Air Quality Impact Assessment for the Uis Tin Mine in Namibia

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

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Revision Record

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Draft Rev 0	3 February 2022	Entire report	Submitted for client review
Final Rev 1	6 September 2022	Added Section 5 to the report	Assessed the changes/ additions to the Processing Plant

Abbreviations

ADMS	Atmospheric Dispersion Modelling System
AEB	Atomic Energy Board
AERPA	Atomic Energy and Radiation Protection Act
AfriTin	AfriTin Mining Limited
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
BFD	Block Flow Diagram
CE	Control efficiency
CERC	Cambridge Environmental Research Consultants
CO	Carbon monoxide
CO_2	Carbon dioxide
CPF	Co-placement facility
DFS	Definitive Feasibility Study
DMS	Dense Medium Separation
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
HF	Hydrogen fluoride
H_2SO_4	Sulfuric acid
I&APs	Interested and Affected Parties
IFC	International Finance Corporation
IT3	Interim target 3
ktpa	Kilotonne per annum
Li_2O	Lithium oxide
LMo	Monin Obukhov Length
LoM	Life of Mine
µg/m³	Microgram per cubic metre
mg/m²/day	Milligram per metre squared per day
m/s	Metres per second

MHCP	Materials handling and concentrating plant
Mtpa	Megatonne per annum
MSF	Metallurgical Support Facility
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
Sn	Tin
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 (Airshed) was commissioned by Environmental Compliance Consultancy (ECC) to undertake a specialist air quality impact study for the proposed Phase 1 Fast-Tracked Stage II expansion of the Uis Tin Mine (hereafter referred to as the Project).

Air pollutants will derive from opencast operations at two pit areas (V1 and V2 open pits) and the associated processing operations. Ore and waste will be removed with haul trucks and taken to the Run of Mine (RoM) stockpile area and waste rock dump (WRD)/Co-placement facility (CPF), respectively. Ore will be crushed at a primary crusher whereafter it will undergo secondary crushing, fines crushing and milling at the processing plant. The waste from the processing plant will be hauled to the CPF. Ore production is currently estimated at 567 kilo tonnes per annum (ktpa); this will increase to 850 ktpa to support the expanded materials handling and concentrating plant (MHCP) capacity.

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 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 Uis;
    d. The characterisation of existing ambient air quality at and around Uis based on available ambient monitoring/modelling data (if available); and
    e. Analysis of dustfall monitoring data collected by Uis Tin Mine.
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.
    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

The Uis Project is located near the town of Uis, approximately 164 km north of Swakopmund and 30 km northwest of the Brandberg mountain, Namibia's highest mountain (2 559 m above sea level). The closest residential developments to the Project consist of Uis (~1.9 km to the northwest), Uis Mining Village (~1.7 km to the east) and Tatamutsi (~3.4 km to the east). Individual farmsteads also surround the Project area.

On-site meteorological data was not available. Use was made of Weather Research and Forecasting Model (WRF) simulated meteorological data for the period 2018 – 2020 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 an increase in winds from the south-southwest and south during the night. Day- and night-time average wind speeds are 4.6 m/s and 5.0 m/s respectively. Calm conditions occur 3.0% of time during the day and 2.5% during the night. On average, air quality impacts are expected to be slightly more notable to the north and north-east of the Project.
- The predominant south-south-westerly, southerly and north-north-easterly winds in the study region may be explained by the topography of the study area. Uis is ~800 m above sea level with the highest point at 900 m above sea level. The terrain is fairly flat in the immediate vicinity of the plant site, with steeper and higher relief areas confined to the northeast and south. The highest wind speeds (more than 6 m/s) were recorded during summer and springtime and are mostly from the south-southwest and southwest.
- Maximum, minimum, and mean temperatures were given as 39.9°C, 1.2°C and 22.5°C respectively from the WRF data for the period Jan 2018 to Dec 2020.
- Average annual rainfall at Uis town for the period 2009 to 2021 was given as 656 mm, with most rain recorded during the summer (December to March) and least during the winter months from May to September.
- 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, windblown dust, mining and exploration activities.
- Sources of atmospheric emissions in the vicinity of the Project include small-stock farming, small-scale mining, activities of the Namclay Brick and Pavers factory, 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 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 is considered very low, especially in a low-density population area such as the one where the Uis mine is located.
- 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 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 Uis area.
- Dustfall monitoring data was provided for the period March 2019 to August 2021. The monitoring network comprised of eight (8) single dustfall units between March 2019 and November 2020 but has been expanded to fourteen (14) single dustfall units from December 2020 forward. Dustfall rates were generally low for the sampling period and well within the dustfall limit of 600 mg/m²/day (adopted limit for residential areas) and 1 200 mg/m²/day (adopted limit for non-residential areas), with the exception of AQ 01 (5 exceedances in 2020 and 4 exceedances in 2021), AQ 05 (2 exceedances in 2019, 5 exceedances in 2020 and 1 exceedance in 2021), AQ 08 (1 exceedance in 2019) and AQ 14 (1 exceedance in 2020).

Impact Assessment

Emissions due to the construction of the secondary crushing and screening plant as well as the Dense Medium Separation (DMS) feed stockpile were quantified using area-wide emission factors for general construction activities. A quantitative air quality impact assessment was conducted for the operational phase activities of the Uis 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.

Construction Phase

- The construction phase during Stage II was designed to allow pre-assembly while the plant is in operation. Construction work include civil works, in-plant erection, piping, erection of conveyors and gantries, conveyor mechanical installation, and electrical, control and instrumentation work. The largest construction works (in terms of land area) are the construction of a new secondary crushing and screening plant and a DMS feed stockpile. The total land area was determined from georeferenced site plans as approximately 1 320 m^2.
- Using US-EPA emissions factors for general construction activities, and assuming that the quantity of dust emissions is proportional to the area of land being worked and the level of construction activity, construction emissions were estimated at 355 kg for TSP, 138 kg for PM_{10} and 69 kg for $PM_{2.5}$.
- Due to the intermittent nature of construction operations, construction 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.

Operational Phase

- Two mining scenarios were assessed to determine the increase in impacts due to the Project, namely a Baseline scenario and Project Scenario. It was assumed that Stage I throughputs as provided in the Definitive Feasibility Study (DFS) summary represent the Baseline scenario (current mining rates) and that Stage II throughputs represent the Project scenario (future mining rates required to support the expanded MHCP). V1 and V2 opencast areas were assumed to be mined concurrently in a 57:43 tonnage split.
- Emissions quantified for the Uis Project were restricted to fugitive releases (non-point releases) with particulates the main pollutant of concern. Emissions were quantified based on provided information on mining rates and mine layout plan.
  - Quantified PM_{10} and $PM_{2.5}$ emissions were similar for unmitigated Baseline and Project operations. TSP emissions were higher for the unmitigated Project Scenario. Quantified PM_{10}, $PM_{2.5}$ and TSP emissions were higher for design mitigated Project operations than its counterpart Baseline operations, apart from crushing activities (due to the high control efficiency of the dual scrubber on the primary and secondary crushers for the Project Scenario).
  - The main sources of controlled $PM_{2.5}$, PM_{10} and TSP emissions due to the Project scenario are, in order of importance: i) in-pit operations (including in-pit haul roads, materials handling and drilling), ii) vehicle entrainment from unpaved surface roads, iii) wind erosion from the WRD, CPF and ROM stockpiles, iv) crushing and screening (primary; secondary, tertiary and fines) operations, v) materials handling and vi) blasting, with blasting a lesser source due to its intermittent nature and variable duration.

- For each of the two scenarios, unmitigated and mitigated options were modelled. Mitigation was applied based on design mitigation measures provided, which included the following:
  - in-pit haul roads: water sprays assuming 50% control efficiency (CE);
  - surface haul roads: water sprays assuming 75% CE;
  - crushing and screening of ROM (primary and secondary): assuming 99% CE for dual scrubber;
  - crushing and screening of ROM (tertiary and fines): assuming >75% CE for wet processes; and
  - materials handling, including conveyor transfer: assuming 50% CE for water sprays.
- Dispersion modelling results for the Baseline Scenario:
  - PM_{10} daily GLCs, for unmitigated activities, result in exceedances of the 24-hour air quality objective (AQO) over a maximum distance of ~700 m from Uis mining activities, but with no exceedances at any of the AQSRs. For mitigated activities, impacts are limited to the Uis mining and processing plant areas with no exceedances at any of the AQSRs. PM_{10} annual GLCs, for both unmitigated and mitigated activities, are within the AQO at 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 ~300 m off-site. For mitigated activities, there are no exceedances at any of the AQSRs and impacts are limited to on-site areas. There are no exceedances of the annual $PM_{2.5}$ AQO, without and with mitigation in place.
  - Maximum daily dustfall rates, for both unmitigated and mitigated activities, do not exceed the AQO (SA NDCR residential limit of 600 mg/m²/day) at any of the AQSRs.
- Dispersion modelling results for the Project Scenario:
  - The daily PM_{10} AQO (WHO IT-3 and SA NAAQS) is exceeded over a maximum distance of 950 m from the Uis mining area (with no mitigation in place) but reduce to smaller areas of exceedance on-site when mitigation is applied. PM_{10} daily GLCs, for unmitigated and mitigated activities, do not result in any exceedances of the 24-hour AQO at the AQSRs. Over an annual average there are no exceedances at any of the AQSRs, without and with mitigation.
  - For daily $PM_{2.5}$ the area of maximum unmitigated GLCs exceedance extends northwest from the Uis mining operations over a maximum distance of ~750 m, with no exceedances at any of the AQSRs. With mitigation in place there are no exceedances at any of the AQSRs and the impact is reduced to much smaller areas of exceedance. Annual average $PM_{2.5}$ GLCs are low at all AQSRs.
  - Maximum daily dustfall rates, for both unmitigated and mitigated activities, are within the AQO (SA NDCR residential limit of 600 mg/m²/day) at all of the AQSRs.
- For both the Uis Baseline and Project 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 Uis modelling results indicate the potential for low regional cumulative impacts, resulting in **minor** significance.

Subsequent to the initial impact assessment (referred to as the Project), additional changes will be made to the processing operations including a bulk sampling and ore sorting and testing facility (referred to as the Petalite Beneficiation Plant) to extract the lithium-bearing ore.

- Two operational scenarios were assessed, namely the incremental and cumulative Petalite Beneficiation Plant scenarios, each with an unmitigated and mitigated sub-scenario.
- Emissions for the Petalite Beneficiation Plant were quantified based on provided information on processing rates and plant layout.

- Drying and Classifying is the main source of PM_{10} and $PM_{2.5}$ emissions from this process, followed by unpaved roads for PM_{10} and crushing and screening for $PM_{2.5}$. The main source of TSP emissions is crushing and screening, followed by unpaved roads.

- Dispersion modelling results for the incremental Petalite Beneficiation Plant
  - Simulated values for PM_{10}, $PM_{2.5}$ and maximum daily dustfall rates at AQSRs are negligibly small.
  - PM_{10} and $PM_{2.5}$ daily GLCs, for unmitigated activities, result in exceedances of the 24-hour air quality objective (AQO) over a maximum distance of ~90 m from on-site activities.
  - The footprint of exceedance of maximum daily dustfall rates exceed the AQO within 125 m from the facility's activities.
- Cumulative air quality impacts (the Project and the Petalite Beneficiation Plant)
  - The cumulative plots including the Petalite Beneficiation Plant are not significantly different from those for the Project Scenario. The numerical results simulated at the AQSRs are also not significantly different from those simulated for the Project only. It may therefore be concluded that the conclusions from this report would not change as a result of the Petalite Beneficiation Plant.

Conclusion

The proposed Uis 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 mining activities. With mitigation in place, the resulting impacts can be limited to on-site areas. Dustfall rates are likely to be low throughout the life of mine.

It is the specialist's opinion that the proposed project could be authorised provided strict enforcement of mitigation measures and the tracking of the effectiveness of these measures to ensure the lowest possible off-site impacts.

Recommendations

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:

- 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:
  - Control of vehicle entrained dust with a CE of 75% on unpaved surface roads through water suppression, and water sprays on the in-pit haul roads, to ensure a 50% CE.
  - In controlling dust from crushing and screening operations, it is understood that the primary and secondary crushers will achieve 99% CE by using a dual scrubber, whereas plants that use wet suppression systems and use spray nozzles can effectively control PM emissions due to tertiary/fines crushing and screening (achieving upwards of 75% CE).
  - Mitigation of materials transfer points should be done using water sprays at all tip points. This should result in a 50% control efficiency. Regular clean-up at loading points is recommended to avoid re-entrainment.

- Minimising windblown dust from the CPF and WRDs can be done through through vegetation on the CPF side walls and keeping the dried-out areas at the CPF wet, and vegetation cover on the side walls of the WRDs.
- Controlling dust from Drying and Classifying can be done using fabric filters. This should result in 90% CE.

- Air Quality Monitoring:
  - The current dustfall monitoring network, comprising of fourteen (14) single dustfall units, should be maintained 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

AfriTin Mining Limited ("AfriTin") is the owner of the Uis Tin Project[1] in Namibia. The Uis Tin Mine infrastructure development commenced in 2018 and is located near the town of Uis, approximately 164 km north of Swakopmund (Figure 1). AfriTin received a mandate to develop the Uis Tin Project in Namibia through two phases (AfriTin Mining, 2021):

- Phase 1: Development of a pilot mining and processing facility, exploration drilling, and the completion of a bankable feasibility study for the final mine configuration.
- Phase 2: Construction of the final mine configuration to mine and process 3.1 Mega tonnes per annum (Mtpa) ore to produce 5 kilo tonnes per annum (ktpa) of saleable tin concentrate.

Phase 1 is to be implemented across four stages (AfriTin Mining, 2021):

- Stage I: Achieve steady-state production. The commissioning of the Phase 1 processing plant commenced in August 2019. Plant throughput has increased steadily month-on-month, although current production remains below the design capacity. Debottlenecking of the plant, combined with various other initiatives to improve availability and utilisation, support the ramp-up to the original steady-state production targets.
- Stage II: Increase production capacity and recovery by:
    - increasing throughput capacity by 50% from 80 tph to 120 tph, which can be achieved by modular expansion of individual circuits;
    - improving overall recovery of tin (Sn) from 60% to 70% by adding comminution and beneficiation capacity for tailings streams in the concentrator, which are currently discarded; and
    - improving overall recovery of tantalum (Ta) from 15% to 30% by optimising liberation between the tin and tantalum bearing minerals and improved magnetic separation efficiency.
- Stage III: Introduce second by-product by adding a circuit to produce a petalite concentrate at 4% Li_2O to sell into the glass and ceramics market.
- Stage IV: Further expand tin and tantalum concentrate production by increasing average concentrator plant feed tin grade from 0.139% to 0.158% through implementation of an automated ore-sorting circuit after the first two crushing stages to reject barren pegmatite before the final stages of comminution and then concentration.

Airshed Planning Professionals (Pty) Ltd (Airshed) was commissioned by Environmental Compliance Consultancy (ECC) to undertake a specialist air quality impact study for the proposed Phase 1 Fast-Tracked Stage II expansion of the Uis Tin Mine (hereafter referred to as the Project).

The Phase 1 Fast-Tracked Stage II expansion includes the following changes to the process flow in various sections of the plant:

- A secondary crusher and screen are added between the primary jaw crusher and the fines crushing section.
- A stockpile is added as a buffer between the crushing and concentrating sections.
- Water rejection capacity is increased in the Dense Medium Separation (DMS) 1 section.
- The medium circuits for DMS 2 and DMS 3 are combined to improve operability of DMS 3 and maximise tin recovery from DMS 2 floats after further liberation.
- The DMS 2 floats re-crush circuit is converted to a closed circuit by adding a classification screen in the circuit. In addition, feed is added before the roll crushers to improve operability.
- Additional spirals to re-process middlings are installed in the spiral plant.

[1] The Uis tin mine is a historical mine that was owned and operated by Imkor Tin, a subsidiary of Iscor South Africa. Mining commenced in 1958, and the operation was closed in 1991 (Maritz and Uludag, 2019).

- The product handling infrastructure is relocated, and an additional shaking table is installed to improve capacity. The existing Wilfley shaking tables are replaced with Holman tables for higher separation efficiency.

The Phase 1 Fast-Tracked Stage II expansion also includes a mining plan to deliver 0.85 Mtpa ore at average grade of 0.138% tin (Sn) to the upgraded materials handling and concentrating plant (MHCP), to produce 1 200 tpa of saleable tin concentrate for export. This is an increase in mining rate when compared to Phase 1 Stage I, where approximately 567 ktpa of pegmatite ore was delivered to the processing plant, to produce 788 tpa of saleable tin concentrate for export.

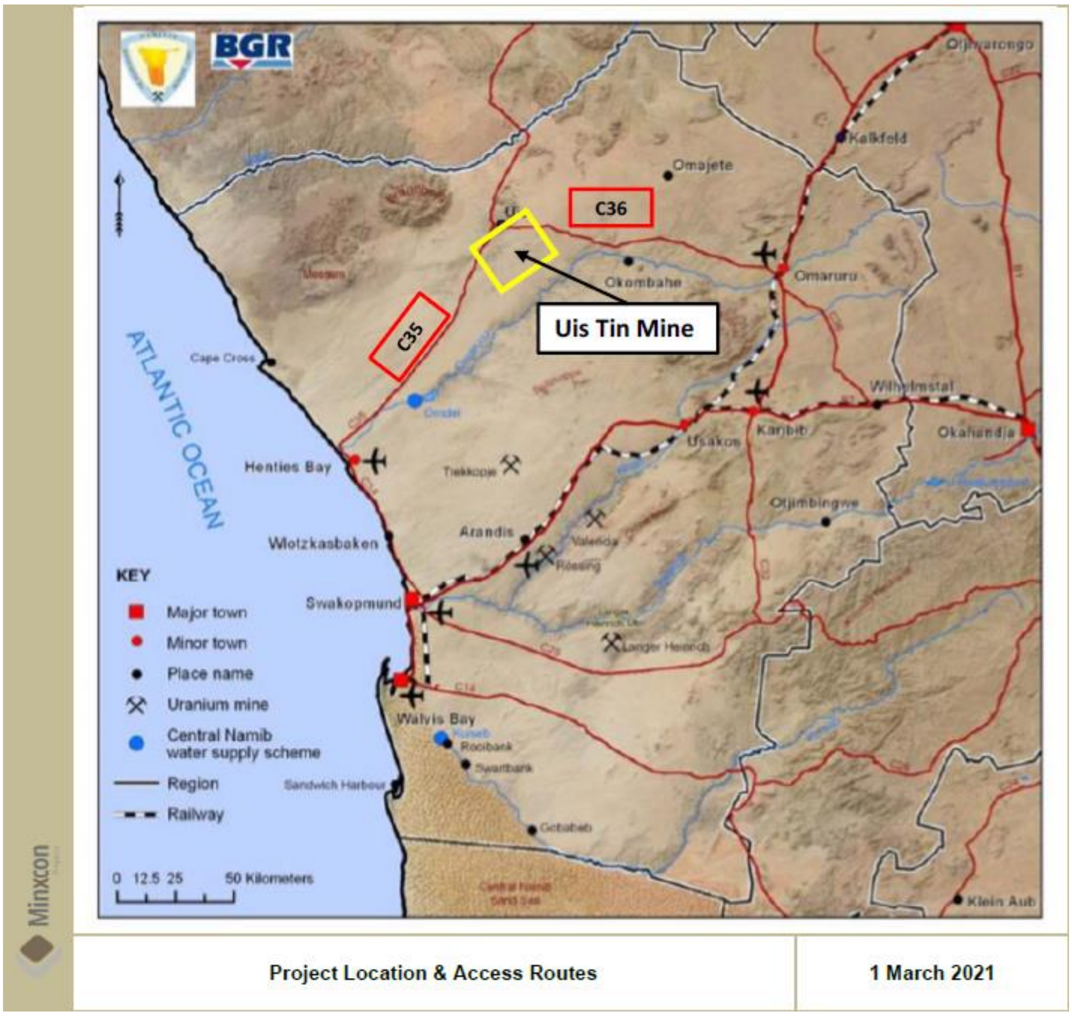

Figure 1: Regional location of the Uis Tin Mine Project

Subsequent to the above-mentioned changes to the mining and processing operations at Uis Tin Project, additional changes have to be made to the processing operations. Lithium and tantalum will be extracted in addition to tin, with a bulk sampling and ore sorting and testing facility to be constructed to extract the lithium-bearing ore. This will then be fed to a petalite beneficiation plant where the lithium will be extracted and processed. The waste from these two processes will be captured and handled in what they term a waste neutralisation facility. The DMS and flotation circuit will use hydrofluoric acid and sulphuric acid. Although the mining fleet will not change, there will be additional external traffic for the bulk sampling and testing campaigns.

1.1 Study Objective

The main objective of the investigation was to quantify the potential impacts resulting from the proposed 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 initial 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 Uis;
    d. The characterisation of existing ambient air quality at and around Uis based on available ambient monitoring/modelling data (if available); and
    e. Analysis of dustfall monitoring data collected by Uis Tin Mine.
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.
    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.

As part of the amendment to account for the bulk sampling and ore sorting and testing facility, the additional SoW include the following:

1. Quantify emissions associated with the bulk sampling and ore sorting and testing facility;
2. Rerun the dispersion model for the future scenario account for the updated proposed impacts form the mine and processing facility;
3. Assess potential for impacts from the mine and processing facility;
4. Provide recommendations and abatement options; and
5. Update the AQIA report to include the additional operations at the processing facility.

1.3 Project Description

The Project has a Life of Mine (LoM) of 18 years mining and 20 years processing to produce on average 1 200 tpa tin concentrate at a concentrate grade of 60%.

The activities that form part of normal operations at the Uis Tin Mine are:

- Opencast mining using the conventional truck and shovel mining method (including drilling and blasting of overburden and ore);
- Loading and hauling of waste from V2 open pit and V1 open pit to the designated waste rock dump and co-placement facility (CPF) respectively;
- Loading and hauling of ore to ROM stockpile at processing plant;

- Primary and secondary crushing and screening;
- Materials handling at crushed ore stockpile and DMS feed stockpile;
- Tertiary crushing and screening;
- Fines crushing and screening;
- Wet process:
  - DMS 1 circuit, followed by DMS 2 & 3;
  - Middlings and sinks re-crush;
  - Spiral plant;
  - Concentrate cleaning;
  - Water recovery and discard handling;
- Loading and hauling of discard to CPF;
- Bagging of concentrate into 1 tonne bulk bags; and
- Loading 26 dry metric tonne (DMT) batches onto flatbed truck for transport to Walvis Bay.

Air pollution associated with Project activities include air emissions emitted during the construction- and operational phases.

1.3.1 Description of Activities from an Air Quality Perspective

The construction phase during Stage II is designed to allow pre-assembly while the plant is in operation. 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 of Stage II are listed in Table 1.

Table 1: 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 (sulfur dioxide [SO_2]; oxides of nitrogen [NOx]; carbon monoxide [CO]; carbon dioxide [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).

Opencast mining and beneficiation plant activities most likely to result in air pollution during the operational phase are listed in Table 2. Activities associated with the additional bulk sampling and ore sorting and testing facility are also included in Table 2.

Table 2: Operational activities resulting in air pollution

Activity	Associated pollutants
Operational Phase	
Open pit mining: drilling and blasting	PM, SO_2; NOx; CO; CO_2
Open pit: excavation of ore and waste	mostly PM, gaseous emissions from mining equipment (PM, SO_2; NOx; CO; CO_2)
Haulage of materials (ore, waste and discard)	PM from road surfaces and windblown dust from trucks, gaseous emissions from truck exhaust (PM, SO_2; NOx; CO; CO_2)
Co-placement facility (discard and waste)	PM from tipping, windblown dust, gaseous emissions from vehicle exhaust (PM, SO_2; NOx; CO; CO_2)
ROM and crushed ore stockpiles (ore)	PM from tipping and windblown dust
Conveyor transfers	PM from tipping and windblown dust
Processing of ore (crushing, screening, milling.)	mostly PM, gaseous emissions from machinery (PM, SO_2; NOx; CO; CO_2)
Transportation of product	PM from road surfaces, gaseous emissions from truck exhaust (PM, SO_2; NOx; CO; CO_2)
Possible explosives magazine	gaseous emissions from open burning (PM, SO_2; NOx; CO; CO_2)
Bulk sampling and ore sorting and testing facility	PM from road surfaces due to haul trucks, tipping, crushing, drying and classification, storage of product and windblown dust

1.4 Approach and Methodology

The air quality study includes the assessment of both Baseline and proposed Project operations. 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:

- Uis Tin Mine, Phase 1 Fast-Tracked Stage II Definitive Feasibility Study (AfriTin Mining, 2021).
- Air EnviroTech Dynamic Scrubber.pdf.
- Nexus-Ino Plant List & Power.
- AQ- MASTER ANALYSIS_20201019 new.xlsx.

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 Uis Mining 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 2018 – 31 December 2020, to (a) describe the dispersion potential of the site and (b) as input into the ADMS 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 a Baseline scenario (based on Stage I throughputs) and a Project scenario (based on Stage II throughputs).

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. As per the National Code of Practice for Air Dispersion Modelling use was made of the internationally recognised ADMS 5 model (Atmospheric Dispersion Modelling System version 5.0.0) developed by the Cambridge Environmental Research Consultants (CERC) for the simulation of ambient air pollutant concentrations and dustfall rates.

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 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 WHO interim targets and 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 ESIA Amendment

The ESIA for the Uis Tin Mine is to be amended to include material changes they intend on adding to their existing operations. A bulk sampling and ore sorting and testing facility will be constructed to extract the lithium-bearing ore. This will then be fed to a petalite beneficiation plant where the lithium will be extracted and processed. The waste from these two processes will be captured and handled in what the mine terms a waste neutralisation facility.

The neutralised discard will undergo a kinetic leach testing campaign before disposal. This will determine the success of the neutralisation process. Until results are obtained from the leach testing campaign, the filter cake discard material will be stored in either a concreted bunded area or directly deposited into Rent-A-Drum skips which will be disposed of at the Walvis Bay Hazardous Waste Disposal Facility. Once the results from the leach testing campaign is received, the mine will then plan waste disposal accordingly.

The reagents that will be used in the wet section of the plant (DMS and flotation circuit) are hydrofluoric acid and sulphuric acid in 5 tonnes and 3 tonnes respectively each per month per the 2000 tonnes sampling campaign. The engineering design for this plant is underway and schematics of its design will be included in the ESIA report with an assessment of the potential impacts associated with such a facility.

1.5.1 Determining the Impact of the Project on the Receiving Environment

An emission inventory was set up for the ESIA Amendment based on the information that was received, which included:

2108600 Afritin Uis Platforms Layout_Rev0_2022-08-08.dwg
Petalite Plant_Hazardous discard calc.xlsx
Project descriptions via email.

To determine the significance of air pollution impacts from the Project, emissions were estimated for an incremental Project scenario (based on approximate throughputs for the proposed petalite beneficiation plant) and a cumulative Project scenario (taking into account the ESIA Amendment operations and Project operations as described in Section 1.3).

The impact of proposed operations on the atmospheric environment was determined through the simulation of ambient pollutant concentrations using the ADMS model. An assessment was made whether cumulative Project impacts differ significantly from Project impacts (assessed in Section 1.4.4).

1.6 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 2018 – December 2020 was used.
- Emissions (mining):
    - The quantification of sources of emission was restricted to the Uis Tin Mine activities only. Although other background sources were identified, such sources were not quantified and modelled.
    - Information required for the calculation of emissions from fugitive dust sources for the mining 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. Total operating hours per annum were provided for different sections of the plant. For ease of modelling and to present a worst-case scenario, however, it was assumed that the plant operated continuously. Blasting was assumed to occur 2 times a week for waste and once a week for ore.
    - Vehicle exhaust emissions were not quantified as the impacts from these sources are localized and unlikely to exceed health screening limits offsite.
    - Particle size distribution for waste, ROM and co-disposal material was based on information from similar mining processes.
    - It was assumed that Stage I throughputs as provided in the DFS summary represent the Baseline scenario (current mining rates) and that Stage II throughputs represent the Project scenario (future mining rates).
    - It was assumed that the flow of materials stays the same proportionally for the Baseline and Project scenarios, apart from the additional (i) crushing and screening stage to enable increased throughput and (ii) buffer stockpile between the crushing and beneficiation sections, for the Project scenario.
    - In the absence of detailed construction plans, emissions were quantified using an area-wide emission factor (for approximate areas earmarked for construction).
- Emissions (ESIA amendment):
    - The quantification of sources of emission was restricted to activities for which data and georeferenced locations were available.
    - Working hours were advised as daytime for crushing activities and continuously for DMS operation.
    - No construction data was available, and construction emissions were therefore not estimated.
- Impact assessment:
    - Impacts due to the construction phase of the Project were assessed qualitatively due to the temporary nature of these operations, whilst the operational phase was assessed quantitatively.

1.7 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. An assessment of the incremental and cumulative impacts due to the proposed testing facility is provided in Section 5. Recommendations of air quality management measures, including mitigation and monitoring are provided in Section 6.

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 World Health Organization (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 ozone (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[2]. 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

[2] 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[3] 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 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 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)

[3] *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.

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 in excess of the WHO AQGs themselves, to promote steady progress towards meeting the WHO AQGs (WHO, 2005). There are two or three interim targets depending on the pollutant, starting at WHO interim target-1 (IT-1) as the most lenient and IT-2 or IT-3 as more stringent targets before reaching the AQGs. The SA NAAQS are, for instance, in line with IT-1 for SO_2 and IT-3 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, lead (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 24-hour 1-hour 10-minute	- 125 (IT1) 50 (IT2) (a) 40 (guideline) - 500 (guideline)	50 125 (b) 350 (c) 500 (d)
Nitrogen Dioxide (NO_2)	1-year 24-hour 1-hour	40 (IT1) 30 (IT2) 20 (IT3) 10 (guideline) 120 (IT1) 50 (IT2) 25 (guideline) 200 (guideline)	40 200 (c)
Particulate Matter (PM_{10})	1-year 24-hour	70 (IT1) 50 (IT2) 30 (IT3) 20 (IT4) 15 (guideline) 150 (IT1) 100 (IT2) 75 (IT3) 50 (IT4) 45 (guideline)	40 (e) 75 (e) (b)
Particulate Matter ($PM_{2.5}$)	1-year	35 (IT1) 25 (IT2) 15 (IT3)	25 (f) 20 (g) 15 (h)

Pollutant	Averaging Period	WHO Guideline Value (µg/m³)	South Africa NAAQS (µg/m³)
		10 (IT4) 5 (guideline)	
	24-hour	75 (IT1) 50 (IT2) 37.5 (IT3) 25 (IT4) 15 (guideline)	65 (f) 40 (g) 25 (h)

Notes:

(a) Intermediate goal based on controlling motor vehicle emissions, industrial emissions and/or emissions from power production. This would be a reasonable and feasible goal to be achieved within a few years for some developing countries and lead to significant health improvement.
(b) 4 permissible frequencies of exceedance per year
(c) 88 permissible frequencies of exceedance per year
(d) 526 permissible frequencies of exceedance per year
(e) Applicable from 1 January 2015
(f) 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). 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/m²-day)	Comment
1	RESIDENTIAL	D < 600	Permissible for residential and light commercial
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 Uis Tin Mine 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 World Health Organisation (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)
	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

The Uis Tin Mining Project is located near the settlement of Uis, which is situated in Damaraland (viz. the rural areas of the Erongo region, Namibia). The small Uis mining village which was developed to support the historical mine lies adjacent to the northeast of the Project. Access to the Project is obtained via an established road network that connects the Project to larger towns and cities with modern infrastructure. The two main access routes to the Project are via the C36 from the town of Omaruru and the C35 from the town of Henties Bay.

The Uis mining area and plant layout, as well as air quality sensitive receptors are shown in Figure 2. The receptor locations were identified from Google Earth and Google Maps satellite imagery. Uis town and Uis mining village lie ~1.9 km northwest and 1.7 km northeast of the mining area respectively, with the informal settlement Tatamutsi situated ~3.4 km northeast.

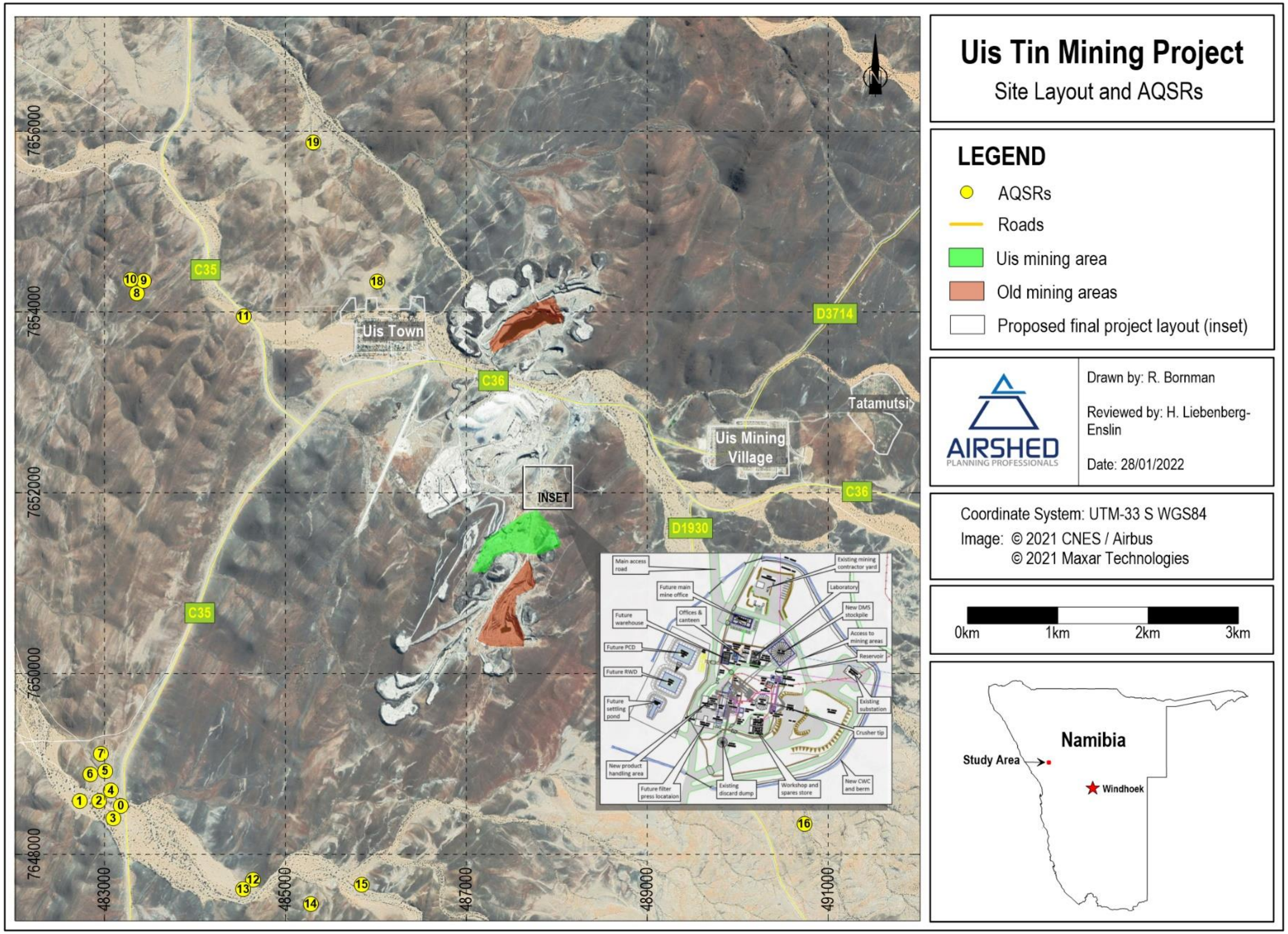


Figure 2: Site layout and air quality sensitive receptors (AQSRs)

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 Uis study area for the period 1 January 2018 to 31 December 2020. 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 an increase in winds from the south-southwest and south during the night. Day- and night-time average wind speeds are 4.6 m/s and 5.0 m/s respectively. Calm conditions occur 3.0% of time during the day and 2.5% during the night. On average, air quality impacts are expected to be slightly more notable to the north and 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 south-southwest and southwest (Figure 4).

The predominant south-south-westerly, southerly and north-north-easterly winds in the study region may be explained by the topography of the study area. Uis is located approximately 30 km northwest of the Brandberg mountain, Namibia's highest mountain (2 559 m above sea level). Uis is ~800 m above sea level with the highest point at 900 m above sea level, as can be seen in Figure 5. The immediate mine surroundings are relatively flat, with steeper and higher relief areas confined to the northeast and south.

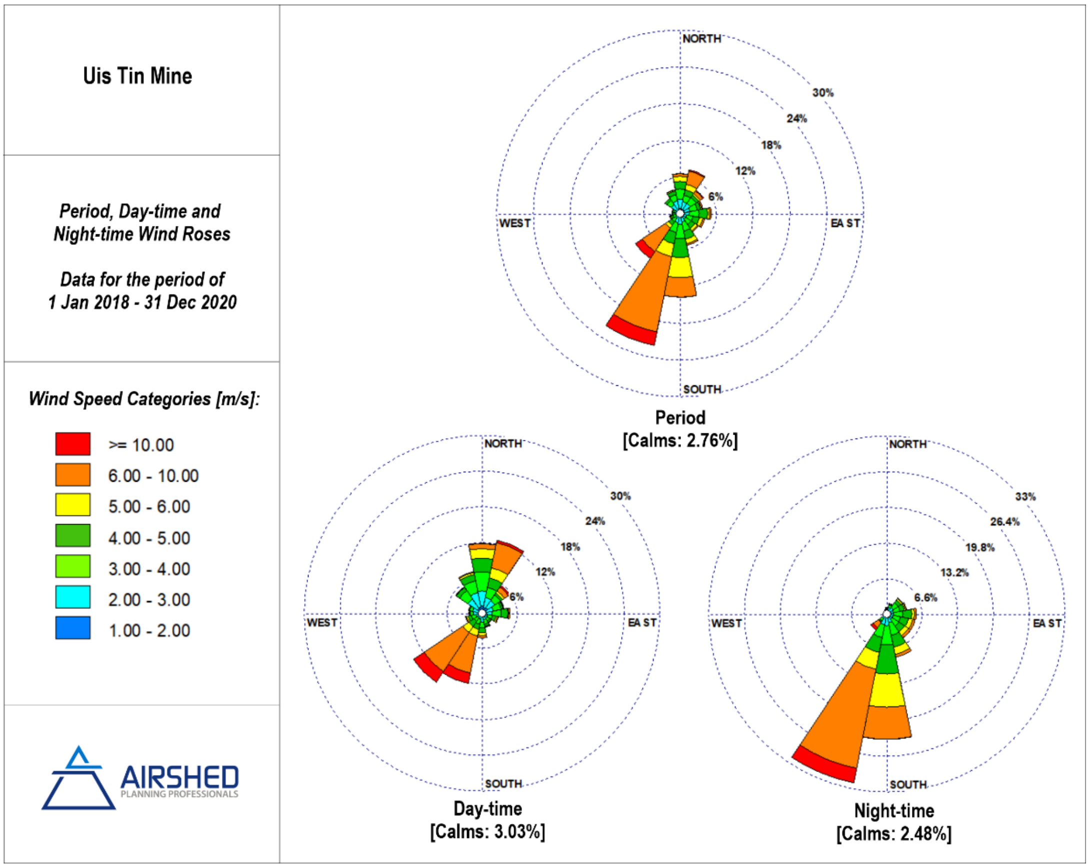


Figure 3: Period, day- and night-time wind roses based on modelled WRF data for Uis Mine (Jan 2018 – Dec 2020)

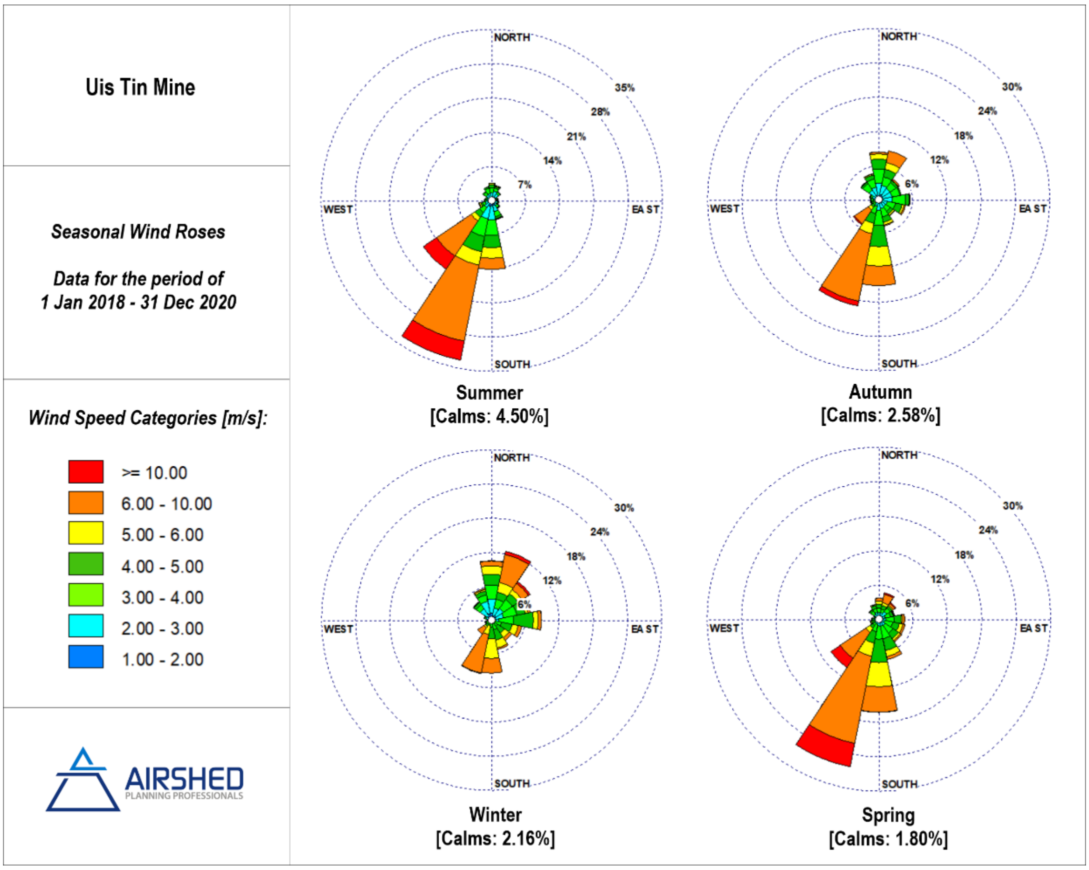


Figure 4: Seasonal wind roses based on modelled MM5 data for Uis Mine (Jan 2018 – Dec 2020)

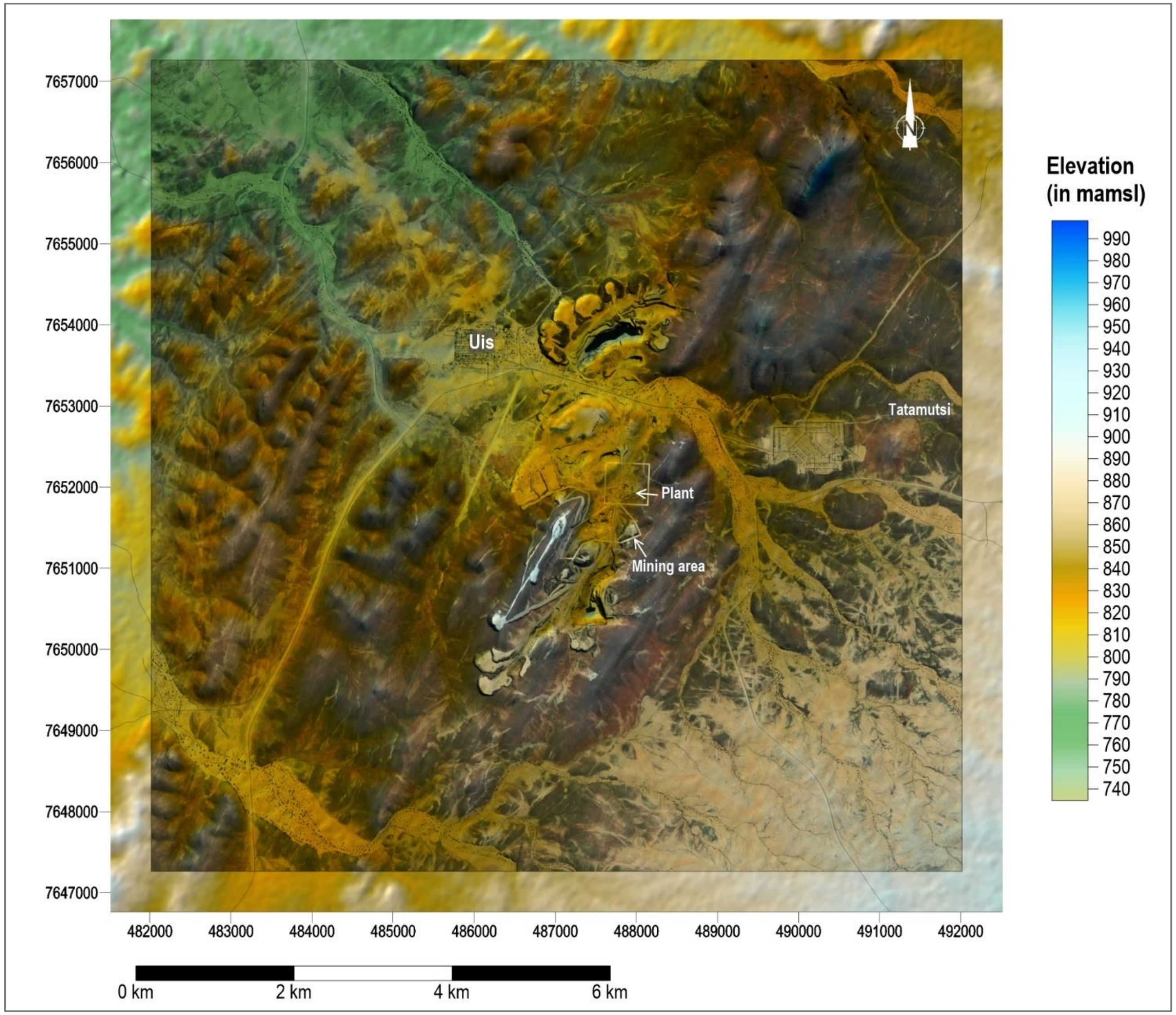


Figure 5: Topography of the study region

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 39.9°C, 1.2°C and 22.5°C respectively, based on modelled WRF data for the period 2018-2020. Maximum temperatures range from 39.9°C in November to 32.6°C in June, with minima ranging from 14.6°C in April to 1.2°C in August (Figure 6).

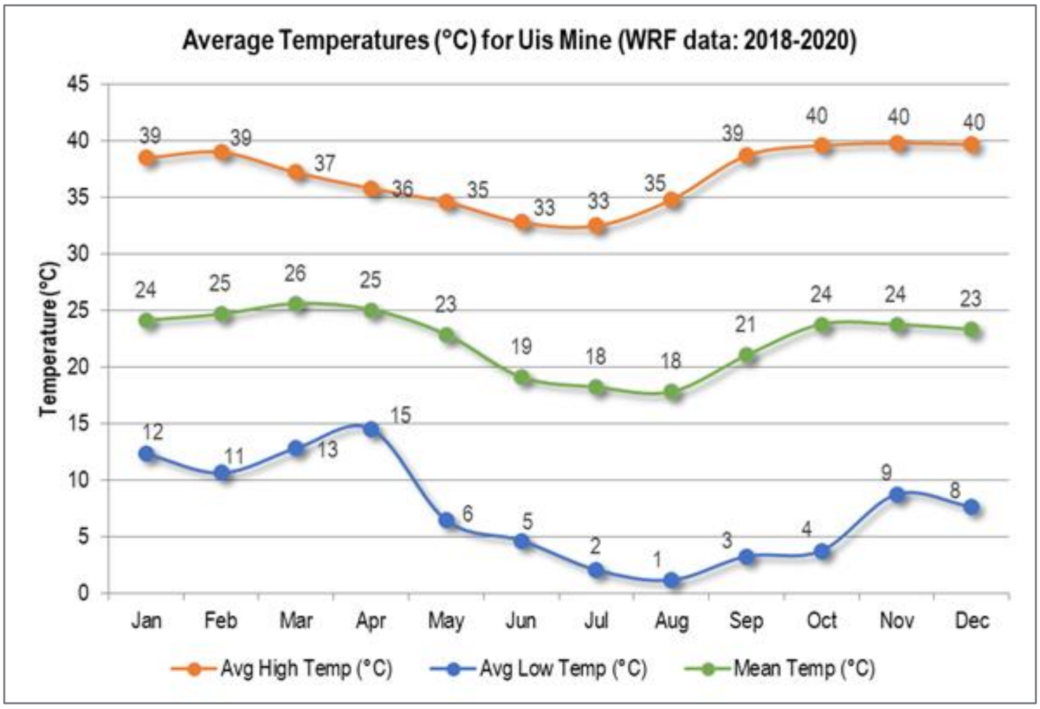


Figure 6: Average temperatures for Uis Mine (WRF data, 2018 – 2020)

Diurnal temperature trends are presented in Figure 7. 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. The average day-time temperature is given as 26.3°C, whereas the average night-time temperature is given as 18.6°C.

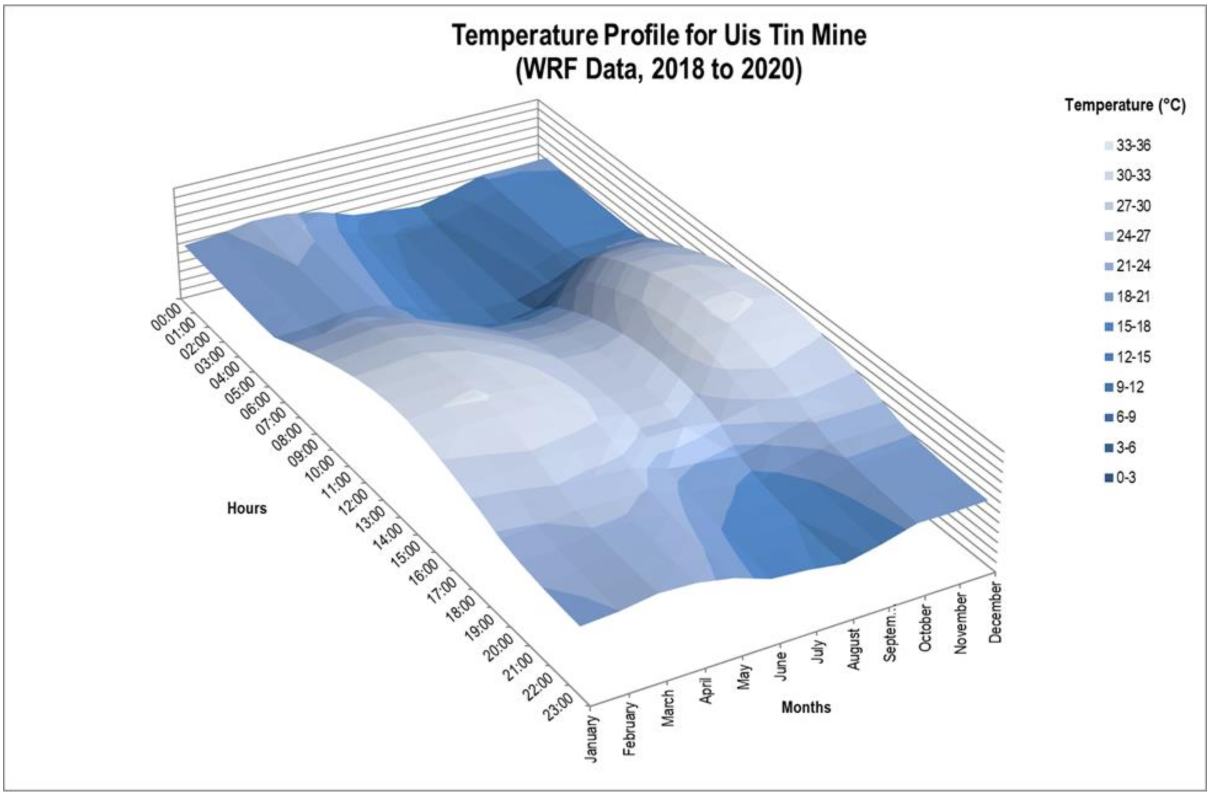


Figure 7: Diurnal temperature profile for Uis Mine (WRF data, 2018 – 2020)

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 8.

On average, the area receives approximately 656 mm of rain per year, with 86 rainy days per year. There is a rainy season from December through March and a dry season from May to September, with February being the wettest month and July the driest.

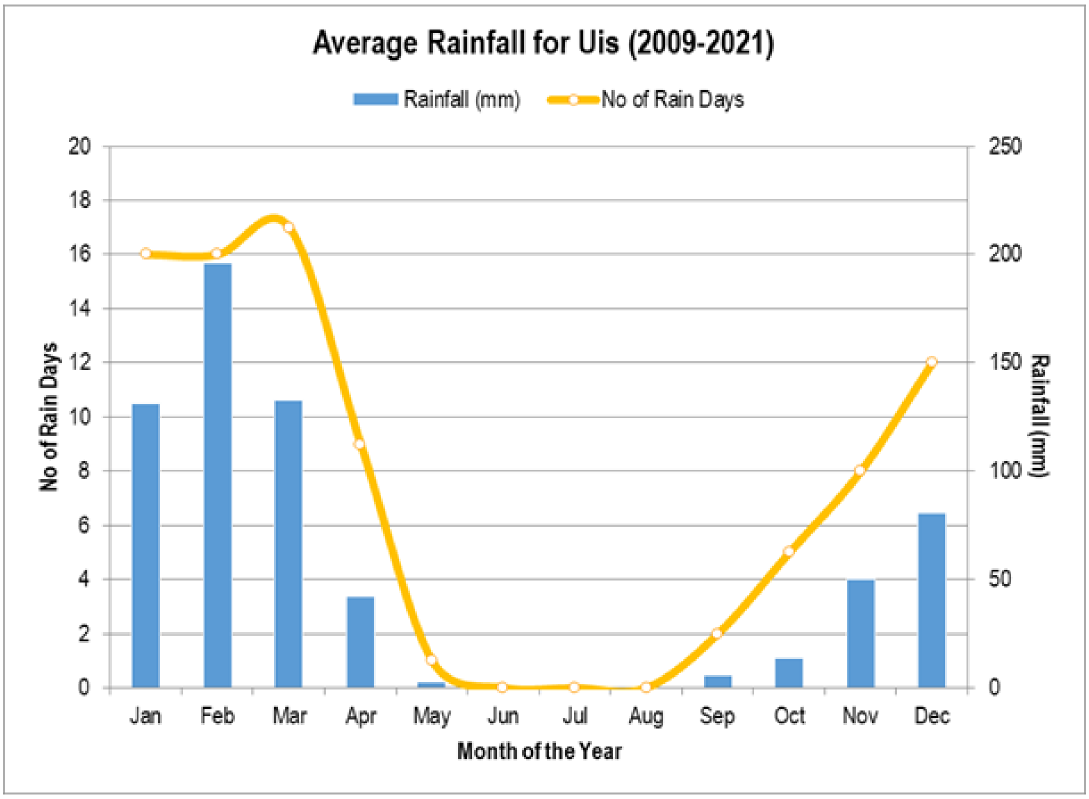


Figure 8: Long-term average rainfall for Uis, Namibia (worldweatheronline.com)

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 9.

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 9(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 9(b)). Stable conditions prevent the plume from mixing vertically, although it can still spread horizontally and is called *fanning* (Figure 9(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.

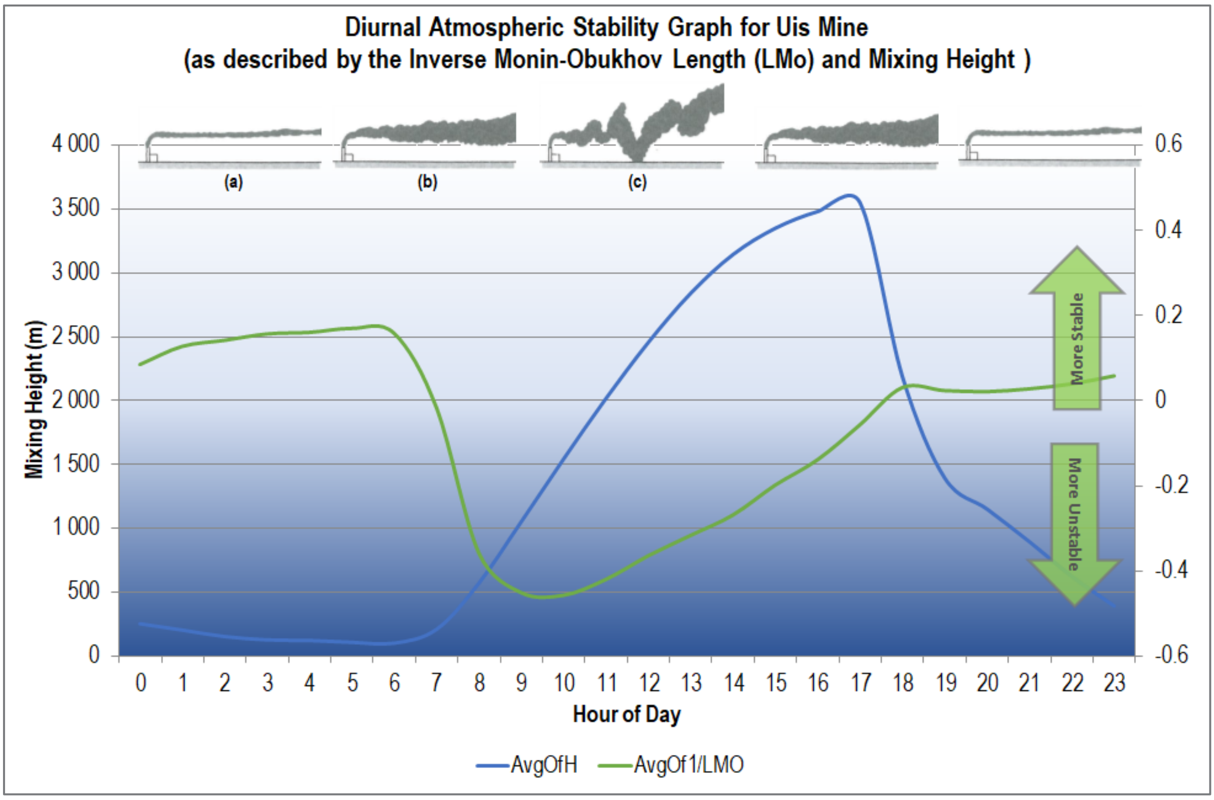


Figure 9: Diurnal atmospheric stability based on WRF modelled data (Jan 2018 – Dec 2020)

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 Uis area is mainly communal land used for small stock farming with tourism, small-scale mining, and operations at the UTMC generating the main sources of income. Additional sources of dust emissions contributing to the overall dust emissions load can be attributed to the activities of the Namclay Brick and Pavers factory and 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 CO_2, CO, NOx, PM, SO_2 and VOC 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

The monitoring network in place at the Uis Project does not include 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 Uis area.

3.3.3 Dustfall Monitoring Data for the Uis Tin Mine Project

Dustfall monitoring data was provided for the period March 2019 to August 2021. The monitoring network comprised of eight (8) single dustfall units between March 2019 and November 2020 but expanded to fourteen (14) single dustfall units from December 2020 forward. The locations of the dustfall stations are shown in Figure 11.

Dustfall deposition rates from the Uis monitoring network are presented in Figure 10. Dustfall rates are generally low for the sampling period and well within the dustfall limit of 600 mg/m²/day (adopted limit for residential areas) and 1 200 mg/m²/day (adopted limit for non-residential areas), with the exception of AQ 01 (5 exceedances in 2020 and 4 exceedances in 2021), AQ 05 (2 exceedances in 2019, 5 exceedances in 2020 and 1 exceedance in 2021), AQ 08 (1 exceedance in 2019) and AQ 14 (1 exceedance in 2020) (Figure 10).

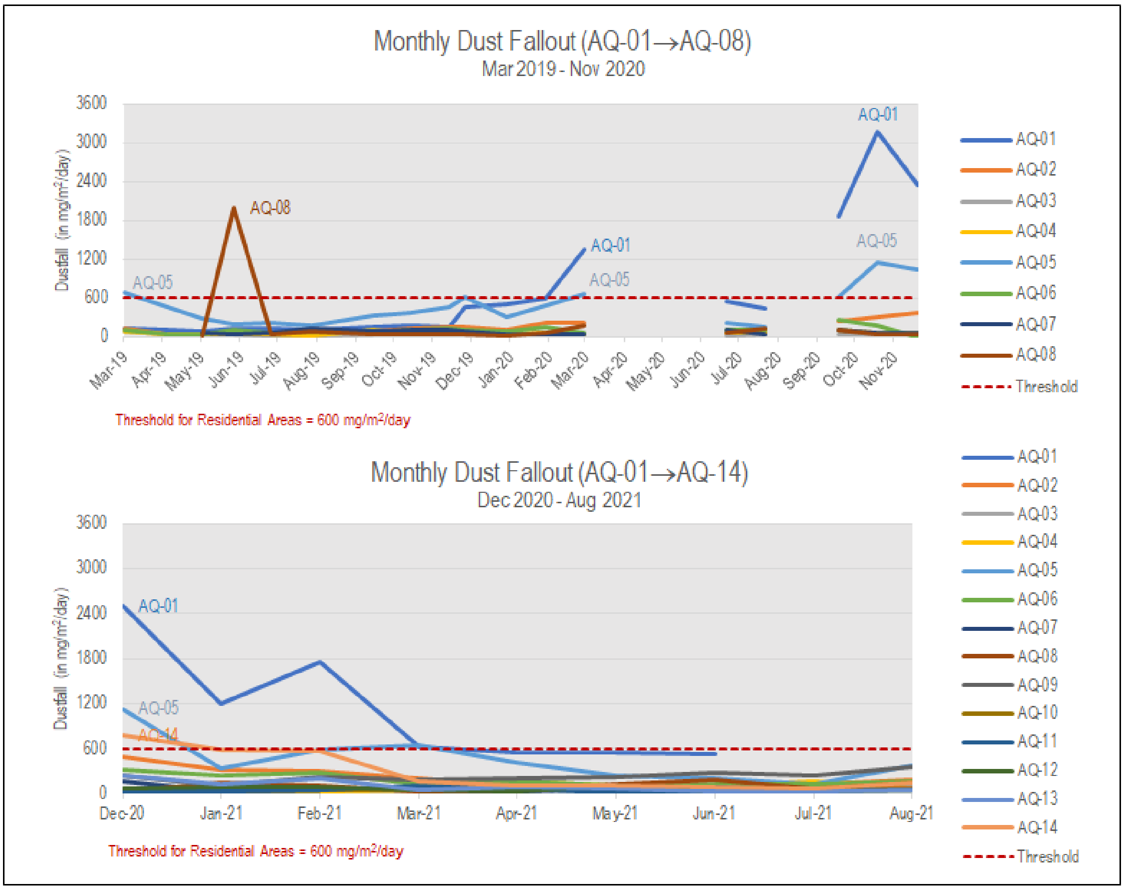


Figure 10: Dustfall rates for Uis Mine monitoring (March 2019 – August 2021)

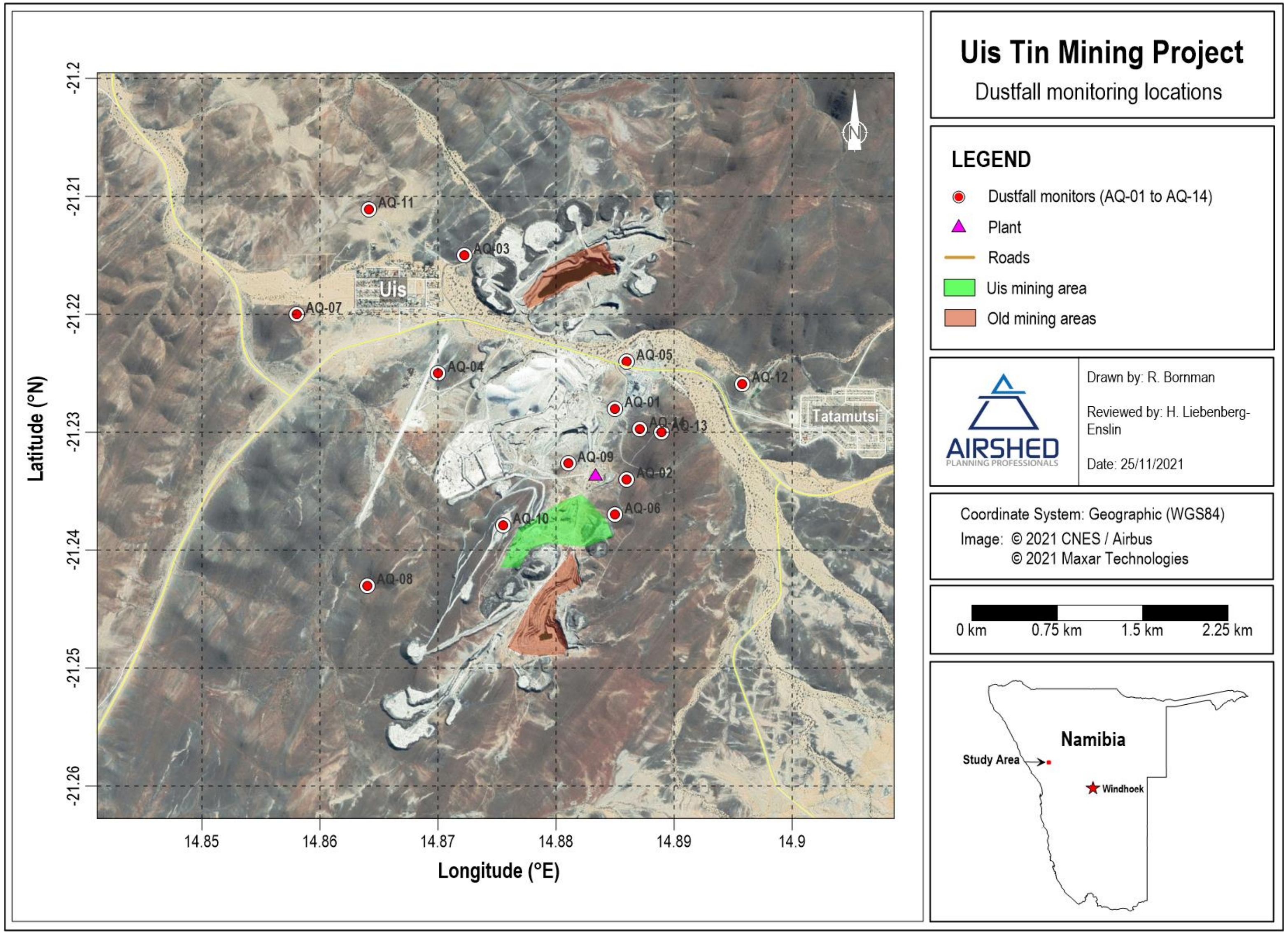


Figure 11: Uis Mine monitoring network

4 Impact of Proposed Project on the Receiving Environment

4.1 Atmospheric Emissions

4.1.1 Construction Phase

The construction phase during Stage II is designed to allow pre-assembly while the plant is in operation. 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 6.

Table 6: 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 of DMS feed stockpile, secondary screen and secondary crushing plant	Clearing of groundcover
		Levelling of area
		Wind erosion from open areas
		Materials handling

Each of the operations in Table 6 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. Emissions were calculated for general infrastructure construction activities during the construction period, which is estimated to last 6 months.

The US-EPA documents emissions factors which aim to provide a general rule-of-thumb as to the magnitude of emissions which may be anticipated from construction operations. The quantity of dust emissions is assumed to be proportional to the area of land being worked and the level of construction activity. The approximate emission factors for general construction activity operations are given as:

E = 2.69 Mg/hectare/month of activity (269 g/m^2/month)

The PM_{10} fraction is given as ~39% of the US-EPA total suspended particulate factor. These emission factors are most applicable to construction operations with (i) medium activity levels, (ii) moderate silt contents, and (iii) semiarid climates. The emission factor for TSP considers 42 hours of work per week of construction activity. Test data were not sufficient to derive the specific dependence of dust emissions on correction parameters. Because the above emission factor is referenced to TSP, use of this factor to estimate particulate matter (PM) no greater than 10 µm in aerodynamic diameter (PM_{10}) emissions will result in conservatively high estimates. Also, because derivation of the factor assumes that construction activity occurs 30 days per month, the above estimate is somewhat conservatively high for TSP as well.

The following areas (in hectare) were estimated from the proposed plant layout (see Inset area in Figure 2 and Figure 13).

DMS feed stockpile	0.0018	ha
Secondary screen	0.0077	ha
Secondary crushing plant	0.1225	ha
Total	**0.132**	**ha**

The total land area extends over 0.132 hectares, and the resultant emissions over the 6-month construction period were estimated at 355 kg for TSP, 138 kg for PM_{10} and 69 kg for $PM_{2.5}$.

4.1.2 Operational Phase

The Phase 1 Fast-Tracked Stage II expansion project involves increasing the throughput capacity of the MHCP by 50% from 80 tph to 120 tph, which can be achieved by modular expansion of individual circuits. It also includes a mining plan to deliver 850 ktpa ore to the upgraded MHCP, to produce 1 200 tpa of saleable tin concentrate for export. This is an increase in mining rate when compared to Phase 1 Stage I, where approximately 567 ktpa of pegmatite ore was delivered to the processing plant to produce 788 tpa of saleable tin concentrate for export.

A description of the project is provided in Section 1.3. The layout of the V1 and V2 mining areas, roads, waste dumps and co-displacement facility and plant area is shown in Figure 12. A detailed layout of the MHCP is provided in Figure 13. A high-level block flow diagram (BFD) describing the flow of materials at the MHCP is shown in Figure 14 (AfriTin Mining, 2021 p 73).

To determine the significance of air pollution impacts from the Project, emissions were estimated for a Baseline scenario (based on Stage I throughputs) and a Project scenario (based on Stage II throughputs).

4.1.2.1 Project throughputs

The throughputs that were used to calculate emissions for the Baseline and Project scenarios are provided in Table 7 (mining inventory) and Table 8 (MHCP inventory).

Table 7: Mining throughputs used in the emissions inventory (in tph and tpa)

	Baseline		Project	
	tph	tpa	tph	tpa
Ore Zone 1 (V1) (a)	37	323 190	55	484 500
Ore Zone 2 (V2) (a)	28	243 810	42	365 500
Waste Zone 1 (V1) (b)	71	620 525	106	930 240
Waste Zone 2 (V2) (b)	53	468 115	80	701 760
Strip ratio (c)		1.92		1.92
ROM stockpile (d)		204 935		307 222
Tin concentrate (e)		720		1 200

Notes:

(a) Calculated using a 57% to 43% split for ore extracted from V1 and V2 opencast areas (AfriTin Mining, 2021 p7)

(b) Calculated using strip ratio of 1.92 (average over LoM) (AfriTin Mining, 2021 p51)

(c) Average strip ratio over LoM (18 years)

(d) Average stockpile closing balance over LoM (AfriTin Mining, 2021 Figure 36)

(e) Tin concentrate product increased from 60 tpm (720 tpa) for the Baseline scenario to 100 tpm (1200 tpa) for the Project scenario (Phase 1 Stage II Fast-Tracked Expansion project description)

Table 8: Plant throughputs used in the emissions inventory (in tph and tpa)

	Baseline		Project		Ratio (a)
	tph	tpa	tph	tpa	
ROM Tip		567 000 (b)		850 000 (b)	
Primary crusher	80 (b)	567 000	120 (b)	850 000	1
Secondary screening (initial + return)	137	969 570	205	1 453 500	1.71
Secondary crusher	57	402 570	85	603 500	0.71
Crushed ore stockpile Tip	54	385 560	82	578 000	0.68
Tertiary screening (initial + return)	103	731 430	155	1 096 500	1.29
Tertiary crusher	9	62 370	13	93 500	0.11
Fines screening (initial + return)	128	907 200	192	1 360 000	1.6
Fines crusher	136	963 900	204	1 445 000	1.7
DMS feed bin	43	306 180	65	459 000	0.54
DMS feed stockpile Tip			65	459 000	0.54
Discard Tip and hauling (to CPF)	50	351 540	74	527 000	0.62

Notes:

(a) Ratios were calculated from material streams provided in the BFD for the Phase 1 Stage II Fast-Tracked Expansion project (Figure 14) (AfriTin Mining, 2021 p73)

(b) See description in Section 4.1.2

4.1.2.2 Emissions Inventory

Two operational scenarios were assessed, viz. the Baseline and Project scenarios, each with an unmitigated and mitigated sub-scenario.

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 9. The particle size distributions assumed for overburden, ROM and CPF material (used in the calculation of emissions due to windblown dust from the proposed stockpiles and co-placement facility) are listed in Table 10 and Table 11. The control efficiencies used in the calculation of emissions due to mitigated operations are listed in Table 12 – these were based on design mitigation measures assumed for the Project.

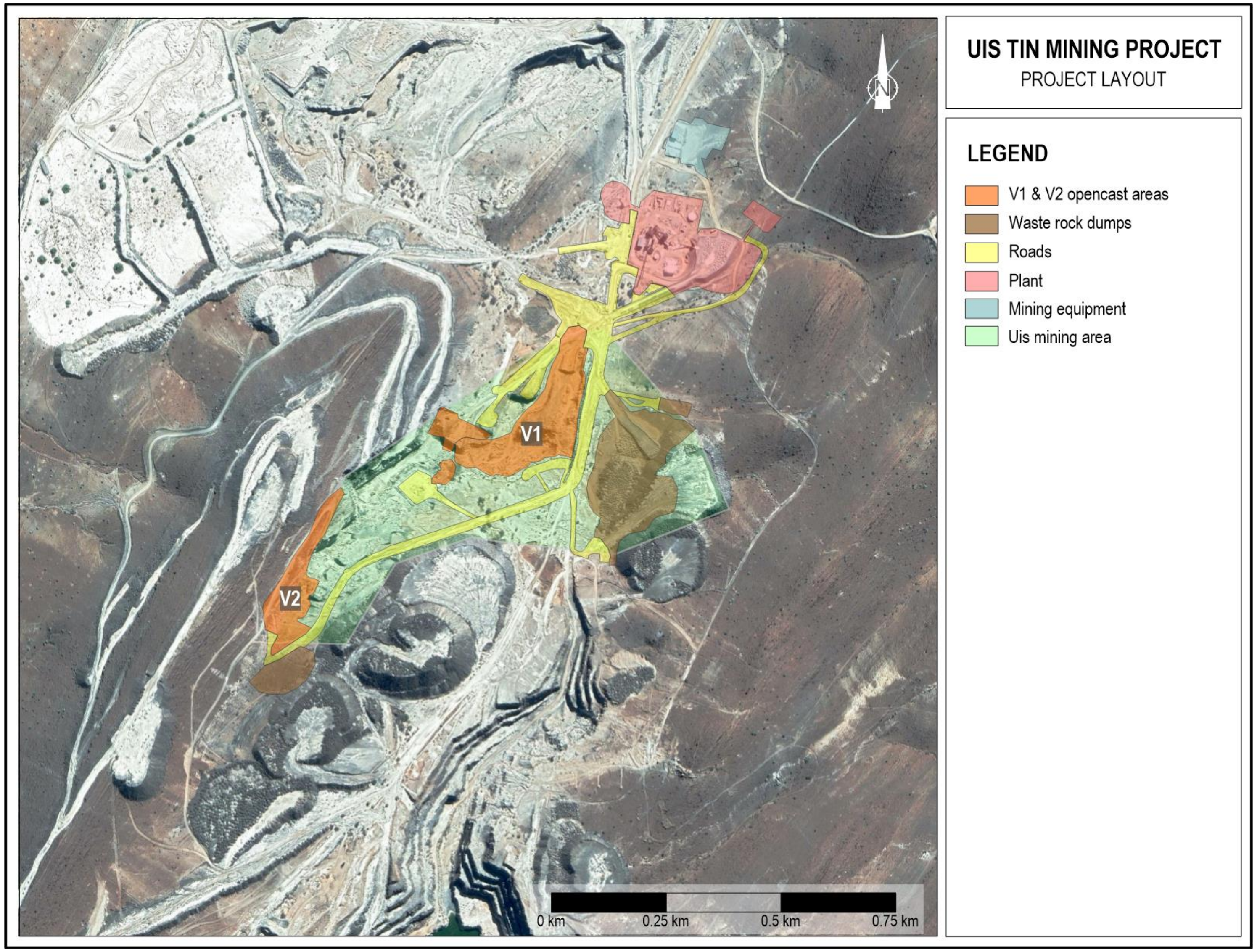


Figure 12: Project Layout

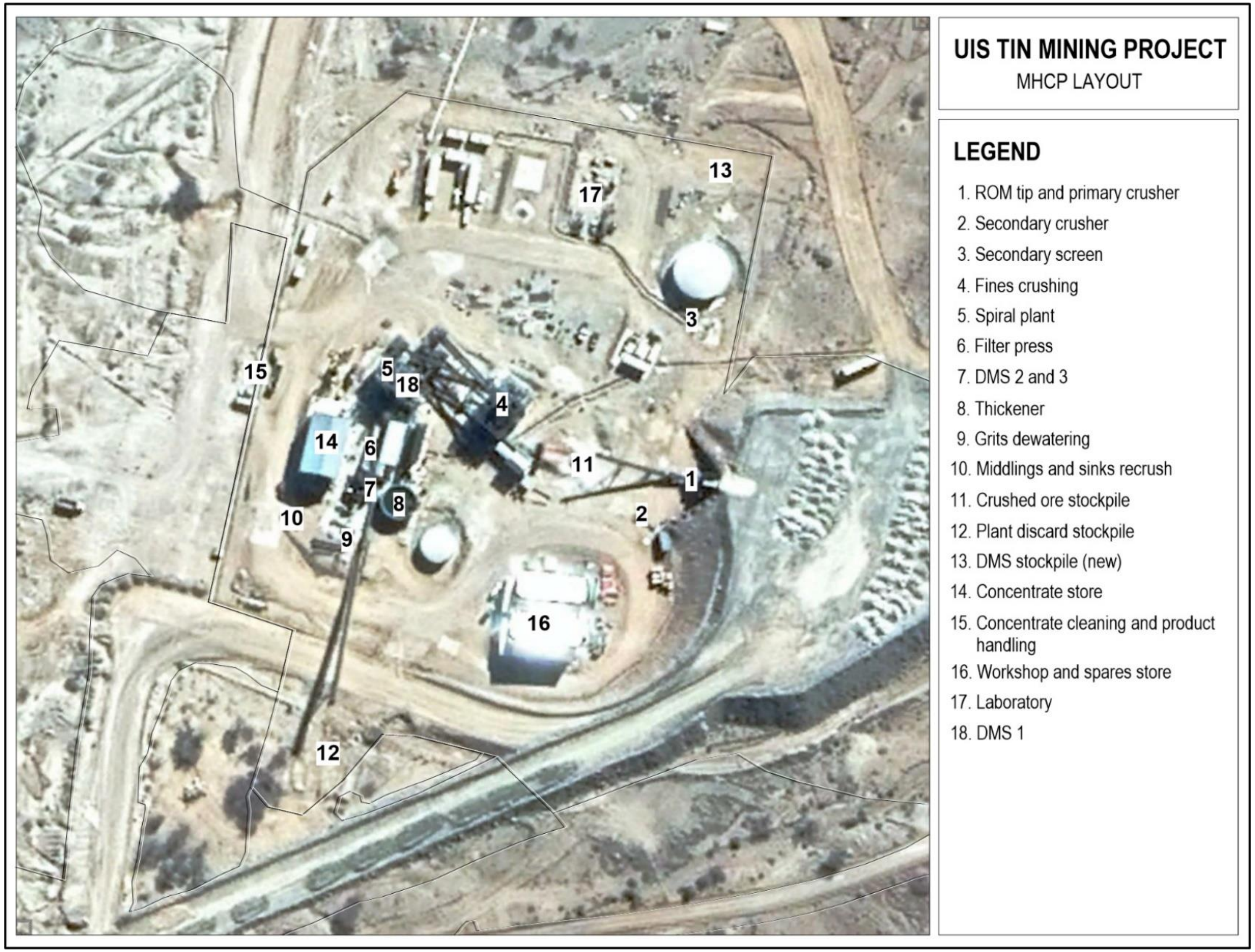
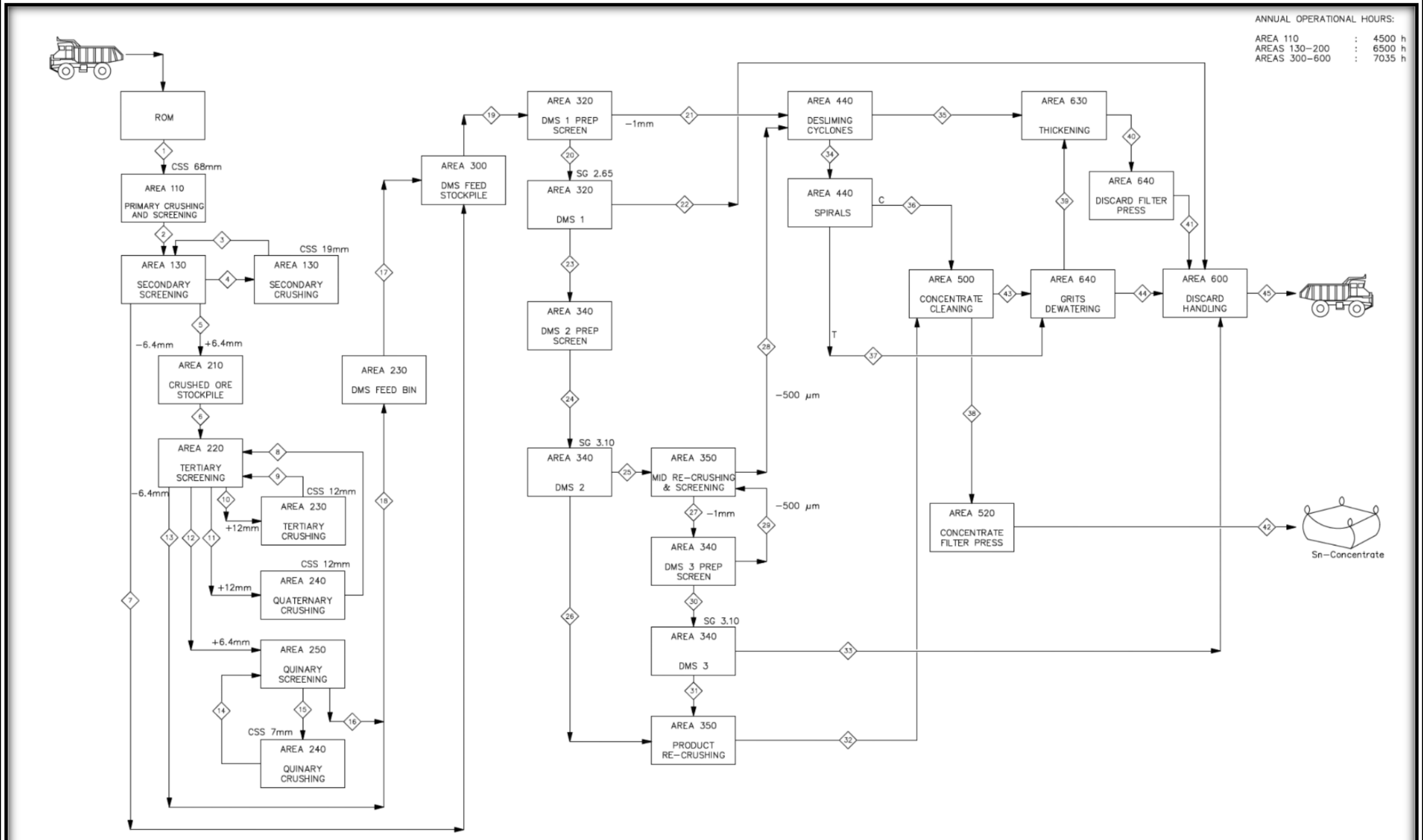


Figure 13: MHCP Layout



Stream Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Solids t/h	189.0	189.0	133.4	133.4	128.1	128.1	60.9	95.0	20.1	20.1	95.0	74.9	27.6	227.4	227.4
Water t/h	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%Solids	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Stream SG	2.75	2.75	2.75	2.75	2.75	2.75	2.75	2.75	2.75	2.75	2.75	2.75	2.75	2.75	2.75
Ta Grade (%)	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Sn Grade (%)	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14

Stream Number	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Solids t/h	74.9	102.5	102.5	118.0	79.6	39.1	51.0	27.8	27.8	26.9	0.8	10.2	17.8	1.1	9.1
Water t/h	0.0	0.0	0.0	0.0	14.1	156.6	0.8	2.4	2.1	1.5	0.1	19.3	79.7	29.2	0.3
%Solids	100	100	100	100	85.0	20.0	98.5	92.1	93.0	94.7	85.0	34.5	18.3	3.8	96.8
Stream SG	2.75	2.75	2.75	2.75	2.18	1.15	2.58	2.56	2.60	2.63	3.14	1.29	1.14	1.03	2.73
Ta Grade (%)	0.03	0.03	0.03	0.01	0.01	0.01	0.00	0.04	0.04	0.01	0.84	0.01	0.01	0.01	0.01
Sn Grade (%)	0.14	0.14	0.14	0.14	0.14	0.14	0.02	0.36	0.36	0.11	8.40	0.11	0.11	0.11	0.11

Stream Number	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
Solids t/h	0.1	0.9	9.0	47.9	9.1	35.7	12.2	0.2	3.8	12.8	12.8	0.2	36.2	44.9	117.8
Water t/h	0.0	8.6	0.2	18.6	217.7	32.1	80.2	0.0	172.3	23.8	0.8	0.0	40.2	7.9	10.0
%Solids	85.0	9.5	97.4	72.0	4.0	52.6	13.2	99.2	2.2	35.0	94.0	99.2	47.4	85.0	92.1
Stream SG	3.01	1.08	2.74	1.85	1.03	1.51	1.09	6.03	1.01	1.29	2.53	6.03	1.47	2.22	2.54
Ta Grade (%)	0.73	0.83	0.00	0.02	0.01	0.01	0.03	3.48	0.02	0.01	0.01	3.48	0.01	0.02	0.00
Sn Grade (%)	7.29	8.31	0.03	0.16	0.07	0.11	0.25	56.76	0.13	0.09	0.09	60.00	0.00	0.11	0.03

Figure 14: Simplified block flow diagram for the proposed Phase 1 Fast-Tracked Stage II Expansion Project

Table 9: Emission equations used to quantify the routine emissions from the operational 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 30t. Average weight of haul trucks was calculated as 37.7t. The layout of the roads was provided (Figure 12). The throughput of ROM and waste materials for the mining area is provided in Table 7 and discard throughputs given in Table 8. Operating hours were given as 24 hours per day, 7 days a week.
Materials handling	$$E = 0.0016\frac{\left(U/_{2.2}\right)^{1.3}}{\left(M/_{2}\right)^{1.4}}$$ Where, E = Emission factor (kg dust / t transferred) U = Mean wind speed (m/s) M = Material moisture content (%) The $PM_{2.5}$, PM_{10} and TSP fraction of the emission factor is 5.3%, 35% and 74% respectively.	US-EPA AP42 Section 13.2.4	An average wind speed of 4.8 m/s was used based on the WRF data for the period 2018 – 2020. The throughput of ROM, overburden and discard material are as specified above (for vehicle entrainment on unpaved surfaces). The moisture content of the ROM material was assumed as 2.4% (from a Google search on pegmatite orebodies) and 15% for the discard material (from AfriTin Mining, 2021). In the absence of site-specific moisture contents, use was made of US-EPA default mean moisture contents of 7.9% for waste rock. Operating hours were given as 24 hours per day, 7 days a week for mining activities. Emissions at the plant area were calculated from the hourly throughputs provided in Table 8, and, as a worst-case scenario, modelled under the assumption of continuous operations.

Activity	Emission Equation	Source	Information assumed/provided
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 calculated as 107 (from drilling and blasting information provided in Maritz and Uludag, 2019). Operating hours were assumed to be 24 hours per day, 7 days a week.
Blasting	$E = 0.00022 \cdot (A)^{1.5}$ Where, E = Emission factor (kg dust / t transferred) A = Blast area (m²) The $PM_{2.5}$, PM_{10} and TSP fraction of the emission factor is 5.3%, 35% and 74% respectively.	NPI Section: Mining	The blast area was calculated as 1500 m² (from drilling and blasting information provided in Maritz and Uludag, 2019). The number of blasts was assumed as 3 times per week (twice a week for overburden and once a week for ore). For modelling purposes it was assumed that blasting occurs over a 1-hour period on Monday, Wednesday and Saturday.
Crushing (primary and secondary)	Primary crushing: $E_{TSP} = 0.2\ kg/t\ material\ processed$ $E_{PM10} = 0.02\ kg/t\ material\ processed$ $E_{PM2.5} = 0.01\ kg/t\ material\ processed$ Secondary crushing: $E_{TSP} = 0.6\ kg/t\ material\ processed$ $E_{PM10} = 0.06\ kg/t\ material\ processed$ $E_{PM2.5} = 0.03\ kg/t\ material\ processed$ Where, E = Default emission factor for low moisture content ore Fraction of $PM_{2.5}$ assumed as 50% of PM_{10}	US-EPA AP42 Section 11.24.2	Primary and secondary crushing emissions were calculated from the hourly throughputs provided in Table 8, and, as a worst-case scenario, modelled under the assumption of continuous operations. For mitigated baseline operations, 50% CE was assumed for primary and secondary crushing (water suppression). For mitigated Project operations, 99% CE was assumed for primary and secondary crushing (dual scrubber).
Crushing (tertiary)	Tertiary crushing (uncontrolled): $E_{TSP} = 0.0027\ kg/t\ material\ processed$ $E_{PM10} = 0.0012\ kg/t\ material\ processed$ $E_{PM2.5} = 0.0002\ kg/t\ material\ processed$	US-EPA AP42 Section 11.19.2	Throughputs: Hourly throughputs provided in Table 8. Operational hours: Assumed to be continuous (as a worst-case scenario) for dispersion modelling purposes.

Activity	Emission Equation	Source	Information assumed/provided
	Tertiary crushing (controlled): $E_{TSP} = 0.0006\ kg/t\ material\ processed$ $E_{PM10} = 0.00027\ kg/t\ material\ processed$ $E_{PM2.5} = 0.00005\ kg/t\ material\ processed$ Where, Fraction of $PM_{2.5}$ for uncontrolled operations calculated from $PM_{2.5}$ and PM_{10} factors given for controlled tertiary crushing operations	Section 11.19.2.2	Emission controls due to crushed stone processing are discussed in US-EPA AP42 Section 11.19.2.2 and emission factors for controlled tertiary crushing operations given in Table 11.19.2-1.
Crushing (fines)	Fines crushing (uncontrolled): $E_{TSP} = 0.0195\ kg/t\ material\ processed$ $E_{PM10} = 0.0075\ kg/t\ material\ processed$ $E_{PM2.5} = 0.0004\ kg/t\ material\ processed$	US-EPA AP42 Section 11.19.2	Throughputs: Hourly throughputs provided in Table 8. Operational hours: Assumed to be continuous (as a worst-case scenario) for dispersion modelling purposes.
	Fines crushing (controlled): $E_{TSP} = 0.0015\ kg/t\ material\ processed$ $E_{PM10} = 0.0006\ kg/t\ material\ processed$ $E_{PM2.5} = 0.000035\ kg/t\ material\ processed$ Where, Fraction of $PM_{2.5}$ for uncontrolled operations calculated from $PM_{2.5}$ and PM_{10} factors given for controlled fines crushing operations	Section 11.19.2.2	Emission controls due to crushed stone processing are discussed in US-EPA AP42 Section 11.19.2.2 and emission factors for controlled fines crushing operations given in Table 11.19.2-1.
Screening (secondary)	Secondary screening (uncontrolled): $E_{TSP} = 0.0125\ kg/t\ material\ processed$ $E_{PM10} = 0.0043\ kg/t\ material\ processed$ $E_{PM2.5} = 0.0003\ kg/t\ material\ processed$	US-EPA AP42 Section 11.19.2	Throughputs: Hourly throughputs provided in Table 8. Operational hours: Assumed to be continuous (as a worst-case scenario) for dispersion modelling purposes.
	Secondary screening (controlled): $E_{TSP} = 0.0011\ kg/t\ material\ processed$ $E_{PM10} = 0.00037\ kg/t\ material\ processed$ $E_{PM2.5} = 0.000025\ kg/t\ material\ processed$ Where,	Section 11.19.2.2	Emission controls due to crushed stone processing are discussed in US-EPA AP42 Section 11.19.2.2 and emission factors for controlled screening operations given in Table 11.19.2-1.

Activity	Emission Equation	Source	Information assumed/provided
	Fraction of $PM_{2.5}$ for uncontrolled operations calculated from $PM_{2.5}$ and PM_{10} factors given for controlled screening operations		
Screening (fines)	Fines screening (uncontrolled): $$E_{TSP} = 0.15\ kg/t\ material\ processed$$ $$E_{PM10} = 0.036\ kg/t\ material\ processed$$ $$E_{PM2.5} = 0.0024\ kg/t\ material\ processed$$ Fines screening (controlled): $$E_{TSP} = 0.0018\ kg/t\ material\ processed$$ $$E_{PM10} = 0.0011\ kg/t\ material\ processed$$ $$E_{PM2.5} = 0.0001\ kg/t\ material\ processed$$ Where, Fraction of $PM_{2.5}$ for uncontrolled operations calculated from $PM_{2.5}$ and PM_{10} factors given for controlled fines screening operations	US-EPA AP42 Section 11.19.2 Section 11.19.2.2	Throughputs: Hourly throughputs provided in Table 8. Operational hours: Assumed to be continuous (as a worst-case scenario) for dispersion modelling purposes. Emission controls due to crushed stone processing are discussed in US-EPA AP42 Section 11.19.2.2 and emission factors for controlled fines screening operations given in Table 11.19.2-1
Wind Erosion	$$E(i) = G(i)10^{(0.134(\%clay)-6)}$$ For $$G(i) = 0.261\left[\frac{P_a}{g}\right]u^{*3}(1+R)(1-R^2)$$ And $$R = \frac{u_*^{\ t}}{u^*}$$ where, $E_{(i)}$ = emission rate (g/m²/s) for particle size class i P_a = air density (g/cm³) G = gravitational acceleration (cm/s³) u_*^t = threshold friction velocity (m/s) for particle size i u^* = friction velocity (m/s)	Marticorena & Bergametti, 1995	ROM, waste rock and co-disposal particle size distributions were obtained from similar processes (see Table 10 and Table 11). The moisture content and particle density of ROM material was assumed as 2.4% and 1.78 t/m³ respectively (from similar processes). The moisture content and particle density of waste rock material was assumed as 2% and 2.20 t/m³ respectively (from similar processes). The moisture content and particle density of co-disposal material was assumed as 3.4% and 2.05 t/m³ respectively (from similar processes). Layout of ROM, WRD stockpiles and CPF was provided. Hourly emission rate files were calculated and simulated.

Table 10: Particle size distribution of waste rock material (given as a fraction)

Waste Rock	
Size µm	**Mass Fraction**
76.32	0.101
65.51	0.183
48.27	0.213
30.53	0.144
19.31	0.130
10.48	0.091
5.69	0.073
2.65	0.064

Table 11: Particle size distributions of co-placement and ROM material (given as a fraction)

Co-disposal facility		ROM Stockpiles	
Size µm	**Mass Fraction**	**Size µm**	**Mass Fraction**
4000.00	0.1257	4000	0.3213
2000.00	0.0399	2000	0.0990
555.71	0.0008	555.71	0.0000
477.01	0.0104	477.01	0.0031
409.45	0.0226	409.45	0.0063
351.46	0.0348	351.46	0.0092
301.68	0.0450	301.68	0.0115
258.95	0.0518	258.95	0.0130
222.28	0.0552	222.28	0.0142
190.80	0.0554	190.8	0.0151
163.77	0.0531	163.77	0.0159
140.58	0.0502	140.58	0.0169
120.67	0.0472	120.67	0.0179
103.58	0.0441	103.58	0.0190
88.92	0.0412	88.91	0.0201
56.23	0.0355	76.32	0.0209
48.27	0.0323	65.51	0.0217
41.43	0.0293	56.23	0.0223
35.56	0.0263	48.27	0.0225
30.53	0.0237	41.43	0.0225
26.20	0.0211	35.56	0.0222
22.49	0.0187	30.53	0.0217
19.31	0.0166	26.2	0.0211
16.57	0.0146	22.49	0.0204
14.22	0.0130	19.31	0.0197
12.21	0.0114	16.57	0.0190
10.48	0.0102	14.22	0.0182
9.00	0.0091	12.21	0.0174
7.73	0.0081	10.48	0.0165

Co-disposal facility		ROM Stockpiles	
Size µm	**Mass Fraction**	**Size µm**	**Mass Fraction**
5.69	0.0068	9	0.0156
4.88	0.0061	7.72	0.0146
4.19	0.0053	6.63	0.0134
3.60	0.0048	5.69	0.0122
3.09	0.0043	4.88	0.0110
2.65	0.0039	4.19	0.0098
2.28	0.0034	3.6	0.0086
1.95	0.0031	3.09	0.0076
1.68	0.0028	2.65	0.0067
1.24	0.0023	2.28	0.0059
1.06	0.0020	1.95	0.0050
0.91	0.0018	1.68	0.0043
0.78	0.0015	1.44	0.0037
0.67	0.0012	1.24	0.0031
0.49	0.0009	1.06	0.0026
0.42	0.0008	0.91	0.0020
0.36	0.0006	0.78	0.0015
0.31	0.0005	0.67	0.0012
0.27	0.0003	0.58	0.0008
0.23	0.0002	0.49	0.0006
0.20	0.0001	0.42	0.0004
0.17	0.0001	0.36	0.0003
0.15	0.0000	0.31	0.0002
0.13	0.0001	0.27	0.0001
0.11	0.0001	0.23	0.0001
		0.2	0.0001
		0.17	0.0001
		0.15	0.0001
		0.13	0.0001
		0.11	0.0001
		0.09	0.0001
		0.08	0.0001
		0.07	0.0000
		0.06	0.0000

Table 12: Estimated control factors for various mining operations

Operation/Activity	Control method and emission reduction
Drilling	No control
Blasting	No control
Materials handling (loading and unloading, conveyor transfer)	50% CE for water suppression
Primary and secondary crushing (Baseline)	50% CE for water suppression
Primary and secondary crushing (Project)	99% CE on primary and secondary crushing (for dual scrubber)
Tertiary crushing	78% CE (wet process)
Fines crushing	92% CE (wet process)
Secondary and fines screening	90% CE and 97% CE respectively (wet process)
Hauling	75% for water sprays on surface roads, 50% CE for water sprays on in-pit roads
Wind erosion from exposed surfaces	No control

4.1.3 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 13.

The contributions of individual source groups to total tons per annum for the Baseline and Project scenarios are illustrated in Figure 15 (a-b) and Figure 15 (c-d) respectively.

Table 13: Calculated emission rates due to unmitigated and mitigated activities for the Baseline and Project scenarios respectively

Description	Baseline Scenario						Project Scenario					
	Unmitigated			Mitigated			Unmitigated			Mitigated		
	$PM_{2.5}$	PM_{10}	TSP	$PM_{2.5}$	PM_{10}	TSP	$PM_{2.5}$	PM_{10}	TSP	$PM_{2.5}$	PM_{10}	TSP
In-pit (including drilling)	51.34	75.99	186.41	49.91	62.24	139.35	52.76	89.71	233.38	50.62	69.10	162.84
Blasting	0.06	1.04	24.40	0.06	1.04	24.40	0.06	1.04	24.40	0.06	1.04	24.40
Materials handling	0.72	4.74	10.01	0.36	2.37	5.01	1.32	8.74	18.47	0.54	3.55	7.51
Crushing and screening	16.85	85.84	572.61	7.00	15.93	182.35	25.27	112.01	796.40	0.43	3.74	12.80
Unpaved roads	8.77	87.69	306.84	2.19	21.92	76.71	13.15	131.46	459.99	3.29	32.86	115.00
Wind erosion	3.59	12.97	49.91	3.59	12.97	49.91	3.59	12.97	49.91	3.59	12.97	49.91
Total	**81**	**266**	**1141**	**63**	**114**	**468**	**96**	**354**	**1573**	**58**	**121**	**363**

Notes:

(a) BASELINE: Mitigation includes 75% control efficiency (CE) on unpaved surface roads and 50% CE on unpaved in-pit roads (using water sprays), 50% CE on primary and secondary crushing and materials handling operations (using water sprays), >75% CE for tertiary and fines crushing and screening (wet process)

(b) PROJECT: Mitigation includes all control measures listed in (a), but with 99% CE on primary and secondary crushing operations (dual scrubber).

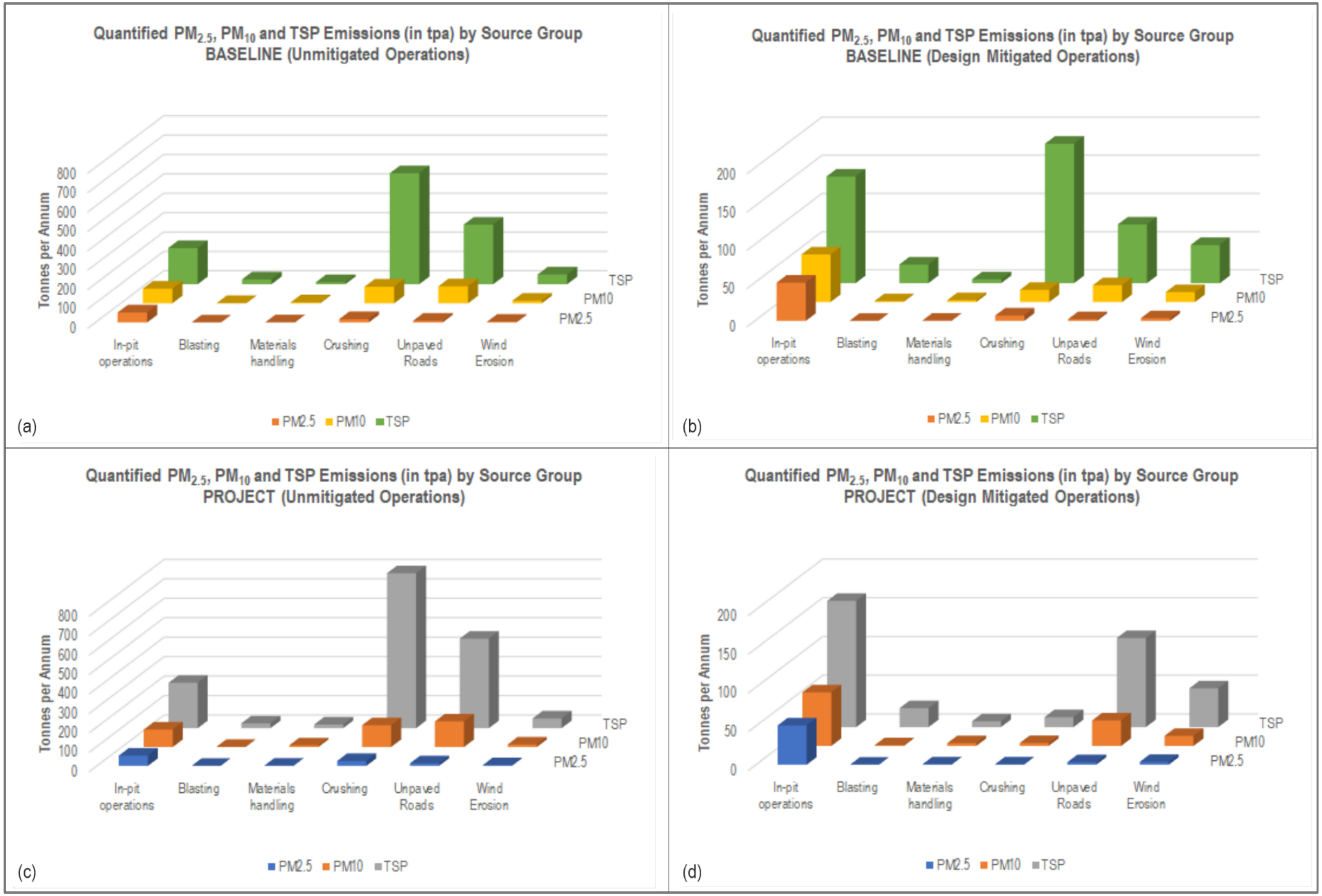


Figure 15: Contribution of particulate emissions per source group

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

In the simulation of ambient air pollutant concentrations use was made of the ADMS 5 model (Atmospheric Dispersion Modelling System version 5.0.0) developed by the Cambridge Environmental Research Consultants (CERC). This model simulates a wide range of buoyant and passive releases to the atmosphere either individually or in combination. It has been the subject of several inter-model comparisons (CERC, 2004) (Hall, et al., 2000), one conclusion of which is that it tends provide conservative values under unstable atmospheric conditions in that, in comparison to the older regulatory models, it predicts higher concentrations close to the source.

The ADMS model was chosen specifically for its capability of modelling flow over complex topography, to account for the local topographical features in the Project region.

4.2.2 Meteorological Requirements

For the current study, use was made of modelled WRF data for the period 2018-2020.

4.2.3 Source Data Requirements

The ADMS model can model point, jet, area, line and volume sources. Materials handling and crushing sources were modelled as volume sources. The following emissions sources were modelled as area sources:

- Open pit;
- Blasting;
- Roads;
- Stockpiles (wind erosion);
- Co-placement facility (wind erosion).

4.2.4 Modelling Domain

The dispersion of pollutants expected to arise from proposed activities was modelled for an area covering 10 km (east-west) by 10 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). ADMS calculates ground-level (1.5 m above ground level) concentrations at each grid and discrete receptor point.

4.2.5 Complex Terrain

Topography was included in dispersion simulations. The effect of complex terrain is modelled in ADMS by changing the plume trajectory and dispersion to account for disturbances in the air flow due to terrain (CERC, 2004). Readily available terrain data was obtained from the Atmospheric Studies Group (ASG) via the United States Geological Survey (USGS) web site (ASG, 2011).

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 ADMS 5 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) were simulated. The proposed AQOs as set out in Table 5 are used as indicators during the assessment.

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}

4.3.1.1 Baseline Scenario

The simulated exceedances of highest daily and annual average PM_{10} AQOs for unmitigated and mitigated Baseline operations are provided in Figure 16 and Figure 17 respectively, with the GLCs at the nearest AQSRs provided in Table 14.

PM_{10} daily GLCs, for unmitigated activities, result in exceedances of the 24-hour air quality objective (AQO) over a maximum distance of ~700 m from Uis mining activities, but with no exceedances at any of the AQSRs. For mitigated activities, impacts are limited to the Uis mining and processing plant areas with no exceedances at any of the AQSRs. PM_{10} annual GLCs, for both unmitigated and mitigated activities, are within the AQO at the AQSRs.

4.3.1.2 Project Scenario

The simulated exceedances of highest daily and annual average PM_{10} AQOs for unmitigated and mitigated Project operations are provided in Figure 18 and Figure 19 respectively, with the GLCs at the nearest AQSRs provided in Table 14.

The daily PM_{10} AQO (WHO IT-3 and SA NAAQS) is exceeded over a maximum distance of 950 m from the Uis mining area (with no mitigation in place) but reduce to smaller areas of exceedance on-site when mitigation is applied. PM_{10} daily GLCs, for unmitigated and mitigated activities, do not result in any exceedances of the 24-hour AQO at the AQSRs. Over an annual average there are no exceedances at any of the AQSRs, without and with mitigation.

Table 14: Simulated PM_{10} ground level concentrations (in µg/m³) at selected AQSRs for BASELINE and PROJECT operations (non-compliance is highlighted)

AQSR	BASELINE						PROJECT					
	Unmitigated			Mitigated			Unmitigated			Mitigated		
	Annual Avg	Highest Day	FOE	Annual Avg	Highest Day	FOE	Annual Avg	Highest Day	FOE	Annual Avg	Highest Day	FOE
AQO	40 µg/m³	75 µg/m³	>4 days/year	40 µg/m³	75 µg/m³	>4 days/year	40 µg/m³	75 µg/m³	>4 days/year	40 µg/m³	75 µg/m³	>4 days/year
0	1.12	10.37	0	0.34	2.85	0	1.56	14.33	0	0.33	2.76	0
1	1.05	8.54	0	0.32	2.79	0	1.47	12.13	0	0.31	2.76	0
2	1.10	9.52	0	0.34	2.81	0	1.54	13.23	0	0.33	2.95	0
3	1.11	10.09	0	0.34	2.87	0	1.55	13.93	0	0.33	2.73	0
4	1.15	9.90	0	0.35	3.00	0	1.61	13.83	0	0.34	3.06	0
5	1.16	9.55	0	0.35	2.88	0	1.63	13.25	0	0.34	2.80	0
6	1.12	9.32	0	0.34	2.71	0	1.56	12.71	0	0.33	2.63	0
7	1.17	10.26	0	0.35	2.98	0	1.64	14.36	0	0.34	2.95	0
8	0.96	7.72	0	0.29	2.06	0	1.34	10.94	0	0.28	1.94	0
9	0.94	7.40	0	0.29	2.11	0	1.32	10.51	0	0.28	2.04	0
10	0.91	7.27	0	0.28	1.99	0	1.28	10.31	0	0.27	1.94	0
11	1.36	11.08	0	0.42	3.02	0	1.91	15.54	0	0.39	2.57	0
12	1.06	11.77	0	0.33	3.25	0	1.47	16.40	0	0.32	3.14	0
13	1.02	11.33	0	0.32	3.19	0	1.42	15.80	0	0.31	3.01	0
14	0.97	11.48	0	0.30	3.30	0	1.35	16.07	0	0.29	3.06	0
15	1.04	14.45	0	0.32	4.18	0	1.44	20.32	0	0.31	3.86	0
16	0.33	9.63	0	0.09	2.76	0	0.46	13.52	0	0.08	2.79	0
17	0.12	5.26	0	0.04	1.34	0	0.17	7.45	0	0.03	1.33	0
18	2.13	14.64	0	0.66	4.22	0	2.99	20.80	0	0.62	4.09	0
19	1.13	9.47	0	0.36	2.60	0	1.59	13.35	0	0.34	2.39	0
Uis Town	3.11	19.93	0	0.95	5.53	0	4.39	28.38	0	0.90	4.79	0
Uis Village	0.71	18.13	0	0.20	4.33	0	0.97	25.76	0	0.16	3.44	0
Tatamutsi	0.27	7.53	0	0.08	1.90	0	0.37	10.33	0	0.07	1.59	0

Notes:

(a) BASELINE: Mitigation includes 75% control efficiency (CE) on unpaved surface roads and 50% CE on unpaved in-pit roads (using water sprays), 50% CE on primary and secondary crushing and materials handling operations (using water sprays), >75% CE for tertiary and fines crushing and screening (wet process)

(b) PROJECT: Mitigation includes all control measures listed in (a), but with 99% CE on primary and secondary crushing operations (dual scrubber).

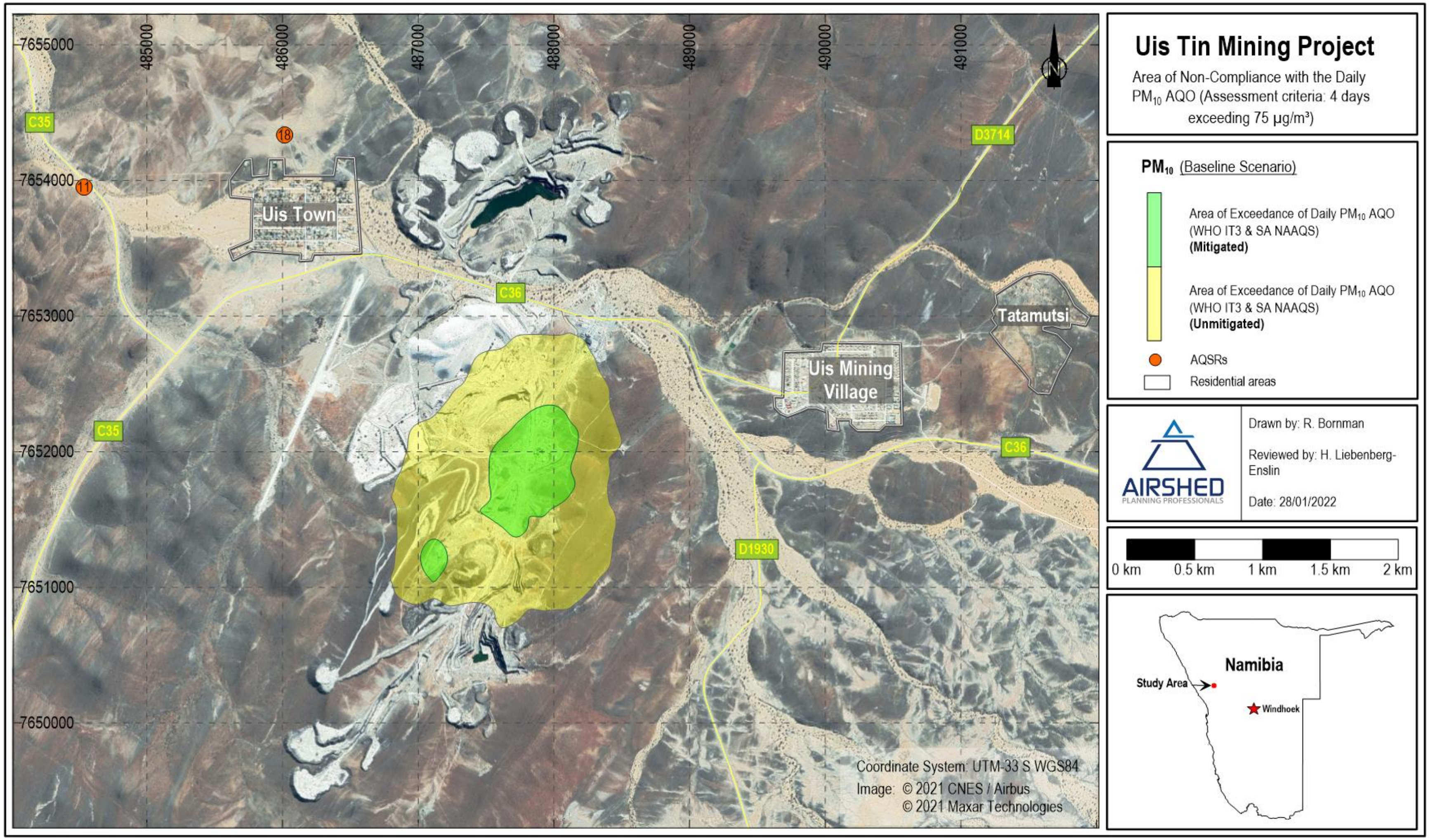


Figure 16: Area of non-compliance of daily PM_{10} AQO for unmitigated and mitigated Baseline operations

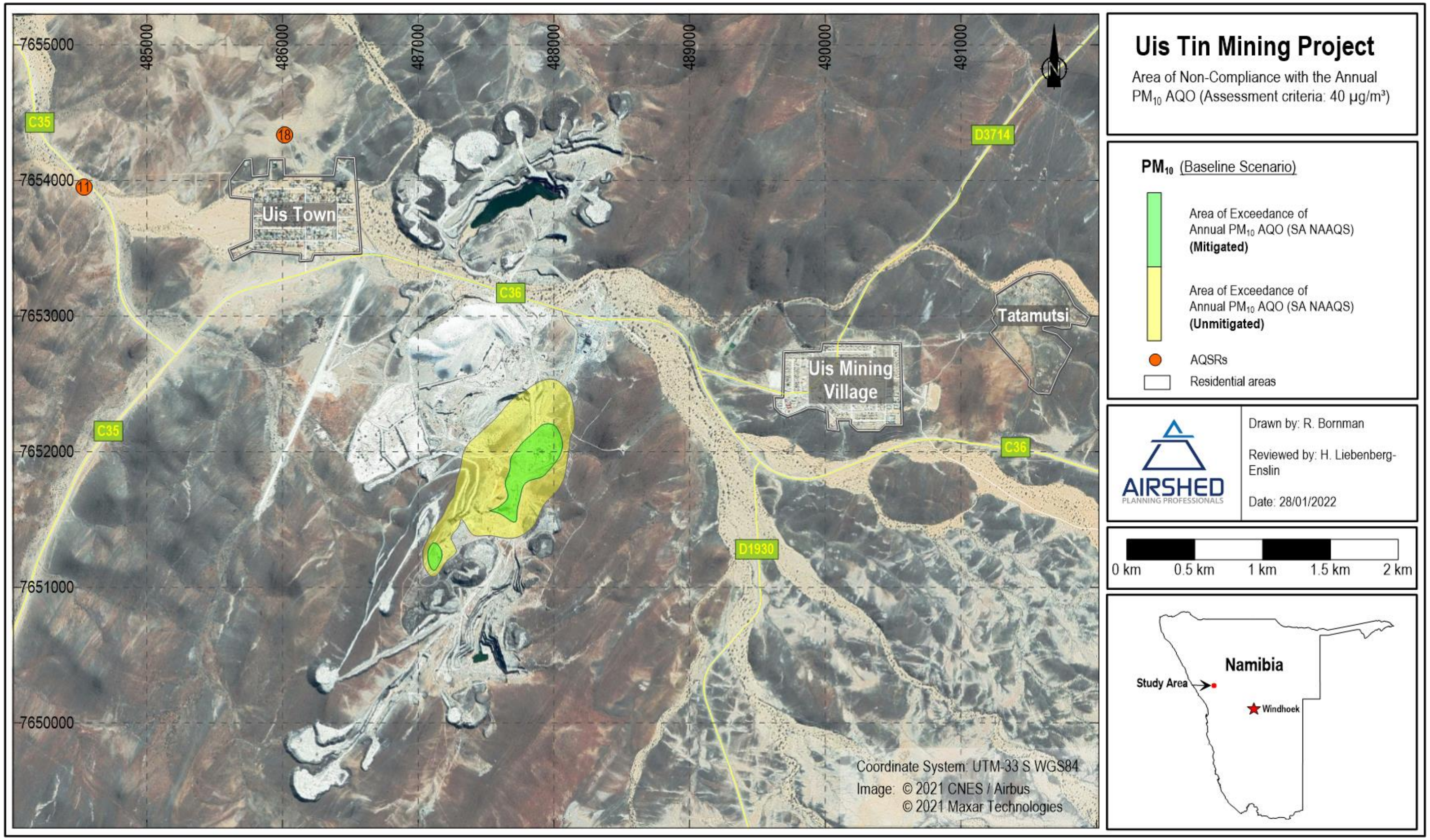


Figure 17: Area of non-compliance of annual PM_{10} AQO for unmitigated and mitigated Baseline operations

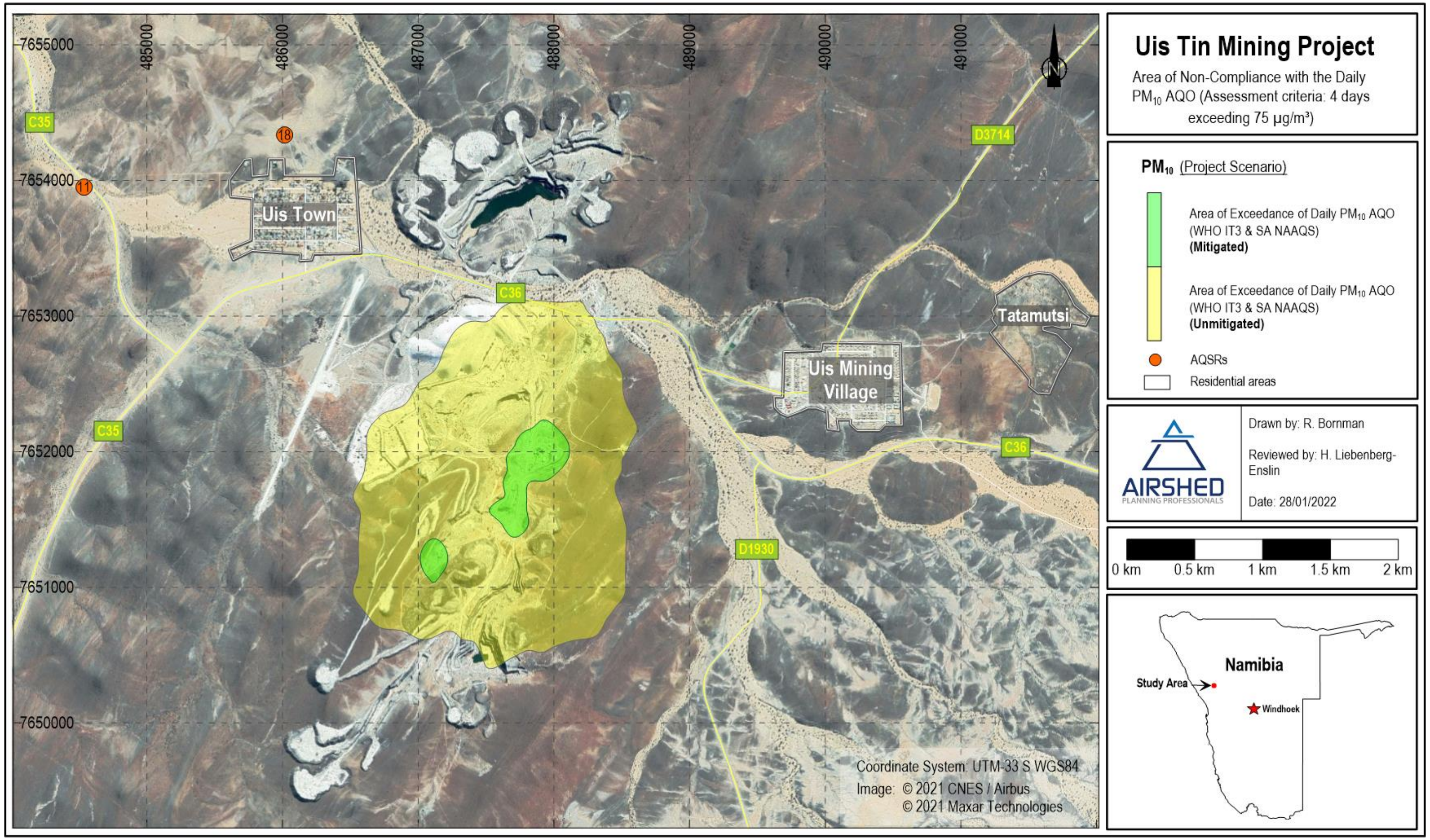


Figure 18: Area of non-compliance of daily PM_{10} AQO for unmitigated and mitigated Project operations

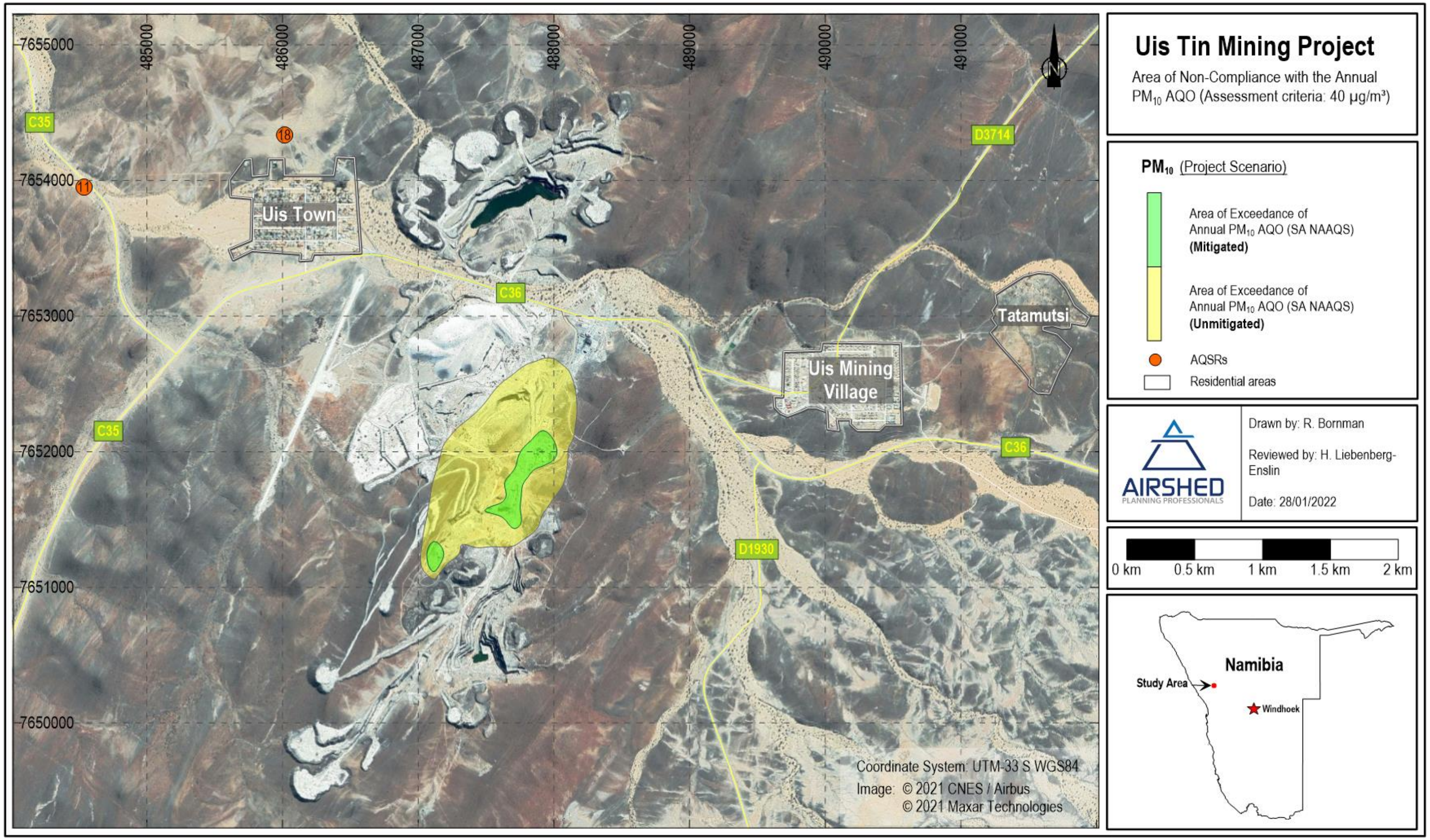


Figure 19: Area of non-compliance of annual PM_{10} AQO for unmitigated and mitigated Project operations

4.3.2 $PM_{2.5}$

4.3.2.1 Baseline Scenario

The simulated exceedances of highest daily and annual average $PM_{2.5}$ AQOs for unmitigated and mitigated Baseline operations are provided in Figure 20 and Figure 21 respectively, with the GLCs at the nearest AQSRs provided in Table 15.

$PM_{2.5}$ daily GLCs, for unmitigated activities, do not exceed the AQO (WHO IT-3) at any of the AQSRs but the footprint of exceedance extends ~300 m off-site. For mitigated activities, there are no exceedances at any of the AQSRs and impacts are limited to on-site areas. There are no exceedances of the annual $PM_{2.5}$ AQO, without and with mitigation in place.

4.3.2.2 Project Scenario

The simulated exceedances of highest daily and annual average $PM_{2.5}$ AQOs for unmitigated and mitigated Project operations are provided in Figure 22 and Figure 23 respectively, with the GLCs at the nearest AQSRs provided in Table 15.

For daily $PM_{2.5}$ the area of maximum unmitigated GLCs exceedance extends northwest from the Uis mining operations over a maximum distance of ~750 m, with no exceedances at any of the AQSRs. With mitigation in place there are no exceedances at any of the AQSRs and the impact is reduced to much smaller areas of exceedance, mainly on-site. Annual average $PM_{2.5}$ GLCs are low at all AQSRs.

Table 15: Simulated $PM_{2.5}$ ground level concentrations (in µg/m³) at selected AQSRs for BASELINE and PROJECT operations (non-compliance is highlighted)

AQSR	BASELINE						PROJECT					
	Unmitigated			Mitigated			Unmitigated			Mitigated		
	Annual Avg	Highest Day	FOE	Annual Avg	Highest Day	FOE	Annual Avg	Highest Day	FOE	Annual Avg	Highest Day	FOE
AQO	15 µg/m³	37.5 µg/m³	>4 days/year	15 µg/m³	37.5 µg/m³	>4 days/year	15 µg/m³	37.5 µg/m³	>4 days/year	15 µg/m³	37.5 µg/m³	>4 days/year
0	0.25	2.10	0	0.15	1.22	0	0.33	2.87	0	0.11	1.00	0
1	0.24	2.06	0	0.14	1.37	0	0.31	2.67	0	0.11	0.98	0
2	0.25	2.09	0	0.15	1.36	0	0.32	2.69	0	0.11	1.05	0
3	0.25	2.10	0	0.15	1.21	0	0.33	2.79	0	0.11	0.95	0
4	0.26	2.23	0	0.15	1.43	0	0.34	2.77	0	0.12	1.08	0
5	0.26	2.13	0	0.15	1.37	0	0.34	2.78	0	0.12	1.11	0
6	0.25	1.97	0	0.15	1.23	0	0.33	2.61	0	0.11	1.08	0
7	0.26	2.13	0	0.15	1.24	0	0.34	2.83	0	0.12	0.96	0
8	0.22	1.54	0	0.13	0.87	0	0.29	2.12	0	0.10	0.68	0
9	0.22	1.55	0	0.13	0.91	0	0.29	2.04	0	0.10	0.66	0
10	0.21	1.46	0	0.13	0.87	0	0.28	2.00	0	0.10	0.66	0
11	0.31	2.33	0	0.19	1.23	0	0.41	3.13	0	0.14	0.87	0
12	0.24	2.36	0	0.14	1.31	0	0.31	3.25	0	0.11	0.96	0
13	0.23	2.32	0	0.14	1.26	0	0.30	3.19	0	0.11	0.93	0
14	0.22	2.47	0	0.14	1.42	0	0.29	3.26	0	0.10	1.00	0
15	0.24	3.13	0	0.14	1.75	0	0.31	4.18	0	0.11	1.13	0
16	0.07	1.93	0	0.04	1.05	0	0.09	2.58	0	0.02	0.79	0
17	0.03	1.06	0	0.02	0.58	0	0.04	1.50	0	0.01	0.39	0
18	0.50	3.11	0	0.30	1.81	0	0.65	4.15	0	0.23	1.30	0
19	0.27	1.98	0	0.17	1.14	0	0.35	2.71	0	0.13	0.88	0
Uis Town	0.72	4.09	0	0.43	2.16	0	0.94	5.75	0	0.33	1.65	0
Uis Village	0.15	3.72	0	0.08	1.65	0	0.20	5.22	0	0.05	1.08	0
Tatamutsi	0.06	1.49	0	0.03	0.77	0	0.08	2.07	0	0.02	0.56	0

Notes:

(a) BASELINE: Mitigation includes 75% control efficiency (CE) on unpaved surface roads and 50% CE on unpaved in-pit roads (using water sprays), 50% CE on primary and secondary crushing and materials handling operations (using water sprays), >75% CE for tertiary and fines crushing and screening (wet process)

(b) PROJECT: Mitigation includes all control measures listed in (a), but with 99% CE on primary and secondary crushing operations.

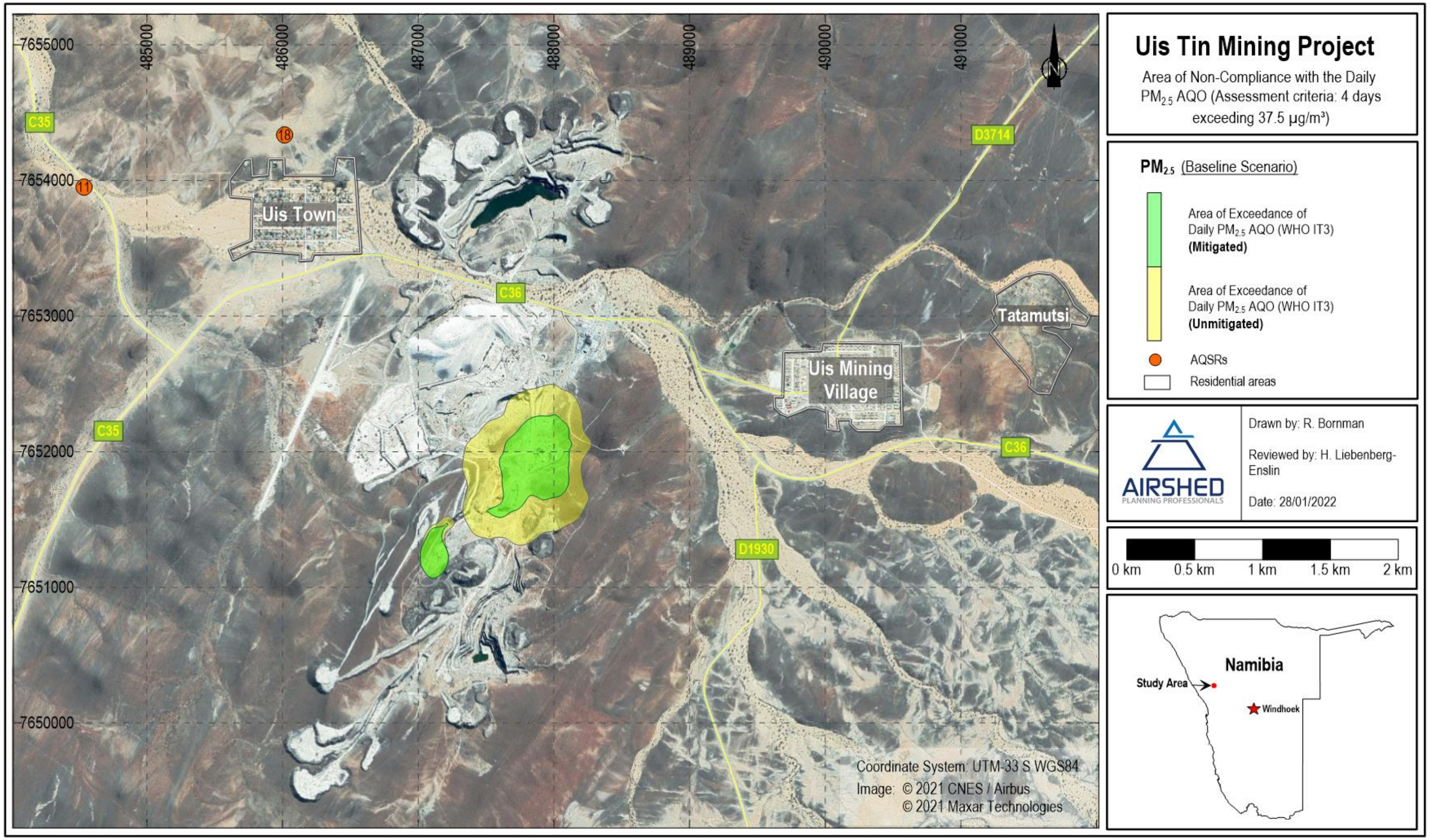


Figure 20: Area of non-compliance of daily $PM_{2.5}$ AQO for unmitigated and mitigated Baseline operations

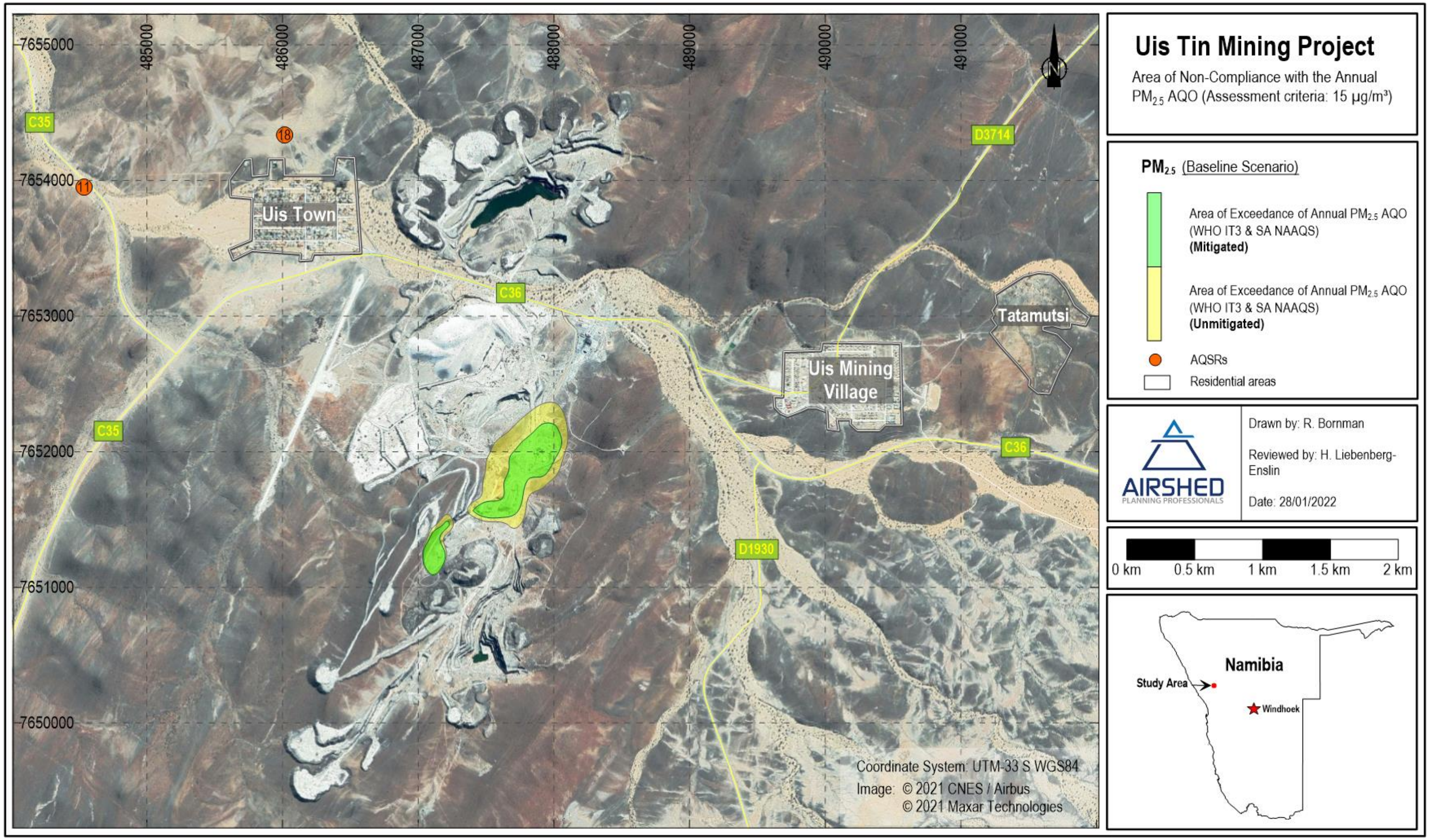


Figure 21: Area of non-compliance of annual $PM_{2.5}$ AQO for unmitigated and mitigated Baseline operations

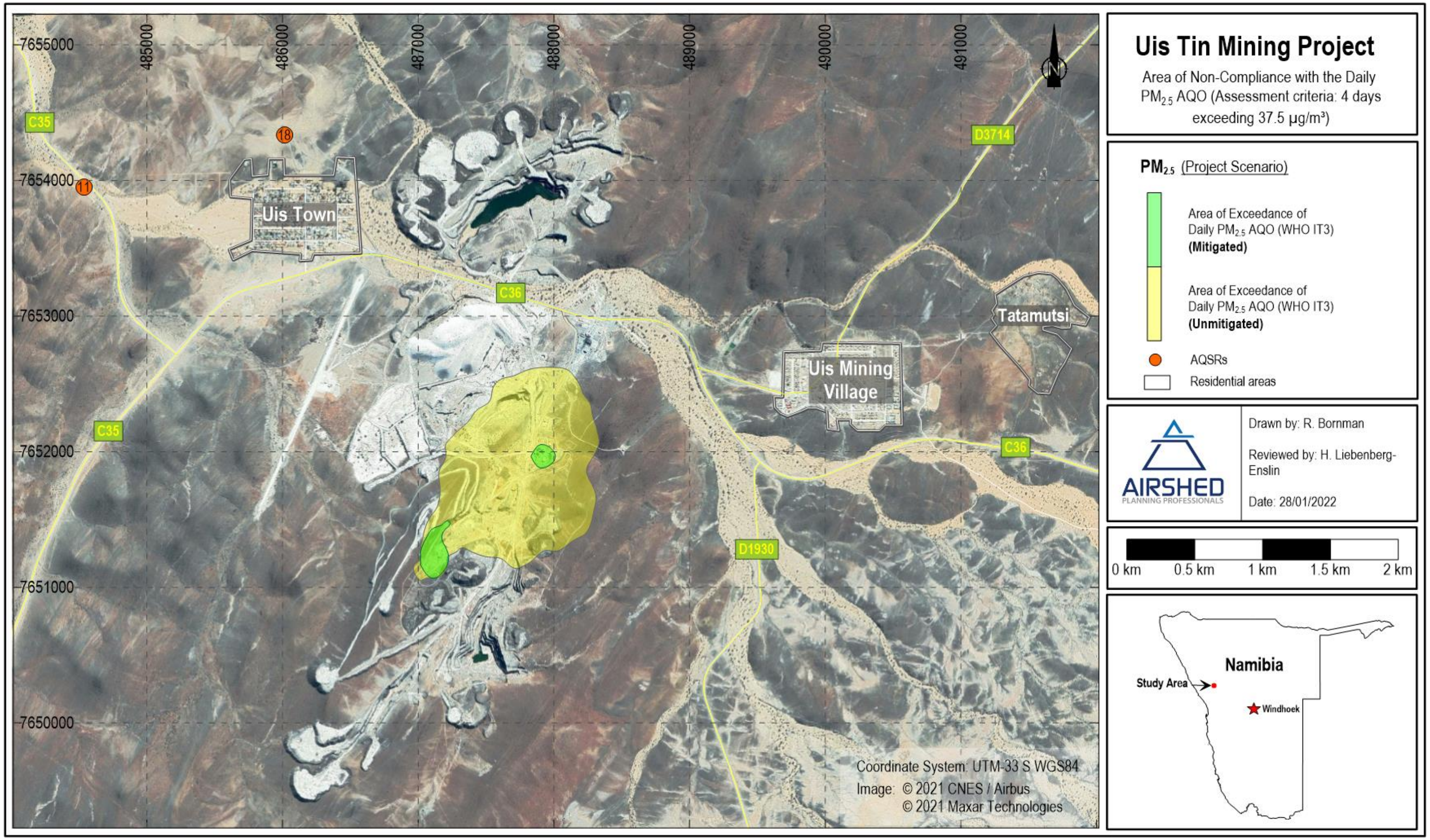


Figure 22: Area of non-compliance of daily $PM_{2.5}$ AQO for unmitigated and mitigated Project operations

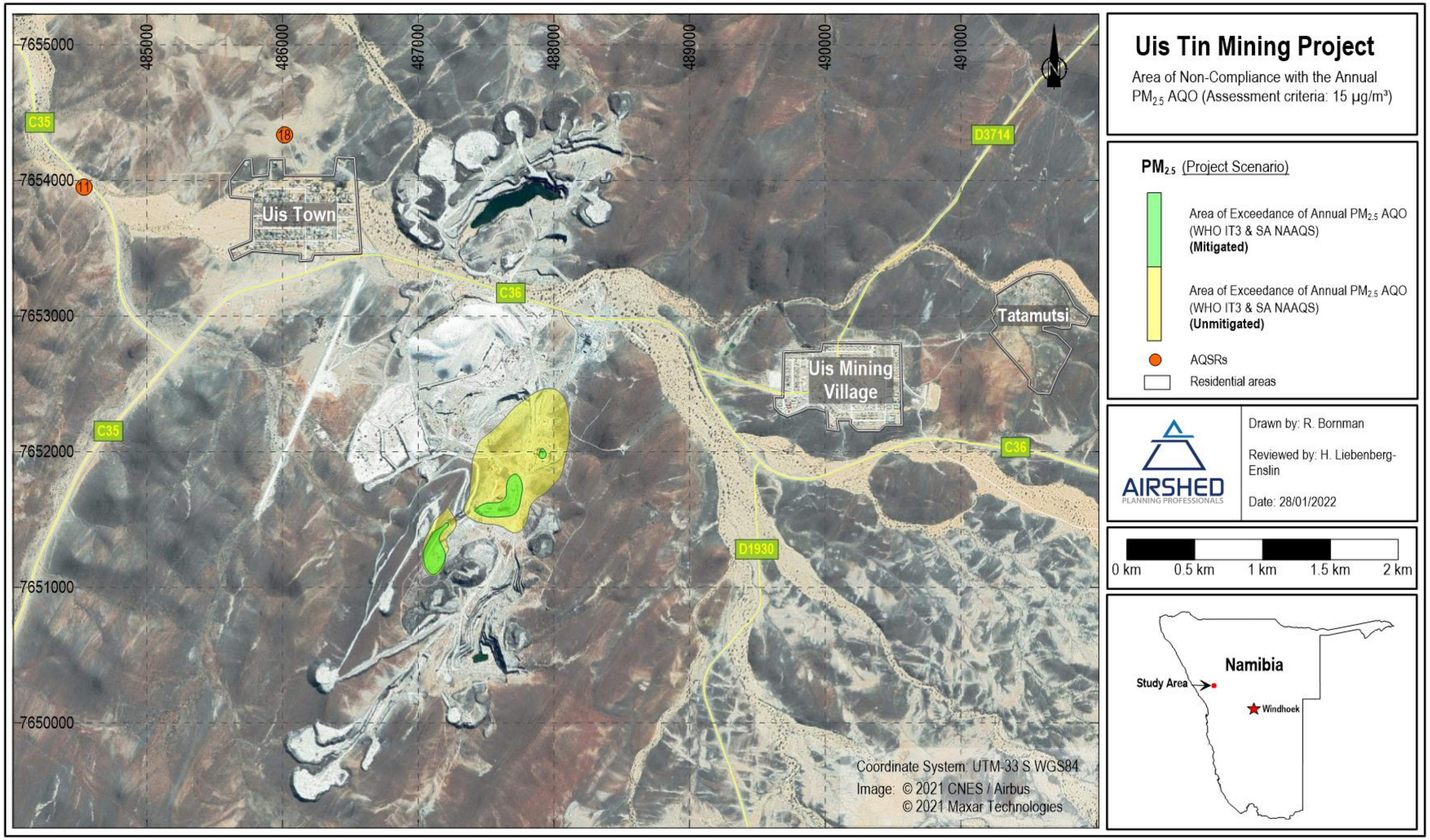


Figure 23: Area of non-compliance of annual $PM_{2.5}$ AQO for unmitigated and mitigated Project operations

4.3.3 Dustfall

The simulated daily dustfall rates for mitigated and unmitigated activities are provided in Figure 24 and Figure 25 respectively, with the values at each of the AQSRs provided in Table 16.

4.3.3.1 Baseline Scenario

Maximum daily dustfall rates, for both unmitigated and mitigated Baseline activities, are within the AQO (SA NDCR residential limit of 600 mg/m²/day) at all of the AQSRs (Table 16). Impacts are limited to on-site areas (Figure 24).

4.3.3.2 Project Scenario

Maximum daily dustfall rates, for both unmitigated and mitigated Project activities, are within the AQO (SA NDCR residential limit of 600 mg/m²/day) at all of the AQSRs (Table 16). Similar to the Baseline scenario, the footprint area of exceedance of the AQO is limited on-site (Figure 25).

Table 16: Simulated dustfall rates (in mg/m²/day) at selected AQSRs for BASELINE and PROJECT operations (non-compliance is highlighted)

AQSR	BASELINE		PROJECT	
	Unmitigated	Mitigated	Unmitigated	Mitigated
	Highest 30-day average	Highest 30-day average	Highest 30-day average	Highest 30-day average
AQO	600 mg/m²/day	600 mg/m²/day	600 mg/m²/day	600 mg/m²/day
0	0.44	0.15	0.63	0.10
1	0.38	0.13	0.55	0.09
2	0.42	0.14	0.60	0.10
3	0.43	0.15	0.62	0.10
4	0.44	0.15	0.64	0.10
5	0.44	0.15	0.63	0.10
6	0.41	0.14	0.59	0.09
7	0.44	0.15	0.64	0.10
8	0.57	0.20	0.83	0.13
9	0.58	0.20	0.84	0.13
10	0.54	0.19	0.79	0.12
11	1.01	0.35	1.46	0.24
12	0.69	0.28	0.98	0.21
13	0.65	0.26	0.92	0.20
14	0.83	0.33	1.17	0.26
15	1.02	0.41	1.44	0.32
16	0.36	0.13	0.51	0.10
17	0.23	0.09	0.32	0.07
18	1.72	0.61	2.50	0.45
19	0.69	0.24	1.01	0.16
Uis Town	3.19	1.14	4.64	0.90
Uis Village	1.30	0.54	1.79	0.42
Tatamutsi	0.36	0.14	0.50	0.11

Notes:

(a) BASELINE: Mitigation includes 75% control efficiency (CE) on unpaved surface roads and 50% CE on unpaved in-pit roads (using water sprays), 50% CE on primary and secondary crushing and materials handling operations (using water sprays), >75% CE for tertiary and fines crushing and screening (wet process).

(b) PROJECT: Mitigation includes all control measures listed in (a), but with 99% CE on primary and secondary crushing operations.

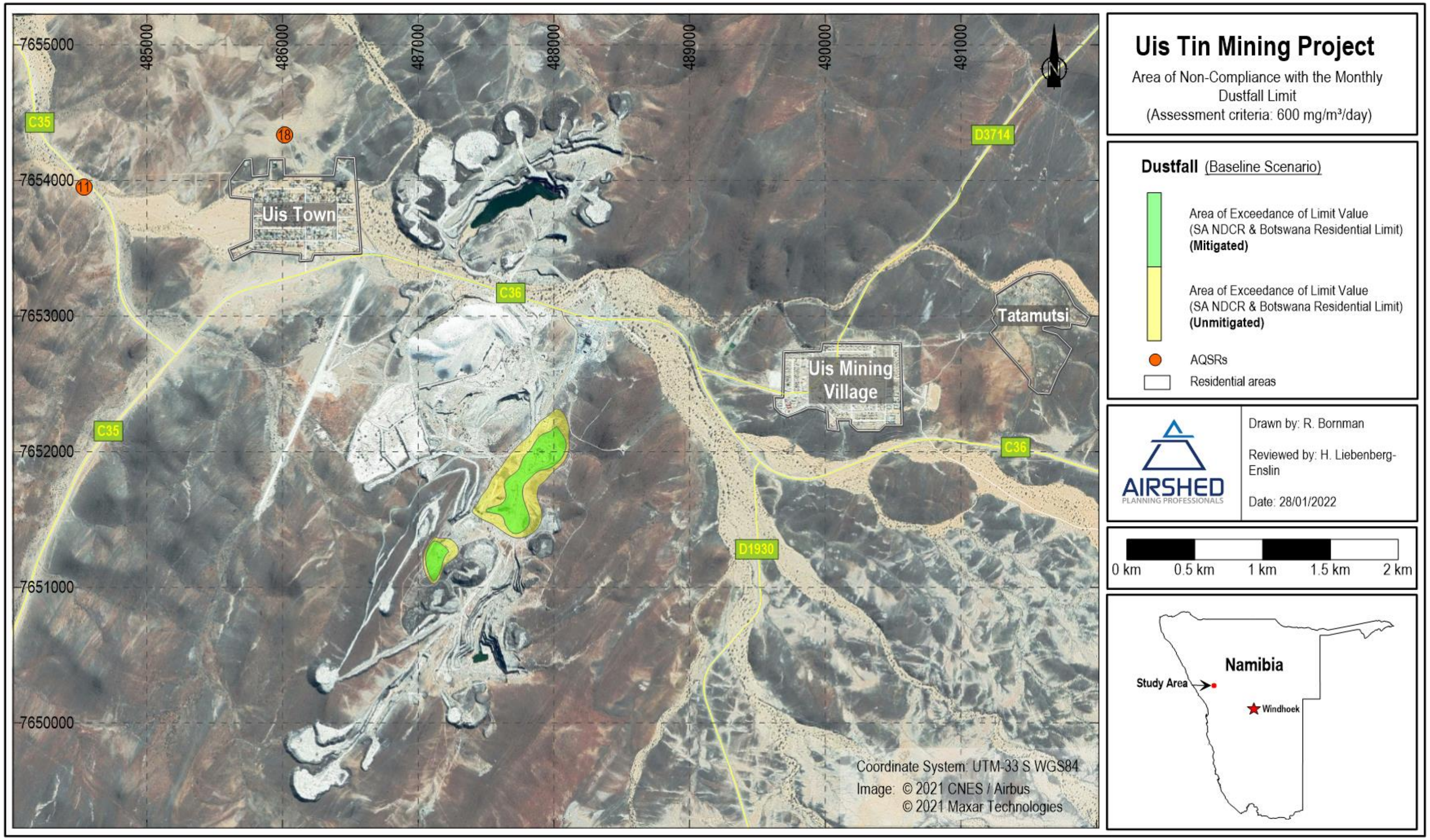


Figure 24: Area of non-compliance of dustfall limit values for unmitigated and mitigated Baseline operations

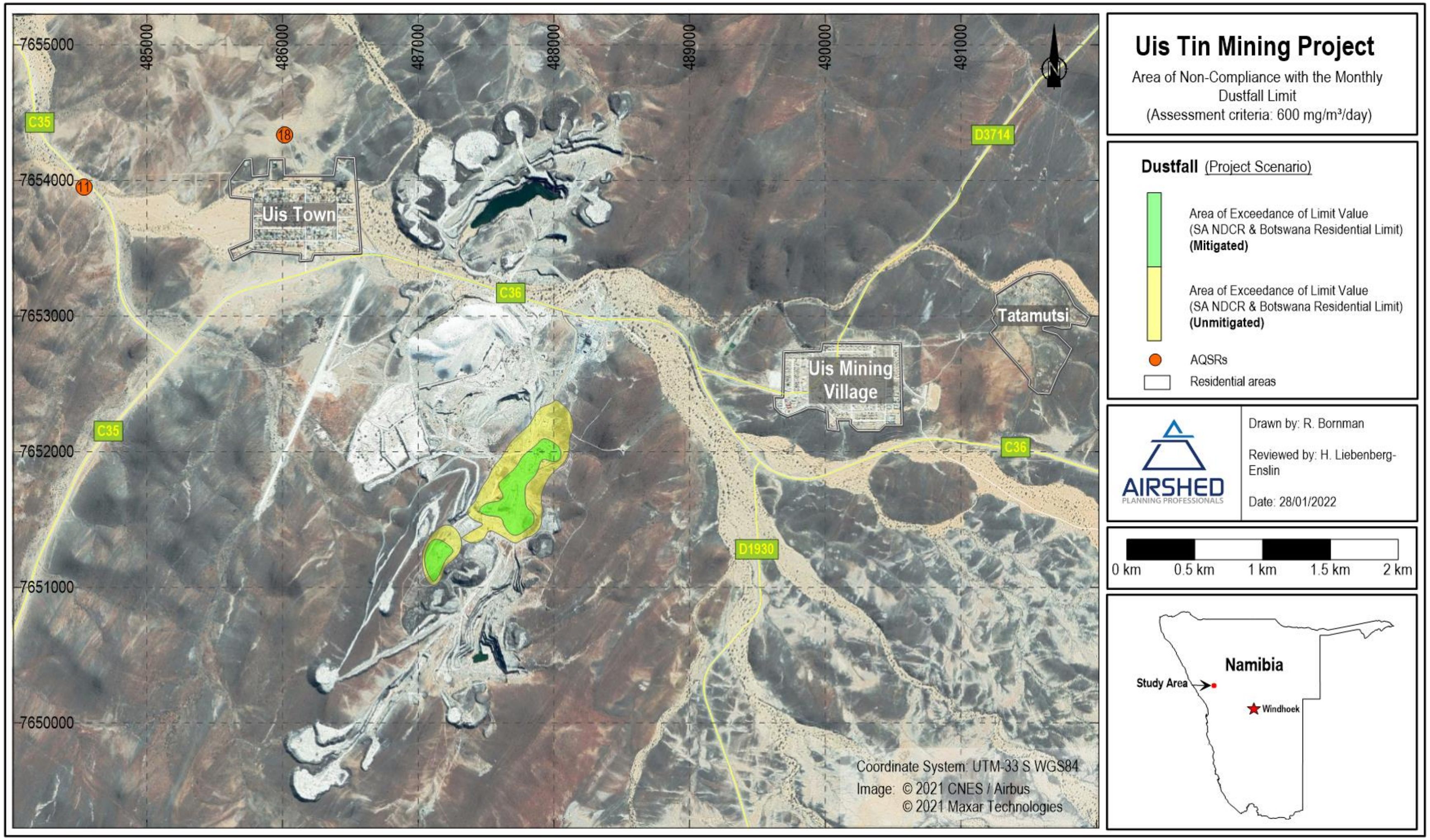


Figure 25: Area of non-compliance of dustfall limit values for unmitigated and mitigated Project operations

5 ESIA AMENDMENT – IMPACT OF PROPOSED PROJECT ON THE RECEIVING ENVIRONMENT

5.1 Project Description

The ESIA for the Uis Tin Mine is to be amended to include material changes they intend to add to their existing operations. A bulk sampling, and ore sorting and testing facility (from now on referred to as the Petalite Beneficiation Plant) will be constructed to extract the lithium-bearing ore. This will then be fed to a petalite beneficiation plant where the lithium will be extracted and processed. The waste from these two processes will be captured and handled in what the mine terms a waste neutralisation facility.

The purpose of the bulk sample processing facility is to undertake metallurgical test work on the material from the existing mine pits, as well as from external areas where exploration work is being undertaken to assess the process required to extract minerals from the ore(s). The proposed location of the facility is shown in Figure 26. Extraction of minerals such as tin, tungsten, tantalum, lithium, copper, silver and gold will be assessed. The facility is a testing facility, which will not run continuously. Testing campaigns will run for a maximum of 100 hours (approximately 4 days) after which the plant will be stopped for cleaning to prevent contamination between sampling campaigns. It is expected that one testing campaign will run per month, with a maximum of two. The facility will comprise a ROM pad, the metallurgical support facility (MSF), the bulk splitting area and the dense media separation (DMS) and flotation processing facilities (Figure 27).

Waste neutralisation will be part of the DMS and flotation circuit and is probably going to take place prior to the filter press (or will occur within the filter press). This means that both the water and discard (filter cakes) will be neutralised.

The mining fleet will not be impacted by this testing facility. Earth moving equipment (i.e., ~ 1 x front-end loader and 1 x bobcat) will be used to move material within the testing facility during the bulk sampling and testing campaigns. External traffic for the bulk sampling and testing campaigns include: 1 x truck delivering hydrogen fluoride (HF) and 1 x truck delivering sulfuric acid (H_2SO_4). This will be separate to the current mining fleet and will be trucks specifically assigned/contracted for this process.

The activities that could potentially give rise to atmospheric emissions are discussed in Section 5.2. The throughputs that were used to calculate emissions for the Incremental Project scenario are provided in Table 17.

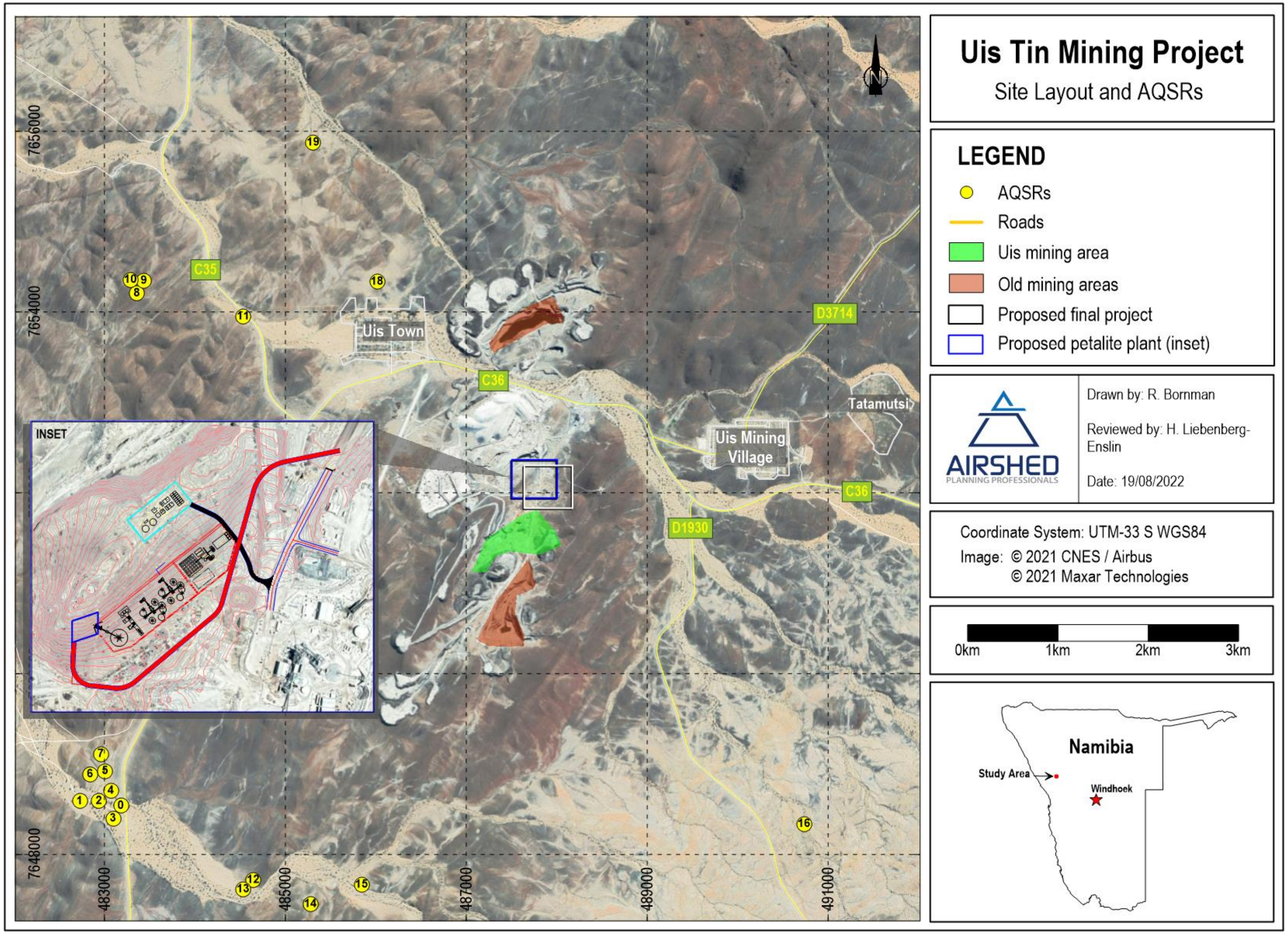


Figure 26: Proposed Petalite Beneficiation Plant location (relative to Uis Mining Project)

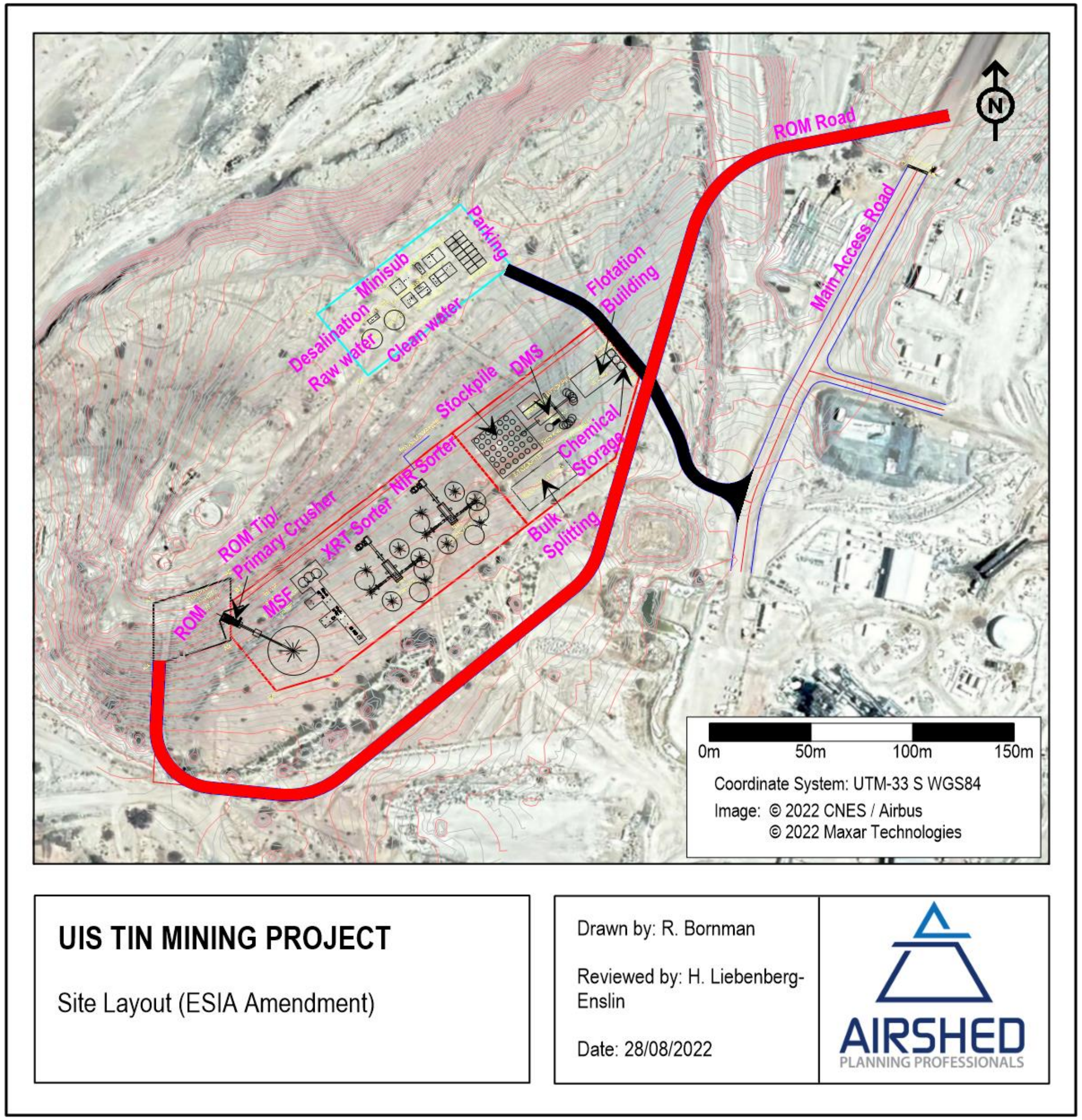


Figure 27: Proposed Petalite Beneficiation Plant layout

5.2 Atmospheric Emissions

The process flow diagram is shown in Figure 28. The proposed operations that may cause atmospheric emissions include:

- materials handling
- crushing
- drying and classification
- unpaved roads, and
- wind erosion.

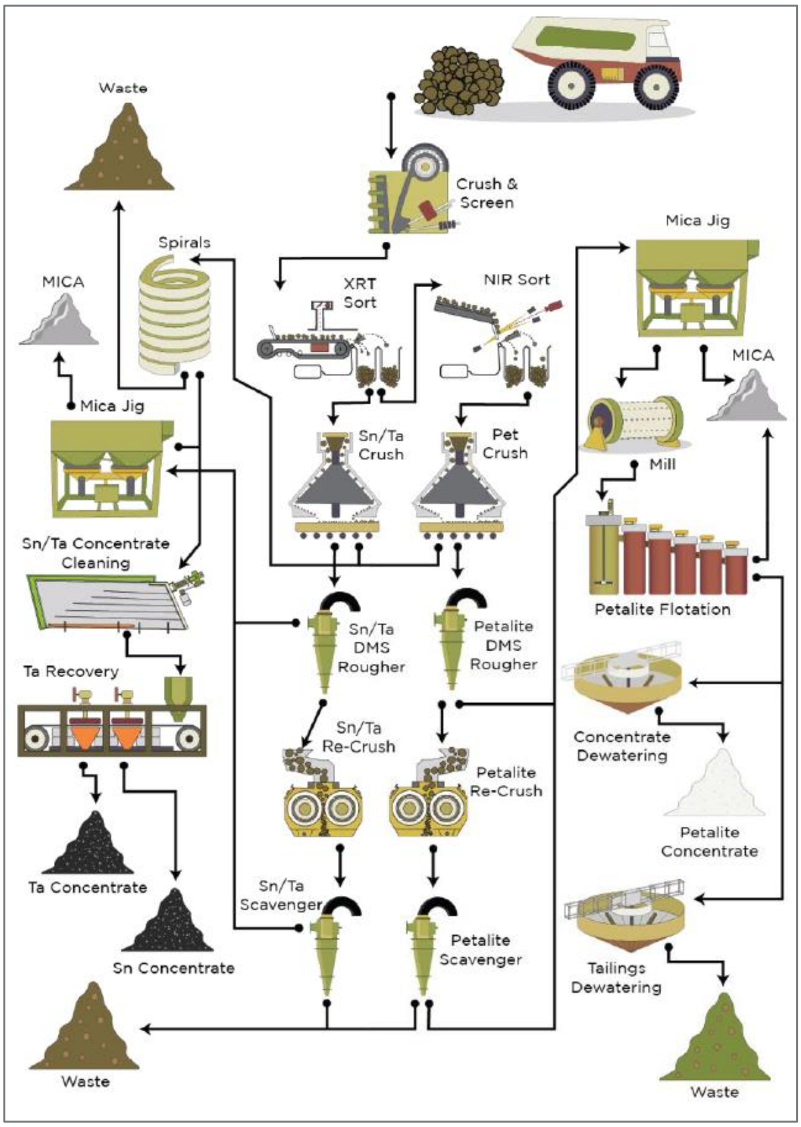


Figure 28: Flow diagram for the proposed Petalite Beneficiation Plant project

5.2.1 Emissions Inventory

Two operational scenarios were assessed, namely the incremental and cumulative Petalite Beneficiation Plant scenarios, each with an unmitigated and mitigated sub-scenario.

Operational hours were provided as continuous for DMS operations and daytime (assumed to be 10 hours) for all other activities. The throughputs that were used in the calculation of emissions are given in Table 17. Emission equations from Table 9 were used for materials handling[4], crushing[5] and unpaved roads[6]. Emission equations for drying and classification and wind erosion[7] are provided in Table 18. Summaries of particulate emissions for routine operations due to the Incremental and Cumulative Project scenarios are provided in Table 19 and source group contributions to total $PM_{2.5}$, PM_{10} and TSP emissions for the Incremental Project scenario are shown in Figure 29 and Figure 30 for unmitigated and design mitigated activities respectively.

Table 17: Throughputs used in the emissions inventory (in tph and tpm)

	Throughput		Comment
	tph (max)	tpm	
ROM	5.00	2000	Maximum 5 tph (client info)
HF	0.02	5	Client info
H_2SO_4	0.01	3	Client info
Product (Petalite)	1.75	700	Client info (35%)
Product (Sn)	0.15	60	Assume same as Mica
Product (Ta)	0.15	60	Assume same as Mica
Product (Mica)	0.15	60	Client info (3%)
Tailings	51.78	932	Client info
Waste	10.44	188	Calculated

[4] Materials handling includes offloading and loading ROM ore at feed pad, tip to ROM crushed ore stockpile, transfer to XRT and NRI sorters, tipping at XRT and NRI stockpiles, tipping at re-crushed ore stockpiles, offloading and loading of HF and H_2SO_4, and loading of product stockpiles.
[5] Primary crushing was assumed to take place at a rate of 5 tph. Secondary cone crushing of Sn/Ta and petalite was assumed to take place at a rate of 1.5 tph and 3.5 tph respectively. Ore was assumed to be low moisture ore.
[6] Unpaved roads include the main access road from the C36, the ROM road and the road to the parking space and office buildings. The load capacity of the vehicle transporting ROM was assumed as 20 tonnes, and the vehicle transporting chemicals was assumed to have 8 tonne capacity.
[7] Since no particle size distributions for the various stockpile materials were available, a general emission equation was used to estimate emissions due to wind erosion and applied in an hourly file for hours where the wind speed exceeds 5.4 m/s.

Table 18: Emission equations used to quantify the routine emissions from the proposed Petalite Beneficiation Plant

<table>
<tr><th>Activity</th><th>Emission Equation</th><th>Source</th><th>Information assumed/provided</th></tr>
<tr><td>Drying and Classifying</td><td>
<table>
<tr><th></th><th>$E_{(Uncontrolled)}$</th><th></th><th></th><th>$E_{(Controlled)}$</th><th></th><th></th></tr>
<tr><th></th><th>$PM_{2.5}$</th><th>PM_{10}</th><th>TSP</th><th>$PM_{2.5}$</th><th>PM_{10}</th><th>TSP</th></tr>
<tr><td>Flash drying</td><td>0.05</td><td>0.087</td><td>0.160</td><td>0.0042</td><td>0.0073</td><td>0.0134</td></tr>
<tr><td>Classifying</td><td>0.024</td><td>0.062</td><td>0.133</td><td>0.0020</td><td>0.0052</td><td>0.0112</td></tr>
<tr><td>Product storage</td><td>0.007</td><td>0.020</td><td>0.134</td><td>0.0003</td><td>0.0008</td><td>0.0055</td></tr>
</table>
Where,
E = particulate emission factor drying, classifying and product storage in kg/ton</td><td>US-EPA AP42
Table 11.19.2-3</td><td>Drying and classifying were modelled at the DMS and bulk splitting areas and product storage at the product stockpile.

Mitigation measures include fabric filter control for flash drying, classifying and product storage activities.</td></tr>
<tr><td>Wind Erosion</td><td>

$$E_{TSP} = 0.4\frac{kg}{ha}/\text{hr}$$

$$E_{PM_{10}} = 0.2\frac{kg}{ha}/\text{hr}$$

Where,
E = particulate emission factor for windblown dust from storage piles in kilogram per hectare per hour.</td><td>NPi Section: Mining</td><td>The areas of the various stockpiles were on-screen digitised from the layout as follows:
<table>
<tr><th></th><th>Hectares (ha)</th></tr>
<tr><td>ROM feed pad:</td><td>0.12</td></tr>
<tr><td>Crushed ROM SP (Sn/Ta):</td><td>0.06</td></tr>
<tr><td>Crushed ROM SP (petalite):</td><td>0.003</td></tr>
<tr><td>Petalite product SP:</td><td>0.06</td></tr>
<tr><td>Sn/Ta concentrate SP:</td><td>0.003</td></tr>
<tr><td>Mica SP:</td><td>0.003</td></tr>
</table></td></tr>
</table>

Table 19: Calculated emission rates due to unmitigated and mitigated activities for the incremental and cumulative Petalite Beneficiation Plant scenarios respectively

Description	Incremental Project Scenario						Cumulative Project Scenario					
	Unmitigated			Mitigated			Unmitigated			Mitigated		
	$PM_{2.5}$	PM_{10}	TSP	$PM_{2.5}$	PM_{10}	TSP	$PM_{2.5}$	PM_{10}	TSP	$PM_{2.5}$	PM_{10}	TSP
In-pit (including drilling)	–	–	–	–	–	–	52.76	89.71	233.38	50.62	69.1	162.84
Blasting	–	–	–	–	–	–	0.06	1.04	24.4	0.06	1.04	24.4
Materials handling	0.04	0.28	0.58	0.02	0.14	0.29	1.36	9.02	19.05	0.56	3.69	7.8
Crushing and screening	0.91	1.83	25.55	0.46	0.91	12.78	26.18	113.84	821.95	0.89	4.65	25.58
Drying and Classifying	1.44	2.97	7.32	0.12	0.24	0.53	1.44	2.97	7.32	0.12	0.24	0.53
Unpaved roads	0.33	3.33	11.72	0.08	0.83	2.93	13.48	134.79	471.71	3.37	33.69	117.93
Wind erosion	0.02	0.15	0.30	0.02	0.15	0.30	3.61	13.12	50.21	3.61	13.12	50.21
Total	**3**	**9**	**45**	**1**	**2**	**17**	**99**	**364**	**1628**	**59**	**126**	**390**

Notes:

(a) Incremental Project: Mitigation includes 75% control efficiency (CE) on unpaved surface roads (using water sprays), 50% CE on primary and secondary crushing and materials handling operations (using water sprays), >90% CE for drying, classifying and product storage (using fabric filters)

(b) Cumulative Project: Mitigation includes all control measures listed in (a), but with additional measures listed under Table 13 (PROJECT scenario).

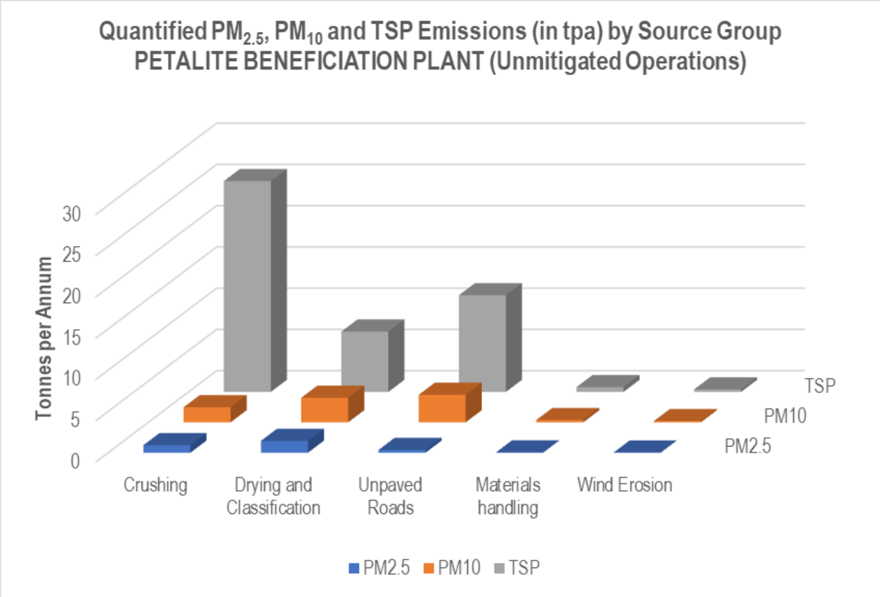


Figure 29: Contribution of particulate emissions per source group (unmitigated)

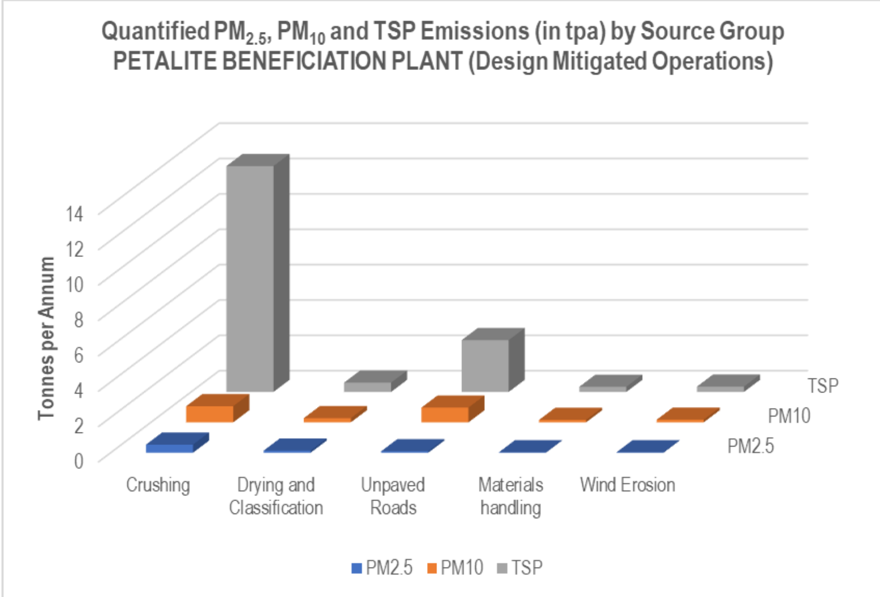


Figure 30: Contribution of particulate emissions per source group (design mitigated)

5.3 Atmospheric Dispersion Modelling

The impact of proposed operations on the atmospheric environment was determined through the simulation of ambient pollutant concentrations using the ADMS model.

The dispersion of pollutants was modelled for an area covering 10 km by 10 km with the grid matrix divided with a resolution of 100 m. The surrounding receptors were included as discrete receptors. Topography was included in dispersion simulations.

5.4 Dispersion Modelling Results

5.4.1 Incremental Petalite Beneficiation Plant Scenario

The isopleth plots in this section reflect simulated PM_{10} daily concentrations due to unmitigated and mitigated activities (Figure 31 and Figure 32), simulated $PM_{2.5}$ daily concentrations due to unmitigated and mitigated activities (Figure 33 and Figure 34) and simulated dust fallout rates due to unmitigated and mitigated activities (Figure 35 and Figure 36). The simulated incremental GLCs for $PM_{2.5}$ and PM_{10} (in µg/m³) and maximum daily dustfall rates (in mg/m²/day) are provided in Table 20.

From Figure 31 and Figure 33 PM_{10} and $PM_{2.5}$ daily GLCs, for unmitigated activities, result in exceedances of the 24-hour air quality objective (AQO) over a maximum distance of ~90 m from on-site activities, and from Figure 35 the footprint of exceedance of maximum daily dustfall rates exceed the AQO within 125 m from the facility's activities, but with no exceedances at any of the AQSRs. For mitigated activities, PM_{10} and $PM_{2.5}$ daily GLCs are within the AQO both on-site and at AQSRs, whereas dustfall rates exceeding the AQO are limited to an area surrounding the primary crusher. From Table 20 it may be seen that simulated values for PM_{10}, $PM_{2.5}$ and maximum daily dustfall rates are negligibly small.

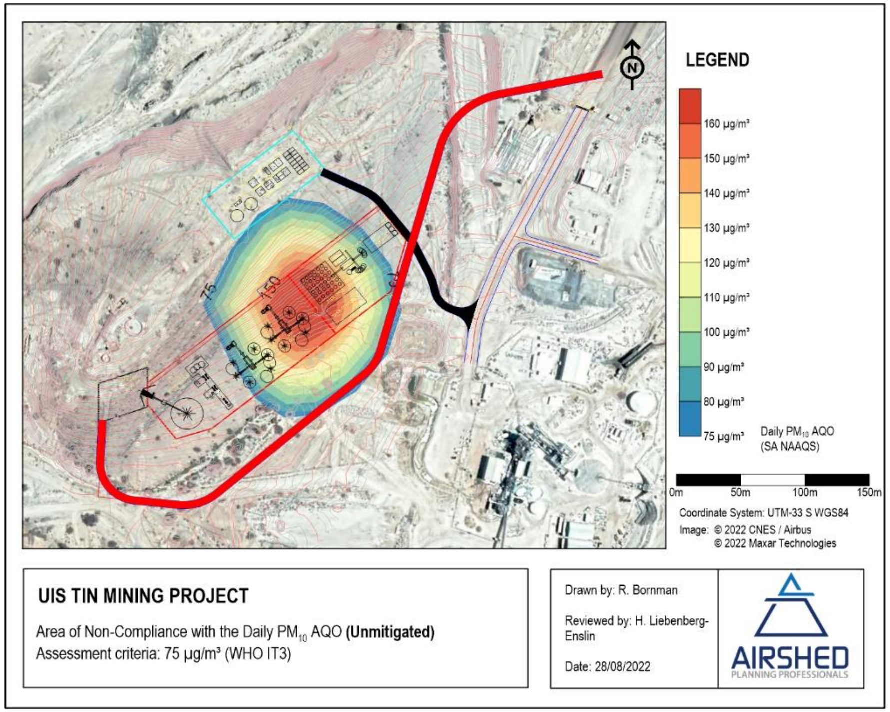


Figure 31: Area of non-compliance of daily PM_{10} AQO for unmitigated incremental operations

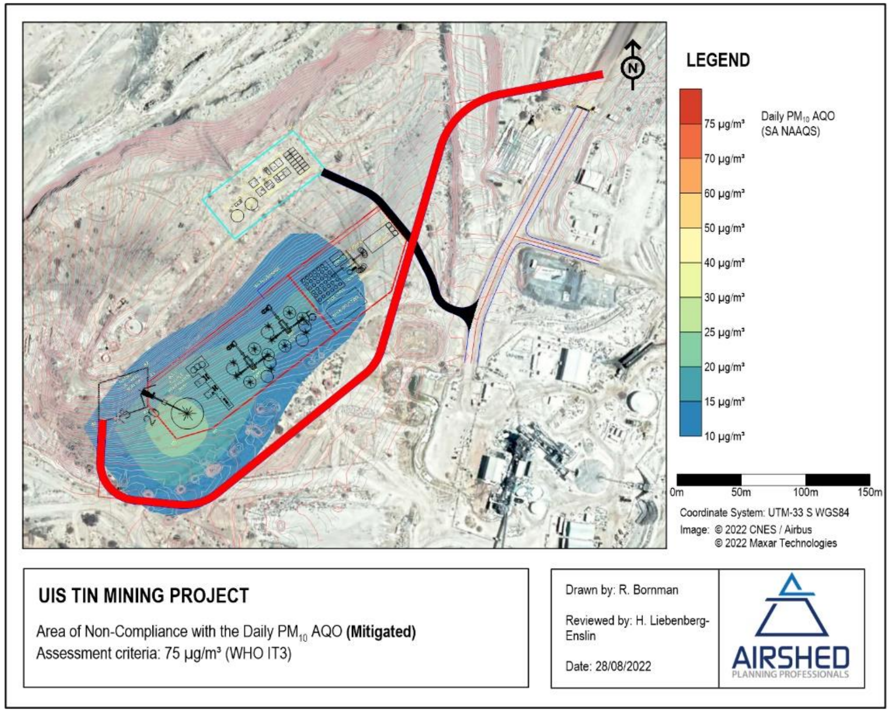


Figure 32: Area of non-compliance of daily PM_{10} AQO for mitigated incremental operations

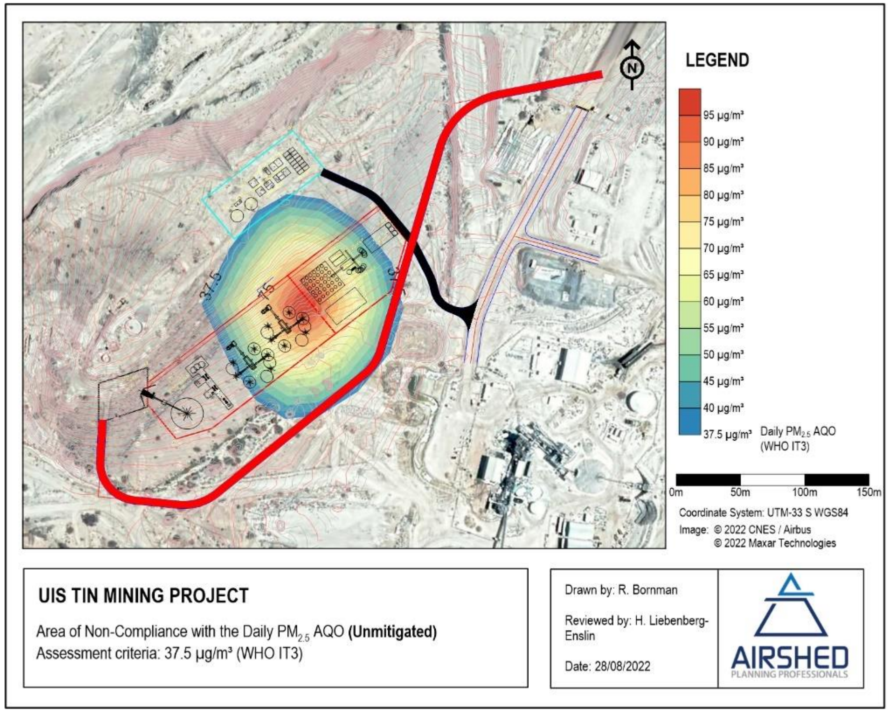


Figure 33: Area of non-compliance of daily $PM_{2.5}$ AQO for unmitigated incremental operations

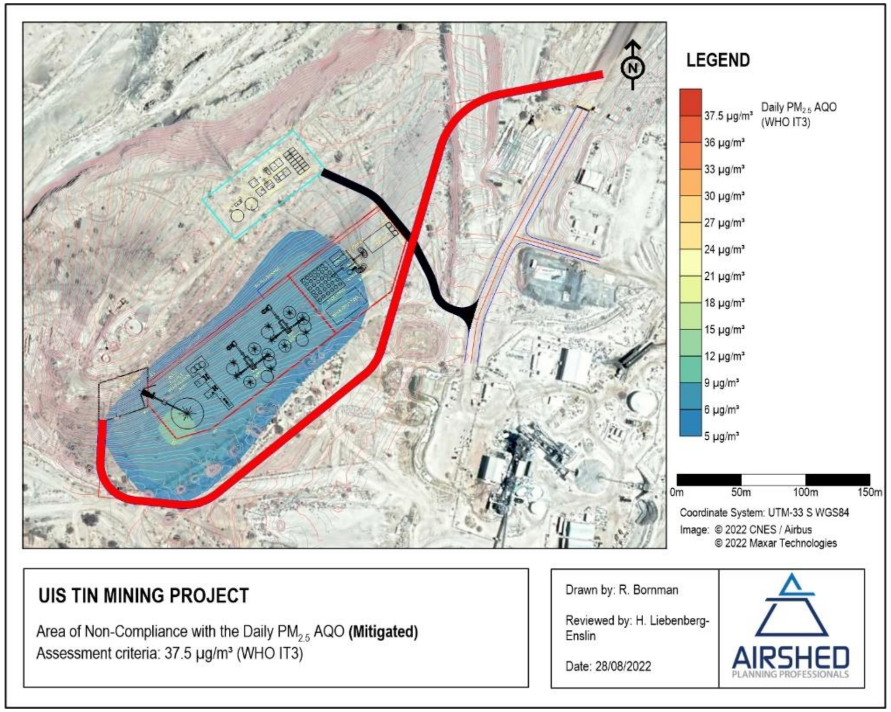


Figure 34: Area of non-compliance of daily $PM_{2.5}$ AQO for mitigated incremental operations

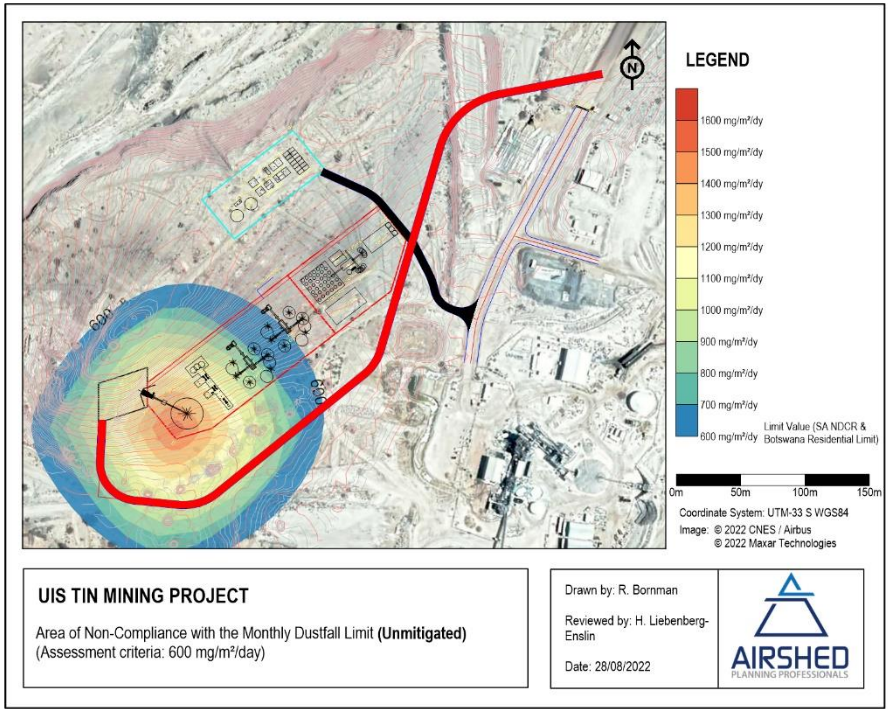


Figure 35: Area of non-compliance of dustfall limit values for unmitigated incremental operations

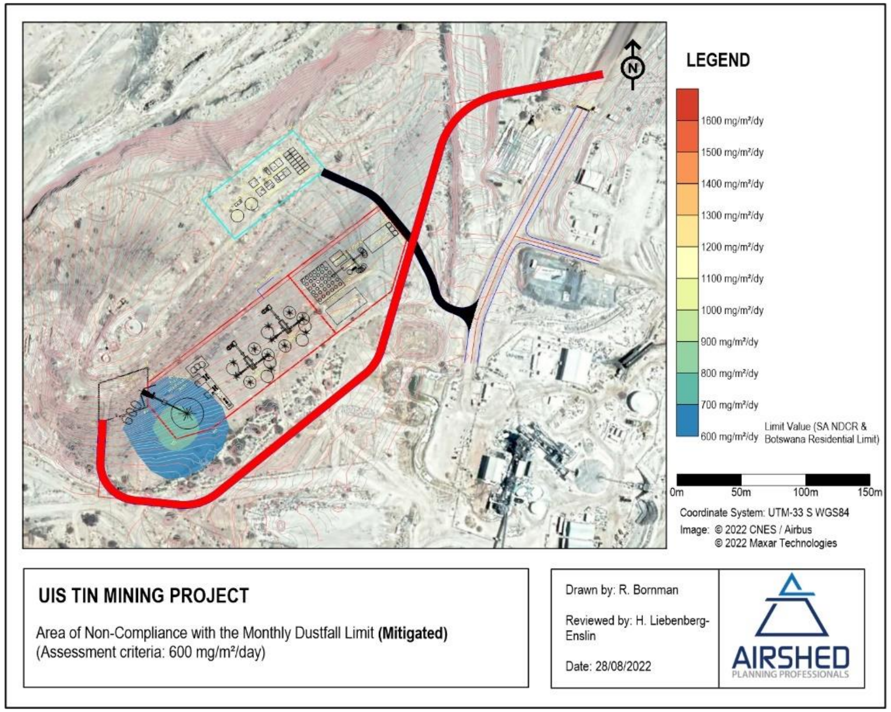


Figure 36: Area of non-compliance of dustfall limit values for mitigated incremental operations

Table 20: Simulated PM_{10} and $PM_{2.5}$ ground level concentrations (in µg/m³) and maximum daily dustfall rates (in mg/m²/day) at selected AQSRs for incremental Petalite Beneficiation Plant operations

AQSR	Petalite Beneficiation Plant (Incremental)					
	Unmitigated			Mitigated		
	$PM_{2.5}$ Highest Day	PM_{10} Highest Day	Dust Fallout Highest Monthly	$PM_{2.5}$ Highest Day	PM_{10} Highest Day	Dust Fallout Highest Monthly
AQO	37.5 µg/m³	75 µg/m³	600 mg/m2/day	37.5 µg/m³	75 µg/m³	600 mg/m2/day
0	0.05	0.10	0.02	0.01	0.02	0.01
1	0.05	0.09	0.01	0.01	0.02	0.00
2	0.05	0.10	0.02	0.01	0.02	0.01
3	0.05	0.09	0.02	0.01	0.02	0.01
4	0.05	0.10	0.02	0.01	0.02	0.01
5	0.05	0.10	0.01	0.01	0.02	0.01
6	0.05	0.09	0.01	0.01	0.02	0.00
7	0.05	0.09	0.01	0.01	0.02	0.00
8	0.04	0.08	0.01	0.00	0.01	0.00
9	0.04	0.08	0.01	0.00	0.01	0.00
10	0.04	0.08	0.01	0.00	0.01	0.00
11	0.06	0.12	0.02	0.01	0.01	0.00
12	0.06	0.11	0.08	0.01	0.02	0.03
13	0.05	0.10	0.07	0.01	0.02	0.03
14	0.06	0.13	0.10	0.01	0.02	0.04
15	0.09	0.16	0.12	0.01	0.03	0.05
16	0.05	0.09	0.03	0.01	0.01	0.01
17	0.03	0.05	0.02	0.00	0.01	0.01
18	0.11	0.20	0.03	0.01	0.02	0.01
19	0.05	0.09	0.01	0.00	0.01	0.00
Uis Town	0.15	0.28	0.08	0.01	0.02	0.03
Uis Village	0.11	0.20	0.05	0.01	0.02	0.01
Tatamutsi	0.04	0.07	0.03	0.00	0.01	0.01

Notes:

INCREMENTAL PROJECT: 50% CE on primary and secondary crushing and materials handling operations (using water sprays), 75% CE on unpaved surface roads, >90% CE on drying, classifying and product storage through fabric filter control.

5.4.2 Cumulative Project Scenario

Simulated PM_{10} exceedances of highest daily AQO due to cumulative unmitigated and mitigated activities are shown in Figure 37. Similarly, simulated $PM_{2.5}$ exceedances of highest daily AQO due to cumulative unmitigated and mitigated activities are shown in Figure 38 and simulated daily dustfall rates due to cumulative mitigated and unmitigated activities are depicted in Figure 39. The simulated cumulative GLCs for $PM_{2.5}$ and PM_{10} (in $\mu g/m^3$) and maximum daily dustfall rates (in $mg/m^2/day$) are provided in Table 21.

A comparison between isopleth plots in this section and Sections 4.3.1.2, 4.3.2.2 and 4.3.3.2 reveals that the cumulative plots including the Petalite Beneficiation Plant are not significantly different from those for the Project Scenario in Section 4.3. The numerical results in Table 14, Table 15 and Table 16 are also not significantly different from those in Table 21. It may therefore be concluded that the conclusions from this report would not change as a result of the Petalite Beneficiation Plant.

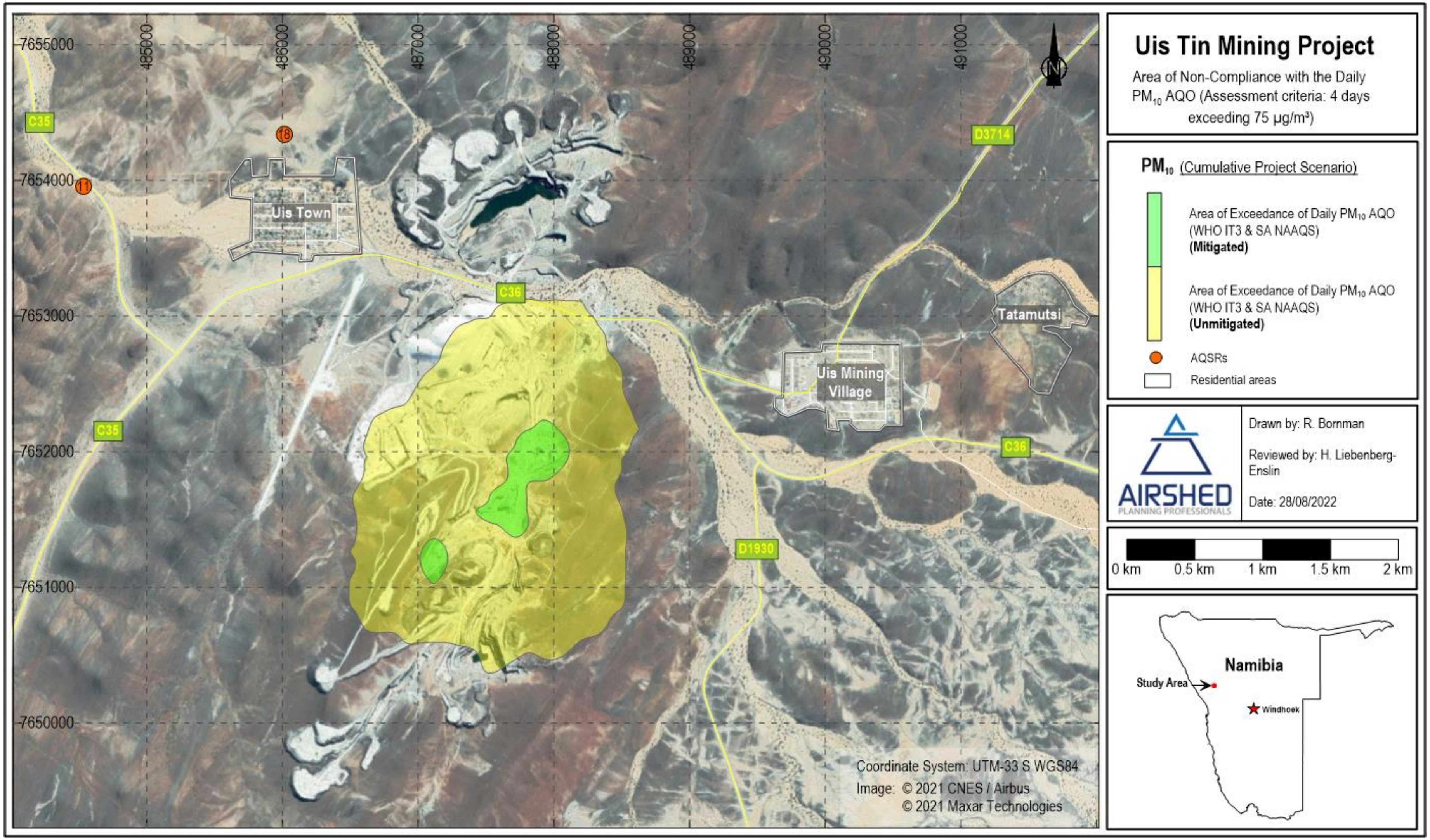


Figure 37: Area of non-compliance of daily PM_{10} AQO for unmitigated and mitigated cumulative Project operations

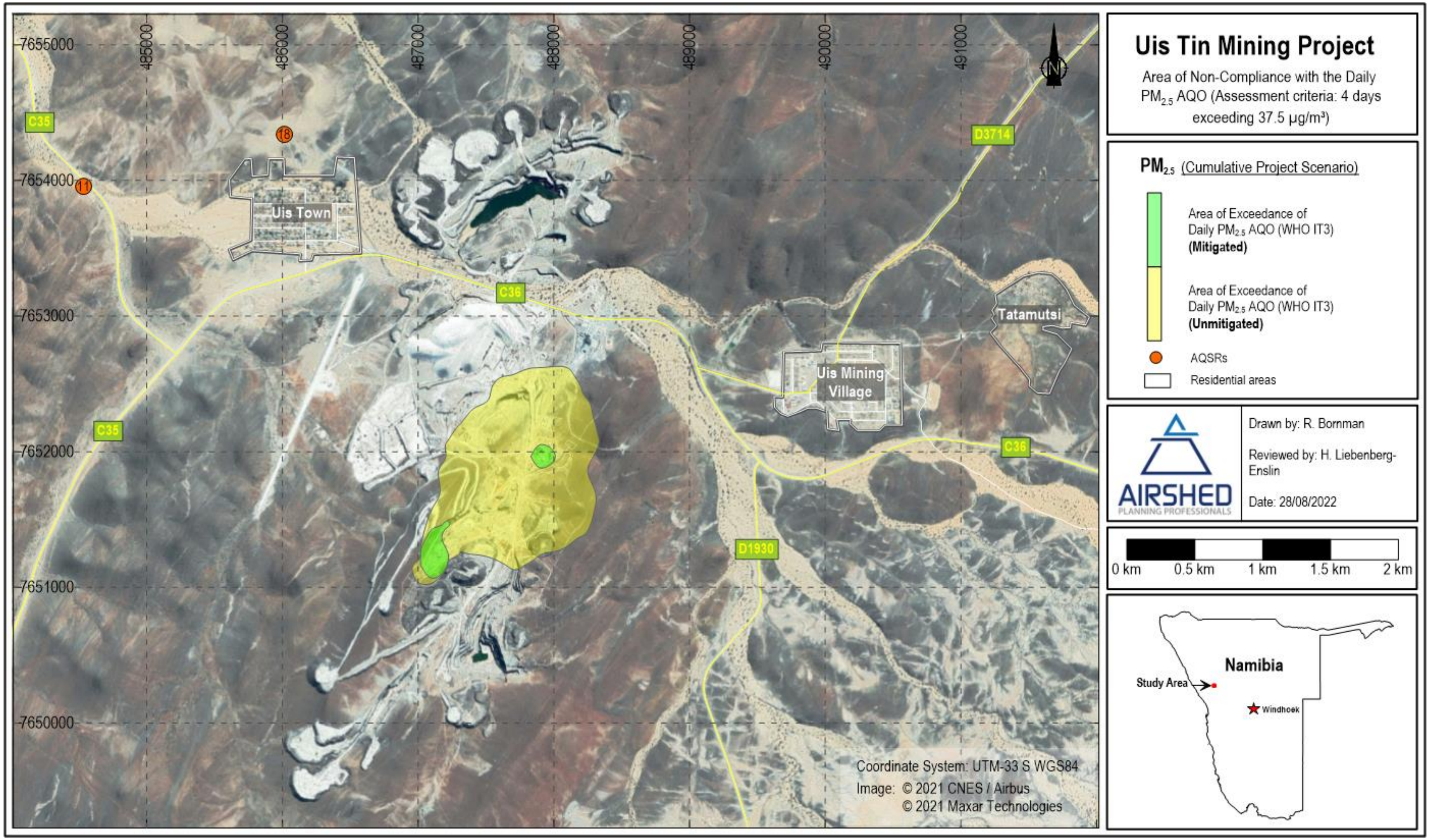


Figure 38: Area of non-compliance of annual $PM_{2.5}$ AQO for unmitigated and mitigated cumulative Project operations

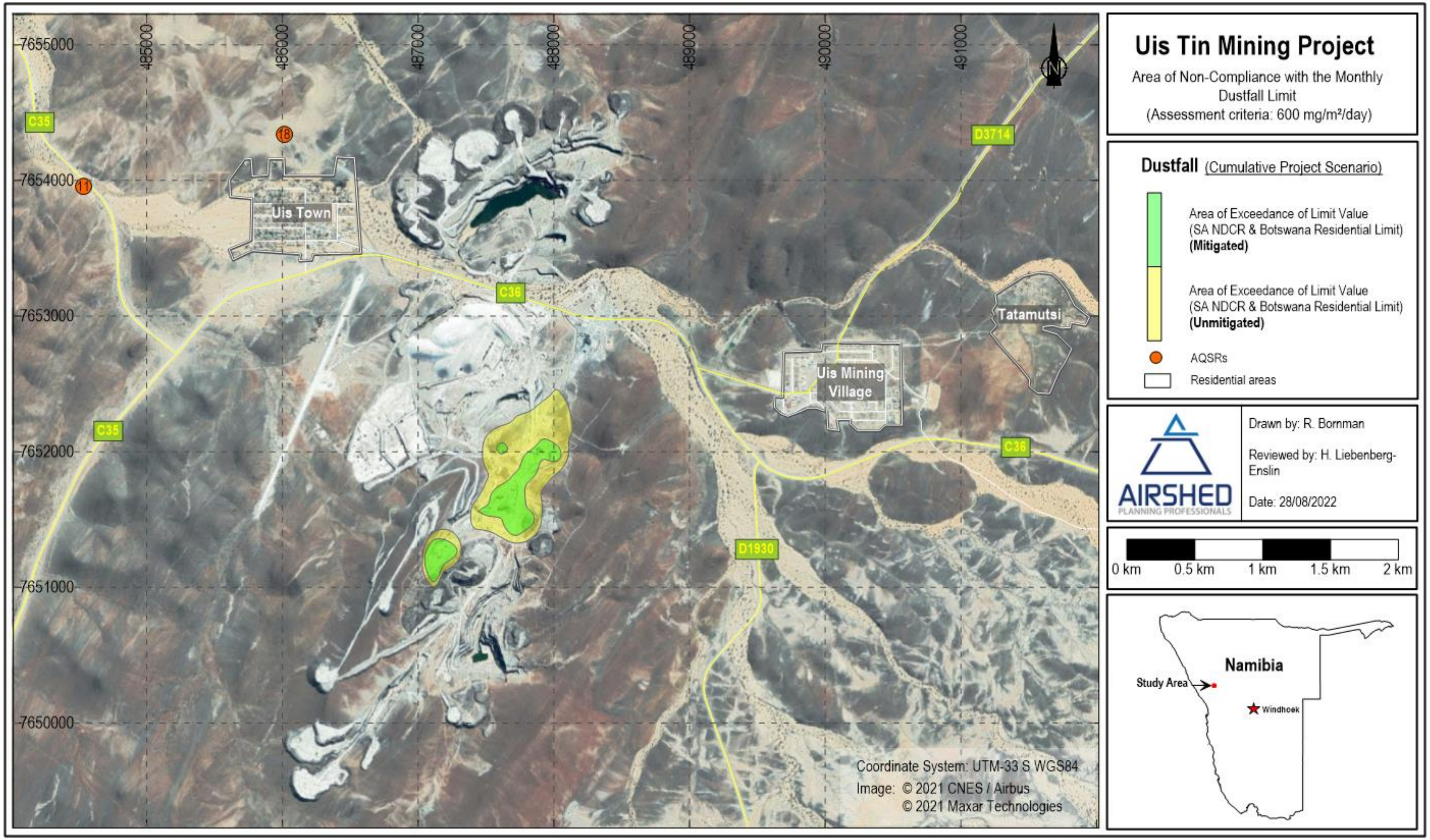


Figure 39: Area of non-compliance with the monthly dustfall AQO for unmitigated and mitigated cumulative Project operations

Table 21: Simulated PM_{10} and $PM_{2.5}$ ground level concentrations (in µg/m³) and maximum daily dustfall rates (in mg/m²/day) at selected AQSRs for cumulative Petalite Beneficiation Plant and Project operations

AQSR	PROJECT (CUMULATIVE)					
	Unmitigated			Mitigated		
	PM2.5 Highest Day	PM10 Highest Day	Dust Fallout Highest Monthly	PM2.5 Highest Day	PM10 Highest Day	Dust Fallout Highest Monthly
AQO	37.5 µg/m³	75 µg/m³	600 mg/m2/day	37.5 µg/m³	75 µg/m³	600 mg/m2/day
0	2.93	14.73	0.65	1.00	2.78	0.28
1	2.67	12.28	0.56	0.99	2.73	0.26
2	2.75	13.17	0.62	1.05	2.92	0.28
3	2.86	14.32	0.64	0.95	2.77	0.27
4	2.84	13.76	0.66	1.08	3.03	0.30
5	2.81	13.18	0.64	1.12	2.76	0.29
6	2.65	12.61	0.60	1.08	2.64	0.27
7	2.87	14.45	0.65	0.97	2.96	0.27
8	2.16	11.01	0.84	0.69	1.99	0.20
9	2.08	10.60	0.85	0.66	2.09	0.20
10	2.04	10.39	0.8	0.66	1.99	0.19
11	3.22	15.91	1.48	0.88	2.58	0.36
12	3.34	16.76	1.06	0.97	3.15	0.72
13	3.28	16.13	0.99	0.94	3.03	0.67
14	3.34	16.55	1.27	1.02	3.13	0.89
15	4.32	21.04	1.56	1.16	4.01	0.99
16	2.64	13.87	0.54	0.80	2.87	0.13
17	1.54	7.48	0.34	0.40	1.35	0.10
18	4.26	21.06	2.53	1.31	4.11	0.69
19	2.77	13.50	1.02	0.89	2.40	0.25
Uis Town	5.91	29.05	4.72	1.66	4.93	1.26
Uis Village	5.34	26.07	1.84	1.09	3.46	0.84
Tatamutsi	2.13	10.65	0.53	0.56	1.59	0.19

Notes:

CUMULATIVE: Mining: Mitigation includes 75% control efficiency (CE) on unpaved surface roads and 50% CE on unpaved in-pit roads (using water sprays), 50% CE on primary and secondary crushing and materials handling operations (using water sprays), >75% CE for tertiary and fines crushing and screening (wet process); Beneficiation plant: 50% CE on primary and secondary crushing and materials handling operations (using water sprays), 75% CE on unpaved surface roads, >90% CE on drying, classifying and product storage through fabric filter control.

6 RECOMMENDED AIR QUALITY MANAGEMENT MEASURES

In the light of the Project being so close to Uis Town and the Uis Mining Village it is recommended that Uis Tin Mine 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 6.3 based on the ranking of emissions sources.

6.1 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.

6.1.1 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:

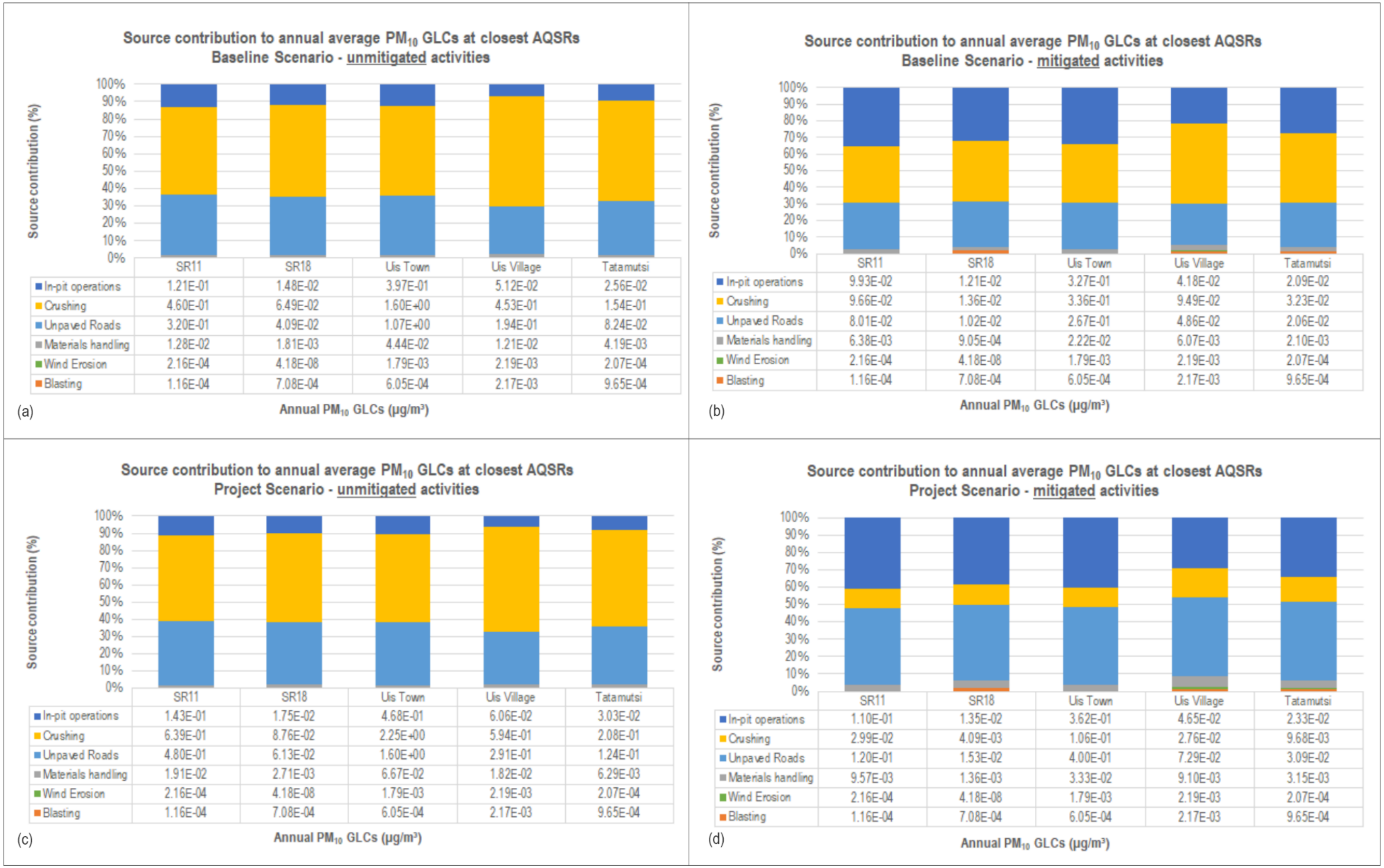
- Emissions ranking; based on the comprehensive emissions inventory established for the operations (Section 4.1); and
- Impacts ranking; based on the simulated pollutant GLCs.

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.

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

- **Project operation**: For the operational phase, PM_{10} emissions due to *unmitigated* Baseline and Project activities are dominated by unpaved roads and crushing, followed by in-pit operations (Figure 15(a) and (c)), whereas for *mitigated* activities, in-pit sources and unpaved roads are the main contributors to total PM_{10} emissions (Figure 15(b) and (d)). PM_{10} impacts at the 5 nearest AQSRs, viz. SR11, SR18, Uis Town, Uis Mining Village and Tatamutsi, due to *unmitigated* Baseline and Project activities are mainly due to crushing (Figure 40(a) and (c)). For *mitigated* Baseline activities (Figure 40(b)), crushing, in-pits and roads contribute equally to PM_{10} impacts at receptors to the northwest of the Project (i.e. SR11, SR18 and Uis Town), whereas crushing is the dominant source of impacts at receptors to the northeast of the project (i.e. Uis Mining Village and Tatamutsi). For *mitigated* Project activities (Figure 40(d)), in-pit sources and unpaved roads contribute equally to PM_{10} impacts at SR11, SR18 and Uis Town, whereas unpaved roads is the dominant source of impacts at Uis Mining Village and Tatamutsi.

- **Petalite Beneficiation Plant**: Drying and Classifying is the main source of PM_{10} and $PM_{2.5}$ emissions from this process, followed by unpaved roads for PM_{10} and crushing and screening for $PM_{2.5}$. The main source of TSP emissions is crushing and screening, followed by unpaved roads.



(a) Baseline Scenario - unmitigated activities: Annual PM_{10} GLCs (µg/m³)

	SR11	SR18	Uis Town	Uis Village	Tatamutsi
In-pit operations	1.21E-01	1.48E-02	3.97E-01	5.12E-02	2.56E-02
Crushing	4.60E-01	6.49E-02	1.60E+00	4.53E-01	1.54E-01
Unpaved Roads	3.20E-01	4.09E-02	1.07E+00	1.94E-01	8.24E-02
Materials handling	1.28E-02	1.81E-03	4.44E-02	1.21E-02	4.19E-03
Wind Erosion	2.16E-04	4.18E-08	1.79E-03	2.19E-03	2.07E-04
Blasting	1.16E-04	7.08E-04	6.05E-04	2.17E-03	9.65E-04

(b) Baseline Scenario - mitigated activities: Annual PM_{10} GLCs (µg/m³)

	SR11	SR18	Uis Town	Uis Village	Tatamutsi
In-pit operations	9.93E-02	1.21E-02	3.27E-01	4.18E-02	2.09E-02
Crushing	9.66E-02	1.36E-02	3.36E-01	9.49E-02	3.23E-02
Unpaved Roads	8.01E-02	1.02E-02	2.67E-01	4.86E-02	2.06E-02
Materials handling	6.38E-03	9.05E-04	2.22E-02	6.07E-03	2.10E-03
Wind Erosion	2.16E-04	4.18E-08	1.79E-03	2.19E-03	2.07E-04
Blasting	1.16E-04	7.08E-04	6.05E-04	2.17E-03	9.65E-04

(c) Project Scenario - unmitigated activities: Annual PM_{10} GLCs (µg/m³)

	SR11	SR18	Uis Town	Uis Village	Tatamutsi
In-pit operations	1.43E-01	1.75E-02	4.68E-01	6.06E-02	3.03E-02
Crushing	6.39E-01	8.76E-02	2.25E+00	5.94E-01	2.08E-01
Unpaved Roads	4.80E-01	6.13E-02	1.60E+00	2.91E-01	1.24E-01
Materials handling	1.91E-02	2.71E-03	6.67E-02	1.82E-02	6.29E-03
Wind Erosion	2.16E-04	4.18E-08	1.79E-03	2.19E-03	2.07E-04
Blasting	1.16E-04	7.08E-04	6.05E-04	2.17E-03	9.65E-04

(d) Project Scenario - mitigated activities: Annual PM_{10} GLCs (µg/m³)

	SR11	SR18	Uis Town	Uis Village	Tatamutsi
In-pit operations	1.10E-01	1.35E-02	3.62E-01	4.65E-02	2.33E-02
Crushing	2.99E-02	4.09E-03	1.06E-01	2.76E-02	9.68E-03
Unpaved Roads	1.20E-01	1.53E-02	4.00E-01	7.29E-02	3.09E-02
Materials handling	9.57E-03	1.36E-03	3.33E-02	9.10E-03	3.15E-03
Wind Erosion	2.16E-04	4.18E-08	1.79E-03	2.19E-03	2.07E-04
Blasting	1.16E-04	7.08E-04	6.05E-04	2.17E-03	9.65E-04

Figure 40: Source contribution to simulated annual average PM_{10} GLCs at the closest AQSRs

6.2 Proposed Mitigation Measures and Target Control Efficiencies

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

- In controlling vehicle entrained PM, it is recommended that water be applied on in-pit haul roads to ensure a CE of at least 50% and that water in excess of 2 litres/m²/hr be applied on surface haul roads to ensure a CE of at least 75%.
- In controlling dust from crushing and screening operations, it is understood that the primary and secondary crushers will achieve 99% CE by using a dual scrubber, whereas plants that use wet suppression systems and use spray nozzles can effectively control PM emissions due to tertiary/fines crushing and screening (achieving upwards of 75% CE).
- Mitigation of materials transfer points should be done using water sprays at all tip points. This should result in a 50% control efficiency. Regular clean-up at loading points is recommended to avoid re-entrainment.
- Minimising windblown dust from the CPF and WRDs can be controlled through vegetation on the CPF side walls and keeping the dried-out areas at the CPF wet, and vegetation cover on the side walls of the WRDs.
- Controlling dust from Drying and Classification can be done using fabric filters. This should result in 90% CE.

Further literature on source specific mitigation measures is provided in Section 9.2.

6.3 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.

6.3.1 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 the current dustfall monitoring network, comprising of fourteen (14) single dustfall units, should be maintained 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.

6.4 Periodic Inspections, Audits and Community Liaison

6.4.1 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.

6.4.2 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.

6.5 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.

Even though the project activities are in close proximity of potential AQSRs, the significance of construction and operation phase air quality impacts (including the ESIA Amendment) is ***minor.*** The impact assessment has been provided in a separate impact assessment spreadsheet to ECC.

7 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 Phase 1 Fast-Tracked Stage II expansion of the Uis Tin Mine.

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.

7.1 Baseline characterisation

The Uis Project is located near the town of Uis, approximately 164 km north of Swakopmund and 30 km northwest of the Brandberg mountain, Namibia's highest mountain (2 559 m above sea level). The closest residential developments to the Project consist of Uis (~1.9 km to the northwest), Uis Mining Village (~1.7 km to the east) and Tatamutsi (~3.4 km to the east). Individual farmsteads also surround the Project area.

On-site meteorological data was not available. Use was made of Weather Research and Forecasting Model (WRF) simulated meteorological data for the period 2018 – 2020 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 an increase in winds from the south-southwest and south during the night. Day- and night-time average wind speeds are 4.6 m/s and 5.0 m/s respectively. Calm conditions occur 3.0% of time during the day and 2.5% during the night. On average, air quality impacts are expected to be slightly more notable to the north and north-east of the Project.
- The predominant south-south-westerly, southerly and north-north-easterly winds in the study region may be explained by the topography of the study area. Uis is ~800 m above sea level with the highest point at 900 m above sea level. The terrain is fairly flat in the immediate vicinity of the plant site, with steeper and higher relief areas confined to the northeast and south. The highest wind speeds (more than 6 m/s) were recorded during summer and springtime and are mostly from the south-southwest and southwest.
- Maximum, minimum, and mean temperatures were given as 39.9°C, 1.2°C and 22.5°C respectively from the WRF data for the period Jan 2018 to Dec 2020.
- Average annual rainfall at Uis town for the period 2009 to 2021 was given as 656 mm, with most rain recorded during the summer (December to March) and least during the winter months from May to September.
- 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, windblown dust, mining and exploration activities.
- Sources of atmospheric emissions in the vicinity of the Project include small-stock farming, small-scale mining, activities of the Namclay Brick and Pavers factory, 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 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 is considered very low, especially in a low-density population area such as the one where the Uis mine is located.

- 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 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 Uis area.
- Dustfall monitoring data was provided for the period March 2019 to August 2021. The monitoring network comprised of eight (8) single dustfall units between March 2019 and November 2020 but has been expanded to fourteen (14) single dustfall units from December 2020 forward. Dustfall rates were generally low for the sampling period and well within the dustfall limit of 600 mg/m²/day (adopted limit for residential areas) and 1 200 mg/m²/day (adopted limit for non-residential areas), with the exception of AQ 01 (5 exceedances in 2020 and 4 exceedances in 2021), AQ 05 (2 exceedances in 2019, 5 exceedances in 2020 and 1 exceedance in 2021), AQ 08 (1 exceedance in 2019) and AQ 14 (1 exceedance in 2020).

7.2 Impact Assessment

Emissions due to the construction of the secondary crushing and screening plant as well as the DMS feed stockpile were quantified using area-wide emission factors for general construction activities. A quantitative air quality impact assessment was conducted for the operational phase activities of the Uis 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.

7.2.1 Construction Phase

- The construction phase during Stage II was designed to allow pre-assembly while the plant is in operation. Construction work include civil works, in-plant erection, piping, erection of conveyors and gantries, conveyor mechanical installation, and electrical, control and instrumentation work. The largest construction works (in terms of land area) are the construction of a new secondary crushing and screening plant and a DMS feed stockpile. The total land area was determined from georeferenced site plans as approximately 1 320 m^2.
- Using US-EPA emissions factors for general construction activities, and assuming that the quantity of dust emissions is proportional to the area of land being worked and the level of construction activity, construction emissions were estimated at 355 kg for TSP, 138 kg for PM_{10} and 69 kg for $PM_{2.5.}$
- Due to the intermittent nature of construction operations, construction 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.

7.2.2 Operational Phase

- Two mining scenarios were assessed to determine the increase in impacts due to the Project, namely a Baseline scenario and Project Scenario. It was assumed that Stage I throughputs as provided in the Definitive Feasibility Study (DFS) summary represent the Baseline scenario (current mining rates) and that Stage II throughputs represent the Project scenario (future mining rates required to support the expanded MHCP). V1 and V2 opencast areas were assumed to be mined concurrently in a 57:43 tonnage split.

- Emissions quantified for the Uis Project were restricted to fugitive releases (non-point releases) with particulates the main pollutant of concern. Emissions were quantified based on provided information on mining rates and mine layout plan.
  - Quantified PM_{10} and $PM_{2.5}$ emissions were similar for unmitigated Baseline and Project operations. TSP emissions were higher for the unmitigated Project Scenario. Quantified PM_{10}, $PM_{2.5}$ and TSP emissions were higher for design mitigated Project operations than its counterpart Baseline operations, apart from crushing activities (due to the high control efficiency of the dual scrubber on the primary and secondary crushers for the Project Scenario).
  - The main sources of controlled $PM_{2.5}$, PM_{10} and TSP emissions due to the Project scenario are, in order of importance: i) in-pit operations (including in-pit haul roads, materials handling and drilling), ii) vehicle entrainment from unpaved surface roads, iii) wind erosion from the WRD, CPF and ROM stockpiles, iv) crushing and screening (primary; secondary, tertiary and fines) operations, v) materials handling and vi) blasting, with blasting a lesser source due to its intermittent nature and variable duration.
- For each of the two scenarios, unmitigated and mitigated options were modelled. Mitigation was applied based on design mitigation measures provided, which included the following:
  - in-pit haul roads: water sprays assuming 50% control efficiency (CE);
  - surface haul roads: water sprays assuming 75% CE;
  - crushing and screening of ROM (primary and secondary): assuming 99% CE for dual scrubber;
  - crushing and screening of ROM (tertiary and fines): >75% CE for wet processes; and
  - materials handling, including conveyor transfer: assuming 50% CE for water sprays.
- Dispersion modelling results for the Baseline Scenario:
  - PM_{10} daily GLCs, for unmitigated activities, result in exceedances of the 24-hour air quality objective (AQO) over a maximum distance of ~700 m from Uis mining activities, but with no exceedances at any of the AQSRs. For mitigated activities, impacts are limited to the Uis mining and processing plant areas with no exceedances at any of the AQSRs. PM_{10} annual GLCs, for both unmitigated and mitigated activities, are within the AQO at 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 ~300 m off-site. For mitigated activities, there are no exceedances at any of the AQSRs and impacts are limited to on-site areas. There are no exceedances of the annual $PM_{2.5}$ AQO, without and with mitigation in place.
  - Maximum daily dustfall rates, for both unmitigated and mitigated activities, do not exceed the AQO (SA NDCR residential limit of 600 mg/m²/day) at any of the AQSRs.
- Dispersion modelling results for the Project Scenario:
  - The daily PM_{10} AQO (WHO IT-3 and SA NAAQS) is exceeded over a maximum distance of 950 m from the Uis mining area (with no mitigation in place) but reduce to smaller areas of exceedance on-site when mitigation is applied. PM_{10} daily GLCs, for unmitigated and mitigated activities, do not result in any exceedances of the 24-hour AQO at the AQSRs. Over an annual average there are no exceedances at any of the AQSRs, without and with mitigation.
  - For daily $PM_{2.5}$ the area of maximum unmitigated GLCs exceedance extends northwest from the Uis mining operations over a maximum distance of ~750 m, with no exceedances at any of the AQSRs. With mitigation in place there are no exceedances at any of the AQSRs and the impact is reduced to much smaller areas of exceedance. Annual average $PM_{2.5}$ GLCs are low at all AQSRs.

  - Maximum daily dustfall rates, for both unmitigated and mitigated activities, are within the AQO (SA NDCR residential limit of 600 mg/m²/day) at all of the AQSRs.
- For both the Uis Baseline and Project 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 Uis modelling results indicate the potential for low regional cumulative impacts, resulting in **minor** significance.

7.3 Impact Assessment Amendment

Subsequent to the initial impact assessment (referred to as the Project), additional changes will be made to the processing operations including a bulk sampling and ore sorting and testing facility (referred to as the Petalite Beneficiation Plant) to extract the lithium-bearing ore.

- Two operational scenarios were assessed, namely the incremental and cumulative Petalite Beneficiation Plant scenarios, each with an unmitigated and mitigated sub-scenario.
- Emissions for the Petalite Beneficiation Plant were quantified based on provided information on processing rates and plant layout.
  - Drying and Classifying is the main source of PM_{10} and $PM_{2.5}$ emissions from this process, followed by unpaved roads for PM_{10} and crushing and screening for $PM_{2.5}$. The main source of TSP emissions is crushing and screening, followed by unpaved roads.
- Dispersion modelling results for the incremental Petalite Beneficiation Plant
  - Simulated values for PM_{10}, $PM_{2.5}$ and maximum daily dustfall rates at AQSRs are negligibly small.
  - PM_{10} and $PM_{2.5}$ daily GLCs, for unmitigated activities, result in exceedances of the 24-hour air quality objective (AQO) over a maximum distance of ~90 m from on-site activities.
  - The footprint of exceedance of maximum daily dustfall rates exceed the AQO within 125 m from the facility's activities.
- Cumulative air quality impacts (the Project and the Petalite Beneficiation Plant)
  - The cumulative plots including the Petalite Beneficiation Plant are not significantly different from those for the Project Scenario described in Section 7.2.2. The numerical results simulated at the AQSRs are also not significantly different from those simulated for the Project only. It may therefore be concluded that the conclusions from this report would not change as a result of the Petalite Beneficiation Plant.

7.4 Conclusion

The proposed Uis Project (including the Petalite Beneficiation Plant) 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 mining activities, and around the Petalite Beneficiation Plant. With mitigation in place, the resulting impacts can be limited to on-site areas. Dustfall rates are likely to be low throughout the life of mine.

It is the specialist's opinion that the proposed project could be authorised provided strict enforcement of mitigation measures and the tracking of the effectiveness of these measures to ensure the lowest possible off-site impacts.

7.5 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:

- 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:
    - Control of vehicle entrained dust with a CE of 75% on unpaved surface roads through water suppression, and water sprays on the in-pit haul roads, to ensure a 50% CE.
    - In controlling dust from crushing and screening operations, it is understood that the primary and secondary crushers will achieve 99% CE by using a dual scrubber, whereas plants that use wet suppression systems and use spray nozzles can effectively control PM emissions due to tertiary/fines crushing and screening (achieving upwards of 75% CE).
    - Mitigation of materials transfer points should be done using water sprays at all tip points. This should result in a 50% control efficiency. Regular clean-up at loading points is recommended to avoid re-entrainment.
    - Minimising windblown dust from the CPF and WRDs can be done through vegetation on the CPF side walls and keeping the dried-out areas at the CPF wet, and vegetation cover on the side walls of the WRDs.
    - Controlling dust from Drying and Classifying can be done using fabric filters. This should result in 90% CE.
- Air Quality Monitoring:
    - The current dustfall monitoring network, comprising of fourteen (14) single dustfall units, should be maintained 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.

8 References

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9 APPENDIX

9.1 Appendix A – Monitoring Methodology

9.1.1 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 41). 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).

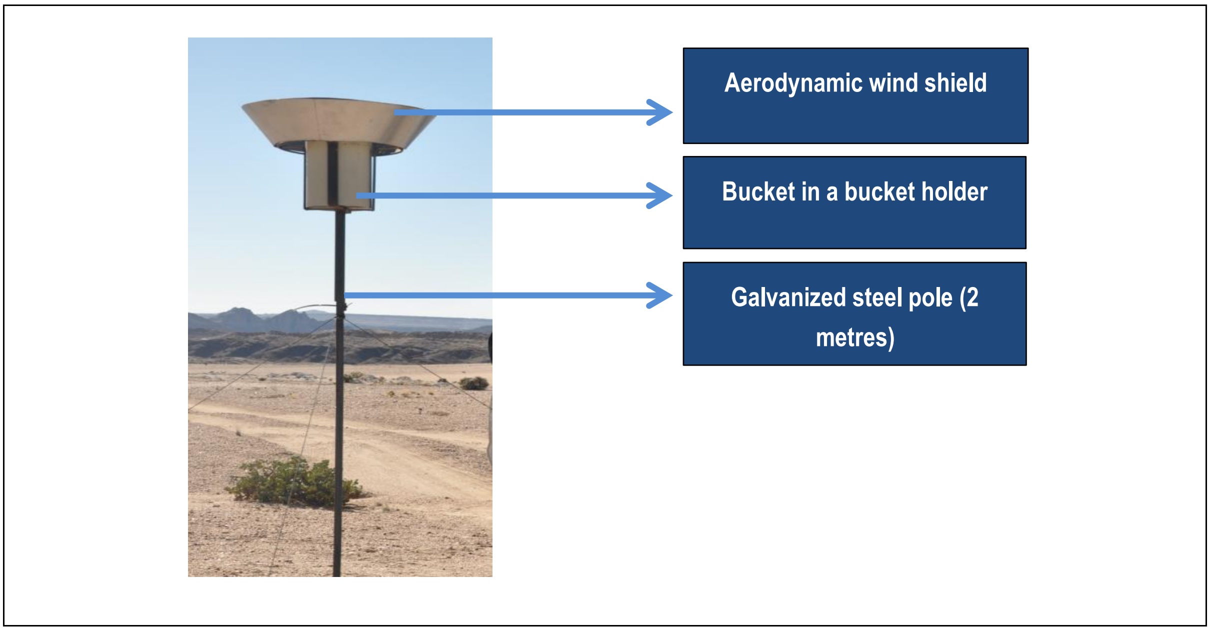

Figure 41: Example of a dustfall bucket

9.2 Appendix B – Source Specific Management and Mitigation Measures

9.2.1 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 22: Unpaved haul roads: Dust suppression improvement plan

Criteria	Description
Unpaved haul roads	• In-pit haul roads. • Haul roads between pits and processing plant • Haul roads to CPF and WRD
Operational hours	24 Hours per day, 7 days per week
Accountable person(s)	Environmental Officer; Mine Production Engineer Dust Suppression Contractor
Target control	At least 75%
Performance indicators	• 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.
Operating procedures	• 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.
Inspections	• Monthly inspections to ensure effectiveness of chemical stabilisation. • This can include daily visual inspections of the site coupled with the dustfall and ambient monitoring data

9.2.2 Crushing and Screening Operations

Enclosure of crushing operations is very effective in reducing dust. The Australian NPI (NPI, 2011) indicates that a telescopic chute with water sprays would ensure 75% control efficiency and enclosure of storage piles where tipping occurs would reduce the emissions by 99%. In addition, chemical suppressants or water sprays on the primary crusher and dry dust extraction units with wet scrubbers on the secondary crushers and screens will assist in the reduction of the cumulative dust impacts. According to the Australian NPI, water sprays can have up to 50% control efficiency and hoods with scrubbers up to 75%. If in addition, the scrubbers and screens were to be enclosed; up to 100% control efficiency can be achieved. Hooding with fabric filters can result in control efficiencies of 83%. It is important that the control equipment be maintained and inspected on a regular basis to ensure that the expected control efficiencies are met (NPI, 2011).

The moisture content of the material processed can have a substantial effect on emissions. This effect is evident throughout the processing operations. Surface wetness causes fine particles to agglomerate on or to adhere to the faces of larger stones, with a resulting dust suppression effect. However, as new fine particles are created by crushing and attrition and as the moisture content is reduced by evaporation, this suppressive effect diminishes and may disappear. Plants that use wet suppression systems (spray nozzles) to maintain relatively high material moisture contents can effectively control PM emissions throughout the process (US-EPA AP42, Chapter 11 Section 19.2.2).

Uncontrolled crushing and screening operations were shown to be a considerable source of dust emissions. Regular maintenance of mitigation measures is critical to meeting the minimum target for dust control. Other actions include regular inspection and clean-up of the crusher area, as well as reducing the loose material on the surface of the crusher area which will reduce the risk of re-entrainment by vehicles moving in the area. Wetting of the loose dust in between clean-up will also reduce potential emissions.

Table 23: Crushing: Dust suppression improvement plan

Criteria	Description
Crushing and Screening Operations	• Processing Plant
Operational hours	24 hours per day, 7 days per week
Accountable person(s)	Environmental Officer; Operator at crusher
Target control	At least 99% (via dual scrubber) at primary and secondary crushers Control efficiencies of >75% at tertiary and fines crushers by maintaining high material moisture content using spray nozzles
Performance indicators	• Regular maintenance of control equipment. • No loose dust around crushing facility • 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.
Operating procedures	• Spillage clean up, at least once a week • Water spraying road surface in loading area.

9.2.3 Options for Reducing Windblown Dust Emissions

The main techniques adopted to reduce windblown dust potential include source extent reduction, source improvement and surface treatment methods:

- Source extent reduction:
  - Disturbed area reduction.
  - Disturbance frequency reduction.
  - Dust spillage prevention and/or removal.

- Source Improvement:
  - Disturbed area wind exposure reduction, e.g. wind fences and enclosure of source areas.
- Surface Treatment:
  - Wet suppression
  - Chemical stabilisation
  - Covering of surface with less erodible aggregate material
  - Vegetation of open areas

The suitability of the dust control techniques indicated will depend on the specific source to be addressed, and will vary between dust spillage, material storage and open areas. The NPI (2011) recommends the following methods for reducing windblown dust:

- Primary rehabilitation - 30%
- Vegetation established but not demonstrated to be self-sustaining. Weed control and grazing control - 40%
- Secondary rehabilitation - 60%
- Re-vegetation - 90%
- Fully rehabilitated (release) vegetation - 100%

Table 24: Wind erosion sources: Dust suppression improvement plan

Criteria	Description	Comments
Wind Blown Dust		• ROM storage pile • Waste rock dump • Co-placement facility
Operational hours	During periods with high wind speeds	
Accountable person(s)	Environmental Officer Mining Engineer	
Target control	At least 50%	
Performance indicators	• 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. • No dust should be visible from the WRD, CPF or ROM stockpiles during episodes of strong winds.	
Operating procedures	• Water sprays at ROM stockpiles and product stockpiles can achieve 50% control efficiency. Increase in moisture content provides higher threshold friction velocity and ensures that particulates are not as easily entrained due to high surface winds. • Reshape all disturbed areas to their natural contours. • Cover disturbed areas with previously collected topsoil and replant native species. • Rock cladding with larger pieces of waste rock is recommended to reduce wind erosion emissions from the overburden storage piles • Backfilling or revegetation of overburden stockpiles is recommended.	

9.3 Appendix C – Impact Significance Rating Methodology

The significance of air quality related impacts was assessed using the risk rating matrix provided by ECC (Table 26). Significance definitions are provided below (Table 25). The numbers corresponding to each significance category are calculated by multiplying the sensitivity of the receptor with the significance of the impact.

Table 25: 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 26: 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)