EAQ Consulting

DUST IMPACT ASSESSMENT OF PROPOSED MINING OPERATIONS

RIO TINTO WINU COPPER-GOLD PROJECT

Dust Impact Assessment of Proposed Mining Operations

Rio Tinto Winu Copper-Gold Project

Prepared for: Rio Tinto Winu

Project Ref: EAQ-24033
May 2026

Environment | Air Quality

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Report Revision(s)				
Version(s)	**Description**	**Date**	**Author(s)**	**Reviewer(s)**
Draft_0.0	Internal Review	16.02.2022	J. Hurley	DSB
Draft_0.1	Internal Version	17.02.2022	J. Hurley	
Draft_1.0	Released to Client	17.02.2022	J. Hurley	OHMS
Draft_1.1	Released to Client	22.02.2022		Rio Tinto
Draft_1.2	Addition of Road Access Corridor	10.06.2024		Rio Tinto
Draft_1.3	Review and Edits	22.06.2024		Rio Tinto
Draft_1.4	Inclusion of Camp Exceedance Counts	02.07.2024		Rio Tinto
Draft_1.5	Revision of Camp Location	22.07.2024		Rio Tinto
Draft_1.6	Paved Roads Reassessment	26.12.2024		
Final		10.01.2025		
Final_v2	Inclusion of Regional Background Dusts	12.05.2026		

Approved for Release		
Name	**Position**	**File Reference**
John Hurley	Principal Consultant	EAQ24033-RioTinto(Winu)+DustImpactAssessment-FINAL_v2

Signature

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Executive Summary

Rio Tinto is undertaking preparations and planning for its Winu Copper-Gold Project.

An air quality assessment for dust was undertaken for mining and processing in year 2032, to predict mining activities' impacts for TSP deposition, PM_{10} and $PM_{2.5}$ at peak throughput, where the mining activities were assessed against human, flora and fauna receptors on the basis of health and nuisance impacts.

The Project is sufficiently distant from other surrounding mining activities that background dust levels would likley only originate from natural sources in proximity to the MIA.

The key findings of the assessment are:

- The maximum predicted 24-hr TSP, PM_{10} and $PM_{2.5}$ concentrations for mining activities at the Winu Project are estimated to exceed the regulatory criteria at the Winu Mining Camp, where:
  - The peak contributions to overall dust impacts are mostly attributable to Haul Road use.
- Annual criteria for PM_{10} and $PM_{2.5}$ are estimated to be below regulatory guidelines at the Winu Mining Camp, where:
  - The PM_{10} annual concentration range is predicted to be within 9 – 11 µg/m^3, and
  - The $PM_{2.5}$ annual concentration range is predicted to be within 3.0 – 4.1 µg/m^3.
- Dust deposition rates at the Winu Camp are also below the dust deposition criterion of 2 g/m^2/30 days (excluding background).

The number (counts) of these exceedances suggests that exposure to these dusts is limited to worst-case meteorological conditions and therefore careful design of the Winu Mining Camp to include outdoor recreational and meeting areas, and appropriate dust controls for sleeping and indoor areas, may provide the necessary protection from these exceedance events.

The mining activities are estimated to emit dust exceeding acceptable nuisance levels within the mining areas. It is however expected that during the planning and preparation stages there will be refinement/adjustment of mining activities, to include dust suppression measures and use of materials for road construction etc., to further reduce airborne dust concentrations.

1 Background & Scope

Environmental & Air Quality Consulting Pty Ltd (EAQ) was engaged by Rio Tinto Winu Pty Ltd (RTW) to undertake a Dust Emissions' Impact Assessment (the Assessment) of RTW's proposed Winu Copper-Gold Project (Winu Project) at RTW's operations which will reside within the Great Sandy Desert in Western Australia. The Winu Project is approximately 320 kilometres (kms) east of Port Hedland in the Pilbara region of Western Australia within both the Nyangumarta and Martu People's Native Title Determination Areas.

The Proposal is anticipated to nominally process 10 Million tonnes per annum (Mtpa) and has an operational life of approximately 40 years.

The Assessment utilised dispersion modelling of dust to support the Winu Project approvals, communication with Traditional Owners, inform future dust controls and monitoring regimes, and to assist in characterising and documenting air quality and meteorological characteristics, risk and impact analysis. Dust suppression methods were also considered within the Assessment to minimise the concentration of airborne dust at the point of emission. The modelling outcomes will be used to develop dust management strategies and control plans.

Dust, also known as particulate matter (PM), is generally described as particles of crustal material that can remain suspended in the air by turbulence for an appreciable length of time. Dust also includes smoke from combustion, pollens, sea salts and liquids (aerosols). PM may range in size from less than 10 nanometres to more than 100 micrometres (µm) in diameter.

PM is characterised by its size, as measured by collection devices specified by regulatory agencies. The particulate size ranges specified in ambient air guidelines and within the Assessment, are:

- Total suspended particulate (TSP),
- Particulate matter measured with a sampler with 50% cut point at 10 µm (PM_{10}), and
- Particulate matter measured with a sampler with 50% cut point at 2.5 µm ($PM_{2.5}$).

TSP is associated with predominantly nuisance impacts such as a reduction in visibility and terrestrial impacts from dust deposition.

PM_{10} and $PM_{2.5}$ are associated with health-based impacts.

In addition, such impacts are dependent on the actual particulate type / content, as some are more likely to have health implications than others.

Dust deposition was also assessed. Deposition refers to gravitational settling of airborne PM on the ground or ground surface features (e.g., fauna, vegetation, houses etc). Deposition can be assessed as 'wet' or 'dry' depending on the climate within the Assessment. In the case of this Assessment there is negligible rainfall within the Winu domain and therefore only 'dry' deposition was considered.

1.1 Assessment Scope

The Assessment was undertaken using desktop methods where the AERMOD Plume Dispersion Model was employed to predict ground level dust emissions from the Winu Project activities.

AERMOD was chosen to best represent the Winu Project, given that:

- No stacks for assessment,
- Long-range pollutant transport is not expected,
- Site is significantly inland from the coast,
- Local terrain is flat and terrain complexity is largely negligible, and therefore:
  - Complex meteorology and subsequently complex dispersive characteristics are not expected based on these points above.

The scope of works for the modelling assessment is as follows.

- Develop and run a conservative risk-based emissions dispersion model for the Site projecting dust impacts,
- Follow the requirements set by Western Australia Department of Water and Environmental Regulation (DWER), formerly Department of Environment – DoE, for dispersion modelling impact assessments (DoE, 2006) as summarised below:
  - Identify and quantify all emissions to atmosphere with a potential to have a non-trivial impact on the environment. Emissions of potential concern include (among others) odorous gases to be considered explicitly, unless the proponent can demonstrate that the emission rates of these are insignificant,
  - For all emission sources that cannot be dismissed as being of no significance, the proponent must provide model predictions of the impact of emissions in the form of concentrations and/or rates of deposition over the range of averaging periods normally associated with relevant standards for each pollutant, and assess the magnitude of this impact against the relevant standards,
  - Modelling results to be presented in the form of:
    - contour plots covering the region of interest (including population centres or isolated residences), with a grid density adequate to avoid significant loss of resolution, and
    - numerical values of concentrations at the point(s) of maximum impact (explain where this occurs) and other locations (receptors) of interest (e.g., places of human residence).
  - When cumulative concentrations are modelled, in order for the contribution to be properly assessed, the modelling results are presented for:
    - the existing emissions plus background concentration (pre-proposal),
    - the proposed development in isolation (excluding existing emissions),
    - the combined (existing plus proposed) without background emissions, and
    - the combined (existing plus proposed plus background) emissions.

- Any estimates of emissions employed in modelling assessments are realistic and that uncertainty is balanced by conservatism,
- The modelling must properly assess both emissions which are continuous in nature and emissions which are intermittent, where;
    - Intermittent emissions which are insignificant in magnitude and/or very improbable in the lifetime of the plant may be screened out and the remaining emissions modelled together on a probabilistic basis to estimate the total plant impact.
- The models and/or worst-case calculation procedures and data employed in the assessment must be demonstrably capable of simulating, or accounting for, all of the features which are important in the context of determining the air quality impact of the project,
- If using a conventional model, the proponent will need to obtain at least one (preferably two or more) years' data on the meteorology of the area, with high data recovery and verifiable data accuracy. In the simplest situations, the data may be limited to that necessary to provide reliable hourly average estimates, at a representative site, of:
    - wind speed,
    - wind direction,
    - air temperature,
    - mixing height, estimated or measured via methods acceptable to the DWER, and
    - atmospheric stability, estimated by a method acceptable to the DWER.

The proponent's report should include a description of the meteorological data used or alternatively a reference to a publicly available report which contains this information.

1.1.1 Types of Emissions

For the purposes of defining the risk of dust emissions impacting at the nearest sensitive receiver, the AERMOD assessment was carried out against the following Draft DWER guideline that discusses modelling impact criterion for dusts.

Table 1-1: Dust Modelling Assessment Criteria

Substance	Averaging period	Percentile	Standard - Maximum ambient Concentration (µg/m³)	Environmental Value	Source
Particles ($PM_{2.5}$)	24 hours	100^{th}	25	Human Health	(DWER, 2019) Air NEPM, 2021
	Annual		8		
Particles (PM_{10})	24 hours		50		
	Annual		25		
TSP	24 hours		90	Human Health & Amenity	(DWER, 2019) Kwinana EPP, 2009
Deposited Dust	4 grams/m²/30 days (maximum)			Amenity / Nuisance	(DWER, 2021) NSW EPA 2016
	2 grams/m²/30 days (above background)				(DWER, 2021) NZ MfE 2016

1.2 Regulatory Guidance for Determining Risk

Dust as an airborne pollutant and potential nuisance and/or health impact risk are regulated in accordance with quantitative emissions assessed against impact criteria.

The magnitude of those ground level dust impacts (concentrations and/or depositions) can then inform the likelihood of dust being a nuisance at the nearest sensitive receiver, however; where dust impacts exceed a prescribed concentration criterion, the risk is realised and the proposal must address the exceedances through management controls, re-design and/or capture and treatment options to mitigate the risk where applicable.

1.3 Dust Dispersion Modelling

The dust dispersion modelling assessment was carried out using the latest Gaussian AERMOD Dispersion Modelling software.

The AERMOD assessment was setup in accordance with the Environmental Protection Authority of Victoria (EPA Victoria), Australia's modelling guidance publication 1550 for the construction of AERMOD ready meteorological data files (Environmental Protection Authority, 2013), and EPA Victoria's Guidance notes for using the regulatory air pollution model AERMOD, publication 1551 (Environmental Protection Authority, 2013). Additionally, the modelling component also followed the WA DWER modelling guidance (DoE, 2006).

The Assessment objectives as they relate to the WA jurisdiction were to deliver the outcomes of the Assessment in accordance with the Government of WA's DWER Draft Guideline for Air Emissions (DWER, 2019) and Draft Guideline for Dust Emissions (DWER, 2021) for activities regulated under the Environmental Protection Act 1986 and Environmental Protection Regulations 1987.

2 Locality Meteorology & Winu Project

The Winu Project is approximately 120 kilometres (kms) south-east from the nearest coastline between the Towns of Port Hedland and Broome, Western Australia (Figure 2-1).

It is located on the Anketell Shelf of the Yeneena Basin, the local geology is dominated by dunes and sandplains. The environment is naturally dusty outside of periodic (seasonal) rainfall events, hence native vegetation is expected to be reasonably tolerant to dust deposition.

2.1 Locality Meteorology

The nearest Bureau of Meteorology (BoM) Automatic Weather Stations (AWS) to the Winu Project are Pardoo (004028) and Mandora (004019), with Mandora being the closest BoM AWS to the Winu Project.

These coastal BoM AWS's show differing meteorological characteristics to the Winu Project location. These coastal characteristics are dominated by north and north-westerly winds, and east, south-easterly winds.

Onsite meteorology at the Winu Project, collected by an onsite meteorological station utilised during exploration and siting, shows similar wind direction patterns to these coastal sites.

Data recovery for onsite meteorological data collected at the Winu Project best represents the 2020 annual period. As a result, the 2020 meteorological period was utilised in this Assessment.

CSIRO's *The Air Pollution Model* (TAPM) was initiated for the 2020 annual period to generate a full prognostic dataset, including upper air characteristics, which was compared to onsite meteorology and further utilised for modelling assessment scenarios.

Local topography is not expected to affect wind direction to any significance. Analysis of monthly wind speed and direction trends for Pardoo, onsite and the TAPM output for wind direction and speed (annually) shows there to be negligible variability in dominant prevailing winds across the locality. Climate trends are illustrated in Figure 2-2 below.

There is no available data for the Mandora station, however; the Pardoo AWS is representative of Mandora given their comparable locations.

Figure 2-3 illustrates the proposed mining operations at the Winu Project, with Figure 2-4 illustrating the Road Access Corridor (RAC) and key sensitive receptor locations.

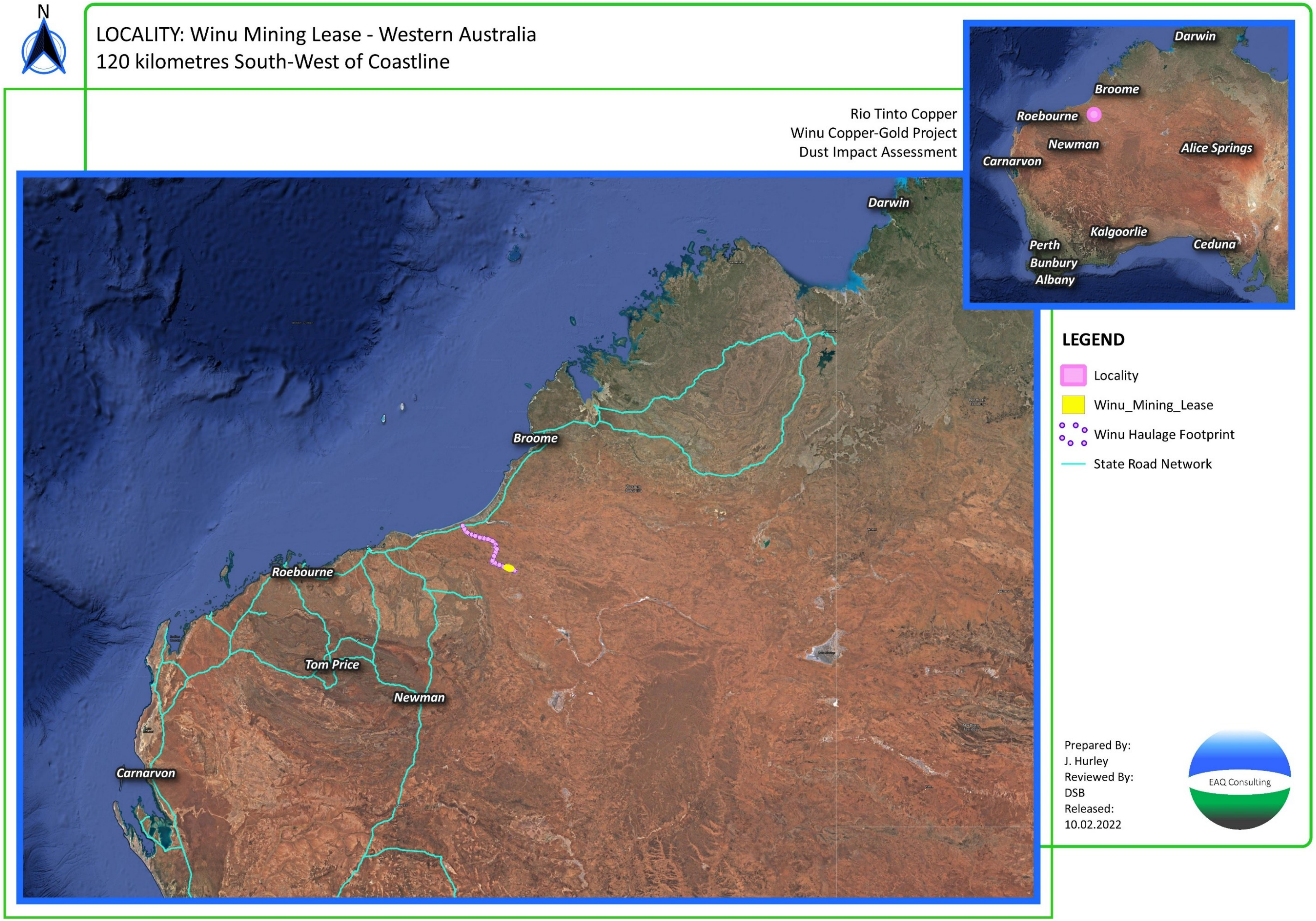
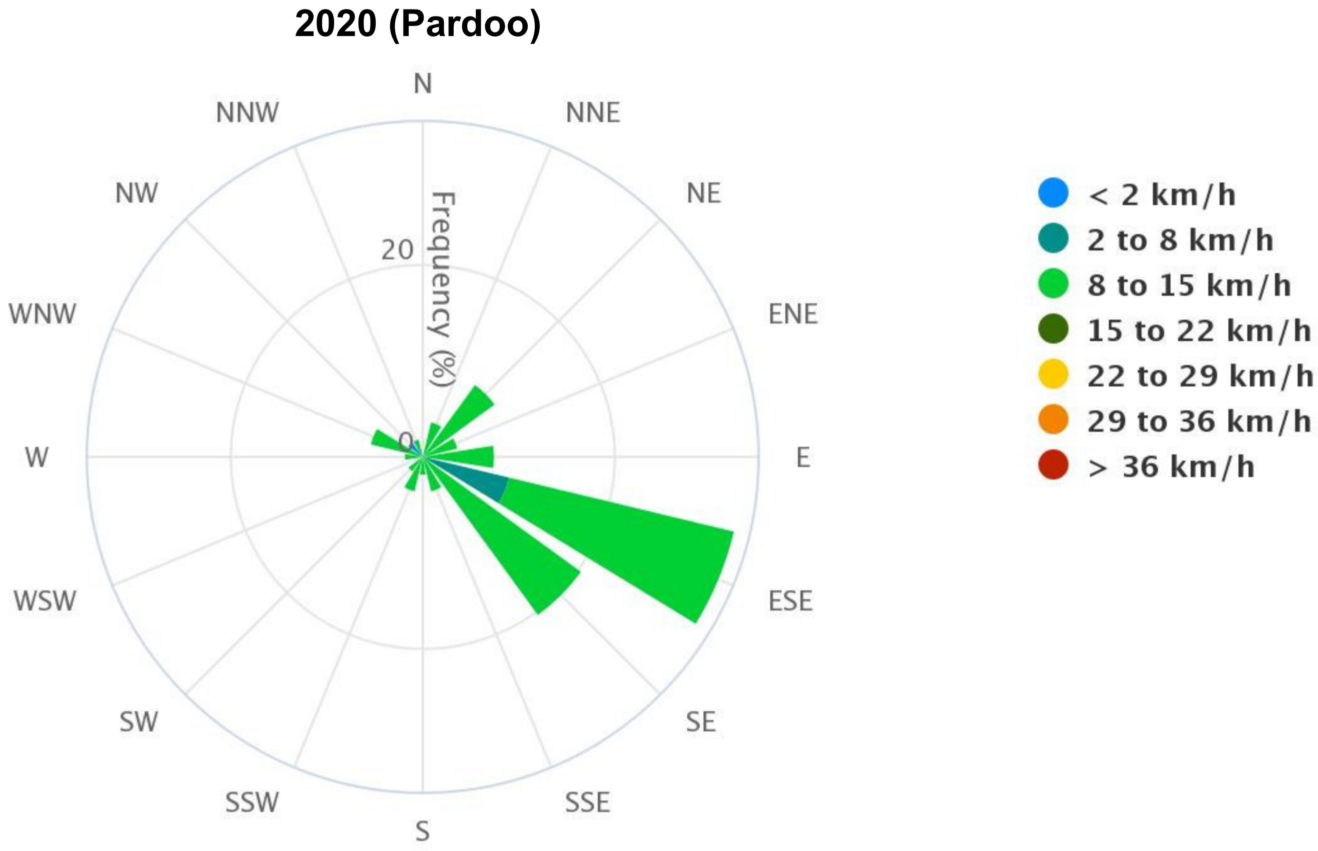
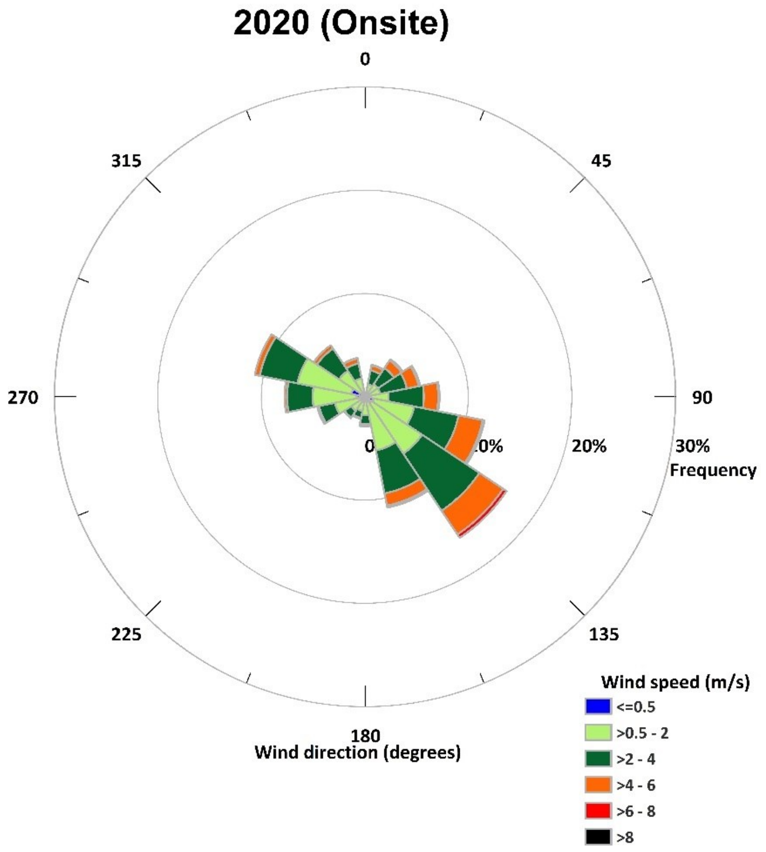


Figure 2-1: Winu Project Locality Map & Winu Mining Lease





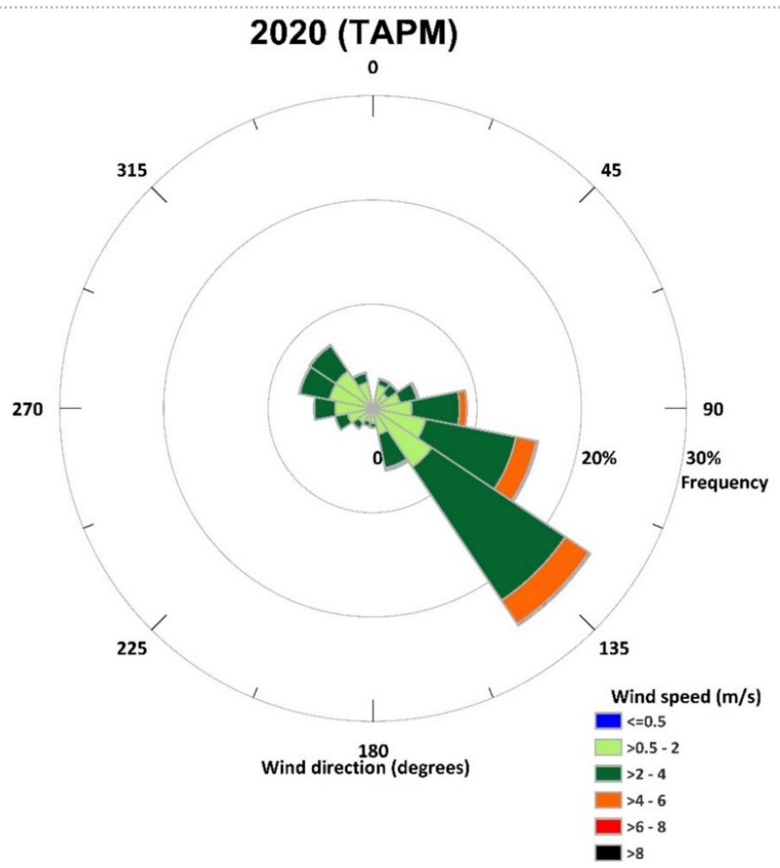


Figure 2-2: Meteorological Trends

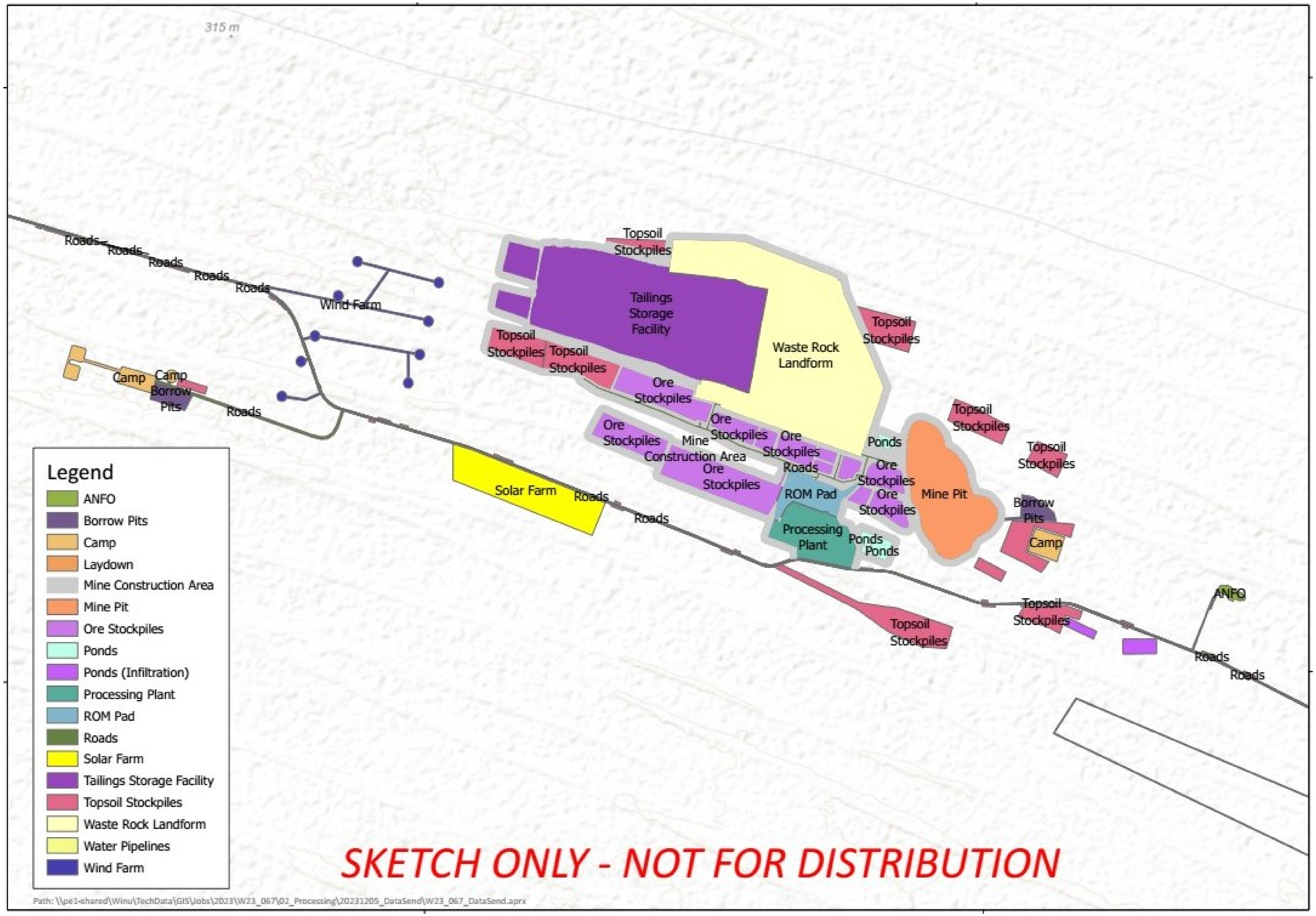


Figure 2-3: Winu Project Proposed Mining Operations

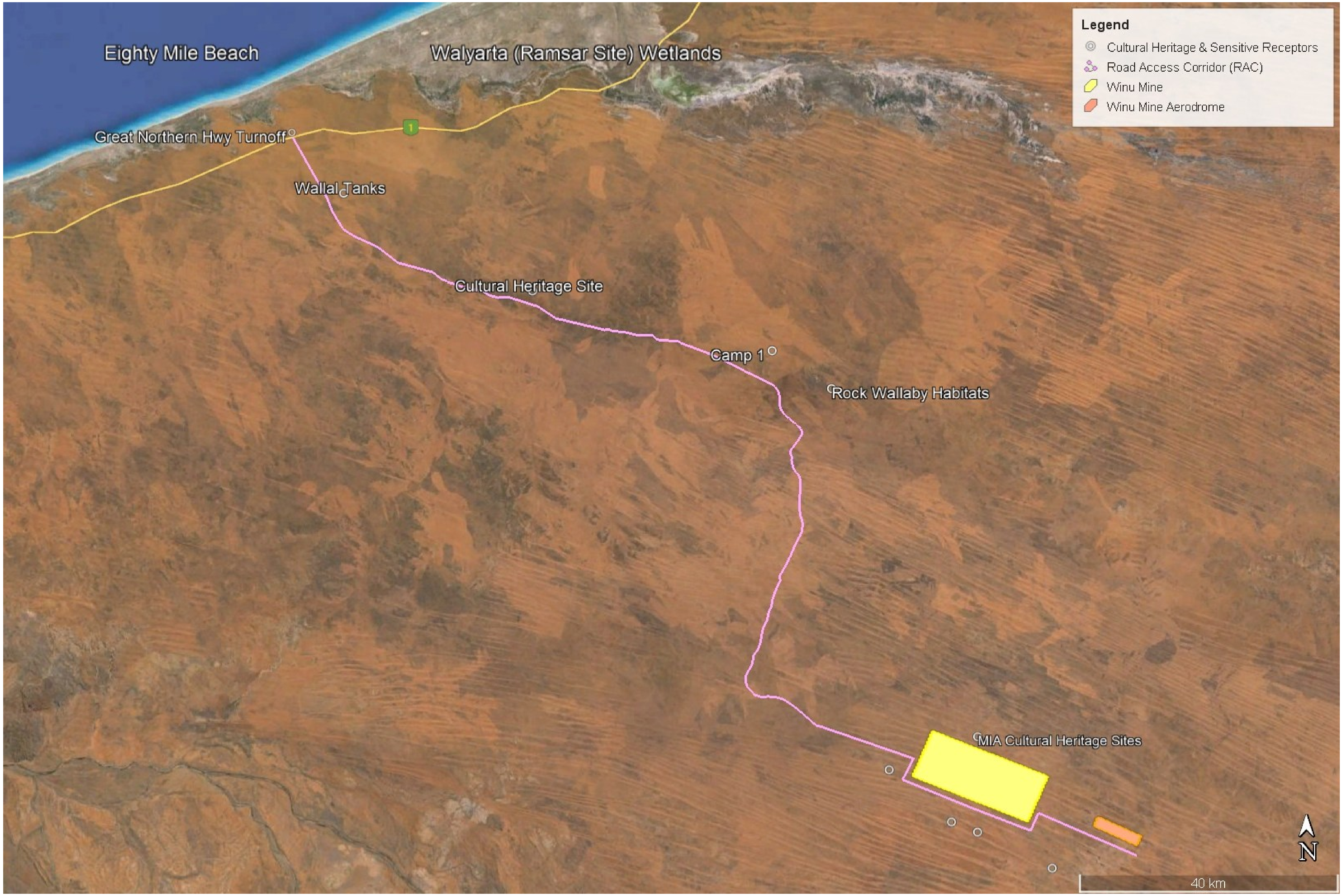


Figure 2-4: Winu Project Road Access Corridor (RAC), Computational Grids and Sensitive Receptors

Table 2-1 lists key monthly climate metrics data for the onsite, Pardoo BoM AWS and the TAPM output to compare and ensure the meteorological data used in subsequent modelling scenarios is representative of the Site.

Table 2-1: Rainfall & Temperature Data for Meteorological Sites

Average Rainfall (mm)												
Meteorological Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Onsite (2020)	57.2	15.8	0.00	0.00	47.6	0.00	0.00	0.40	0.00	4.80	24.2	35.0
Pardoo (all years)	69.0	79.3	63.7	19.5	23.8	26.6	9.3	4.5	2.7	0.9	3.2	23.7
Maximum Temp. (^{0}C)												
Meteorological Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
TAPM (2020)	40.6	39.5	38.3	36.9	29.6	24.0	24.5	31.5	33.9	38.1	39.0	39.0
Onsite (2020)	43.5	42.5	41.7	40.7	34.7	30.7	30.6	37.1	38.3	41.6	43.4	42.8
Pardoo (all years)	46.5	44.9	45.6	42.7	38.5	35.2	34.8	38.3	41.6	46.7	45.6	48.0
Average Wind (m/s)												
Meteorological Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
TAPM (2020)	2.4	2.3	1.9	2.2	2.8	2.5	2.7	2.2	2.3	2.2	2.2	2.3
Onsite (2020)	2.9	2.7	1.8	2.1	2.5	2.4	2.4	1.9	2.0	2.5	2.3	2.7
Average Wind (degrees)												
Meteorological Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
TAPM (2020)	201	204	171	153	120	124	121	153	162	207	224	180
Onsite (2020)	199	220	191	185	126	118	123	183	182	215	222	182

Pardoo meteorology shows large rainfall events given its coastal location. Rainfall events at the Winu Project tend to characterise seasonal 'bursts' of rain rather than persistent rains over monthly periods.

Maximum monthly rainfall statistics for the TAPM and onsite datasets are illustrated in Figure 2-5 where TAPM overestimates rainfall albeit with a similar trend to what is experienced at the Winu Project.

Maximum temperatures are comparable across onsite, TAPM and Pardoo meteorological stations, albeit that Pardoo represents all years and therefore shows larger maximum temperature ranges compared to the 2020 dataset for onsite and TAPM. Notwithstanding, onsite and TAPM are comparable for maximum temperatures except where TAPM shows lower maximum temperatures from late Autumn to early Spring. Average wind speed and wind direction for onsite and TAPM are comparable across all months.

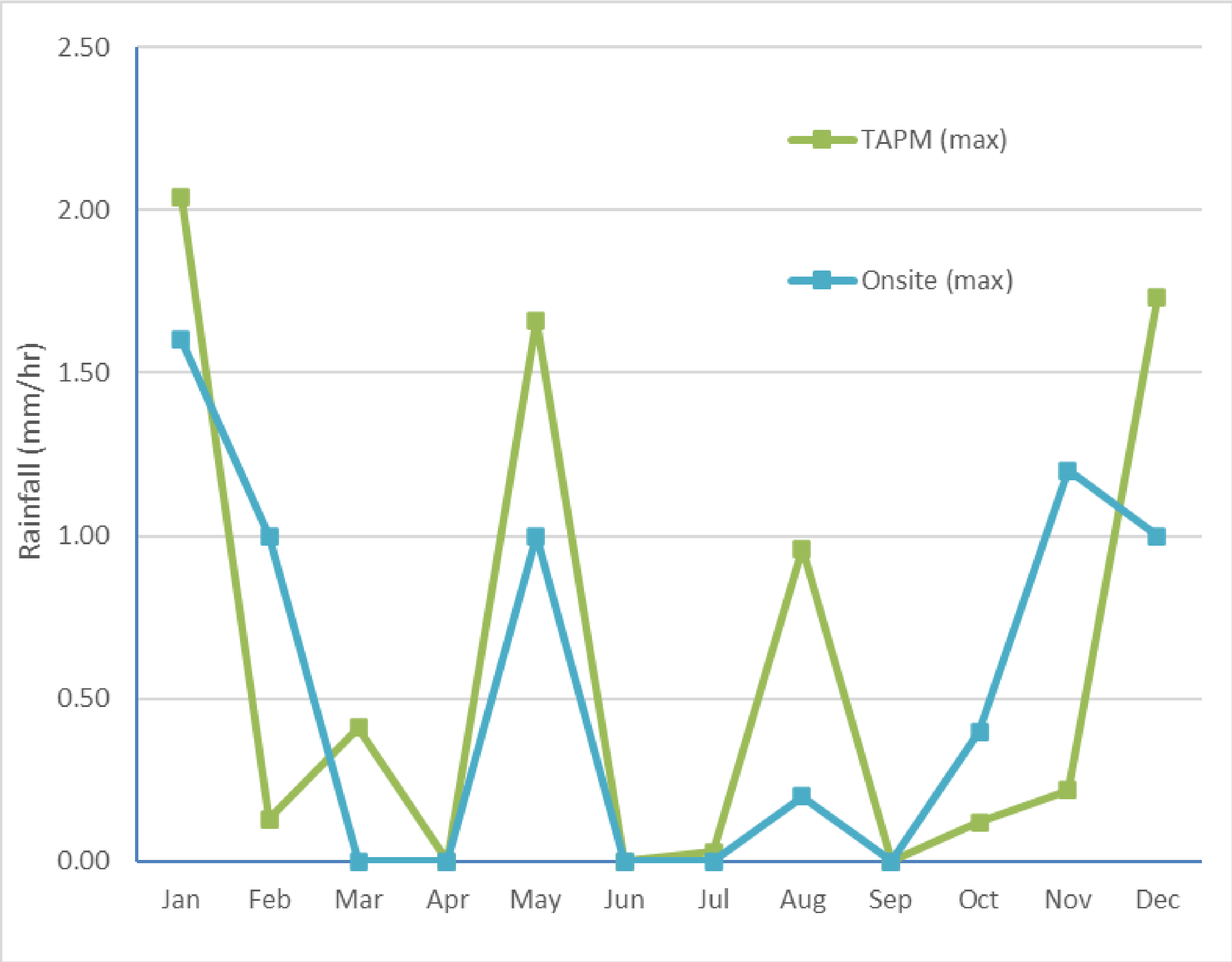


Figure 2-5: Monthly rainfall comparisons (onsite 2020 vs TAPM 2020)

Based on the local meteorology and that of the TAPM prognostic output, the TAPM dataset is reliably comparable to that of onsite data collected. A hybrid meteorological dataset was developed to represent the Winu Project for subsequent modelling applications.

3 Emission Estimation

The estimate of dust emissions has been derived from mining production predictions by RTW based on operations in 2032.

The 2032 Total Materials Moved (TMM) target is estimated at 32 Mega tonnes (Mt).

Emissions have been estimated (operations only) to reflect the Mine and infrastructure Area (MIA) mining activities that include drilling, mine blasting, loading/unloading and stockpiling (inc. topsoil), dust impacts from mine haulage routes (vehicle movements), topsoil stockpiling and erosion.

Concentrate loading at site and port have not been considered in this assessment.

3.1 MIA Sources of Emissions

Key areas for operational dust emissions for the Winu Project are:

- Drilling,
- Blasting,
- Dozing,
- Excavation loading of Materials,
- Haul Truck unloading to ROM,
- Stockpiling,
- Wheel generated dust, and
- Wind erosion from Stockpiles.

Emission estimation techniques have been primarily sourced from the National Pollution Inventory Emission Estimation Technique Manual for Mining (NPI, 2012).

3.2 Estimated Annual Emissions for MIA

Emissions for TSP, PM_{10} and $PM_{2.5}$ were derived using direct emission estimation equations and default TSP/PM_{10} and PM_{10}/$PM_{2.5}$ ratios referenced from (NPI, 2012).

The estimated PM_{10} annual emissions (kg/yr) from the Winu Project, based on the mining activity footprint, are listed in Table 3-1 with corresponding emission control factors referenced from (NPI, 2012).

PM_{10} Emission rates (g/s) are listed in Table 3-2.

Table 3-1: PM_{10} Emissions (mining) for Winu 2032 Operations (Mine Only)

Activity	PM_{10} (kg/year)	Controls	Control Efficiency (%)
Drilling	34,598	In Pit Retention	5%
Blasting	20,817		
Bulldozing	33,905		
Wind Erosion (Topsoil)	34,671	-	-
Wind Erosion (Stockpiles)	60,929		
Unloading (ROM, Waste)	134,530		
Loading (Ore/Waste)	352,510	In Pit Retention	5%
On-Mine Wheel Generated Dust	7,415,801	Water Carts	50%

Table 3-2: Mining Specifics & PM_{10} Emission Rates for Peak Operations (Mine Only)

Activity/Item	Value	PM_{10} (g/s)
No. Holes Drilled (yr)	117,482	1.096
No. Blasts/yr (3 Drill Rigs)	578	0.660
Tonnages of Ore Loaded	9,815,945	3.472
Tonnages of Ore Unloaded		0.663
Tonnages of Waste Loaded	21,763,919	7.698
Tonnages of Waste Unloaded		1.469
Bulldozer (Ore/Waste)	-	0.537
Moisture Content of Ore (t/yr)	2	-
Silt Content of Haul Roads (%)	10	-
Haul (CAT 777F) Truck Empty Weight (t)	73	-
Haul Truck Payload (t)	90	-
No. Haul Truck Trips per year (ROM)	24,496	7.202
Haul (Komatsu 830E-AC) Truck Empty Weight (t)	164	-
Haul Truck Payload (t)	221	-
No. Haul Truck Trips per year (Waste)	132,328	110.297

3.2.1 Wind Erosion of Stockpiles

Wind erosion is exacerbated in high winds and dependent (among others) on the 'erodible' fraction of the stockpile surface.

Non-erodible roughness elements will dampen the momentum transferred from atmospheric conditions to the surface and thus reduce wind shear and subsequently reduce mobility of surface particles. Wind erosion is prominent in daytime hours due in part to the stronger wind shear in the surface layer.

Wind erosion was calculated using the general formulae from Shao (YP Shao, 1996), and further reviewed and reported by SKM (SKM, 2005) where (for PM_{10}):

$$EF_{PM10} = k\,[WS^3 \times (1 - WS_0^2 / WS^2) \qquad \textit{when } WS > WS_0$$

$$k = 6.2 \times 10^{-7}\ (g/m^2/s)$$

$$EF_{PM10} = 0 \qquad \textit{when } WS < WS_0$$

$$EF_{PM10(g/s)} = EF\,(PM_{10}) \times A \times (100 - CE_{PM10})/100 \qquad A = \text{Total exposed } (m^2)$$

CE = Overall Control Efficiency (%)

- The wind speed threshold (WS_0) was set to an hourly average of 4.17 m/s (15 km/hr).
- Rainfall was not considered in the wind erosion calculations.

The wind erosion calculations utilised in this Assessment derived significantly larger values for g/s emissions when compared to the NPI default values of 0.4 kg/ha/hr for TSP (PM_{10} = 50% of TSP) (NPI, 2012), and also when applying the AP-42 emission factor equation, from NPI, for wind erosion of stockpiles (Section 1.1.17, (NPI, 2012)). As a result, the wind erosion approach utilised herein is considered conservative compared to currently accepted methods.

Further details including emission estimation equations and workings are presented in Appendix A.

3.3 Background Regional Dust Concentrations

The collection of baseline ambient dust data and the subsequent dust impact assessment for the Winu Project were undertaken to support early-stage stakeholder engagement and to facilitate informed consultation with affected parties, including Traditional Owners.

In Western Australia, mining developments are required to consider and engage with Native Title holders and Aboriginal stakeholders under the future act provisions of the Native Title Act 1993, as well as through State-based environmental and heritage approval processes. These frameworks recognise that a significant proportion of Western Australia is subject to Native Title rights and interests and require proponents to engage with Traditional Owners in relation to potential impacts on land, environment, and cultural values.

Consistent with these obligations, the baseline dust monitoring program was designed to characterise existing ambient air quality conditions in the Winu locality and provide a transparent, evidence-based foundation for discussions with stakeholders. The monitoring was not intended to serve as a regulatory compliance dataset, but rather to establish an indicative understanding of background dust levels in a remote environment where limited historical data exist.

The instruments utilised in the Winu baseline monitoring program (e.g. Met One E-Sampler) are widely used across the Western Australian resources sector for ambient dust monitoring, particularly for operational management and environmental performance tracking. While not Australian Standard reference methods under the AS/NZS 3580 series, their use is well established for indicative monitoring, screening and trend analysis, particularly in remote environments. Accordingly, their application in this context is appropriate for characterising background conditions and supporting stakeholder engagement, noting that the data are used for contextual interpretation rather than formal compliance assessment.

Table 3-3: Measured Background Dust Results (Red OHMS 2021-2022)

Parameter	Background PM_{10}
Typical Range (μg/m³)	2 – 10
Maximum Observed 24-hr Average (μg/m³)	16.5
NEPM 24-hr Criterion (μg/m³)	50
Maximum as % of Criterion	33%
Assessment	Contextual / indicative

The baseline monitoring program undertaken by Red OHMS in 2022 (Table 3-3) provides a qualitative characterisation of ambient dust levels at the Winu Project, indicating generally low background concentrations. While not undertaken using Australian Standard reference methods, the data, together with the remote project setting and absence of identified nearby major anthropogenic dust sources, supports the conclusion that background dust levels are predominantly influenced by natural arid-zone dust processes and provides a reasonable contextual basis for understanding ambient conditions.

The Red OHMS 2022 PM_{10} baseline dust results are further supported by previous regional background dust measurements undertaken in 2015, albeit these 2015 results represent regional dusts within the broader Pilbara iron ore operational region, including areas associated with the Port Hedland export corridor and related mine, rail and port infrastructure.

The maximum 24-hour PM_{10} concentrations measured by Red OHMS in their 2021-2022 program was 16.5 µg/m³. This is comparable to the BHP, 2015 result for PM_{10}, albeit the Red OHMS value was a maximum.

The BHP Pilbara Strategic Environmental Assessment (SEA) – Cumulative Air Quality Assessment (BHP, 2015) evaluated regional particulate monitoring data collected across the Pilbara and identified representative regional background concentrations as listed in Table 3-4.

Table 3-4: BHP SEA Background Dust Concentrations (Pilbara)

$PM_{2.5}$ (24-hour average)	3 µg/m³ (15% of the PM_{10} background concentration)
PM_{10} (24-hour average)	18 µg/m³
TSP (24-hour average)	33 µg/m³

The assessment noted that while the SEA provided regional background particulate concentrations suitable for cumulative air quality assessment purposes, it did not provide corresponding background dust deposition rates.

These background concentrations have subsequently been adopted and referenced within multiple Western Australian mining and environmental assessment studies for regional cumulative dust impact assessment within the Pilbara.

Relevant published references reproducing these values include:

- Hemi Gold Project Air Quality Assessment, and
- Ministers North Dust Modelling Assessment.

The BHP, 2015 background dust values have been adopted within the Assessment.

4 Dispersion Modelling Methods

4.1 Meteorology

As discussed in Section 2-1, the nearest Bureau of Meteorology (BoM) Automatic Weather Stations (AWS) to the Winu Project are Pardoo (004028) and Mandora (004019), however; Mandora does not have available data to review. Pardoo is comparable to Mandora given the coastal locations.

RTW has collected onsite meteorological data at the Winu Project during exploration and siting. This data was reviewed to determine if wind and temperature characteristics are comparable to the nearest BoM AWS. Data recovery for onsite meteorology at the Winu Project best represents the 2020 annual period. As a result, the 2020 meteorological period was utilised in this Assessment.

Additionally, CSIRO's The Air Pollution Model (TAPM) was utilised for the 2020 period to develop an annual prognostic met file for upper air met trends.

To ascertain if the TAPM output was comparable to the onsite and BoM wind data, the wind data from TAPM was extracted and plotted to a windrose along with the onsite and Pardoo BoM. These windroses are presented in Figure 2-2. All three meteorological datasets are highly comparable for wind characteristics with a resultant vector for prevailing winds from the south-east quadrant. Based on these comparable wind characteristics the TAPM output is reflective of actual winds at the Winu Project.

4.1.1 TAPM Meteorological Configuration

The TAPM (v4.0.4) model produces a 3D data tile representative of surface and upper air met characteristics with the following setup:

- 41 grid points (nx, ny),
- Five nests with the outer grid spacing (dx1, dy1) of 30 kms and subsequent nests approximately 1/3rd of the preceding nest (30, 10, 3, 1 and 0.3 kms),
- 25 vertical grid levels, and
- The innermost nest (0.3 km spacing) was extracted for data use.

4.2 Meteorological Data Analysis

The TAPM meteorological dataset had key characteristics extracted for the dispersion modelling application. These included:

- Total Solar Radiation - TSR (W/m^2),
- Net Radiation - NETR (W/m^2),
- Relative Humidity - RH (%),
- Mixing Height - ZMIX(m),
- Surface Friction Velocity - USTAR (m/s), and
- Change in Vertical Temperature Profile - DT01.

These prognostic characteristics were hybridised with the onsite meteorological characteristics to include wind, temperature and rain.

Figure 4-1 shows the 'hybrid' output from the onsite and TAPM meteorological datasets that was used in the dispersion modelling.

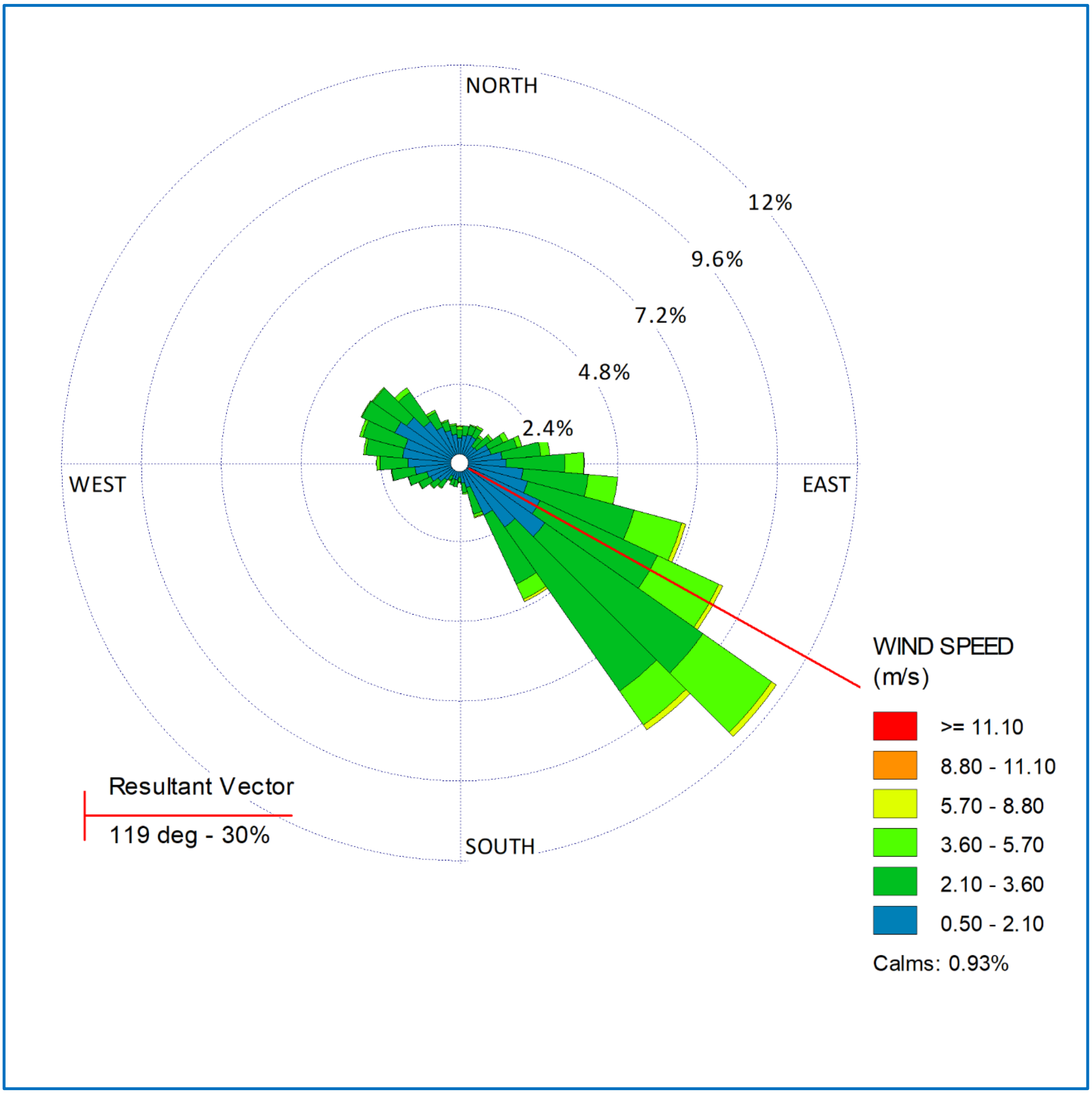


Figure 4-1: 2020 Meteorological Wind Characteristics (modelled)

Stable and Very Stable atmospheric conditions are prominent across the Winu Project. Under stable conditions mechanical dispersion plays a larger role in dispersing and vertical mixing of emission plumes when there is complexity in the terrain and surface roughness. In low surface roughness terrain, the effects of mechanical turbulence are weakened, to include a decrease in vertical mixing, and ground level emission plumes tend to have larger impacts over longer downwind distances from the emission source.

Stability refers to the atmosphere's ability to resist or enhance vertical motion resulting in turbulence. Stability encompasses (among others) temperature changes with atmospheric height (lapse rate), wind speed and surface roughness.

The six classes of stability are:

A	very unstable	• Unstable conditions enhance turbulence and subsequent dispersion; • Neutral stability neither enhances nor reduces turbulence; and • Stable conditions reduce turbulence and therefore dispersion is reduced.
B	unstable	
C	slightly unstable	
D	neutral	
E	stable	
F	very stable	

Dispersive conditions based on the vertical meteorological profile can be illustrated using the diurnal stability relationship. Figure 4-2 illustrates the diurnal trends of atmospheric stability during annual wind conditions across the locality, by plotting the averaged inverse Monin-Obukhov length (m) against each hour of the day.

The Monin-Obukhov length describes the effects of buoyancy on turbulent flows, which can simply be defined as the height at which turbulence is generated more by buoyancy than by wind shear.

Stability trends show that unstable conditions begin around approximately 5AM and continue through until approximately 6-7PM.

Figure 4-3 illustrates the mixing height above ground which shows that mixing heights increase during daytime hours from approximately 7AM and begin to decline around 7PM. During these daytime hours the increased mixing height is due to convective forces (vertical dispersion) and its decline is due to the change from convective to mechanical mixing. A rapid decrease in mixing heights after sunset is consistent with the atmospheric transition from convective to mechanical.

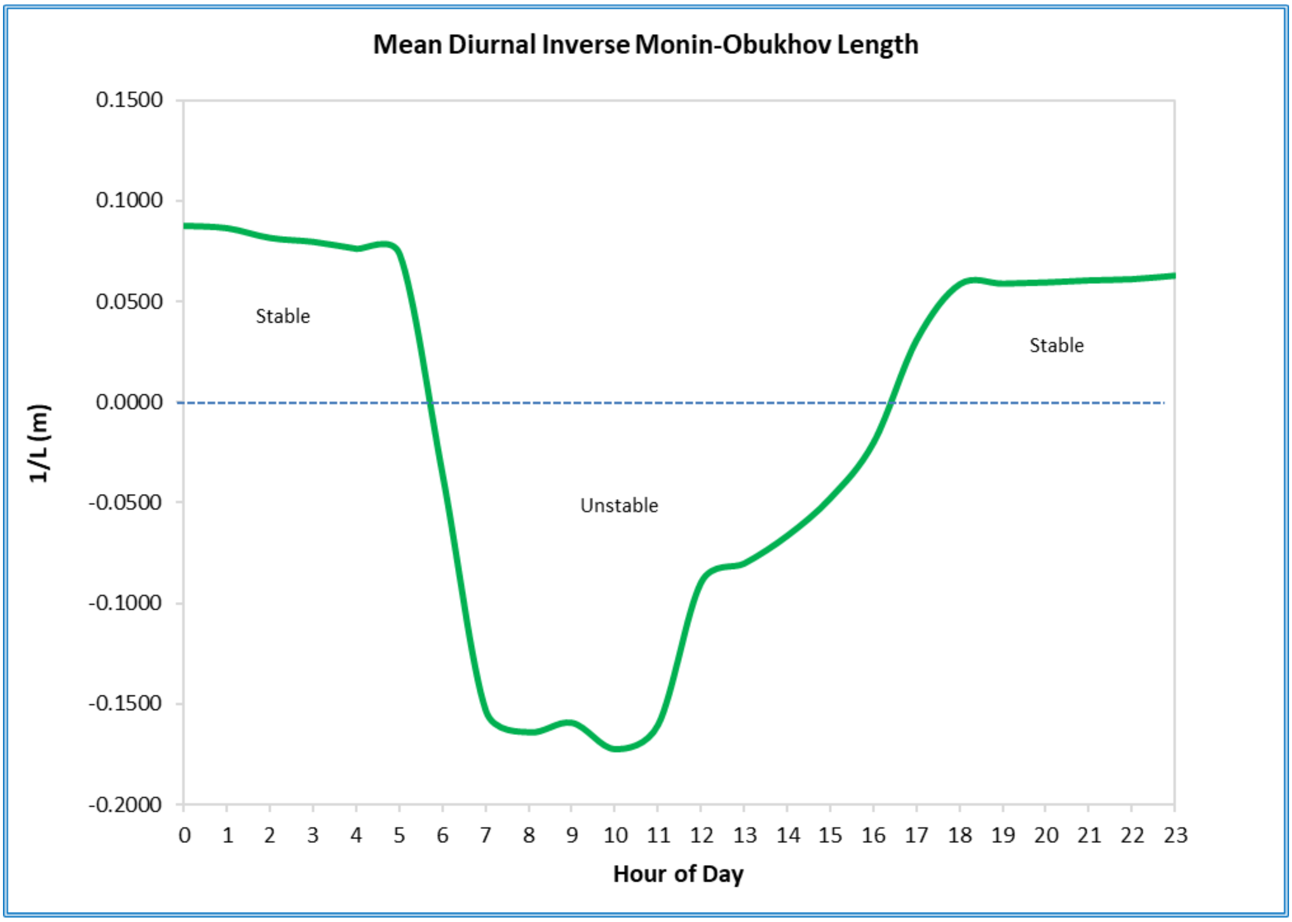


Figure 4-2: Diurnal Trends of Atmospheric Stability (modelled)

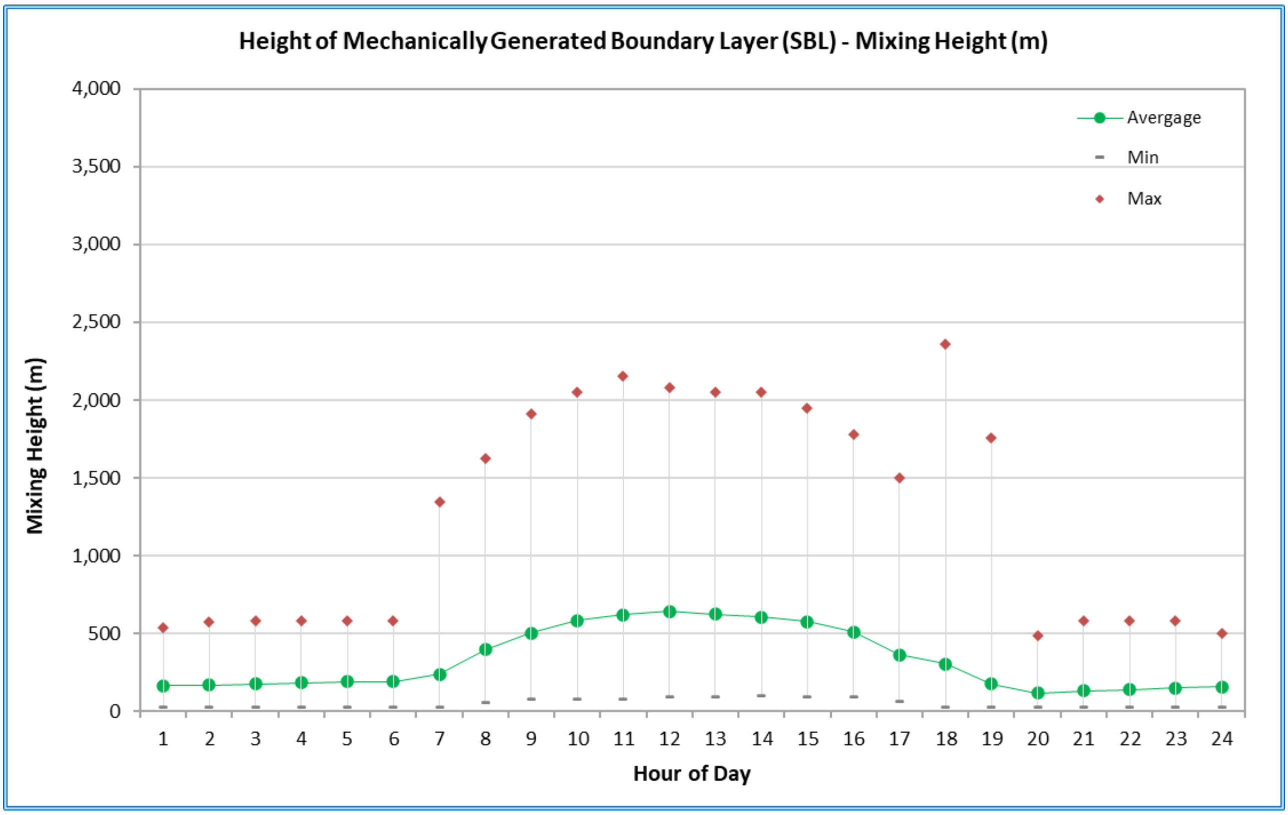


Figure 4-3: Diurnal Trends of Mixing Height (modelled)

4.3 AERMOD Configuration

The air emissions dispersion modelling impact assessment was carried out using the Gaussian AERMOD Modelling System (Version 10.0.1). The methods for undertaking AERMOD assessments are in accordance with the EPA Victoria publication documents 1550 and 1551 which detail the modelling setup.

The EPA Victoria guidance is relevant in so much as the modelling setup and execution, where the AERMOD system is the accepted plume model that supersedes Ausplume according to EPA Victoria as it contains (among others) advanced algorithms accounting for impacts that cause a plume to act in a non-Gaussian manner and more readily reflects emissions impacts affected by terrain within the modelling domain. This modelling setup is the general instruction for setting up and executing the AERMOD model and is accepted statewide throughout Australia.

The AERMOD modelling methodology was based upon the EPA Publication 1551 [1].

Presently, the WA DWER guidance for dispersion modelling is under review and subsequently the previous and existing guidance from 2006 for Dispersion Modelling has also been adopted where relevant.

An example of the AERMOD input configuration is presented in Appendix B.

AERMOD options and assumptions were:

- All emissions sources were modelled as Volume Sources,
- Surface and Upper air meteorological data generated by AERMET,
- Terrain information obtained from Shuttle Radar Topography Missions (SRTM), 3-arc at 90 m resolution, and
- Pollutant concentrations were modelled against key sensitive receptors, and across uniform gridded receptors.

4.3.1 AERMET

AERMET options and assumptions were:

- Threshold wind speed of 0.5 m/s was used,
- Adjust surface friction velocity (ADJ_U*) option was used for low winds, and
- Adjust horizontal meander was used for low winds.

TAPM parameters were extracted and supplemented the onsite data.

The TAPM upper air parameters that were input into the AERMET module were:

- Net Radiation (NRAD)
- Total Solar Radiation (TSR)
- Mixing Height (ZMIX)
- Surface Friction Velocity (USTAR)

[1] https://www.epa.vic.gov.au/~/media/Publications/1551.pdf

- Temperature Differential (DT01)

Surface characteristics are needed to supplement the meteorological parameters and thus allow AERMET to produce surface and profile meteorological data ready for modelling. Surface characteristics are developed within the aersurface utility in AERMET.

4.3.1.1 Aersurface Processing

Aersurface was run as a single sector.

The surface roughness length relates to the height of obstacles and is a factor in determining the magnitude of mechanical turbulence and the height of the mechanically generated boundary layer. Surface roughness length was minimised to reflect a conservative assessment.

Albedo refers to the fraction of total solar radiation reflected by the Earth's surface back to space with no absorption.

The Bowen Ratio has reference to the Earth's surface moisture and is utilised in determining the planetary boundary layer parameters for convective conditions.

Table 4-1: Aersurface Parameters

Sector	Albedo	Bowen Ratio	Surface Roughness (Zo)
1	0.20	1.5	0.05

4.3.2 Deposition Modelling

Table 4-3 lists the particle sizes' mean diameter and geometric mean values adopted in the Assessment.

Table 4-2: Particle Size Inputs into AERMOD

Particle Size	Mean Diameter	% by Weight
PM_{10} to PM_5	7.5	48
PM_5 to $PM_{2.5}$	3.75	37
< $PM_{2.5}$	1.25	15

4.3.3 Dispersion Modelling Limitations

By definition, air quality models can only approximate atmospheric processes. Many assumptions and simplifications are required to describe real phenomena in mathematical equations. Model uncertainties can result from:

- Simplifications and accuracy limitations related to source data,
- Extrapolation of meteorological data from selected locations to a larger region, and
- Simplifications to model physics to replicate the random nature of atmospheric dispersion processes.

Models are reasonable and reliable in estimating the maximum concentrations occurring on an average basis. That is, the maximum concentration that may occur at a given time somewhere within the model domain, as opposed to the exact concentration at a point at a given time will usually be within the ±10% to ±40% range (US EPA, 2003).

Typically, a model is viewed as replicating dispersion processes if it can predict within a factor of two, and if it can replicate the temporal and meteorological variations associated with monitoring data. Model predictions at a specific site and for a specific hour, however, may correlate poorly with the associated observations due to the above-indicated uncertainties. For example, an uncertainty of 5° to 10° in the measured wind direction can result in concentration errors of 20% to 70% for an individual event (US EPA, 2003).

5 Assessment Results & Conclusion

The dispersion modelling undertaken for the Winu Project incorporated conservative assumptions in both emissions' estimation and meteorological representation, including the use of established emission factors for mining activities, conservative treatment of wind erosion from exposed surfaces, and the application of a full-year prognostic meteorological dataset.

The outcomes of the dust assessment were used to inform stakeholder discussions, including engagement with Traditional Owner groups, by providing a clear and accessible representation of potential environmental impacts at sensitive locations. This approach is consistent with contemporary expectations under Western Australian mining and environmental approval processes, which emphasise the need to consider environmental, cultural and community values and to support meaningful participation of stakeholders in consultation processes.

The maximum ground level concentrations of dust fractions for predicted concentrations and deposition of dust within the MIA have been predicted across the modelling computational domain. The results are presented in the following sub-sections.

- **NOTE:** The results reflect mine-only dust concentrations.

The RAC runs from Great Northen Highway and into the MIA. Approaching the MIA is the proposed Worker's Camp and various Cultural Heritage locations. The MIA is expected to emit high concentrations of dusts and deposition of these dusts, and subsequent risk to the Workers within the Camp areas have been assessed based on TSP, PM_{10} and $PM_{2.5}$, where TSP relates to nuisance dusts and dust deposition, and PM_{10} and $PM_{2.5}$ relates to human health exposure.

5.1.1 TSP Concentration and Deposition

Modelled 24-hr TSP concentrations of MIA activities are compared to the criterion of 90 µg/m^3.

The 24-hr TSP model results for the MIA indicate that:

- The TSP concentrations exceed the criterion of 90 µg/m3 at the Winu Mining Camp which is west of the central Winu Mining activities at approximately 10 kms from the central Winu Mining activities,
- Dust concentration decay is 'rapid' when moving north and south,
- Concentration decay to the east and west is 'slow' given the persistence of winds in these directions that will carry the dusts for longer distances over time, and
- Refer Figure 5-1 for MIA model illustration of ground level TSP concentrations.

The monthly dust deposition rates for the MIA indicate that:

- Monthly deposition is predicted to be low at the Winu Mining Camp, which is approximately 10 kms west from the central Winu Mining activity's location, where:
  - The low deposition rates of 0.16 – 0.26 g/m^2/month at the Mining Camp is attributed to wind speeds allowing entrained dust to settle to ground nearer to the MIA, whereas the

smaller dust particles are carried farther downwind resulting in dust concentrations over larger distances.

It is clear the MIA Haul Roads pose a significant risk for dust concentration impacts. The MIA Haul Roads have been assumed to have a 50% reduction in airborne dust concentrations due to Water Cart applications for dust suppression.

The RAC will be a sealed road which will remove wheel-generated dust from transportation into and out of the MIA. As a result, only dust impacts from the MIA will persist.

5.1.2 PM_{10}

5.1.2.1 24-Hr Average

Modelled 24-hr PM_{10} concentrations of mining activities are compared to the latest DWER and subsequent NEPM criteria of 50 µg/m³.

The model results indicate that:

- The PM_{10} 24-Hr concentrations exceed the criterion of 50 µg/m³ at the Winu Mining Camp,
- The number of exceedances of the PM_{10} 24-Hr criterion within the Camp range between 19 – 50 i.e., 19 - 50 hours annually, and
- Refer Figure 5-2 for maximum ground level concentrations modelling illustration.

5.1.2.2 Annual Average

Modelled Annual PM_{10} concentrations of mining activities are compared to the latest DWER and subsequent NEPM criteria of 25 µg/m³.

The model results indicate that:

- The PM_{10} annual concentrations do not exceed the criterion of 25 µg/m³ at the Winu Mining Camp, where the concentration range is predicted to be within 9 – 11 µg/m³, and
- Refer Figure 5-3 for maximum ground level concentrations modelling illustration.

5.1.3 $PM_{2.5}$

5.1.3.1 24-Hr Average

Modelled 24-hr $PM_{2.5}$ concentrations of mining activities are compared to the latest DWER and subsequent NEPM criteria of 25 µg/m³.

The model results indicate that:

- The $PM_{2.5}$ 24-Hr concentrations exceed the criterion of 25 µg/m³ at the Winu Mining Camp,
- The number of exceedances of the $PM_{2.5}$ 24-Hr criterion within the Camp range between 14 – 36 i.e., 14 - 36 hours annually, and
- Refer Figure 5-4 for maximum ground level concentrations modelling illustration.

5.1.3.2 Annual Average

Modelled Annual $PM_{2.5}$ concentrations of mining activities are compared to the latest DWER and subsequent NEPM criteria of 8 µg/m³.

The model results indicate that:

- The $PM_{2.5}$ annual concentrations do not exceed the criterion of 8 µg/m³ at the Winu Mining Camp, where the concentration range is predicted to be within 3.0 – 4.1 µg/m³, and
- Refer Figure 5-5 for maximum ground level concentrations modelling illustration.

5.1.4 PM_{10} and $PM_{2.5}$ Exceedances at Winu Mining Camp

The proposed Winu Mining Camp at the entrance to the MIA was assessed for the number of exceedances (counts) of PM_{10} and $PM_{2.5}$ dusts over the annual modelling period.

Three (3) discrete receptors were placed within the Camp area representing the entrance (1,2) and the middle (3) and are listed in Table 5-1.

Table 5-1: Winu Mining Camp Discrete Receptors

Receptor I.D	X – UTM (metres)	Y – UTM (metres)
1	357355.8	7711293.9
2	357239.0	7710874.9
3 (middle)	355748.4	7710964.2

The peak dust concentrations for PM_{10} and $PM_{2.5}$ at the Winu Mining Camp Discrete Receptor locations are listed in Table 5-2.

- For PM_{10}, the 24-hour criterion for exposure is 50 µg/m³, and the annual criterion is 25 µg/m³, and
- For $PM_{2.5}$, the 24-hour criterion for exposure is 25 µg/m³, and the annual criterion is 8 µg/m³.

Table 5-2: Winu Mining Dust Exceedances Peak Concentrations (µg/m³)

Receptor I.D	24-hour PM_{10} Exceedance Range (counts)	24-hour PM_{10} Peak Concentrations (µg/m³)	Annual PM_{10} Peak Concentrations (µg/m³)	24-hour $PM_{2.5}$ Exceedance Range (counts)	24-hour $PM_{2.5}$ Peak Concentrations (µg/m³)	Annual $PM_{2.5}$ Peak Concentrations (µg/m³)
1	19 - 50	179.5	12.7	14 - 36	58.6	4.1
2		149.7	11.4		48.3	3.7
3 (middle)		148.1	9.7		49.4	3.1

Whilst the maximum modelling predictions have shown there are 24-hour exceedances of PM_{10} and $PM_{2.5}$ dusts at the Winu Mining Camp, the number of days (counts) of these exceedances suggests that exposure to these dusts is limited to worst-case meteorological conditions and therefore careful design of the Winu Mining Camp to include outdoor areas and appropriate dust controls for sleeping and indoor areas may provide the necessary protections from these exceedance events.

5.2 Cumulative Dust Impacts (Mine Activities & Background)

The modelling plots (Figure 5-1 to Figure 5-5) represents mine-only contributions; therefore, any addition of background dust would increase total concentrations.

The background dust concentration as measured within the BHP SEA (Table 3-4) have been added to the key MIA receptors and presented in Table 5-3.

Table 5-3: Dispersion Modelling Mining Dust Predictions Including Background Dusts

Parameter	Comms	Camp 1	Camp 2	Camp 3
X Coordinate (UTM)	357288.39	356747.98	355819.16	355726.27
Y Coordinate (UTM)	7709650.77	7709574.78	7709988.53	7709692.99
Modelled 24-hr PM2.5 (µg/m³)	46.5	41.1	45.0	36.4
Background PM2.5 (24-hr average) (µg/m³)	3	3	3	3
Cumulative 24-hr PM2.5 (µg/m³)	49.5	44.1	48.0	39.4
PM2.5 24-hr Criterion (µg/m³)	25	25	25	25
PM2.5 % of Criterion	198%	176%	192%	158%
PM2.5 Annual (µg/m³)	3.5	3.3	3.0	2.9
PM2.5 Annual Criterion (µg/m³)	8	8	8	8
PM2.5 Annual % of Criterion	44%	41%	38%	36%
PM2.5 Assessment	24-hr above; Annual below for all			
Modelled 24-hr PM10 (µg/m³)	339.8	239.0	210.2	173.8
Background PM10 (24-hr average) (µg/m³)	18	18	18	18
Cumulative 24-hr PM10 (µg/m³)	357.8	257.0	228.2	191.8
PM10 24-hr Criterion (µg/m³)	50	50	50	50
PM10 % of Criterion	716%	514%	456%	384%
PM10 Annual (µg/m³)	56.0	31.7	22.4	15.4
PM10 Annual Criterion (µg/m³)	25	25	25	25
PM10 Annual % of Criterion	224%	127%	90%	61%
PM10 Assessment	24-hr above; Annual above for Comms & Camp 1			
Modelled 24-hr TSP (µg/m³)	384.5	316.8	274.4	285.6
Background TSP (24-hr average) (µg/m³)	33	33	33	33
Cumulative 24-hr TSP (µg/m³)	417.5	349.8	307.4	318.6
TSP 24-hr Criterion (µg/m³)	90	90	90	90
TSP % of Criterion	464%	389%	342%	354%
TSP Concentration Assessment	Above for all			
Max Monthly TSP Deposition (g/m²/30 days)	0.244	0.211	0.186	0.142
Deposition Criterion (g/m²/30 days)	4	4	4	4
Deposition % of Criterion	6%	5%	5%	4%
Above-background Criterion (g/m²/30 days)	2	2	2	2
Above-background % of Criterion	12%	11%	9%	7%
Deposition Assessment	Below for all			

The results indicate that maximum 24-hour $PM_{2.5}$ and PM_{10} concentrations may exceed the relevant criteria at the camp receptors under the conservative peak operating scenario. Annual $PM_{2.5}$ concentrations remain below the annual criterion at all assessed camp receptors, while annual PM_{10} concentrations exceed the annual criterion at Comms and Camp 1 only.

TSP 24-hour concentrations exceed the nuisance/amenity criterion; however, modelled monthly dust deposition remains well below both the maximum and above-background deposition criteria.

5.3 Conclusions

The MIA activities are estimated to emit dust exceeding acceptable nuisance levels within the mining areas. It is however expected that during the planning and preparation stages of the MIA there will be refinement/adjustment of mining activities, to include dust suppression measures and use of materials for road construction etc., to further reduce airborne dust concentrations.

These results indicate a localised and manageable camp design and operational dust control issue, rather than a broad regional impact.

The sealing of the RAC limits dust emissions to the MIA alone, which with persistent application of water (i.e., water carts) may deliver up to a 50% reduction in airborne dusts within the MIA.

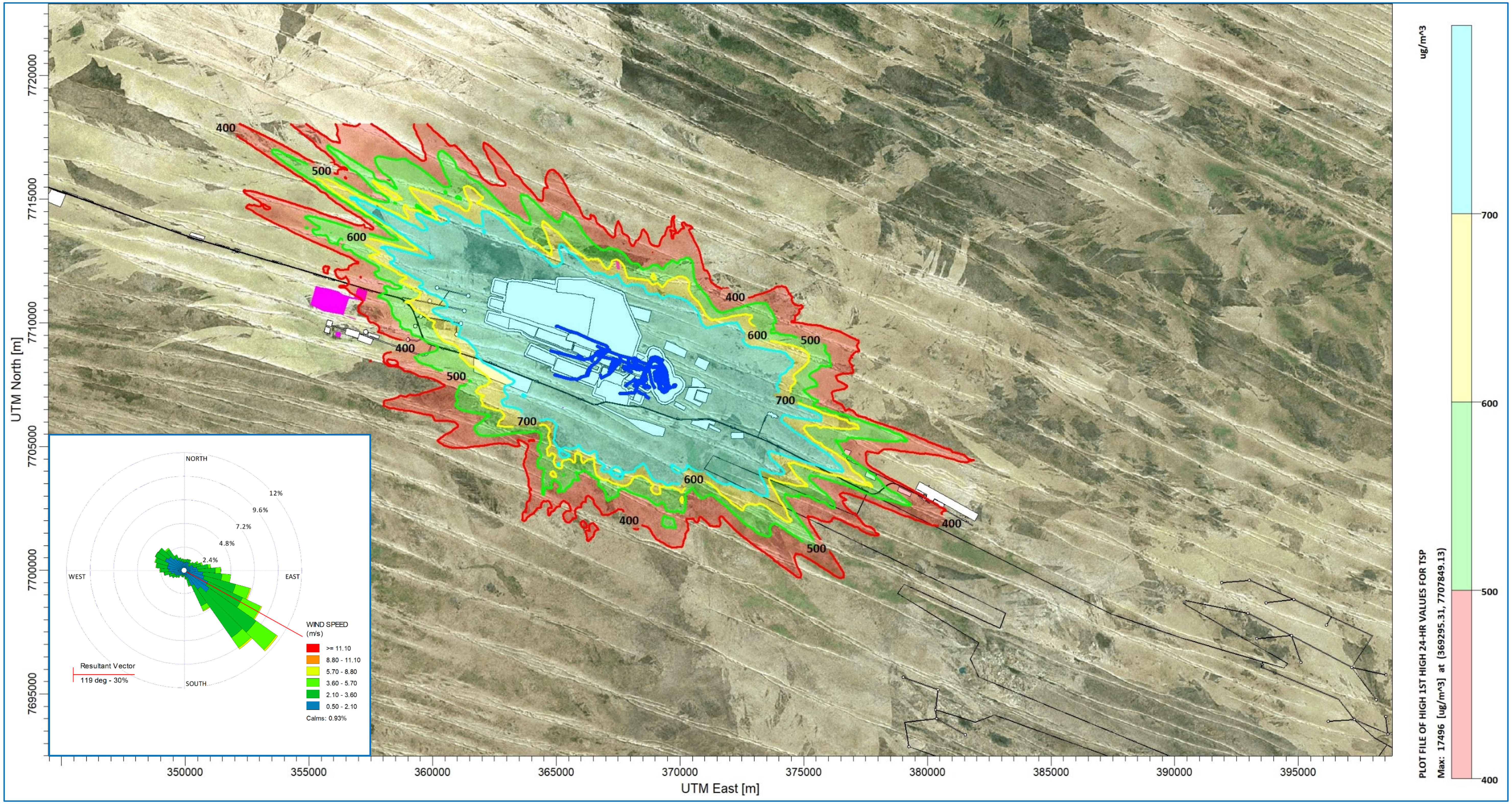


Figure 5-1: Mine-Only TSP 24-Hr Ground Level Concentrations (µg/m³)

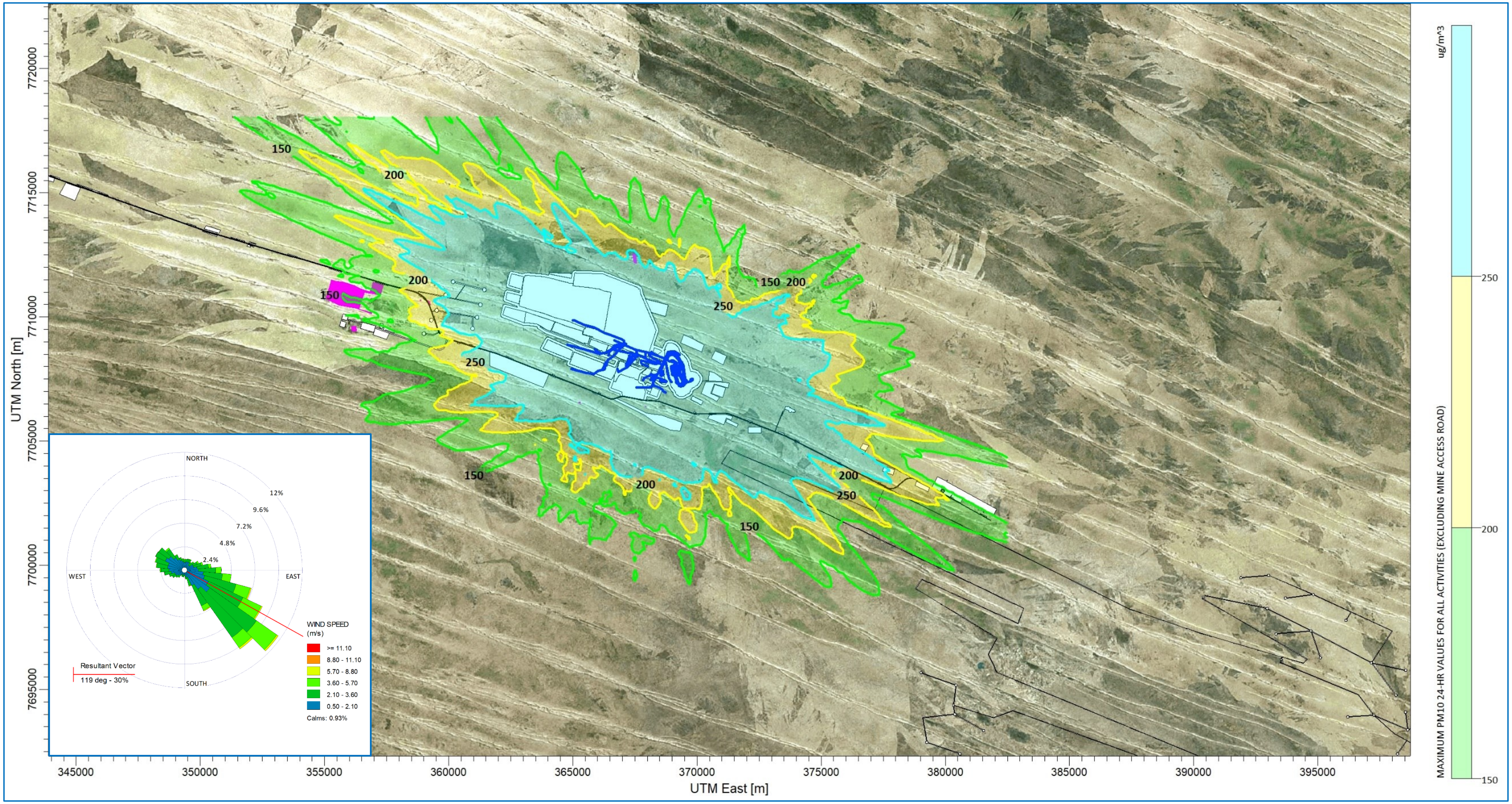


Figure 5-2: Mine-Only PM_{10} 24-Hr Ground Level Concentrations (µg/m^3)

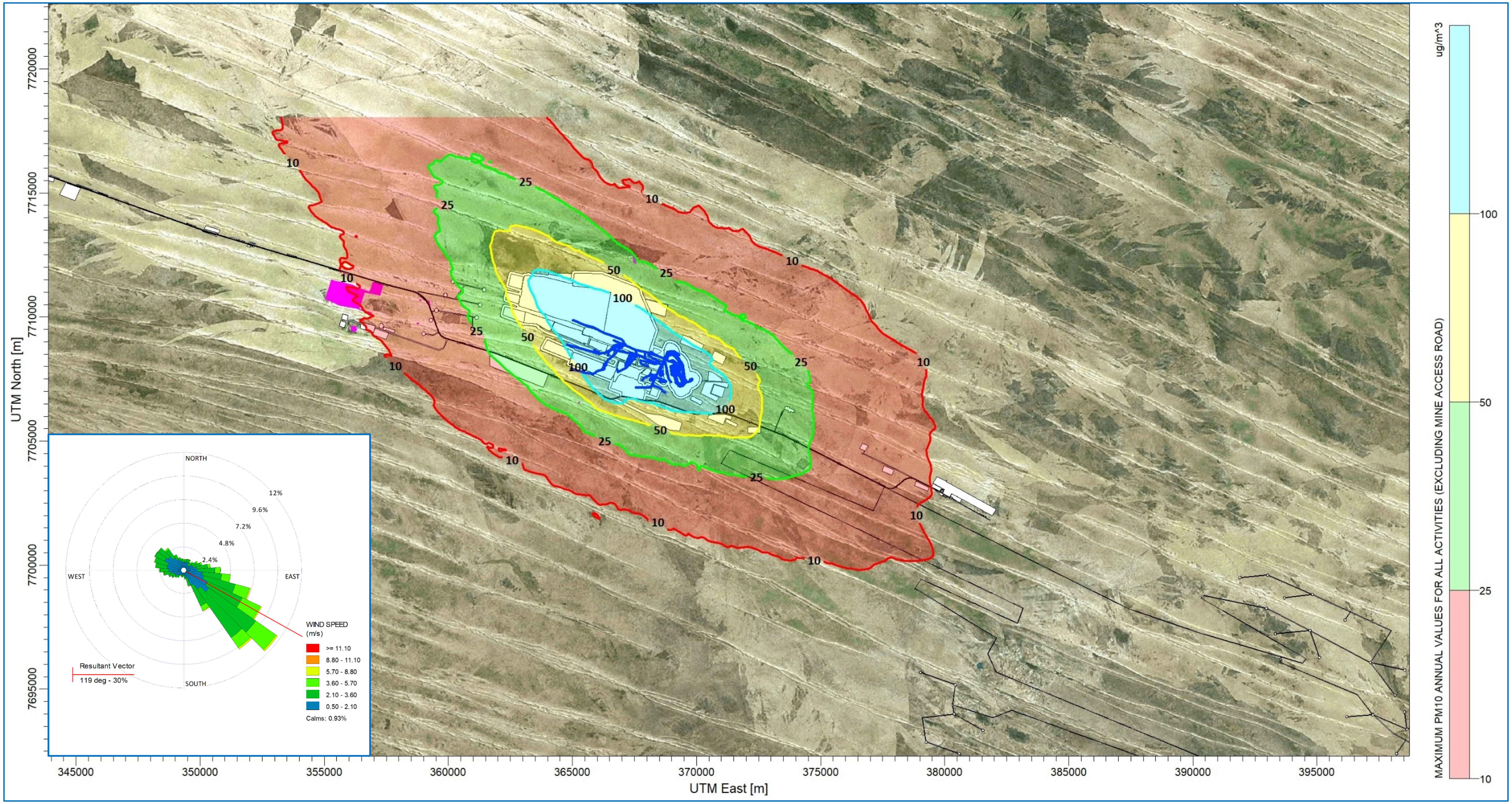


Figure 5-3: Mine-Only PM_{10} Annual Ground Level Concentrations (µg/m³)

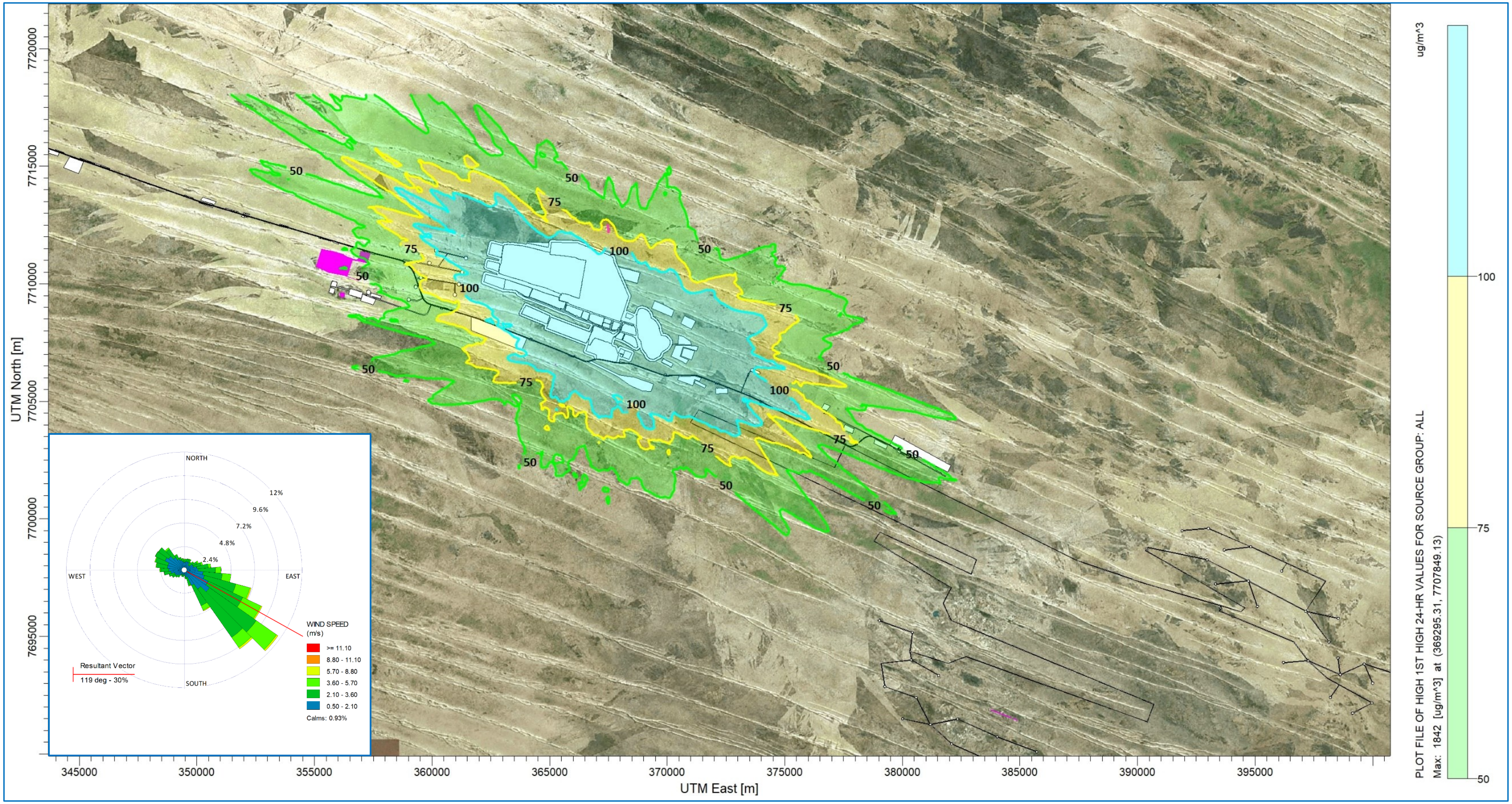


Figure 5-4: Mine-Only $PM_{2.5}$ 24-hr Ground Level Concentrations (µg/m³)

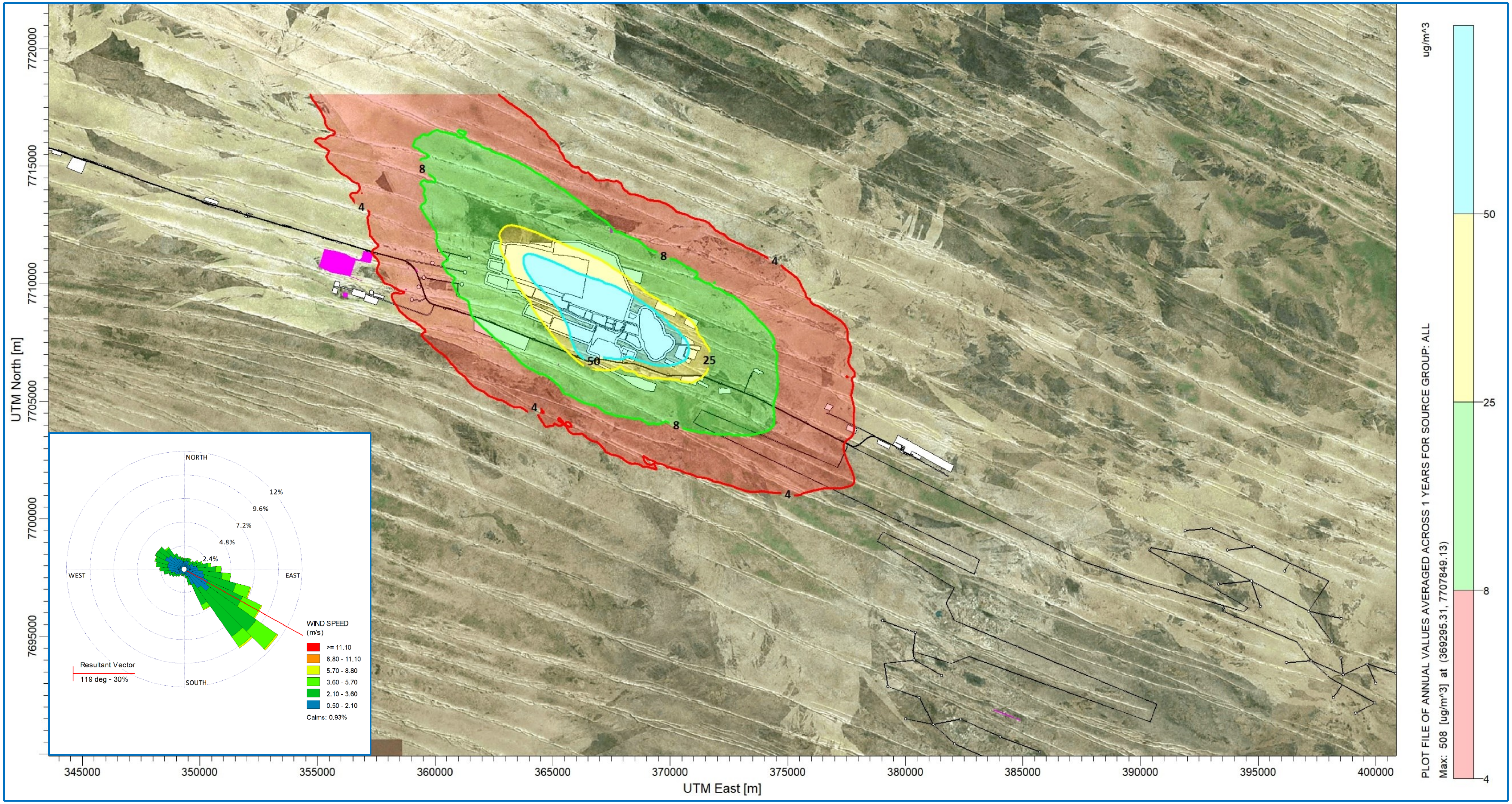


Figure 5-5: Mine-Only $PM_{2.5}$ Annual Ground Level Concentrations (µg/m³)

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Appendix A: Emissions Estimation Calculations MIA

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Appendix B: Example of AERMOD Input File