Air Quality Impact Assessment for the ML133 Exploration Project in Namibia

Project done for **Environmental Compliance Consultancy (ECC)**

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Report Details

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Revision Record

Version	**Date**	**Section(s) Revised**	**Summary Description of Revision(s)**
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Abbreviations

AEB	Atomic Energy Board
AERPA	Atomic Energy and Radiation Protection Act
AQG	Air Quality Guideline
AQMP	Air Quality Management Plan
AQO	Air Quality Objective
AQSR	Air Quality Sensitive Receptor
ASG	Atmospheric Studies Group
ASTM	American Society for Testing and Materials
CE	Control efficiency
CERC	Cambridge Environmental Research Consultants
CO	Carbon monoxide
CO_2	Carbon dioxide
EA	Environment Australia
EC	European Commission
ECC	Environmental Compliance Consultancy
EETMs	Emission Estimation Technique Manuals
EF	Emission factor
EHS	Environmental, Health and Safety (IFC)
EQOs	Environmental Quality Objectives
FOE	Frequency of Exceedance
GIIP	Good International Industry Practice
GLC	Ground level concentration
I&APs	Interested and Affected Parties
IFC	International Finance Corporation
IT3	Interim target 3
LDVs	Light delivery vehicles
LMo	Monin Obukhov Length
LoM	Life of Mine
$\mu g/m^3$	Microgram per cubic metre
$mg/m^2/day$	Milligram per metre squared per day
m/s	Metres per second
MHCP	Materials handling and concentrating plant
ML133	Mining Licence 133
NO_2	Nitrogen dioxide
NOx	Nitrous oxide
NPi	National Pollutant Inventory (Australia)
O_3	Ozone
Pb	Lead
$PM_{2.5}$	Particulate Matter with an aerodynamic diameter of less than 2.5μm
PM_{10}	Particulate Matter with an aerodynamic diameter of less than 10μm

ROM	Run-of-Mine
SA NAAQS	South African National Ambient Air Quality Standards
SA NDCR	South African National Dust Control Regulations
SEMP	Strategic Environmental Management Plan
SO_2	Sulfur dioxide
SoW	Scope of Work
Ta	Tantalum
TSP	Total Suspended Particles
US EPA	United States Environmental Protection Agency
USGS	United States Geological Survey
UTMC	Uis Tin Mining Company
VOC	Volatile Organic Compounds
WBG	World Bank Group
WHO	World Health Organisation
WRD	Waste rock dump
WRF	Weather Research and Forecasting

Executive Summary

Airshed Planning Professionals (Pty) Ltd was commissioned by Environmental Compliance Consultancy (Pty) Ltd (ECC) to undertake an Air Quality Impact Assessment for the proposed exploration activities for ML133 (hereafter referred to as the project).

Exploration activities giving rise to air pollutants include drilling, and movement of trucks and vehicles on unpaved roads. The equipment that are used include:

- Three (3) drill rigs;
- 3 water trucks; and
- 10 light delivery vehicles (LDVs).

The main objective of the air quality specialist study was to determine the potential for dust on the surrounding people and environment, and to provide practical mitigation measures on how to reduce the potential impacts.

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. A review of the air quality legislative and regulatory context, including ambient air quality guidelines.
3. A study of the receiving (baseline) environment, including:
    a. The identification of Air Quality Sensitive Receptors (AQSRs) from available maps and field observations;
    b. A study of site-specific atmospheric dispersion potential by referring to available weather records, land use and topography data sources;
    c. The identification of existing sources of dust emissions at and around the ML133 site; and
    d. The characterisation of existing ambient air quality at and around the ML133 site based on available ambient monitoring/modelling data (if available).
4. An impact assessment, including:
    a. The establishment of a source inventory for proposed activities;
    b. Atmospheric dispersion simulations to determine ground level air concentrations (GLCs) and fallout levels as a result of the Project; and
    c. The screening of GLCs and fallout levels against environmental air criteria.
5. The identification and recommendation of suitable mitigation measures and monitoring requirements.
6. The preparation of a comprehensive specialist air quality impact assessment report.

Baseline characterisation

ML 133 is located ~45 km south of Uis, in the Erongo Region, Namibia. ML 133 is bordering the Omaruru River to the southeast, within the Nai Nais community in the Dâures Constituency. Uis is located approximately 20 km east-southeast of the Brandberg mountain, Namibia's highest mountain (2 559 m above sea level).

On-site meteorological data was not available, and use was made of Weather Research and Forecasting Model (WRF) simulated meteorological data for the period 2023 – 2025 for a location at the mine.

The baseline characterisation can be summarised as follows:

- The wind field in the area is dominated by winds from the southwest during the day and night, with a decrease in winds from the southwest and an increase of winds from the northeast during the night. Day- and night-time average wind speeds are 10 m/s and 6 m/s respectively. Calm conditions occur 3.21% of time during the day and 6.75%

during the night. On average, air quality impacts are expected to be slightly more notable to the northeast of the Project due to the prevailing south-westerly winds.

- The predominant south- westerly and north-easterly winds in the study region may be explained by the surrounding topography. The ML133 exploration site is between 600 and 900 m above sea level with the orientation of the hills and ridges in a northeast – southwest alignment. The immediate exploration site surroundings consist of low hills increasing in height towards the southeast, with a flat open plain to the north and northwest of the ML133 site.
- Maximum temperatures range from 40.5°C in December to 31.2 °C in June, with minima ranging from 10.5°C in March to -0.5°C in June.
- On average, the area receives approximately 363 mm of rain per year. There is a rainy season from December through March and a dry season from May to September, with December being the wettest month and both July and August the driest.
- 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 and other exploration activities.
- Sources of atmospheric emissions in the vicinity of the Project include small-stock farming, dust generated from historically mined areas and, to a lesser extent, emissions from vehicle tailpipes along the C36 and D1930 public roads. Other regional sources that may have an influence on the ambient air quality around the Project are the Uis Tin Mine and NamClay, both located just outside of Uis, biomass burning (natural bush fires or those employed for agricultural purposes) and de-bushing to increase the grazing capacity of farmland. Given these activities, it is expected that fugitive dust may be present during dry, windy conditions. However, the contribution of all these sources to existing ambient air quality at and around the exploration site is considered to be low.
- Regional scale transport of mineral dust and ozone (due to vegetation burning) from the north of Namibia is a potential contributing source to background PM concentrations.
- There is no ambient air quality data or dustfall available for the study site. PM concentrations measured as part of the SEMP AQMP monitoring network were limited to the coastal towns of Swakopmund, Walvis Bay and Henties Bay with a station in the central western part of the region on the farm Jakalswater. None of these locations are representative of the air quality in the ML 133 area.

Impact Assessment

A quantitative air quality impact assessment was conducted for the exploration phase activities of the ML133 project. The assessment included an estimation of atmospheric emissions, the simulation of pollutant concentrations and determination of the significance of impacts.

The impact assessment was limited to airborne particulate (including TSP, PM_{10} and $PM_{2.5}$). Gaseous emissions (i.e. SO_2, NOx, CO and VOCs) were not included and will primarily result from diesel combustion from mobile and stationary sources.

Exploration Phase

- Two exploration scenarios were assessed to determine the increase in impacts due to the Project, namely an Unmitigated Scenario and Mitigated Scenario.
- Emissions quantified for the ML133 Project were restricted to fugitive releases (non-point releases) with particulates the main pollutant of concern. Emissions were quantified based on information provided on the road and drilling area layout plan.

- The main sources of $PM_{2.5}$, PM_{10} and TSP emissions due to the Project are, in order of importance: i) vehicle entrainment from unpaved surface road, ii) drilling.
- Mitigation assumed included the following:
    - surface haul roads: water sprays assuming 75% CE;
    - drilling: assuming 75% CE for water sprays.
- Dispersion modelling results for the Unmitigated and Mitigated Scenarios are:
    - PM_{10} daily GLCs, for unmitigated activities, result in exceedances of the 24-hour air quality objective (AQO) at a maximum distance of ~200 m from the road. The only AQSR that shows an exceedance is the Contractors camp, which is located close to the road. Annual GLCs only exceed intermittently at some areas along the road, with the maximum of ~80 m, but with no exceedances at any of the AQSRs. For mitigated activities, no impacts are predicted for both daily and annual GLCs with no exceedances at any of the AQSRs.
    - $PM_{2.5}$ daily GLCs, for unmitigated activities, do not exceed the AQO (WHO IT-3) at any of the AQSRs but the footprint of exceedance extends ~200 m from the road. There are intermittent small areas of exceedances of the annual $PM_{2.5}$ AQO on the road. For mitigated activities, no area of exceedances is predicted and there are no exceedances at any of the AQSRs.
    - Maximum daily dustfall rates, for unmitigated exploration activities, are within the AQO (SA NDCR residential limit of 600 mg/m²/day) at all but one of the AQSRs. Daily impacts are limited to ~200 m from the site road. With mitigation measure taken into account, no impact footprints are predicted and all the AQSR are within the AQO.
- For both the Unmitigated and Mitigated Scenarios, the significance is expected to be **minor** with and without mitigation in place.
- 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 ML133 modelling results indicate the potential for low regional cumulative impacts, resulting in **minor** significance.

Construction Phase

- The construction will entail the construction of an open pit, a waste rock dump (WRD) and the haul roads.
- Emissions will include gaseous emissions (SO_2, NO_x, CO, CO_2) from vehicle tail pipes, volatile organic compounds (VOCs) from construction materials and waste, and dustfall, PM_{10} and $PM_{2.5}$ from construction of the WRD and stockpiles, open pit and haul roads.
- Due to the intermittent nature of construction operations, impacts are expected to have a small but potentially harmful impact at the nearest AQSRs depending on the level of activity. With mitigation measures in place these impacts are expected to have **minor** significance.

Conclusion

The proposed exploration project is not likely to result in $PM_{2.5}$ and PM_{10} ground level concentrations in exceedance of the selected AQOs at any of the AQSRs, for both unmitigated and mitigated activities. Impacts due to unmitigated activities are likely to extend over a localised area around exploration activities. With mitigation in place, the resulting impacts can be limited to on-site areas. Dustfall rates are likely to be low throughout the exploration phase.

It is the specialist's opinion that the proposed project exploration activities 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

The most practical approach in controlling PM emissions would be the application of water sprays where and as often as possible. Other measures are also proposed. These include:

- Exploration phase:
  - Control of vehicle entrained dust with a CE of 75% on unpaved surface roads through water suppression.
- Construction phase:
  - Air quality impacts during construction would be reduced through basic control measures such as limiting the speed of haul trucks; limiting unnecessary travelling of vehicles on untreated roads; and applying water suppression to achieve a control efficiency (CE) of 75%.
  - 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 Phase:
  - Once a project plan exists for the proposed project mining operations, an air quality assessment needs to be conducted to determine the potential impact on nearby AQSRs and the surrounding environment.
- Air Quality Monitoring:
  - It is recommended that a dustfall monitoring network, comprising of fourteen (5) single dustfall units, should be installed and the monthly dustfall results used as indicators to track the effectiveness of the applied mitigation measures. Dustfall collection should follow the American Society for Testing and Materials (ASTM) method.

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1 INTRODUCTION

Environmental Compliance Consultancy (Pty) Ltd (ECC) has been retained by Andrada Mining (Pty) Ltd to update the environmental and social impact assessment for mining licence (ML) 133 to bring the impact assessment to improved standards and ensure best international practises are met. The proponent holds an environmental clearance certificate to mine pegmatite-hosted deposits on ML 133. The mining method includes open pit mining, blasting, loading and hauling of ore to ML 134 and waste rock, with waste rock to be stockpiled at a waste rock dumpsite that is still to be determined.

Andrada plan to increase production and propose to commence mining operations on the ML 133. ML 133 is located ~30 km southeast of Uis, in the Erongo Region, Namibia. ML 133 is bordering the Omaruru River to the southeast, within the Nai Nais community in the Dâures Constituency. The Uis town can be accessed via the C36 road from Omaruru or the C35 from Henties Bay and Khorixas. The locality is shown in Figure 1.

Airshed Planning Professionals (Pty) Ltd was commissioned by Environmental Compliance Consultancy (Pty) Ltd (ECC) to undertake an Air Quality Impact Assessment for the exploration activities for ML133 (hereafter referred to as the Project).

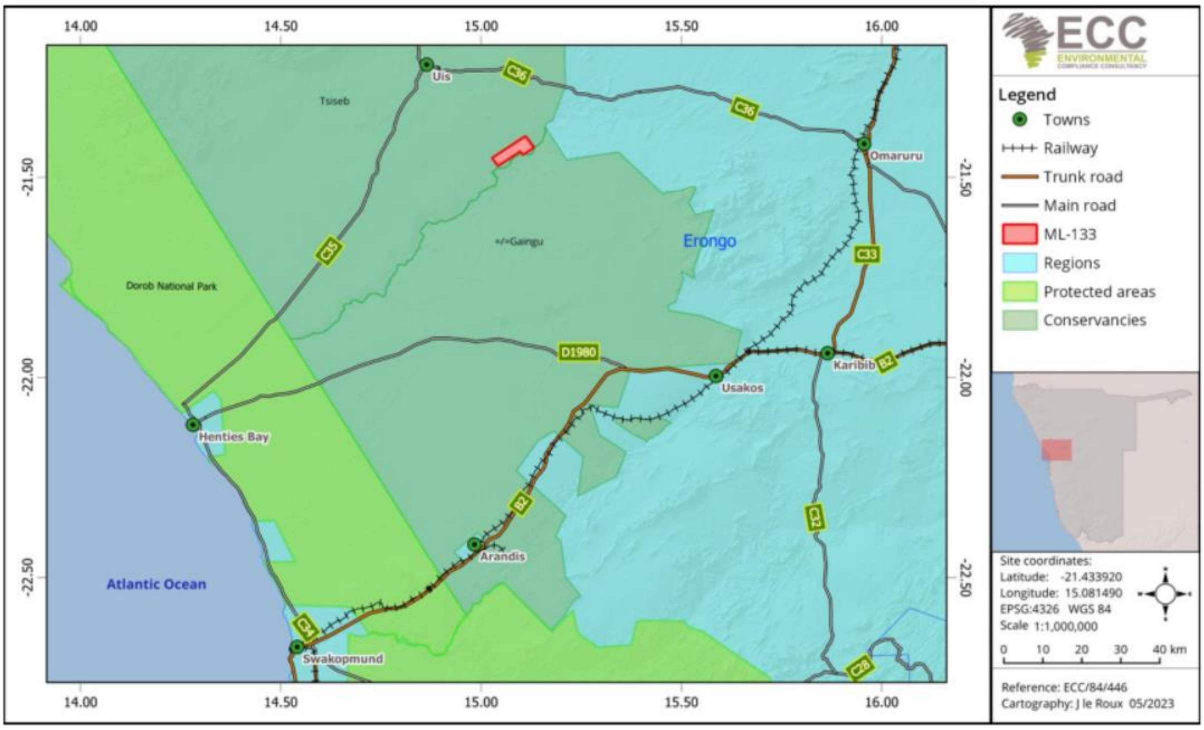

Figure 1: Regional location of the ML133 Exploration Project

1.1 Study Objective

The main objective of the investigation was to quantify the potential impacts resulting from the proposed exploration activities on the surrounding environment and human health, 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):

7. A review of available technical project information.

8. A review of the air quality legislative and regulatory context, including ambient air quality guidelines.
9. A study of the receiving (baseline) environment, including:
    e. The identification of AQSRs from available maps and field observations;
    f. A study of site-specific atmospheric dispersion potential by referring to available weather records, land use and topography data sources;
    g. The identification of existing sources of dust emissions at and around the ML133 site;
    h. The characterisation of existing ambient air quality at and around the ML133 site based on available ambient monitoring/modelling data (if available); and
10. An impact assessment, including:
    d. The establishment of a source inventory for proposed activities.
    e. Atmospheric dispersion simulations to determine ground level air concentrations (GLCs) and fallout levels as a result of the project.
    f. The screening of GLCs and fallout levels against environmental air criteria.
11. The identification and recommendation of suitable mitigation measures and monitoring requirements.
12. The preparation of a comprehensive specialist air quality impact assessment report.

1.3 Project Description

The project will cover exploration operations at the ML133 site. Exploration activities giving rise to air pollutants include drilling, and movement of trucks and vehicles on unpaved roads. The equipment will include:

- Three (3) drill rigs;
- 3 water trucks
- 10 light delivery vehicles (LDVs).

Air pollution associated with Project activities include air emissions emitted during exploration phases.

1.3.1 Description of Activities from an Air Quality Perspective

The exploration activities most likely to result in air pollution are listed in Table 1.

Table 1: Exploration activities resulting in air pollution

Activity	Associated pollutants
Exploration Phase	
Exploration drilling	PM, SO_2; NOx; CO; CO_2
Truck and LDV traveling onsite	PM from road surfaces and windblown dust from trucks, gaseous emissions from truck and LDV exhaust (PM, SO_2; NOx; CO; CO_2)

Construction work packages include civil works, in-plant erection, piping, erection of conveyors and gantries, conveyor mechanical installation, and electrical, control and instrumentation work. Typical activities that would result in air pollution during the construction phase are listed in Table 2.

Table 2: Construction activities resulting in air pollution

Activity	Associated pollutants
Construction Phase	
Handling and storage area for construction materials (paints, solvents, oils, grease) and waste	particulate matter (PM)[(a)] and fumes (Volatile Organic Compounds [VOCs])
Clearing and other earth moving activities	mostly PM, gaseous emissions from earth moving equipment (SO_2; NOx; CO; CO_2)
Foundation excavations	mostly PM, gaseous emissions from excavators (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).

1.4 Approach and Methodology

The air quality study includes the assessment of the proposed exploration phase, with the construction operations assessed qualitatively. The approach to, and methodology followed in the completion of tasks (or scope of work) are discussed below.

1.4.1 Project Information and Activity 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:

- Layout maps;
- Process descriptions; and
- Project equipment details.

Documentation reviewed included the following:

- ECC-85-446(C)-REP-05-A.pdf.
- ML133RaodLayout.jpg
- ML133 Drilling Areas.kml
- ECC_Info.xlsx
- Contractors_Camp.kmz
- Core_Shed.kmz

1.4.2 The Identification of Regulatory Requirements and Health Thresholds

In the evaluation of ambient air quality impacts and dustfall rates reference was made to:

- National and international standards and guidelines, including but not limited to the World Health Organisation (WHO); US EPA, European Community, Namibia and South Africa.

1.4.3 Study of the Receiving Environment

Air quality sensitive receptors generally include private residences, community buildings such as schools, hospitals and any publicly accessible areas outside an industrial facility's property.

As part of the air quality assessment, a good understanding of the regional climate and local dispersion potential of the site is necessary, as well as an understanding of existing sources of air pollution in the region and the current and potential future air quality. Physical environmental parameters that influence the dispersion of pollutants in the atmosphere include terrain, land cover and meteorology.

The ML133 Project does not have a weather station, and use was made of Weather Research and Forecasting Model (WRF) modelled meteorological data for the Uis study area for the period 1 January 2023 – 31 December 2025, to (a) describe the dispersion potential of the site and (b) as input into the AERMOD dispersion model.

1.4.4 Determining the Impact of the Project on the Receiving Environment

1.4.4.1 Emissions Inventory

The establishment of a comprehensive emission inventory formed the basis for the assessment of the air quality impacts from the Project's emissions on the receiving environment. In the quantification of emissions, use was made of emission factors which associate the quantity of release of a pollutant to the activity. Emissions were calculated using emission factors and equations published by the United States Environmental Protection Agency (US EPA) and Environment Australia (EA) in their National Pollutant Inventory (NPI) Emission Estimation Technique Manuals (EETMs).

To determine the significance of air pollution impacts from the Project, emissions were estimated for the exploration phase showing unmitigated and unmitigated impacts from drilling and vehicle activities.

1.4.4.2 Air Dispersion modelling

The impact of proposed operations on the atmospheric environment was determined through the simulation of ambient pollutant concentrations. The US Environmental Protection Agency's (US EPA) approved regulatory model – AERMOD – was selected for this study. It is one of the models recommended for Level 2 assessments, for near-source (less than 50 km from source) applications in all terrain types, in the South African Regulations Regarding Air Dispersion Modelling (Government Gazette No. 37804, 11 July 2014).

The dispersion model uses the specific input data to run various algorithms to estimate the dispersion of pollutants between the source and receptor. The model output is in the form of a simulated time-averaged concentration at the receptor. These simulated concentrations are compared with the relevant ambient air quality standard or guideline. Ambient air quality guidelines and standards are applicable to areas where the general public has access i.e. off-site.

1.4.5 Compliance Assessment

The legislative and regulatory context, including emission limits and guidelines, ambient air quality guidelines and dustfall classifications were used to assess the impact and recommend additional emission controls, mitigation measures and air quality management plans to maintain the impact of air pollution to acceptable limits in the study area. The model results were analysed against the Air Quality Objectives (AQO) recommended as part of the Strategic Environmental Management Plan

(SEMP) Air Quality Management Plan (AQMP) (Liebenberg-Enslin, et al., 2019). These objectives are based on the World health Organisation (WHO) interim targets and the South African (SA) National Air Quality Standards and dustfall criteria.

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1.4.6 Impact Significance

Potential impacts of the proposed Project were identified based on the baseline data, project description, review of other studies for similar projects and professional experience. The significance of air quality impacts was assessed according to the methodology provided by ECC, considering both an unmitigated and mitigated scenario. Refer to Appendix C of this report for the methodology. The impact significance was rated for unmitigated operations and assuming the effective implementation of design mitigation measures.

1.4.7 The Development of an Air Quality Management Plan

The findings of the above components informed recommendations of air quality management measures, including mitigation and monitoring.

1.5 Assumptions, Exclusions and Limitations

The main assumptions, exclusions and limitations are summarized below:

- Meteorological data: WRF modelled meteorological data for the site over the period January 2023 – December 2025 was used.
- Emissions:
    - The quantification of sources of emission was restricted to the ML133 exploration activities only. Although other background sources were identified, such sources were not quantified.
    - Information required for the calculation of emissions from fugitive dust sources for the exploration operations was provided. The assumption was made that this information was accurate and correct.
    - Only routine emissions were estimated and modelled. This was done for the provided operational hours.
    - Working hours were provided as 24-hour days, 7 days a week for open-pit mining activities.
    - Vehicle exhaust emissions were not quantified as the impacts from these sources are localized and unlikely to exceed health screening limits offsite.
    - Two (2) daily trips for each light delivery vehicle (LDV) and truck were assumed.
    - The provided camp road was used to simulate dust entrainment from onsite vehicles.
    - Exploration holes were assumed to drilled 25 m apart from each other, this was then together with the 12 holes drilled per day to estimate the total area drilled in the year.
    - In the absence of detailed construction plans, emissions were quantified using an area-wide emission factor (for approximate areas earmarked for construction).
- Impact assessment:
    - Impacts due to the construction phase were assessed qualitatively due to the temporary nature of these operations, whilst the exploration phase was assessed quantitatively.

1.6 Outline of Report

The regulatory requirements and assessment criteria are discussed in Section 2. The basic site description and identification of possible environmental aspects are discussed in Section 3. This is followed by the impact assessment, comprising of an emission inventory, atmospheric dispersion modelling and inhalation health risk screening in Section 4. Recommendations of air quality management measures, including mitigation and monitoring are provided in Section 5.

2 LEGAL OVERVIEW

Prior to assessing the potential impacts from the proposed mine on the surrounding environment and human health, reference needs to be made to the environmental regulations and guidelines governing the emissions and impact of such activities. 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, organizations such as the World Bank Group (WBG), International Finance Corporation and private companies also issue standards for internal compliance. The benchmark concentrations issued by the 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 99th percentile.

Standards are normally issued for criteria pollutants, i.e. those most commonly emitted by the 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 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, including regional neighbours such as South Africa and Botswana who have air quality standards. As part of the AQMP developed for the 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 current study and discussed in the following sub-sections.

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 VI	:	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 those premises.

The Hazardous Substances Ordinance, 1974 (Ordinance No. 14 of 1974) that has now been preceded by the Atomic Energy and Radiation Protection Act (AERPA), (Act No. 5 of 2005) seeks to provide for adequate protection of the environment and of people in current and future generations against the harmful effects of radiation by controlling and regulating the production, processing, handling, use, holding, storage, transport and disposal of radiation sources and radioactive materials, and controlling and regulating prescribed non-ionising radiation sources; to establish an Atomic Energy Board (AEB) and to provide for its composition and functions.

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 November 2019 (NCE, 2019). 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 Uis Mining Project can be summarised as follows:

- The benefits of the SEMP for industry are highlighted, and the SEMP Environmental Quality Objectives (EQOs) require as a minimum management objective that "any change to the environment must be within acceptable limits, and that proactive intervention will be triggered by the responsible party to avoid unwanted changes that breach a specific threshold." All mining companies within the region submit reports annually as part of the SEMP annual report which is available in the public domain.
- 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

[2] *Director* means the Director of Health Services of the Administration, and, where applicable, includes any person who, in terms of any authority is granted to him under section 2(2) or (3) of the Ordinance.

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 the SEMP AQMP (Liebenberg-Enslin, et al., 2019) guidelines which were determined to provide the necessary performance indicators for the region. These are discussed in more detail under Section 2.4.
- 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.
- 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 under Section 6.2.3 of the Guide and reference is made again to the SEMP guidelines as performance indicators for the region. All the uranium mines in Namibia are located in the Erongo Region, and all these mines have extensive air quality monitoring programmes in place.
- Section 5 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. The PM guidelines selected as part of the SEMP AQMP for the Erongo Region were based on these international guidelines and standards, and the following subsections provide the relevant background.

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).

Since WHO's last 2005 global update, there has been a marked increase of evidence that shows how air pollution affects different aspects of health. For that reason, and after a systematic review of the accumulated evidence, WHO has adjusted almost all the AQGs levels downwards, warning that exceeding the new air quality guideline levels is associated with significant risks to health (WHO, 2021). Across nearly all pollutants, the new recommended limits for concentrations and exposures are lower than the previous guidelines. The 2021 update reflects far-reaching evidence that shows how air pollution affects many aspects of health, even at low levels.

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 AQG with the purpose to promote steady progress towards meeting the WHO AQG (WHO, 2005) (WHO, 2021). There are two to four interim targets depending on the pollutant, starting at WHO interim target-1 (IT-1) as the most lenient and IT-3 or IT-4 as more stringent targets before reaching the AQG. The SA NAAQS are, for instance, in line with IT-1 for SO_2 and IT-3 targets 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 3 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 3.

Table 3: International assessment criteria for criteria pollutants

Pollutant	Averaging Period	WHO Guideline Value (µg/m³)	South Africa NAAQS (µg/m³)
Sulfur Dioxide (SO_2)	1-year	-	50
	24-hour	125 (IT1) 50 (IT2) (a) 40 (AQ level)	125 (b)
	1-hour	-	350 (c)
	10-minute	500 (guideline)	500 (d)
Nitrogen Dioxide (NO_2)	1-year	40 (IT1) 30 (IT2) 20 (IT3) 10 (AQ level)	40
	24-hour	120 (IT1) 50 (IT2) 25 (AQ level)	
	1-hour	200 (AQ level)	200 (c)
Particulate Matter (PM_{10})	1-year	70 (IT1) 50 (IT2) 30 (IT3) 20 (IT4) 15 (AQ level)	40 (e)
	24-hour	150 (IT1) 100 (IT2) 75 (IT3) 50 (IT4) 45 (AQ level)	75 (e) (b)

Pollutant	Averaging Period	WHO Guideline Value (µg/m³)	South Africa NAAQS (µg/m³)
Particulate Matter ($PM_{2.5}$)	1-year	35 (IT1) 25 (IT2) 15 (IT3) 10 (IT4) 5 (AQ level)	25 (f) 20 (g) 15 (h)
	24-hour	75 (IT1) 50 (IT2) 37.5 (IT3) 25 (IT4) 15 (AQ level)	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) 4 permissible frequencies of exceedance per year

(g) Applicable immediately to 31 December 2015

(h) Applicable 1 January 2016 to 31 December 2029

(i) Applicable 1 January 2030

2.2.3 Dustfall Rates

Air quality standards are not defined by all countries for dust deposition, although some countries may make reference to annual average dustfall 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 natural sources, mining operations, waste rock dumps, stockpiles, tailings and other fugitive dust sources.

South Africa published the National Dust Control Regulations (NDCR) on the 1st of November 2013 (Government Gazette No. 36974) and new regulations published in March 2026 (GN 7335 GG No. 54440 of 31 March 2026). 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). The four-band scale published by the Botswana Bureau of Standards is presented in Table 4.

Table 4: Bands of dustfall rates

Band Number	Band Description Label	30 Day Average Dustfall Rate (mg/m^2-day)	Comment
1	RESIDENTIAL	D < 600	Permissible for residential and light commercial

Band Number	Band Description Label	30 Day Average Dustfall Rate (mg/m^2-day)	Comment
2	INDUSTRIAL	600 < D < 1 200	Permissible for heavy commercial and industrial
3	ACTION	1 200 < D < 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 < D	Immediate action and remediation required following the first exceedance. Incident report to be submitted to relevant authority.

Source: BOS 498:2013

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 ML133 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 potential non-compliance 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 particulate 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 3). The criteria were selected on the following basis:

- The WHO IT3 was selected for particulates since these limits are in line with the South African NAAQSs, and the latter is 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.
- 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 AQOs as set out in Table 5 are used as indicators during the impact assessment.

Table 5: Proposed evaluation criteria for Namibia

Pollutant	Averaging Period	Selected Criteria	Origin
$PM_{2.5}$	24-hour Mean (µg/m³)	37.5 (a)	WHO IT3 (as per SEMP AQMP)
	Annual Mean (µg/m³)	15	WHO IT3 & SA NAAQS (as per SEMP AQMP)
PM_{10}	24-hour Mean (µg/m³)	75 (a)	WHO IT3 & SA NAAQS (as per SEMP AQMP)

Pollutant	Averaging Period	Selected Criteria	Origin
	Annual Mean (µg/m³)	40	SA NAAQS (as per SEMP AQMP)
Dustfall	30-day average (mg/m²/day)	600 (b)	SA NDCR & Botswana residential limit
		1200 (b)	SA NDCR & Botswana industrial limit
		2400 (c)	Botswana Alert Threshold

Notes:

(a) Not to be exceeded more than 4 times per year (SA).

(b) Not to be exceeded more than 3 times per year or 2 consecutive months.

(c) First exceedance requires remediation and compulsory report to authorities.

3 Description of the Receiving/Baseline Environment

3.1 Site Description

ML 133 is located ~30 km southeast of Uis, in the Erongo Region, Namibia. ML 133 is bordering the Omaruru River to the southeast, within the Nai Nais community in the Dâures Constituency. The Uis town can be accessed via the C36 road from Omaruru or the C35 from Henties Bay and Khorixas. Uis is located approximately 30 km northwest of the Brandberg mountain, Namibia's highest mountain (2 559 m above sea level).

The Project covers an area with dimensions of about ~10 km northeast-southwest and ~4 km northwest-southeast at it widest. The terrain is hilly, with low lying ridges running through the centre from southeast to northwest. The receptor locations were identified from Google Earth and Google Maps satellite imagery and their locations, distance and direction from the project boundary are listed in Table 6. The project layout and AQSRs are shown in Figure 2 and the topography of the Project site is shown in Figure 5.

Table 6: Identified AQSRs located near the ML133 exploration project

Sensitive Receptor	Description	Longitude	Latitude	Distance from Project (m)	Direction from Project
1	Houses	15.010888	-21.463147	2 000	SW
2	Houses	15.011725	-21.470197	2 400	SW
3	Houses	15.02294	-21.470979	1500	SW
4	Houses	15.037836	-21.47317	500	SW
5	Houses	15.049218	-21.473324	537	SW
6	Houses	15.049553	-21.474577	Within project boundary	
7	Houses	15.059917	-21.441673	278	NW
8	Houses	15.126997	-21.413905	275	NW
9	Houses	15.131346	-21.412649	585	NW
10	Houses	15.131347	-21.413432	1 050	NW
11	Houses	15.133853	-21.409983	1105	NW
12	Houses	15.128504	-21.415784	290	NW
13	Houses	15.129174	-21.41641	316	NW
14	Houses	15.129677	-21.417037	314	NW
15	Houses	15.131015	-21.417192	422	NW
16	Houses	15.148599	-21.432688	1 772	SWW
17	Contractors Camp	15.069548	-21.443878	Within project boundary	
18	Core Shed	15.106922	-21.416551	Within project boundary	

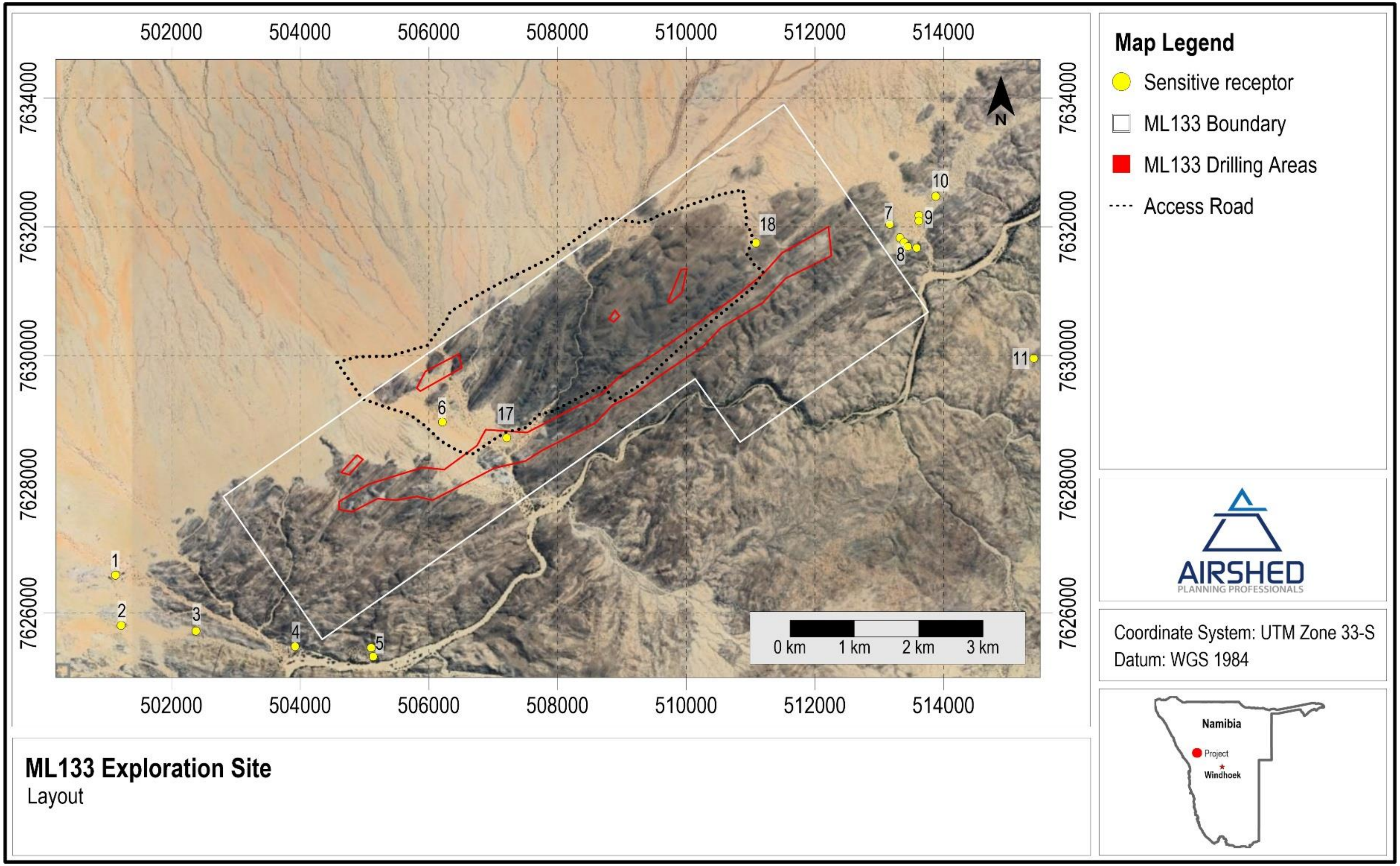


Figure 2: Site layout and AQSRs

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.

3.2.1 Surface Wind Field

The wind direction, and the variability in wind direction, determines the general path 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 10 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.

Reference was made to WRF modelled meteorological data for the ML133 study area for the period 1 January 2023 to 31 December 2026. Period, daytime and night-time wind roses for the study area are depicted in Figure 3.

The wind field in the area is dominated by winds from the southwest during the day and night, with a decrease in winds from the southwest and an increase of winds from the northeast during the night. Day- and night-time average wind speeds are 10 m/s and 6 m/s respectively. Calm conditions occur 3.21% of time during the day and 6.75% during the night. On average, air quality impacts are expected to be slightly more notable to the north-east of the Project.

The seasonal variability in the wind field is shown in Figure 4. The highest wind speeds (more than 6 m/s) occur during summer and springtime and are mostly from the southwest (Figure 4).

The predominant south-westerly and north-easterly winds in the study region may be explained by the topography of the study area. The ML133 exploration site is between 600 and 900 m above sea level with the the orientation of the hills and ridges in a northeast – southwest alignment, as can be seen in Figure 5. The immediate exploration site surroundings consist of low hills increasing in height towards the southeast, with a flat open plain to the north and northeast of the ML133 site.

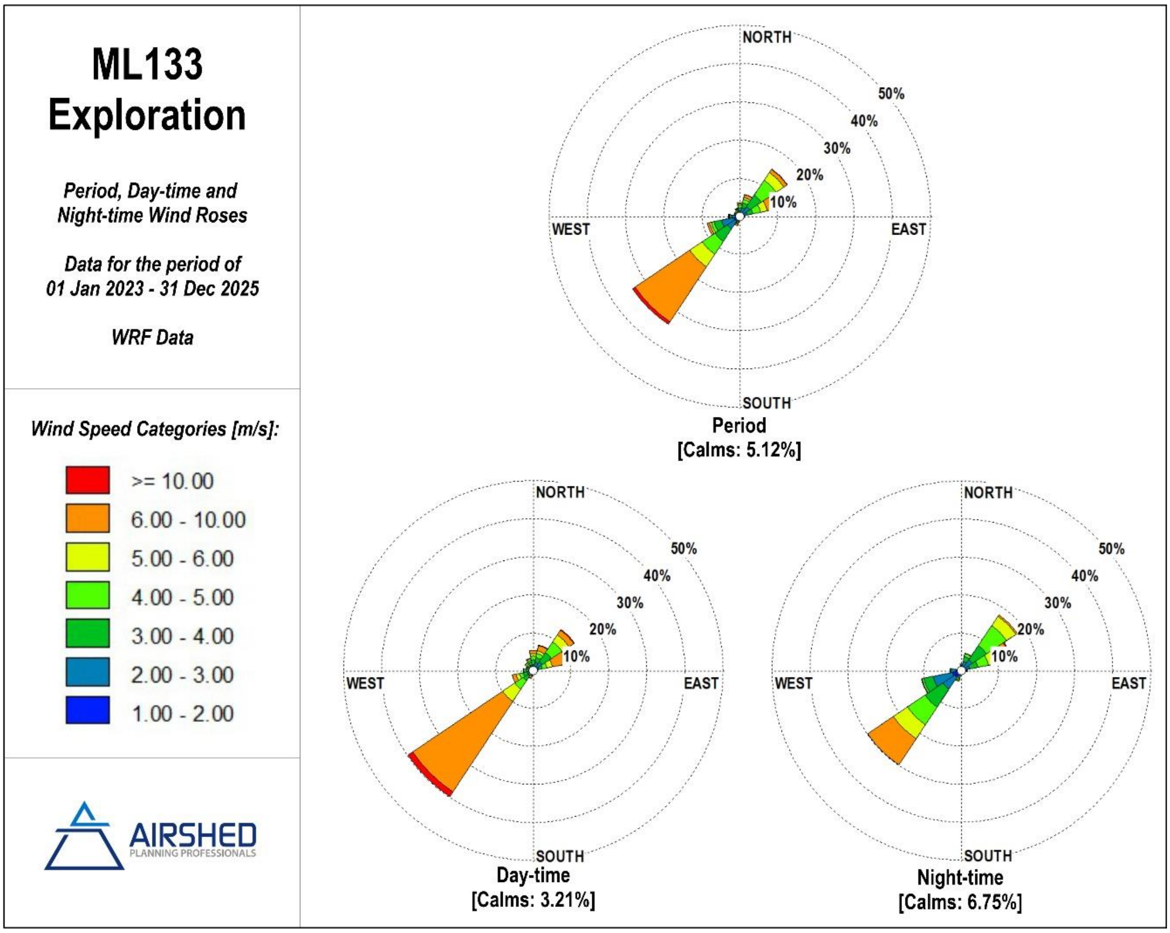


Figure 3: Period, day- and night-time wind roses for the ML133 Exploration Site (WRF data, 2023 – 2025)

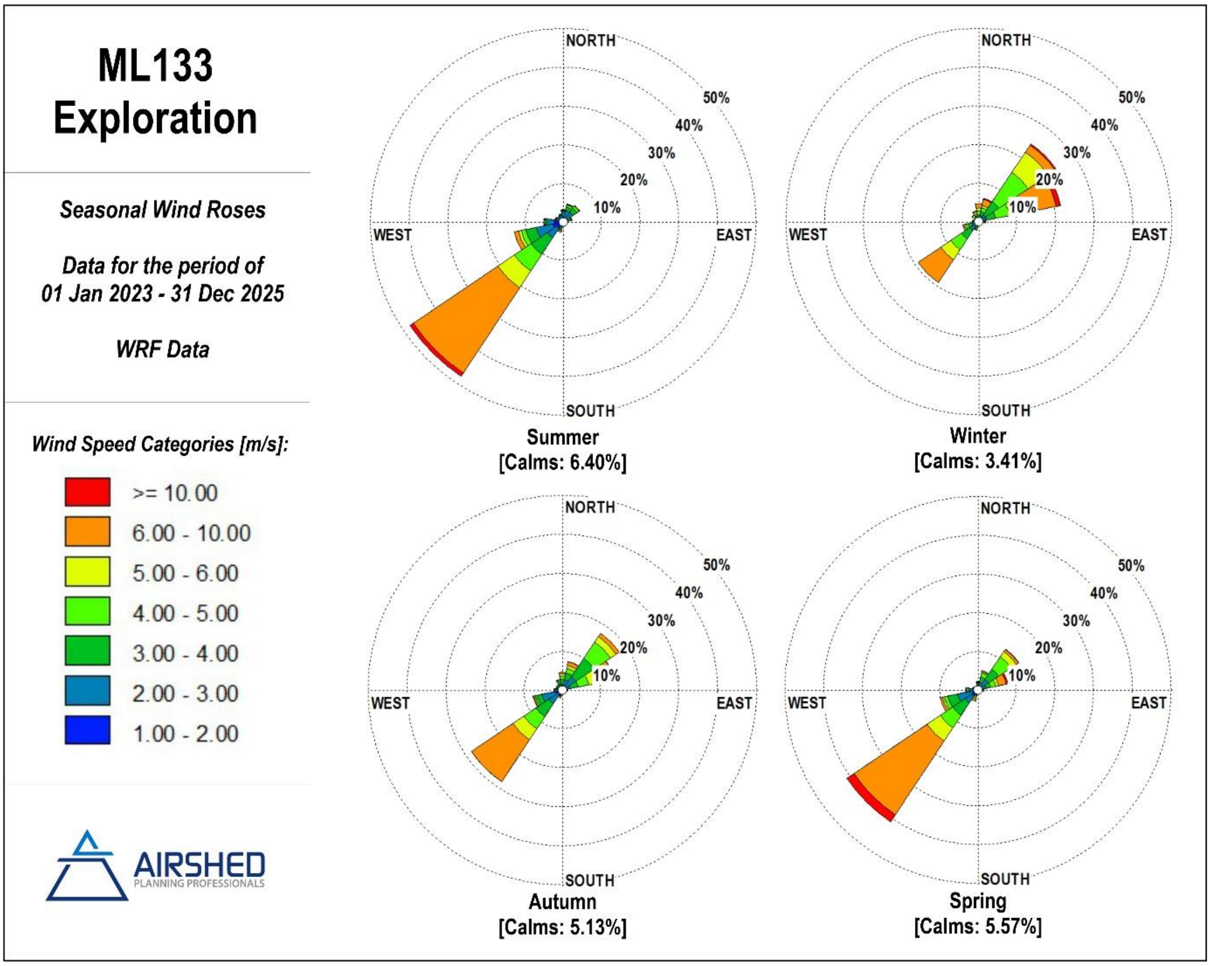


Figure 4: Seasonal wind roses for the ML133 Exploration Site (WRF data, 2023 – 2025)

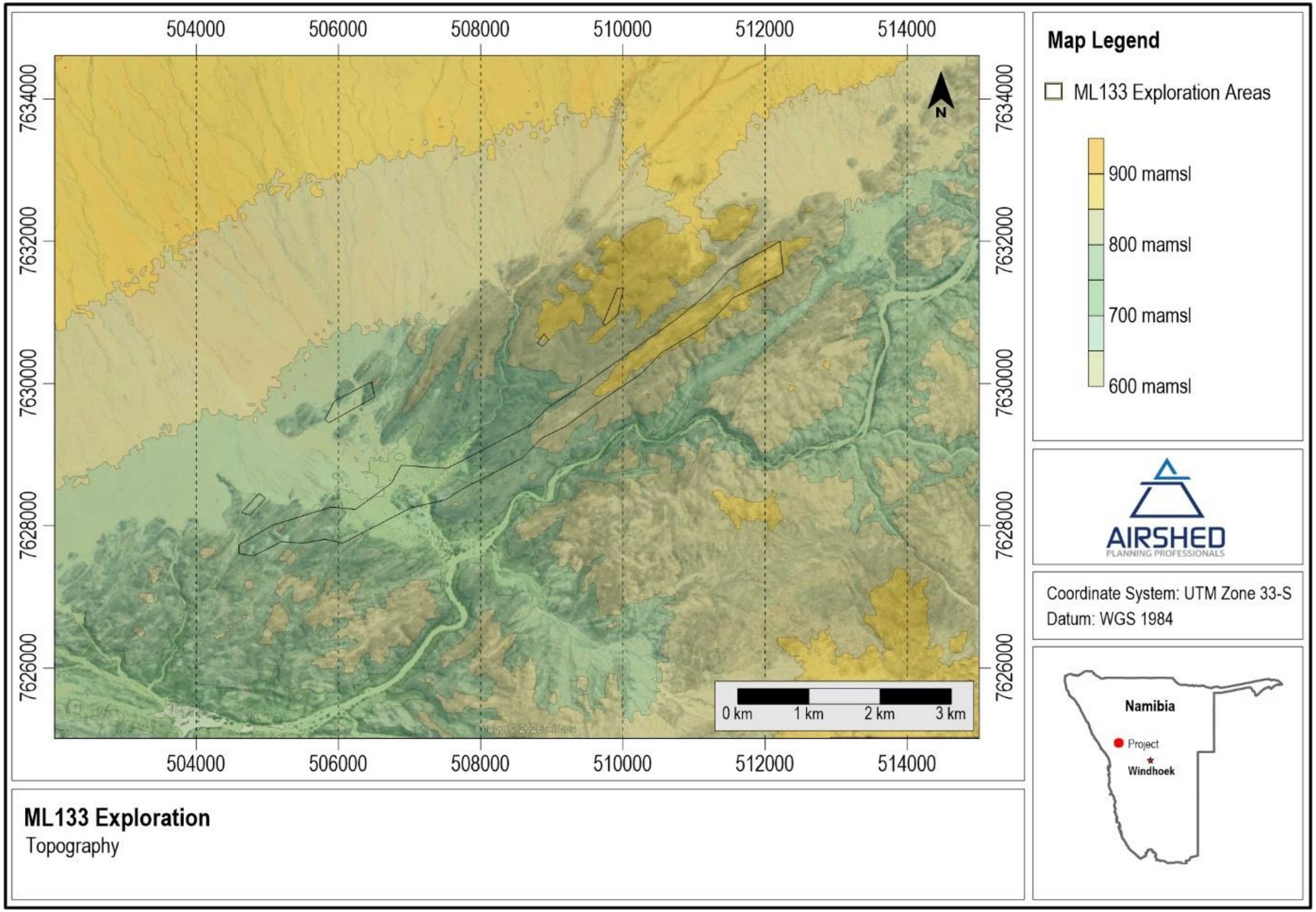


Figure 5: Topography of the study region

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.

Maximum, minimum and mean temperatures for the study area are given as 40.5°C, -0.5°C and 21.8°C respectively, based on modelled WRF data for the period 2023-2026. Maximum temperatures range from 40.5°C in December to 31.2 °C in June, with minima ranging from 10.5°C in March to -0.5°C in June (Table 7).

Table 7: Average temperatures for the ML133 Exploration Site (WRF data, 2023 – 2025)

Hourly Minimum, Hourly Maximum and Monthly Average Temperatures (°C)												
Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean temperature (°C)	22.7	24.3	24.9	24.4	22.0	17.3	16.8	19.2	20.5	22.4	24.0	23.9
Maximum (°C)	38.8	38.7	40.0	36.9	35.2	31.2	31.8	35.9	36.7	39.8	38.3	40.5
Minimum (°C)	9.6	9.7	10.5	8.0	3.7	-0.5	0.7	0.0	1.3	4.9	8.6	9.5

Diurnal temperature trends are presented in Figure 6. During the day, temperatures increase to reach maximum at around 12:00 in the afternoon. Ambient air temperatures decrease to reach a minimum at around 06:00 i.e. just before sunrise.

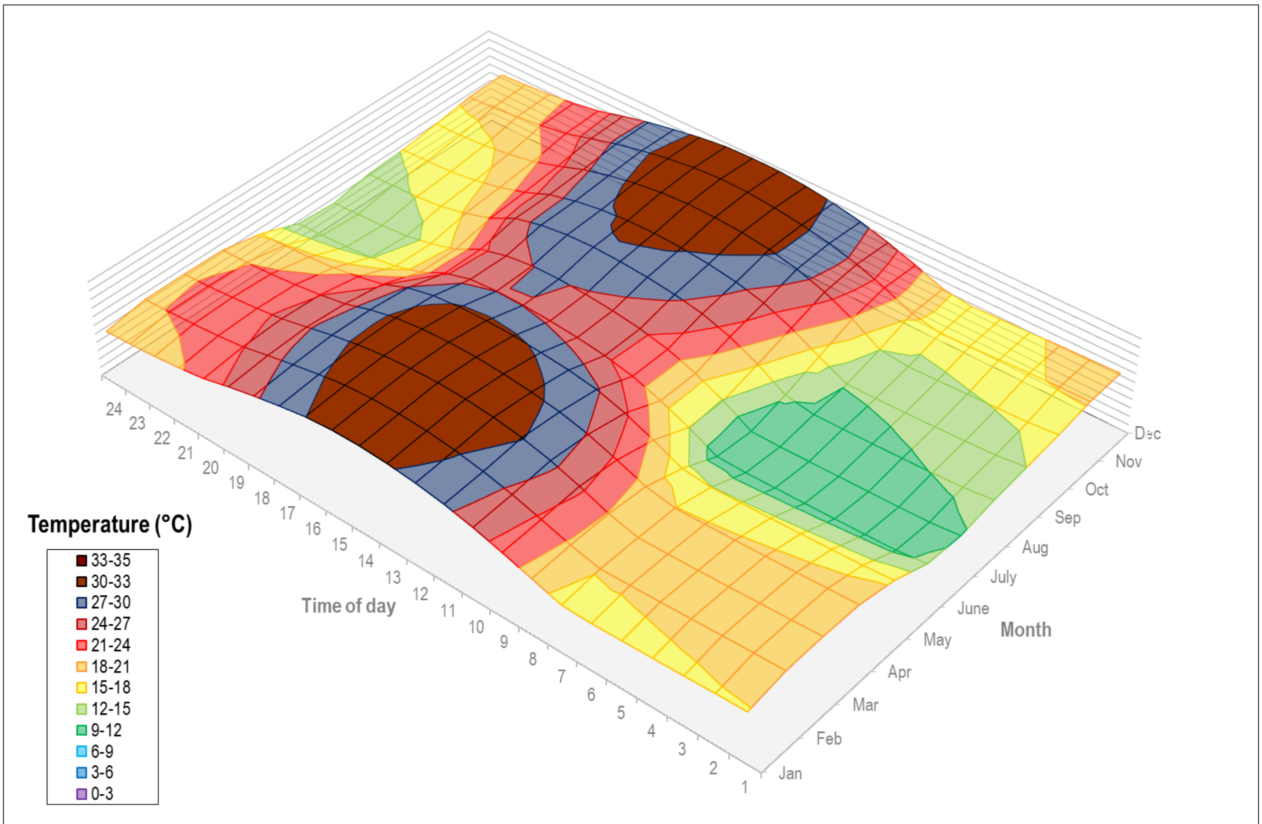
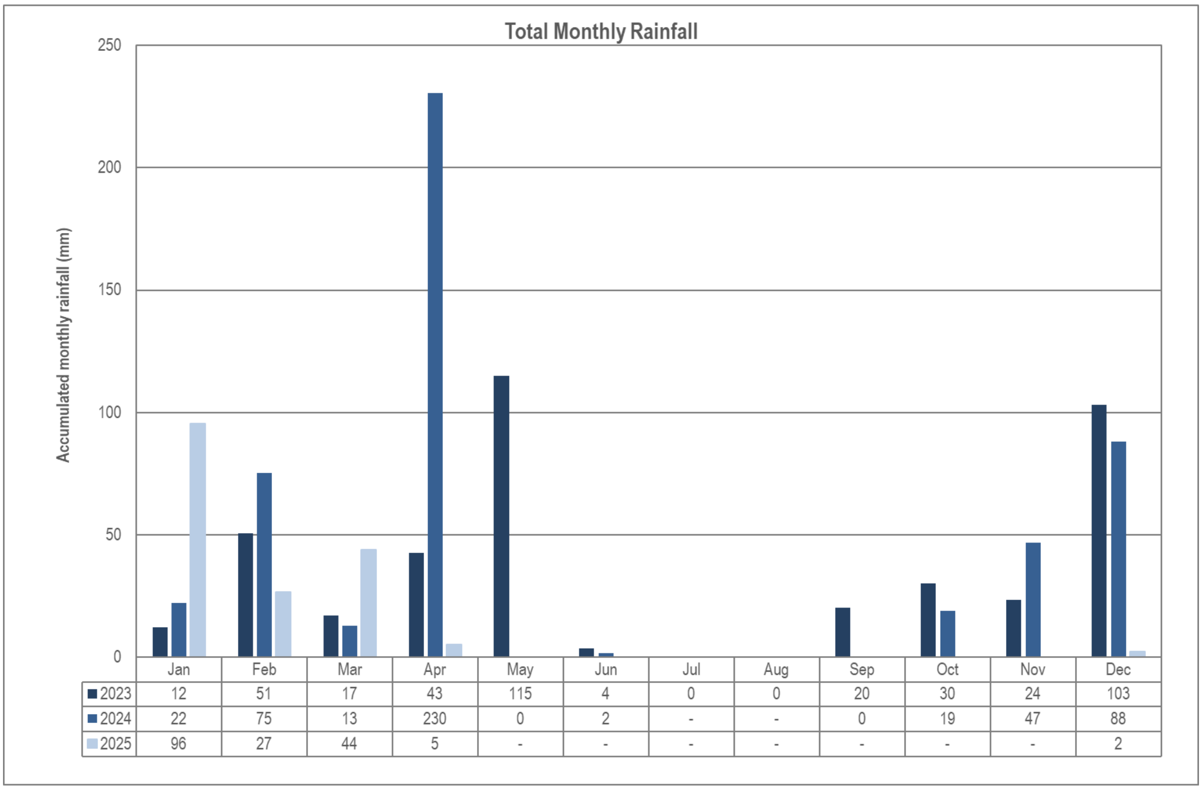


Figure 6: Diurnal temperature profile for the ML133 Exploration Site (WRF data, 2023 – 2025)

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. Long-term monthly average rainfall figures obtained from worldweatheronline.com are illustrated in Figure 7.

On average, the area receives approximately 363 mm of rain per year based on the WRF data. There is a rainy season from December through March and a dry season from May to September, with December being the wettest month and both July and August the driest.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2023	12	51	17	43	115	4	0	0	20	30	24	103
2024	22	75	13	230	0	2	-	-	0	19	47	88
2025	96	27	44	5	-	-	-	-	-	-	-	2

Figure 7: Long-term average rainfall for the ML133 Exploration Site (WRF data, 2023 – 2025)

3.2.4 Atmospheric Stability

The new generation air dispersion models differ from the 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 therefore described by two parameters; the boundary layer depth and the Monin-Obukhov length, rather than in terms of the single parameter Pasquill Class. The Monin-Obukhov length (L_{Mo}) 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 daytime, the atmospheric boundary layer is characterised by thermal turbulence due to the heating of the earth's surface. 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 lower dilution potential.

Diurnal variation in atmospheric stability described by the inverse Monin-Obukhov length and the mixing height is provided in Figure 8.

The highest concentrations for ground level, or near-ground level releases from non-wind dependent sources would occur during weak wind speeds and stable (night-time) atmospheric conditions. For elevated releases, such as a stack, unstable conditions can result in very high concentrations of poorly diluted emissions close to the stack. This is called *looping* and occurs mostly during daytime hours (Figure 8(c)). Neutral conditions disperse the plume fairly equally in both the vertical and horizontal planes and the plume shape is referred to as *coning* (Figure 8(b)). Stable conditions prevent the plume from mixing vertically, although it can still spread horizontally and is called *fanning* (Figure 8(a)) (Tiwary & Colls, 2010). For ground level releases, such as fugitive dust from mining activities, the highest ground level concentrations will occur during stable night-time conditions.

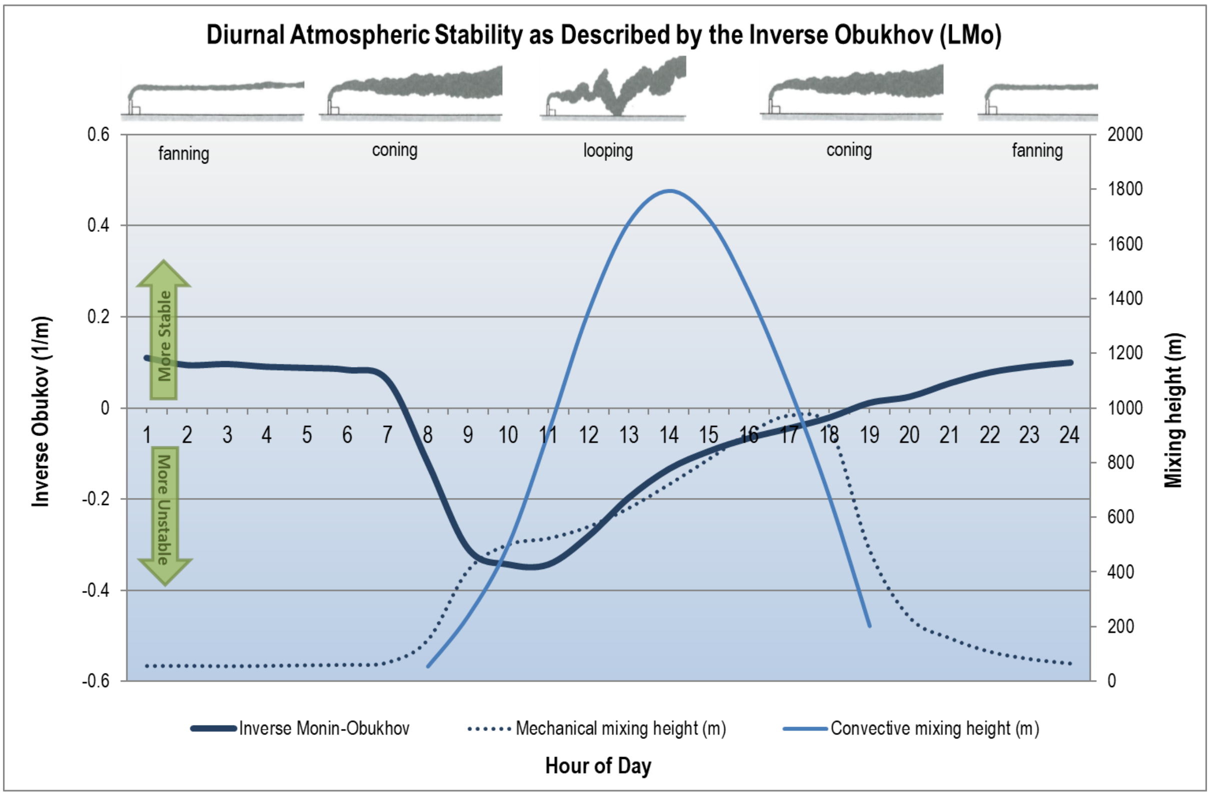


Figure 8: Diurnal atmospheric stability based on WRF modelled data (Jan 2023 – Dec 2025)

3.3 Current Ambient Air Quality

3.3.1 Existing Sources of Emissions in the Area

3.3.1.1 Atmospheric Emissions

The land in ML133 area is mainly communal land used for small stock farming with tourism. Small-scale mining, operations at the Uis Tin Mining Company (UTMC) and the NamClay operations just outside of Uis generate the main sources of income. Additional sources of dust emissions contributing to the overall dust emissions load can be attributed to dust generated from historically mined areas. Given these activities, it is expected that fugitive dust may be present during dry, windy conditions.

Vehicles travelling on the nearby national, district and secondary roads release carbon dioxide, carbon monoxide, oxides of nitrogen, particulate matter, sulphur dioxide and volatile organic emission. These vehicles are also responsible for wheel-entrained dust.

Other potential sources of air pollution include

- Residential use of wood for heating and cooking purposes;
- Biomass burning (veld fires);
- De-bushing to increase the grazing capacity of farmland;
- Windblown dust from exposed surfaces and unpaved roads; and
- Charcoal making by heating wood (or other organic substances) in the absence of oxygen

These sources are mainly associated with the release of airborne particulates, although combustion sources would also emit carbon dioxide, carbon monoxide, oxides of nitrogen, sulphur dioxide and volatile organic compounds.

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).

3.3.2 Existing Ambient Air Pollutant Concentrations in the Project Area

No monitoring network in place currently at the Project and it also does not include any ambient monitoring locations. PM concentrations measured as part of the SEMP AQMP monitoring network were limited to the coastal towns of Swakopmund, Walvis Bay and Henties Bay with a station in the central western part of the region on the farm Jakalswater. None of these locations are representative of the air quality in the ML133 area.

4 Impact of Proposed Project on the Receiving Environment

4.1 Atmospheric Emissions

4.1.1 Exploration Phase

A description of the project is provided in Section 1.3. The layout of ML133 exploration areas and road is shown in Figure 9.

To determine the significance of air pollution impacts from the Project, emissions were estimated for an unmitigated scenario and a mitigated scenario.

4.1.1.1 Emissions Inventory

Emissions inventories provide the source input required for the simulation of ambient air concentrations. In the quantification of these releases use was made of the predictive emission factors published by the US-EPA (EPA, 1996) and Australian NPi (Australian NPi Manual for Mining, 2012), since no local emission factors are available. The emission equations are provided in Table 8. The control efficiencies used in the calculation of emissions due to mitigated operations are listed in Table 9 – these were based on design mitigation measures assumed for the Project.

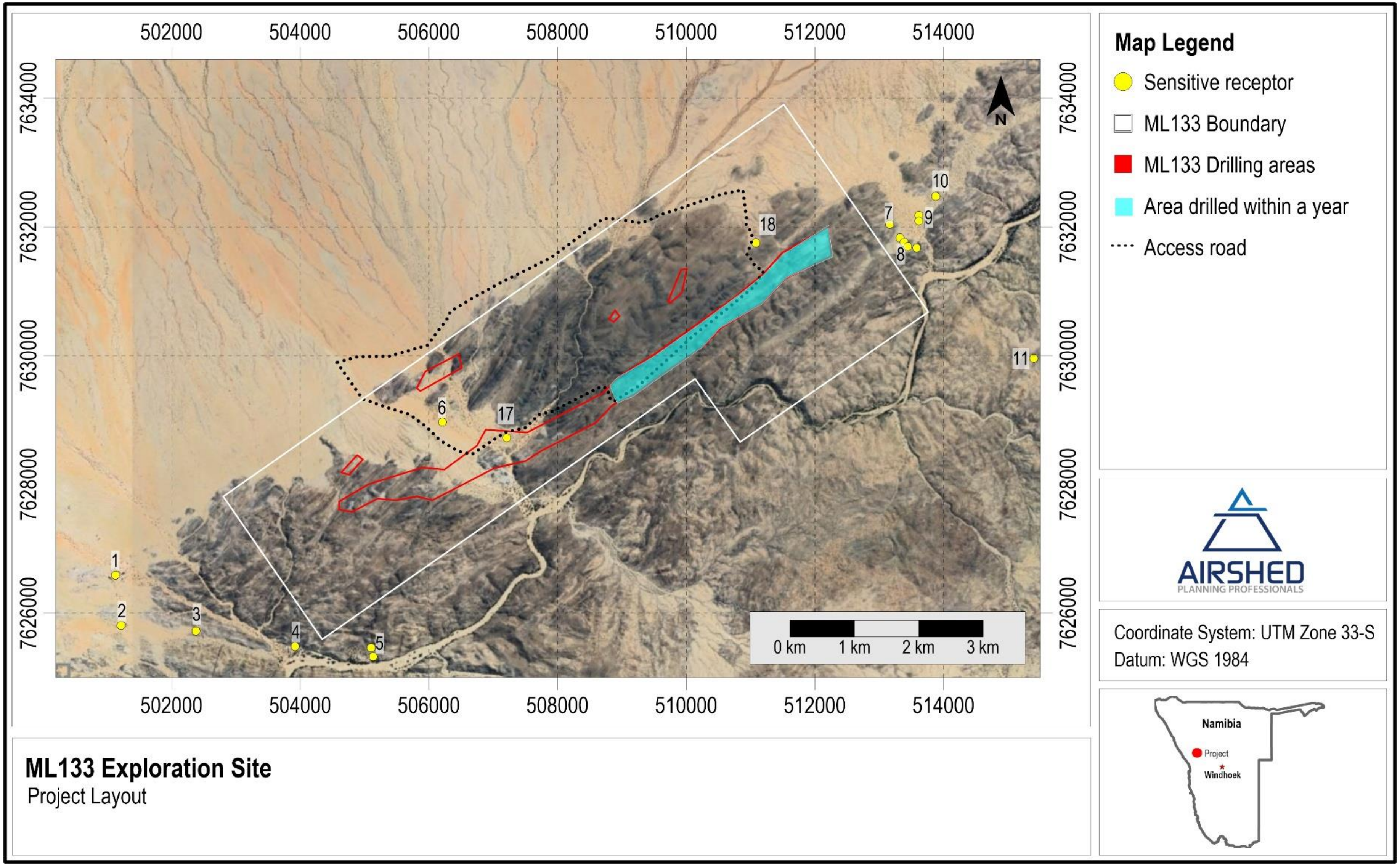


Figure 9: Project Layout

Table 8: Emission equations used to quantify the routine emissions from the exploration phase

Activity	Emission Equation	Source	Information assumed/provided
Vehicle entrainment on unpaved surfaces	$$E = k\left(\frac{s}{12}\right)^{a}\left(\frac{W}{3}\right)^{b} \cdot 281.9$$ 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 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	US-EPA AP42 Section 13.2.2	In the absence of site-specific silt data, use was made of US EPA default mean silt content of 8.4%. The capacity of the haul trucks to be used was given as 10 t. Average weight of haul trucks was calculated as 10.5 t. The capacity of the water trucks was assumed to be 10 000L (8.5 t). Average weight was calculated at 13.53 t. The layout of the roads was provided (Figure 9). Operating hours were given as 24 hours per day, 7 days a week. It was assumed that all vehicles will travel 2 times per day.
Drilling	$E_{TSP} = 0.59\, kg/hole\ drilled$ $E_{PM_{10}} = 0.31\, kg/hole\ drilled$ $E_{PM_{2.5}} = 0.31\, kg/hole\ drilled$	NPI Section: Mining	Drill holes per day were given as 12 (provided by ECC). Operating hours were assumed to be 24 hours per day, 7 days a week. The holes were assumed to be spaced 25 m × 25 m from each other. An annual area was then estimated as input for the model (shown Figure 9).

Table 9: Estimated control factors for various mining operations

Operation/Activity	Control method and emission reduction
Drilling	75% for water sprays.
Roads	75% for water sprays on surface roads.

4.1.2 Summary of Emissions due to Baseline and Project Scenarios

Summaries of particulate emissions for routine operations due to the Baseline and Project scenarios are provided in Table 10.

The contributions of individual source groups to total tons per annum for the Baseline and Project scenarios are illustrated in Table 10

Table 10: Calculated emission rates due to unmitigated and mitigated activities for exploration scenarios respectively

ACTIVITY	Emissions (tpa)			% Contribution		
	TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$
Unmitigated						
Roads	272.58	154.95	54.98	99.06	99.14	99.86
Drilling	2.58	1.34	0.076	0.94	0.86	0.14
TOTAL	**275.16**	**156.30**	**55.06**	**100.00**	**100.00**	**100.00**
Mitigated: control efficiency of 75% applied to unpaved roads and drilling activities						
Roads	68.14	38.74	13.75	99.06	99.14	99.86
Drilling	0.65	0.36	0.019	0.94	0.86	0.14
TOTAL	**68.79**	**39.07**	**13.76**	**100.00**	**100.00**	**100.00**

4.1.3 Construction Phase

The construction will entail the construction of an open pit, a waste rock dump (WRD) and the haul roads. Construction work packages include civil works, in-plant erection, piping, erection of conveyors and gantries, conveyor mechanical installation, and electrical, control and instrumentation work. Typical sources of fugitive particulate emissions associated with construction are given in Table 11.

Table 11: Typical sources of fugitive particulate emission associated with construction

Impact	Source	Activity
Gaseous emissions (SO_2, NO_x, CO, CO_2)	Vehicle tailpipes	Transport and general construction activities
Fumes (Volatile Organic Compounds -VOCs)	Construction materials (paints, solvents, oil and grease) and waste	Handling and storage
Dustfall, PM_{10} and $PM_{2.5}$	Construction WRD pit and haul roads	Clearing of groundcover
		Levelling of area
		Wind erosion from open areas
		Materials handling

Each of the operations in Table 11 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. Currently the layout of the mine has not been finalised so no emissions could be estimated for the construction phase at this time.

4.2 Atmospheric Dispersion Modelling

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

Dispersion models compute 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 from 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.

The US EPA AERMOD was selected for this study.

AERMOD is an advanced new-generation model. It is designed to predict pollution concentrations from continuous point, flare, area, line, and volume sources. AERMOD offers new and potentially improved algorithms for plume rise and buoyancy, and the computation of vertical profiles of wind, turbulence and temperature however retains the single straight-line trajectory limitation. AERMET is a meteorological pre-processor for AERMOD. Input data can come from hourly cloud cover observations, surface meteorological observations and twice-a-day upper air soundings. Output includes surface meteorological observations and parameters and vertical profiles of several atmospheric parameters. AERMAP is a terrain pre-processor designed to simplify and standardise the input of terrain data for AERMOD. Input data includes receptor terrain elevation data. The terrain data may be in the form of digital terrain data. The output includes, for each receptor, location, and height scale, which are elevations used for the computation of air flow around hills.

A disadvantage of the model is that spatial varying wind fields, due to topography or other factors cannot be included. Input data types required for the AERMOD model include: source data, meteorological data (supplied in the required format with the WRF data), terrain data, information on the nature of the receptor grid and pre-development or background pollutant concentrations or dustfall rates.

4.2.2 Meteorological Requirements

For the current study, use was made of modelled WRF data for the period 2023-2025.

4.2.3 Source Data Requirements

The AERMOD model is able to model point, area, volume and line sources. Sources were modelled as follows:

- Unpaved roads – modelled as area sources;

- Drilling – modelled as area sources.

4.2.4 Modelling Domain

The dispersion of pollutants expected to arise from proposed activities was modelled for an area covering 17 km (east-west) by 13.6 km (north-south). The area was divided into a grid matrix with a resolution of 100 m, with the Project located centrally. The surrounding receptors were included as discrete receptors (see Figure 2). AERMOD calculates ground-level (1.5 m above ground level) concentrations at each grid and discrete receptor point.

4.3 Dispersion Modelling Results

Dispersion modelling was undertaken to determine highest 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 AERMOD for each of the receptor grid points specified.

Isopleth plots reflect the incremental GLCs for $PM_{2.5}$ and PM_{10} where exceedances of the relevant Air Quality Objectives (AQOs) (The proposed AQOs as set out in Table 5 are used as indicators during the impact assessment.

Table 5) were simulated.

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, viz. off-site.

4.3.1 PM_{10}

The simulated exceedances of highest daily and annual average PM_{10} AQOs for unmitigated and mitigated exploration operations are provided in Figure 10 and Figure 11 respectively, with the GLCs at the nearest AQSRs provided in Table 12.

PM_{10} daily GLCs, for unmitigated activities, result in exceedances of the 24-hour air quality objective (AQO) at a maximum distance of ~200 m from the road. The only AQSR that shows an exceedance is at the Contractors camp, which is located close to the road. Annual GLCs only exceed intermittently at some areas on the road, with the maximum of ~80 m, but with no exceedances at any of the AQSRs. For mitigated activities, no impacts are predicted for both daily and annual GLCs with no exceedances at any of the AQSRs

Table 12: Simulated PM_{10} ground level concentrations (in µg/m³) at selected AQSRs for exploration operations (non-compliance is highlighted)

AQSR	Untigated			Mitigated		
	Annual Average	Highest Day	FOE	Annual Average	Highest Day	FOE
	40 µg/m³	75 µg/m³	<4 days/year	40 µg/m³	75 µg/m³	<4 days/year
1	1.03	7.27	0	0.26	1.82	0
2	1.02	6.97	0	0.25	1.74	0
3	1.16	6.46	0	0.29	1.61	0
4	1.23	6.94	0	0.31	1.74	0
5	1.12	7.11	0	0.28	1.78	0
6	1.05	6.62	0	0.26	1.66	0
7	8.77	37.81	0	2.19	9.45	0
8	1.92	14.15	0	0.48	3.54	0
9	1.55	13.27	0	0.39	3.32	0
10	1.52	12.72	0	0.38	3.18	0
11	1.45	13.42	0	0.36	3.35	0
12	1.65	14.77	0	0.41	3.69	0
13	1.54	14.60	0	0.39	3.65	0
14	1.45	14.17	0	0.36	3.54	0
15	1.33	13.49	0	0.33	3.37	0
16	0.47	6.49	0	0.12	1.62	0
17 - Contractors Camp	27.46	102.23	4	6.86	25.56	0
18 - Core Shed	15.21	70.46	0	3.80	17.62	0

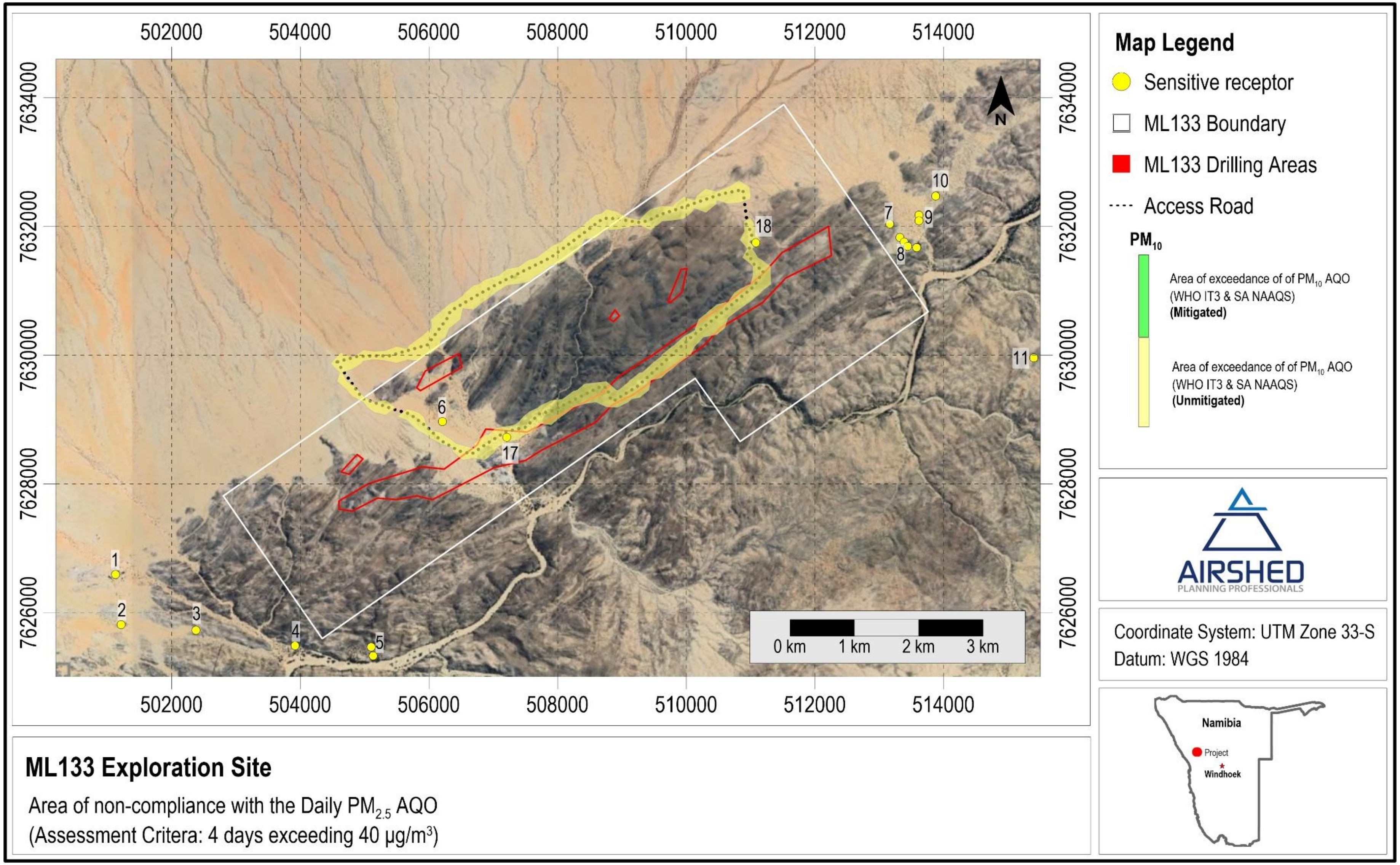


Figure 10: Area of non-compliance of daily PM_{10} AQO for unmitigated and mitigated exploration operations

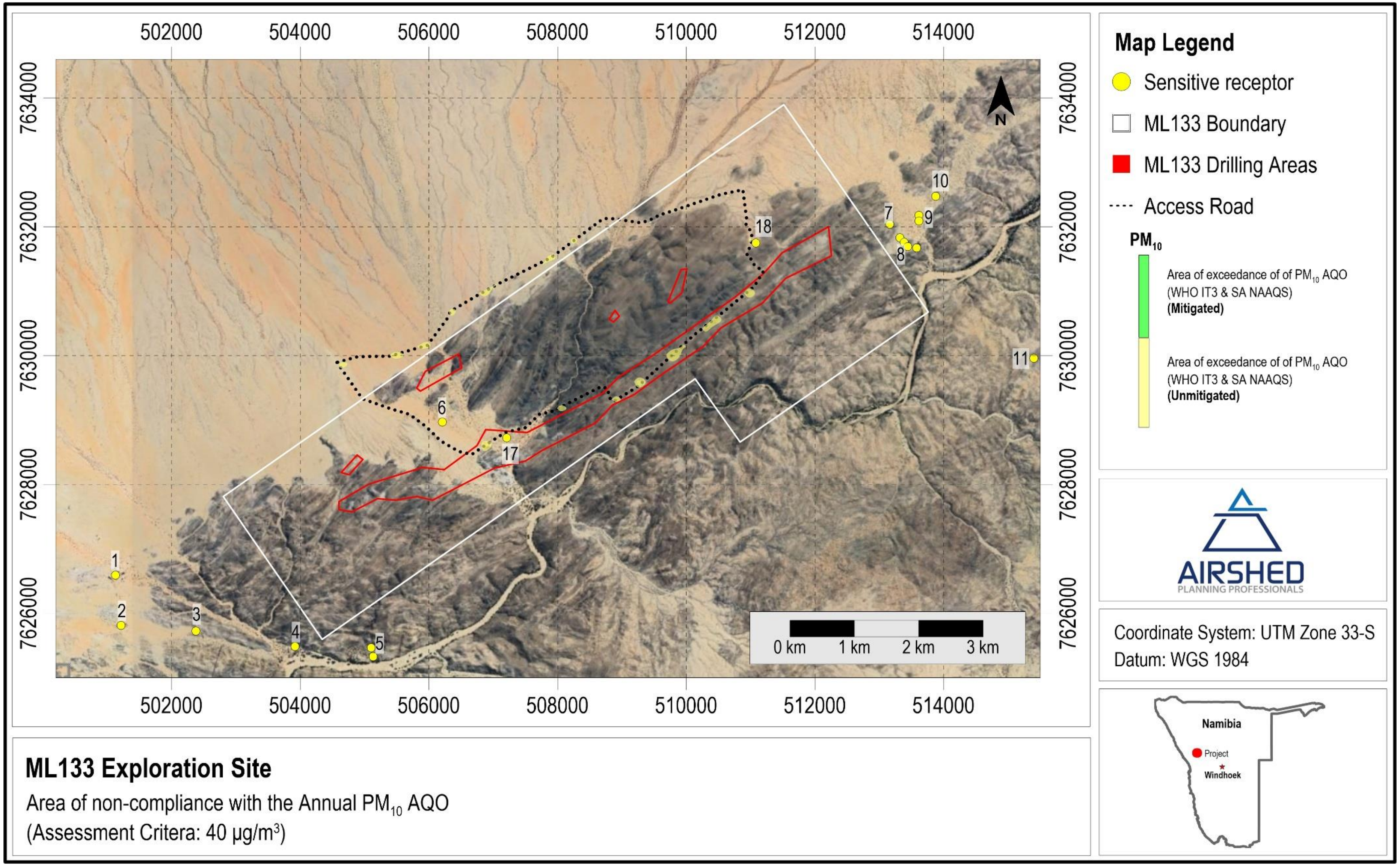


Figure 11: Area of non-compliance of annual PM_{10} AQO for unmitigated and mitigated exploration operations

4.3.2 $PM_{2.5}$

The simulated exceedances of highest daily and annual average $PM_{2.5}$ AQOs for unmitigated and mitigated exploration operations are provided in Figure 12 and Figure 13 respectively, with the GLCs at the nearest AQSRs provided in Table 13.

$PM_{2.5}$ daily GLCs, for unmitigated activities, do not exceed the AQO (WHO IT-3) at any of the AQSRs but the footprint of exceedance extends ~200 m from the road. There are intermittent small areas of exceedances of the annual $PM_{2.5}$ AQO on the road. For mitigated activities, no area of exceedances is predicted and there are no exceedances at any of the AQSRs.

Table 13: Simulated $PM_{2.5}$ ground level concentrations (in µg/m³) at selected AQSRs exploration operations (non-compliance is highlighted)

AQSR	Unmitigated			Mitigated		
	Annual Average	Highest Day	FOE	Annual Average	Highest Day	FOE
	15 µg/m³	37.5 µg/m³	<4 days/year	15 µg/m³	37.5 µg/m³	<4 days/year
1	0.37	2.28	0	0.09	0.57	0
2	0.36	2.15	0	0.09	0.54	0
3	0.41	2.14	0	0.10	0.53	0
4	0.43	2.16	0	0.11	0.54	0
5	0.39	2.09	0	0.10	0.52	0
6	0.37	2.03	0	0.09	0.51	0
7	3.11	11.64	0	0.78	2.91	0
8	0.66	4.70	0	0.17	1.17	0
9	0.54	4.04	0	0.13	1.01	0
10	0.53	3.90	0	0.13	0.98	0
11	0.50	4.02	0	0.13	1.00	0
12	0.57	4.15	0	0.14	1.04	0
13	0.53	4.02	0	0.13	1.00	0
14	0.50	3.64	0	0.13	0.91	0
15	0.46	3.58	0	0.12	0.90	0
16	0.17	1.77	0	0.04	0.44	0
17 - Contractors Camp	9.74	30.15	1	2.43	7.54	0
18 - Core Shed	5.38	20.05	0	1.34	5.01	0

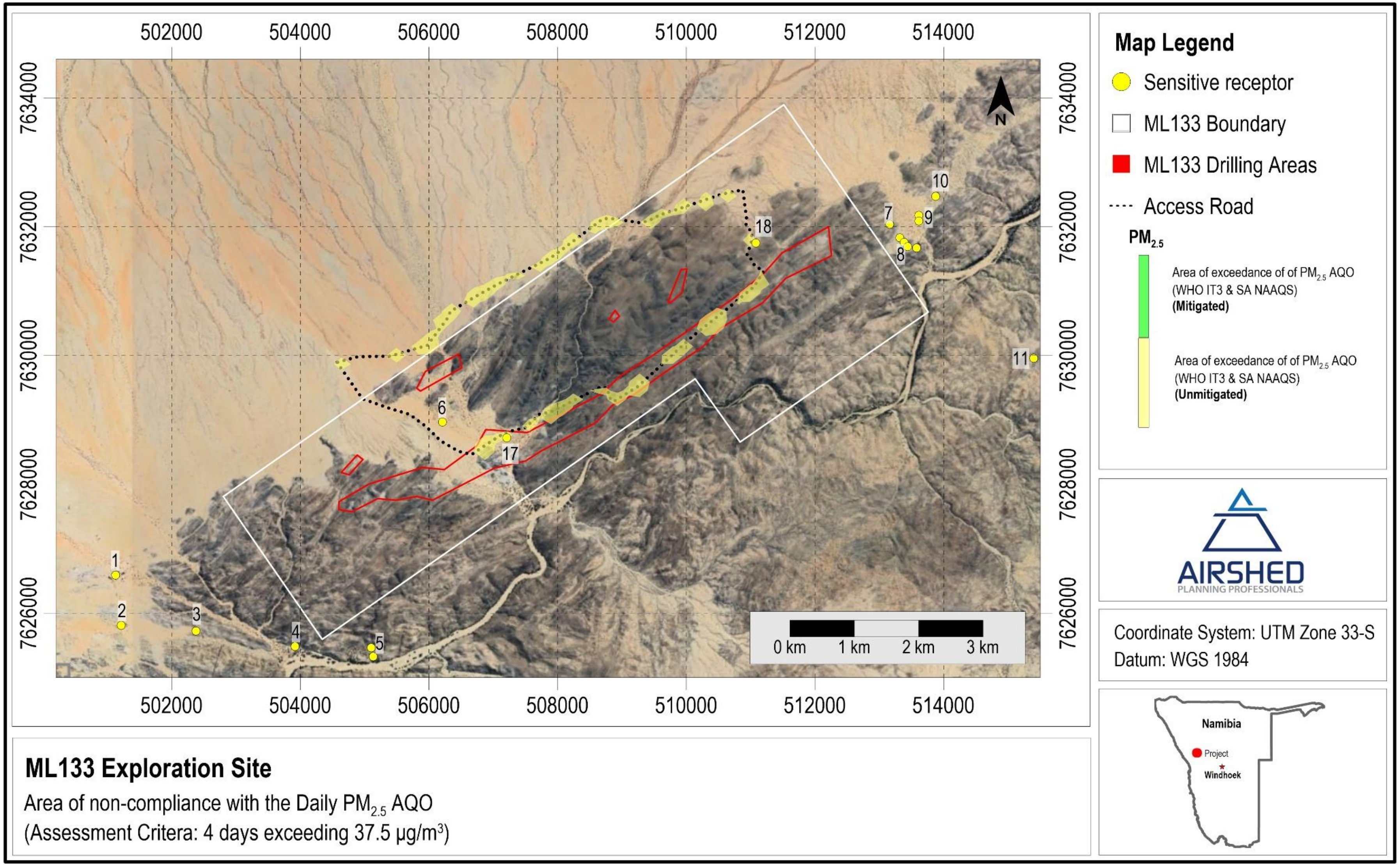


Figure 12: Area of non-compliance of daily $PM_{2.5}$ AQO for unmitigated and mitigated exploration operations

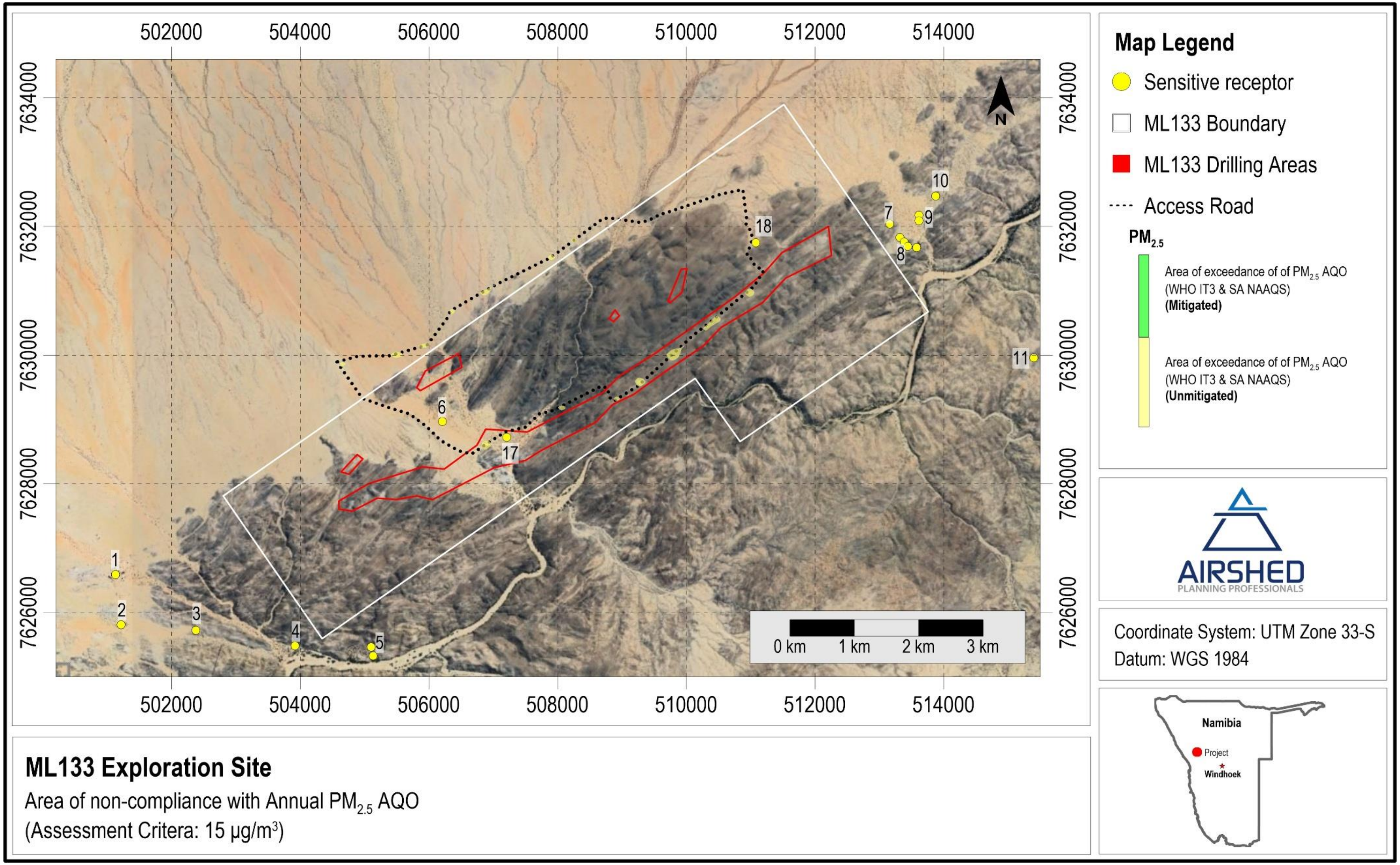


Figure 13: Area of non-compliance of annual $PM_{2.5}$ AQO for unmitigated and mitigated exploration operations

4.3.3 Dustfall

The simulated daily dustfall rates for mitigated and unmitigated activities are provided in Figure 14 and respectively, with the values at each of the AQSRs provided in Table 14.

Maximum daily dustfall rates, for unmitigated exploration activities, are within the AQO (SA NDCR residential limit of 600 mg/m²/day) at all but one of the AQSRs (Table 14). Daily impacts are limited to ~200 m from the site road (Figure 14). With mitigation measure taken into account, no impact footprints are predicted and all the AQSR are within the AQO.

Table 14: Simulated dustfall rates (in mg/m²/day) at selected AQSRs for exploration operations (non-compliance is highlighted)

AQSR	Unmitigated	Mitigated
	Highest 30-day average	**Highest 30-day average**
AQO	600 mg/m²/day	600 mg/m²/day
1	23.36	0.008
2	21.99	0.007
3	23.98	0.007
4	31.93	0.008
5	27.43	0.006
6	24.92	0.005
7	205.78	0.069
8	43.71	0.008
9	33.59	0.006
10	33.03	0.006
11	32.00	0.006
12	36.86	0.006
13	35.21	0.006
14	33.56	0.005
15	31.41	0.005
16	10.53	0.002
17 - Contractors Camp	747.39	0.353
18 - Core Shed	442.08	0.167

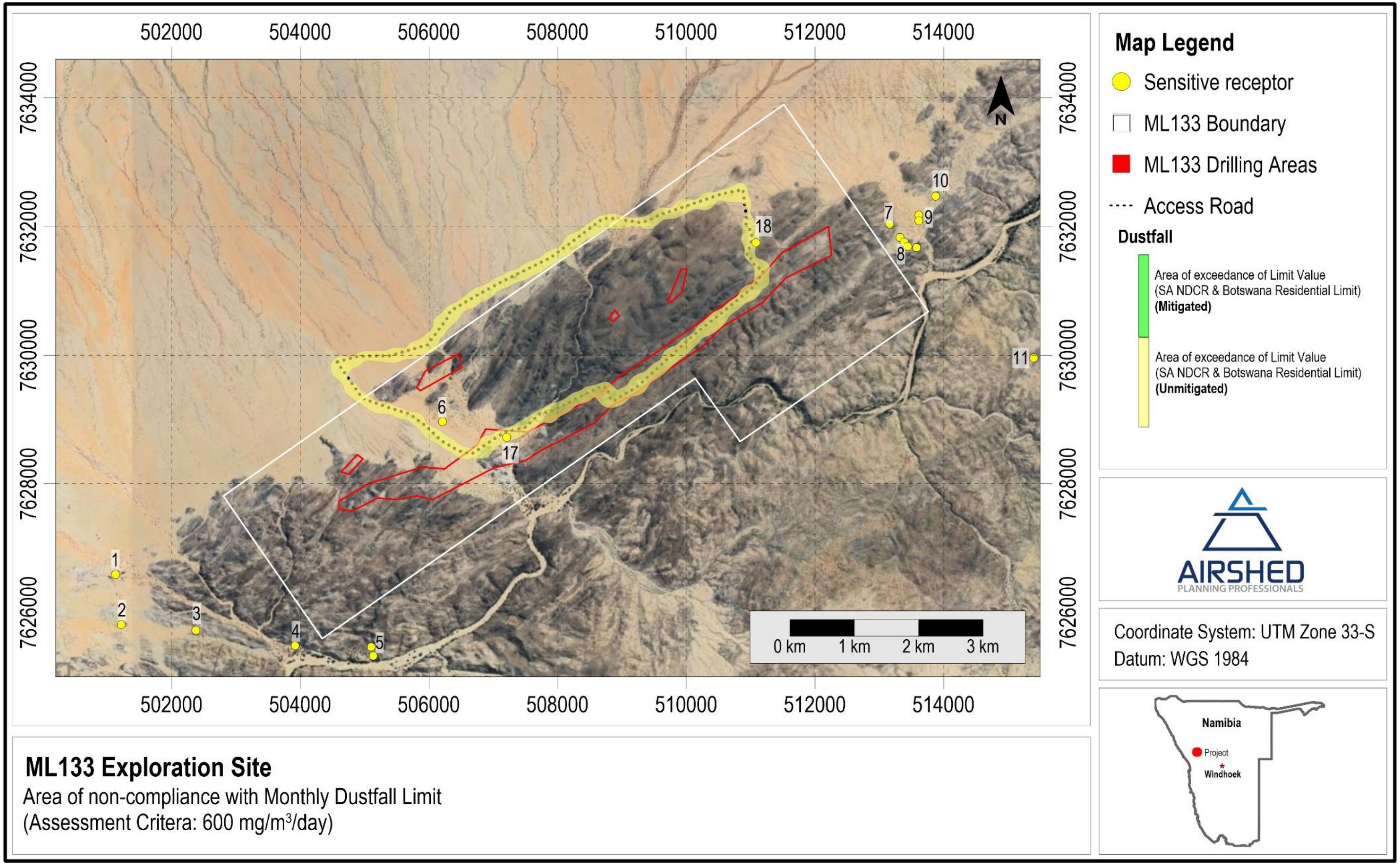


Figure 14: Area of non-compliance of dustfall limit values for unmitigated and mitigated exploration operations

5 Recommended Air Quality Management Measures

In the light of the Project being so close to houses located to the west and east of the project area it is recommended that Aranda commit itself to adequate air quality management planning throughout the life of the Project.

The air quality management plan in this section 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, site-specific management objectives are developed in Section 5.3 based on the ranking of emissions sources.

5.1 Air Quality Management Objectives

The main objective of the proposed air quality management measures for the Project is to ensure that operations result in ambient air concentrations (specifically $PM_{2.5}$ and PM_{10}) and dustfall rates that are within the relevant ambient air quality standards and regulations outside the mining area and at the relevant AQSRs. In order to define site specific management objectives, the main sources of pollution need to be identified. Once the main sources have been identified, target control efficiencies for each source can be defined to ensure acceptable cumulative ground level concentrations.

5.1.1 Ranking of Sources

The ranking of sources serves to confirm the current understanding of the significance of specific sources, and to evaluate the emission reduction potentials required for each. Sources ranking can be established on:

- Emissions ranking; based on the comprehensive emissions inventory established for the operations (Section 4); and
- Impacts ranking; based on the simulated pollutant GLCs.

Sources were ranked based on PM_{10} emissions and PM_{10} GLCs simulated at the 5 nearest AQSRs, since PM_{10} impacts were considered most significant among the three pollutants assessed (see Table 15).

Ranking of source- based quantified emissions and impacts for the exploration phase are as follows:

- The main contribution will be from the vehicles using the onsite road (99%). The impact of drilling on any AQSRs are very low (1% or lower). Highest impacts will be at both onsite camps due to proximity at to the onsite road.

Table 15: Source contribution to simulated annual average PM_{10} GLCs at the closest AQSRs

AQSR	Unmitigated Impacts (µg/m³)					Mitigated Impacts (µg/m³)				
	SR4	SR6	SR7	S17	S18	SR4	SR6	SR7	S17	S18
Roads	1.222	1.037	8.762	27.433	15.151	0.305	0.259	2.190	6.858	3.788
Drilling	0.009	0.010	0.011	0.026	0.059	0.002	0.003	0.003	0.007	0.015
Roads %	99%	99%	100%	100%	100%	99%	99%	100%	100%	100%
Drilling %	1%	1%	0%	0%	0%	1%	1%	0%	0%	0%
Total	**1.231**	**1.047**	**8.772**	**27.459**	**15.211**	**0.308**	**0.262**	**2.193**	**6.865**	**3.803**

5.2 Proposed Mitigation Measures and Target Control Efficiencies

From the above discussion, it is recommended that the Project include the following mitigation measures:

- Exploration phase:
  - Control of vehicle entrained dust with a CE of 75% on unpaved surface roads through water suppression.
- Construction phase:
  - Air quality impacts during construction would be reduced through basic control measures such as limiting the speed of haul trucks; limiting unnecessary travelling of vehicles on untreated roads; and applying water suppression to achieve a control efficiency (CE) of 75%.
  - 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.

Further literature on source specific mitigation measures is provided in Section 8.2.

5.3 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 direct source of the emission (source monitoring) and the impact on the receiving environment (ambient air quality monitoring). For instance, ensuring that no visible evidence of windblown dust exists represents an example of a source-based indicator, whereas maintaining off-site dustfall levels to below 600 mg/m²/day represents an impact- or receptor-based performance indicator.

5.3.1 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 and source quantification;
- Temporal and spatial trend analysis; and
- Tracking progress made by control measures.

It is recommended that a dustfall monitoring network, comprising of five (5) single dustfall units, should be installed before construction starts and the monthly dustfall results used as indicators to track the effectiveness of the applied mitigation measures. Dustfall collection should follow the American Society for Testing and Materials (ASTM) method (see section 8.1 below for more details monitoring methodology). It is also recommended that once the design of future mining location have been finalised that the monitoring network should be updated so the additional sources impact can be assessed. The recommended locations are listed below in

Table 16 and are shown in Figure 15.

Table 16: Recommended dust fallout monitoring locations

Dust fallout monitor	Description	UTM WGS84 (33S)	
		Longitude (°)	Latitude (°)
ML133-1	SRs located on the north-eastern boundary	15.12706	-21.41417
ML133-2	Core Shed	15.10691	-21.41632
ML133-3	North-eastern boundary	15.11472	-21.40188
ML133-4	SRs located on the south-eastern boundary	15.03781	-21.47296
ML133-5	North-western boundary	15.06490	-21.42295

5.4 Periodic Inspections, Audits and Community Liaison

5.4.1 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 of unsatisfactory progress towards targets as indicated by the quarterly/annual reviews.

5.4.2 Liaison Strategy for Communication with Interested and Affected Parties (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. Since the operations are located in close proximity (within 2 km) from community areas, it is recommended that such meetings be scheduled and held on a regular basis.

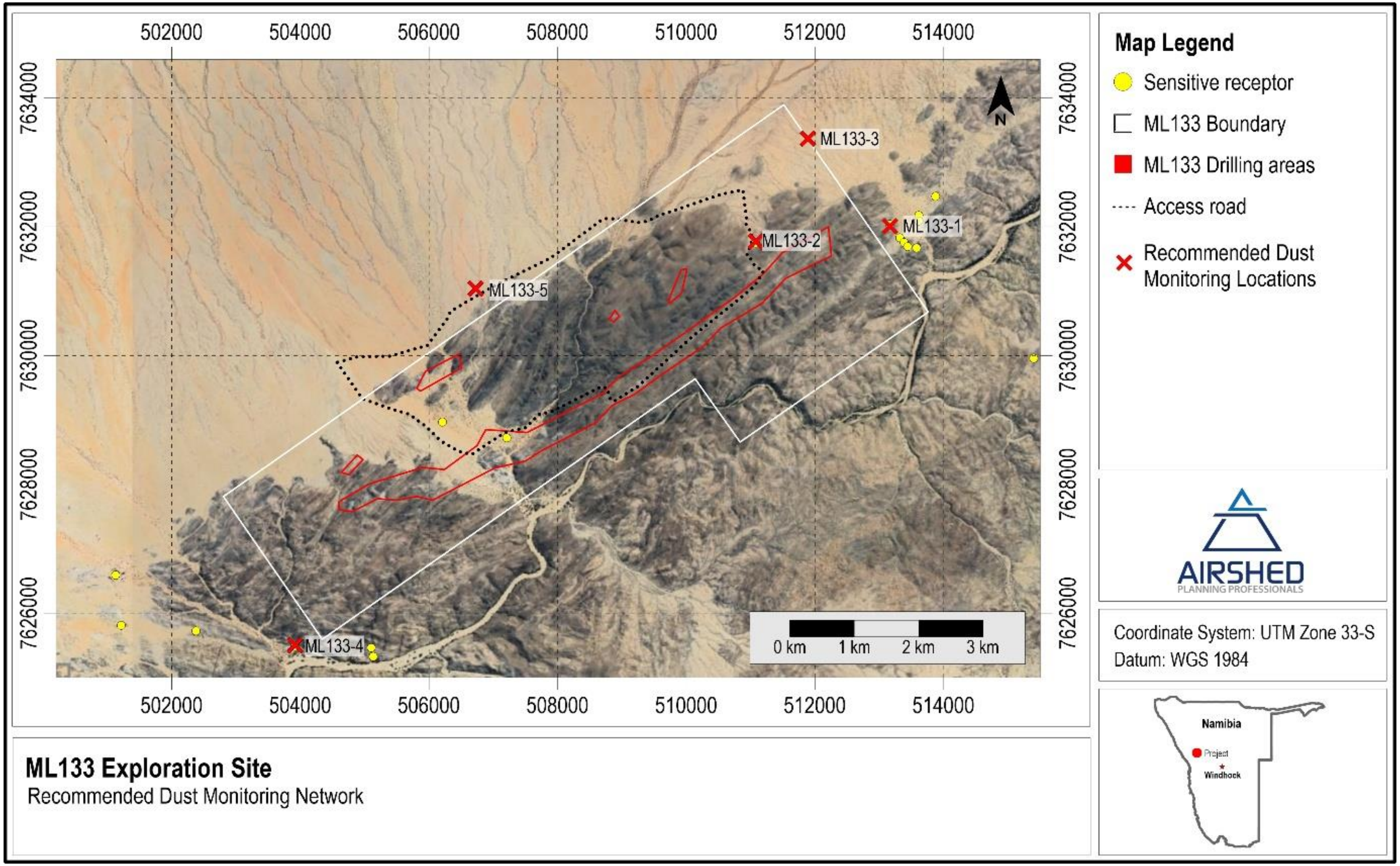


Figure 15: Recommended dust fallout network locations

5.5 Impact Significance Rating

The significance of environmental air quality impacts was assessed according to the methodology adopted by ECC. The definitions of the significance ratings and EIA ratings matrix are provided in Appendix C.

Due to the proximity of potential AQSRs to the project activities, the significance of construction and operation phase air quality impacts is ***minor.*** The impact assessment has been provided in a separate impact assessment spreadsheet to ECC.

6 Conclusions And Recommendations

Airshed Planning Professionals (Pty) Ltd (Airshed) was commissioned by Environmental Compliance Consultancy (ECC) to undertake a specialist air quality impact study for the proposed exploration activities at the MLL133 site located 30 km southeast of the Uis town.

The main objective of the air quality specialist study was to determine the potential for dust on the surrounding people and environment, and to provide practical mitigation measures on how to reduce the potential impacts. The investigation followed the methodology required for a specialist report, comprising the baseline characterisation and the impact assessment study.

6.1 Baseline characterisation

Andrada plan to increase production and propose to commence mining operations on the ML 133. ML 133 is located ~45 km south of Uis, in the Erongo Region, Namibia. ML 133 is bordering the Omaruru River to the southeast, within the Nai Nais community in the Dâures Constituency. The Project covers an area with dimensions of about ~10 km northeast-southwest and ~4 km northwest-southeast at it widest.

On-site meteorological data was not available. Use was made of Weather Research and Forecasting Model (WRF) simulated meteorological data for the period 2023 – 2025 for a location at the mine.

The baseline characterisation can be summarised as follows:

- The wind field in the area is dominated by winds from the southwest during the day and night, with a decrease in winds from the southwest and an increase of winds from the northeast during the night. Day- and night-time average wind speeds are 10 m/s and 6 m/s respectively. Calm conditions occur 3.21% of time during the day and 6.75% during the night. On average, air quality impacts are expected to be slightly more notable to the northeast of the Project due to the prevailing south-westerly winds.
- The predominant south- westerly and north-easterly winds in the study region may be explained by the surrounding topography. Uis is located approximately 20 km east-southeast of the Brandberg mountain, Namibia's highest mountain (2 559 m above sea level). The ML133 exploration site is between 600 and 900 m above sea level with the orientation of the hills and ridges in a northeast – southwest alignment. The immediate exploration site surroundings consist of low hills increasing in height towards the southeast, with a flat open plain to the north and northwest of the ML133 site.
- Maximum temperatures range from 40.5°C in December to 31.2 °C in June, with minima ranging from 10.5°C in March to -0.5°C in June.
- On average, the area receives approximately 363 mm of rain per year. There is a rainy season from December through March and a dry season from May to September, with December being the wettest month and both July and August the driest.
- 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 and other exploration activities.
- Sources of atmospheric emissions in the vicinity of the Project include small-stock farming, dust generated from historically mined areas and, to a lesser extent, emissions from vehicle tailpipes along the C36 and D1930 public roads. Other regional sources that may have an influence on the ambient air quality around the Project are the Uis Tin Mine and NamClay, both located just outside of Uis, biomass burning (natural bush fires or those employed for agricultural purposes) and de-bushing to increase the grazing capacity of farmland. Given these activities, it is

expected that fugitive dust may be present during dry, windy conditions. However, the contribution of all these sources to existing ambient air quality at and around the explaration site is considered to be low.

- Regional scale transport of mineral dust and ozone (due to vegetation burning) from the north of Namibia is a potential contributing source to background PM concentrations.
- There is no ambient air quality data or dustfall available for the study site. PM concentrations measured as part of the SEMP AQMP monitoring network were limited to the coastal towns of Swakopmund, Walvis Bay and Henties Bay with a station in the central western part of the region on the farm Jakalswater. None of these locations are representative of the air quality in the ML 133 area.

6.2 Impact Assessment

A quantitative air quality impact assessment was conducted for the exploration phase activities of the ML133 project. The assessment included an estimation of atmospheric emissions, the simulation of pollutant concentrations and determination of the significance of impacts.

The impact assessment was limited to airborne particulate (including TSP, PM_{10} and $PM_{2.5}$). Gaseous emissions (i.e. SO_2, NOx, CO and VOCs) were not included and will primarily result from diesel combustion and from mobile and stationary sources.

6.2.1 Exploration Phase

- Two exploration scenarios were assessed to determine the increase in impacts due to the Project, namely an Unmitigated Scenario and Mitigated Scenario.
- Emissions quantified for the ML133 Project were restricted to fugitive releases (non-point releases) with particulates the main pollutant of concern. Emissions were quantified based on information provided on the road and drilling area layout plan.
- The main sources of $PM_{2.5}$, PM_{10} and TSP emissions due to the Project are, in order of importance: i) vehicle entrainment from unpaved surface road, ii) drilling.
- Mitigation assumed included the following:
    - surface haul roads: water sprays assuming 75% CE;
    - drilling: assuming 75% CE for water sprays.
- Dispersion modelling results for the Unmitigated and Mitigated Scenarios are:
    - PM_{10} daily GLCs, for unmitigated activities, result in exceedances of the 24-hour air quality objective (AQO) at a maximum distance of ~200 m from the road. The only AQSR that shows an exceedance is the Contractors camp, which is located close to the road. Annual GLCs only exceed intermittently at some areas along the road, with the maximum of ~80 m, but with no exceedances at any of the AQSRs. For mitigated activities, no impacts are predicted for both daily and annual GLCs with no exceedances at any of the AQSRs.
    - $PM_{2.5}$ daily GLCs, for unmitigated activities, do not exceed the AQO (WHO IT-3) at any of the AQSRs but the footprint of exceedance extends ~200 m from the road. There are intermittent small areas of exceedances of the annual $PM_{2.5}$ AQO on the road. For mitigated activities, no area of exceedances is predicted and there are no exceedances at any of the AQSRs.
    - Maximum daily dustfall rates, for unmitigated exploration activities, are within the AQO (SA NDCR residential limit of 600 mg/m²/day) at all but one of the AQSRs. Daily impacts are limited to ~200 m from

the site road. With mitigation measure taken into account, no impact footprints are predicted and all the AQSR are within the AQO.

- For both the Unmitigated and Mitigated Scenarios, the significance is expected to be **minor** with and without mitigation in place.
- 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 ML133 modelling results indicate the potential for low regional cumulative impacts, resulting in **minor** significance.

6.2.1.1 Construction Phase

- The construction will entail the construction of an open pit, a waste rock dump (WRD) and the haul roads.
- Emissions will include gaseous emissions (SO_2, NO_x, CO, CO_2) from vehicle tail pipes, volatile organic compounds (VOCs) from construction materials and waste, and dustfall, PM_{10} and $PM_{2.5}$ from construction of the WRD and stockpiles, open pit and haul roads.
- Due to the intermittent nature of construction operations, impacts are expected to have a small but potentially harmful impact at the nearest AQSRs depending on the level of activity. With mitigation measures in place these impacts are expected to have **minor** significance.

6.2.2 Conclusion

The proposed exploration project is not likely to result in $PM_{2.5}$ and PM_{10} ground level concentrations in exceedance of the selected AQOs at any of the AQSRs, for both unmitigated and mitigated activities. Impacts due to unmitigated activities are likely to extend over a localised area around exploration activities. With mitigation in place, the resulting impacts can be limited to on-site areas. Dustfall rates are likely to be low throughout the exploration phase.

It is the specialist's opinion that the proposed project exploration activities 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

The most practical approach in controlling PM emissions would be the application of water sprays where and as often as possible. Other measures are also proposed. These include:

- Exploration phase:
  - Control of vehicle entrained dust with a CE of 75% on unpaved surface roads through water suppression.
- Construction phase:
  - Air quality impacts during construction would be reduced through basic control measures such as limiting the speed of haul trucks; limiting unnecessary travelling of vehicles on untreated roads; and applying water suppression to achieve a control efficiency (CE) of 75%.
  - 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 Phase:
  - Once a project plan exists for the proposed project mining operations, an air quality assessment needs to be conducted to determine the potential impact on nearby AQSRs and the surrounding environment.
- Air Quality Monitoring:

- It is recommended that a dustfall monitoring network, comprising of fourteen (5) single dustfall units, should be installed and the monthly dustfall results used as indicators to track the effectiveness of the applied mitigation measures. Dustfall collection should follow the American Society for Testing and Materials (ASTM) method.

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8 APPENDIX

8.1 Appendix A – Monitoring Methodology

8.1.1 Dustfall Sampling

It is recommended that the dustfall network comprise of single dustfall buckets following the American Society for Testing and Materials (ASTM) standard method for collection and analysis of dustfall (ASTM D1739-98). This method employs a simple device consisting of a cylindrical container (not less than 150 mm in diameter) exposed for one calendar month (30 ± 2 days). Even though the method provides for a dry bucket, de-ionised water can be added to ensure the dust remains trapped in the bucket.

The bucket stand comprises a wind shield at the level of the rim of the bucket to provide an aerodynamic shield. The bucket holder is connected to a 2m galvanized steel pole, which is attached to a galvanized steel base plate. This allows for a variety of placement options for the fallout samplers (Figure 16). Exposed buckets, when returned to the laboratories, are rinsed with deionised water to remove residue from the sides of the bucket, and the bucket contents filtered through a coarse (>1 mm) filter to remove insects and other course organic detritus. The sample is then filtered through a pre-weighed paper filter to remove the insoluble fraction, or dustfall. This residue and filter are dried, and gravimetrically analysed to determine the insoluble fraction (dustfall).

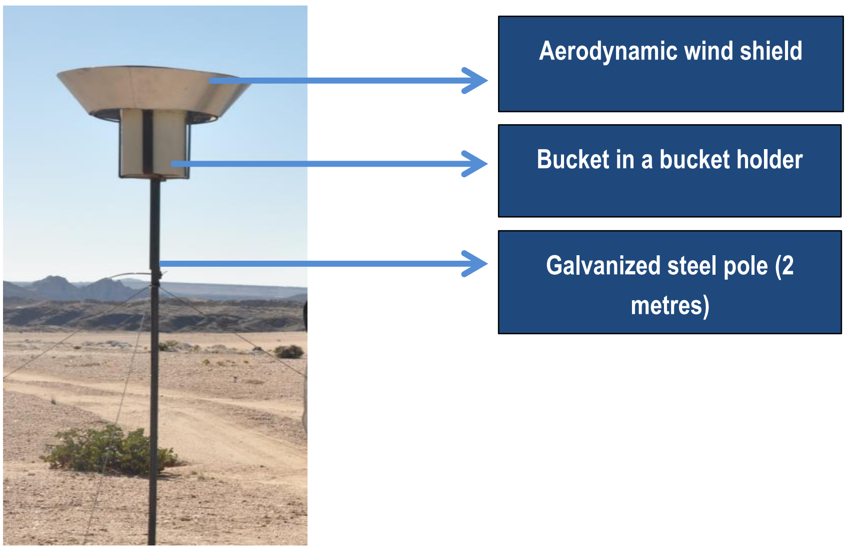

Figure 16: Example of a dustfall bucket

8.2 Appendix B – Source Specific Management and Mitigation Measures

8.2.1 Dust Control Options for Unpaved Roads

Three types of measures may be taken to reduce emissions from unpaved roads:

- Measures aimed at reducing the extent of unpaved roads, e.g. paving;
- Traffic control measures aimed at reducing the entrainment of material by restricting traffic volumes and reducing vehicle speeds; and
- Measures aimed at binding the surface material or enhancing moisture retention, such as wet suppression and chemical stabilization (Cowherd, et al., 1988).

The main dust generating factors on unpaved road surfaces include:

- Vehicle speeds;
- Number of wheels per vehicle;
- Traffic volumes;
- Particle size distribution of the aggregate;
- Compaction of the surface material;
- Surface moisture; and
- Climate

According to research conducted by the Desert Research Institute at the University of Nevada, an increase in vehicle speed of 16 km per hour resulted in an increase in PM_{10} emissions of between 1.5 and 3 times. A similar study conducted by Flocchini (Flocchini, et al., 1994) found a decrease in PM_{10} emissions of 42±35% with a speed reduction from 40 km/hr to 24 km/hr (Stevenson, 2004). An evaluation of control efficiencies resulting from reductions in traffic volumes can be calculated due to the linear relationship between traffic volume, given in terms of vehicle kilometres travelled, and fugitive dust emitted. Similar affects will be achieved by reducing the truck volumes on the roads.

Water sprays on unpaved roads is the most common means of suppressing fugitive dust due to vehicle entrainment, but it is not necessarily the most efficient means (Thompson & Visser, 2000). Thompson and Visser (2000) developed a model to determine the cost and management implications of dust suppression on haul roads using water or other chemical palliatives. The study was undertaken at 10 mine sites in Southern Africa. The model was first developed looking at the re-application frequency of water required for maintaining a specific degree of dust palliation. From this the cost effectiveness of water spray suppression could be determined and compared to other strategies. Factors accounted for in the model included climate, traffic, vehicle speed and the road aggregate material. A number of chemical palliative products, including hygroscopic salts, lignosulponates, petroleum resins, polymer emulsions and tar and bitumen products were assessed to benchmark their performance and identify appropriate management strategies. Cost elements taken into consideration included amongst others capital equipment, operation and maintenance costs, material costs and activity related costs.

The main findings were that water-based spraying is the cheapest dust suppression option over the short term. Over the longer term however, the polymer-emulsion option is marginally cheaper with added benefits such as improved road surfaces during wet weather, reduced erosion and dry skid resistance (Thompson & Visser, 2000). The empirical model, developed by the US EPA (US EPA, 1996), can also be used to estimate the average control efficiency of certain quantifies of water applied to a road. The model takes into account rainfall, evaporation rates and traffic.

Chemical suppressant has been proven to be effective due to the binding of fine particulates in the road surface, hence increasing the density of the surface material. In addition, dust control additives are beneficial in the fact that it also improves the compaction and stability of the road. The effectiveness of a dust palliative includes numerous factors such as the application rate, method of application, moisture content of the surface material during application, palliative concentrations, mineralogy of aggregate and environmental conditions. Thus, for different climates and conditions you need different chemicals, one chemical might not be as effective as another under the same conditions and each product comes with various advantages and limitations of its own. In general, chemical suppressants are given to achieve a PM_{10} control efficiency of 80% when applied regularly on the road surfaces (Stevenson, 2004).

Spillage and track-on from the surrounding unpaved areas may result in the deposition of materials onto the chemically treated or watered road resulting in the need for periodic "housekeeping" activities (Cowherd, et al., 1988). In addition, the gradual abrasion of the chemically treated surface by traffic will result in loose material on the surface which would have to be controlled. The minimum frequency for the reapplication of watering or chemical stabilizers thus depends not only on the control efficiency of the suppressant but also on the degree of spillage and track-on from adjacent areas, and the rate at which the treated surface is abraded.

The best way to avoid dust generating problems from unpaved roads is to properly maintain the surface by grading and shaping to prevent dust generation caused by excessive road surface wear (Stevenson, 2004).

Table 17: Unpaved haul roads: Dust suppression improvement plan

<table>
<tr><th>Criteria</th><th colspan="2">Description</th></tr>
<tr><td colspan="2">Unpaved haul roads</td><td>• In-pit haul roads.
• Haul roads between pits and processing plant
• Haul roads</td></tr>
<tr><td>Operational hours</td><td colspan="2">24 Hours per day, 7 days per week</td></tr>
<tr><td>Accountable person(s)</td><td colspan="2">Environmental Officer;
Mine Production Engineer
Dust Suppression Contractor</td></tr>
<tr><td>Target control</td><td colspan="2">At least 75%</td></tr>
<tr><td>Performance indicators</td><td colspan="2">• Monthly physical inspection of road surface, daily visual observation of entrained dust emissions from unpaved road surfaces.
• Dustfall rates less than 600 $mg.m^{-2}.day^{-1}$ at sensitive receptor locations.
• Dustfall rates less than 1200 $mg.m^{-2}.day^{-1}$ at on-site locations.</td></tr>
<tr><td>Operating procedures</td><td colspan="2">• Water suppression on all haul roads i.e. between the various pits and plants to ensure >75% control efficiency.
• Truck speeds are one of the main parameters affecting entrainment emissions from unpaved roads, truck speeds should be kept as low as possible to minimise fugitive dust emissions. 20km/h is recommended.</td></tr>
<tr><td>Inspections</td><td>• Monthly inspections to ensure effectiveness of chemical stabilisation.</td><td>• This can include daily visual inspections of the site coupled with the dustfall and ambient monitoring data</td></tr>
</table>

8.3 Appendix C – Impact Significance Rating Methodology

The significance of air quality related impacts was assessed using the risk rating matrix provided by ECC (Table 19). Significance definitions are provided below (Table 18). The numbers corresponding to each significance category are calculated by multiplying the sensitivity of the receptor with the significance of the impact.

Table 18: Definitions of significance ratings

7 to 12	**Major**	An impact of major significance is one where an accepted limit or standard may be exceeded, or large magnitude impacts occur to highly valued/sensitive resource/receptors. A goal of the EIA process is to get to a position where the Project does not have any major residual impacts, certainly not ones that would endure into the long term or extend over a large area. However, for some aspects there may be major residual. Impacts are expected to be permanent and non-reversible on a national scale and/or have international significance or result in legislative non-compliance.
4 to 6	**Moderate**	An impact of moderate significance is one within accepted limits and standards. The emphasis for moderate impacts is on demonstrating that the impact has been reduced to a level as low as reasonably practicably. This does not necessarily mean that 'moderate' impacts have to be reduced to 'minor' impacts, but that moderate impacts are being managed effectively and efficiently. Impacts are long-term, but reversible and/or have regional significance.
3 to 4	**Minor**	An impact of minor significance is one where an effect will be experienced, but the impact magnitude is sufficiently small (with and without mitigation) and well within accepted standards, and/or the receptor is of low sensitivity/value. Impacts are considered to be short-term, reversible and/or localised in extent.
1 to 2	**Low**	An impact of low significance (or an insignificant impact) is where a resource or receptor (including people) will not be affected in any way by a particular activity, or the predicted effect is deemed to be 'negligible' or 'imperceptible' or is indistinguishable from natural background variations.

Table 19: EIA significance matrix

				Significance of Impact			
			Significance of Impact	Impacts are considered to be local factors that are unlikely to be critical to decision-making.	Impacts are considered to be important factors but are unlikely to be key decision-making factors. The impact will be experienced, but the impact magnitude is sufficiently small (with and without mitigation) and well within accepted standards, and/or the receptor is of low sensitivity/value. Impacts are considered to be short-term, reversible and/or localised in extent.	Impacts are considered within acceptable limits and standards. Impacts are long-term, but reversible and/or have regional significance. These are generally (but not exclusively) associated with sites and features of national importance and resources/features that are unique and which, if lost, cannot be replaced or relocated.	Impacts are considered to be key factors in the decision-making process that may have an impact of major significance, or large magnitude impacts occur to highly valued/sensitive resource/receptors. Impacts are expected to be permanent and non-reversible on a national scale and/or have international significance or result in legislative non-compliance.
	Biophysical	**Social**		**Low (1)**	**Minor (2)**	**Moderate (3)**	**Major (4)**
Sensitivity	A biophysical receptor that is protected under legislation or international conventions listed as rare threatened or endangered IUCN species. Highly valued/sensitive resource/receptors.	Those affected people/communities will not be able to adapt to changes or continue to maintain pre-impact livelihoods.	**High (3)**	**Minor (3)**	**Moderate (6)**	**Major (9)**	**Major (12)**
	Of value, importance or rarity on a regional scale, and with limited potential for substitution; and/or not protected or listed globally but may be a rare or threatened species in country; with little resilience to ecosystem changes, important to ecosystem functions, or one under threat or population decline.	Able to adapt with some difficulty and maintain preimpact status but only with a degree of support.	**Medium (2)**	**Low (2)**	**Minor (4)**	**Moderate (6)**	**Major (8)**
	Not protected or listed as common/abundant; or not critical to other ecosystems functions	Those affected are able to adapt with relative ease and maintain preimpact status. There is no perceptible change to people's livelihood.	**Low (1)**	**Low (1)**	**Low (2)**	**Minor (3)**	**Moderate (4)**