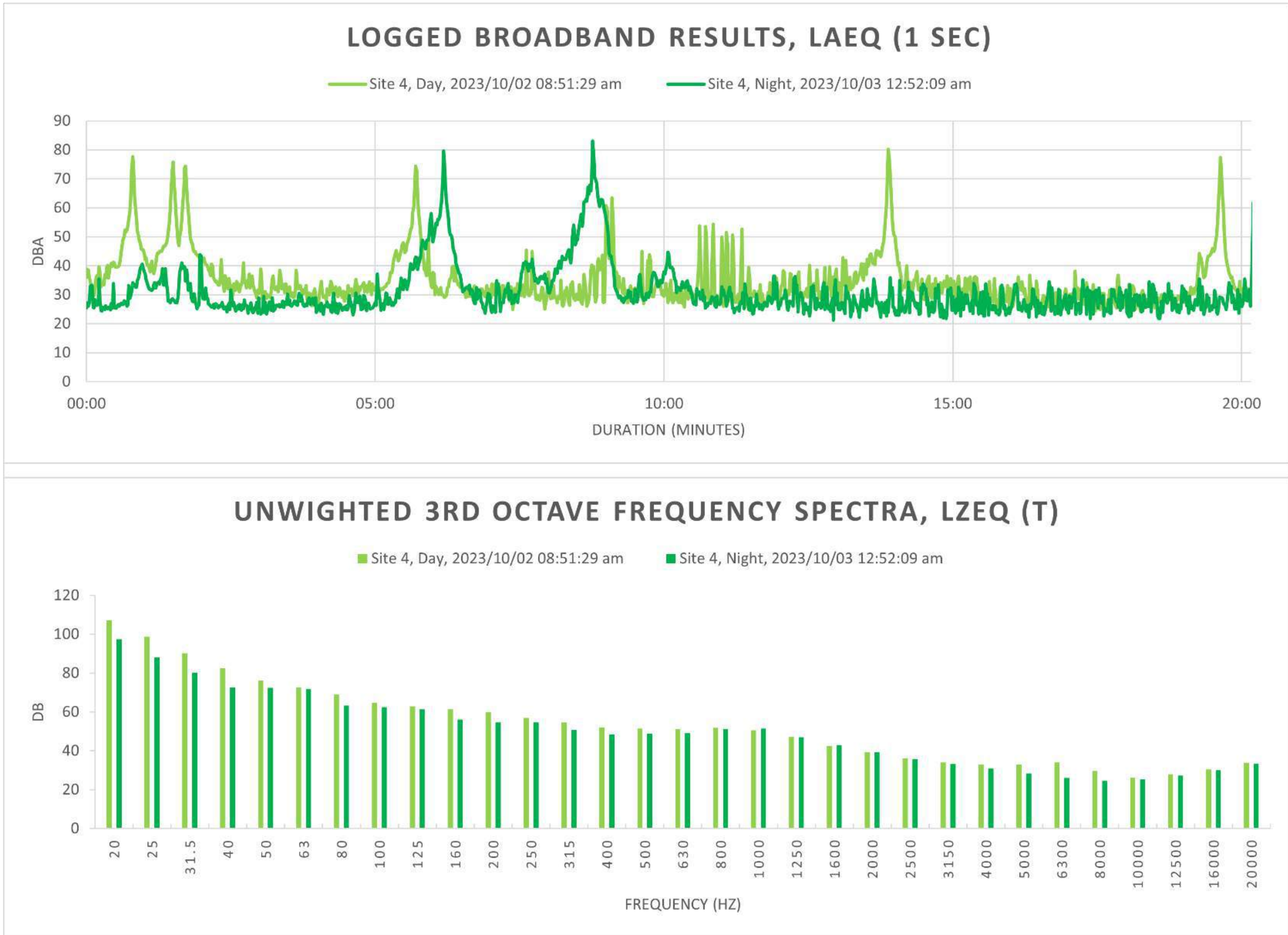


Figure D-4: Detailed day-time survey results for Site 4

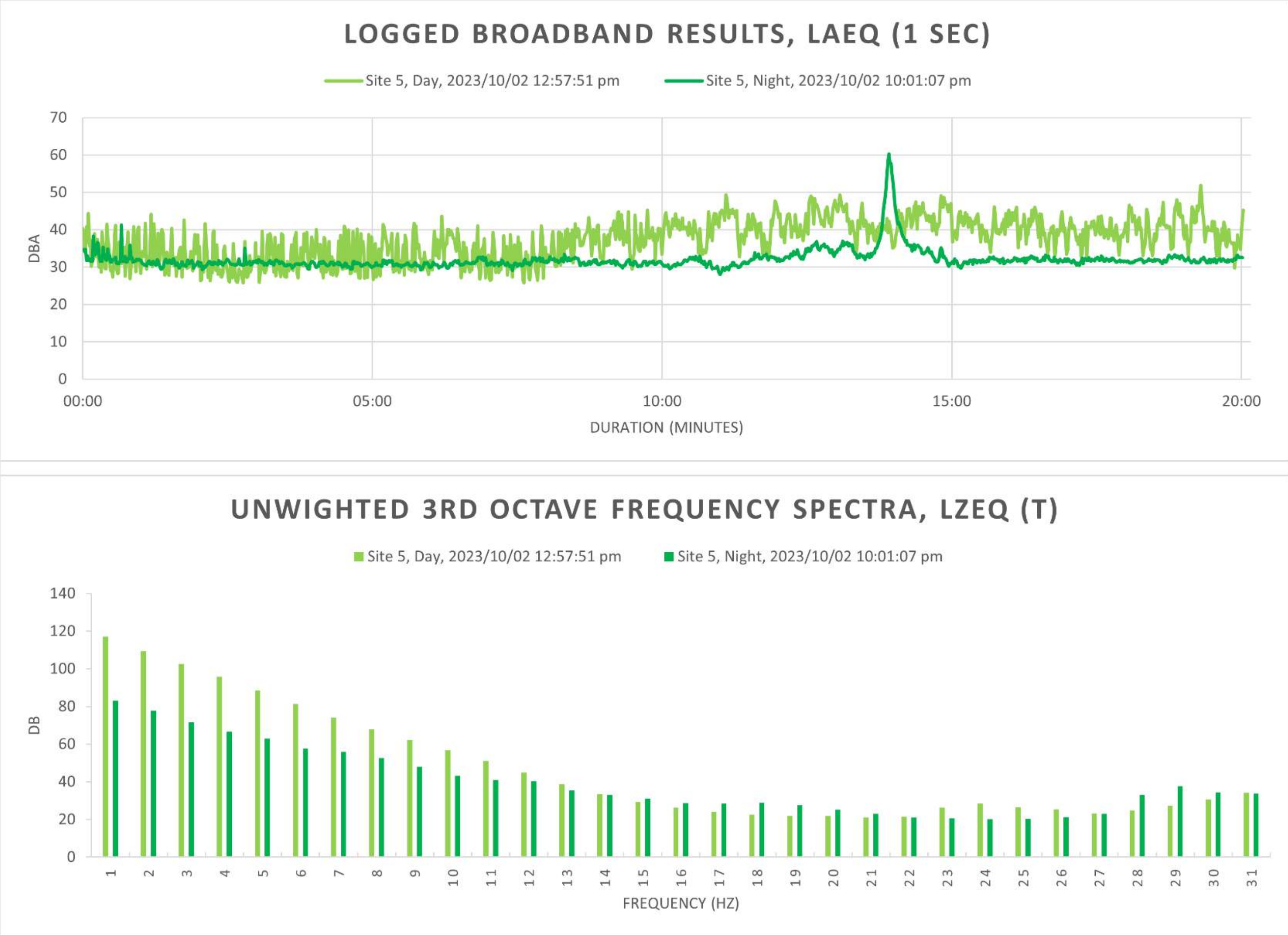
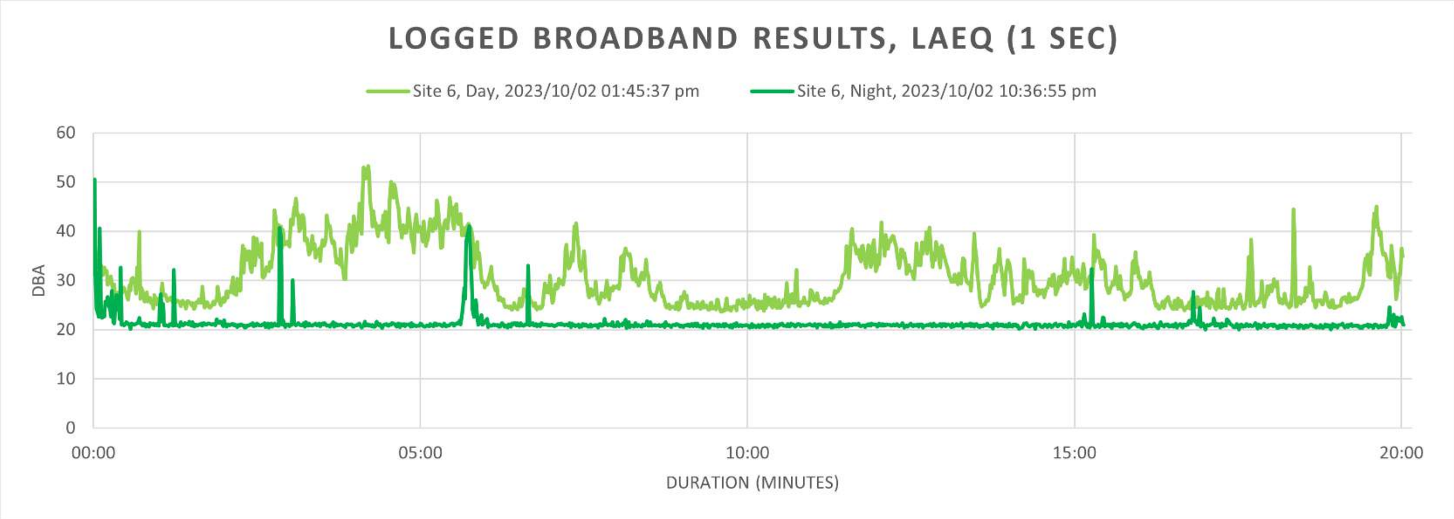


Figure D-5: Detailed day-time survey results for Site 5



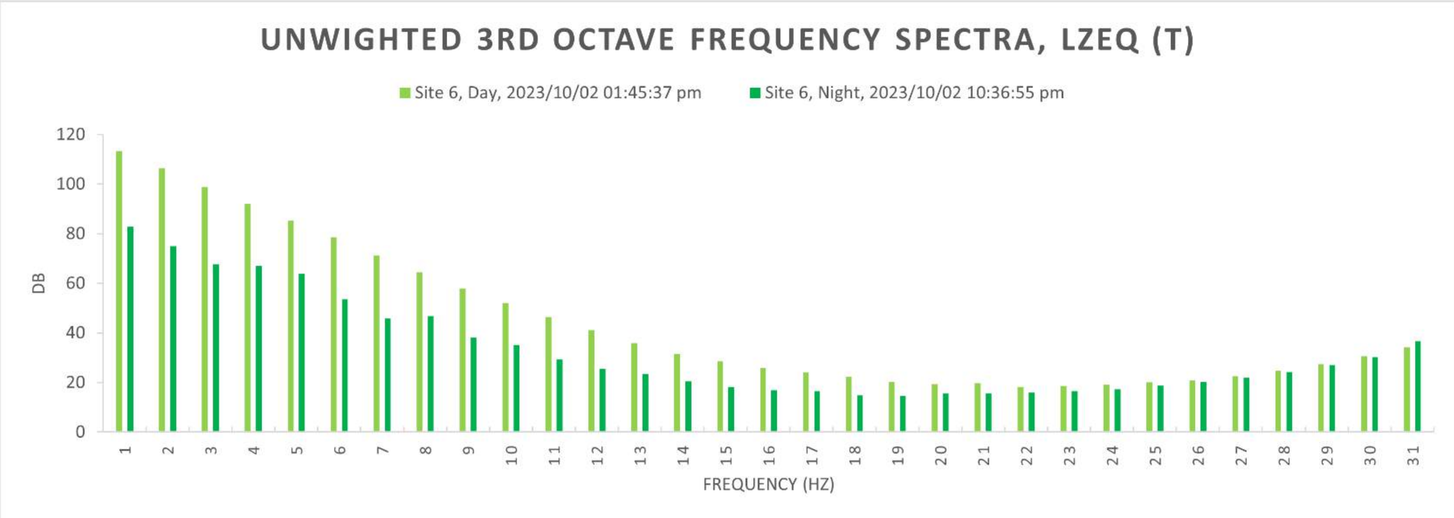


Figure D-6: Detailed day-time survey results for Site 6

Appendix E – Site Photographs

Facing north

Facing east

Facing south

Facing west

Figure E-1: Photographs of environmental noise survey Site 1

Facing north

Facing east

Facing south

Facing west

Figure E-2: Photographs of environmental noise survey Site 2

Facing north

Facing east

Facing south

Facing west

Figure E-3: Photographs of environmental noise survey Site 3

Facing north

Facing east

Facing south

Facing west

Figure E-4: Photographs of environmental noise survey Site 4

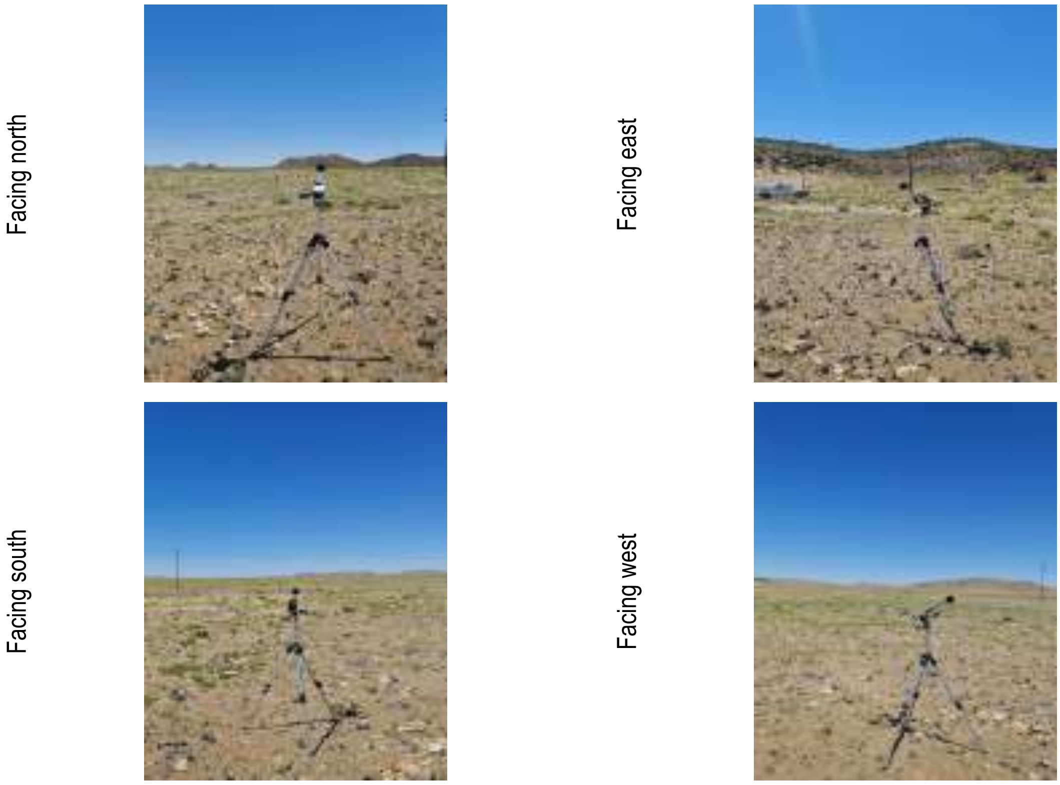


Figure E-5: Photographs of environmental noise survey Site 5

Figure E-6: Photographs of environmental noise survey Site 6

Blast Management & Consulting

Quality Service on Time

Report: Blast Impact Assessment Gergarub Mining Project		
Report Date:	27 September 2023	
BM&C Ref No:	ECC_Gergarub Mining Project_EIAReport_230912V00	
Client Ref No:	ECC-99-425-LET-19-A	
Document Authorised:	JD Zeeman	

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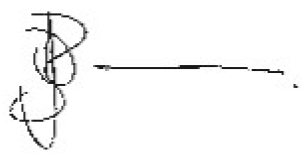
ii. Independence Declaration

A declaration that the specialist is independent in a form as may be specified by the competent authority

I, JD Zeeman, declare that -

- I act as the independent specialist in this application;
- I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant;
- I declare that there are no circumstances that may compromise my objectivity in performing such work;
- I have expertise in conducting the specialist report relevant to this application, including knowledge of the relevant legislation and any guidelines that have relevance to the proposed activity;
- I will comply with the applicable legislation;
- I have not, and will not engage in, conflicting interests in the undertaking of the activity;
- I undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing - any decision to be taken with respect to the application by the competent authority; and - the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority;
- All the particulars furnished by me in this form are true and correct.



Signature of the Specialist

iii. Document Control:

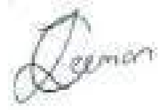
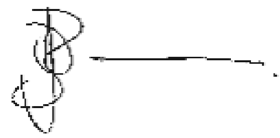
Name & Company	Responsibility	Action	Date	Signature
C Zeeman Blast Management & Consulting	Document Preparation	Report Prepared	12/09/2023	
JD Zeeman Blast Management & Consulting	Consultant	Report Finalised	27/09/2023	

Table of Contents

List of Acronyms used in this Report

a and b	Site Constant
BH	Blast Hole
BMC	Blast Management & Consulting
D	Distance (m)
E	Explosive Mass (kg)
EIA	Environmental Impact Assessment
Freq.	Frequency
GRP	Gas Release Pulse
POI	Points of Interest
PPV	Peak Particle Velocity
USBM	United States Bureau of Mine

List of Units used in this Report

%	percentage
cm	centimetre
Hz	frequency
kg	kilogram
m	metre
mm/s	millimetres per second

List of Figures

List of Tables

1 Executive Summary

Blast Management & Consulting (BMC) was contracted as part of Environmental Impact Assessment (EIA) to perform an initial review of possible impacts with regards to blasting operations in the proposed opencast mining operation.

Ground vibration is an aspect as a result from blasting operations. The report evaluates the effects of ground vibration from the underground blasting operations and intends to provide information, calculations, predictions, possible influences, and mitigations of blasting operations for this project.

The evaluation of effects yielded by blasting operations was evaluated over an area as wide as 1500 m from the underground mining area considered. The range of structures observed is typical roads (tar and gravel), heritage sites, powerlines and Hydrocencus boreholes.

The location of structures on surface around the underground works are such that the charges evaluated showed possible influences due to ground vibration. The closest structures observed are the Road (C1), Hydrocencus Boreholes and Heritage Sites. The influences do also vary with distances from the underground operations. The model used for evaluation does indicate varying levels ranging between 488.8 mm/s and low insignificant levels within the 1500 m area investigated. It will be imperative to ensure that a monitoring program is done to confirm levels of ground vibration to ensure that restriction on ground vibration levels is not exceeded.

There are no houses in proximity of the operations where human perception may have an effect. However it can be noted that perceptible levels of vibration that may be experienced up to 1420 m, unpleasant up to 530 m and intolerable up to 238 m for the underground blasting operation.

Various heritage sites which include rock shelters and burial mounts were identified by the Heritage Specialist. HIA indicated that the specific rock shelter (QRS 177/15 Rock Shelter) that is indicated as concern has a Low Enviro Dynamics vulnerability rating. The expected levels of ground vibration may have no significant influence. However it should be monitored for any negative influence.

Hydrocencus boreholes identified showed two borehole of concern due to location close to the underground works. A mitigation plan will be required to determine if these boreholes will be retained or replaced.

Mitigation of ground vibration was considered and discussed.

2 Introduction

Gergarub Mining and Exploration (Pty) Ltd owns the Gergarub project (Project), a joint venture agreement between Vedanta Zinc International (51 %), via its Namibian subsidiary Skorpion Zinc Mine, and Rosh Pinah Zinc Corporation, or Rosh Pinah (49 %) (JV).

The proposed Project area is located in the Oranjemund Constituency, 15km north of the town of Rosh Pinah in the Karas Region in southern Namibia.

The proposed Gergarub Project will be an underground mine using the long hole open stoping (LHOS) and Drift and Fill (DAF) with a backfill mining method.

Figure 1 indicates the project site locality.

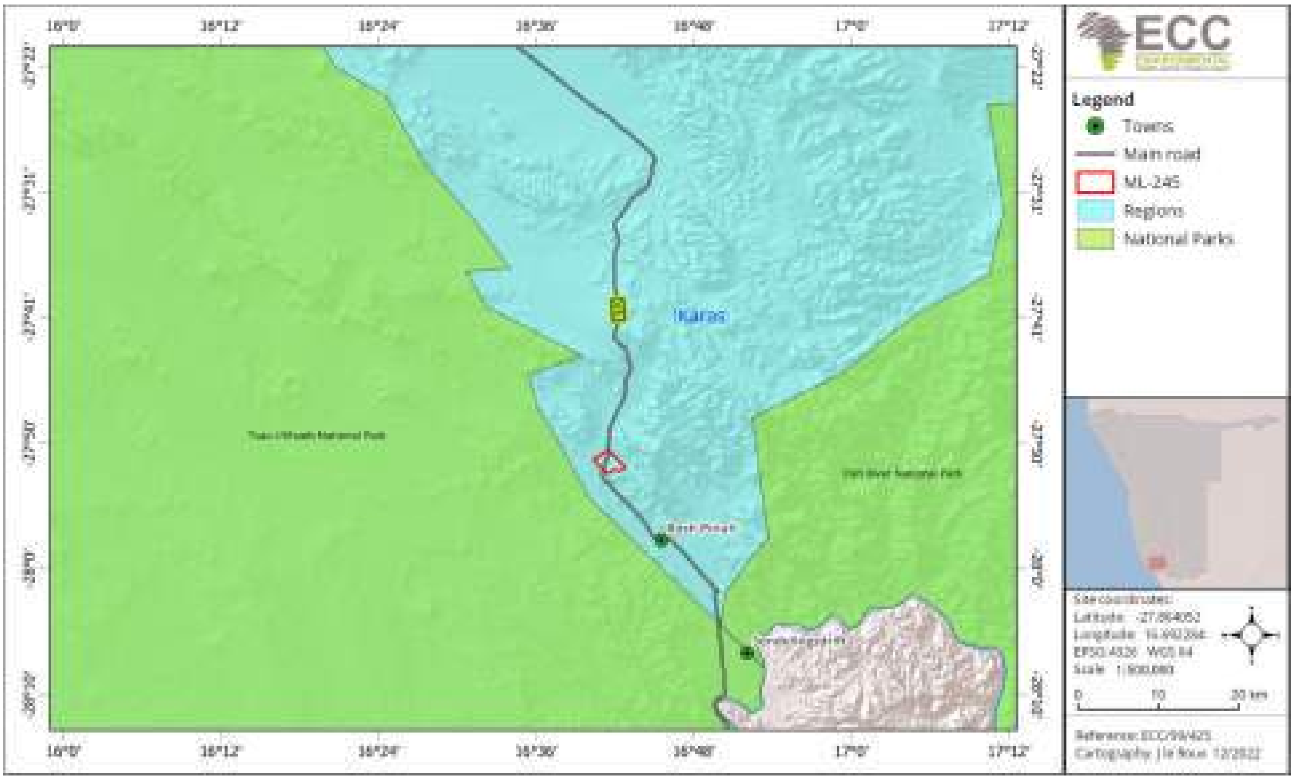


Figure 1: Project Locality

3 Objectives

The objectives of this document are outlining the expected environmental effects that blasting operations could have on the surrounding environment; and proposing the specific mitigation measures that will be required. This study investigates the related influences from blasting operations in this underground operation. Being an underground operation mainly ground vibration is the expected influence. The effect of ground vibration is investigated in relation to the underground works and surface surrounds which may include nearby private installations or infrastructure.

4 Scope of blast impact study

The scope of the study is determined by the terms of reference to achieve the objectives. The terms of reference can be summarised according to the following steps taken as part of the EIA study with regards to ground vibration, air blast and fly rock due to blasting operations.

- Background information of the proposed site.
- Blasting Operation Requirements.
- Site specific evaluation of blasting operations according to the following:
  - Evaluation of expected ground vibration levels from blasting operations at specific distances and on structures in surrounding areas;
  - Evaluation of expected ground vibration influence on neighbouring communities;
  - Evaluation of expected blasting influence on national and provincial roads surrounding the blasting operations if present;
  - Evaluation of expected ground vibration levels on water boreholes if present within 1500 m from blasting operations;
- Impact Assessment.
- Mitigations.
- Recommendations.
- Conclusion.

5 Study area

The proposed Project area is located in the Oranjemund Constituency, 15km north of the town of Rosh Pinah in the Karas Region in southern Namibia. The proposed Gergarub Project will be an underground mine using the long hole open stoping (LHOS) and Drift and Fill (DAF) with a backfill mining method. The centre point of the site is 27°52'4.97"S and 16°41'20.63"E. Figure 2 shows the location of the Gergarub deposit.

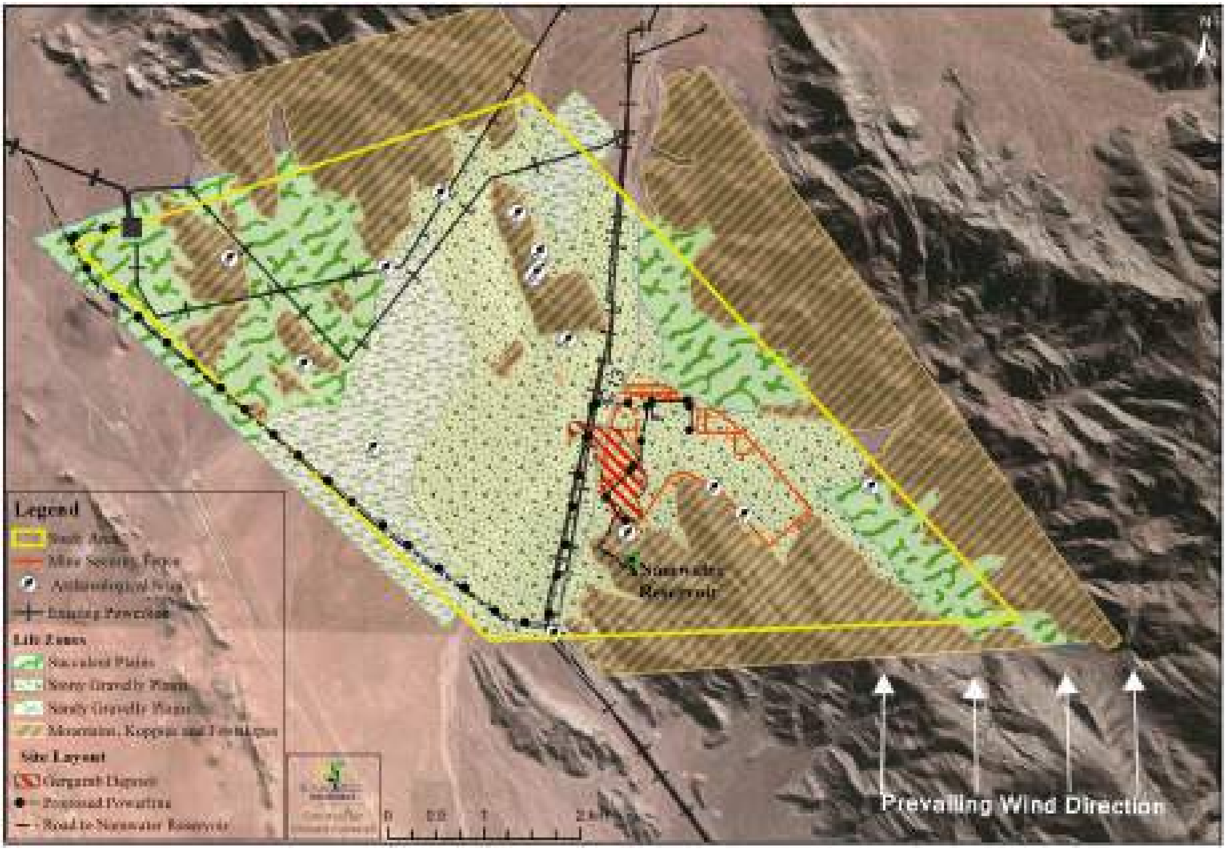


Figure 2: Locality Map

6 Methodology

The detailed plan of study consists of the following sections:

- A desktop impact assessment study was done.
- Site evaluation: This consists of evaluation of the mining operations and the possible influences from blasting operations. The methodology is modelling the expected impact based on the expected drilling and blasting information for the project. Various accepted mathematical equations are applied to determine the attenuation of ground vibration. These values are then calculated over the distance investigated from site and shown as amplitude level contours. Overlaying these contours on the location of the various receptors then gives an indication of the possible impacts and the expected results of potential impacts. Evaluation of each receptor according to the predicted levels then gives an indication of the possible mitigation measures to be applied. The possible environmental or social impacts are then addressed in the detailed EIA phase investigation.
- Reporting: All data is prepared in a single report and provided for review.

7 Season applicable to the investigation

The drilling and blasting operations are not season dependable. The investigation into the possible effects from blasting operations is not season bounded.

8 Assumptions and Limitations

The following assumptions have been made:

- The anticipated levels of influence estimated in this report are calculated using standard accepted methodology according to international and local regulations.
- The assumption is made that the predictions are a good estimate with significant safety factors to ensure that expected levels are based on worst case scenarios. These will have to be confirmed with actual measurements once the operation is active.
- No confirmation of the predicted values could be made.
- The project is at a stage that no formal blast designs were available. Basic planned layout of development ends was provided with indication of block caving operation to be done. This information was used and estimates were made for expected charge masses that may applicable.
- Being and underground operation the effects of air blast and fly rock does not have any value for the influence on the surface environment. Air blast and fly rock is then not be considered as part of the evaluation.
- The work done is based on the author’s knowledge and information provided by the project applicant.

9 Legal Requirements

The Namibian legislation has been considered. There is no direct reference in the consulted acts specifically regarding limiting levels for ground vibration and air blast. Impacts of mining are addressed but no specific reference to the blast impacts in relation to ground vibration and air blast. The following Namibian acts has been reviewed:

Petroleum Products Regulations : Petroleum Products And Energy Act 13 of 1990
Minerals (Prospecting And Mining) Act 33 of 1992
Mine Health & Safety Regulations, 10th Draft
Diamond Act 13 of 1999
Mineral Act, 1992
Annotated Statutes Explosives Act 26 of 1956.

The protocols applied in this document are based on the author’s experience, guidelines elicited by the literature research, client requirements and international standards. Where applicable South African legislation has been consulted as well.

The guidelines and safe blasting criteria applied in this study are as per internationally accepted standards, and specifically the United States Bureau of Mines (USBM) criteria for safe blasting for ground vibration and the recommendations on air blast.

10 Sensitivity of Project

A review of the project and the surrounding areas is done before any specific analysis is undertaken and sensitivity mapping is done, based on typical areas and distance from the proposed mining area. This sensitivity map uses distances normally associated where possible influences may occur and where influence is expected to be very low or none. Three different areas were identified in this regard:

- A highly sensitive area of 250 m around the mining area. In underground operations of this type it is expected that worst case influence may manifest within this 250 m. Levels of ground vibration and air blast are also expected to be higher closer to the underground operations.
- An area 250 m to 500 m on surface can be considered as being a medium sensitive area. In this area, the possibility of impact may still be expected, but it is lower. The expected level of influence may be low, but there may still be reason for concern, as levels could be low enough not to cause structural damage but still upset people.
- An area greater than 500 m is considered low sensitivity area. In this area, it is relatively certain that influences will be low with low possibility of damages and limited possibility to upset people.

Figure 3 shows the sensitivity mapping with the identified points of interest (POI) in the surrounding areas for the proposed project area. The specific influences will be determined through the work done for this project in this report.

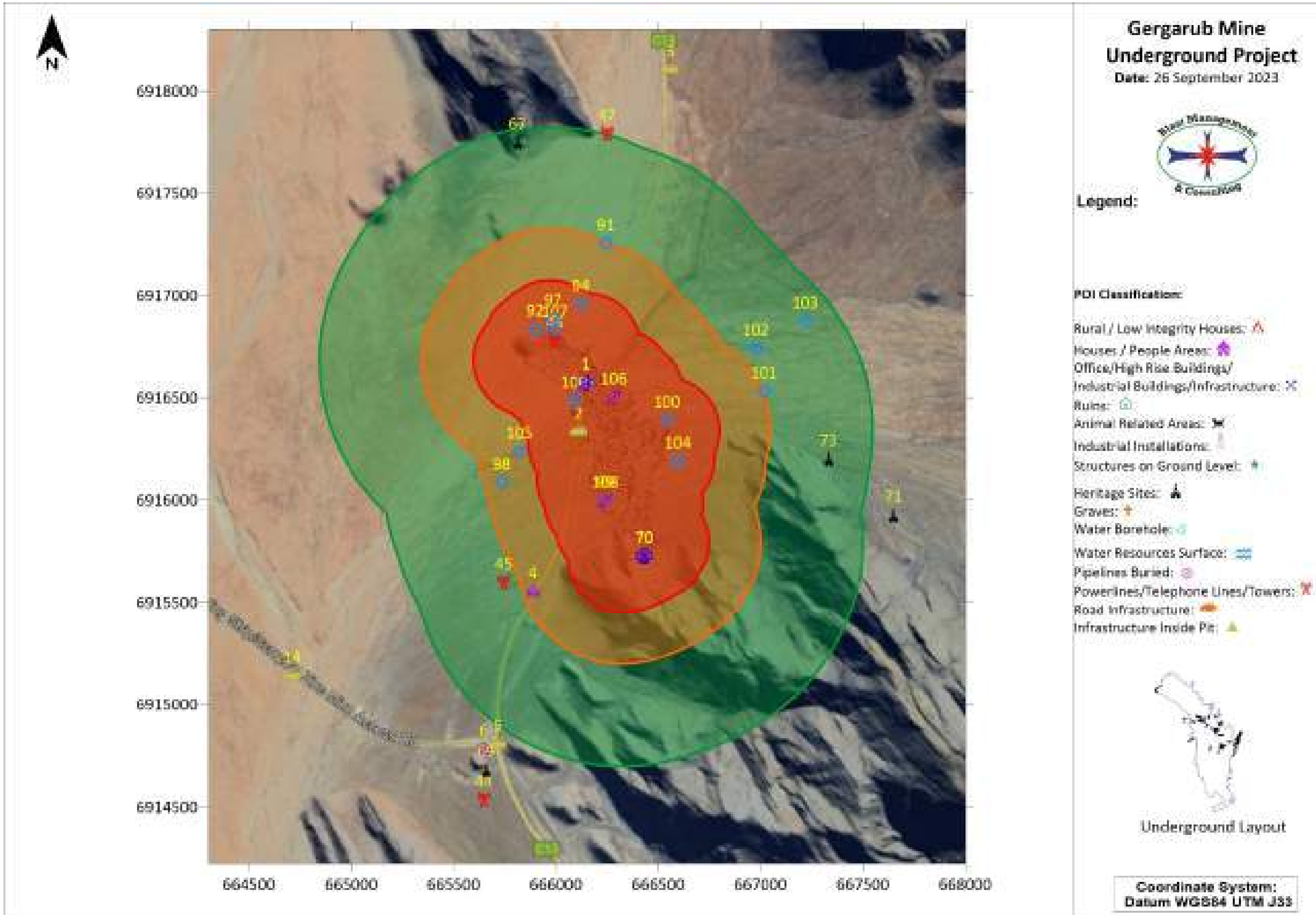


Figure 3: Identified sensitive areas

11 Consultation process

Consultation was only done with the client via the Environmental Practitioner. No other consultation with external parties was utilised. The work done is based on the author's knowledge, information provided by the client and information captured during site visit.

12 Influence from blasting operations

Blasting operations are required to break rock for excavation to access the targeted ore material. Explosives in blast holes provide the required energy to conduct the work. Ground vibration, air blast and fly rock are a result of the blasting process. Based on the regulations of the different acts consulted and international accepted standards these effects are required to be within certain limits. The following sections provide guidelines on these limits. As indicated, there are no specific South African ground vibration and air blast limit standard.

12.1 Ground vibration limitations on structures

Ground vibration is measured in velocity with units of millimetres per second (mm/s). Ground vibration can also be reported in units of acceleration or displacement if required. Different types of structures have different tolerances to ground vibration. A steel structure or a concrete structure will have a higher resistance to vibrations than a well-built brick and mortar house. A brick-and-mortar house will be more resistant to vibrations than a poorly constructed or a traditionally built mud house. Different limits are then applicable to the different types of structures. Limitations on ground vibration take the form of maximum allowable levels or intensity for different installations or structures. Ground vibration limits are also dependent on the frequency of the ground vibration. Frequency is the rate at which the vibration oscillates. Faster oscillation is synonymous with higher frequency and lower oscillation is synonymous with lower frequency. Lower frequencies are less acceptable than higher frequencies because structures have a low natural frequency. Significant ground vibration at low frequencies could cause increased structure vibrations due to the natural low frequency of the structure and this may lead to crack formation or damages.

Guidelines applied in this document consists of the United States Bureau of Mines (USBM) according to report RI8507[1] and levels recommended by BMC as safe for the structures observed.
The USBM criteria for safe blasting are applied as the industry standard where private structures are of concern. Ground vibration amplitude and frequency is recorded and analysed. The data is

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1. Siskind, D. E., Stagg, M.S., Kopp, J. W. and Dowding, C. H. (1980). Structural Response and Damage Produced by Ground Vibration from Surface Mine Blasting. Report of Investigations 8507. US Bureau of Mines.

then evaluated accordingly. The USBM graph is used for plotting of data and evaluating the data. Figure 4 below provides a graphic representation of the USBM analysis for safe ground vibration levels. The USBM graph is divided mainly into two parts. The red lines in the figure are the USBM criteria:

- Analysed data displayed in the bottom half of the graph shows safe ground vibration levels,
- Analysed data displayed in the top half of the graph shows potentially unsafe ground vibration levels:

Added to the USBM graph is a blue line and green dotted line that represents 6 mm/s and 12.5 mm/s additional criteria that are applied by BMC.

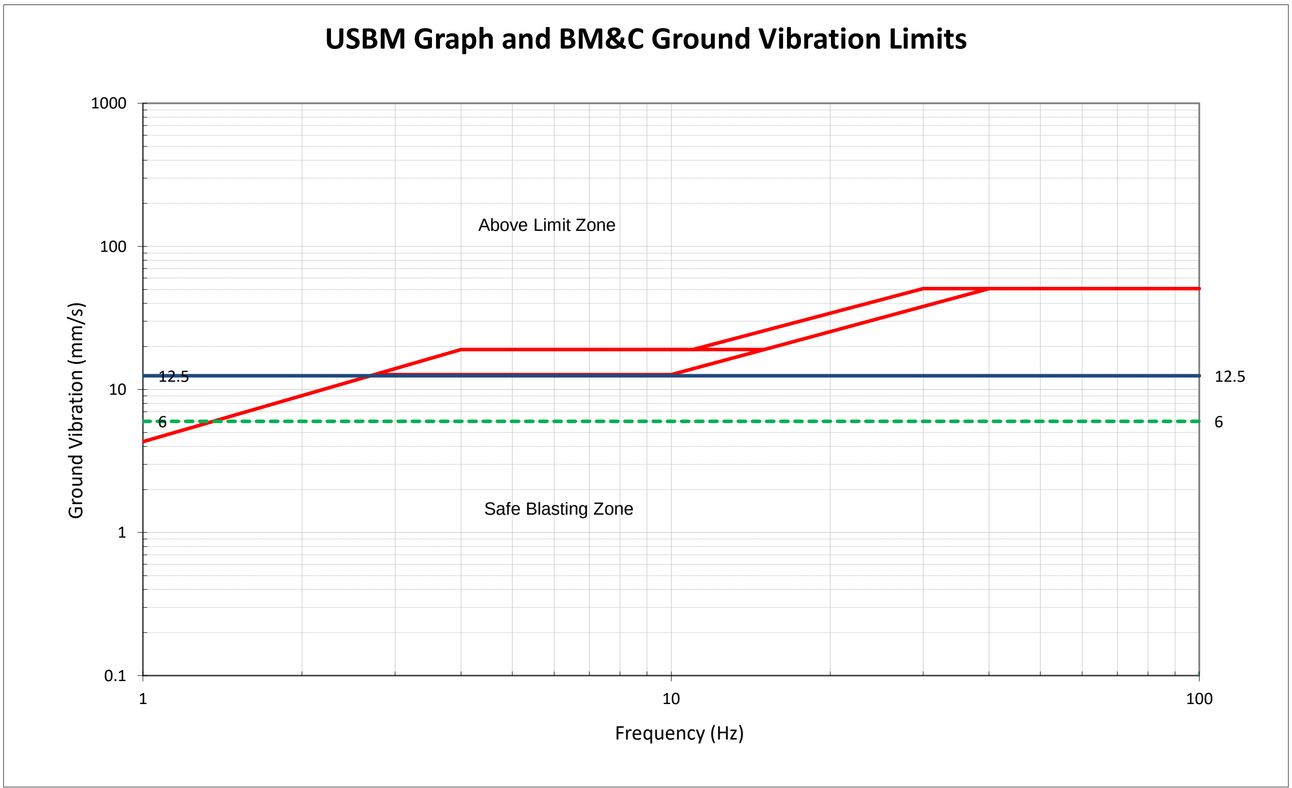


Figure 4: USBM Analysis Graph

The following additional limitations is used by BMC in general and that should be considered. These limitations were determined through research and prescribed by the various institutions; these are as follows:

- National roads/tar roads: 150 mm/s (BMC).
- Steel pipelines: 50 mm/s (Rand Water Board).
- Electrical lines: 75 mm/s (Eskom).
- Sasol Pipelines: 25 mms/s (Sasol).
- Railways: 150 mm/s (BMC).

- Concrete less than 3 days old: 5 mm/s [2].
- Concrete after 10 days: 200 mm/s [2].
- Sensitive plant equipment: 12 mm/s or 25 mm/s, depending on type. (Some switches could trip at levels of less than 25 mm/s.)[2].
- Waterwells or Boreholes: 50 mm/s [3].

BMC work considering the above limitations as well as the following:

- USBM criteria for safe blasting.
- Consideration of private structures in the area of influence.
- Should structures be in poor condition, the basic limit of 25 mm/s is halved to 12.5 mm/s or when structures are in very poor condition limits will be restricted to 6 mm/s. It is a standard accepted method to reduce the limit allowed with poorer condition of structures.
- Traditionally built mud houses are limited to 6 mm/s. The 6 mm/s limit is used due to unknowns on how these structures will react to blasting. There is also no specific scientific data available that would indicate otherwise.
- Input from other consultants in the field locally and internationally.

12.2 Ground vibration limitations and human perceptions

A further aspect of ground vibration and frequency of vibration that must be considered is human perceptions. It should be realized that the legal limit set for structures is significantly greater than the comfort zone of human beings. Humans and animals are sensitive to ground vibration and the vibration of structures. Research has shown that humans will respond to different levels of ground vibration at different frequencies.

Ground vibration is experienced at different levels; BMC considers only the levels that are experienced as “Perceptible”, “Unpleasant” and “Intolerable”. This is indicative of the human being’s perceptions of ground vibration and clearly indicates that humans are sensitive to ground vibration and humans perceive ground vibration levels of 0.8 mm/s as perceptible (See Figure 5). This guideline helps with managing ground vibration and the complaints that could be received due to blast induced ground vibration.

[2] Chiapetta F., Van Vreden A., 2000. Vibration/Air blast Controls, Damage Criteria, Record Keeping and Dealing with Complaints. 9th Annual BME Conference on Explosives, Drilling and Blasting Technology, CSIR Conference Centre, Pretoria, 2000.

[3] Berger P. R., & Associates Inc., Bradfordwoods, Pennsylvania, 15015, Nov 1980, Survey of Blasting Effects on Ground Water Supplies in Appalachia., Prepared for United States Department of Interior Bureau of Mines.

Indicated on Figure 5 is a blue solid line that indicates a ground vibration level of 12.5 mm/s and a green dotted line that indicates a ground vibration level of 6 mm/s. These are levels that are used in the evaluation.

Generally, people also assume that any vibration of a structure - windows or roofs rattling - will cause damage to the structure.

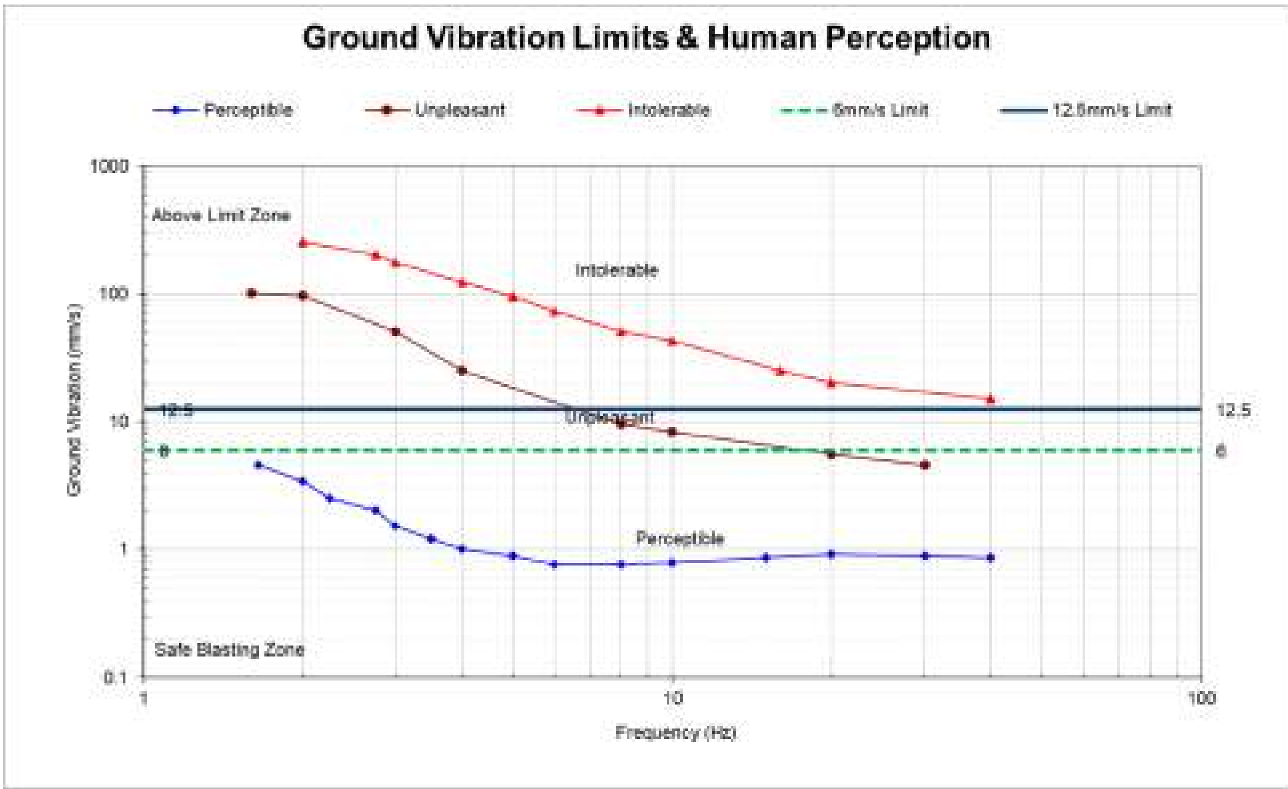


Figure 5: Ground Vibration and Human Perception

12.3 Vibration impact on provincial and national roads

The influence of ground vibration on tarred roads are expected when levels is in the order of 150 mm/s and greater. Or when there is actual movement of ground when blasting is done too close to the road or subsidence is caused due to blasting operations. Normally 100 blast hole diameters are a minimum distance between structure and blast hole to prevent any cracks being formed into the surrounds of a blast hole. Crack forming is not restricted to this distance. Improper timing arrangements may also cause excessive back break and cracks further than expected. Fact remain that blasting must be controlled in the vicinity of roads. Air blast from blasting does not have influence on road surfaces. There is no record of influence on gravel roads due to ground vibration. The only time damage can be induced is when blasting is done next to the road and there is movement of ground. Fly rock will have greater influence on the road as damage from falling debris may impact on the road surface if no control on fly rock is considered.

12.4 Vibration will upset adjacent communities

The effects of ground vibration will have influence on people. This effects tend to create noises on structures in various forms and people react to these occurrences even at low levels. As with human perception given above – people will experience ground vibration at very low levels. These levels are well below damage capability for most structures.
Much work has also been done in the field of public relations in the mining industry. Most probably one aspect that stands out is “Promote good neighborship”. This is achieved through communication and more communication with the neighbours. Consider their concerns and address them in a proper manner.

The first level of good practice is to avoid unnecessary problems. One problem that can be reduced is the public's reaction to blasting. Concern for a person's home, particularly where they own it, could be reduced by a scheme of precautionary, compensatory, and other measures which offer guaranteed remedies without undue argument or excuse.

Independent structural surveys are one way of ensuring good neighbour ship. There is a part of inherent difficulty in using surveys as the interpretation of changes in crack patterns that occur may be misunderstood. Cracks open and close with the seasonal changes of temperature, humidity and drainage, and numbers increase as buildings age. Additional actions need to be done in order to supplement the surveys as well such as monitoring of blast impacts.

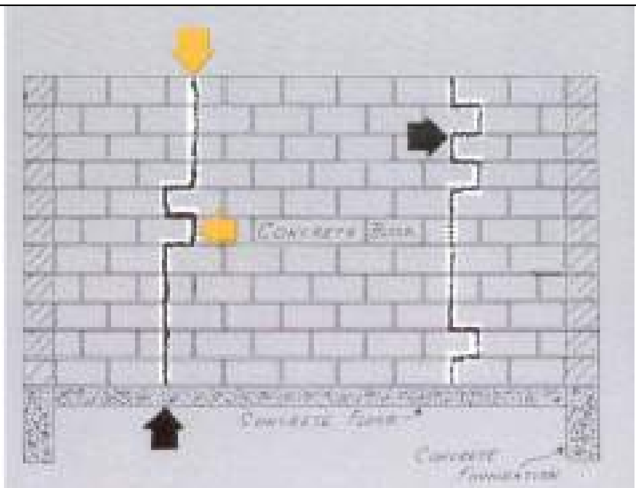
12.5 Cracking of houses and consequent devaluation

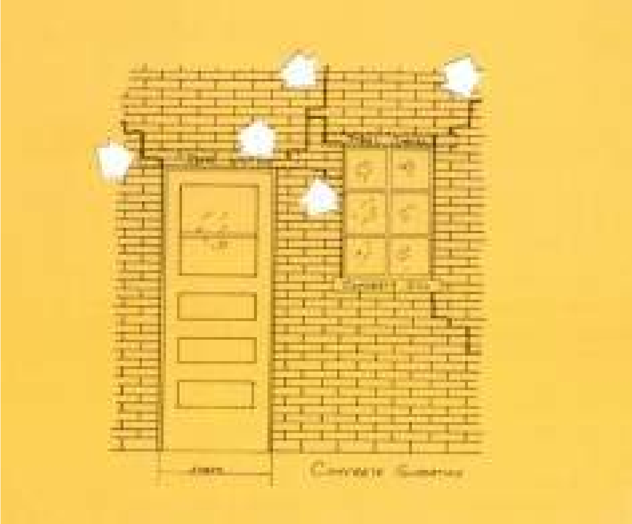
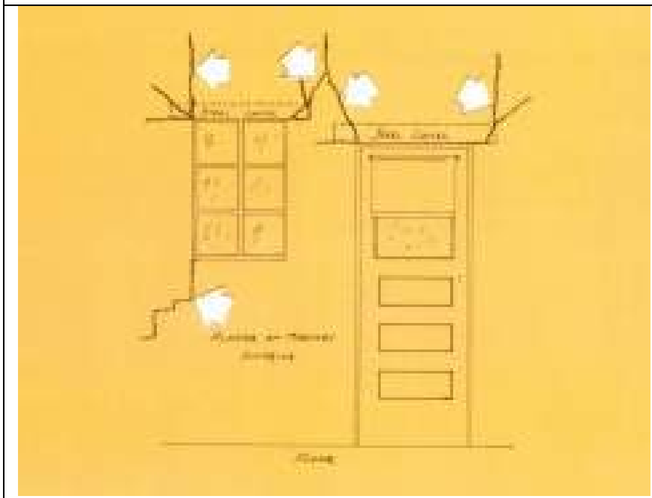
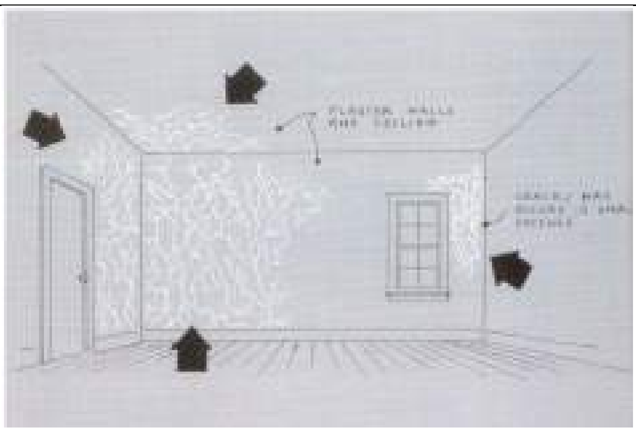
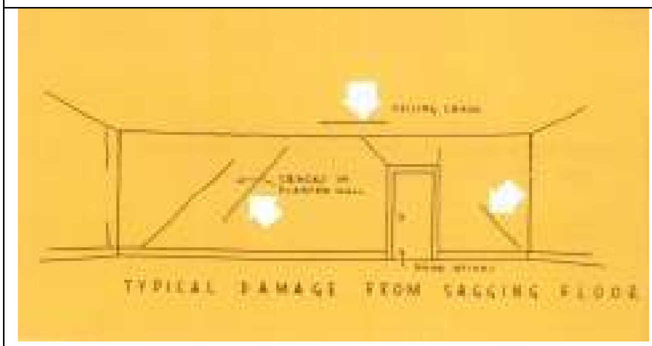
Houses in general have cracks. It is reported that a house could develop up to 15 non-blasting cracks a year. Ground vibration will be mostly responsible for cracks in structures if high enough and at continued high levels. The influences of environmental forces such as temperature, water, wind etc. are more reason for cracks that have developed. Visual results of actual damage due to blasting operations are limited. There are cases where it did occur, and a result is shown in Figure 6 below. A typical X crack formation is observed.

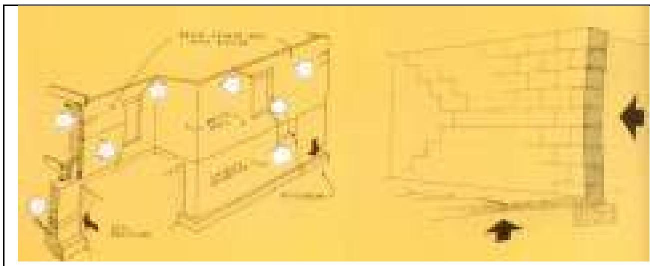
Figure 6: Example of blast induced damage.

The table below with figures show illustrations of non-blasting damage that could be found.

Table 1: Examples of typical non-blasting cracks

	Cracks Resulting from Shrinkage of Concrete Blocks

	Typical Lintel Cracks
	Typical Lintel Cracks
	"Crazing" Cracks on Plaster
	Plaster Cracks Caused by Sagging Floors

	Cracks Resulting from Foundational Failure

Observing cracks in the form indicated in Figure 6 on a structure will certainly influence the value as structural damage has occurred. The presence of general vertical cracks or horizontal cracks that are found in all structures does not need to indicate devaluation due to blasting operations but rather devaluation due to construction, building material, age, standards of building applied. Proper building standards are not always applied, and the general existence of cracks may be due to materials used. Thus, damage in the form of cracks will be present. Exact costing of devaluation for normal cracks observed is difficult to estimate. A property valuator will be required for this and I do believe that property value will include the total property and not just the house alone. Mining operations may not have influence to change the status quo of any property.

13 Baseline Structure Profile

Work was done familiarising oneself with the surroundings. The site was reviewed using Google Earth imagery. All possible structures in a possible influence area are identified. Information sought during the review was to identify surface structures present in a 1500 m radius from the proposed underground operation, which will require consideration during modelling of blasting operations, e.g. houses, general structures, power lines, pipelines, reservoirs, mining activity, roads, shops, schools, gathering places, possible historical sites, etc. A list was prepared of all structures in the vicinity of the operation. The list includes structures and POI within the 1500 m boundary – see Table 3 below. A list of structure locations was required to determine the allowable ground vibration limits. Figure 3 shows an aerial view of the planned area of the underground operations and surroundings with POIs. The type of POIs identified is grouped into different classes. These classes are indicated as “Classification” in Table 2. The classification used is a BMC classification and does not relate to any standard or national or international code or practice. Table 2 shows the descriptions for the classifications used.

Table 2: POI Classification used

Class	Description
1	Rural Building and structures of poor construction
2	Private Houses and people sensitive areas
3	Office, High-rise buildings and Industrial buildings / Infrastructure
4	Ruins
5	Animal related installations and animal sensitive areas
6	Industrial Installations
7	Earth like structures – no surface structure

Class	Description
8	Heritage sites (buildings, infrastructure, activity)
9	Graves
10	Water Borehole
11	Water Resources Surface
12	Pipelines Buried
13	Powerlines / Telephone Lines / Towers
14	Road Infrastructure
15	Infrastructure Inside Pit

Table 3: List of points of interest identified (WGS84 – LO 15°)

Tag	Description	Classification	Y	X	Z
1	C13 Road	14	666144.94	6916573.08	610.4
2	C13 Road	14	666110.76	6916334.46	607.8
3	C13 Road	14	666558.09	6918104.41	640.1
4	Buildings/Structures / Weighbridge	2	665887.85	6915552.95	595.5
5	Road Intersection	14	665716.77	6914807.13	579.4
6	Buildings/Structures	2	665646.24	6914783.29	577.8
44	Power Lines/Pylons	13	665645.70	6914535.45	570.3
45	Power Lines/Pylons	13	665744.70	6915597.04	593
46	Power Lines/Pylons	13	665994.21	6916777.25	611.4
47	Power Lines/Pylons	13	666249.82	6917789.87	632
67	Heritage Site (QRS 177/12 Large Rock Shelter)	8	665810.15	6917747.73	632.2
69	Heritage Site (QRS 177/14 Rock Shelter)	8	665657.72	6914681.19	578
70	Heritage Site (QRS 177/15 Rock Shelter)	8	666432.33	6915725.54	618.4
71	Heritage Site (QRS 177/16 Suspected Burial Mound)	8	667647.40	6915924.82	646.2
73	Heritage Site (QRS 177/18 Confirmed Burial Cairn)	8	667331.27	6916200.72	634
91	Hydrocencus Borehole (SPDD004)	10	666243.61	6917253	612.4
92	Hydrocencus Borehole (SPDD005)	10	665899.04	6916834.4	660.3
94	Hydrocencus Borehole (SPDD012)	10	666121.33	6916955.5	657.5
97	Hydrocencus Borehole (SPDD049)	10	665985.41	6916884.2	598.1
98	Hydrocencus Borehole (SPDD093)	10	665735.08	6916083.1	606.8
99	Hydrocencus Borehole (SPDD099)	10	666242.06	6915996.4	616.5
100	Hydrocencus Borehole (SPDD100)	10	666541.93	6916387.8	626.5
101	Hydrocencus Borehole (SPDD127)	10	667016.62	6916529.8	625.4
102	Hydrocencus Borehole (SPDD129)	10	666976.2	6916739.8	631.8
103	Hydrocencus Borehole (SPDD134)	10	667218.34	6916871.6	616.4
104	Hydrocencus Borehole (SPDD154)	10	666595.31	6916188.7	601
105	Hydrocencus Borehole (SPDD159)	10	665820.88	6916234.9	610.5
106	Hydrocencus Borehole (SPDD228)	10	666282.5	6916501.1	611.7
107	Hydrocencus Borehole (SPDD265)	10	665994.51	6916829.8	606.7
108	Hydrocencus Borehole (SPDD278)	10	666241.06	6915995.3	607.3
109	Hydrocencus Borehole (SPDD289)	10	666089.23	6916483.9	610.4

14 Blasting Operations

In order to evaluate the possible influence from blasting operations with regards to ground vibration a planned blast design is required to determine possible influences.

Planned development blast is according to the following Figure 7.

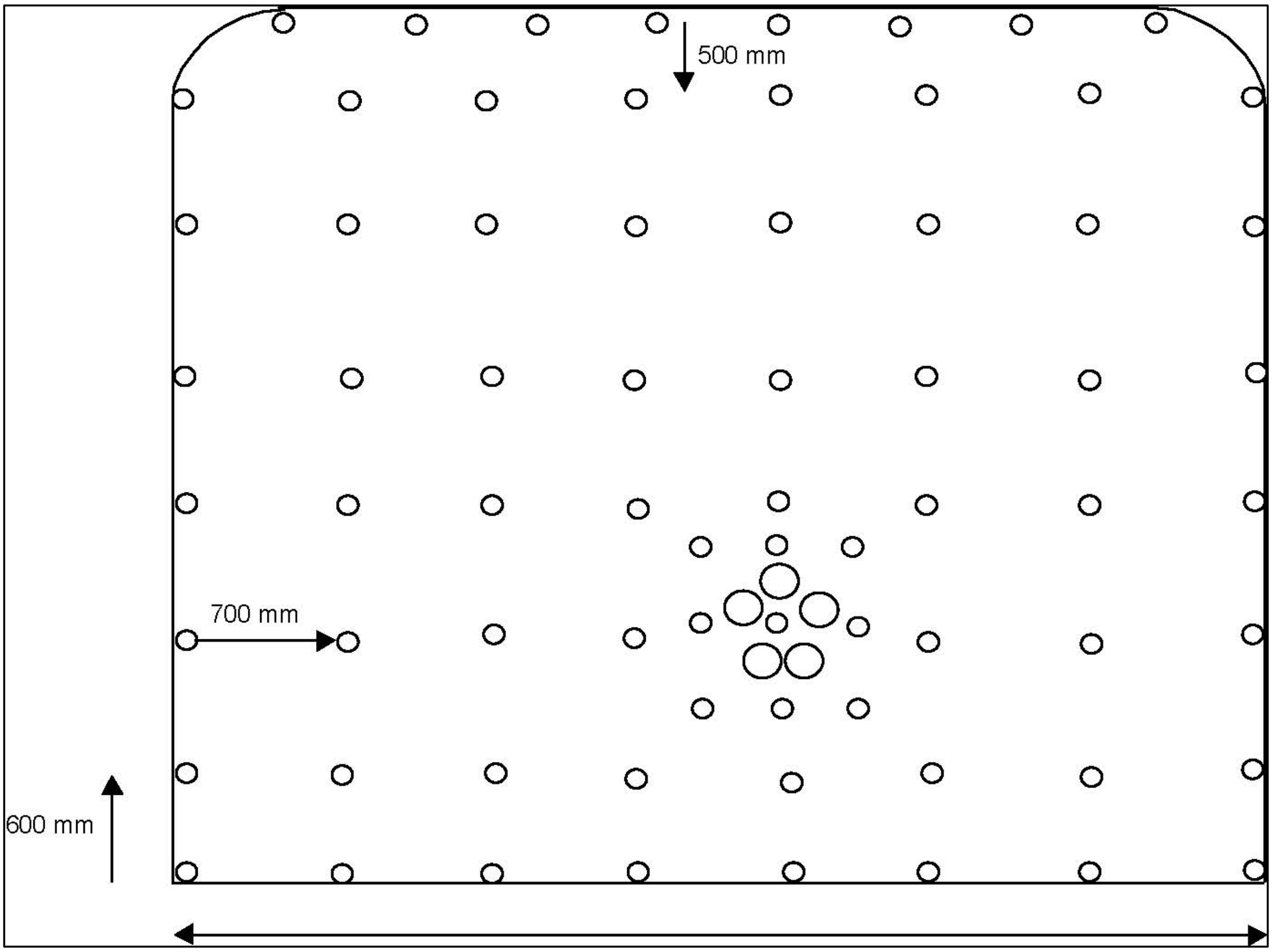


Figure 7: Example of development blast layout planned

Based on general timing a maximum of 16 blastholes may be tied on the same delay number. This with the planned 6 m depth 45 mm diameter blastholes will results in a charge mass of 121 kg detonating on one delay number.
The block caving is expected to have 15 m long 64 mm diameter blastholes. In a ring design and timing a possible total mass equivalent of 8 blastholes may detonated in the same time delay. This results in a charge mass of 426 kg per delay.

Evaluation of the blasting operations considered a minimum charge and a maximum charge. The minimum charge was derived from the development end blasting operations and the maximum charge from block caving operations. The minimum charge relates to 121 kg and the maximum charge relates to 426 kg. These values were applied in all predictions for ground vibration and air blast.

14.1 Ground Vibration

Predicting ground vibration and possible decay, a standard accepted mathematical process of scaled distance is used. The equation applied (Equation 1) uses the charge mass and distance with two site constants. The site constants are specific to a site where blasting is to be done. In the absence of measured values an acceptable standard set of constants is applied.

Equation 1:

$$PPV = a(\frac{D}{\sqrt{E}})^{-b}$$

Where:
PPV = Predicted ground vibration (mm/s)
a = Site constant
b = Site constant
D = Distance (m)
E = Explosive Mass (kg)

Applicable and accepted factors a and b for new operations is as follows:
Factors:
a = 1143
b = -1.65

Utilizing the abovementioned equation and the given factors, allowable levels for specific limits and expected ground vibration levels can then be calculated for various distances.

Review of the type of structures that are found within the possible influence zone of the proposed mining area and the limitations that may be applicable, different limiting levels of ground vibration will be required. This is due to the typical structures and installations observed surrounding the site and location of the project area. Structure types and qualities vary greatly and this calls for limits to be considered as follows: 6 mm/s, 12.5 mm/s levels and 25 mm/s at least.

Based on the designs presented on expected drilling and charging design, the following Table 4 shows expected ground vibration levels (PPV) for various distances calculated at the two different charge masses. The charge masses are 121 kg and 426 kg for the Pit areas.

Table 4: Expected Ground Vibration at Various Distances from Charges Applied in this Study

No.	**Distance (m)**	**Expected PPV (mm/s) for 121 kg Charge**	**Expected PPV (mm/s) for 426 kg Charge**
1	50.0	94.0	265.5
2	100.0	48.1	136.0
3	150.0	15.3	43.3
4	200.0	9.5	27.0
5	250.0	6.6	18.7
6	300.0	4.9	13.8
7	400.0	3.0	8.6
8	500.0	2.1	5.9
9	600.0	1.6	4.4
10	700.0	1.2	3.4

No.	Distance (m)	Expected PPV (mm/s) for 121 kg Charge	Expected PPV (mm/s) for 426 kg Charge
11	800.0	1.0	2.7
12	900.0	0.8	2.3
13	1000.0	0.7	1.9
14	1250.0	0.5	1.3
15	1500.0	0.3	1.0

15 Operational Phase: Impact Assessment and Mitigation Measures

The area on surface surrounding the proposed mining area was reviewed for structures, traffic, roads, human interface, animals' interface etc. Various installations and structures were observed. These are listed in Table 3. This section concentrates on the outcome of modelling the possible effects of ground vibration specifically to these points of interest or possible interfaces. In evaluation, the charge mass scenarios selected as indicated in section 14 is considered with regards to ground vibration and air blast.

Ground vibration and air blast was calculated from an outline of the top levels of the underground operations and modelled accordingly. Blasting at deeper levels will certainly have lesser influence on the surroundings. A worst case is then applicable with calculation from top elevations of the underground operations. As explained previously reference is only made to some structures and these references covers the extent of all structures surrounding the mine.

The following aspects with comments are addressed for each of the evaluations done:

- Ground Vibration Modelling Results
- Ground Vibration and human perception
- Vibration impact on national and provincial road
- Vibration will upset adjacent communities
- Cracking of houses and consequent devaluation

Please note that this analysis does not take geology or actual final drill and blast pattern into account. The data is based on good practise applied internationally and considered very good estimates based on the information provided and supplied in this document.

15.1 Review of expected ground vibration

Presented herewith are the expected ground vibration level contours and discussion of relevant influences. Expected ground vibration levels were calculated for each POI identified surrounding the mining area and evaluated with regards to possible structural concerns and human perception. Tables are provided for each of the different charge models done with regards to:

- "Tag" No. is the number corresponding to the POI figures.
- "Description" indicates the type of the structure.
- "Distance" is the distance between the structure and edge of the pit area.

- "Specific Limit" is the maximum limit for ground vibration at the specific structure or installation.
- "Predicted PPV (mm/s)" is the calculated ground vibration at the structure.
- The "Structure Response @ 10Hz and Human Tolerance @ 30Hz" indicates the possible concern and if there is any concern for structural damage or potential negative human perception, respectively. Indicators used are "perceptible"," unpleasant", "intolerable" which stems from the human perception information given and indicators such as "high" or "low" is given for the possibility of damage to a structure. Levels below 0.76 mm/s could be considered to have negligible possibility of influence.

Ground vibration is calculated and modelled for the underground area at the minimum and maximum charge mass at specific distances from the underground operations. The charge masses applied are according to blast information as discussed in Section 14. These levels are then plotted and overlaid with current mining plans to observe possible influences at structures identified. Structures or POI's for consideration are also plotted in this model. Ground vibration predictions were done considering distances ranging from 50 m to 1500 m on surface around the underground operation area.

The simulation provided shows ground vibration contours only for a limited number of levels. The levels used are considered the basic limits that will be applicable for the type of structures observed surrounding the pit area. These levels are: 6 mm/s, 12.5 mm/s, 25 mm/s and 50 mm/s. This enables immediate review of possible concerns that may be applicable to any of the privately-owned structures, social gathering areas or sensitive installations.

Data is provided as follows: Vibration contours; a table with predicted ground vibration values and evaluation for each POI. Additional colour codes used in the tables are as follows:

Structure Evaluations:
Vibration levels higher than proposed limit applicable to Structures / Installations is coloured "Red"
People's Perception Evaluation:
Vibration levels indicated as Intolerable on human perception scale is coloured "Red"
Vibration levels indicated as Unpleasant on human perception scale is coloured "Mustard"
Vibration levels indicated as Perceptible on human perception scale is coloured "Light Green"
POI's that are found inside the pit area is coloured "Olive Green"

Simulations for expected ground vibration levels from minimum and maximum charge mass are presented below.

15.1.1 Ground vibration minimum charge mass per delay – 121 kg

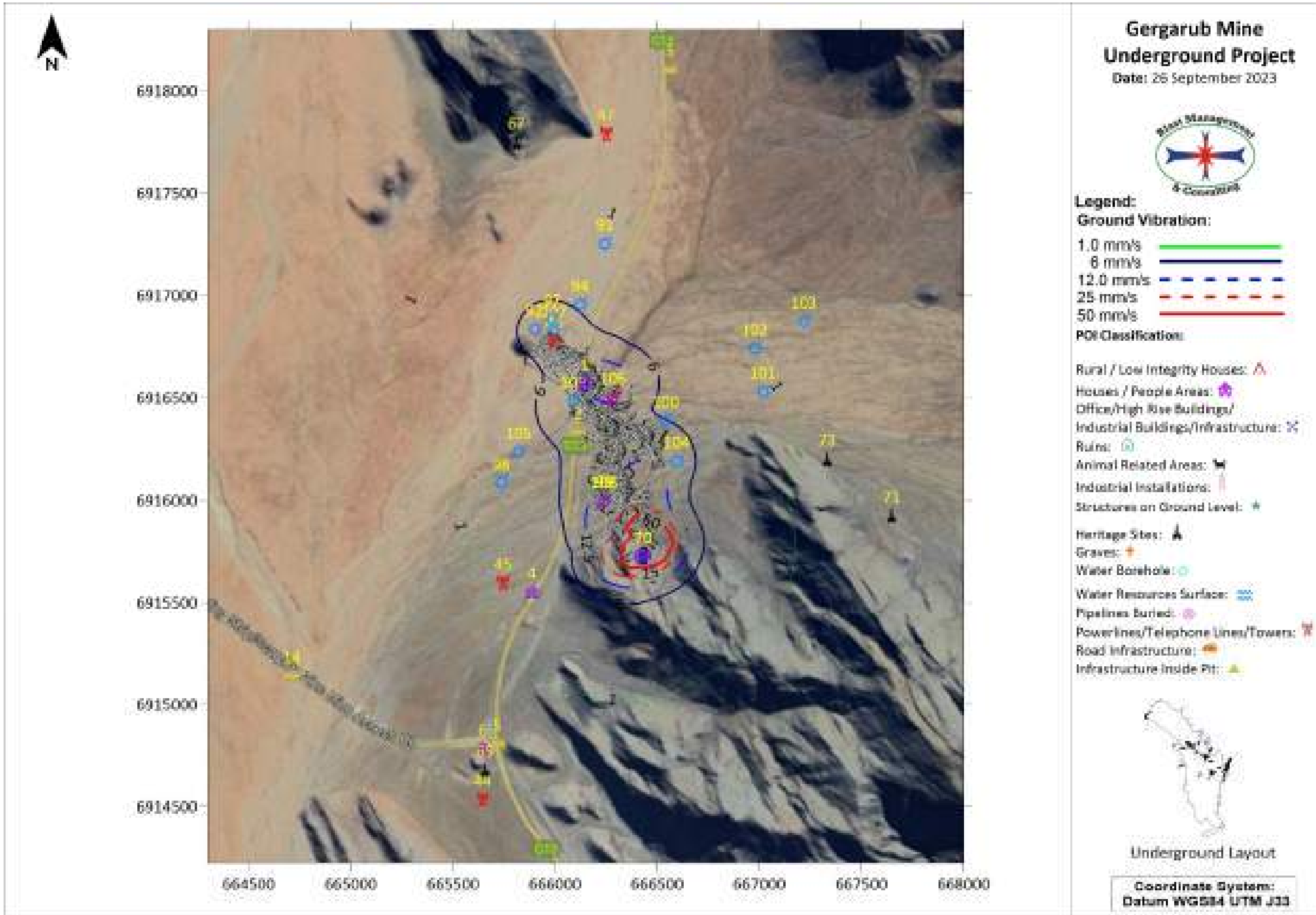


Figure 8: Ground vibration influence from minimum charge per delay

Table 5: Ground vibration evaluation for minimum charge

Tag	Description	Ground Vibration Limit (mm/s)	Distance (m)	Min Charge Total Mass/Delay (kg)	Min Charge Predicted PPV (mm/s)	Min Charge Structure Response @ 10Hz	Min Charge Human Tolerance @ 30Hz
1	C13 Road	150	154	121	14.7	Acceptable	N/A
2	C13 Road	150	179	121	11.5	Acceptable	N/A
3	C13 Road	150	1421	121	0.4	Acceptable	N/A
4	Buildings/Structures / Weighbridge	25	452	121	2.5	Acceptable	Perceptible
5	Road Intersection	150	1077	121	0.6	Acceptable	N/A
6	Buildings/Structures	25	1136	121	0.5	Acceptable	Too Low
44	Power Lines/Pylons	75	1345	121	0.4	Acceptable	N/A
45	Power Lines/Pylons	75	577	121	1.7	Acceptable	N/A
46	Power Lines/Pylons	75	170	121	12.4	Acceptable	N/A
47	Power Lines/Pylons	75	1023	121	0.6	Acceptable	N/A
67	Heritage Site (QRS 177/12 Large Rock Shelter)	50	958	121	0.7	Acceptable	Too Low
69	Heritage Site (QRS 177/14 Rock Shelter)	50	1214	121	0.5	Acceptable	Too Low
70	Heritage Site (QRS 177/15 Rock Shelter)	50	35	121	173.1	Problematic	Intolerable
71	Heritage Site (QRS 177/16 Suspected Burial Mound)	50	1157	121	0.5	Acceptable	Too Low
73	Heritage Site (QRS 177/18 Confirmed Burial Cairn)	50	832	121	0.9	Acceptable	Perceptible
91	Hydrocencus Borehole (SPDD004)	50	530	121	1.9	Acceptable	N/A
92	Hydrocencus Borehole (SPDD005)	50	230	121	7.6	Acceptable	N/A
94	Hydrocencus Borehole (SPDD012)	50	282	121	5.4	Acceptable	N/A
97	Hydrocencus Borehole (SPDD049)	50	167	121	12.8	Acceptable	N/A
98	Hydrocencus Borehole (SPDD093)	50	485	121	2.2	Acceptable	N/A
99	Hydrocencus Borehole (SPDD099)	50	142	121	16.7	Acceptable	N/A
100	Hydrocencus Borehole (SPDD100)	50	238	121	7.2	Acceptable	N/A
101	Hydrocencus Borehole (SPDD127)	50	604	121	1.5	Acceptable	N/A
102	Hydrocencus Borehole (SPDD129)	50	695	121	1.2	Acceptable	N/A
103	Hydrocencus Borehole (SPDD134)	50	947	121	0.7	Acceptable	N/A
104	Hydrocencus Borehole (SPDD154)	50	161	121	13.7	Acceptable	N/A
105	Hydrocencus Borehole (SPDD159)	50	362	121	3.6	Acceptable	N/A
106	Hydrocencus Borehole (SPDD228)	50	135	121	18.3	Acceptable	N/A
107	Hydrocencus Borehole (SPDD265)	50	162	121	13.5	Acceptable	N/A
108	Hydrocencus Borehole (SPDD278)	50	134	121	18.4	Acceptable	N/A
109	Hydrocencus Borehole (SPDD289)	50	159	121	13.9	Acceptable	N/A

15.1.2 Ground vibration maximum charge mass per delay – 426 kg

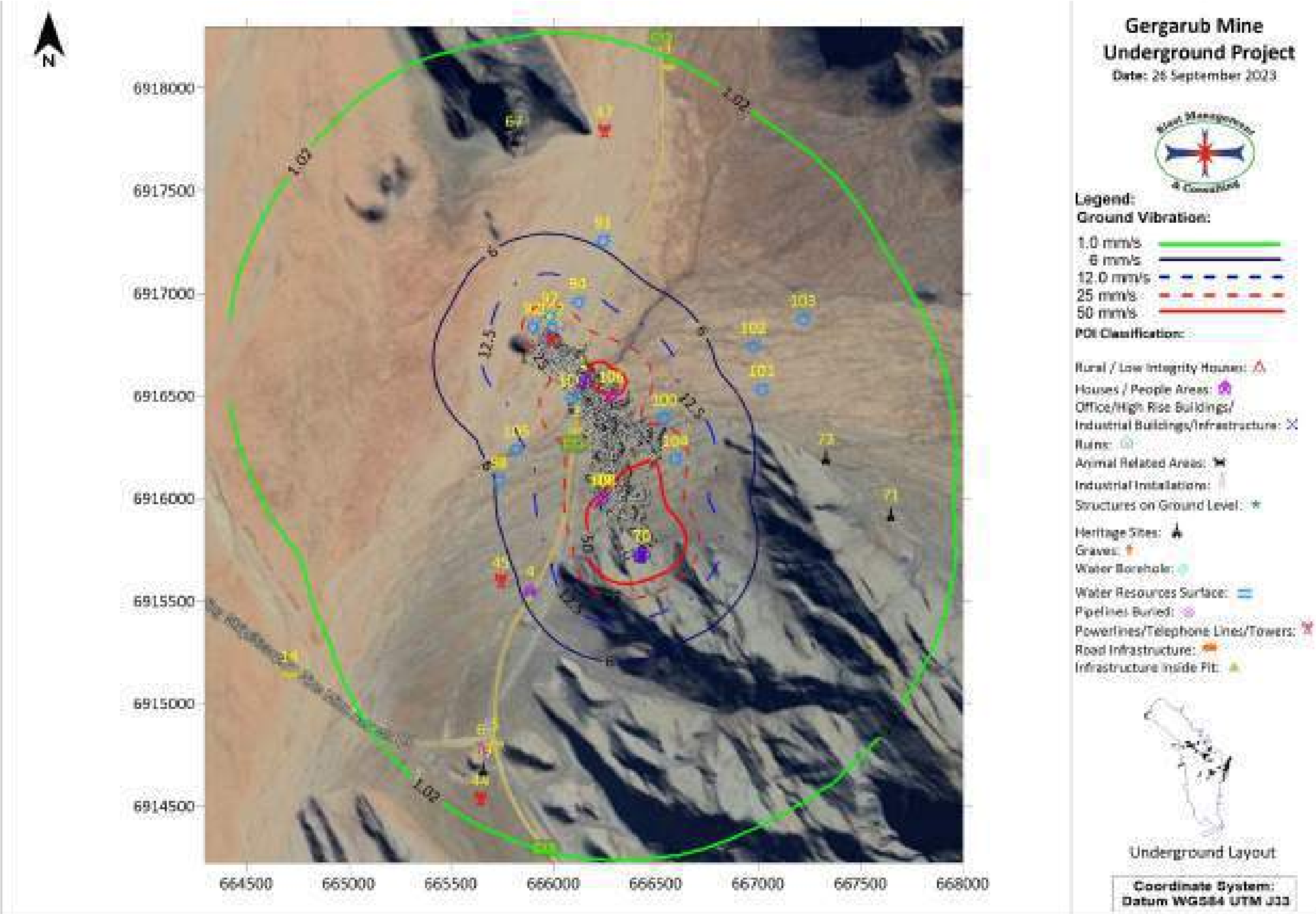


Figure 9: Ground vibration influence from maximum charge per delay

Table 6: Ground vibration evaluation for maximum charge

Tag	Description	Ground Vibration Limit (mm/s)	Distance (m)	Max Charge Total Mass/Delay (kg)	Max Charge Predicted PPV (mm/s)	Max Charge Structure Response @ 10Hz	Max Charge Human Tolerance @ 30Hz
1	C13 Road	150	154	426	41.4	Acceptable	N/A
2	C13 Road	150	179	426	32.4	Acceptable	N/A
3	C13 Road	150	1421	426	1.1	Acceptable	N/A
4	Buildings/Structures	25	452	426	7.0	Acceptable	Unpleasant
5	Road Intersection	150	1077	426	1.7	Acceptable	N/A
6	Buildings/Structures	25	1136	426	1.5	Acceptable	Perceptible
44	Power Lines/Pylons	75	1345	426	1.2	Acceptable	N/A
45	Power Lines/Pylons	75	577	426	4.7	Acceptable	N/A
46	Power Lines/Pylons	75	170	426	35.1	Acceptable	N/A
47	Power Lines/Pylons	75	1023	426	1.8	Acceptable	N/A
67	Heritage Site (QRS 177/12 Large Rock Shelter)	50	958	426	2.0	Acceptable	Perceptible
69	Heritage Site (QRS 177/14 Rock Shelter)	50	1214	426	1.4	Acceptable	Perceptible
70	Heritage Site (QRS 177/15 Rock Shelter)	50	35	426	488.8	Problematic	Intolerable
71	Heritage Site (QRS 177/16 Suspected Burial Mound)	50	1157	426	1.5	Acceptable	Perceptible
73	Heritage Site (QRS 177/18 Confirmed Burial Cairn)	50	832	426	2.6	Acceptable	Perceptible
91	Hydrocencus Borehole (SPDD004)	50	530	426	5.4	Acceptable	N/A
92	Hydrocencus Borehole (SPDD005)	50	230	426	21.4	Acceptable	N/A
94	Hydrocencus Borehole (SPDD012)	50	282	426	15.3	Acceptable	N/A
97	Hydrocencus Borehole (SPDD049)	50	167	426	36.2	Acceptable	N/A
98	Hydrocencus Borehole (SPDD093)	50	485	426	6.2	Acceptable	N/A
99	Hydrocencus Borehole (SPDD099)	50	142	426	47.2	Acceptable	N/A
100	Hydrocencus Borehole (SPDD100)	50	238	426	20.2	Acceptable	N/A
101	Hydrocencus Borehole (SPDD127)	50	604	426	4.4	Acceptable	N/A
102	Hydrocencus Borehole (SPDD129)	50	695	426	3.4	Acceptable	N/A
103	Hydrocencus Borehole (SPDD134)	50	947	426	2.1	Acceptable	N/A
104	Hydrocencus Borehole (SPDD154)	50	161	426	38.7	Acceptable	N/A
105	Hydrocencus Borehole (SPDD159)	50	362	426	10.1	Acceptable	N/A
106	Hydrocencus Borehole (SPDD228)	50	135	426	51.6	Problematic	N/A
107	Hydrocencus Borehole (SPDD265)	50	162	426	38.2	Acceptable	N/A
108	Hydrocencus Borehole (SPDD278)	50	134	426	51.9	Problematic	N/A
109	Hydrocencus Borehole (SPDD289)	50	159	426	39.4	Acceptable	N/A

15.2 Summary of ground vibration levels

The underground blasting operations were evaluated for expected levels of ground vibration on the surface environment. Review of the site and the surrounding surface installations which include roads, structures, boreholes, heritage sites and powerlines showed that these infrastructure vary in distances from the underground operations. The influences do also vary with distances from the underground operations. The model used for evaluation does indicate varying levels ranging between 488.8 mm/s and low insignificant levels within the 1500 m area investigated. It will be imperative to ensure that a monitoring program is done to confirm levels of ground vibration to ensure that restriction on ground vibration levels is not exceeded.

It is observed that for the different charge masses evaluated that levels of ground vibration will change as well. In view of the minimum and maximum charge specific attention will need to be given to specific areas.

Minimum charge: Expected ground vibration levels for minimum charge ranged between 173.4 mm/s and 0.4 mm/s for the identified POI's. One POI (POI70 – Rock Shelter) was identified where the ground vibration levels may exceed the permitted ground vibration level.

Maximum charge: Expected ground vibration levels for minimum charge ranged between 488 mm/s and 1.1 mm/s for the identified POI's. Three POI's (POI70 – Rock Shelter, POI106 and 108 – Hydrocencus Boreholes) was identified where the ground vibration levels may exceed the permitted ground vibration level.

There are no houses in proximity of the operations where human perception may have an effect. However it can be noted that perceptible levels of vibration that may be experienced up to 1420 m, unpleasant up to 530 m and intolerable up to 238 m for the underground blasting operation.

Various heritage sites which include rock shelters and burial mounts were identified by the Heritage Specialist. HIA indicated that the specific rock shelter (QRS 177/15 Rock Shelter) that is indicated as concern has a Low Enviro Dynamics vulnerability rating. The expected levels of ground vibration may have no significant influence. However it should be monitored for any negative influence.

Hydrocencus boreholes identified showed two borehole of concern due to location close to the underground works. A mitigation plan will be required to determine if these boreholes will be retained or replaced.

Mitigation of ground vibration was considered and discussed in Section 16.5. A detail inspection of the area and accurate identification of infrastructure will also need to be done to ensure the levels of ground vibration allowable and limit to be applied.

15.3 Ground Vibration and human perception

Considering the effect of ground vibration with regards to human perception, vibration levels calculated were applied to an average of 30Hz frequency and plotted with expected human perceptions on the safe blasting criteria graph (see Figure 10 below). The frequency range selected is the expected average range for frequencies that will be measured for ground vibration when blasting is done. Based on the maximum charge and ground vibration predicted over distance it can be seen from Figure 10 that up to a distance of 1421 m people may experience levels of ground vibration as perceptible. At 530 m and closer the perception of ground vibration could be unpleasant. Closer than 238 m the levels will be intolerable and generally greater than limits applied for structures in the areas.

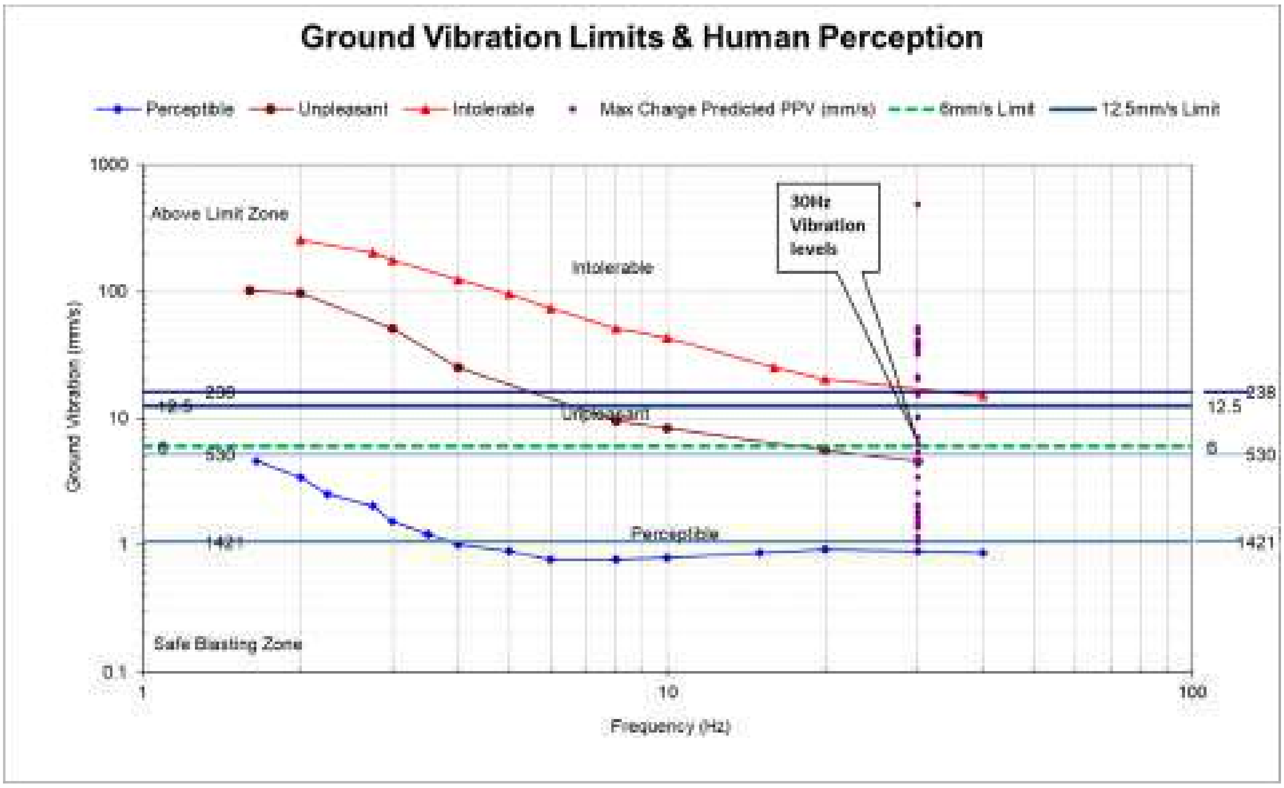


Figure 10: The effect of ground vibration with human perception and vibration limits

15.4 Potential that vibration will upset adjacent communities

Ground vibration and air blast generally upset people living in the vicinity of mining operations. There is however no human settlement within 1500 m from the planned underground operation. The expected perceivable levels of ground vibration are only up to a distance of 1421 m from the underground works. No impact on communities is expected.

15.5 Water Borehole Influence

Location of known Hydrocencus boreholes was evaluated for possible influence from blasting. Hydrocencus boreholes were identified within the influence area of the underground works. There are two boreholes that are in close proximity of the blasting areas and of ground vibration concern. Table 7 shows all the identified boreholes and Table 8 shows the possible problematic borehole. Figure 11 shows the location of the boreholes in relation to the pit areas. The expected levels are just greater that preferred limit. It is however expected that no influence may be possible.

Table 7: Identified Water Boreholes

Tag	Description	Y	X	Specific Limit (mm/s)	Distance (m) to nearest Pit	Predicted PPV (mm/s)
108	Hydrocencus Borehole (SPDD278)	666241.057	6915995.256	50	134	51.9
106	Hydrocencus Borehole (SPDD228)	666282.498	6916501.139	50	135	51.6
99	Hydrocencus Borehole (SPDD099)	666242.057	6915996.351	50	142	47.2

Tag	Description	Y	X	Specific Limit (mm/s)	Distance (m) to nearest Pit	Predicted PPV (mm/s)
109	Hydrocencus Borehole (SPDD289)	666089.226	6916483.853	50	159	39.4
104	Hydrocencus Borehole (SPDD154)	666595.312	6916188.74	50	161	38.7
107	Hydrocencus Borehole (SPDD265)	665994.514	6916829.81	50	162	38.2
97	Hydrocencus Borehole (SPDD049)	665985.414	6916884.238	50	167	36.2
92	Hydrocencus Borehole (SPDD005)	665899.043	6916834.448	50	230	21.4
100	Hydrocencus Borehole (SPDD100)	666541.925	6916387.847	50	238	20.2
94	Hydrocencus Borehole (SPDD012)	666121.326	6916955.509	50	282	15.3
105	Hydrocencus Borehole (SPDD159)	665820.875	6916234.872	50	362	10.1
98	Hydrocencus Borehole (SPDD093)	665735.079	6916083.118	50	485	6.2
91	Hydrocencus Borehole (SPDD004)	666243.614	6917253.043	50	530	5.4
101	Hydrocencus Borehole (SPDD127)	667016.624	6916529.786	50	604	4.4
102	Hydrocencus Borehole (SPDD129)	666976.196	6916739.799	50	695	3.4
103	Hydrocencus Borehole (SPDD134)	667218.337	6916871.648	50	947	2.1

Table 8: Problematic Water Borehole

Tag	Description	Y	X	Specific Limit (mm/s)	Distance (m) to Pit	Predicted PPV (mm/s)
108	Hydrocencus Borehole (SPDD278)	666241.057	6915995.256	50	134	51.9
106	Hydrocencus Borehole (SPDD228)	666282.498	6916501.139	50	135	51.6

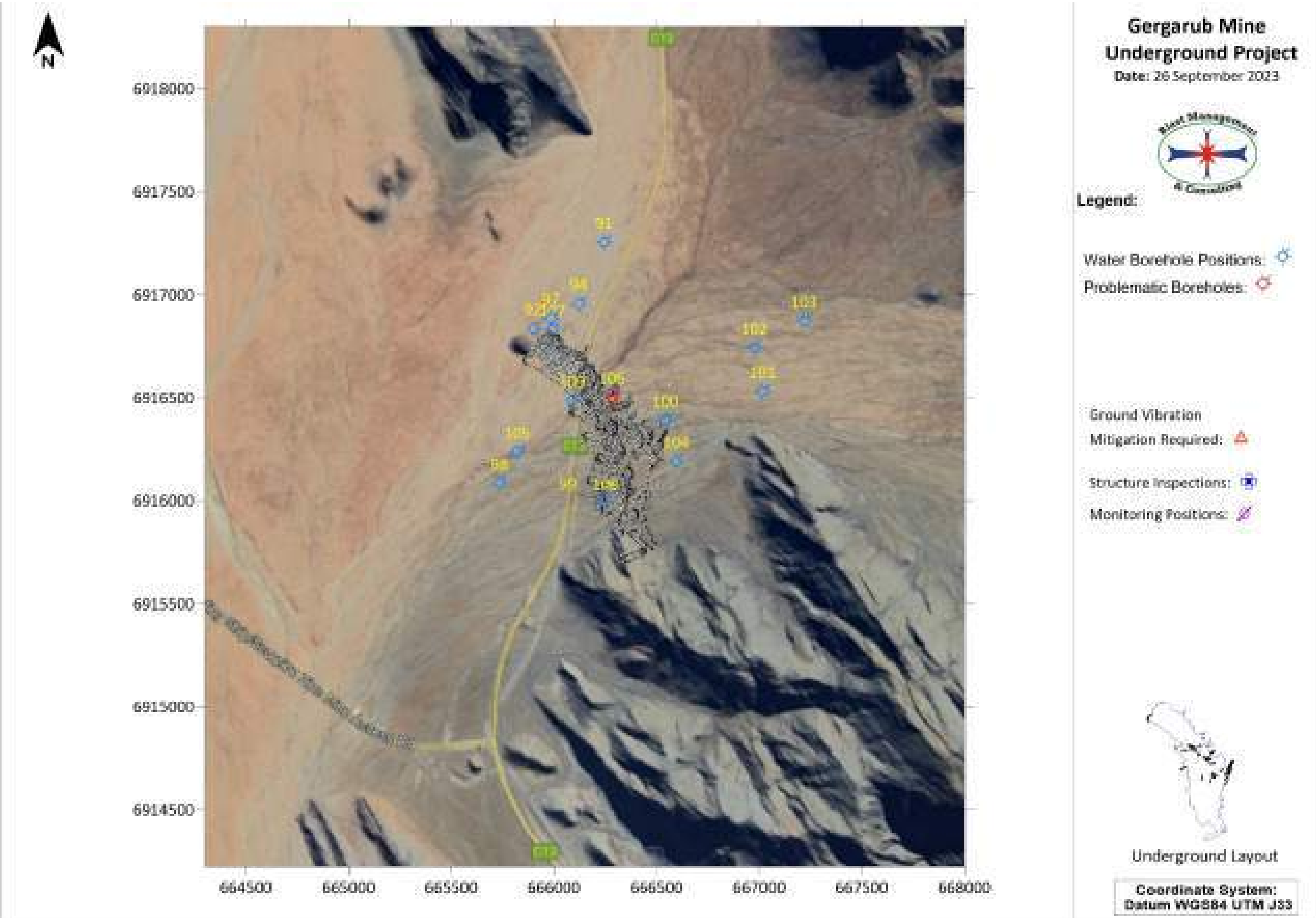


Figure 11: Location of the Boreholes

16 Potential Environmental Impact Assessment: Operational Phase

The following is the impact assessment of the various concerns covered by this report. The impact assessment and evaluation below were used for analysis and evaluation of aspects discussed in this report. The outcome of the analysis is provided in Table 9 with before mitigation and after mitigation. This risk assessment is a one-sided analysis and needs to be discussed with role players in order to obtain a proper outcome and mitigation.

16.1 Assessment Criteria

The following principal documents were used to inform the assessment method:

- International Finance Corporation standards and models, in particular performance standard 1: 'Assessment and management of environmental and social risks and impacts' (International Finance Corporation, 2012 and 2017);
- International Finance Corporation Cumulative Impact Assessment (CIA) and Management Good Practice Handbook (International Finance Corporation, 2013);
- Namibian Draft Procedures and Guidance for EIA and EMP (Republic of Namibia, 2008); and
- Requirements encapsulated in IFC Performance Standard 3 (PS 3)
- Equator Principles 4 (ep 4) - Guidance on environmental and social impact assessment

16.2 Limitations, Uncertainties and Assumptions

The following limitations and uncertainties associated with the assessment methodology were considered in the assessment phase:

- Topic specific assessment guidance has not been developed in Namibia. A generic assessment methodology will be applied to all topics using IFC guidance and professional judgement;
- Guidance for CIA has not been developed in Namibia, but a single accepted state of global practice has been established. The IFC's guidance document (International Finance Corporation, 2013) will be used for the CIA; and
- The climate change methodology was determined by an external specialist in this field in order to comply with international, national and lender reporting requirements.

16.3 Assessment Methodology

The ESIA methodology applied to this assessment has been developed by ECC using the International Finance Corporation (IFC) standards and models, in particular performance standard 1: 'Assessment and management of environmental and social risks and impacts' (International Finance Corporation, 2017); Namibian Draft Procedures and Guidance for EIA and EMP (Republic of

Namibia, 2008); international and national best practice; and over 25 years of combined ESIA experience. The methodology is set out in Figure 12 and Figure 13.

The methodology utilised for the climate change assessment was developed by the specialist conducting this assessment to adhere to the requirements of IFC Performance Standard 3 (PS 3) and Equator Principles 4 (ep 4). ECC will not amend this methodology used, however impact significance will be scored.

The evaluation and identification of the environmental and social impacts require the assessment of the Project characteristics against the baseline characteristics, ensuring that all potentially significant impacts are identified and assessed. The significance of an impact is determined by taking into consideration the combination of the sensitivity and importance/value of environmental and social receptors that may be affected by the proposed Project, the nature and characteristics of the impact, and the magnitude of any potential change. The magnitude of change (the impact) is the identifiable changes to the existing environment that may be negligible, low, minor, moderate, high, or very high; temporary/short-term, long-term or permanent; and either beneficial or adverse.

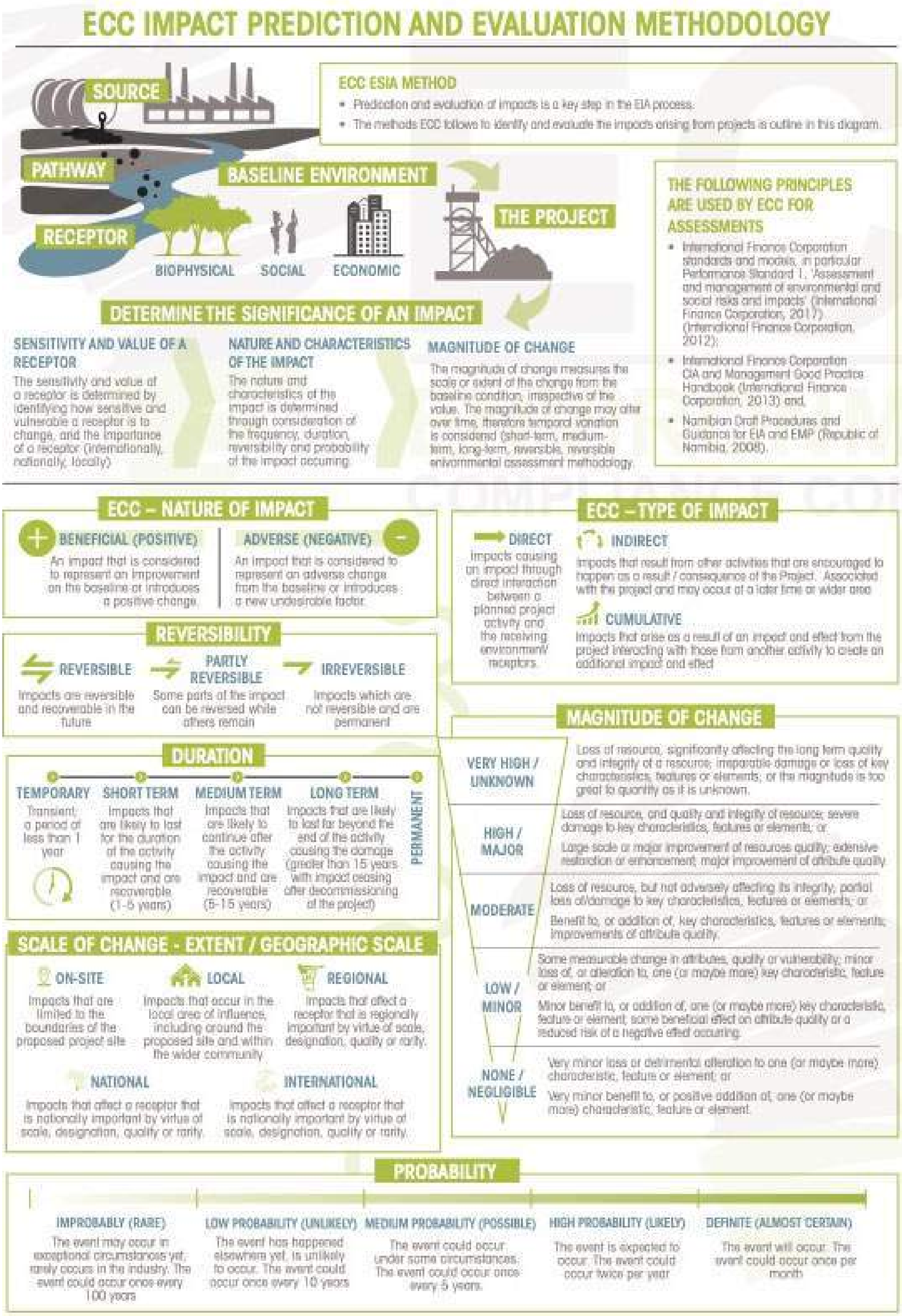


Figure 12: ECC ESIA methodology based on IFC standards

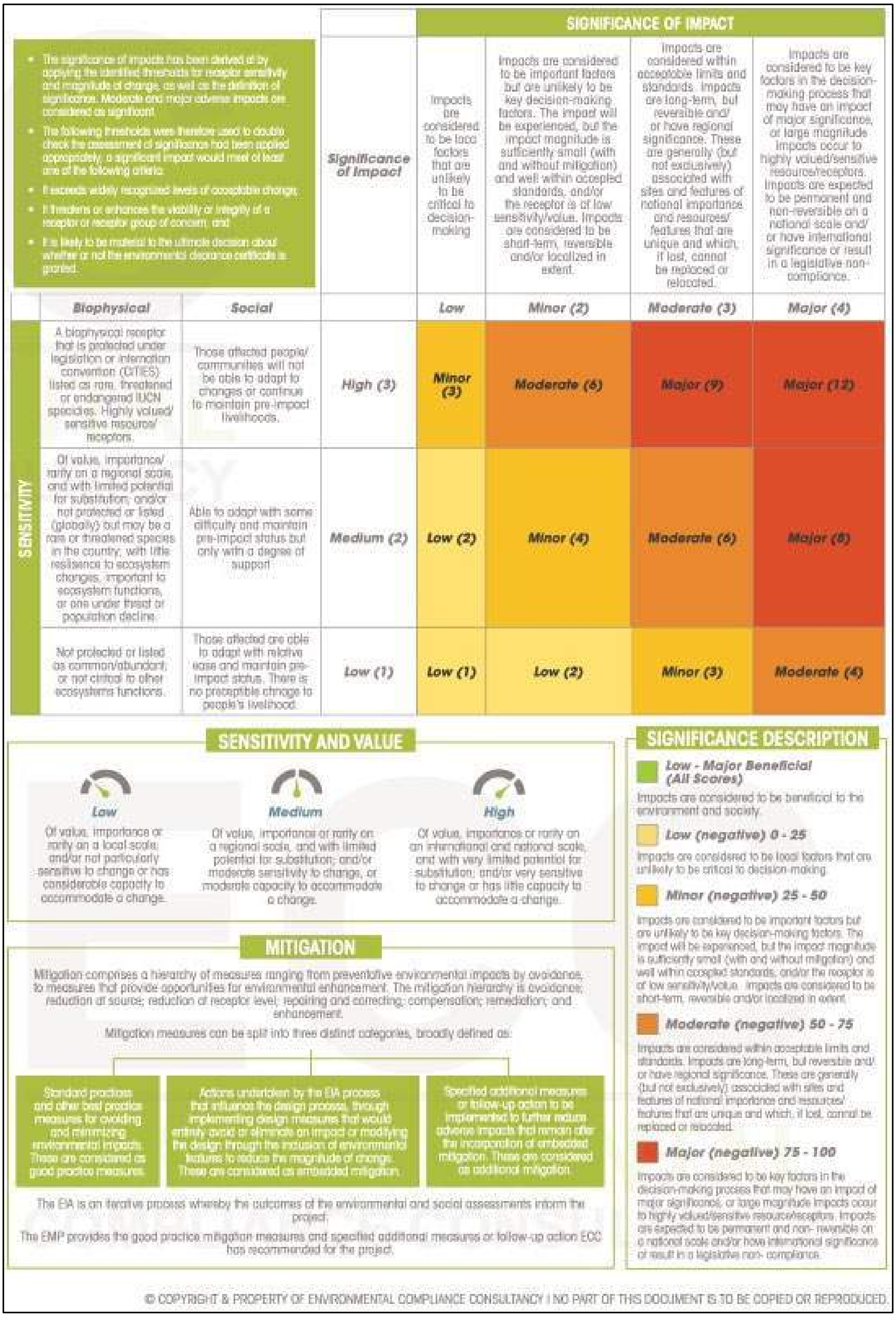


Figure 13: ECC ESIA methodology based on IFC standards

16.4 Assessment

The assessment done was based on evaluating the points of interested that showed expected levels greater than limits. This is however based on the worst-case scenario where blasting is done at the shortest distance from pit area to the point of interest. In after mitigation consideration was given to the fact that blasting will not be constantly at the short distance and the period of time that the influence may be present is significantly reduced due to that only areas or blocks will be blasted at a time.

Table 9: Potential Impacts Without Mitigation Measures

	Activity	**Receptor**	**Impact**	**Nature of impact**	**Value & Sensitivity**	**Magnitude of change**	**Significance of impact**
1	Blasting	Buildings/Structures	Ground Vibration	Regional, Life of Mine	Low	Low	Low
2	Blasting	C13 Road	Ground Vibration	Regional, Life of Mine	Low	Low	Low
3	Blasting	Gravel Road	Ground Vibration	Regional, Life of Mine	Low	Low	Low
4	Blasting	Heritage Site	Ground Vibration	Regional, Life of Mine	Medium	Moderate	Moderate
5	Blasting	Hydrocencus Borehole	Ground Vibration	Regional, Life of Mine	High	Moderate	Moderate
6	Blasting	Power Lines/Pylons	Ground Vibration	Regional, Life of Mine	Low	Low	Low

16.5 Mitigations

In review of the evaluations made in this report it is certain that specific mitigation will be required with regards to ground vibration. Ground vibration is the primary possible cause of structural damage and requires more detailed planning in preventing damage and maintaining levels within accepted norms. Ground vibration requires more detailed planning and forms the focus for mitigation measures.

Specific impacts are expected at the following POI's identified. Table 10 shows list of POI's that will need to be considered. Figure 14 shows the location of these POI's in relation to the pit areas.

Table 10: Structures identified as problematic in and around the project area

Tag	Description	Y	X	Ground Vibration Limit (mm/s)	Distance (m)	Max Charge Predicted PPV (mm/s)	Max Charge Structure Response
70	Heritage Site (QRS 177/15 Rock Shelter)	666432.33	6915725.54	50	35	488.8	Problematic
108	Hydrocencus Borehole (SPDD278)	666241.057	6915995.256	50	134	51.9	Problematic
106	Hydrocencus Borehole (SPDD228)	666282.498	6916501.139	50	135	51.6	Problematic

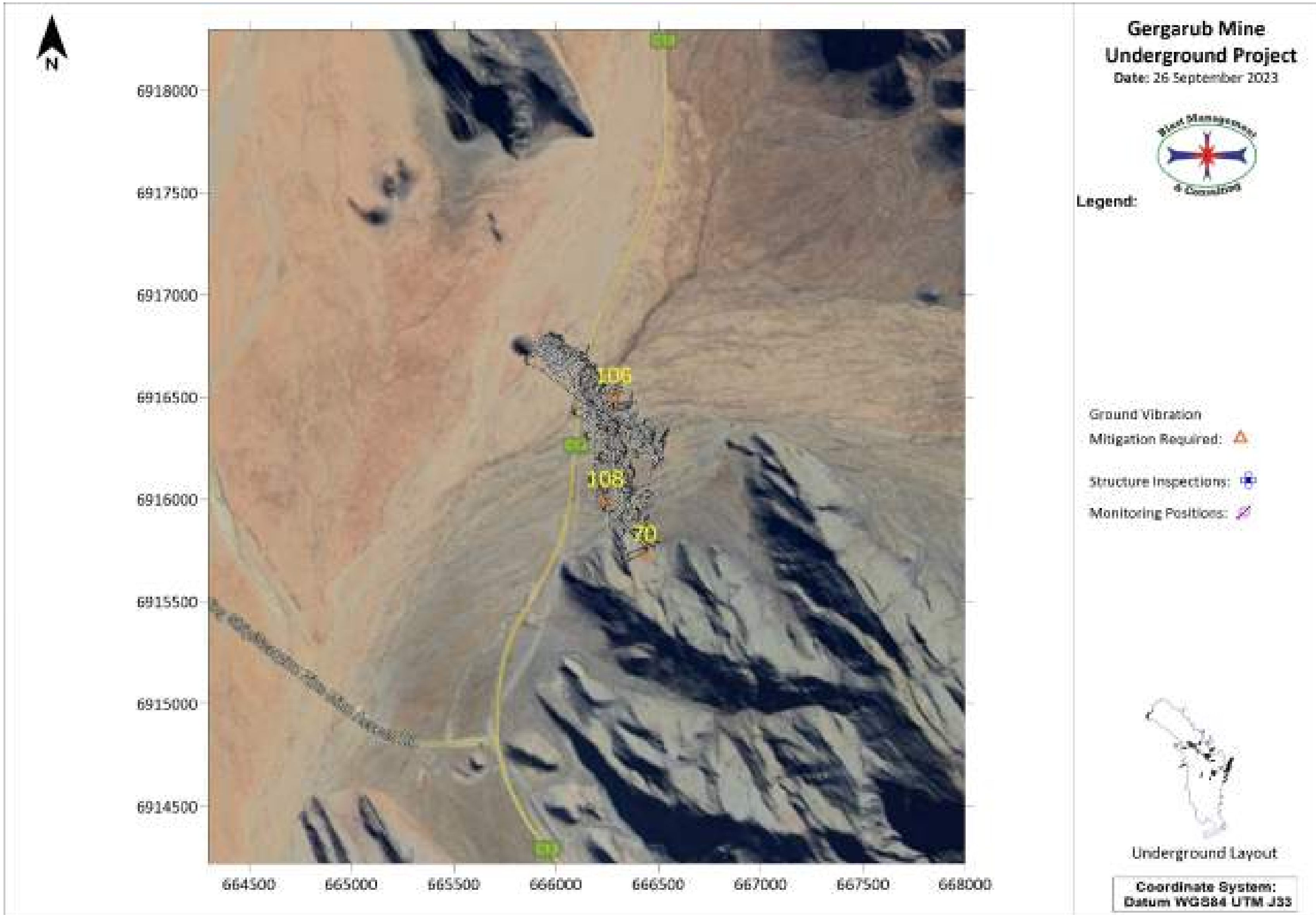


Figure 14: Mitigation POI's

Based on the modelling done, high levels of influence are specifically observed up to 150 m from blasting operations. The following specific mitigations may be considered.:

Ground Vibration: Mitigation of ground vibration for this can be done applying the following methods:

- Specific measurement of distance between blast operation and POI of concern,
- Do blast design that considers the actual blasting, and the ground vibration levels to be adhered too,
- Changes to the timing design to facilitate less charge mass per delay,
- Only apply electronic initiation systems to facilitate single hole firing,
- Do design for smaller diameter blast holes that will use fewer explosives per blast hole.

The identified POI's of concern is found in close proximity of the actual operations. In order to give indication of the possibilities of mitigation to consider two basic indicators are presented. Firstly, the maximum charge per delay that can be allowed for the shortest distance between blast and POI. Secondly the minimum distance between blast and POI to maintain ground vibration limits for minimum and maximum charge per delay. These table gives indication for planning of blasts when blasts at shortest distance to the POI's.

Table 11 do show mitigation in the form of maximum charge mass that will be allowed to maintain safe levels of ground vibration. Table 12 shows minimum distance between blast and POI to maintain ground vibration limits for minimum and maximum charge per delay.

Table 11: Mitigation measures: Maximum charge per delay for distance to POI

Tag	Description	Y	X	Ground Vibration Limit (mm/s)	Distance (m)	Maximum allowable charge for current distance (kg)
70	Heritage Site (QRS 177/15 Rock Shelter)	666432.33	6915725.54	50	35	27
108	Hydrocencus Borehole (SPDD278)	666241.057	6915995.256	50	134	407
106	Hydrocencus Borehole (SPDD228)	666282.498	6916501.139	50	135	410

These POI's vary in distance and it will be required that each be evaluated in relation to a blast to be done. The distance should be checked, the charge mass allowed be calculated and then a design of charging or timing applied to ensure that the limits are not exceed. In most cases basic planned design does not need to change but timing can be adjusted as well electronic timing can used to reduce the charge mass per delay. This must be confirmed with monitoring of ground vibration at the POI.

The following Table 12 shows the minimum distance required between blast and POI for the minimum and maximum charge per delay to maintain the ground vibration limits applied.

Table 12: Mitigation measures: Minimum distances required

Example POI	Specific Limit (mm/s)	Distance (m)	Total Mass/Delay (kg)
Minimum charge per delay			
Heritage Site rock shelter	50	73	121
Hydrocencus Borehole	50	73	121
Maximum charge per delay			
Heritage Site Rock Shelter	50	138	426
Hydrocencus Borehole	50	138	426

Data provided in tables above clearly indicate that distance between blast and POI will have influence on the allowed charge mass per delay with regards to the different ground vibration limits.

17 Monitoring

A monitoring programme for recording blasting operations is recommended. The following elements should be part of such a monitoring program:

- Ground vibration results;
- Blast Information summary;

Most of the above aspects do not require specific locations of monitoring. Ground vibration monitoring requires identified locations for monitoring. Monitoring of ground vibration is done to ensure that the generated levels of ground vibration comply with recommendations. Proposed positions were selected to indicate the nearest points of interest at which levels of ground vibration should be within the accepted norms and standards as proposed in this report. The monitoring of ground vibration will also qualify the expected ground vibration and assist in mitigating these aspects properly.

Four monitoring points were identified as possible locations that will need to be considered for all the pit areas. Not all the identified points will be required simultaneously. The identified points are guidelines to consider for each pit area. Monitoring positions (for all pits) are indicated in Figure 15 and Table 13 lists the positions with coordinates. These points will need to be re-defined after the first blasts done and the monitoring programme defined.

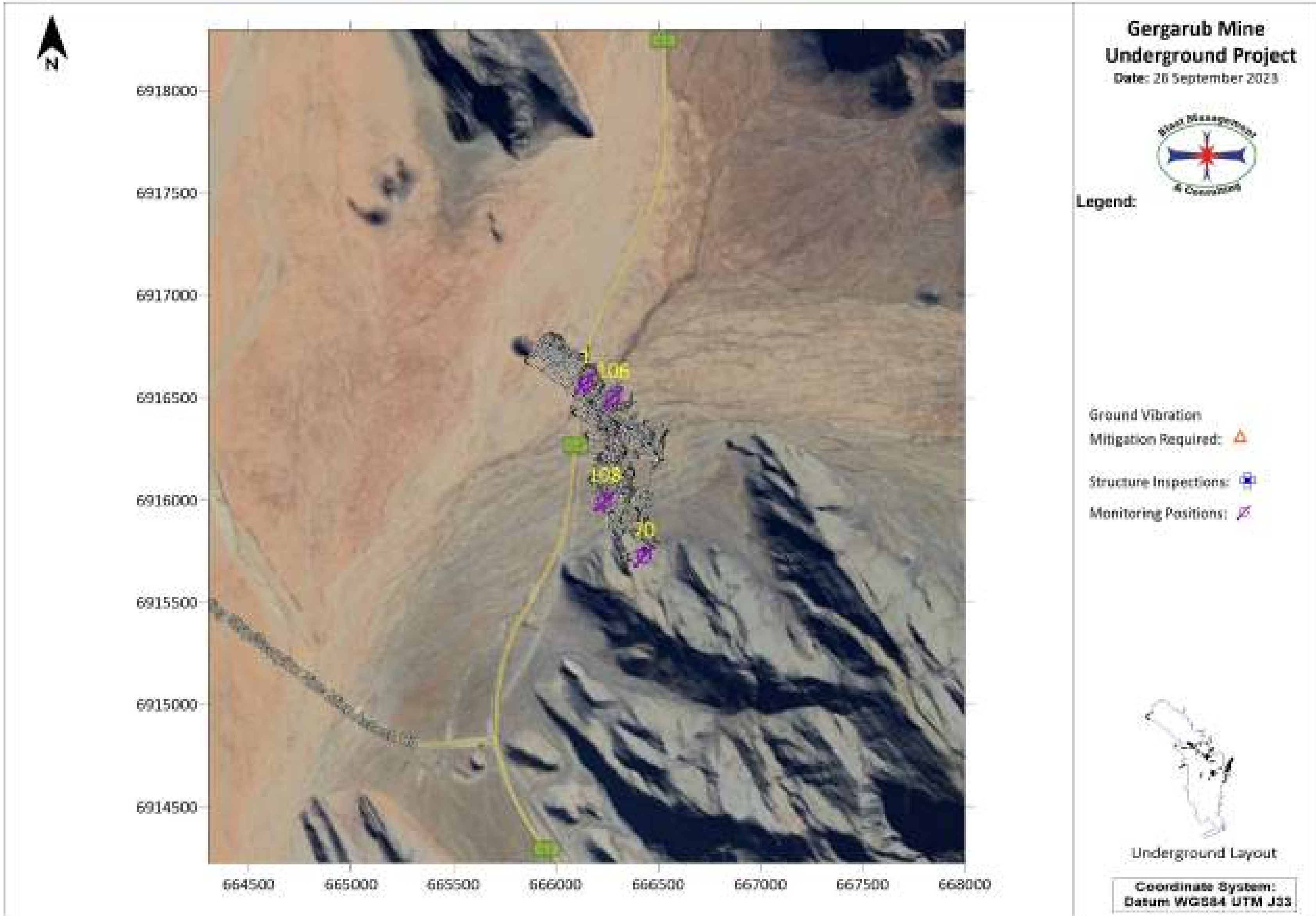


Figure 15: Suggested monitoring positions

Table 13: List of possible monitoring positions

Tag	Description	Y	X
1	C13 Road	666144.94	6916573.08
70	Heritage Site (QRS 177/15 Rock Shelter)	666432.33	6915725.54
106	Hydrocencus Borehole (SPDD228)	666282.498	6916501.139
108	Hydrocencus Borehole (SPDD278)	666241.057	6915995.256

18 Recommendations

The following recommendations are proposed.

18.1 Blast Designs

Blast designs can be reviewed prior to the first blast planned and done. Specific attention can be given to the possible use of electronic initiation rather than conventional timing systems. This will allow for single blast hole firing instead of multiple blast holes. Single blast hole firing will provide single hole firing – thus less charge mass per delay and less influence. Please refer to section 16.5 for detail regarding mitigations required.

18.2 Recommended ground vibration and air blast levels

The ground vibration and air blast levels limits recommended for blasting operations in this area are provided in Table 14.

Table 14: Recommended ground vibration air blast limits

Structure Description	Ground Vibration Limit (mm/s)	Air Blast Limit (dBL)
National Roads/Tar Roads:	150	N/A
Electrical Lines:	75	N/A
Railway:	150	N/A
Transformers	25	N/A
Water Wells	50	N/A
Telecoms Tower	50	134
General Houses of proper construction	USBM Criteria or 25 mm/s	Shall not exceed 134dB at point of concern but 120 dB preferred
Houses of lesser proper construction (preferred)	12.5	
Rural building – Mud houses	6	

18.3 Third party monitoring

Third party consultation and monitoring should be considered for all ground vibration and air blast monitoring work. This will bring about unbiased evaluation of levels and influence from an independent group. Monitoring could be done using permanent installed stations. Audit functions may also be conducted to assist the mine in maintaining a high level of performance with regards to blast results and the effects related to blasting operations. Please refer to section 17 regarding proposed monitoring positions.

19 Knowledge Gaps

The data provided from client and information gathered was sufficient to conduct this study. Surface surroundings change continuously, and this should be considered prior to initial blasting operations considered. This report may need to be reviewed and updated if necessary. This report is based on data provided and internationally accepted methods and methodology used for calculations and predictions.

20 Project Result

Specific problems were identified, and recommendations made. The successful resolving of these concerns will allow that the project can be executed successfully with proper management and control on the aspects of ground vibration.

21 Conclusion

Ground vibration is an aspect as a result from blasting operations. The report evaluates the effects of ground vibration from the underground blasting operations and intends to provide information, calculations, predictions, possible influences, and mitigations of blasting operations for this project.

The evaluation of effects yielded by blasting operations was evaluated over an area as wide as 1500 m from the underground mining area considered. The range of structures observed is typical roads (tar and gravel), heritage sites, powerlines and Hydrocencus boreholes.

The location of structures on surface around the underground works are such that the charges evaluated showed possible influences due to ground vibration. The closest structures observed are the Road (C1), Hydrocencus Boreholes and Heritage Sites. The influences do also vary with distances from the underground operations. The model used for evaluation does indicate varying levels ranging between 488.8 mm/s and low insignificant levels within the 1500 m area investigated. It will be imperative to ensure that a monitoring program is done to confirm levels of ground vibration to ensure that restriction on ground vibration levels is not exceeded.

There are no houses in proximity of the operations where human perception may have an effect.

However it can be noted that perceptible levels of vibration that may be experienced up to 1420 m, unpleasant up to 530 m and intolerable up to 238 m for the underground blasting operation.

Various heritage sites which include rock shelters and burial mounts were identified by the Heritage Specialist. HIA indicated that the specific rock shelter (QRS 177/15 Rock Shelter) that is indicated as concern has a Low Enviro Dynamics vulnerability rating. The expected levels of ground vibration may have no significant influence. However it should be monitored for any negative influence.

Hydrocencus boreholes identified showed two borehole of concern due to location close to the underground works. A mitigation plan will be required to determine if these boreholes will be retained or replaced.

Mitigation of ground vibration was considered and discussed.

This concludes this investigation for the proposed Gergarub Mining and Exploration (Pty) Ltd Project. There is no reason to believe that this operation cannot continue if attention is given to the recommendations made.

22 Curriculum Vitae of Author

J D Zeeman was a member of the Permanent Force - SA Ammunition Core for period January 1983 to January 1990. During this period, work involved testing at SANDF Ammunition Depots and Proofing ranges. Work entailed munitions maintenance, proofing and lot acceptance of ammunition.

From July 1992 to December 1995, Mr Zeeman worked at AECI Explosives Ltd. Initial work involved testing science on small scale laboratory work and large-scale field work. Later, work entailed managing various testing facilities and testing projects. Due to restructuring of the Technical Department, Mr Zeeman was retrenched but fortunately was able to take up an appointment with AECI Explosives Ltd.'s Pumpable Emulsion Explosives Group for underground applications.

From December 1995 to June 1997 Mr Zeeman provided technical support to the Underground Bulk Systems Technology business unit and performed project management on new products.

Mr Zeeman started Blast Management & Consulting in June 1997. The main areas of focus are pre-blast monitoring, insitu monitoring, post-blast monitoring and specialized projects.

Mr Zeeman holds the following qualifications:

1985 - 1987	Diploma: Explosives Technology, Technikon Pretoria
1990 - 1992	BA Degree, University of Pretoria
1994	National Higher Diploma: Explosives Technology, Technikon Pretoria
1997	Project Management Certificate: Damelin College

2000 Advanced Certificate in Blasting, Technikon SA

Member: International Society of Explosives Engineers

Blast Management & Consulting has been active in the mining industry since 1997, with work being done at various levels for all the major mining companies in South Africa. Some of the projects in which BM&C has been involved include:

Iso-Seismic Surveys for Kriel Colliery in conjunction with Bauer & Crosby Pty Ltd.; Iso-Seismic surveys for Impala Platinum Limited; Iso-Seismic surveys for Kromdraai Opencast Mine; Photographic Surveys for Kriel Colliery; Photographic Surveys for Goedehoop Colliery; Photographic Surveys for Aquarius Kroondal Platinum – Klipfontein Village; Photographic Surveys for Aquarius – Everest South Project; Photographic Surveys for Kromdraai Opencast Mine; Photographic inspections for various other companies, including Landau Colliery, Platinum Joint Venture – three mini-pit areas; Continuous ground vibration and air blast monitoring for various coal mines; Full auditing and control with consultation on blast preparation, blasting and resultant effects for clients, e.g. Anglo Platinum Ltd, Kroondal Platinum Mine, Lonmin Platinum, Blast Monitoring Platinum Joint Venture – New Rustenburg N4 road; Monitoring of ground vibration induced on surface in underground mining environment; Monitoring and management of blasting in close relation to water pipelines in opencast mining environment; Specialized testing of explosives characteristics; Supply and service of seismographs and VOD measurement equipment and accessories; Assistance in protection of ancient mining works for Rhino Minerals (Pty) Ltd.; Planning, design, auditing and monitoring of blasting in new quarry on new road project, Sterkspruit, with Africon, B&E International and Group 5 Roads; Structure Inspections and Reporting for Lonmin Platinum Mine Limpopo Pandora Joint Venture 180 houses – whole village; Structure Inspections and Reporting for Lonmin Platinum Mine Limpopo Section - 1000 houses / structures.

BMC have installed a world class calibration facility for seismographs, which is accredited by Instantel, Ontario Canada as an accredited Instantel facility. The projects listed above are only part of the capability and professional work that is done by BMC.

23 References

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4. Siskind, D. E., Stagg, M.S., Kopp, J. W. and Dowding, C. H. (1980). Structural Response and Damage Produced by Ground Vibration from Surface Mine Blasting. Report of Investigations 8507. US Bureau of Mines.

INNOVATIVE TRANSPORT SOLUTIONS

ECC ENVIRONMENTAL COMPLIANCE CONSULTANCY

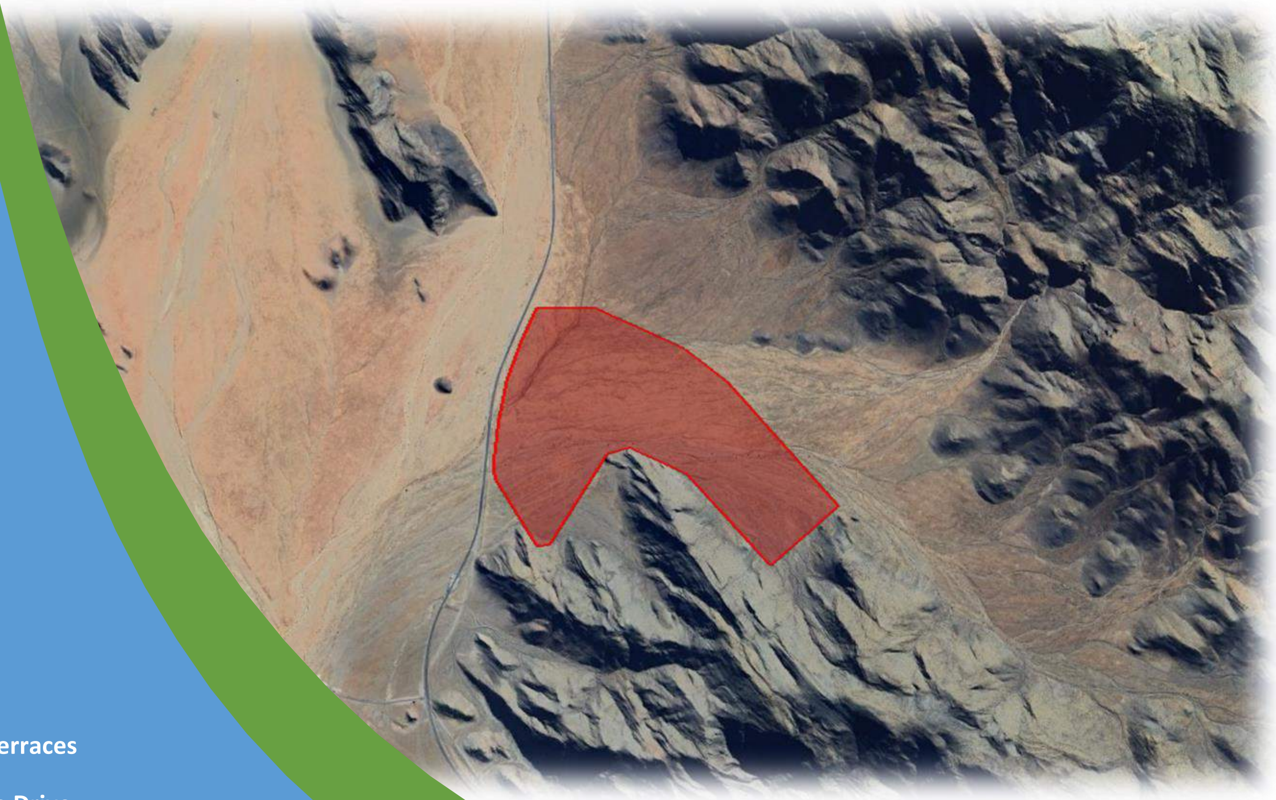
Transport Impact Assessment (TIA)

Gergarub Mine

Rosh Pinah, Karas Region, Namibia

Report Status – **Final**

Date - **January 2024**



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SUMMARY SHEET

Report Type	Transport Impact Assessment (TIA)
Title	Gergarub Mine
Location	Rosh Pinah, Karas Region, Namibia
Client	Environmental Compliance Consultancy (ECC)
Reference Number	ITS 4626
Project Team	Christoff Krogscheepers – christoff@itsglobal.co.za Hugo Engelbrecht – hugo@itsglobal.co.za Alain Rousseau – alain@itsglobal.co.za
Contact Details	Tel: 021 914 6211
Date	January 2024
Report Status	Final
File Name	G:\4626 TIA Gergarub Mine, Karas Namibia\12 Report\Issue\4626_TIA Gergarub Mine-Report_AR_2024-01-15.docx

TABLE OF CONTENTS

ANNEXURE

Transport Impact Assessment *Gergarub Mine, Rosh Pinah, Karas Region, Namibia*	
1 Purpose of Study	This report summaries an investigation of the transport impacts, expected as part of the Gergarub Mine, planned to the north of Rosh Pinah in Namibia. The purpose of this assessment is to identify constraints within the surrounding road network and to recommend appropriate mitigation measures, if/where applicable.
2 Locality	The Gergarub Mine is planned on Farm Spitskop 111, approximately 14km north of Rosh Pinah and 2,5km north of the Skorpion Zinc mine access, in the Karas Region, Namibia. See **Figure 1** for a Locality Plan.
3 Land Use & Extent	**Existing use** – the site is currently vacant/un-developed. **Proposed use** – A zinc and lead ore mine is planned on a 180 hectares portion of this farm. The western boundary of the mine will be the C13 Road. See **Figure 2** for the Site Development Plan.
4 Development	The Gergarub Mine is planned to process a total of 800 000 tonnes of material per annum, which will include the following: • About 150ktpa of zinc (export), • about 30ktpa of lead (export), • about 180ktpa of pyrite (export) and • about 450ktp of flotation tailings (to remain on site) Only about 360 kilo tonnes per annum (ktpa) of the zinc, lead and pyrite will be transported by road to mainly Lüderitz for export. The tailings will remain on site since it is a waste product. The mine is expected to operate at about 85 percent of its full export production and capacity within the first three (3x) years. Thereafter the mine would operate at 100 percent production and capacity for its remaining lifetime, which is expected to be 18 years.
5 Existing Access	There is no existing direct vehicular access from the C13 Road to this mine site, in the vicinity of the proposed development. A new formal vehicular access is planned from the C13 Road, roughly 2.5km north of the Scorpion Zinc mine access. This proposed access to this mine is discussed further in Section 17 of the report.

6 Existing Roadways	The major roadways in the site vicinity include: **B4 Road** (T0402) – a typical Class 2 major arterial, with one surfaced lane per direction, without shoulders and a 120km/h posted speed limit. **C13 Road** (M0118) – a typical Class 3 minor arterial, with one surfaced lane per direction, with narrow shoulders and a 120km/h posted speed limit. See **Figure 1** for the location of these roads, relative to the development.
7 Study Intersections & Existing Control	Int. 1: B4 Road / C13 Road — Stop/Priority Control Int. 2: C13 / Scorpion Zinc Mine Access Road — Stop/Priority Control Int. 2: C13 Road / Gergarub Mine Access — Future Access
8 Analyses Hours	The 30th highest peak hour traffic volumes were used to determine the expected impact from this development on the surrounding road network. This peak hour traffic volumes will only be exceeded 29 times a year and are higher than typical weekday AM and PM peak hour traffic volumes, and it is generally used in the evaluation and design of rural highways.
9 Scenarios Analysed	The following scenarios were analysed: **Scenario 1**: 2023 Existing Traffic conditions - Based on existing 30th highest peak hourly traffic volumes. See Section 10 for more details. **Scenario 2**: 2028 Background Traffic conditions - Based on Scenario 1 traffic volumes, escalated with a 4.5% growth rate per year over a five-year period. See Section 11 for more details. **Scenario 3**: 2028 Total Traffic conditions - Based on Scenario 2 traffic volumes, *plus* the expected Gergarub Mine development trips. See Section 15 for more details. **Scenario 4:** 2038 Total Traffic conditions *(future sensitivity analysis)* - Based on Scenario 3 traffic volumes escalated with a 3% growth rate per year over a following ten-year period, *plus* the expected Gergarub Mine development trips. See Section 16 for more details. Intersection analyses were done with Traffix version 8.0 Software, which is based on the Highway Capacity Manual (HCM). The intersections were analysed to determine the level of service (LOS), delay per vehicle (in seconds), and volume-to-capacity (V/C) ratio during peak periods.

10 2023 Existing Traffic – Scenario 1	The 2023 traffic volumes are based on the calculated 30th highest peak hour volumes. These existing volumes along the C13 at the proposed mine access, is about 52 vehicles total both directions, which is relatively low volumes. The intersection analyses for this scenario are based on existing intersection geometries and controls. Based on the capacity analyses for the Existing Traffic scenario, all study intersections are currently operating at acceptable Level-Of-Service LOS A with sufficient spare capacity. Hence, no intersection upgrades are required or proposed for this scenario from a capacity analyses point of view. See **Figure 3** for the Existing Traffic volumes and operations.
11 2028 Background Traffic – Scenario 2	The 2028 Background Traffic volumes were calculated by escalating the existing 30th highest hour traffic volumes, with a 4.5 percent growth rate per year over a 5-year period. This growth rate is based on historic traffic counting data along the C13. The intersection analyses for this scenario are based on existing intersection geometries and controls. Based on the capacity analyses for the Background Traffic scenario, all study intersections are expected to continue to operate acceptably (LOS A) with sufficient spare capacity. Hence, no intersection upgrades are required or proposed for this scenario from a capacity analyses point of view. See **Figure 4** for the Background Traffic volumes and operations.
12 Trip Generation	The South African Trip Data Manual (TMH17) from the Committee of Transport Officials (CoTO) does not provide vehicular trip generation rates for mines, since there are various factors that could affect development trips, including size/type of mine and proposed mining process/activities. Hence, the expected vehicular trip generation for this development is based on the number of people that will be working at this mine per shift, plus the number of truck trips that will be generated as part of mining activities. Worker Trips: Approximately 679 people are expected to work at the mine in three (3x) 8-hour shifts, resulting in approximately 226 workers per shift. The split between public (i.e. bus) and private trips was assumed to be 90%/10% and the bus/private car occupancy was assumed to be 40/1,5 people on average. See **Table 1** in Annexure B for detail calculations of the expected peak hour vehicular trips for the workers. Truck Trips: Approximately 360 000 ton of material will be exported by truck per annum with 34-ton trucks. See **Table 2** in Annexure B for the detailed calculations of the expected truck trips.

13 Development Trips	Based on Table 1 and Table 2, the mine is expected to generate the following trips per peak hour: • Worker bus trips – 6 in / 6 out / 12 total • Worker private trips – 16 in / 16 out 32 total • Truck expert trips - 3 in / 3 out / 6 total • Total development - 25 in / 25 out / **50 Total** per peak hour See **Table 3** in Annexure B and **Figure 5** in Annexure A for a summary of the expected development trips.
14 Trip Distribution	The following trip distribution was used: • 50% of trips to/from north along C13 Road (to Lüderitz) • 50% of trips to/from south along C13 Road (to Scorpion Mine / Rosh Pinah) See **Figure 5** in Annexure A for the expected distribution of trips.
15 2028 Total Traffic – Scenario 3	The 2028 Total Traffic volumes were calculated by adding the Gergarub Mine development trips onto the 2028 Background Traffic volumes. The intersection analyses for this scenario are based on existing intersection geometries and controls. Based on the capacity analyses for the 2028 Total Traffic scenario, all study intersections are expected to continue to operate acceptably (LOS A) with sufficient spare capacity. Hence, no intersection upgrades are required or proposed for this scenario from a capacity analyses point of view. See **Figure 6** in Annexure A for the 2028 Total Traffic volumes & operations.
16 2038 Total Traffic – Scenario 4	The 2038 Total Traffic volumes were calculated by escalating the 2028 Background Traffic volumes with a 3% growth rate per year over a ten-year period plus adding the Gergarub Mine development trips to the network. This scenario aims to tests the **sensitivity** of the road network, especially the operations and safety at the mine access. The intersection analyses for this scenario are based on existing intersection geometries and controls. Based on the capacity analyses for the 2038 Total Traffic scenario, all study intersections are expected to continue to operate acceptably (LOS A) with sufficient spare capacity. Hence, no intersection upgrades are required for this scenario from a capacity analyses point of view. However, it is recommended that separated turning lanes be constructed at the mine access from a safety point of view, as discussed in Section 17 below. See **Figure 7** in Annexure A for the 2038 Total Traffic volumes & operations.

<table>
<tr>
<td>17 Site Access</td>
<td>
Access to the Gergarub Mine is proposed from the C13 Road, approximately 2,5km north of the existing Skorpion Zinc mine access intersection.
Although no upgrades are proposed at this mine access intersection from a capacity analyses point of view, it is recommended to construct a separate northbound right-turn lane (30m storage) plus a separated southbound left-turn lane (30m storage) at the mine access, from a safety point of view. Albeit the turning lanes are not warranted from a safety point of view, the separated turning lanes still provides safety in term of the traveling speeds for the various vehicles approaching the Gergarub Mine Access.
The minimum bell-mouth radii at this intersection should be 15 meters, to accommodate the tuning movements of large articulated tucks.
The required shoulder sight distances with the current 120km/h posted speed limit along C13 Road is:

Passenger car – 220m
Single unit – 340m
Single unit & Trailer – 455m

However, it is recommended to reduce the speed limit along the C13 Road to 80 km/h on the approaches toward the Gergarub Mine access intersection, from a safety point of view. The required shoulder sight distances for the proposed 80km/h are:

Passenger car – 155m
Single unit – 245m
Single unit & Trailer – 300m

Note that the currently available Shoulder Sight Distance (SSD) at the mine access was evaluated and it is more that 455m SSD in both directions along the C13 Road. Hence, sufficient SSD would be available, even for the existing 120km/h design speed environment.
See Photos 1 and 2 in Annexure C as well as Figure 8 in Annexure A.
</td>
</tr>
<tr>
<td>18 Surrounding Roads</td>
<td>
C13 Road - The road is currently surfaced (asphalt) and in a relatively good condition. Signage is provided where typically expected.
B4 Road - The road is currently surfaced (asphalt) and in a relatively good condition. Signage is provided where typically expected.
See Photo 3, 4 and 5 in Annexure C.
</td>
</tr>
</table>

19 Public Transport	Most trips to and from this development will make use of public transport (i.e. buses) and therefore appropriate infrastructure should be provided. It is recommended that bus embayments with sufficient circulating radii (minimum 15 meters), lighting and shelter be provided on-site.
20 Receptor Identification	See **Figure 9, 10 and 11** in Annexure A for the current public facilities and pedestrian desire lines across the B4 and C13, near the towns. The following can be concluded, based on this investigation: • At Lüderitz – There is a school to the west of the B4 and the majority of the residential area is located to the east. This results in a relatively strong pedestrian desire line across the B4. • At Aus – There are residential areas to the north of the B4 and there are work opportunities to the south. This results in pedestrian desire lines across the B4. • At Rosh Pinah - There are several schools to the south of the C13. Although most of the residential areas are also located to the south, some informal residential areas are located to the north. These informal residential areas do not have school and need to cross the C13. The above highlights the issues created by poor land use planning. From a transport or route assessment point of view, there is little that can be done to address this issue, apart from the advance warning signs to highlight pedestrians in the road, which is already in place. It is suggested that these issues be considered as part of future land use planning in these areas, by establishing self-sufficient towns on both sides of these major roads, if possible. Alternatively, the relevant road authority could evaluate safer and more appropriate cross opportunities of these roads.
21 Conclusion & Recommendations	This report summaries an investigation of the transport impacts, expected as part of the Gergarub Mine, planned to the north of Rosh Pinah in Namibia. The following can be concluded, based on this investigation: **2023 Existing Traffic**: No upgrades are required or proposed. **2028 Background Traffic**: No upgrades are required or proposed. **Trip Generation**: expected to generate 50 total trips (25 in and 25 out) **2028 Total Traffic**: No upgrades are required or proposed. **2038 Total Traffic** - No upgrades are proposed, *from an intersection capacity point of view*. However, turning lanes are recommended at the C13/Gergarub Mine access intersection, *from a safety point of view.*

	Site Access: It is recommended that the speed limit along the C13 Road be reduced from the existing 120km/h to 80km/h in the vicinity of the mine access. Sufficient Shoulder Sight Distance would be available from the mine access along the C13 Road in both directions. **Public Transport**: It is recommended that bus embayments with sufficient circulating radii (min. 15 meters), lighting and shelter be provided on-site. **Receptor Identification**: Public facilities and pedestrians desire lines were identified. However, little can be done to addresses these issues, apart from the existing advancing warning signs in the area. A suggestion is that the relevant road authority could evaluate safer and more appropriate cross opportunities of these roads. Based on the findings in this investigation, it is evident that the impact of the proposed development would be relatively low on the surrounding road network. Hence, it is recommended that the Gergarub Mine development be considered for approval, *from a transport point of view*, provided that the upgrades discussed in this report are in place.

REFERENCES

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3. Innovative Transport Solutions. 4324 Route Assessment Oranjemund-Rosh Pinah-Luderitz. April 2021.
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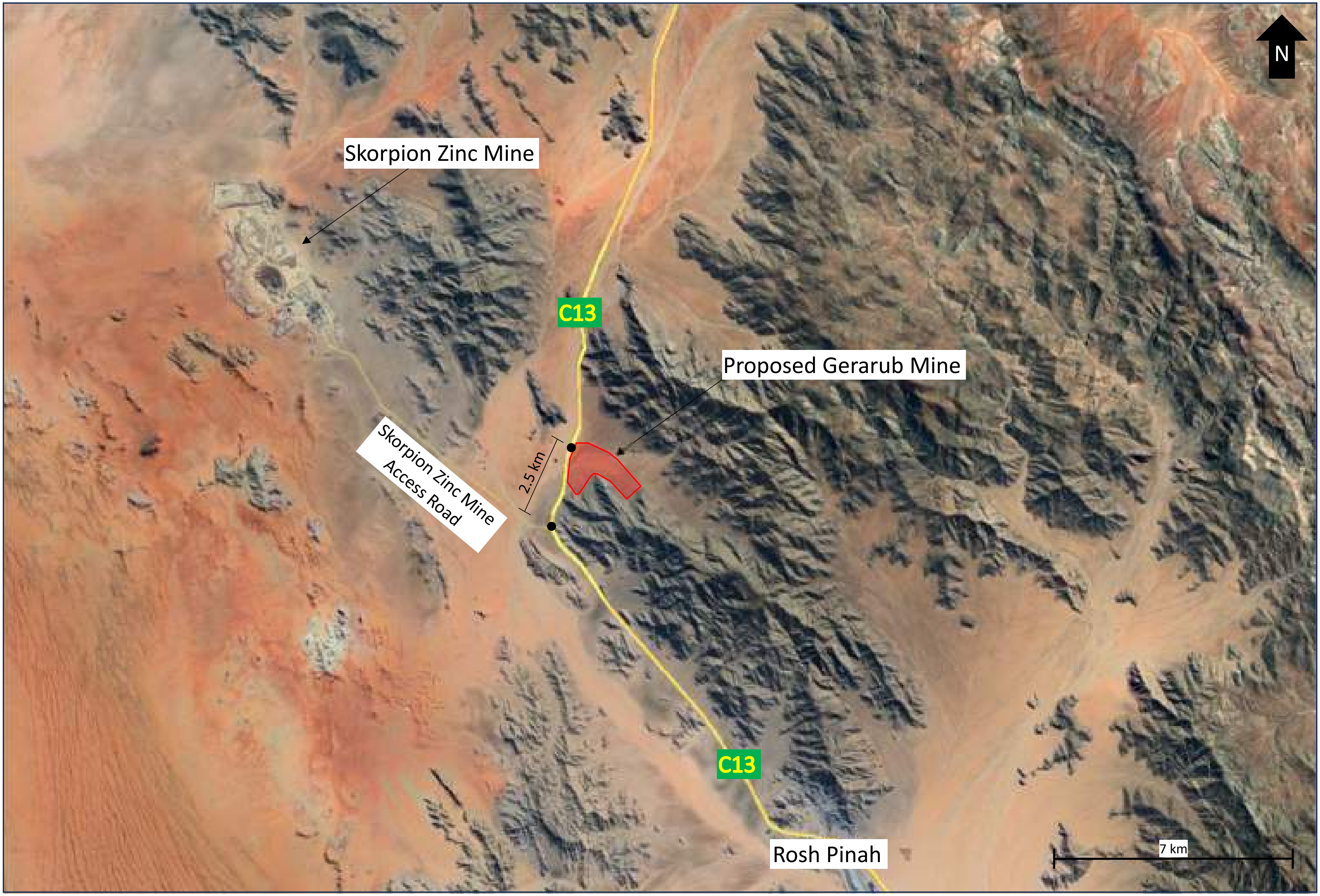
5. SRK Consulting. 447029 Gergarub Feasibility Study. March 2015.
6. Western Cape Government, Access Management Guidelines, November 2019

Annexure A

Figures

List of Figures

PROJECT:	FIGURE:	NUMBER:
GERGARUB MINE, KARAS REGION NAMIBIA	LOCALITY PLAN (Wider Area)	1A



PROJECT: GERGARUB MINE, KARAS REGION NAMIBIA	FIGURE: LOCALITY PLAN (zoomed in view)	NUMBER: 1B

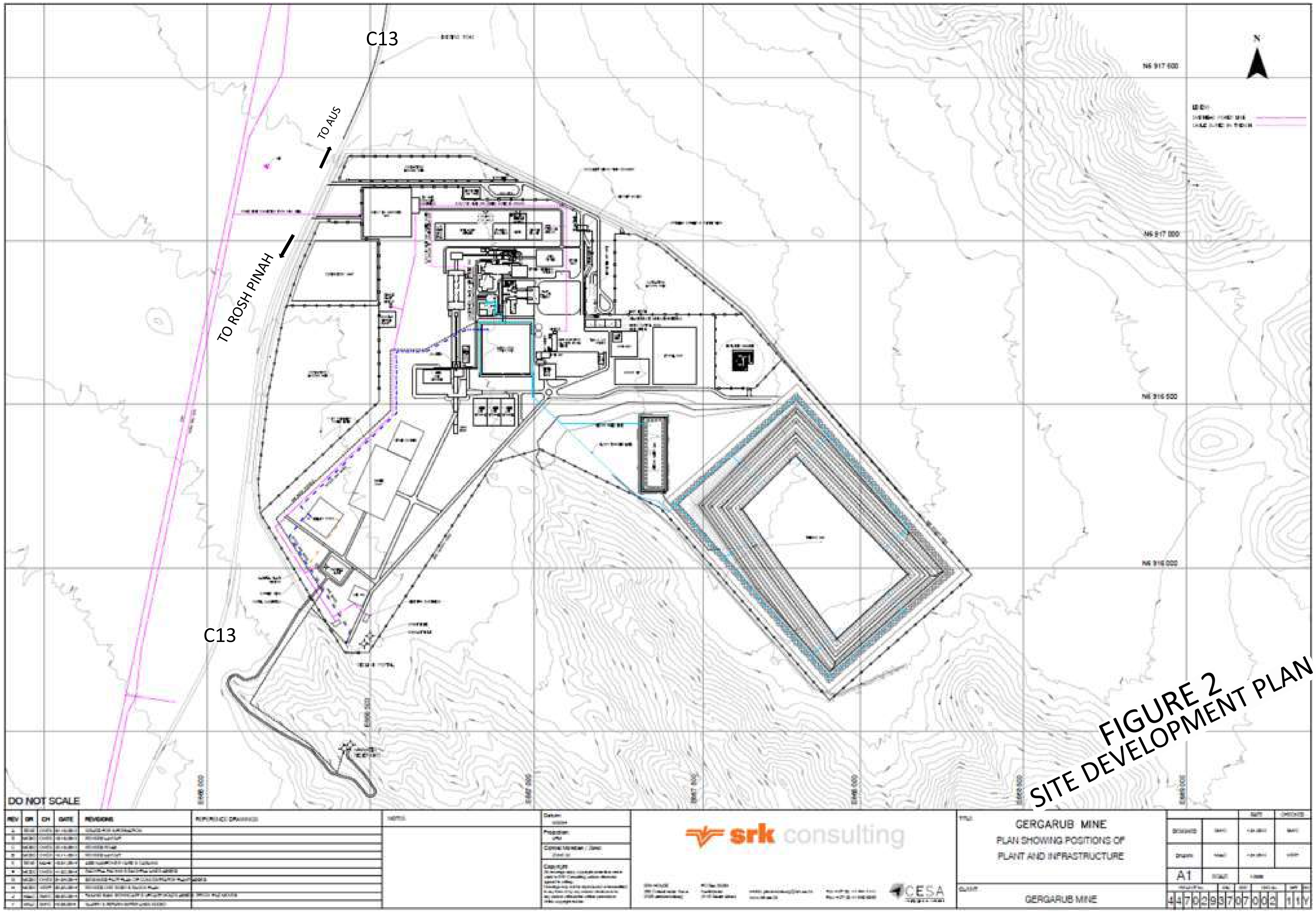
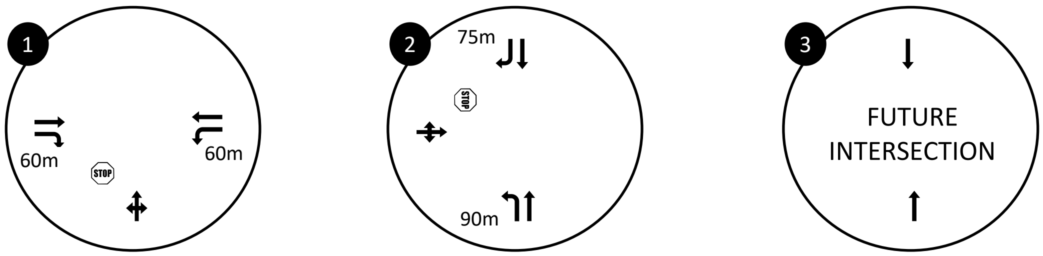


Figure 2-2: Overall site layout

Existing Intersection Geometry and Control

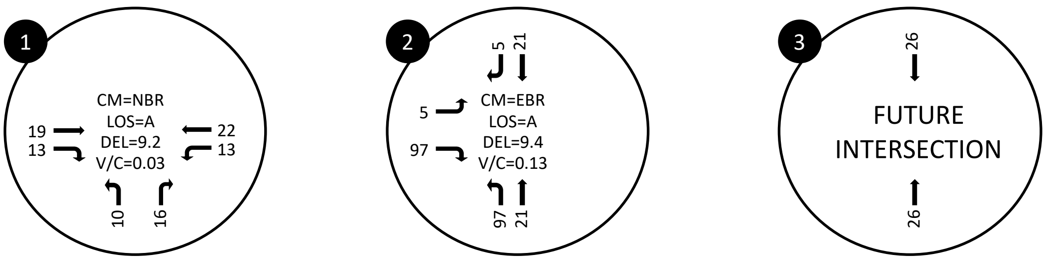


B4 / C13 intersection

C13 / Sorpion Zinc Mine intersection

C13 / Gergarub Mine intersection

2023 Exisiting Traffic Conditions - 30th Highest Hourly Volumes

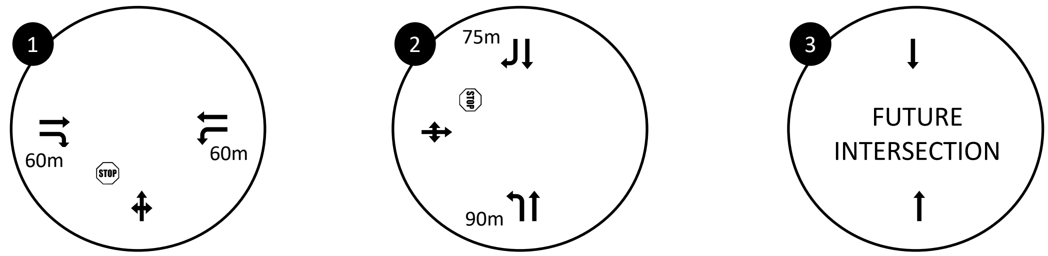


CM : Critical Movement
LOS: Level of Service of intersection if Signal or 4-way Stop or of Critical movement if unsignalised
DEL: Avg Delay per vehicle if signalised or for critical movement if unsignalised
V/C: Critical V/C Ratio
Turning movement and turning volume over the period

Legend:
Turning lanes and turning movements
Stop Control
Traffic Signal Control

Project:	Figure:	Number:
Gergarub Mine, Karas Region Namibia	**2023 Existing Traffic Scenario**	**3**

Existing Intersection Geometry and Control

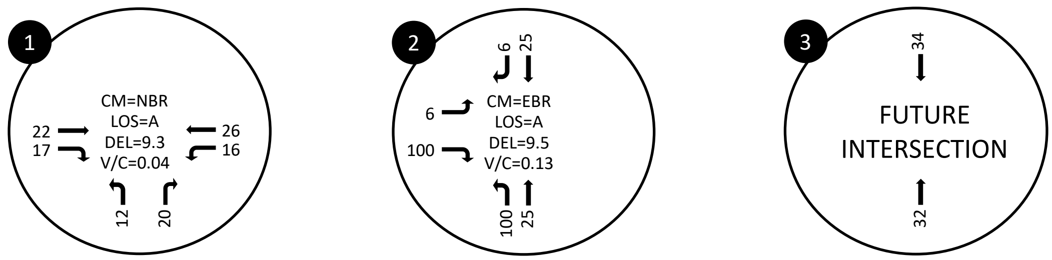


B4 / C13 intersection

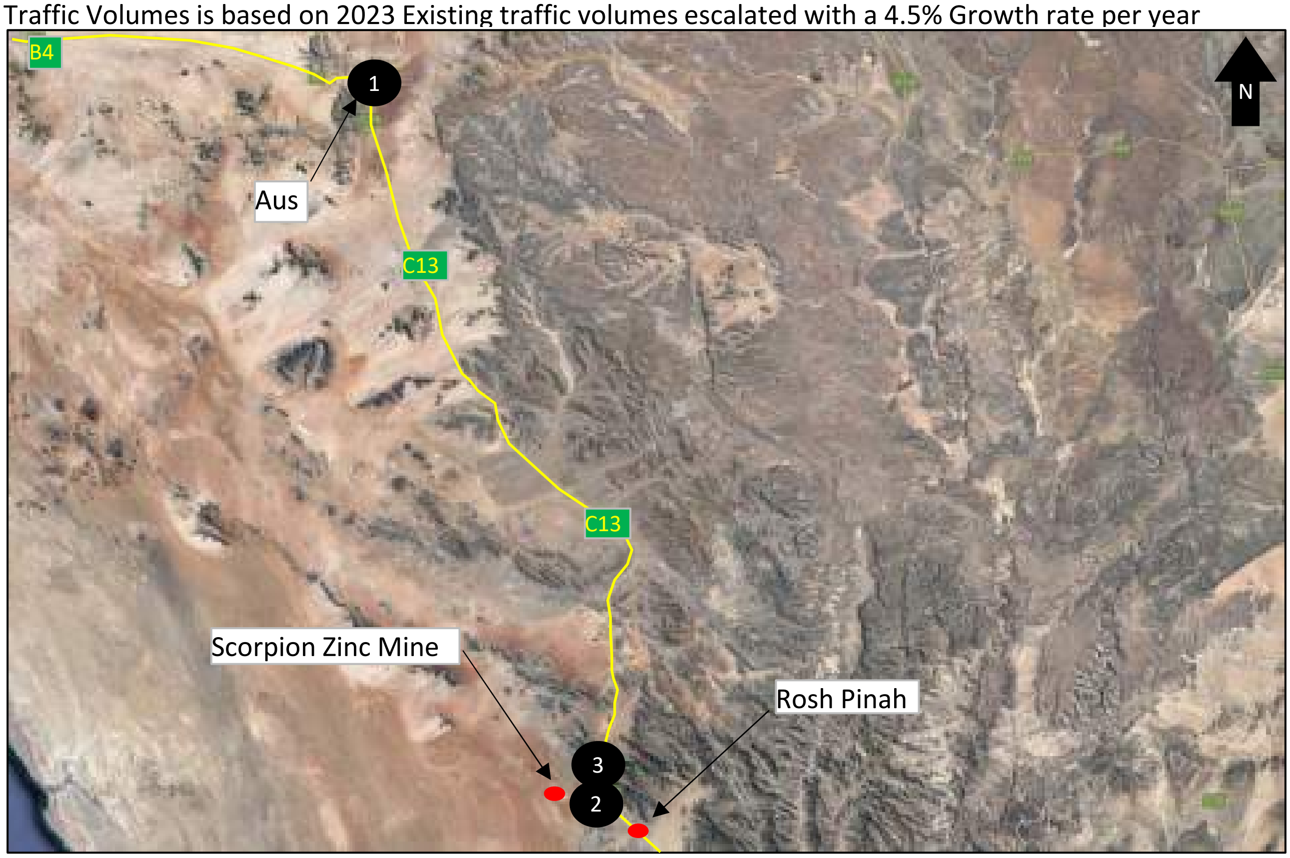
C13 / Sorpion Zinc Mine intersection

C13 / Gergarub Mine intersection

2028 Background Traffic Conditions - 30th Highest Hourly Volumes



Traffic Volumes is based on 2023 Existing traffic volumes escalated with a 4.5% Growth rate per year

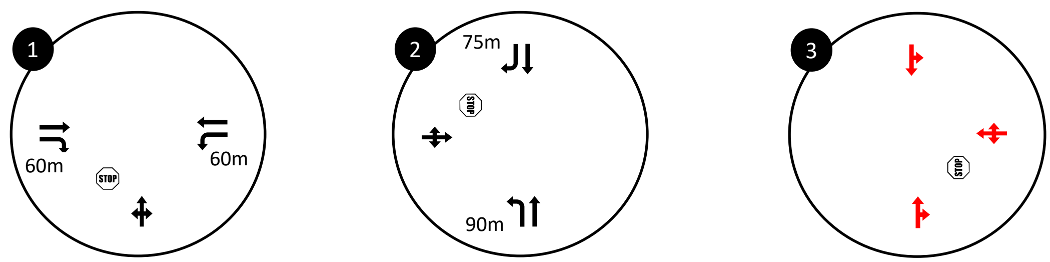


CM : Critical Movement
LOS: Level of Service of intersection if Signal or 4-way Stop or of Critical movement if unsignalised
DEL: Avg Delay per vehicle if signalised or for critical movement if unsignalised
V/C: Critical V/C Ratio
Turning movement and turning volume over the period

Legend:
Turning lanes and turning movements
Stop Control
Traffic Signal Control

Project:	Gergarub Mine, Karas Region Namibia	Figure:	2028 Background Traffic Scenario	Number: 4

Intersection Geometry and Control

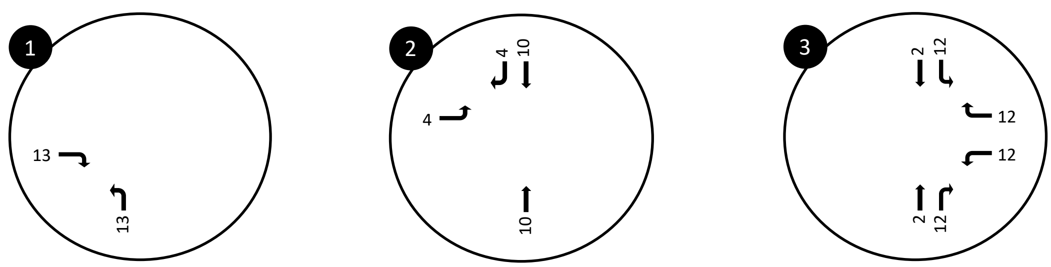


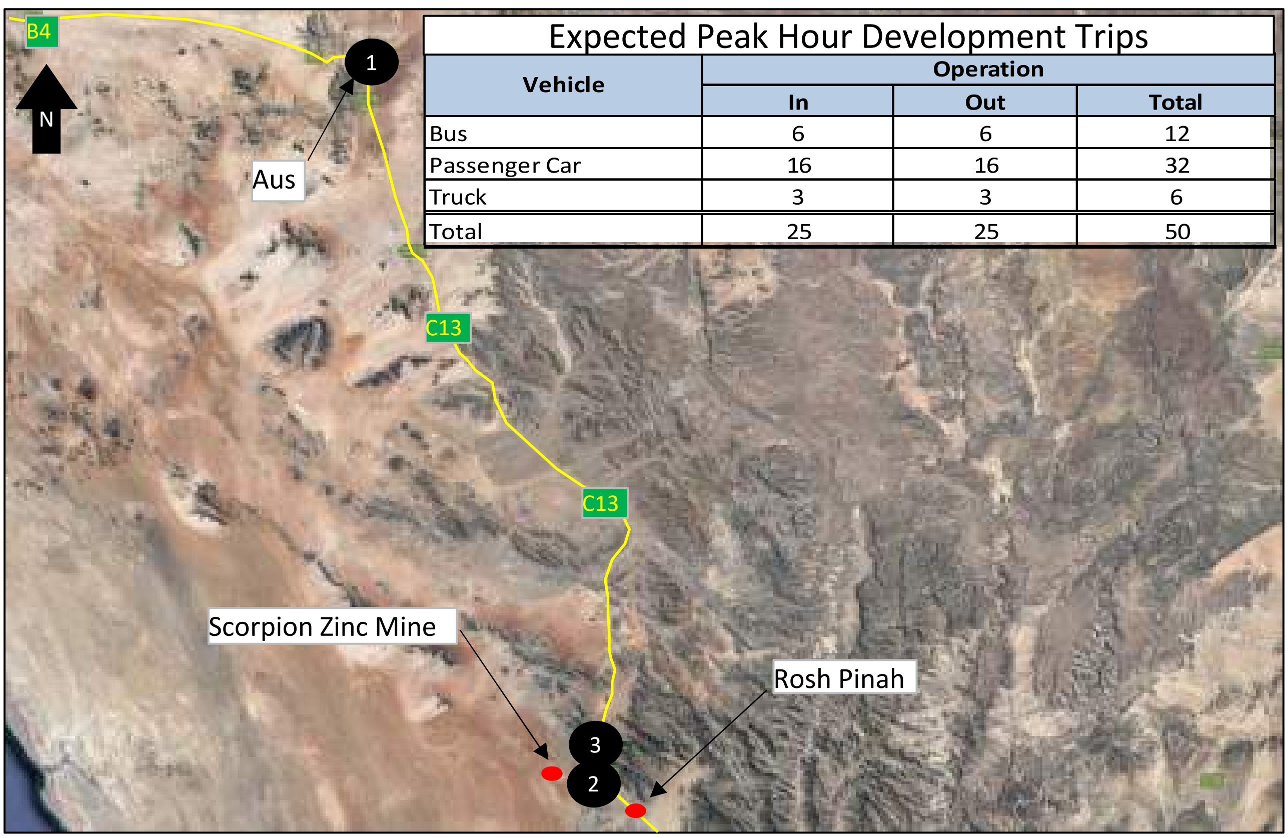
B4 / C13 intersection

C13 / Sorpion Zinc Mine intersection

C13 / Gergarub Mine intersection

Development Trips





Expected Peak Hour Development Trips

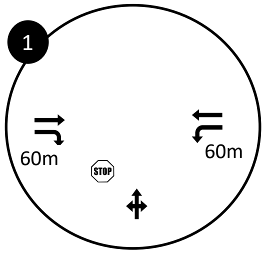
Vehicle	Operation		
	In	Out	Total
Bus	6	6	12
Passenger Car	16	16	32
Truck	3	3	6
Total	25	25	50

CM : Critical Movement
LOS: Level of Service of intersection if Signal or 4-way Stop or of Critical movement if unsignalised
DEL: Avg Delay per vehicle if signalised or for critical movement if unsignalised
V/C: Critical V/C Ratio
Turning movement and turning volume over the period

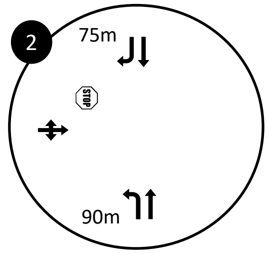
Legend:
Turning lanes and turning movements
Stop Control
Traffic Signal Control

Project:	Figure:	Number:
Gergarub Mine, Karas Region Namibia	**Development Trips**	**5**

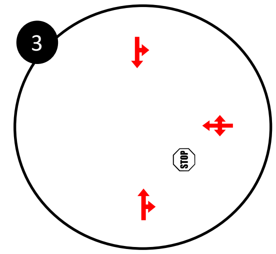
Intersection Geometry and Control



B4 / C13 intersection

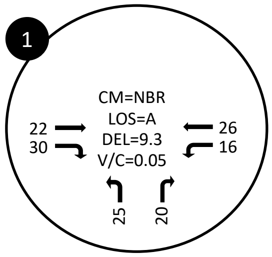


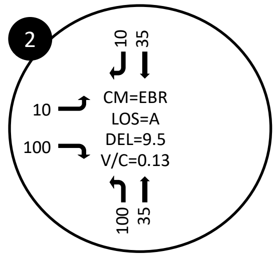
C13 / Sorpion Zinc Mine intersection

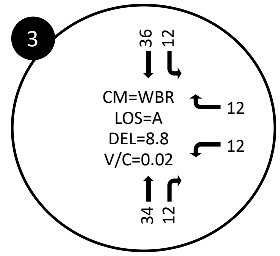


C13 / Gergarub Mine intersection

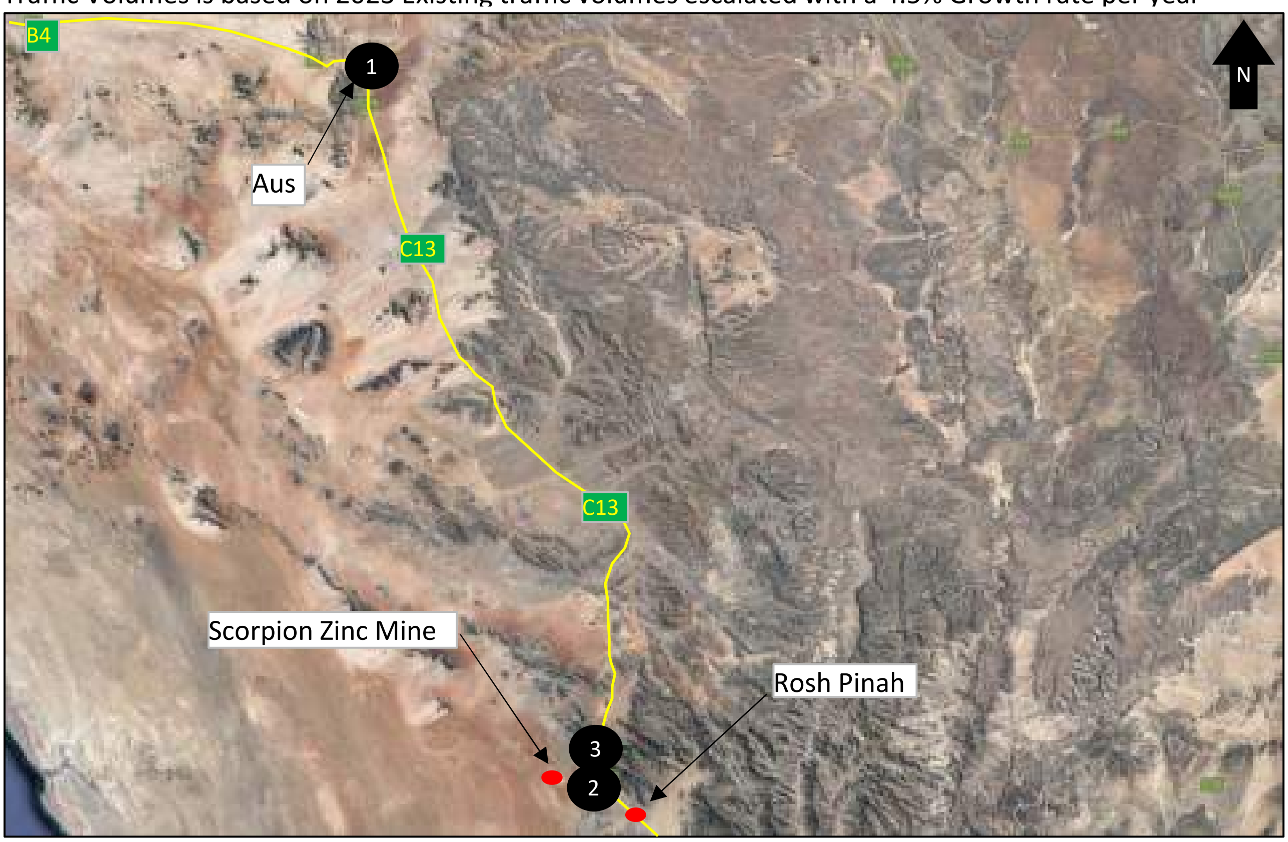
2028 Total Traffic Conditions - 30th Highest Hourly Volumes







Traffic Volumes is based on 2023 Existing traffic volumes escalated with a 4.5% Growth rate per year

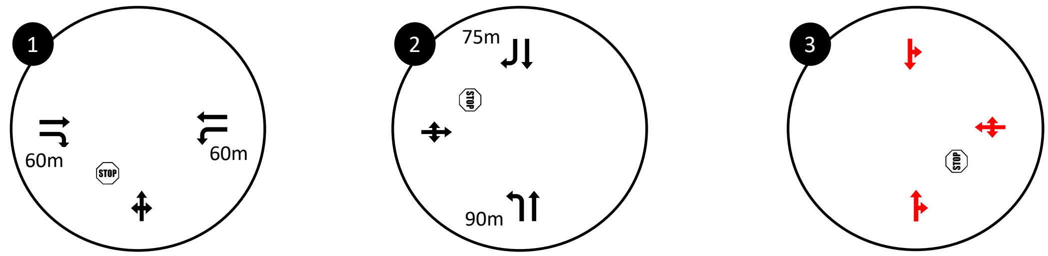


CM : Critical Movement
LOS: Level of Service of intersection if Signal or 4-way Stop or of Critical movement if unsignalised
DEL: Avg Delay per vehicle if signalised or for critical movement if unsignalised
V/C: Critical V/C Ratio
Turning movement and turning volume over the period

Legend:
Turning lanes and turning movements
Stop Control
Traffic Signal Control

Project:	Figure:	Number:
Gergarub Mine, Karas Region Namibia	**2028 Total Traffic Scenario**	**6**

Intersection Geometry and Control

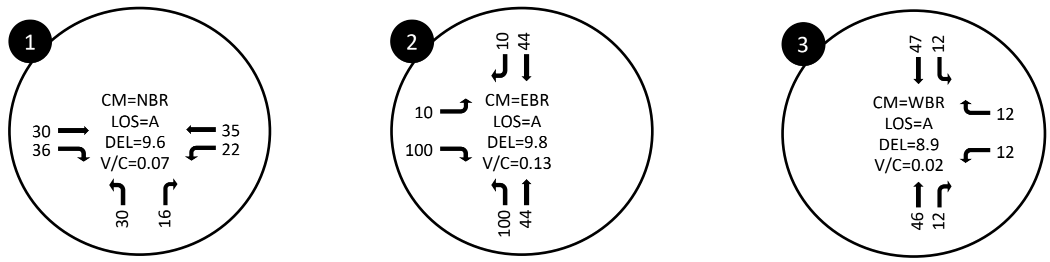


B4 / C13 intersection

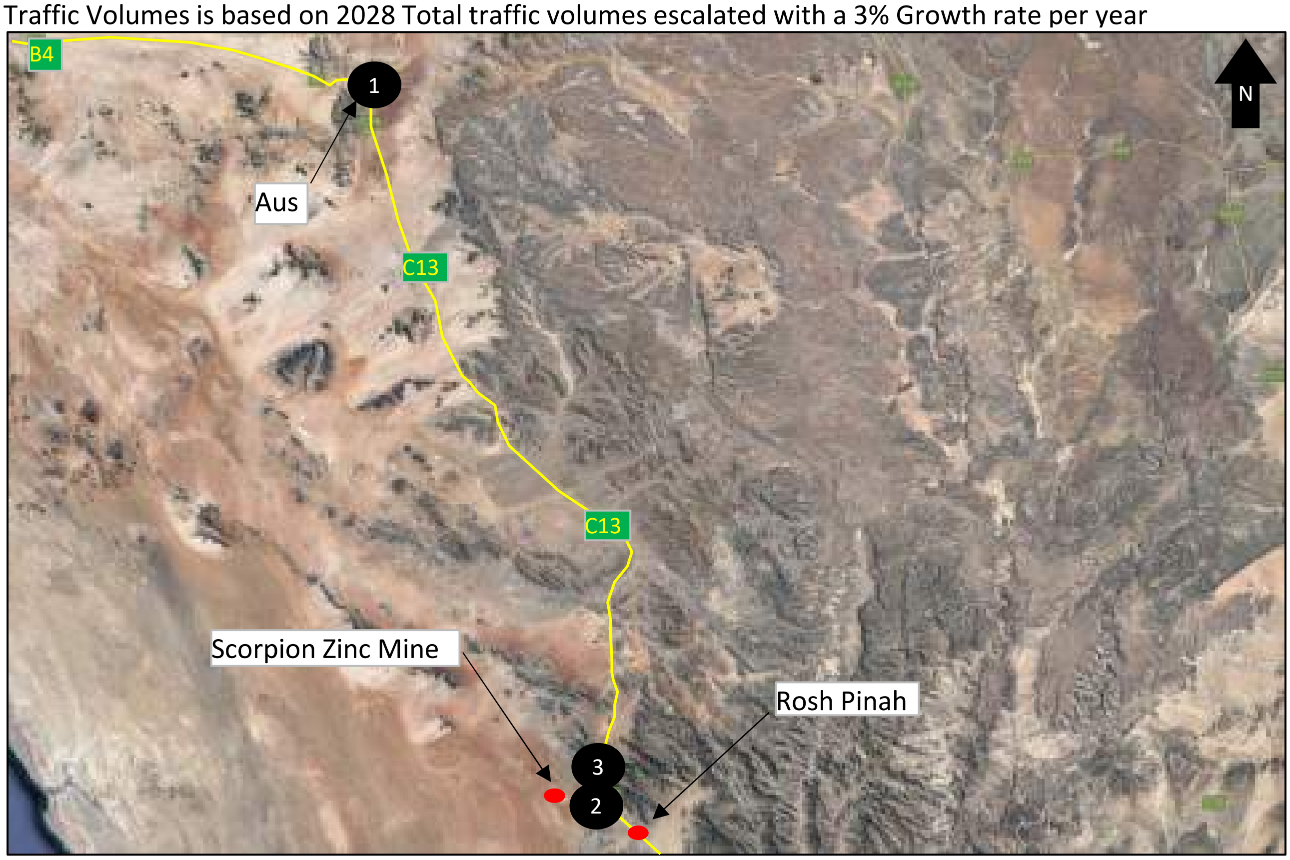
C13 / Sorpion Zinc Mine intersection

C13 / Gergarub Mine intersection

2038 Total Traffic Conditions - 30th Highest Hourly Volumes



Traffic Volumes is based on 2028 Total traffic volumes escalated with a 3% Growth rate per year



CM : Critical Movement

LOS: Level of Service of intersection if Signal or 4-way Stop or of Critical movement if unsignalised

DEL: Avg Delay per vehicle if signalised or for critical movement if unsignalised

V/C: Critical V/C Ratio

Turning movement and turning volume over the period

Legend:

Turning lanes and turning movements

Stop Control

Traffic Signal Control

Project:	Figure:	Number:
Gergarub Mine, Karas Region Namibia	**2038 Total Traffic Scenario**	**7**

PROJECT:	FIGURE:	NUMBER:
GERGARUB MINE, KARAS REGION NAMIBIA	SHOULDER SIGHT DISTANCE	8

its

PROJECT:	FIGURE:	NUMBER:
GERGARUB MINE, KARAS REGION NAMIBIA	PUBLIC FACILITIES, LUDERITZ	9

its

PROJECT:

GERGARUB MINE, KARAS REGION NAMIBIA

FIGURE:

PUBLIC FACILITIES, AUS

NUMBER:

10

its

PROJECT:	FIGURE:	NUMBER:
GERGARUB MINE, KARAS REGION NAMIBIA	PUBLIC FACILITIES, ROSH PINAH	11

Annexure B

Tables

Table 1: Person Trip Generation

PROPOSED DEVELOPMENTS	
Operation phase	
SIZE OF DEVELOPMENTS	679
Land use	**Mine**
Number of employees	226
PERSON TRIP GENERATION RATES	
Person/worker trip generation rate per household	1
DEMAND DURING PEAK HOUR	
Proportion of person trips during the peak period	100%
Person trips during peak hour	
Demand	226
PRIMARY MODAL SPLIT (PUBLIC TRANSPORT, INCLUDING WALKING, VS PRIVATE TRANSPORT)	
Modal split (public transport share, including walking)	90%
Number of public transport passengers and pedestrians	204
SECONDARY MODAL SPLIT	
Public transport modal split	
Bus	100%
No of people using public transport	
Bus	204
Private Motor Vehicles	23
Bus Trips	
Bus capacity (pax)	40
% of bus trips In	100%
% of bus trips Out	100%
No of bus pax In	204
No of bus pax Out	204
Total no of bus trips In	**5**
Total no of bus trips Out	**5**
NUMBER OF PRIVATE VEHICLE TRIPS	
Motor vehicle capacity (pax)	1.5
% of Motor Vehicle trips In	100%
% of Motor Vehicle trips Out	100%
No of Motor Vehicle pax In	23
No of Motor Vehicle pax Out	23
Total no of Motor Vehicle trips In	**15**
Total no of Motor Vehicle trips Out	**15**

Table 2: Truck Trip Generation and Development Trips

360 000	Material exported in tons per annum
34	Truck capacity in tons
30	no. of trucks per day
3	No. of trucks per hour per direction (assume trucks only drive during the day)
6	Total Truck trips per hour

Table 3: Peak Hour Development Trips Sumamry

Vehicle	Operation		
	In	Out	Total
Bus	6	6	12
Passenger Car	16	16	32
Truck	3	3	6
Total	**25**	**25**	**50**

Annexure C

Photo's

Photo 1: Access about 2.5km north of Scorpion Zinc Mine, sight distance towards Rosh Pinah

Photo 2: Access about 2.5km north of of Scorpion Zinc Mine, sight distance towards Aus

Photo 3: Westbound view along the B4 from the C13 / B4 intersection

Photo 4: Eastbound view along the B4 from the C13/B4 intersection

Photo 5: Westbound view along the B4 toward Lüderitz, 30km from Lüderitz

14 September 2023

Environmental Compliance Consultancy

P.O. Box 91193

Klein Windhoek

Windhoek

Namibia

For attention: Jessica Mooney

ARCHAEOLOGICAL ASSESSMENT AND MITIGATION REPORT ON THE PROPOSED GERGARUB MINE

DECLARATION

I hereby declare that I do:

(a) have knowledge of and experience in conducting archaeological assessments, including knowledge of Namibian legislation, specifically the National Heritage Act (27 of 2004), as well as regulations and guidelines that have relevance to the proposed activity;

(b) perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant;

(c) comply with the aforementioned Act, relevant regulations, guidelines and other applicable laws.

I also declare that I have no interests or involvement in:

(i) the financial or other affairs of either the applicant or his consultant

(ii) the decision-making structures of the National Heritage Council of Namibia.

John Kinahan, Archaeologist

EXECUTIVE SUMMARY

The proposed Gergarub zinc project, near Rosh Pinah in the Karas Region of Namibia, is located in an area of known archaeological significance. A detailed assessment carried out in 2014 showed that the project will disrupt the protected landscape setting of eighteen archaeological heritage sites and will pose a direct threat of damage or destruction to three of these sites, including a sensitive pre-colonial burial. The individual significance and vulnerability of the sites to direct impact is relatively low where they lie at some distance from the planned mine and associated surface works. The report presented here is an updated assessment and includes the results of an excavation of the burial site QRS 177/18. The remains recovered from the site are housed in the National Museum of Namibia Archaeology Collection under accession number B4367.

TABLE OF CONTENTS

Introduction

Skorpion Zinc (Vedanta Resources) intends to develop a mining operation at Gergarub, located between the existing Skorpion Zinc and Rosh Pinah mines in the Karas Region of southern Namibia. The Gergarub ore body lies beneath up to 100m of alluvial cover, and feasibility studies suggest that the depth of the ore body may require an underground mining operation. The mine would also require waste rock and tailings facilities, a processing plant and other surface infrastructure.

Gergarub lies at the foot of the Namibian escarpment, on the western edge of the Namus mountains, an outlier of the Huib Hoch mountain terrain. To the west, lies the southern Namib dune sea. Although Gergarub falls within the relatively cool winter rainfall region of southwestern Namibia, it receives less than 100mm of rainfall annually, and this is reflected in generally sparse Succulent Karoo vegetation cover, and a low density of animal life.

Although the archaeology of this region is not known in detail, studies at a number of sites have revealed a documented sequence of early hominin and modern human occupation spanning the last one million years, as well as securely dated evidence of some of the earliest known examples rock art on the African continent. On the basis of this and other evidence the Gergarub project is recognized to lie within an area of high archaeological significance.

A series of detailed archaeological surveys have been carried out at Gergarub, at Skorpion Zinc and at a number of infrastructure development sites in the vicinity of Rosh Pinah, making this one of the most intensively surveyed areas in Namibia. The area has also been the focus of several archaeological excavations which have formed the basis of a securely dated record of human occupation[1].

For the purposes of the Gergarub project, Skorpion Zinc followed the environmental assessment process as directed by the Environmental Management Act (2007) and its Regulations (2012). The National Heritage Act (2004) also makes provision for the assessment of archaeological impacts, and Enviro Dynamics cc. engaged QRS to prepare a baseline study which was completed and submitted in February 2013 (QRS Report 177). The report was updated in 2014 to include details of the proposed mine and infrastructure.

Although the layout of the proposed Gergarub mine may be subject to change its likely impact on the archaeology of the area has been established by these studies. At the present stage only the

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1 Kinahan, J. 2005. The late Holocene human ecology of the Namib Desert. In Smith, M. & Hesse, P. Eds. *23 Degrees South: Archaeology and environmental history of the Southern Deserts.* Canberra: National Museum of Australia, pp. 120–31; Kinahan, J. & Kinahan, J.H.A. 2003. Excavation of a late Holocene cave deposit in the southern Namib Desert, Namibia. *Cimbebasia* 18: 1–10; Sievers, C. 1984. Test excavations at Rosh Pinah Shelter, southern Namibia. *Cimbebasia* (B) 4 (3): 29–40.

excavation of the burial site QRS 177/18 was required to ensure an adequate level of protection of archaeological resources in the vicinity of the proposed mine. This report reviews the 2014 assessment and presents the results of the burial excavation. It also reviews and reiterates the main recommendations for the continued protection of the Gergarub archaeological landscape.

Methodology

The archaeological survey and assessment of the Gergarub project is based on protocols developed for archaeological assessment in Namibia, intended to take into account the terms of the National Heritage Act (2004). Thus, the archaeological study identified potential sources of risk posed by the Gergarub project, and specific to the archaeology of the area as it is known from existing data and from the additional field survey carried out at Gergarub (QRS 177, February 2013).

Following these protocols, the archaeological *significance* of the sites, and their *vulnerability* to disturbance in the course of project development activities are evaluated according to parallel 0-5 scales, summarized in Error! Reference source not found.. Unlike conventional sensitivity scales, these allow independent assessments of significance and vulnerability. Archaeological *sensitivity* is represented as the arithmetic product of the significance and vulnerability rating.

The individual site descriptions and assessments presented in The Receiving Environment, below, provide both the three archaeological ratings as the basis for the Impact Assessment.

Table 1: Archaeological Significance and Vulnerability ranking scales

SIGNIFICANCE RANKING		**VULNERABILITY RANKING**	
0	no significance	0	not vulnerable
1	disturbed or secondary context	1	no threat posed
2	isolated minor find	2	low or indirect threat
3	archaeological site	3	probable threat
4	multi-component site	4	high likelihood of disturbance
5	major archaeological site	5	direct and certain threat

Assumptions & Limitations

The archaeological survey carried out for this baseline study relies on the indicative value of surface finds, augmented by the results of excavations carried out in the course of previous work in the same area. Based on these data, it is possible to predict the likely occurrence of further archaeological sites with some accuracy, and to present a general statement (see below: 4. The

Receiving Environment) of the local archaeological site distribution. However, since the Gergarub survey is limited to surface observations, it is necessary to caution the proponent that hidden, or buried archaeological remains might be exposed as the project proceeds.

Following standard practice both in Namibia and internationally, a Chance Finds procedure (Appendix A) is recommended as a component of the project Environmental Management Plan (EMP). A further limitation, regarding the archaeological assessment itself, is that continuing development in the project area will over time raise the significance of finds reported here as the extent of undisturbed ground steadily diminishes. The implications of this loss of archaeological landscape context are discussed in the report.

Project Description

The proposed Gergarub mine will occupy a footprint of about 3 km^2 in an area of mixed terrain comprising dunefields and outwash fans on the western margins of the Namus Mountains. The mine will add appreciably to the industrialization of the Rosh Pinah area which will accommodate three mines (Gergarub, Skorpion and Rosh Pinah) and their associated infrastructure within an area of approximately 150 km^2. These developments, both those directly concerned with the mine, and the provision of supporting infrastructure, represent a considerable modification or disturbance of the local landscape.

Several archaeological surveys and research excavations mentioned in the Introduction, and the baseline study for the present project, have demonstrated the archaeological importance of the project area and its sensitivity to disturbance and possible destruction of archaeological remains that are protected under Namibian law (see Legal & Regulatory Requirements, below). The Gergarub project poses a number of impact threats both to the archaeological sites and their landscape setting as defined under the National Heritage Act (27 of 2004).

Legal & Regulatory Requirements

<u>Acts & Ordinances</u>

The principal instrument of legal protection for heritage resources in Namibia is the National Heritage Act (27 of 2004). Part V Section 46 of the Act prohibits removal, damage, alteration or excavation of heritage sites or remains (defined in Part 1, Definitions 1), while Section 48 *ff* sets out the procedure for application and granting of permits such as might be required in the event of damage to a protected site occurring as an inevitable result of development. Section 51 (3) sets out the requirements for impact assessment. Part VI Section 55 Paragraphs 3 and 4 require that any person who discovers an archaeological site should notify the National Heritage Council.

It is important to be aware that no regulations have been formulated and gazetted for the implementation of the National Heritage Act, and there is no official procedure concerning impact assessment. However, archaeological impact assessment of large projects has become accepted practice in Namibia, and project proponents are required to obtain an NHC letter of consent. Where proponents need to consider international guidelines, the most appropriate are those of the World Bank OP and BP 4.11 guidelines in respect of "Physical Cultural Resources" and Performance Standard 8. Those relating to project screening, baseline survey and mitigation are the most relevant.

Archaeological impact assessment in Namibia may also take place under the rubric of the Environmental Management Act (7 of 2007) which specifically includes anthropogenic elements in its definition of environment. The list of activities that may not be undertaken without Environmental Clearance Certificate: Environmental Management Act, 2007 (Govt Notice 29 of 2012), and the Environmental Impact Assessment Regulations: Environmental Management Act, 2007 (Govt Notice 30 of 2012) both apply to the management of impacts on archaeological sites and remains whether these are considered in detail by the environmental assessment or not.

<u>Namibian Commitment to International Standards and/or Guidelines</u>

The Republic of Namibia is signatory to the 1972 World Heritage Convention, which supposes a degree of general commitment to heritage conservation beyond the narrower definitions of the National Heritage Act (27 of 2004). The Government of the Republic of Namibia has not however developed any specific domestic guidelines or adopted any other internationally agreed guidelines. Projects intending to qualify for International Finance Corporation (IFC) assistance, whether initiated by the Government of the Republic of Namibia or any other corporation operating in Namibia, would nonetheless be obliged to conform to the requirements set out in the IFC Performance Standard 8, Cultural Heritage.

In brief, these instruments and guidelines require that measures are taken to protect cultural heritage from adverse effects of project activities are to be established during the environmental impact assessment process. The definitions of archaeological cultural heritage used by the IFC Performance Standard 8 are essentially the same as those used in the Namibian National Heritage Act (27 of 2004). The IFC standards require that adequate data collection is carried out and competent professionals should carry out any excavation if this is required in order to rescue cultural heritage threatened by the project.

Where excavation of archaeological sites is to be carried out, the IFC standards stipulate that the project "should apply internationally recognized practices to site surveys, excavation, preservation and publication, in addition to compliance with national law. An internationally recognized practice is defined as the exercise of professional skill, knowledge, diligence, prudence and foresight that would reasonably be expected from experienced professionals engaged in the same type of undertaking under the same or similar circumstances globally" (IFC Guidance Note 8, p3).

The specific application of the IFC standards and guidance notes to the Gergarub project are set out in detail under Impact Assessment, Mitigation, and the Conclusions & Recommendations, below.

Local, National and International Policies and Guidelines

In the absence of clear regulatory standards concerning the possible impact of mining in Namibia, the Namibia Archaeological Trust has compiled *Archaeological Guidelines for Mineral exploration and Mining in the Namib Desert.* This document may be freely downloaded at www.archaeologynamibia.com.

More general standards are contained in the Environmental Quality Objectives (EQO's) proposed by the Strategic Environmental Assessment for the Central Namib Uranium Rush[2]. The following four standards are relevant to the potential archaeological impact of the Gergarub project.

- To practice good corporate citizenship in the conservation of the archaeological record.
- To improve awareness of sensitive archaeological sites.
- To implement archaeological guidelines for mineral exploration in the Namib Desert.
- To recognize the archaeological record as the material "memory" of the Namib Desert.

Archaeological setting

Due to its aridity, south-western Namibia presents a marginal environment for human occupation, and in the past, particularly during periods of climatic cooling and hyper-aridity, the region may have been quite inimical to settlement. These conditions are reflected in the available archaeological evidence, which spans the last 0.8 million years with a sequence that is characterized by short periods of relatively intensive occupation, and long periods in which there appears to have been little or no human presence.

The regional sequence may be simplified as follows:

- Early to mid-Pleistocene (ca. 2my to 0.128my; OIS 6, 7, 19 &c): represented by surface scatters of stone tools and artefact debris, usually transported from original context by fluvial action, and seldom occurring in sealed stratigraphic context.
- Mid- to upper Pleistocene (ca. 0.128my to 0.040my; OIS 3, 4 & 5a-e): represented by dense surface scatters and rare occupation evidence in sealed stratigraphic context, with occasional associated evidence of food remains.
- Late Pleistocene to late Holocene (ca. 0.040my to recent; OIS 1 & 2): represented by increasingly dense and highly diverse evidence of settlement, subsistence practices and ritual art, as well as grave sites and other remains.
- Historical (the last ca. 250 years): represented by remains of crude buildings, livestock enclosures, wagon routes and watering points. Some evidence of trade with indigenous communities, including metals, ceramics and glass beads.

For the most part, early to mid-Pleistocene sites are associated with pans, outwash gravels, drainage lines and river gravels. These sites are difficult to detect and are usually overlooked in the course of construction work. Mid- to upper Pleistocene sites occur in similar contexts to the earlier material, but hill foot-slopes and outcrops of rock suitable for artefact production (e.g. chert, fine-grained

2 Ministry of Mines and Energy, Windhoek (2011).

quartzites) are also focal points. Late Pleistocene to late Holocene sites occur in almost every terrain setting, with the exception of very steep slopes and mountain tops. These sites often exhibit locally integrated distribution patterns which allow some reconstruction of land-use and subsistence. Major sites include rock shelters with well stratified occupation deposits, containing an array of organic and inorganic residues. Early historical sites tend to be concentrated along routes suitable for wagon transport, and a more recent, broader landscape distribution associated with the establishment of farming settlement.

The Gergarub project area consists of two basic land units: the Namus mountain terrain in the east, and the gravel outwash fans with aeolian sand cover in the west.

- The mountains are marginal to the project area and are generally of little archaeological significance, except on their lowest western foot-slopes.
- The gravel outwash land unit accounts for roughly 80% of the project area, and contains two archaeologically important sub-units: gravel plains, and isolated rocky hills and outcrops.

Of the 18 archaeological sites located in the course of the field survey (see Figure **5**), and described in more detail below, 88% are associated with isolated rocky hills and outcrop features, the remaining 12% being associated with gravel plains. Ten of the sites, representing 58% of the total are rock shelters; 23% are stone features, including two suspected grave sites, and 17% are surface scatters of stone artefact debris, ostrich eggshell and other remains. The high concentration of rock shelter sites is significant, and as many as five of these sites may contain stratified archaeological deposits. One of the sites, QRS 177/18 is considered to be highly vulnerable to the proposed Gergarub project; two others, QRS 177/15 and 177/16 are also considered to be vulnerable, and one site QRS 177/10, while not directly vulnerable, is considered to have significant research potential.

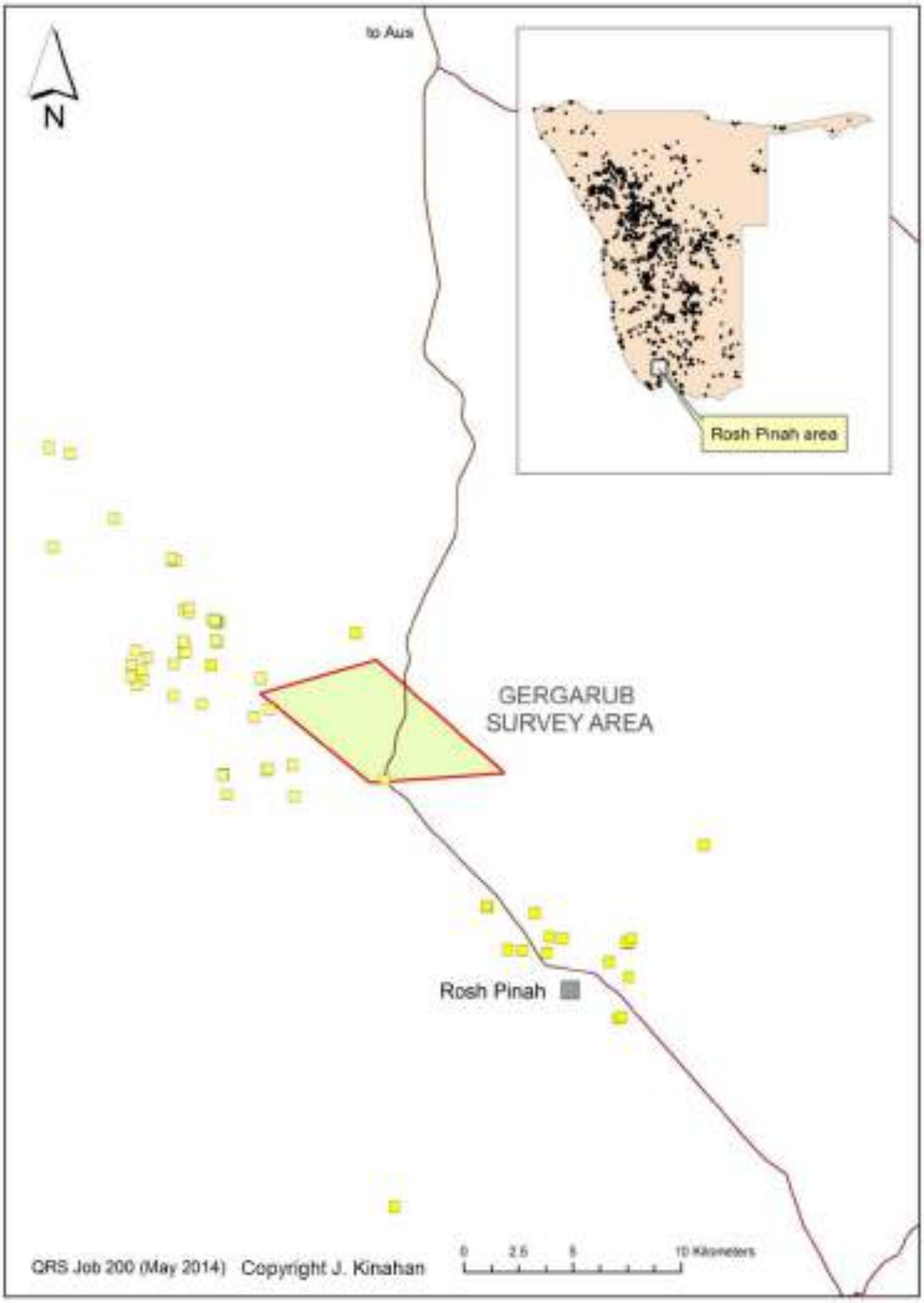

Figure 1: The regional archaeological setting of the Gergarub project area, showing undifferentiated distribution of known archaeological sites (yellow squares).

Figure 2: View across the Gergarub project area from the north-west, showing major land units (Namus mountain terrain, and gravel outwash with aeolian sand cover). Isolated rocky hills in the latter are visible in the middle distance.

Figure 3: Site QRS 177/10 viewed from the west and showing outwash fan with aeolian sand cover in the middle distance (right). The site is situated in a high saddle on a schist ridge.

The archaeological potential of the Gergarub project area, especially the concentration of rock shelter sites mentioned above, is shown by the results of previous studies at two rock shelter sites in the near vicinity: Rosh Pinah Shelter, and Skorpion Cave.

Rosh Pinah Shelter (Sievers 1984) is located on the property Spitzkop West, and systematic excavations over an area totalling $7m^2$ revealed a stratified deposit with a rich accumulation of stone artefact material and organic remains including food plant remains, wood, animal bone and land snail shell. The stone artefact assemblages were dominated by quartz, with minor quantities of hornfels and chert, all locally derived. Evidence of plant foods included !nara *Acanthosicyos horrida* and tsamma *Citrillus lanatus,* while evidence of animals hunted or snared represented a range of antelope, zebra, rock hyrax, hare, tortoise and the land snail *Trigonephrus.* Radiocarbon dates (summarized in Figure **4**, below), indicated a series of short occupation events during the last 10 000 years, punctuated by long periods of inactivity. The most recent occupation event at the site is associated with a red-on-white glass trade bead probably dating to the second half of the 19^{th} century.

Skorpion Cave (Kinahan & Kinahan 2003) is located on a low ridge overlooking the Rosh Pinah airstrip, and excavations over an area totalling $4m^2$ revealed a stratified deposit with well-preserved evidence of occupation, including stone artefact material and pottery, as well as plant and animal remains, including large quantities of land snail *Trigonephrus* sp. Shell with traces of charring, indicating that the snails were cooked. The range of evidence was similar to that of Rosh Pinah Shelter although it included a fragment of marine limpet *Patella* sp shell from the Atlantic coast, as well as a single Indian Ocean cowrie *Cypraea* sp which seemed to have formed part of an item of decoration. Radiocarbon dates (summarized in Figure **4**, below), indicate a two short occupation events during the last 2 000 years, separated by a long period of inactivity.

In summary, the evidence from Rosh Pinah Shelter and Skorpion Cave shows intermittent occupation, probably in response to climatic variation; a degree of specialized dependence on desert resources such as land snails and melons, combined with a broad spectrum of animal prey. The associated evidence shows that people living at these sites were integrated by either movement or trade, with regional networks, and that they were probably present in the 19^{th} century when the first traders and missionaries moved through the Gergarub area after crossing the Orange River at Sendelings Drift.

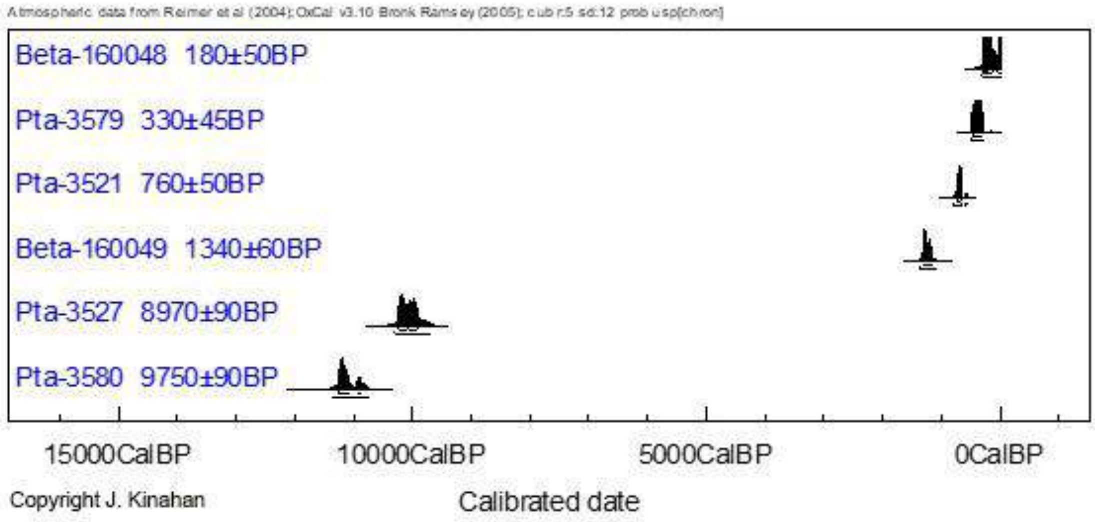

Figure 4: Combined calibrated radiocarbon dates for occupation events at Rosh Pinah Shelter (Sievers 1984) and Skorpion Cave (Kinahan & Kinahan 2003). The data show intermittent occupation and an apparent hiatus between 10 000 Cal BP and 2000 Cal BP.

The following 18 archaeological sites were recorded in the course of the Gergarub baseline field survey and impact assessment. The distribution of the archaeological sites, and their proximity to the proposed footprint of the Gergarub mine is shown in Figure **5.** A GIS file for the sites, with database attribute table is submitted with this report. The archaeological vulnerability rating of the sites (see 1. Background, Methodology, above) as given in the baseline survey report, is augmented in each site entry below with an Enviro Dynamics vulnerability rating (Low, Medium, High), allocated according to the impact risk as understood from the Gergarub project surface works design of April 2014.

Archaeological site gazetteer

QRS 177/1

Site coordinates:	S27.86515 E16.66346
Setting:	Gravel plain with dolomite outcrops
Description:	Dispersed stone feature associated with remains of fenced sheep enclosure, probably early to mid-20th century
Records:	Site record and photographs, bottle collected (Reckitt & Coleman, Jik)
Significance rating:	2
Vulnerability rating:	3
Sensitivity rating:	6

QRS 177/2

Site coordinates:	S27.84756 E16.64805
Setting:	Dolomite hill, mid-slope
Description:	Small rock shelter, ca. 1.5m on drip line, flaked quartz on talus
Records:	Site record
Significance rating:	2
Vulnerability rating:	3
Sensitivity rating:	6

QRS 177/3

Site coordinates:	S27.84823 E16.66459
Setting:	Dolomitic schist hill, foot-slope
Description:	Surface scatter, flaked quartz and ostrich eggshell
Records:	Site record
Significance rating:	2
Vulnerability rating:	3
Sensitivity rating:	6

QRS 177/4

Site coordinates:	S27.84114 E16.67026
Setting:	Dolomitic schist hill, foot-slope
Description:	Surface scatter, flaked quartz and ostrich eggshell
Records:	Site record
Significance rating:	2
Vulnerability rating:	3
Sensitivity rating:	6

QRS 177/5

Site coordinates:	S27.92399 E16.82633
Setting:	Schist outcrop
Description:	Rock shelter, facing 280° mag, 3x1.5m, possible deposit estimated 0.2m depth, surface scatter quartz and ostrich eggshell.
Records:	Site record
Significance rating:	3
Vulnerability rating:	2
Sensitivity rating:	6

QRS 177/6

Site coordinates:	S27.84304 E16.67812
Setting:	Dolomitic schist ridge
Description:	Rock shelter, facing 180° mag., single quartz flake.
Records:	Site record
Significance rating:	2
Vulnerability rating:	2
Sensitivity rating:	4

QRS 177/7

Site coordinates:	S27.84296 E16.67849
Setting:	Dolomitic schist ridge
Description:	Rock shelter, facing 150° mag, 3x3m, deposit estimated 0.2m depth, extensive and dense surface scatter flaked quartz, also imported late 19th century annular ware (blue, black, mustard-coloured banding), lower grindstone and some schist fragments with surface striations.
Records:	Site record, photographs.
Significance rating:	3
Vulnerability rating:	2
Sensitivity rating:	6

QRS 177/8

Site coordinates:	S27.84649 E16.68084
Setting:	Dolomitic schist ridge
Description:	Low shelter with fallen rocks cleared to top of talus, no deposit, surface scatter flaked quartz and ostrich eggshell.
Records:	Site record
Significance rating:	2
Vulnerability rating:	2
Sensitivity rating:	4

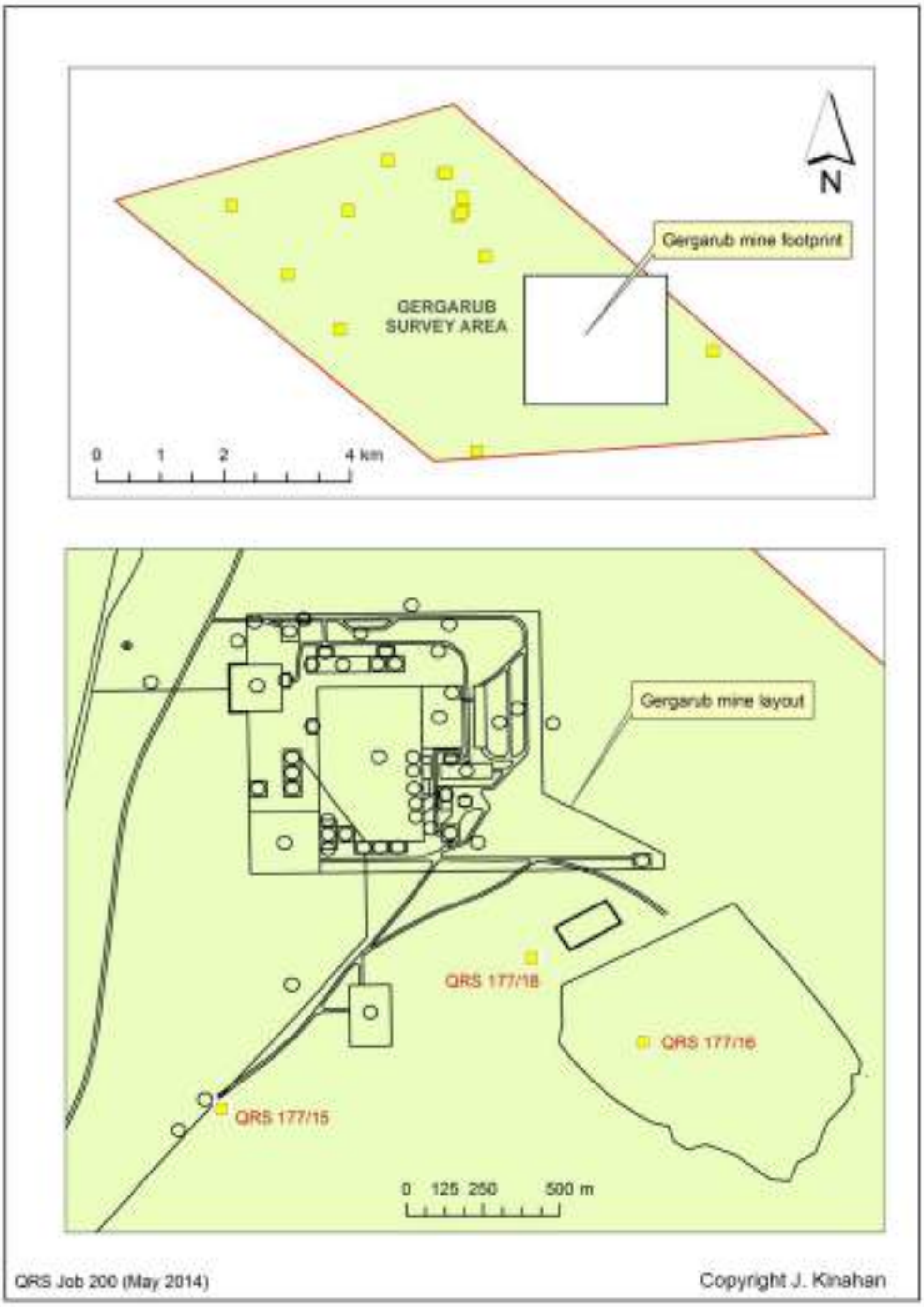

Figure 5: The distribution of archaeological sites within the Gergarub project area, and the proximity of archaeological sites to the elements of the proposed Gergarub mine layout as at April 2014

QRS 177/9

Site coordinates:	S27.84811 E16.68103
Setting:	Dolomitic schist ridge
Description:	Mid-slope rock shelter, facing 150° mag, 4x1.5m, could have shallow deposit, abundant flaked quartz and cryptocrystalline silicate (grey) on talus.
Records:	Site record
Significance rating:	2
Vulnerability rating:	2
Sensitivity rating:	4

QRS 177/10

Site coordinates:	S27.84899 E16.68012
Setting:	Schist ridge, saddle
Description:	Two large rock shelters adjacent, facing 160° mag, 5x3 and 8x3m, with deposit in largest shelter 0.3 – 0,5m depth, surface scatter flaked quartz, yellow chert, ostrich eggshell, and several sherds red burnished pottery (non-diagnostic).
Records:	Site record, photographs.
Significance rating:	4
Vulnerability rating:	3
Sensitivity rating:	12

QRS 177/11

Site coordinates:	S27.84851 E16.68059
Setting:	Schist ridge, foot of low cliff.
Description:	Surface scatter ostrich eggshell
Records:	Site record
Significance rating:	3
Vulnerability rating:	3
Sensitivity rating:	9

QRS 177/12

Site coordinates:	S27.85476 E16.68400
Setting:	Schist outcrop, foot-slopes
Description:	Large rock shelter, 8x4m, estimated 0.5m deposit, talus scatter includes flaked quartz, yellow chert, yellow ochre, specularite, ostrich eggshell, dispersed stone feature.
Records:	Site record
Significance rating:	3
Vulnerability rating:	3
Sensitivity rating:	9

QRS 177/13

Site coordinates:	S27.85735 E16.65601
Setting:	Dolomitic schist outcrop, mid-slope
Description:	Cairn, approximately 1.5m high inside rock shelter, below cavity which is a possible bees' nest. No trace of soot observed.
Records:	Site record, photograph
Significance rating:	2
Vulnerability rating:	2
Sensitivity rating:	4

QRS 177/14

Site coordinates:	S27.88245 E16.68288
Setting:	Isolated schist outcrop
Description:	Rock shelter, facing 160° mag, talus has flaked quartz
Records:	This site previously recorded as QRS 12/37 and allocated National Museum accession number B4250.
Significance rating:	2
Vulnerability rating:	2
Sensitivity rating:	4

QRS 177/15

Site coordinates:	S27.87293 E16.69060
Setting:	Base of low cliff
Description:	Rock shelter facing 100° mag, talus scatter flaked quartz, yellow chert and ostrich eggshell
Records:	Site record
Significance rating:	2
Vulnerability rating:	2
Sensitivity rating:	4

QRS 177/16

Site coordinates:	S27.87098 E16.70291
Setting:	Foot-slope, outwash fan, coarse gravel
Description:	Suspected burial mound, 2m diameter
Records:	Site record, photograph
Significance rating:	3
Vulnerability rating:	3
Sensitivity rating:	9

QRS 177/17

Site coordinates:	S27.86819 E16.71631
Setting:	Foot-slope, outwash fan, coarse gravel
Description:	Suspected burial mound, 2.5m elongate, oriented roughly E-W
Records:	Site record
Significance rating:	3
Vulnerability rating:	3
Sensitivity rating:	9

QRS 177/18

Site coordinates:	S27.86853 E16.69966
Setting:	Foot-slope, outwash fan, coarse gravel
Description:	Confirmed burial cairn, 2.1m Ø circular, with partially intact kerbing and associated with well-worn upper grindstone.
Records:	Site record, sketch plan and photographs (see Figure **6** & Figure **7**)
Significance rating:	3
Vulnerability rating:	5
Sensitivity rating:	15

Figure 6: The physical setting of the burial site QRS 177/18 at Gergarub

Figure 7: Plan view of QRS 177/18; note remnants of kerbing on the perimeter of the burial cairn, and upper grindstone (arrowed, centre).

Impact Assessment

At the construction stage of the Gergarub project it is expected that the most important types of impact on the archaeological heritage will be *physical disturbance or destruction* of sites or remains within or close to the designated footprint of the proposed mine and its associated surface works. Related to this is a second type of impact which may be described as the *disruption of the landscape setting or physical context* of the archaeological sites or remains. It therefore follows that the extent of such impacts will be both local, in the sense of the specific site, and at the landscape level. Because damage to, or destruction of archaeological heritage sites cannot be reversed, the duration of such impacts is considered to be permanent.

Where a *high risk of impact* is associated with a significant archaeological site and the certainty of disrupting the landscape setting of the site, it is imperative that appropriate mitigation measures are adopted. Due to the fact that archaeological heritage sites in Namibia are characterized by highly dispersed distributions of small sites which together define the archaeological landscape, mitigation of impacts usually involves direct, site-specific actions including mapping, systematic surface collection and excavation and removal in the case of sites such as burials, or graves. Experience has shown that *piecemeal protection measures (e.g. site cordons) are ineffective* where the site concerned is in the near vicinity of the mine or similar development. This means that mitigation involving sites such as burials is also led by the precautionary principle.

Such impacts as occur at the construction stage are expected to accumulate through the operational stage of the project, through *successive minor impacts*, such as for example the continued development of the mine area and the consequent erosion of landscape integrity, and by more subtle cumulative impacts such as dust pollution and wind-blown litter, both largely unavoidable collateral impacts associated with mining developments. It is to be expected that negative impacts on the archaeological heritage and its landscape setting would *accelerate* during the decommissioning stage of the project, bringing comparable levels of disturbance to those associated with the construction stage.

The intensity of direct impacts is *expected to vary according to the proximity* of both formal components of the mine layout (i.e. as designed), and where a degree of uncontrolled spill-over of activities occurs (e.g. wind-blown litter, unplanned borrow-pits, soil erosion resulting from earthmoving activities). Some parts of the archaeological heritage site distribution may therefore remain entirely unaffected. The probability of these impacts occurring is related to the planned layout and the adoption of an appropriate EMP and land management programme at Gergarub. It is absolutely essential that the EMP and/or land programme is GIS-based, in order to facilitate regular audit (i.e. monitoring), and that the archaeological heritage component is integrated with this management tool. It is suggested that an archaeological audit should be carried out on completion of the construction phase. The audit should be based on a field condition assessment of all archaeological sites documented during the baseline study. The audit should indicate at what intervals further audits may be required.

Due to the relatively small size of the Gergarub project area, combined with generally good visibility of archaeological heritage remains, the assessment presented here is based on a high level of confidence. This is limited however, by a degree of uncertainty about the final layout of the mine and associated infrastructure, and the possibility of unanticipated impacts occurring during the construction stage. For this reason, it is recommended that the project EMP adopt the Chance Finds procedure presented as Appendix A.

Mitigation

Following both established best practice standards as well as the Namibian legislation and the IFC Standards and Guidance Notes 8, mitigation of archaeological heritage impacts at Gergarub should include:

a. Systematic excavation of the burial site QRS 177/18. This requires a permit issued by the National Heritage Council and agreement from the National Museum of Namibia to house the remains. Excavation of the site will require a total of six days including travel, fieldwork, curation and description of the remains. This level of archaeological attention follows the requirements of the IFC Guidance Note 8, as well, as established best practice.

b. Integration of the archaeological heritage GIS database with the project EMP and the development of a framework for a site audit procedure.

c. Adoption of the archaeological Chance Finds procedure as part of the project EMP.

Excavation of QRS 177/18

<u>Method and procedure</u>

The burial cairn QRS 177/18 was excavated under Permit 17/2023 issued by the National Heritage Council on 21 August 2023. In the field, the burial shown in Figures 6 and 7 was drawn at a scale of 1:10 and its height in relation to the surrounding surface determined with a builder's level. The cairn was dismantled and packed to one side, with the grindstone and pestle observed on the cairn retained as associated cultural material. The visible kerbing at the foot of the cairn was left in place to guide the excavation of the burial shaft and removed only when the dimensions of the shaft were apparent. The sub-surface filling of the shaft included a number of rocks exceeding 20kg and these had slipped deeper into the shaft as the soil filling settled, causing considerable damage to the human skeletal remains buried therein.

Human bones were encountered in the shaft at a depth of 1.64m below surface. The bones were exposed by dry brushing to reveal a skeleton in foetal position with a northward orientation. The upper limbs were across the sternum and ribs indicating that the deceased was buried face-upward and turned to the right. The lower limbs were drawn up to the lower ribcage. Although approximately 91% complete[3], the skeleton was very poorly preserved. Apart from damage due to the weight of large rocks used in the filling of the burial shaft, the bones were extensively leached[4] and extremely fragile. Dark grey spots on the surface of the bones indicated that the leaching

3 Anatomical Preservation Index (API) = Class 5, following Bello, S. M. et al 2006. Age and sex bias in the reconstruction of past population structures. American Journal of Physical Anthropology 129: 24-38.
4 Qualitative Bone Index (QBI) = Class 2 (1 – 24% sound cortical surface) cf Bello *et al* 2006.

process had resulted in the transfer of some soil minerals to the bones. The skeleton was removed, brushed dry and most consolidated sediment cleaned from the bones with a dental pick and further dry brushing. Thereafter the bones were securely packed for transport and the burial shaft backfilled to approximate its original appearance.

Analysis

Estimation of sex was based on standard techniques using primary skeletal indicators[5]. Of the standard pelvic indicators only that of the sciatic notch could be reliably used due to the fragmentary condition of the bones. The angle of the sciatic notch at 93° falls within the range for females. The distal humerus, of which both left and right were well preserved, provides a secondary indicator. On this element the trochlear outline shows typically female characteristics, as does that of trochlear symmetry and the overall shape of the olecranon fossa and medial epicondyl[6].

Cranial fragments from the skeleton showed female characteristics in four of five conventional indicators, the mastoid process, the supra orbital margin, the supra orbital ridge, or glabella, and the mental eminence of the mandible[7]. The preservation of both left and right proximal femora allowed an additional source of corroboration for the apparent female sex of the skeleton by employing the femoral neck method[8], based on the formula Sex=0.51 x SID – 15.356, where <0 indicates female sex and >0 indicates male sex, and SID is the supero-inferior diameter of the femoral neck at its narrowest point. The derived value for the skeleton was -5.41, indicating female sex.

The age of the individual at death could not be determined with accuracy due to the fact that although all indicators of age suggested that the individual was fully adult, there were clear indications of degenerative disease in the lumbar vertebrae which showed advanced amphiarthroidal growth. Despite such indications of advanced age, there was no premortem tooth loss; although nearly all teeth were loose, there was no indication of alveolar resorption. However, the apex of the mandibular arch showed a large perforation that was probably due to an abscess. Also indicative of adulthood was the marked degree of suture closure in the cranium, leaving only small sections of suture unfused.

Beside the indications of degenerative disease in the lumbar spine, there were no signs of other common indicators of hypertrophy and anaemia commonly found in in precolonial skeletal remains. The cranium, a common site for such indicators showed neither cribra orbitalia in the inner eye socket, nor porotic hyperostosis as is found on the ectocranial surface of the cranium. The general absence of well-preserved cortical material on the long bones made it difficult to reliably determine the presence of periostitis osseous plaques. There was slight lipping of the sacro-iliac joint and the corresponding surfaces of the obsturator externis.

5 Buikstra, J. and Uberlaker, D.H. 1994. *Standards for data collection from human skeletal remains.* Fayetteville: Arkansas Archaeological Survey research series No. 44.
6 Following Rogers T.L. 1999. A visual method of determining the sex of skeletal remains using the distal humerus. *Journal of Forensic Science* 44: 57-60.
7 Buikstra, J. and Uberlaker, D.H. 1994. *Standards for data collection from human skeletal remains.* Fayetteville: Arkansas Archaeological Survey research series No. 44.
8 Following Seidemann J.H.P. *et al* 1998. The use of the supero-inferior femoral neck diameter as a sex assessor. *American Journal of Physical Anthropology* 107: 305-313.

The skeletal and living stature of the individual was calculated from the length of two long bones, the femur and the tibia, using standard formulae[9]. Based on the preceding evidence of female sex, the stature was calculated using the appropriate female statistics. Skeletal height based on the maximum length of the left femur was calculated as follows:

$$Y = c + mx \pm \text{estimated standard error}$$

Where y is skeletal stature, c is the length of the femur, mx is the regression slope, thus

27.424 + [40.3 x 2.769] ± 2.789 yields a stature estimate of **139mm** ± 2.789

Skeletal height based on the maximum length of the left tibia was calculated using the same formula with the following values, thus

55.968 + [34.65 x 2.485] ± 3.056 yields a stature estimate of **142** ± 3.056

The average skeletal height based on these two values is **140mm** which corrects to living stature as **150mm**. This corrected stature compares well with mean stature estimates of 150.6 for female skeletons from the Namib Desert[10].

Results

The excavation of QRS 177/18 yielded the skeleton of an adult female without skeletal evidence of perimortem trauma. The individual was estimated to have a living stature of 150.5mm which is closely similar to stature estimates for precolonial females from the Namib Desert based on archaeological skeletons preserved in the collection of the National Museum of Namibia. The grindstone and pestle found on the burial cairn indicated the burial of an adult female and this was confirmed by the skeleton itself. The remains recovered from the site are housed in the National Museum of Namibia Archaeology Collection under accession number B4367.

Monitoring

An essential tool of archaeological heritage mitigation is the site audit, a form of regular, systematic monitoring that is integrated with the project EMP, usually in the form of a GIS-based system which allows for periodic condition assessment and impact risk assessment. This impact assessment and the accompanying GIS database should form the basis of a site audit procedure to be developed at the next stage of the project.

9 Lundy, J.K 1983. Regression equations for estimating living staturefrom long bones in the South African Negro. *South African Journal of Science* 79: 337-338; Lundy, J.K. and Feldesman, M.R. 1987. Revised equations for estimating living stature from the long bones of the South African Negro. *South African Journal of Science* 83: 54-55.

10 Kinahan, J. 2013. The use of skeletal and complementary evidence to estimate human stature and identify the presence of women in the recent archaeological record of the Namib Desert. *South African Archaeological Bulletin* 68: 72–8.

Conclusions & Recommendations

There is a high probability of direct or collateral impact on three archaeological sites at Gergarub, namely QRS 177/15, 177/16 and 177/18, and a relatively low or medium probability of such impacts on the remaining fifteen sites. These impacts or risks of impact can be reduced to acceptable levels by the adoption of appropriate mitigation measures including systematic collection and excavation, as well as the integration of the archaeological heritage record and Chance Finds procedure in the project EMP. Excavation of QRS 177/18 as reported here represents mitigation of the most immediate threat of impact.

The proposed Gergarub project is located in an area of high archaeological significance, and the project area itself contains several sites that are considered to be archaeological assets worthy of stringent protection measures including mitigation. A reassessment of the conservation status of archaeological sites associated with the Gergarub project should therefore be carried out when a final design and works programme is available.

It is therefore recommended that the Gergarub project should integrate the archaeological site database GIS, as well as Chance Finds procedure within its EMP and land management programme. To this end, the client should be made aware of the archaeological sensitivity of the project area, and the fact that the archaeological sites are protected under the National Heritage Act (2004). When the Gergarub project is underway, the client should make sure that all personnel and contractors are aware of the protected nature of the archaeological sites as well as the legal obligation to report any new finds to the National Heritage Council as soon as possible.

It is also recommended that the client should adopt as working procedure the *Archaeological Guidelines for Mineral exploration and Mining in the Namib Desert,* which provides explicit and detailed instructions regarding the steps to be taken and methods to be adopted for appropriate protection of archaeological heritage. This should include not only sensitization of personnel and contractors, but also promotion of knowledge regarding archaeological heritage occurring within the Gergarub project area and the surrounding region.

APPENDIX A

Recommended archaeological chance finds procedure

The “chance finds” procedure covers the actions to be taken from the discovery of a heritage site or item, to its investigation and assessment by a trained archaeologist or other appropriately qualified person. The “chance finds” procedure is intended to ensure compliance with the relevant provisions of the National Heritage Act (27 of 2004), especially Section 55 (4): *“ a person who discovers any archaeological …. object ……must as soon as practicable report the discovery to the Council”.* The procedure of reporting set out below must be observed so that heritage remains reported to the NHC are correctly identified in the field.

RESPONSIBILITIES

Operator	To exercise due caution if archaeological remains are found
Foreman	To secure site and advise management timeously
Superintendent	To determine safe working boundary and request inspection
Archaeologist	To inspect, identify, advise management, and recover remains

PROCEDURE

Action by person identifying archaeological or heritage material

a) If operating machinery or equipment stop work
b) Identify the site with flag tape
c) Determine GPS position if possible
d) Report findings to foreman

Action by foreman

a) Report findings, site location and actions taken to superintendent
b) Cease any works in immediate vicinity

<u>Action by superintendent</u>

e) Visit site and determine whether work can proceed without damage to findings
f) Determine and mark exclusion boundary
g) Site location and details to be added to GIS for field confirmation by archaeologist

<u>Action by archaeologist</u>

a) Inspect site and confirm addition to GIS
b) Advise NHC and request written permission to remove findings from work area
c) Recovery, packaging and labelling of findings for transfer to National Museum

<u>In the event of discovering human remains</u>

a) Actions as above
b) Field inspection by archaeologist to confirm that remains are human
c) Advise and liaise with NHC and Police
d) Recovery of remains and removal to National Museum or National Forensic Laboratory, as directed.