Environmental Consultants

Air Quality Impact Assessment:

Matai Mining (Pty) Ltd Mining Right Application for Vanadium, Titanium and Iron Ore on various Farms within the Magisterial District of Mankwe, North West Province

kimopax

GONDWANA
ENVIRONMENTAL SOLUTIONS

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Specialist Declaration of Independence

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I, Martin van Nierop, declare that:

- I act as the independent air quality practitioner in this application;
- I have expertise in conducting air quality impact assessments, including knowledge of the National Environmental Management Act (NEMA) (Act No. 107, 1998) and its amendments, the Environmental Impact Assessment (EIA) Regulations, as amended (Government Notice No. R982, 2014; Government Notice No. 326, 2017) and any guidelines that have relevance to the proposed activity;
- I will comply with the NEMA, and the EIA Regulations;
- I will perform the work relating to the application in an objective manner, even if this results in views and findings that are *not favourable to the application*;
- I will take into account, to the extent possible, the matters listed in the National Environmental Management: Air Quality Act, 2004 (NEM:AQA) (Act No. 39, 2005); Listed Activities established in terms of the NEM:AQA (Government Notice No. 248, 2010; Government Notice No. 551, 2015); National Ambient Air Quality Standards (NAAQS) established in terms of the NEM:AQA (Government Notice No. 1210, 2009; Government Notice No. 486, 2012); Priority Areas established in terms of the NEM:AQA (Government Notice No. 365, 2006; Government Notice No. 1123, 2007; Government Notice No. 494, 2012); and Regulations Regarding Air Dispersion Modelling (Government Notice No. R533, 2014) developed in terms of the NEM:AQA, when preparing the Air Quality Impact Assessment report relating to the application;
- I undertake to disclose to the applicant, registered interested and affected parties and the competent authority all material information in my possession that reasonably has or may have the potential of influencing: any decision to be taken with respect to the application by the competent authority; and the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority;
- I declare that there are no circumstances that may compromise my objectivity in performing such work;
- I have no, and will not engage in, conflicting interests in the undertaking of the activity;
- I do not have and will not have any vested interest (either business, financial, personal or other) in the proposed activity proceeding other than remuneration for work performed in terms of the Regulations;

- All the information submitted by me for the purposes of the application is true and correct to the best of my knowledge;
- All the particulars furnished by me in this form are true and correct; and
- I realise that a false declaration is an offence in terms of Regulation 48(1)(a) of the EIA Regulations, as amended, 2017 (Government Notice No. R982, 2014; Government Notice No. 326, 2017).

SIGNATURE:

I, Anja van Basten, declare that:

- I act as the independent air quality practitioner in this application;
- I have expertise in conducting air quality impact assessments, including knowledge of the National Environmental Management Act (NEMA) (Act No. 107, 1998) and its amendments, the Environmental Impact Assessment (EIA) Regulations, as amended (Government Notice No. R982, 2014; Government Notice No. 326, 2017) and any guidelines that have relevance to the proposed activity;
- I will comply with the NEMA, and the EIA Regulations;
- I will perform the work relating to the application in an objective manner, even if this results in views and findings that are *not favourable to the application*;
- I will take into account, to the extent possible, the matters listed in the National Environmental Management: Air Quality Act, 2004 (NEM:AQA) (Act No. 39, 2005); Listed Activities established in terms of the NEM:AQA (Government Notice No. 248, 2010; Government Notice No. 551, 2015); National Ambient Air Quality Standards (NAAQS) established in terms of the NEM:AQA (Government Notice No. 1210, 2009; Government Notice No. 486, 2012); Priority Areas established in terms of the NEM:AQA (Government Notice No. 365, 2006; Government Notice No. 1123, 2007; Government Notice No. 494, 2012); and Regulations Regarding Air Dispersion Modelling (Government Notice No. R533, 2014) developed in terms of the NEM:AQA, when preparing the Air Quality Impact Assessment report relating to the application;
- I undertake to disclose to the applicant, registered interested and affected parties and the competent authority all material information in my possession that reasonably has or may have the potential of influencing: any decision to be taken with respect to the application by the competent authority; and the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority;
- I declare that there are no circumstances that may compromise my objectivity in performing such work;
- I have no, and will not engage in, conflicting interests in the undertaking of the activity;
- I do not have and will not have any vested interest (either business, financial, personal or other) in the proposed activity proceeding other than remuneration for work performed in terms of the Regulations;
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- All the particulars furnished by me in this form are true and correct; and
- I realise that a false declaration is an offence in terms of Regulation 48(1)(a) of the EIA Regulations, as amended, 2017 (Government Notice No. R982, 2014; Government Notice No. 326, 2017).

SIGNATURE:

Executive Summary

Niara Environmental Consultants (Pty) Ltd was appointed by Kimopax (Pty) Ltd to undertake a suite of specialist studies in support of its application for Environmental Authorisation (EA) as encapsulated in:

- The National Environmental Management Act, 1998 (Act No 107 of 1998) (NEMA);
- The NEMA Environmental Impact Assessment (EIA) Regulations (Government Notice Regulations [GN R] 982 as amended by GN R 326); and
- National Environmental Management: Air Quality Act, 2004 (Act No. 39 of 2004) (NEM:AQA).

The scope of work for the overall environmental authorisation process encompasses several specialist studies of which Air Quality Impact Assessment (AQIA) forms an integral component. The main objective of the AQIA study is to assess the potential air quality impacts on the surrounding environment from the proposed Matai Mining Project activities and recommend mitigation measures to reduce emission to the ambient environment thereforth.

The proposed project area is situated in the Moses Kotane Local Municipality within the Mankwe Magisterial District of Northwest Province. The mining right is held on the farm Wildebeestkuil 7 JQ, and certain portions of the farms Magazynskraal 3 JQ, Haakdoorn 6 JQ, Syferkuil 9 JQ and Middelkuil 8 JQ. The main objective of the assessment is to evaluate the impact of the mining operations on the ambient air quality of the surrounding areas.

The most significant pollutant that is generated from open pit mining and related crushing and screening activities is particulate matter (PM). Particulate emissions will be generated from stripping of topsoil and overburden, materials handling operations, vehicle entrainment from roads, and crushing and screening activities on site. There will also be wind erosion of PM from ore, soil, waste and overburden stockpiles and from exposed areas of the site. Particulate matter with an aerodynamic diameter of less than 2.5 micrometers (µm) ($PM_{2.5}$) and particulate matter with an aerodynamic diameter of less than 10µm (PM_{10}) are criteria pollutants. Maximum permissible ambient air quality concentrations of these pollutants have been prescribed in the National Ambient Air Quality Standards (NAAQS) (Government Notice No. 1210, 2009; Government Notice No. 486, 2012). Ambient air pollutant concentrations are of significance in terms of their potential to impact human health and the broader environment.

Dispersion simulations were used to determine ambient air concentrations of PM_{10} and $PM_{2.5}$ resulting from all operations at the proposed mine site including crushing and screening on site. For this purpose, AERMOD, the United States Environmental Protection Agency's preferred regulatory model for both simple and complex terrain was used. Three scenarios were selected for modelling – an uncontrolled scenario; a scenario taking into account emission reductions possible by implementing mitigation measures on all haul roads, conveyor transfer points and the processing plant; and a scenario with the added mitigation measure of tarring the access road off site. The predicted ambient air concentrations were then evaluated against the relevant NAAQS.

The modelling results indicate that uncontrolled emissions will result in exceedances of the NAAQS over the Sefikile and Mantserre residential areas as well as over the southern parts of the Union South Mine. Even with maximum efficiency mitigation measures in place on both the haul roads and the processing plant, exceedances of the $PM_{2.5}$ 24-hour standards may be expected over the southern areas of the Union South Mine. Considering that the emissions from the Union South Mine and from the proposed Matai Mining project will be cumulative, stringent mitigation measures must be applied at all times to reduce emissions and to keep the impact of the mine to a minimum. This must include:

- Using the best possible mitigation methods on the crushing and screening activities at the processing plant.
- Wet suppression on the ROM and product stockpiles.
- Tarring and sweeping/vacuuming of the access haul road.
- Tarring of the road earmarked for upgrade (See Figure 1).
- Efficient, regular wet suppression or chemical suppression of all unpaved haul roads, including roads to the backfill areas in the pits.
- Wet suppression or enclosure of all conveyor transfer points.
- Covering of all conveyors.
- Reducing the number of transfer points through careful planning and design, because each time the ore is dropped onto a stockpile, emissions are generated.

Furthermore, a comprehensive, continuous air quality monitoring programme must be implemented in order to ensure that the above mitigation measures are applied at all times to keep emissions within the NAAQS in residential areas.

As the proposed Matai Mining Project is still in the planning phase, many of the parameters required for the modelling were unavailable. Average values from the literature were used for many of the parameters, and in some cases, conservative estimates and 'worst-case' values were used in the model. Whilst care has been taken to assess the potential air pollution impact from the proposed mining activities, more accurate input data may result in different conclusions.

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List of Acronyms and Abbreviations

AQIA	Air Quality Impact Assessment
AQMP	Air Quality Management Plan
DEA	Department of Environmental Affairs
Mg	Megagram (1 Mg = 10^6 g = 10^3 kg = 1 t)
NAAQS	National Ambient Air Quality Standard
NEMA	National Environmental Management Act (Act No. 107 of 1998)
NEM:AQA	National Environmental Management: Air Quality Act (Act No. 39 of 2004)
PM_{10}	Particulate matter with an aerodynamic diameter of less than 10 µm
$PM_{2.5}$	Particulate matter with an aerodynamic diameter of less than 2.5 µm
Ppb	Parts per billion
SAAQIS	South African Air Quality Information System
SAWS	South African Weather Service
TSP	Total Suspended Particulates
µg/m³	Micrograms per cubic meter
µm	Micrometres
US EPA	United States Environmental Protection Agency
VKT	Vehicle Kilometre Travelled
WHO	World Health Organisation
WRF	Weather Research and Forecasting Model

1 Introduction

Niara Environmental Consultants (Pty) Ltd was appointed by Kimopax (Pty) Ltd to undertake an air quality impact assessment of the mining operations and associated activities of the proposed Matai Mining Project. The proposed project area is situated in the Moses Kotane Local Municipality within the Mankwe Magisterial District of Northwest Province. The mining right is held on the farm Wildebeestkuil 7 JQ, and certain portions of the farms Magazynskraal 3 JQ, Haakdoorn 6 JQ, Syferkuil 9 JQ and Middelkuil 8 JQ. The main objective of the assessment is to evaluate the impact of the mining operations on the ambient air quality of the surrounding areas.

From a review of available literature, it was established that the most significant pollutant that is generated from open pit mining and related crushing and screening activities is particulate matter (PM). Particulate emissions will be generated from stripping of topsoil and overburden, materials handling operations, vehicle entrainment from roads, and crushing and screening activities on site. There will also be wind erosion of PM from ore, soil, waste and overburden stockpiles and from exposed areas of the site. Particulate matter with an aerodynamic diameter of less than 2.5 micrometers (µm) ($PM_{2.5}$) and particulate matter with an aerodynamic diameter of less than 10µm (PM_{10}) are criteria pollutants. Maximum permissible ambient air quality concentrations of these pollutants have been prescribed in the National Ambient Air Quality Standards (NAAQS) (Government Notice No. 1210, 2009; Government Notice No. 486, 2012). Dispersion simulations were used to determine ambient air concentrations of PM_{10} and $PM_{2.5}$ resulting from all operations at the proposed mine site including crushing and screening on site. Three scenarios were selected for modelling – an uncontrolled scenario; a scenario taking into account emission reductions possible by implementing mitigation measures on all haul roads, conveyor transfer points and the processing plant; and a scenario with the added mitigation measure of tarring the access road off site. The predicted ambient air concentrations were then evaluated against the relevant NAAQS.

2 Scope of Work

2.1 Terms of Reference

This report aims to investigate the potential impact that the proposed Matai Mining Project will have on ambient air quality. The following tasks were completed in order to achieve the broad objective of the project:

- Literature review of air pollutant emissions from open pit mines and crushing and screening activities.
- Literature review of potential health effects associated with these emissions.
- Outlining of relevant air quality legislation and ambient air quality standards.

- Description of the site location, topography, general surroundings of the site, as well as the relevant site-specific environment.
- Establishment of the baseline air quality from Air Quality Management Plans and Air Quality Monitoring Reports in the area.
- Description of the nature of other major sources of air pollution in the study area.
- Sourcing and evaluation of Weather and Research Forecasting Model (WRF) meteorological data to facilitate modelling.
- Description of the process flow of the proposed Matai Mining Project. This forms the basis for identifying sources of emissions for the emissions inventory.
- Compilation of an emissions inventory – a list of activities which are sources of air pollution in the project.
- Characterisation of the emission sources and the pollutants emitted from them.
- Calculations of emission rates from the sources identified in the emissions inventory.
- Preparation of Met data for modelling.
- Determining and preparing the input parameters for modelling:
    - Source type: Area source, point source, volume source or open pit source.
    - Source dimensions: lateral, vertical.
    - Source location and orientation.
    - Emission parameters: emission rate/emission height.
    - Emission times.
    - Receptor grid.
- Dispersion modelling of the emissions, using the AERMOD model, in order to predict maximum ground level concentrations of particulate pollutants resulting from the activities and in order to determine the zones of influence around the emission sources accordingly.
- Presentation of model outputs/results in the form of contour plots and a summary of the results.
- Evaluation of the results of the air dispersion modelling against NAAQS as set out by the Department of Environmental Affairs (DEA).
- Assessment of any potential cumulative impacts in terms of the NAAQS.
- Provision of practical and implementable mitigation measures by which to manage and reduce the identified impacts.
- A recommendation in terms of an air quality monitoring programme.

2.2 Outline of Report

An introduction to the proposed Matai Mining Project and associated activities and an outline of the scope of this report are provided in **Sections 1 and 2.** Brief CVs of the specialists running the AERMOD model and compiling the report are given in **Section 3**. An overview of the site location is provided in **Section 4.** A brief overview of the mining process at the proposed Matai Mining Project is given in **Section 5**. The South African air quality legislation and ambient air quality standards for particulate pollutants are presented in **Section 6**, while the health effects of particulate matter are presented in **Section 7**. **Section 8** presents the regional meteorological overview, followed by the ambient air quality review in **Section 9.** The local meteorology assessment of **Section 10** is the first stage preparation for the modelling process. In **Section 11** to **Section 15** an overview of the model and its data requirements are outlined, the emissions inventory is compiled, and the site-specific emission factors used as inputs into the model are discussed. Thereafter, in **Section 16,** the dispersion model results are presented, and the main findings of the air quality compliance and impact assessments are documented. Mitigation measures and a monitoring programme are recommended in **Sections 17** and **18.** The conclusions and recommendations are discussed in **Section 19**. **Appendix A** contains the methodology used in determining the significance of environmental impacts in an impact assessment matrix as required by the National Environmental Management Act, Environmental Impact Assessment regulations, as amended (Government Notice No. R982, 2014; Government Notice No. 326, 2017). The impact assessment matrix is presented in the conclusion. Electronic input and output files for the modelling for both AERMET and AERMOD have been submitted with this report. A list of these filenames is included in **Appendix B**. A brief overview of the possible effects of particulate matter emissions on agriculture is included in **Appendix C**.

3 Expertise of the Specialists

3.1 Dr Martin van Nierop

Dr Martin van Nierop has a doctorate in Chemical Engineering from the University of the Witwatersrand, Johannesburg. While studying for his doctorate, Dr van Nierop was employed at the University as a research officer. Dr van Nierop became interested in research management, and he managed a number of large contract research projects at the University. One of these was a study of the Brown Haze air pollution problem over Cape Town. The project was conducted by the Climatology Research Group under the leadership of Dr Stuart Piketh during 2003. Dr van Nierop became the managing director of Gondwana Environmental Solutions International in 2004, and he has been involved in many atmospheric impact assessment studies since then.

3.2 Anja van Basten

Anja van Basten completed her BA (hons) degree in Physical Geography cum laude at Wits University in 1988. She taught high school Geography between 1989 and 1994. She has ten years' experience in atmospheric impact assessments and modelling and completed an AERMOD course in March 2010. She has worked on numerous projects since then, including air quality impact assessments, air quality management plans and other environmental research projects.

4 Site Location

The Matai Mining Project is located in the Moses Kotane Municipality, Bojanala Platinum District Municipality, North West Province, South Africa. It lies about 13 km south-west of the closest town Northam, approximately, 70 km north of Rustenburg and 150 km north-west of Johannesburg. The Pilanesberg Nature Reserve lies approximately 13 km to the south of the proposed pit area. Other large sources of particulate matter in the area include the Union North and South Mines, the Pilanesberg Platinum mine, and the Dishaba Mine, all of which mine for platinum group minerals, and the Kalaka Mine which mines for limestone (Figure 1).

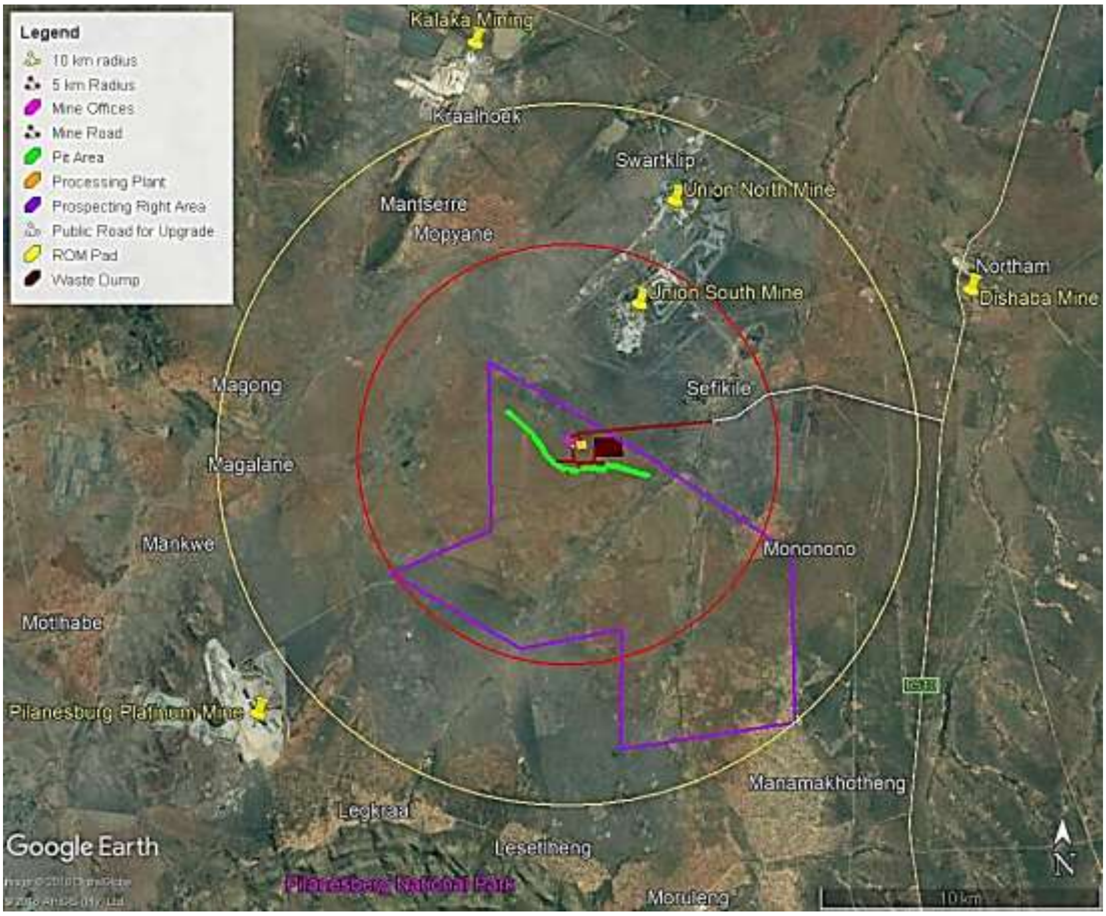

Figure 1: Location of the proposed Matai Mining Project.

Sensitive receptors within a 10 km range of the Matai Mining Project open pit area include the residential areas of Sefikile, Mantserre, Mopyane, Mononono, Magong, Magalane, Kraaihoek and parts of Manamakhotheng. The remainder of the land-use surrounding the mine is predominantly agricultural with a few farmsteads.

The topography immediately surrounding the site is gently undulating with no prominent topographic features in the project area. The Pilanesberg formation to the south, rises from the surrounding plains and consists of the crater of a long extinct volcano fringed by three concentric ridges or rings of hills.

5 Overview of the Matai Project Mining Process

Opencast mining starts with the stripping of usable soil and soft overburden material using a fleet of diesel trucks and shovels. This topsoil and overburden is stockpiled for use in the rehabilitation of the area once the mining is completed. A process of roll-over or strip mining is then followed in which the overburden of each strip is drilled and blasted and then placed in the excavation produced by the previous strip. This backfilling and rehabilitation will be undertaken as the mining progresses. The ore will be mined from the open pit using excavators, bulldozers, trucks, bowl scrapers and shovels.

Crushers will be used to reduce large rocks into smaller rocks, gravel, or rock dust. Three stages of crushing are planned. Trucks will deposit material into a receiving bin at the primary tip. A single jaw crusher will be used as the primary crusher. A static grizzly is placed at the primary tip to remove oversize material, with a vibrating grizzly placed before the crusher to screen off the fines before it enters the crusher. For the purposes of modelling for this report, it was assumed that this primary crushing will take place in the pit. From there, apron feeders will be utilised to extract ore from the bins and feed it to downstream equipment at a predetermined rate. Cone crushers or toothed roll crushers will be used for the secondary and tertiary crushing phases at the processing plant to reduce the size of the material to less than 32mm. Conveyors will also be used to transport the overburden (Kimopax, 2018).

A tripper conveyor will also be used to stack ore onto the stockpile. The ore will be removed from the stockpile by means of bottom extraction. This consists of a tunnel underneath the stockpile with a travelling rotary plough feeder and a conveyor (Kimopax, 2018).

From the crushing plant, ore will be transported in trucks on a gravel road to the R510, and from there by tarred road to its final destination. The final void will be backfilled with the overburden from the initial boxcut.

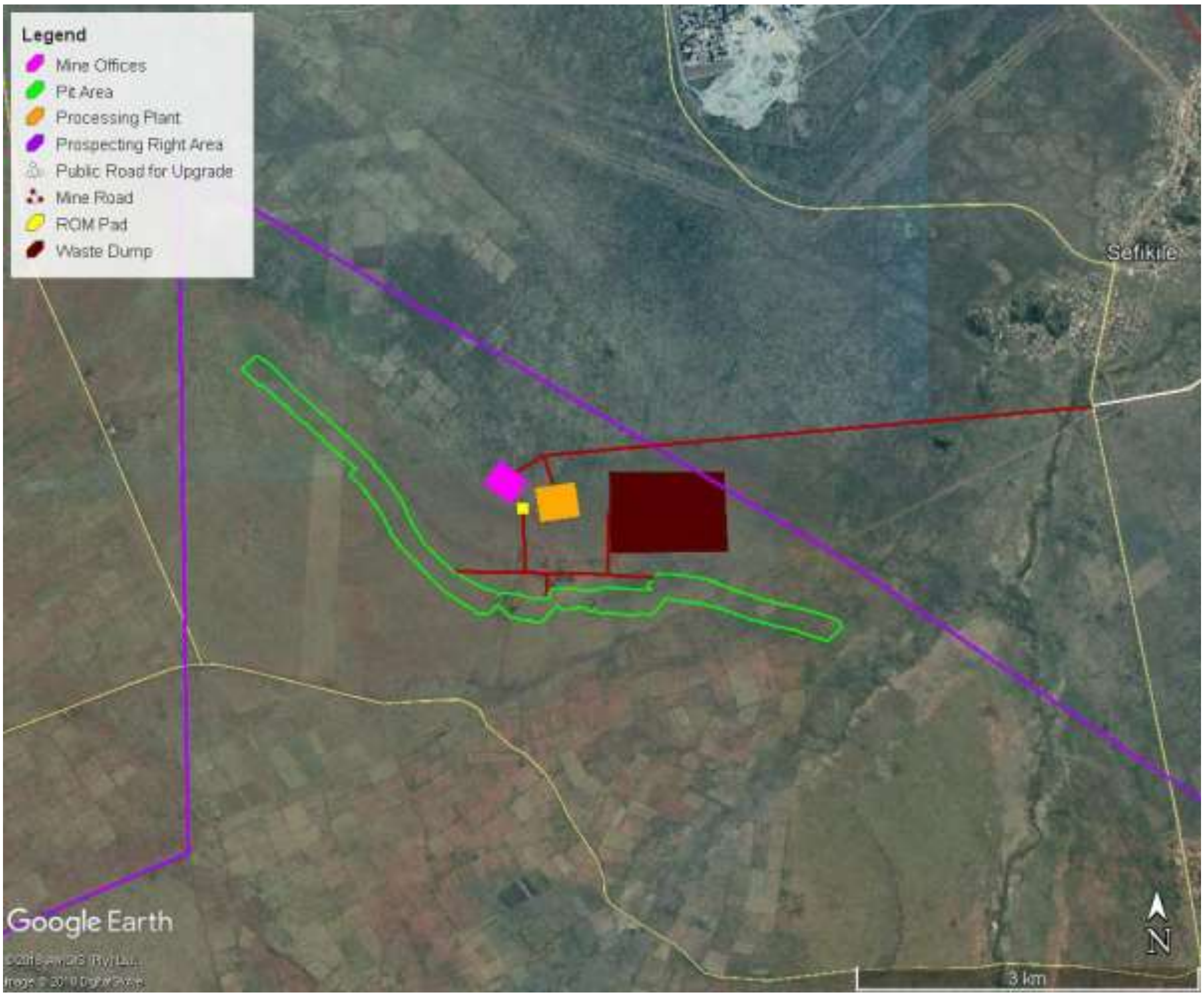

Figure 2: Proposed mine layout.

6 Air Quality Legislation and Standards

The prevailing legislation in the Republic of South Africa with regards to the Air Quality field is the National Environment Management: Air Quality Act (Act No. 39 of 2004) (NEM: AQA). The NEM: AQA repealed the Atmospheric Pollution Prevention Act (45 of 1965) (APPA) and various other laws dealing with air pollution.

The purpose of NEM:AQA is to set norms and standards which relate to:

- Institutional frameworks, roles and responsibilities;
- Air quality management planning;
- Air quality monitoring and information management;
- Air quality management measures; and
- General compliance and enforcement.

In addition, it is intended that the establishment and implementation of these set norms and standards will achieve:

- The protection, restoration and enhancement of air quality in South Africa;
- Increased public participation in the protection of air quality and improved public access to relevant and meaningful information about air quality;
- The reduction of risks to human health; and
- The prevention of the degradation of air quality.

The NEM:AQA shifted some of the approach of air quality management from source-based control to receptor-based control. With receptor-based control the ambient air quality of receptors is the factor which is used to determine the compliance of the emission source. The measured, or expected, ambient air quality of receptors is compared to National Standards. These standards prescribe the maximum ambient concentrations of pollutants permitted (and the number of exceedances allowed) during a specified time period in a defined area. If the air quality standards are exceeded, the ambient air quality is poor and the potential for health effects is greatest. The ambient air quality standards, therefore, provide a basis for protecting public health from adverse effects of air pollution and for eliminating, or reducing to a minimum, those contaminants of air that are known, or likely, to be hazardous to human health and wellbeing (WHO, 2000). The South African National Ambient Air Quality Standards for PM_{10} (particulate matter with an aerodynamic diameter of less than 10 µm) were published in 2009 (Government Notice No. 1210, 2009) in terms of Section 9(1) of the NEM:AQA (Table 1). The National Ambient Air Quality Standards for $PM_{2.5}$ (particulate matter with an aerodynamic diameter of less than 2.5 µm) were published in 2012 (Government Notice No. 486, 2012) (Table 1). In terms of the Air Quality Act, air quality management, control and enforcement is the responsibility of local government. This includes the control of all major sources, including mining, industrial, vehicle and domestic sources, in terms of ambient air concentrations. District and Metropolitan Municipalities are the licensing authorities. Provincial government is primarily responsible for ambient monitoring and ensuring municipalities fulfil their legal obligations and national government is primarily the policy maker and co-ordinator.

It is important to note that the proposed Matai Mining Project falls within the declared Waterberg-Bojanala Priority Area (WBPA) for Air Quality. The Minister declared the WBPA on 15 June 2012 as the third National Priority Area (Government Notice No. 494, 2012).

Table 1: National Standards for Ambient Air Quality for PM_{10} (Government Notice No. 1210, 2009) and for $PM_{2.5}$ (Government Notice No. 486, 2012).

National Ambient Air Quality Standards for Particulate Matter (PM_{10})			
AVERAGING PERIOD	**CONCENTRATION (µg/m³)**	**FREQUENCY OF EXCEEDANCE**	**COMPLIANCE DATE**
24 hours	75	4	1 January 2015

1 year	40	0	1 January 2015
The reference method for the determination of the PM_{10} fraction of suspended particulate matter shall be EN 12341.			
National Ambient Air Quality Standards for Particulate Matter ($PM_{2.5}$)			
AVERAGING PERIOD	**CONCENTRATION ($\mu g/m^3$)**	**FREQUENCY OF EXCEEDANCE**	**COMPLIANCE DATE**
24 hours	40	4	1 January 2016 – 31 December 2029
24 hours	25	4	1 January 2030
1 year	20	0	1 January 2016 – 31 December 2029
1 year	15	0	1 January 2030
The reference method for the determination of the $PM_{2.5}$ fraction of suspended particulate matter shall be EN 14907.			

The acceptable dustfall rates as set out in the National Dust Control Regulations (Government Notice No. R827, 2013) are shown in Table 2.

Table 2: National Dust Control Regulations (Government Notice No. R827, 2013).

Level	Dustfall Rate (D) ($mg/m^2/day$) (30-days average)	Permitted Frequency of Exceeding Dustfall Rate
Residential area	D < 600	Two within a year, not sequential months.
Non-residential area	600 < D < 1 200	Two within a year, not sequential months.

The method to be used for measuring dustfall rate and the guideline for locating sampling points shall be ASTM D1739: 1970, or equivalent method approved by any internationally recognised body.

7 Health Effects of Particulate Air Pollutants

With regards to health effects, the World Health Organisation (WHO) confirms that particulate air pollution is often associated with complaints of the respiratory system (WHO, 2000). PM size is relevant in terms of health as it is responsible for where in the respiratory system a given particle is deposited. There are an increasing number of research studies highlighting the impact of gases and air pollutants on humans. Many of these emissions, even in small quantities, have adverse effects on workers and neighbouring residents alike.

Particles can be classified by their aerodynamic properties into coarse particles, PM_{10} and fine particles, $PM_{2.5}$ (Harrison & Van Grieken, 1998). The fine particles contain the secondarily formed aerosols such as sulphates and nitrates, combustion particles and re-condensed organic and metal vapours. The coarse particles contain earth crust materials and fugitive dust from roads and industries (Fenger, 2002).

In terms of health effects, particulate air pollution is associated with respiratory and cardiovascular morbidity, such as aggravation of asthma, respiratory symptoms and an increase in hospital admissions. Inhalable PM also leads to increased mortality from cardiovascular and respiratory diseases and from lung cancer (WHO, 2013). Particle size is important for health because it controls where in the respiratory system a given particle is deposited. Fine particles are thought to be more damaging to human health than coarse particles, as they are able to penetrate deeper into the lungs (Manahan, 1991). Larger particles are deposited into the extrathoracic part of the respiratory tract while smaller particles are deposited into the smaller airways leading to the respiratory bronchioles (WHO, 2000).

In the past, daily particulate concentrations were in the range 100 to 1000µg/m^3 whereas in more recent times, daily concentrations are between 10 and 100µg/m^3. Overall, exposure-response can be described as curvilinear, with small absolute changes in exposure at the low end of the curve having similar effects on mortality to large absolute changes at the high end (WHO, 2000). Both short-term and long-term exposure to particulate matter in the air can have health impacts (Table 3).

Table 3: Short-term and long-term health effects associated with exposure to PM (WHO, 2004).

Pollutant	Short-term exposure	Long-term exposure
Particulate matter	• Lung inflammatory reactions • Respiratory symptoms • Adverse effects on the cardiovascular system • Increase in medication usage • Increase in hospital admissions • Increase in mortality	• Increase in lower respiratory symptoms • Reduction in lung function in children • Increase in chronic obstructive pulmonary disease • Reduction in lung function in adults • Reduction in life expectancy • Reduction in lung function development

7.1. Short-term Exposure

There is good evidence that short-term exposure to particulate matter is associated with health effects (WHO, 2013). Health effects associated with short-term exposure to particulates include increases in lower respiratory symptoms, medication use and small reductions in lung function. Susceptible groups with pre-existing lung or heart disease, as well as elderly people and children, are particularly vulnerable. For example, exposure to particulate matter affects lung development in children, including reversible deficits in lung function as well as chronically reduced lung growth rate and a deficit in long-term lung function (WHO, 2011). There is no evidence of a safe level of exposure or a threshold below which no adverse health effects occur (WHO, 2013).

7.2. Long-term Exposure

Long-term exposure to low concentrations (~10µg/m^3) of particulates is associated with mortality and other chronic effects such as increased rates of bronchitis and reduced lung function (WHO, 2000). Studies have indicated an association between lung function, chronic respiratory disease and airborne particles. Relative risk estimates suggest an 11% increase in cough and bronchitis rates for each 10µg/m^3 increase in annual average particulate concentrations (WHO, 2000). Based on studies conducted in the USA, Europe and Canada, mortality is estimated to increase by 0.2–0.6% per 10 µg/m^3 of PM_{10} (WHO, 2005; Samoli, et al., 2008). $PM_{2.5}$ is a higher risk factor than the coarse part of PM_{10} (particles in the 2.5–10 µm range), especially as a consequence of long-term exposure. Long-term exposure to $PM_{2.5}$ is associated with an increase in the long-term risk of cardiopulmonary mortality by 6–13% per 10 µg/m^3 of $PM_{2.5}$ (Beelen, et al., 2008; Krewski, et al., 2009; Pope III, et al., 2002).

8 Regional Meteorological Overview

Ambient air quality in the Bushveld region of South Africa is strongly influenced by regional atmospheric movements, together with local climatic and meteorological conditions. The most important of the regional atmospheric movement routes is the direct transport towards the Indian Ocean and the recirculation over the sub-continent around a continental high-pressure system (Scholes, 2002). The seasonal shifts of this regional upper-air high pressure system, northwards during winter and southwards during summer, have a pronounced influence on the airflow and atmospheric stability of the area. During summer, the southward extension of troughs and low-pressure systems enables the tropical easterlies to bring moisture into the region from the east. During winter, the high-pressure belt moves northwards, allowing circumpolar westerlies to displace the tropical easterlies.

In summer, solar radiation and unstable atmospheric conditions result in mixing of the atmosphere and rapid dispersion of pollutants. Summer rainfall also aids in removing pollutants through wet deposition. In contrast, winter is characterised by atmospheric stability caused by the persistent high-pressure system over South Africa. This dominant high-pressure system results in subsidence, causing clear skies and a pronounced temperature inversion over the central plateau region. This inversion layer traps the pollutants in the lower atmosphere, which results in reduced dispersion and a poorer ambient air quality. Preston-Whyte and Tyson (Preston-Whyte &

Tyson, 1998) describe the atmospheric conditions in the winter months as highly unfavourable for the dispersion of atmospheric pollutants.

9 Ambient Air Quality

The proposed Matai Mining Project is located in the Bojanala Platinum District, in the North West Province. This forms part of the declared Waterberg-Bojanala Priority Area (WBPA) for Air Quality. The Minister declared the WBPA on 15 June 2012 as the third National Priority Area (Government Notice No. 494, 2012). Although pollution levels in the WBPA are not continuously exceeding National Standards, the declaration is in line with the precautionary principle of the National Environmental Management Act (Act No. 107, 1998) that negative impacts on the environment and on people's environmental rights should be anticipated and prevented.

The Waterberg-Bojanala Priority Area Air Quality Management Plan and Threat Assessment (WBPA AQMP) found that mining contributes the greatest proportion (over 70%) of PM_{10} emissions in the area. Industry contributions are lower but still significant at 27%. However, historically (i.e. between 2008 and 2011), only 3.45% and only 0.004% of the Bojanala DM PM_{10} emissions originated from industries and from mining activities respectively in the Moses Kotane Municipality (Government Notice No. 1207, 2015). Ambient air quality monitoring is relatively limited in the WBPA. The closest monitoring station, run by the North West Provincial Government, is situated in Phokeng which lies approximately 62 km south of the proposed mining area. This is too far to give an indication of ambient air quality in the area of the proposed Matai Mining Project.

Sources that may contribute to ambient concentrations of PM_{10} and $PM_{2.5}$ in the area include: the mining activities of the Rustenburg Platinum – Union Mines, the Pilanesberg Platinum mine, Kalaka Mining and Dishaba Mine; domestic fuel burning; vehicle entrainment from untarred road surfaces; biomass burning; and wind-blown dust from open areas and stockpiles.

10 Local Meteorology

Horizontal dispersion of atmospheric pollutants is a function of the prevailing wind characteristics at any site, while the vertical dispersion of pollution is largely a function of the stability of the atmosphere and the depth of the surface mixing layer. By day, vertical mixing due to incoming solar radiation is most efficient at dispersing pollutants. At night a surface temperature inversion may develop which decreases the dispersion potential. Pollutants tend to accumulate near the point of release under these conditions, particularly if they are released close to ground level. The dispersion potential is generally poorer on winter nights than on summer nights. Mechanical turbulence is another contributor to dispersion of pollutants. Mechanical turbulence is a function of a combination of the wind speed and surface roughness. Thus, higher wind speeds facilitate the vertical dilution of pollutants as well as the distance of downwind transport.

The preferred data for modelling would be data collected on site. This, however, is very seldom feasible given that three years of both surface and upper air meteorological data is required. To substitute for, or supplement, measured data, data from numerical models may be used. For this project AERMET pre-processed Weather Research and Forecasting Model (WRF) meteorological data was used. The WRF is a next-generation mesoscale numerical weather prediction system designed for both atmospheric research and operational forecasting applications which reflects recent advances in physics, numerics, and data assimilation contributed by developers from the expansive research community.

Wind roses graphically present wind conditions over a period of time at a specific location. Wind roses for the project are presented in Figure 3 to Figure 4 below. In the wind roses, the length of each spoke represents the percentage of time that the wind blew from that direction during the period. The percentage scale is presented on the concentric grey lines (the circle scale increment is indicated on each of the wind roses). Each spoke is divided by colour into wind speed ranges.

The predominant wind direction at the Matai Mining site (as given by the WRF data for the period from 2015 to 2017 for the project area) is from the south-south-easerly (for approximately 10.7 % of the time) (Figure 3). However, the highest number of winds with speeds greater than 6.5 m/s are expected from a northerly direction. The average hourly wind speed predicted by the WRF model is approximately 1.41 m/s. Calm conditions (wind speeds below 0.5 m/s) are predicted for approximately 4.68 % of the time.

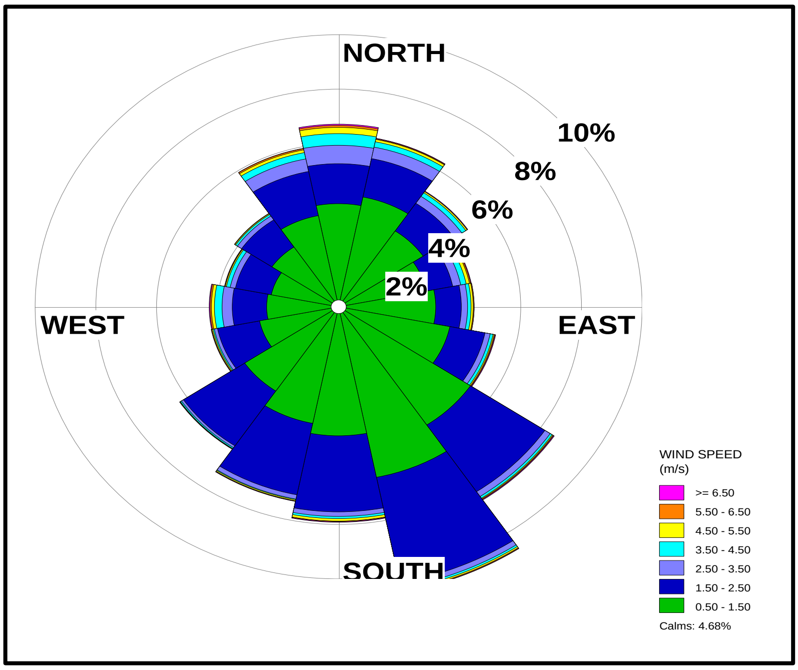

Figure 3: Wind rose of the average winds produced by the WRF model for the Matai Mining Project site, for the years 2015-2017.

There is a clear diurnal variation in both wind direction and wind speed at the Matai Mining Project site. During the warmer hours of the day, calm conditions are expected for approximately 9.24 % of the time, and average wind speeds are 1.36 m/s. Wind speeds above 6.5 m/s are expected for approximately 0.4 % of the time. The most frequent wind directions are from the northerly and north-north-easterly directions. During the night, calm conditions are expected for approximately 0.13 % of the time, and average wind speeds are 1.45 m/s. The winds tend to blow more from the south-south-westerly to south-easterly quadrant (Figure 4).

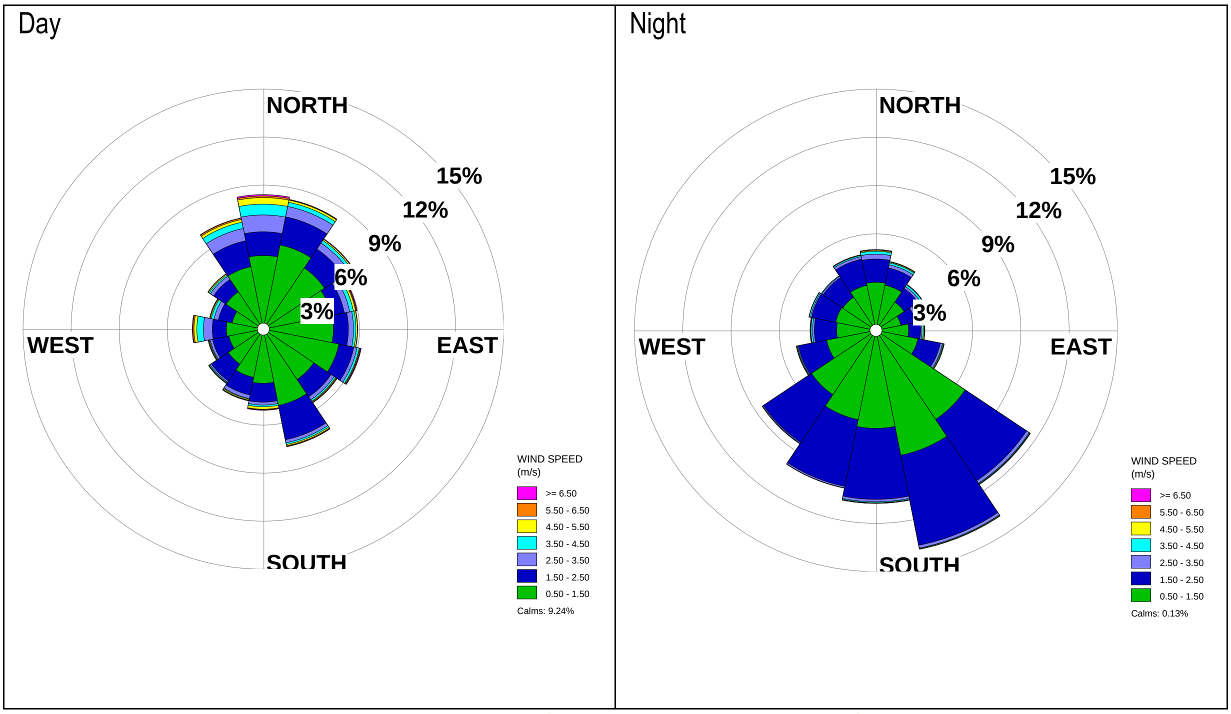

Figure 4: Diurnal wind roses predicted by the WRF model for the Matai Mining Project site, for the years 2015-2017.

The seasonal variations in wind direction for the Matai Mining Project site are illustrated in Figure 5. The highest number of wind speeds above 6.5 m/s are experienced in Summer, while the highest average wind speeds occur in Spring. The maximum number of calm conditions is experienced in winter.

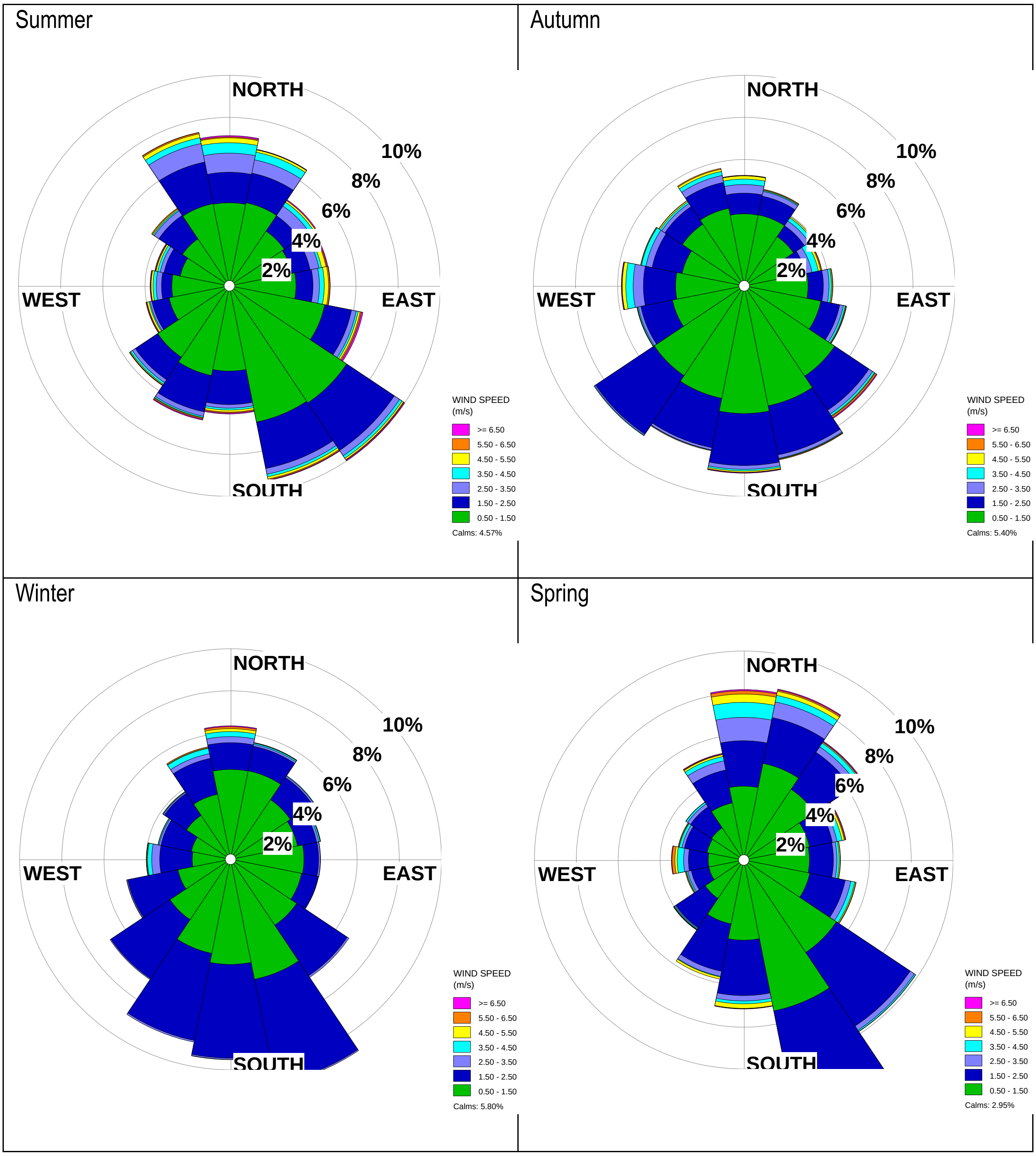

Figure 5: Seasonal wind roses of winds predicted by the WRF model for the Matai Mining Project site, for the years 2015-2017.

11 Model Overview

Dispersion models are used to predict the ambient concentration in the air of pollutants emitted to the atmosphere from a variety of processes. Ambient concentrations are computed 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 select a dispersion model carefully for the purpose.

AERMOD is a steady-state plume dispersion model developed by The American Meteorological Society/Environmental Protection Agency Regulatory Model Improvement Committee (AERMIC). It has been adopted as the EPA's preferred regulatory model for both simple and complex terrain. AERMOD incorporates air dispersion based on planetary boundary layer (PBL) turbulence structure and scaling concepts, including treatment of both surface and elevated sources, and both simple and complex terrain.

The modelling system consists of one main program (AERMOD) and two pre-processors (AERMET and AERMAP). The basic purpose of AERMET is to use meteorological measurements, representative of the modelling domain, to compute certain boundary layer parameters used to estimate profiles of wind, turbulence and temperature. AERMET uses these parameters to generate profiles of the needed meteorological variables. In addition, AERMET passes all meteorological observations to AERMOD. Surface characteristics in the form of albedo, surface roughness and Bowen ratio, plus standard meteorological observations (wind speed, wind direction, temperature, and cloud cover), are input to AERMET. AERMET then calculates the PBL parameters: friction velocity, Monin-Obukhov length, convective velocity scale, temperature scale, mixing height, and surface heat flux. AERMOD is designed to run with a minimum of observed meteorological parameters (Cimorelli, et al., 2004).

Modelled data from the Weather Research and Forecasting (WRF) Model was used to initialize the AERMET pre-processor in this project. Electronic input and output files for the modelling for both AERMET and AERMOD have been submitted with this report. A list of these files is included in Appendix B.

12 Methodology

Particulate matter is emitted into the air during open pit mining. Smaller particles (particles with an aerodynamic diameter smaller than 10µm (PM_{10}) and smaller than 2.5µm ($PM_{2.5}$)) are subsets of the total suspended particulates (TSP). PM_{10} and $PM_{2.5}$ are a health concern because these fine particles can be breathed into the lungs. The larger particles of TSP, on the other hand, are primarily a nuisance factor.

The maximum amounts of PM_{10} and $PM_{2.5}$, originating from the proposed Matai Mining Project, that can be expected to be found suspended in the air surrounding the site, were calculated by the following series of steps. First, an emissions inventory was compiled. This identified all the potential sources of air pollutants (Section 13). Secondly, in order to quantify the emissions from each source, a set of predictive emission factors was established (Section 14). For this purpose, use was made of the comprehensive set of emission factors and emission factor equations published by: the United States Environmental Protection Agency (US EPA) in its AP-

42 document *Compilation of Air Pollution Emission Factors* (US EPA, 1995); and the Australian Department of Sustainability, Environment, Water, Population and Communities in its National Pollutant Inventory Emission Estimation Technique Manual for Mining (NPi, 2012). These factors are usually expressed as the weight of pollutant emitted, divided by a unit weight, volume, distance, or duration of the activity emitting the pollutant (e.g., kilograms of particulate emitted per megagram of material bulldozed). In most cases, these factors are averages of all available data of acceptable quality (from source test data, material balance studies, and engineering estimates), and are generally assumed to be representative of long-term averages for all facilities in the source category.

The general equation for emissions estimation is:

$$E = A \times EF \times (1 - ER/100)$$

where:

E = emissions

A = activity rate

EF = emission factor

ER =overall emission reduction efficiency (%)

While the emission factor specifies the quantity of pollutant that can be expected to be emitted from a particular activity, the emission rate is calculated by multiplying the emission factor by how much of that activity is executed at the source in question. The emission rate gives the number of grams of pollutant emitted from a particular activity in one second. The emission rates from all the sources are added together to calculate the total emission rate from the mine (Section 15). Finally, modelled surface meteorological data, modelled upper air data and the predicted site-specific emission rates were used to run the AERMOD model (Section 16). The predicted air pollutant concentrations were then evaluated against the National Ambient Air Quality Standards (Government Notice No. 486, 2012; Government Notice No. 1210, 2009).

13 Emissions Inventory

An emissions inventory provides a list of all sources that would generate pollutants of concern. $PM_{2.5}$ and PM_{10} are the criteria pollutants of concern expected from the proposed Matai Mining Project. The activities and the associated emissions are outlined in Table 4.

Table 4: Activities and related atmospheric emissions identified for the operational phase of the proposed Matai Mining Project.

Emission	Source	Activity
Generation of TSP, PM_{10} and $PM_{2.5}$	Materials handling operations	Soil removal by shovel and truck.
		Overburden removal by shovel and truck.
		Offloading of topsoil.
		Tipping onto waste rock stockpile.
		Backfilling.
		Loading of ore into crushers.
		Conveyor transfer points.
		Tipping of ore from crushers onto storage piles.
		Stockpiling of product.
	Vehicle activity on unpaved roads	Haul trucks transporting topsoil to stockpiles.
		Haul trucks transporting overburden/waste from the mine to waste rock dumps or stockpiles.
		Haul trucks transporting ore from the PP off site.
	Wind erosion	Soil storage piles.
		Waste/overburden rock dumps.
		Conveyors.
		Ore storage piles.
	Crushing and screening	Crushing and screening activities.
NO_2	Vehicle activity	Tailpipe emissions from haul vehicles, and vehicles for mine personnel movement.
SO_2	Vehicle activity	Tailpipe emissions from haul vehicles, and vehicles for mine personnel movement.

14 Predictive Emission Factors

In order to determine the significance of the potential for impacts, it is necessary to quantify atmospheric emissions and predicted airborne pollutant concentrations occurring as a result of each emission source identified in the emissions inventory. Both emission factors and empirically derived predictive emission factor equations are used for this purpose. Emission factors require activity rates to quantify the pollutant released into the atmosphere. Predictive emission factor equations require inputs of parameters that are specific to the site being evaluated as well as activity rates to quantify emissions.

In the quantification of PM, empirically derived predictive emission factor equations are available for sources such as vehicle entrained dust from unpaved roadways, aeolian erosion from open areas, materials handling operations, bulldozing and blasting etc. The parameters used for the proposed Matai Mining Project are documented in r equations are outlined below.

Table 5 and the resulting emission factors used to quantify emissions from the different activities are documented in Table 6. Some of the factors taken into consideration when applying emission factor equations are outlined below.

Table 5: Site-Specific Parameters for the proposed Matai Mining Project.

Site parameters	Units	Total
Waste Rock (Year 6 (Ukwazi Mining Studies (Pty) Ltd, 2018b))	Mg / year	5 916 164
Product (Year 6 (Ukwazi Mining Studies (Pty) Ltd, 2018b))	Mg / year	2 005 479
Moisture in ore (AME Research, 2016)	%	0.5
Moisture in overburden (lowest in US EPA, 1995)	%	2.2
Silt content of haul roads (average in US EPA, 1995)	%	8.4
Silt content of ROM (average in US EPA, 1995)	%	8.6
Silt content of overburden (average in US EPA, 1995)	%	6.9
Area exposed to wind erosion (Pits, waste dump and ROM pad)	ha	9.1
Annual days operational (5 days a week) [a]	days	260
Work hours (6am to 10pm) [a]	hours	16
Frequency of grading total road length (assumed)	n/week	2
Haul road width (Ukwazi Mining Studies (Pty) Ltd, 2018a)	m	16
Grader runs per road width	n	6

Grader speed	km/h	9
Mean wind speed (WRF modelled data)	m/s	1.41
Waste dump (Kimopax, 2018)	m^2	700 000
Run of Mine pad	m^2	10 027
Haul truck (CAT 745C) weight (unladen)	Mg	33.4
Haul truck (CAT 745C) average load	Mg	41
Haul truck (CAT 745C) height	m	4.04
Material hauled to waste dump (Y6) (Ukwazi Mining Studies (Pty) Ltd, 2018b)	Mg	457 121
Waste haul distance (Y6) (Ukwazi Mining Studies (Pty) Ltd, 2018b)	km	1.85
Backfill material east (Y6) (Ukwazi Mining Studies (Pty) Ltd, 2018b)	Mg	2 383 687
Backfill east haul distance (Y6) (Ukwazi Mining Studies (Pty) Ltd, 2018b)	km	0.55
Backfill material west (Y6) (Ukwazi Mining Studies (Pty) Ltd, 2018b)	Mg	3 075 356
Backfill west haul distance (Y6) (Ukwazi Mining Studies (Pty) Ltd, 2018b)	km	0.75
Haulage distance to public road (Kimopax, 2018)	km	6
Albedo		0.2
Bowen ratio by month: 0.56, 0.70, 0.48, 1.39, 2.79, 3.97, 3.85, 3.92, 3.98, 3.76, 2.55, 1.06		
Surface roughness length by month: 0.14000, 0.14000, 0.14000, 0.08956, 0.0500, 0.0500, 0.0500, 0.0500, 0.0500, 0.09913, 0.14000, 0.14000		

a. Days and hours operational was calculated from the total ore production of 2 005 479 t per annum (Ukwazi Mining Studies (Pty) Ltd, 2018b) divided by 5 days a week and 16 hours a day gives a throughput of 482.09 t per hour at the processing plant which closely approximates the 517 t/hr throughput proposed in the Matai Concept Study (Ukwazi Mining Studies (Pty) Ltd, 2018a).

Table 6: Activities at the proposed Matai Mining Project and emission factors.

Mining Operations	Unit	$PM_{2.5}$	PM_{10}	Emission factor rating
Bulldozing overburden (US EPA, 1995)	kg/hr	0.99	2.04	D D
Bulldozing other material (NPi, 2012)	kg/hr	2.55	4.10	_ B
Truck loading operations (NPi, 2012)	kg/Mg	0.0037	0.012	_ _
Drilling (US EPA, 1995)	kg/hole	0.089	0.30	C _
Topsoil removal by scraper (US EPA, 1995)	kg/Mg	0.0044	0.015	_ _

Wind erosion of exposed areas (Seeded land, stripped overburden, graded overburden) (NPi, 2012)	Mg/ha/year	0.53	1.79	– –
Blasting (US EPA, 1995)	kg/blast	0.42	7.25	B C
Overburden replacement (NPi, 2012)	kg/Mg	0.0018	0.0043	– –
Conveyor transfer points (No mitigation) (NPi, 2012)	kg/Mg	0.00069	0.0022	– –
Conveyor transfer points (Wet mitigation 70% control)	kg/Mg	0.00021	0.00066	– –
Primary crushing [a] (No mitigation) (NPi, 2012)	kg/Mg	0.03	0.02	_ C
Secondary crushing (No mitigation) (NPi, 2012)	kg/Mg	0.09	0.05	– –
Secondary crushing (Wet mitigation 50% control) (NPi, 2012)	kg/Mg	0.045	0.025	– –
Tertiary crushing (No mitigation) (NPi, 2012)	kg/Mg	0.21	0.08	_ E
Tertiary crushing (Wet mitigation 50% control) (NPi, 2012)	kg/Mg	0.11	0.04	– –
Grading (US EPA, 1995)	kg/VKT	0.026	0.27	D E
Loading and unloading storage piles (US EPA, 1995)	Mg/ha/year	0.00033	0.0022	A A
Haul truck emissions	kg/VKT	0.11	1.13	D D
Haul truck emissions (chemical dust suppressants 80% control efficiency) (US EPA, 1995)	kg/VKT	0.023	0.23	– –
Haul truck emissions (tar and sweeping/vacuuming 92% control efficiency) (Thompson & Visser, 2007)	kg/VKT	0.01	0.09	– –

1 Mg = 10^6 g = 10^3 kg = 1 t

a. Crushing includes screening, the surge bin, the apron feeder, and conveyor belt transfer points that are integral to the crusher (NPi, 2012).

14.1 Vehicle Activity on Unpaved Roads

Although particulate emissions from paved roads would include direct emissions in the form of exhaust, brake wear and tyre wear emissions, the main source of emissions is from the resuspension of loose material on the road surface. Vehicle-entrained dust emissions from the unpaved haul roads within the proposed Matai Mining Project mining area potentially represent the most significant source of fugitive dust for the mine (Huertas, Camacho, & Huertas, 2012; US EPA, 1995). This includes hauling soil to the soil stockpiles; hauling waste and overburden to the dump areas and backfill areas; off-site hauling on unpaved roads; and maintenance of these temporary roads. Such sources have been found to account for the greatest portion of fugitive emissions from many mining operations. For the modelling, it was assumed that apron feeders and conveyors will be used to move ore from the pit to the Processing Plant (Ukwazi Mining Studies (Pty) Ltd, 2018a).

In terms of the South African modelling code (Government Notice No. R533, 2014), traffic carrying materials processed at a facility must be modelled as part of the facility. The roads must include the portion of the roads that are not publicly accessible. For the modelling of emissions from the Matai Mining Project, it was assumed that the ore product will be hauled by truck to the R510. The roads indicated as 'mine roads' in Figure 1 and Figure 2 were included in the modelling. The routes for hauling of overburden and waste were not known, therefore, these had to be assumed for the modelling. The length of these haul roads was taken from the mining schedule (Ukwazi Mining Studies (Pty) Ltd, 2018b) (see r equations are outlined below.

Table 5).

Fugitive dust emissions from unpaved roads depend on traffic volumes, average vehicle speed, mean vehicle weight, road surface silt content, and road surface moisture. For vehicles traveling on unpaved surfaces at industrial sites, emissions can be estimated from the following equation (US EPA, 1995):

$$E = k\left(\frac{s}{12}\right)^{a}\left(\frac{W}{3}\right)^{b}$$

Where: k, a and b are empirical constants

k = 0.15 for $PM_{2.5}$, 1.5 for PM_{10}, 4.9 for TSP

a = 0.9 for $PM_{2.5}$ and for PM_{10}, 0.7 for TSP

b = 0.45

E = size specific emission factor (lb/VMT)

s = surface material silt content (%)

W = mean vehicle weight (tons)

In the absence of site-specific silt content information, the average silt content of 8.4% measured at Western surface coal mines (US EPA, 1995) was used as a default value for the modelling. This reduces the quality rating for this emission rate from a B to a D. The weight for haul trucks was taken as an average of the expected fully loaded weight in one direction and empty on the return trip (r equations are outlined below.

Table 5). Field testing of emissions from controlled unpaved roads has shown that chemical dust suppressants provide a PM_{10} control efficiency of about 80% when applied at regular intervals (US EPA, 1995). This is the reduction in emissions used for the mitigated scenario in the modelling.

One of the options for reducing emissions from the haul roads would be to tar or otherwise pave the roads. This is particularly an option for the roads leading off site, as these will be comparatively permanent. The equation generally used to calculate emissions from vehicles traveling on paved surfaces at industrial sites (US EPA, 1995) is not suitable for the roads at the Matai Mining Project because the expected weight of the haul trucks exceeds the 38 Mg maximum for which the equation was designed. Therefore, a 92% mitigation of the uncontrolled emission rate was assumed for the modelling of the tarred road scenario. This is the maximum mitigation efficiency for tar or bitumen emulsions immediately after application (Thompson & Visser, 2007). Loose material on the road from spillage of material from the haul trucks and dust fallout from other activities such as the processing plant will again increase emissions. The modelled mitigation efficiency will only be possible if accompanied by regular sweeping or vacuuming and covering of the load in the haul trucks. Grading of the roads also results in PM emissions, which can be estimated from the following equation (US EPA, 1995):

$$EF^a = 0.0034(S)^{2.5}$$

$$EF^b = 0.6(0.0056(S)^{2.0})$$

Where: EF^a = Emission factor for TSP in kg/Vehicle Kilometre Travelled (VKT)

EF^b = Emission factor for PM_{10} in kg/VKT

S = mean vehicle speed (kph)

The TSP emission factor for grading was multiplied by a scaling factor of 0.031 to establish an emission factor for $PM_{2.5}$ from these activities (US EPA, 1995). A mean grader speed of 9 km/hr was taken for the modelling.

Haul roads were modelled as adjacent volume sources as recommended by the US EPA haul road workgroup for all haul roads, except for cases where ambient air receptors are within the volume's exclusion zone i.e. ((2.15 x Sigma Y) + 1 meter) from the center of the volume (US EPA, 2012). The following configuration was used, as recommended by the workgroup:

- Top of Plume Height – 1.7 x Vehicle Height
- Volume Source Release Height – 0.5 x Top of Plume Height
- Width of Plume – Vehicle Width + 6m for single lane roadways / Road Width + 6m for two lane roadways.
- Initial Sigma Z – Top of Plume / 2.15 (AERMOD User's Guide, Table 3-1 for use when modeling multiple volumes).
- Initial Sigma Y – Width of Plume / 2.15 (AERMOD User's Guide, Table 3-1).
- Emissions input as g/s.

The values of parameters used in the modelling are given in r equations are outlined below.

Table 5.

14.2 Materials Handling

Materials handling operations which are predicted to result in significant fugitive dust emissions from mining operations include the transfer of material by means of loading and offloading of trucks, loading and offloading conveyors, transfer from one conveyor to another and bulldozing. The quantity of dust which will be generated will depend on various non-climatic parameters such as the nature (moisture content and silt content) and volume of the material handled. An increase in the moisture content of the material being transferred would decrease the potential for dust emissions since moisture promotes the aggregation and cementation of fines to the surfaces of larger particles. Furthermore, fine silt particulates are more readily disaggregated and released to the atmosphere during the material transfer process as a result of exposure to strong winds than larger particles. The silt and moisture contents of the overburden and ore were not known for the Matai Mining Project. Mining above the water table in an arid environment typically results in a moisture content of 0.5% to 3% in iron ore (AME Research, 2016). The worst-case moisture content of 0.5% was used for the modelling.

The TSP default emission factors from the Australian NPi (NPi, 2012) were used for bulldozing, truck loading operations and overburden replacement. Where specific emission factors were not given for $PM_{2.5}$ and PM_{10}, 15% of the TSP emissions were assumed for $PM_{2.5}$, while 47% and 35.5% of the TSP emissions were taken for the PM_{10} emissions of truck loading operations and overburden replacement respectively, as these were the proportions found in the Australian Hunter Valley studies (SPCC, 1983) (Table 6).

The US EPA (US EPA, 1995) equation for loading and unloading storage pile is:

$$EF^{a} = k \times 0.0016 \times \frac{\frac{U}{2.2}^{1.3}}{\frac{M}{2}^{1.4}}$$

Where: k = 0.053 for $PM_{2.5}$, 0.35 for PM_{10}, 0.74 for TSP

U = mean wind speed (m/s)

M = moisture content (%)

The NPi (NPi, 2012) recommends using the same equation for conveyor transfer points. The resulting emission factors are given in Table 6. The NPi (NPi, 2012) control efficiency of 70% for enclosing transfer points was used for the mitigated scenarios in the modelling.

14.3 Wind Erosion from Exposed Areas

Dust emissions due to the erosion of open storage piles and exposed areas occur when the threshold wind speed is exceeded (Cowherd, Muleski, & Kinsey, 1988; US EPA, 1995). The threshold wind speed is dependent on the erosion potential of the exposed surface, which is expressed in terms of the availability of erodible material per unit area (mass/area). Any factor which binds the erodible material or otherwise reduces the availability of erodible material on the surface thus decreases the erosion potential of the surface. According to Darwish (Darwish, 1991), threshold friction velocity varies widely for different particle sizes, shapes and moisture levels. Studies have also shown that when the threshold wind speeds are exceeded, particulate emission rates tend to decay rapidly due to the reduced availability of erodible material (Cowherd, Muleski, & Kinsey, 1988).

It is anticipated that significant amounts of dust will be eroded from the open areas at the proposed Matai Mining Project site under wind speeds of greater than 5.4 m/s. Wind speeds of more than 5.5 m/s are expected to occur in the area approximately 7% of the time as indicated by the WRF modelled data for the years 2015 to 2017. An average wind speed of 1.41 m/s was calculated from the WRF data.

The NPi default emission factor for TSP from exposed areas 0.4 kg/(ha)(hr) was used (NPi, 2012). PM_{10} was considered to be 50% and $PM_{2.5}$ 15% of the TSP emissions. For modelling purposes, it was assumed that, as a worst-case scenario, the open pit areas, the ROM pad and the waste dump area are susceptible to wind erosion.

14.4 Crushing and Screening Activities

Crushing and screening operations represent significant dust-generating sources if uncontrolled. The large percentage of fines in this dustfall material enhances the potential for it to become airborne. It was assumed that primary crushing (crushing to achieve particles of <300 mm) will take place in the pit to reduce the ore to a transportable size for the conveyor system.

The NPi ((2012) distinguishes between high- and low-moisture ores. They define a high-moisture ore as one that, either naturally or as a result of additional moisture at the primary crusher, has a moisture content of more than 4% by weight. AME Research (2016) found that mining above the water table in an arid environment typically results in in iron ore with a moisture content of 0.5% to 3%. The NPi default emission factors for low-moisture ore were, therefore, used (Table 6). These emission factors include screening and all transfer points that are part of the crushing process.

For the mitigated modelling scenario, it was assumed that wet suppression would be used for both the secondary and tertiary crushing stages. A 50% mitigation efficiency (NPi, 2012) was applied to the modelling.

14.5 Drilling and Blasting

Drilling and blasting operations represent intermittent sources of fugitive dust emissions. Emissions from drilling are a relatively minor component of the overall emission from an open pit mine. The only available emission factor for drilling is a simple uncontrolled TSP emission factor of 0.59kg/hole for overburden (US EPA, 1995). Clearly, other variables such as the depth of the holes, diameter of the holes, and moisture content of the material being drilled would also be relevant and it might be supposed that an emission factor equation should take account of these variables. However, in the absence of other data (and given the relatively minor contribution of this source to overall emissions from mining operations), it is reasonable to accept the 0.59 kg/hole factor for TSP.

US EPA (1995) does not provide an emission factor for the PM_{10} component. However, some measurements were obtained during the Hunter Valley studies (State Pollution Control Commission, 1986). The mean fraction of PM_{10}/TSP for the four available samples was 0.52 (with a standard deviation of 0.10). These relate to drilling of overburden, and probably, there will be a difference for ore. However, in the absence of other information, the best estimate of the emission factor for drilling for PM_{10} was taken as 0.31kg/hole, with 15% of emissions taken as $PM_{2.5}$.

Estimating the TSP emission from blasting is difficult, given the complex and variable nature of each blast. Clearly, there are many factors that may be relevant, such as the degree of fragmentation achieved and whether the blast is a 'throw-blast' or not. The time of day will also affect the dispersion of emissions from blasting. For the purposes of the modelling it was assumed that all of the overburden and ore zones will require blasting (worst case). Using average blasting figures (r equations are outlined below.

Table 5), approximately 70 blasts would be required per year. The US EPA estimates that the PM_{10} fraction for blasting constitutes 52% of the TSP (US EPA, 1995).

The NPi (2012) recommends the following equation to estimate emissions from blasting:

$$EF = 0.00022 \times A^{1.5}$$

Where: A = the area blasted (m^2)

15 Emissions Rates

Emissions from each of the activities at the proposed Matai Mining Project were quantified by using the above set of emission factors and equations in combination with site-specific parameters for the mine area. The relative emissions of PM_{10} from mining activities at the proposed Matai Mining Project are summarised in pie chart format in Figure 6 (uncontrolled) and Figure 7 (mitigated). The pit emissions include emissions from haul trucks carrying material to the backfill areas. Haul roads and the crushing and screening activities represent the biggest sources of PM. Both of these sources can be mitigated efficiently, resulting in a substantial reduction in emissions. This is illustrated in Figure 8.

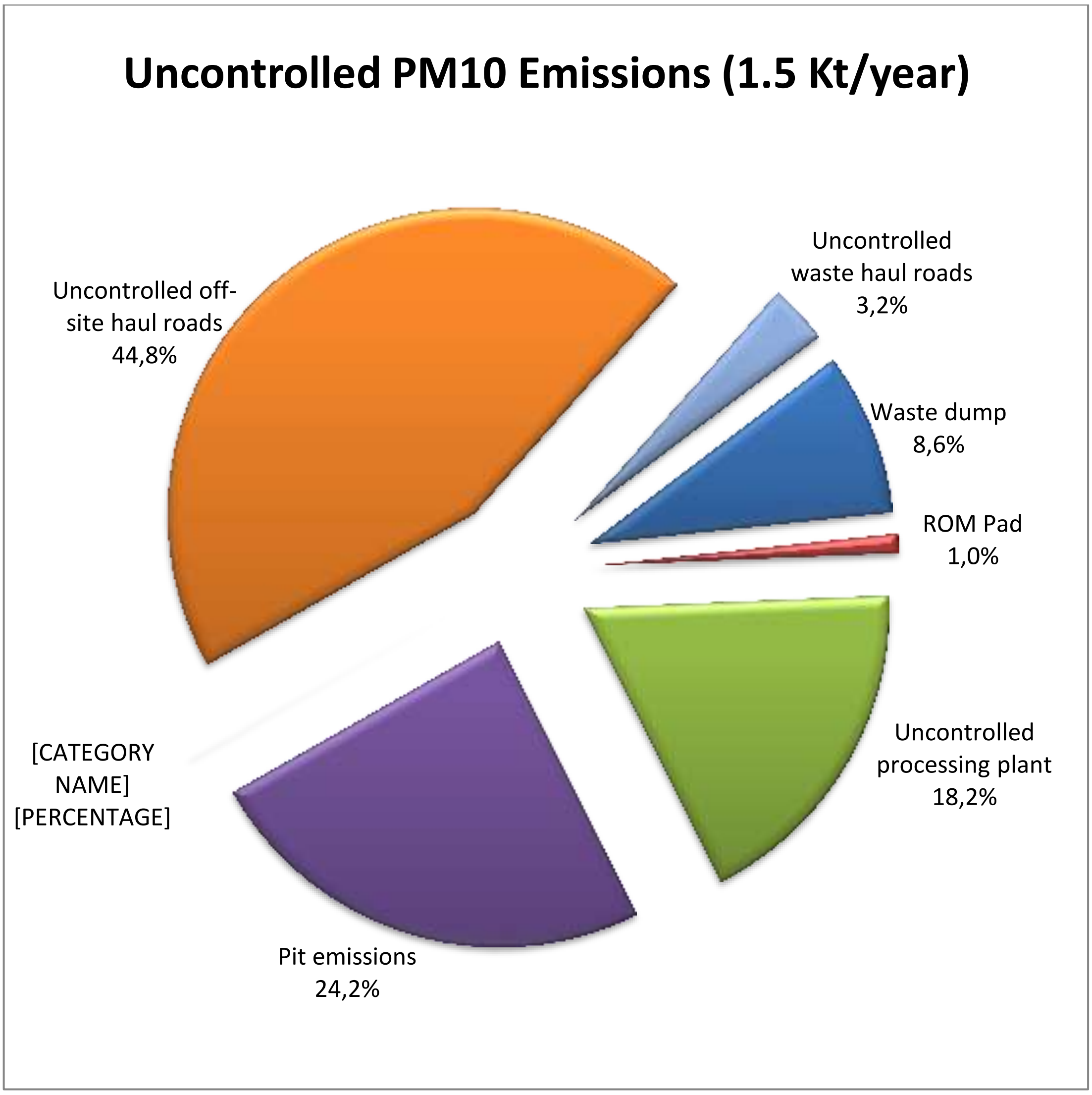

Figure 6: Relative uncontrolled emissions of PM10 from mining activities for year 6.

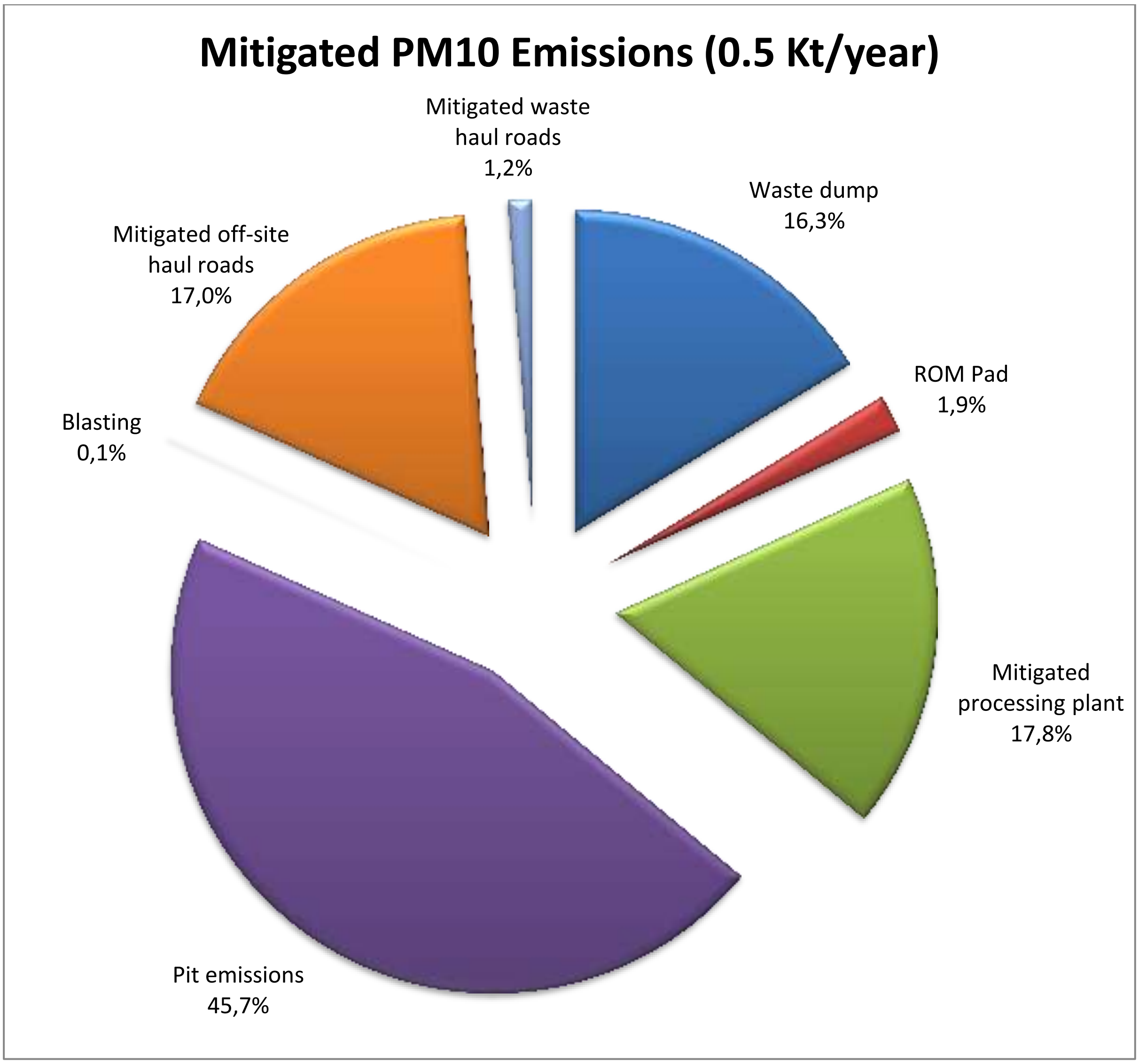

Figure 7: Relative mitigated emissions of PM10 from mining activities for year 6.

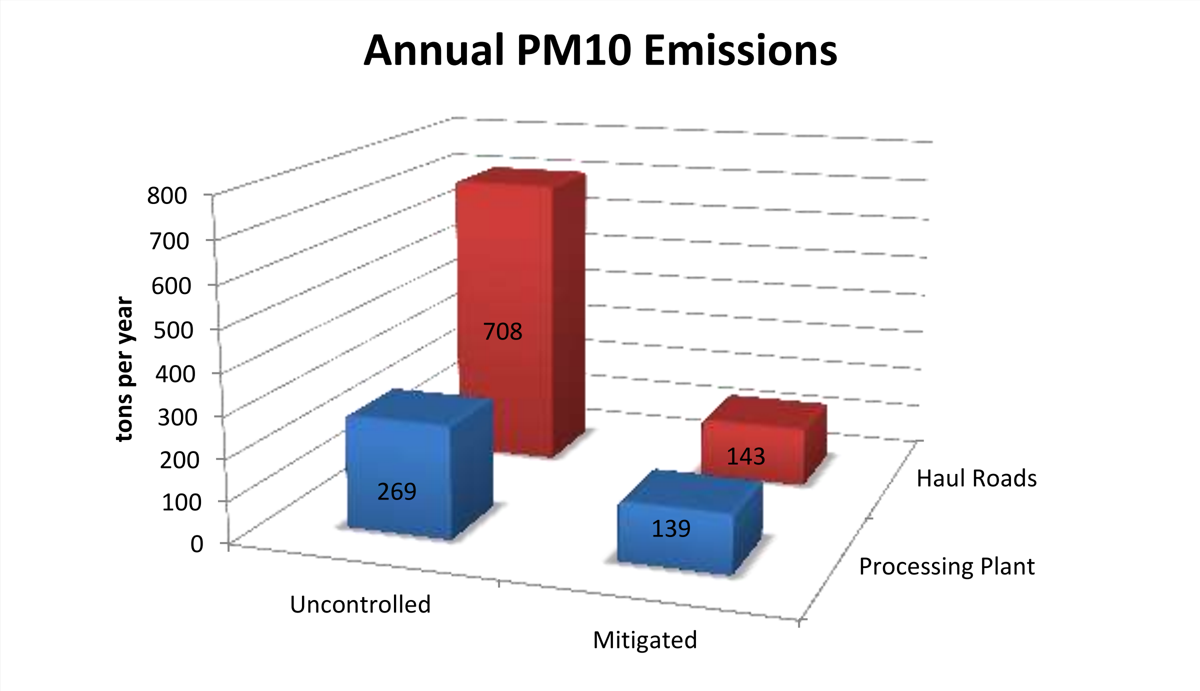

Figure 8: Annual PM10 emissions of uncontrolled and mitigated haul roads and the processing plant at the proposed Matai Mining Project.\

16 Air Quality Impact Assessment

16.1 Assumptions and Limitations

Heavy construction is a source of dust emissions that may have a substantial temporary impact on local air quality. Building and road construction are two examples of construction activities with high emissions potential. However, dust emissions often vary substantially from day to day, depending on the level of activity, the specific operations, and the prevailing meteorological conditions. Construction of the processing plant, workshops, material stockpiles, storage facilities, access roads, etc. will be required. However, information on the time scale and order of these construction projects was not available. Too many assumptions would, therefore, have to be made in order to model the emissions in the construction phase of the proposed Matai Mining Project, and a conservative estimate of this nature is likely to produce results that would unrealistically exceed the NAAQS. Wet suppression, chemical stabilization and wind speed reduction are methods that should be used to control open dust sources at the construction sites.

As the proposed Matai Mining Project is still in the planning phase, many of the parameters required for the modelling were unavailable. Furthermore, no site-specific particle size fraction data, moisture content or silt content information was available. Average values from the literature were used for many of the parameters, and in some cases, considering the mandate for regulatory modelling, conservative estimates and 'worst case' values were used in the model. Whilst care has been taken to assess the potential air pollution impact from the proposed mining, more accurate input data may result in different conclusions.

For the modelling, it was assumed that primary crushing will take place in the pit and that apron feeders and conveyors will be used to move all ore from the pit to the ROM pad (Ukwazi Mining Studies (Pty) Ltd, 2018a). For the mitigated scenario, it was assumed that all conveyor transfer points will be enclosed, resulting in a 70% mitigation efficiency.

Tailpipe emissions were not included. Although the activities at the proposed Matai Mining Project would emit gases, primarily by haul trucks and mining vehicles, the impact of these compounds were not included in this assessment. The sulphur content of South African diesel is too low (0.05% for Sasol Turbodiesel™) and mining equipment is too widely dispersed over mine sites to cause sulphur dioxide (SO_2) levels to be exceeded even in mines that use large quantities of diesel.

The scope of the work only covers ambient concentration impacts beyond the mine's boundaries, occupational health issues were not addressed.

16.2 Modelling

Dispersion simulations were undertaken to determine ambient concentrations of $PM_{2.5}$ and PM_{10} resulting from all operations at the proposed Matai Mining Project. Three scenarios were simulated – an uncontrolled scenario; a scenario taking into account emission reductions possible by implementing mitigation measures on all haul roads, conveyor transfer points and the processing plant; and a scenario with the added mitigation measure of tarring the access road off site.

Dispersion simulations were executed incorporating all significant sources for the mining area. The waste dump, the ROM pad and the Processing Plant were all simulated as area sources. Activities in the pit (drilling, bulldozing, primary crushing, loading and unloading of haul trucks, loading of conveyors, hauling to the backfill area and wind erosion of exposed areas) were simulated as a single, open pit source, with the advantage that an area below ground level could be simulated by AERMOD. Roads were simulated as adjacent volume sources as recommended by the US EPA haul road workgroup (US EPA, 2012).

The dispersion of pollutants was modelled up to a distance of 40 km from the proposed site. The isopleths are given in Figure 9 to Figure 20 below. Isopleths higher than the National Standards have not been included in the figures below – all areas within the red coloured isopleth can be expected to experience exceedances of the National Standards.

It should be noted that isopleth plots reflecting the 24-hour averaging periods contain the average of the fifth-highest predicted ground level concentrations, over the three-year period for which simulations were undertaken. In other words, the model calculates the fifth-highest concentration at each receptor for each year modelled, averages those fifth-highest concentrations at each receptor across the three years of meteorological data, and then selects the highest across all receptors, of the three-year averaged fifth-highest values for plotting. This is in line with the NAAQS which allows for four exceedances per year. Concentrations are presented in µg m^{-3}.

PM_{10} Modelling Results (Year 6)

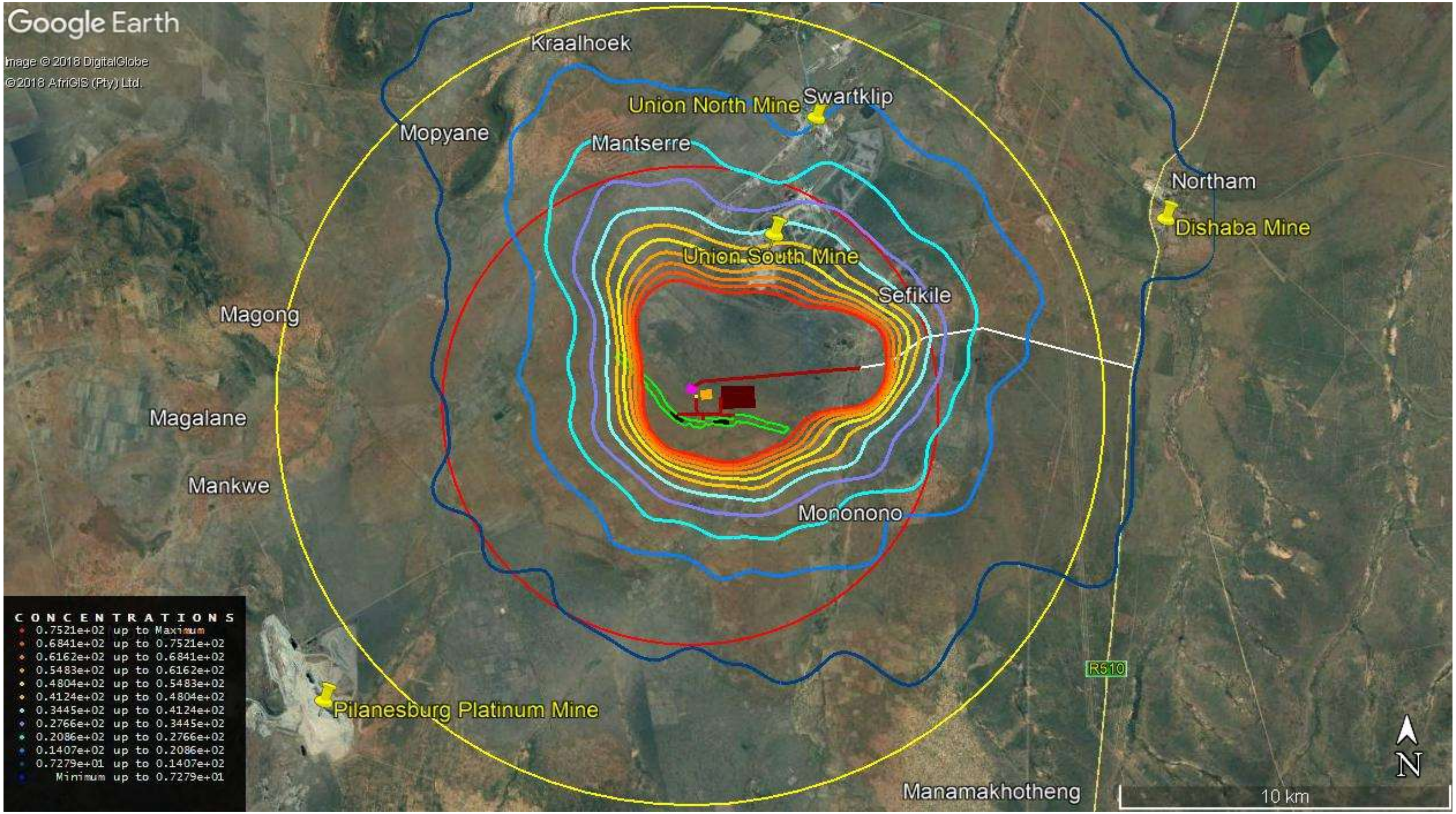

Figure 9: Modelled prediction of highest 24-hour average PM10 concentrations, without mitigation measures, resulting from the proposed Matai Mining Project.

PM$_{10}$ Modelling Results (Year 6)

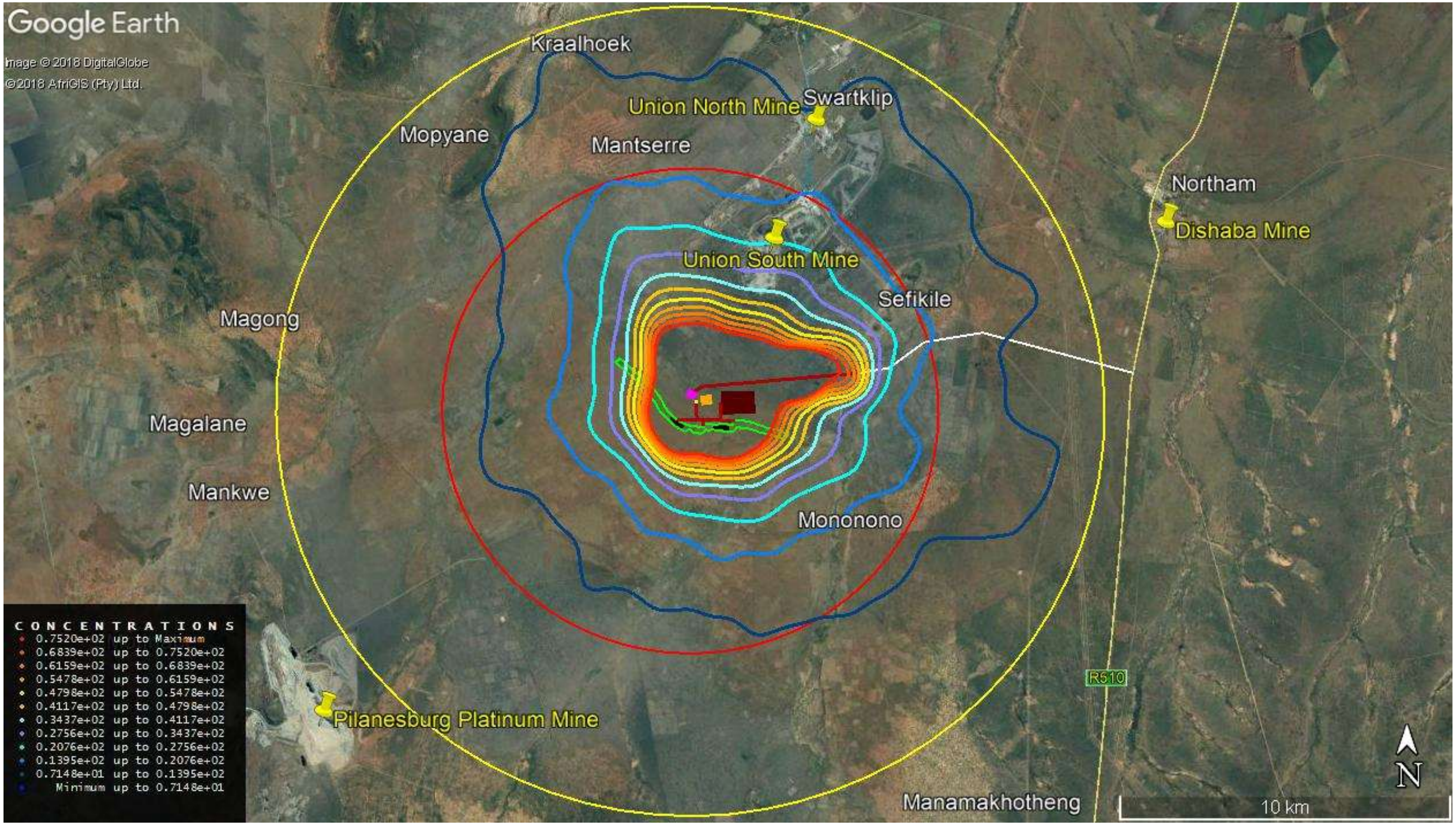

Figure 10: Modelled prediction of highest 24-hour average PM10 concentrations, with mitigation measures, resulting from the proposed Matai Mining Project.

PM_{10} Modelling Results (Year 6)

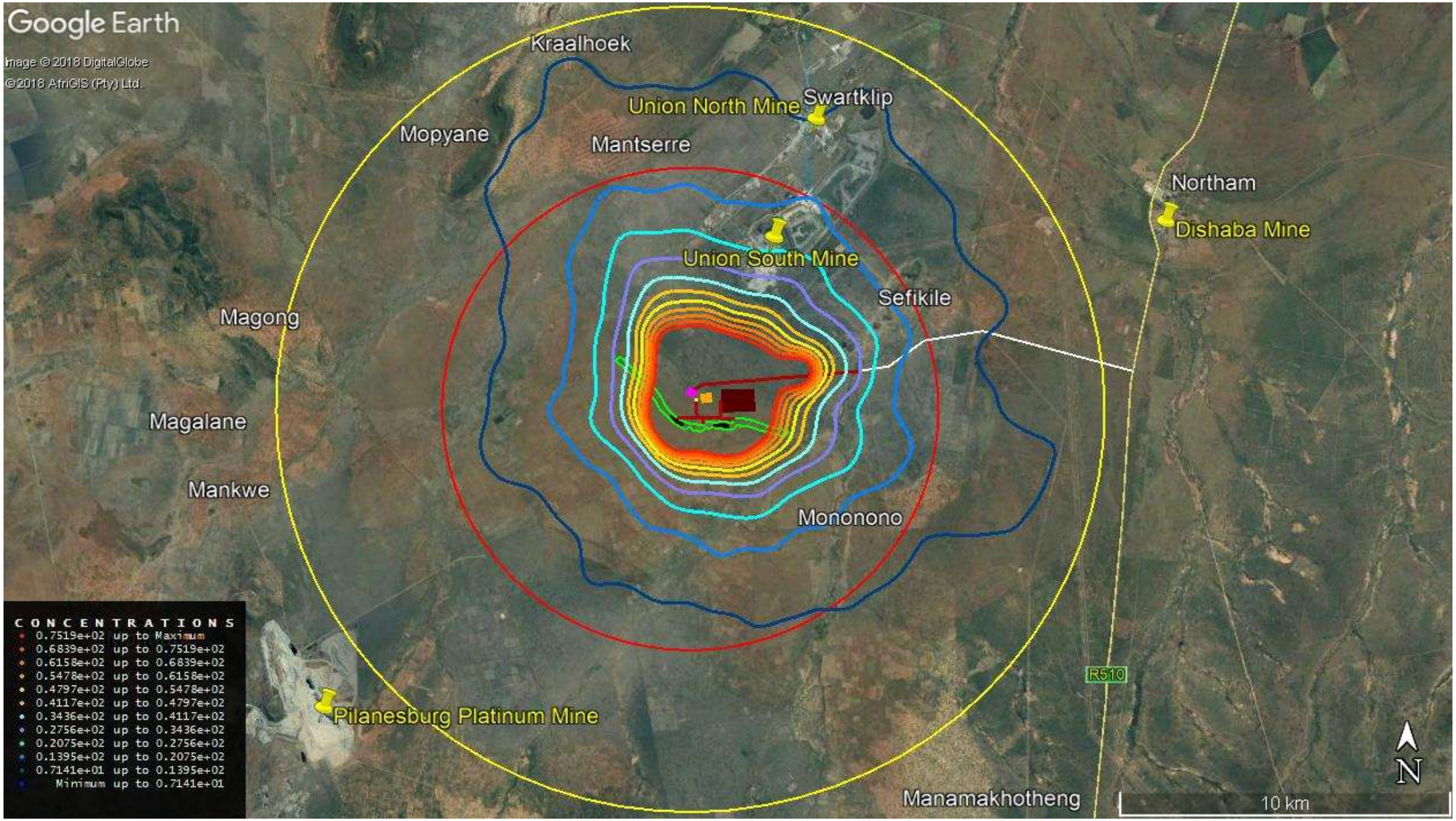

Figure 11: Modelled prediction of highest 24-hour average PM10 concentrations, with mitigation measures (including tarred off-site roads), resulting from the proposed Matai Mining Project.

PM_{10} Modelling Results (Year 6)

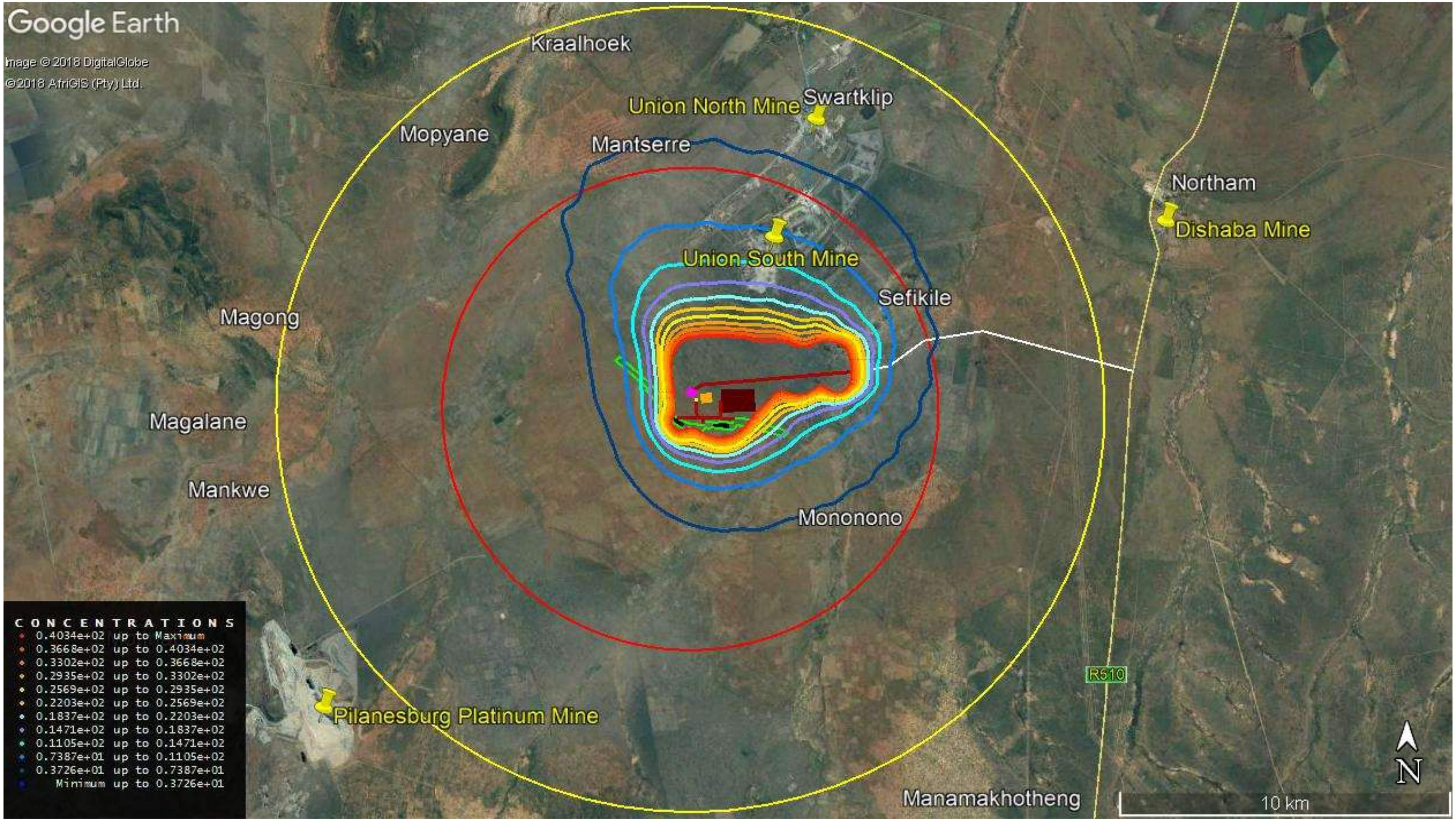

Figure 12: Modelled prediction of annual average PM10 concentrations, without mitigation measures, resulting from the proposed Matai Mining Project.

PM_{10} Modelling Results (Year 6)

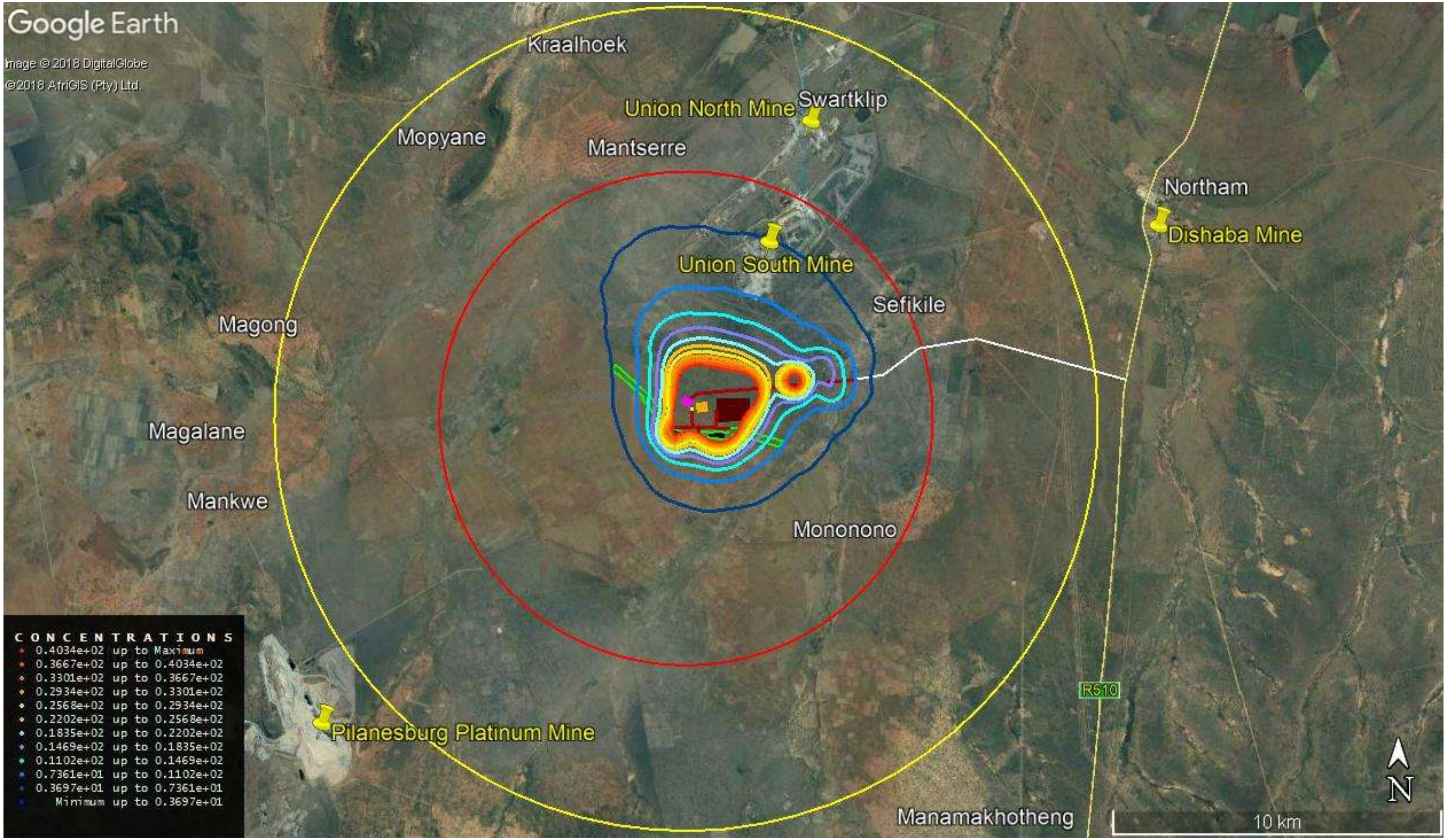

Figure 13: Modelled prediction of annual average PM10 concentrations, with mitigation measures, resulting from the proposed Matai Mining Project.

PM_{10} Modelling Results (Year 6)

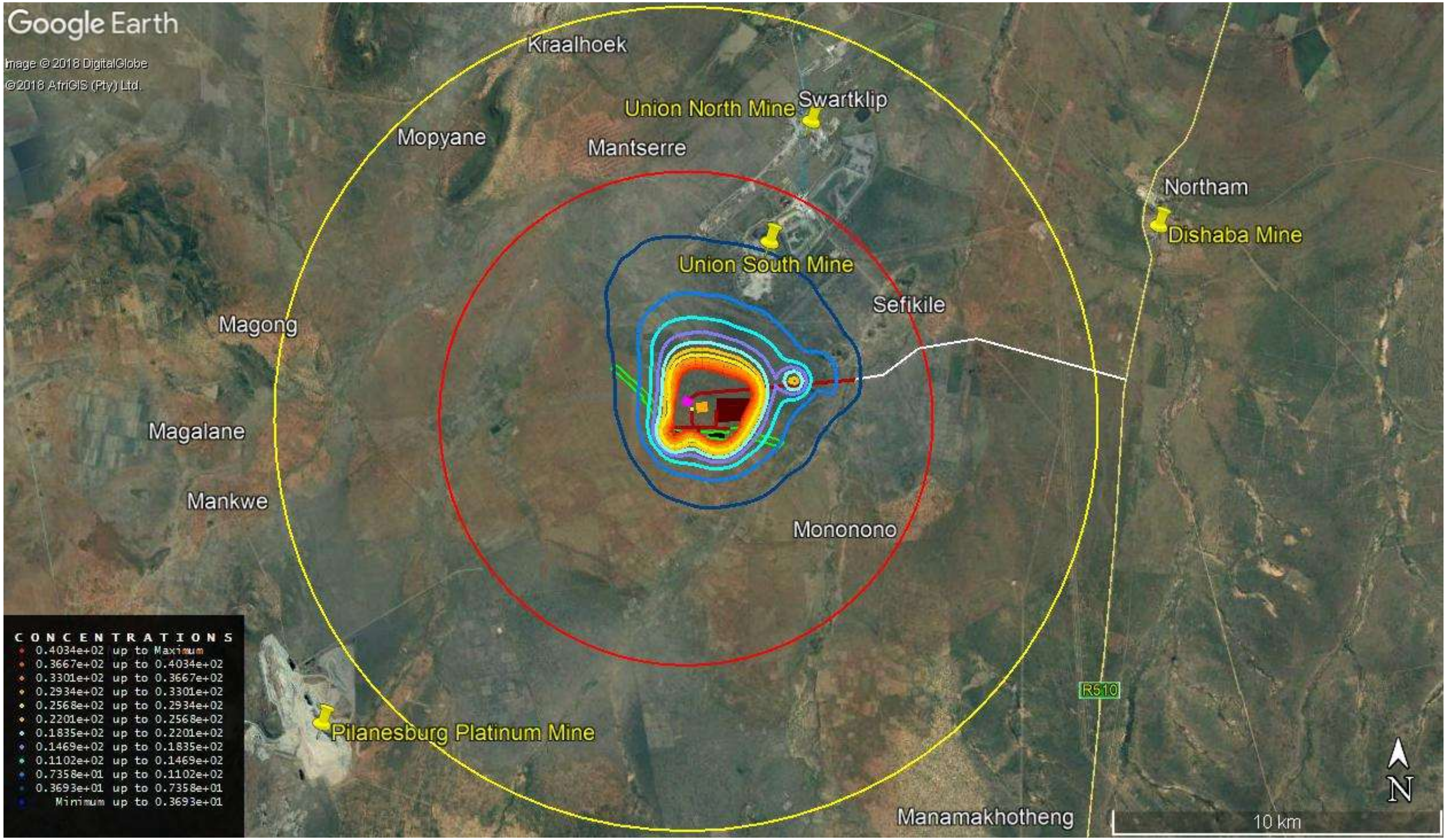

Figure 14: Modelled prediction of annual average PM10 concentrations, with mitigation measures (including tarred off-site roads), resulting from the proposed Matai Mining Project.

16.3 Evaluation of the PM_{10} Modelling Results

16.3.1 Without mitigation measures

- PM_{10} (24-hour Average Concentrations) – Without any mitigation measures, the predicted highest daily average concentrations exceed the national daily standard of 75µg/m^3 up to approximately 3 km from the mine footprint, **including exceedances over parts of the Sefikile residential area. This is a health risk for these people.** Furthermore, the proximity of Sefikile to the Union South Mine means that ambient concentrations will already be elevated and the cumulative PM_{10} concentrations resulting from the two mines together will be even higher.
- PM_{10} (Annual Average Concentrations) – Without any mitigation measures, the predicted maximum annual average concentrations exceed the national annual average standard of 40µg/m^3 up to a distance of approximately 1.3 km to the north of the proposed haul road leading to the R510. **This is a health risk for residents of Sefikile, particularly those living closest to this road.**

16.3.2 With mitigation measures

- PM_{10} (24-hour Average Concentrations) – With mitigation measures, the predicted maximum daily average concentrations exceed the national daily standard of 75µg/m^3 up to approximately 2 km from the mine footprint, particularly to the north of the mine. With cumulative concentrations from the Union South Mine, **this is a health risk for residents of Sefikile, particularly those living closest to the access haul road.**
- PM_{10} (Annual Average Concentrations) – With mitigation measures, the predicted maximum annual average concentrations exceed the national annual average standard of 40µg/m^3, extending up to approximately 800 m from the mine footprint, particularly to the north of the mine.

16.3.3 With mitigation measures and a tarred access haul road

- PM_{10} (24-hour Average Concentrations) – With mitigation measures and a tarred access haul road, the predicted maximum daily average concentrations exceed the national daily standard of 75µg/m^3 up to approximately 1.9 km from the mine footprint. However, exceedances to the north of the access road are reduced to a maximum of approximately 600 m.
- PM_{10} (Annual Average Concentrations) – With mitigation measures and a tarred access haul road, the predicted maximum annual average concentrations exceed the national annual average standard of 40µg/m^3, extending up to approximately 800 m from the mine footprint, particularly to the north of the mine. Emissions from the access road for this scenario do not exceed the annual average standard.

$PM_{2.5}$ Modelling Results (Year 6)

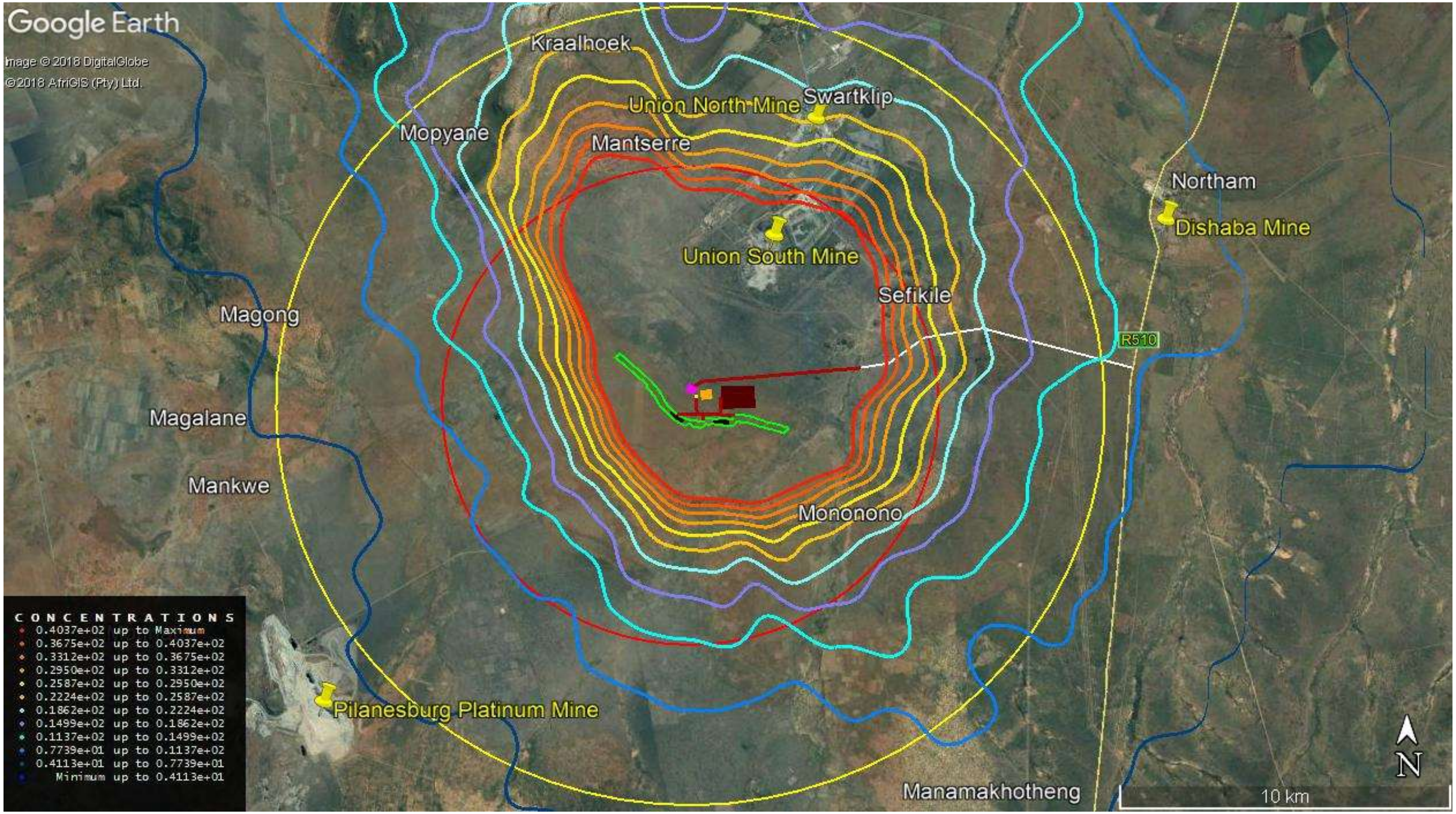

Figure 15: Modelled prediction of highest 24-hour average PM2.5 concentrations, without mitigation measures, resulting from the proposed Matai Mining Project.

$PM_{2.5}$ Modelling Results (Year 6)

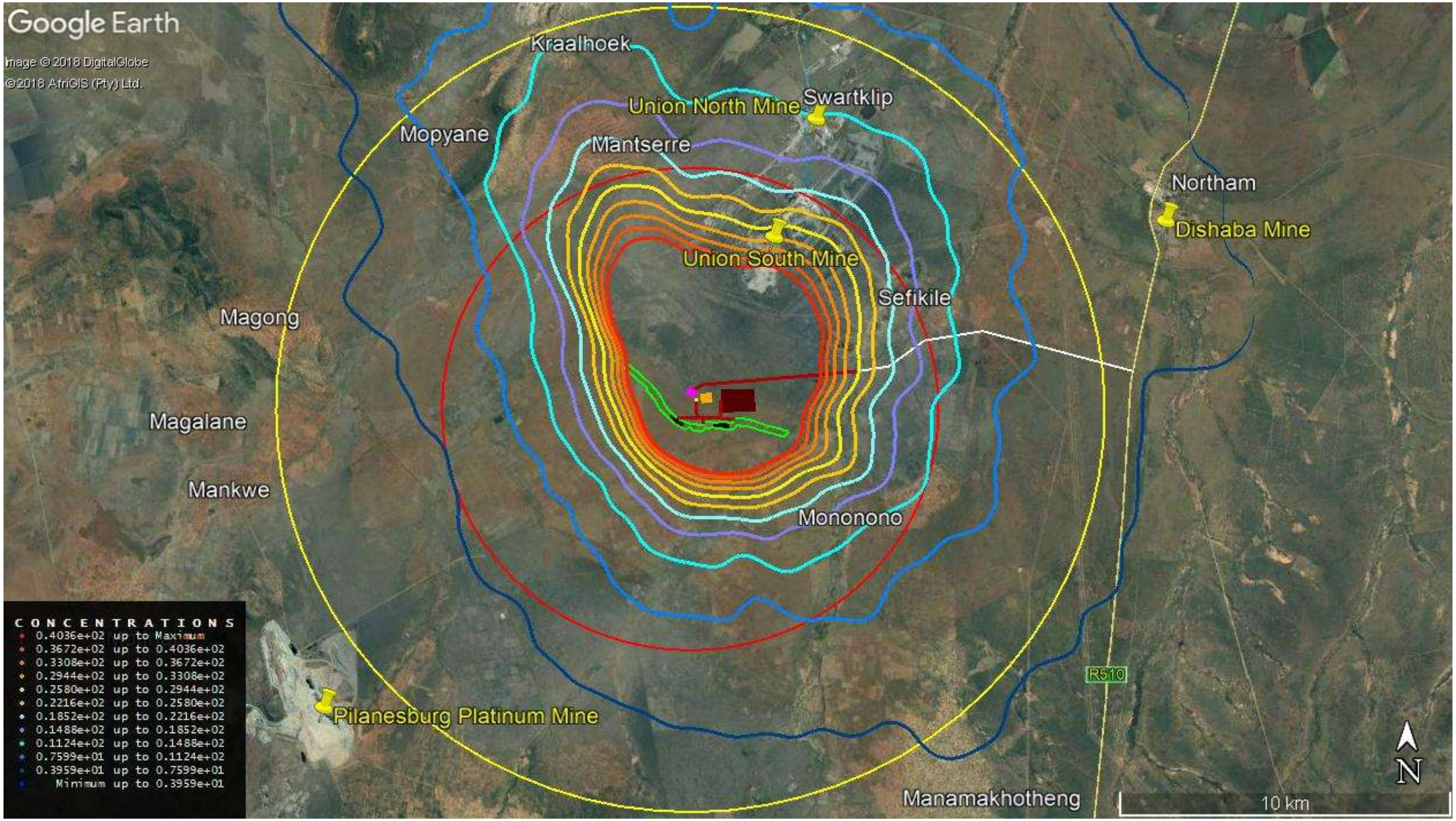

Figure 16: Modelled prediction of highest 24-hour average PM2.5 concentrations, with mitigation measures, resulting from the proposed Matai Mining Project.

$PM_{2.5}$ Modelling Results (Year 6)

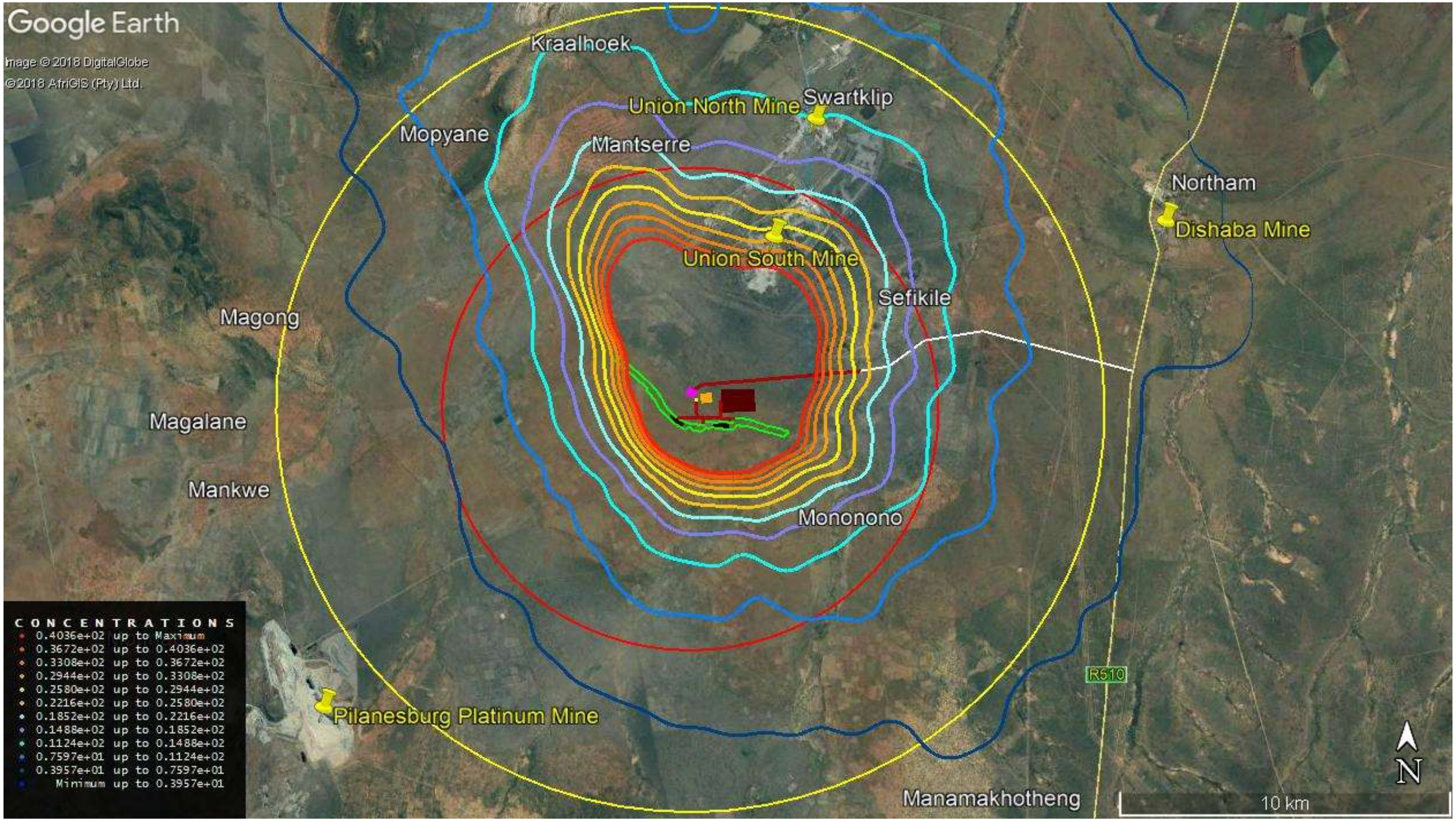

Figure 17: Modelled prediction of highest 24-hour average PM2.5 concentrations, with mitigation measures (including tarred off-site roads), resulting from the proposed Matai Mining Project.

$PM_{2.5}$ Modelling Results (Year 6)

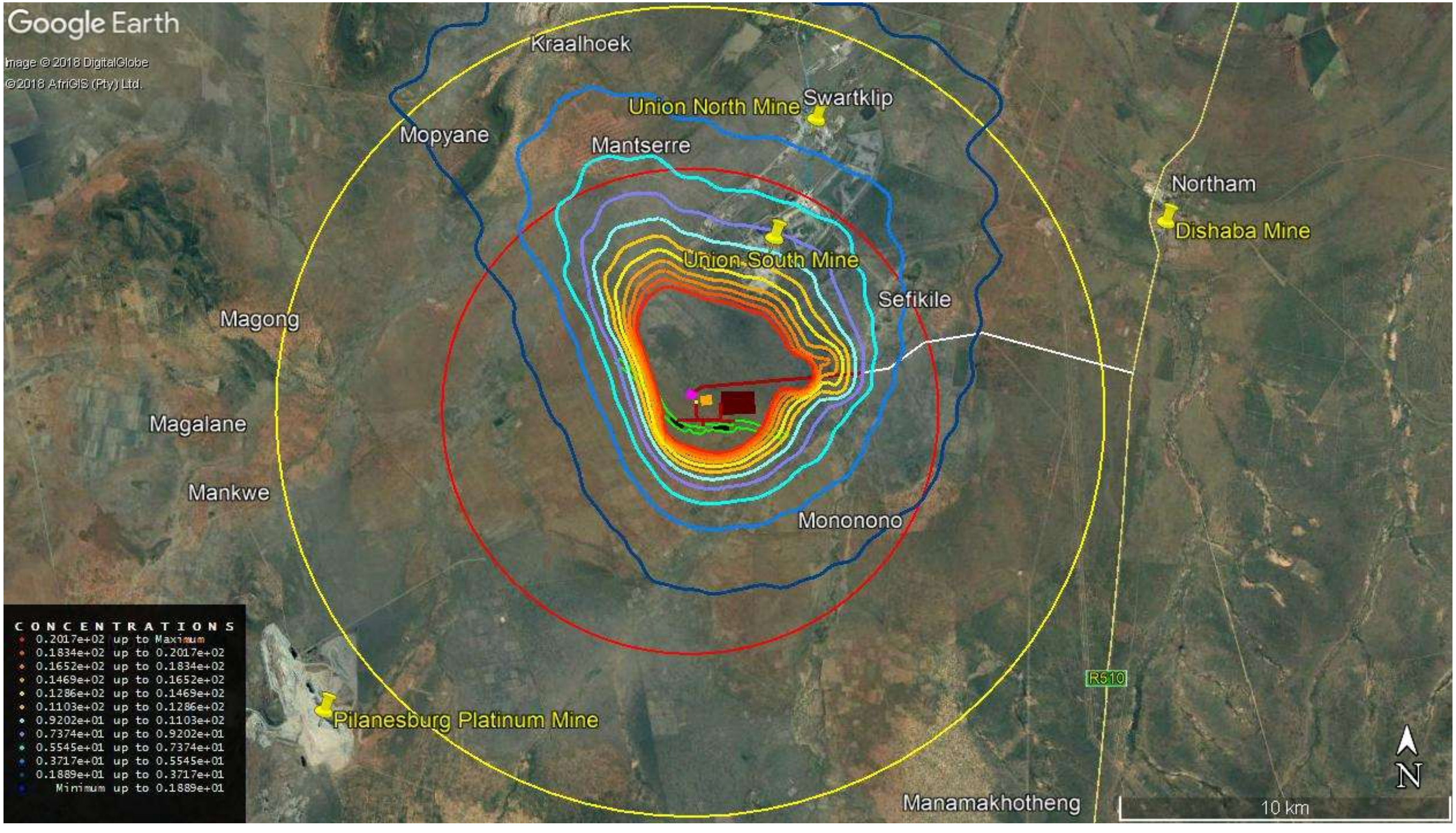

Figure 18: Modelled prediction of annual average PM2.5 concentrations, without mitigation measures, resulting from the proposed Matai Mining Project.

$PM_{2.5}$ Modelling Results (Year 6)

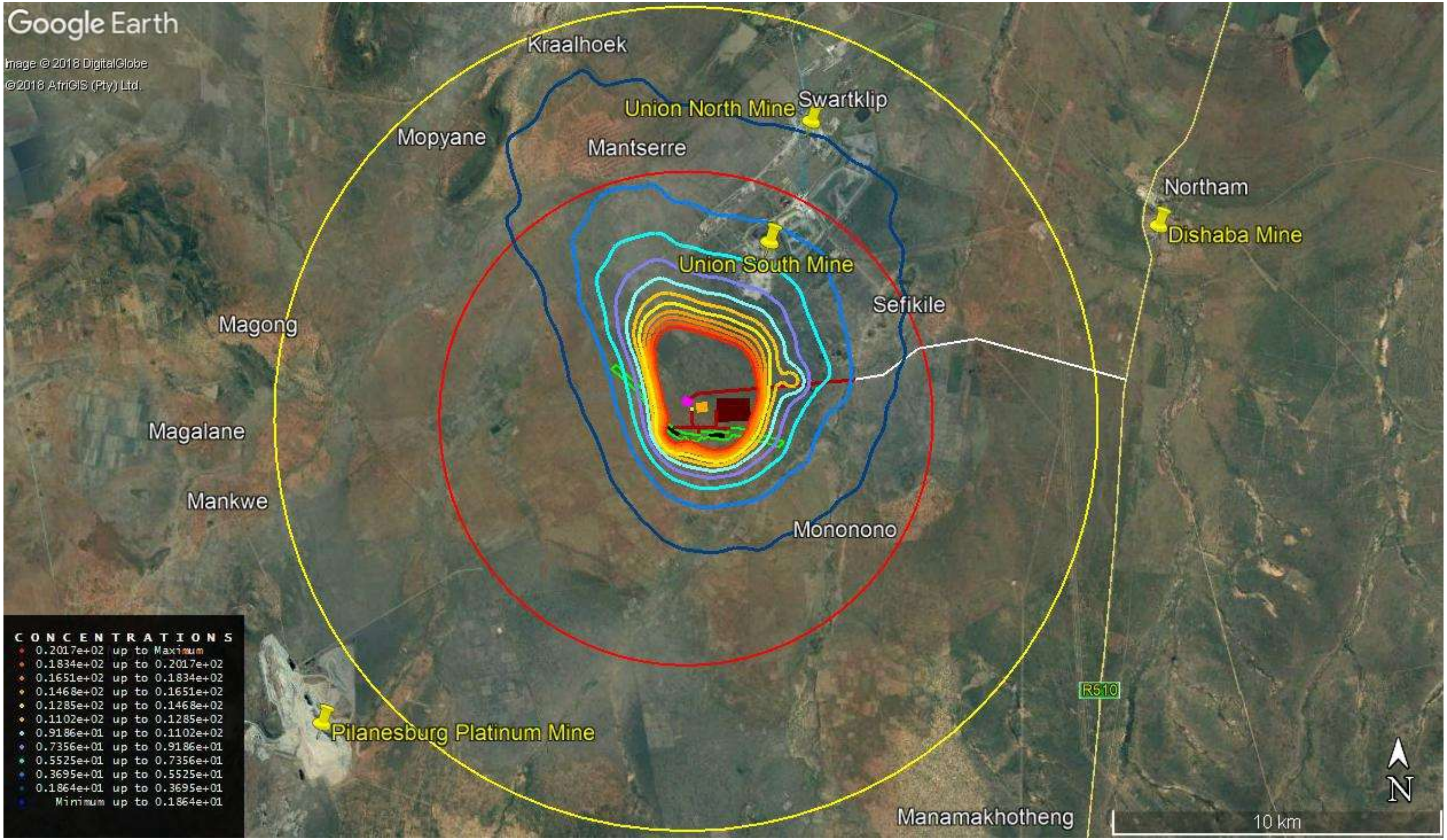

Figure 19: Modelled prediction of annual average PM2.5 concentrations, with mitigation measures, resulting from the proposed Matai Mining Project.

$PM_{2.5}$ Modelling Results (Year 6)

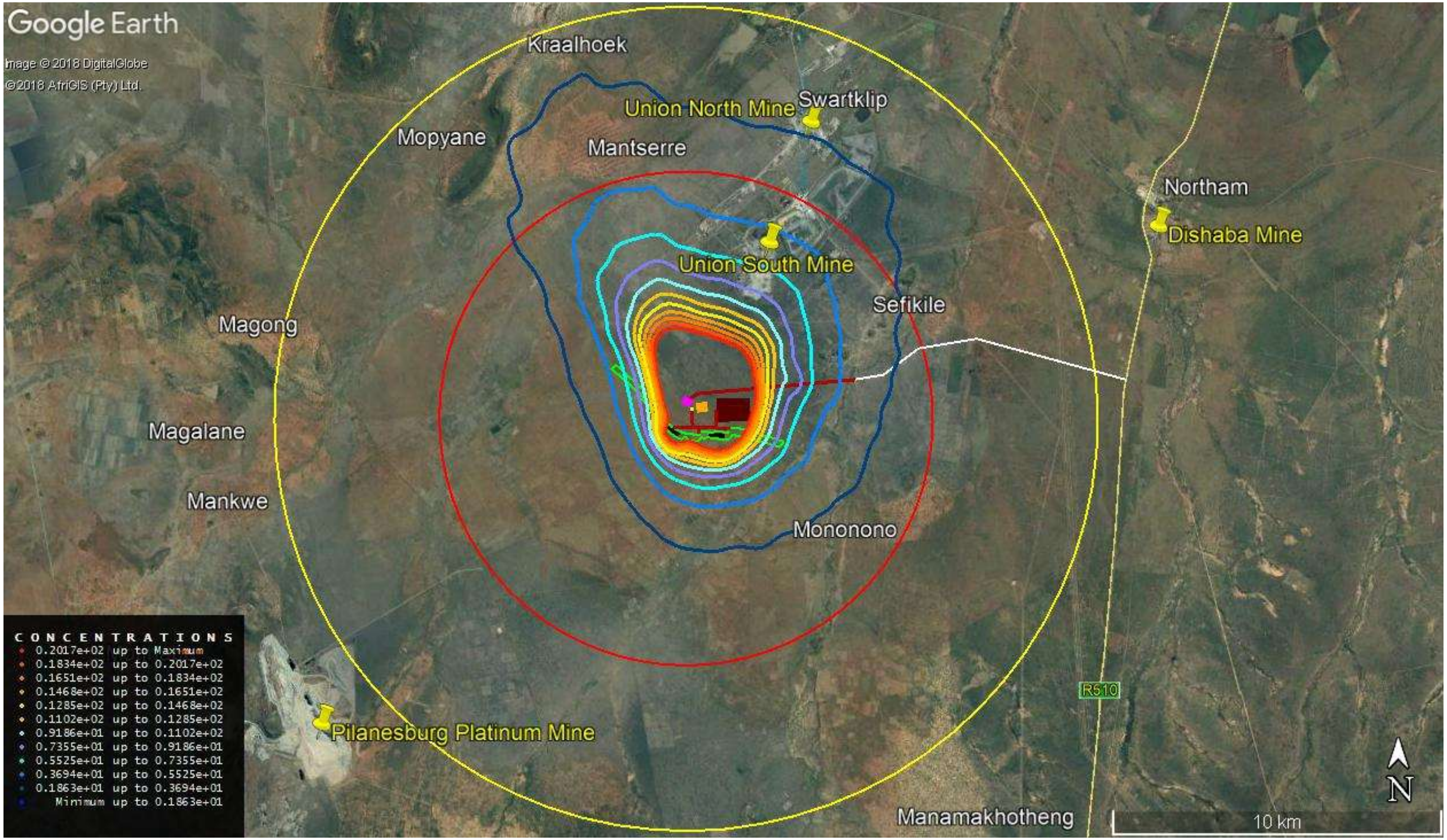

Figure 20: Modelled prediction of annual average PM2.5 concentrations, with mitigation measures (including tarred off-site roads), resulting from the proposed Matai Mining Project.

16.4 Evaluation of the $PM_{2.5}$ Modelling Results

16.4.1 Without mitigation measures

- $PM_{2.5}$ (24-hour Average Concentrations) – Without any mitigation measures, the predicted highest daily average concentrations exceed the national daily standard of 40µg/m^3 up to approximately 7.6 km from the mine footprint, particularly to the north of the mine, **including exceedances over the Sefikile and Mantserre residential areas as well as over the southern parts of the Union South Mine. This is a health risk for the people in these areas.** Furthermore, the proximity of these residential areas to the Union South Mine means that ambient concentrations will already be elevated and the cumulative $PM_{2.5}$ concentrations resulting from the two mines together will be even higher.
- $PM_{2.5}$ (Annual Average Concentrations) – Without any mitigation measures, the predicted maximum annual average concentrations exceed the national annual average standard of 20µg/m^3 up to a distance of approximately 3.2 km from the mine footprint, particularly to the north of the mine. This is a concern for cumulative $PM_{2.5}$ concentrations in the area, particularly because of the proximity of Sefikile to the Union South Mine.

16.4.2 With mitigation measures

- $PM_{2.5}$ (24-hour Average Concentrations) – With mitigation measures, the predicted maximum daily average concentrations exceed the national daily standard of 40µg/m^3 up to approximately 4.8 km from the mine footprint, particularly to the north of the mine, **including exceedances over the southern areas of the Union South Mine. This is a health risk for the people in these areas.** Furthermore, the proximity of Sefikile to the Union South Mine means that ambient concentrations will already be elevated and the cumulative $PM_{2.5}$ concentrations resulting from the two mines together may result in exceedances over this area.
- $PM_{2.5}$ (Annual Average Concentrations) – With mitigation measures, the predicted maximum annual average concentrations exceed the national annual average standard of 20µg/m^3, extending up to approximately 2.1 km from the mine footprint, particularly to the north of the mine.

16.4.3 With mitigation measures and a tarred access haul road

- $PM_{2.5}$ (24-hour Average Concentrations) – With mitigation measures and a tarred access haul road, the predicted maximum daily average concentrations exceed the national daily standard of 40µg/m^3 up to approximately 4.8 km from the mine footprint, particularly to the north of the mine, **including exceedances over the southern areas of the Union South Mine. This is a health risk for the people in these areas.** Furthermore, the proximity of Sefikile to the Union South Mine means that ambient concentrations will already be elevated and the cumulative $PM_{2.5}$ concentrations resulting from the two mines together may result in exceedances over this area.

- $PM_{2.5}$ (Annual Average Concentrations) – With mitigation measures and a tarred access haul road, the predicted maximum annual average concentrations exceed the national annual average standard of 20µg/m^3, extending up to approximately 2.1 km from the mine footprint, particularly to the north of the mine.

Section 17 gives an overview of mitigation measures that can be put in place to significantly reduce the impact of the mining activities on the surrounding environment. Furthermore, due to the health implications of $PM_{2.5}$ and PM_{10} emissions on the residents of the surrounding areas, continuous monitoring is essential. Recommendations for a monitoring programme are given in Section 18.

17 Mitigation Measures

Heavy construction is a source of dust emissions that may have a substantial temporary impact on local air quality. Building and road construction are two examples of construction activities with high emissions potential. However, dust emissions often vary substantially from day to day, depending on the level of activity, the specific operations, and the prevailing meteorological conditions. Wet suppression, chemical stabilization and wind speed reduction are methods that should be used to control open dust sources at the construction sites.

The breakdown of uncontrolled emissions from mining activities at the proposed Matai Mining Project (Figure 6) shows that haul roads and the processing plant are expected to produce the largest percentage of particulate emissions. For this reason, these activities should be prioritised for mitigation measures.

17.1 Haul Road Mitigation Measures

Haul roads represent the largest source of particulate emissions at the mine. Haul road mitigation measures include: tarring or paving, wet suppression and chemical surface treatments. Regular, light watering of the road is needed for water spraying to be effective in reducing particulate emissions. Other surface treatments include the use of chemicals such as calcium chloride or magnesium chloride. These chemicals attract moisture – drawing moisture out of the air during periods of high humidity, and also reducing the evaporation rate of water during hot periods. Some products contain surfactants which act as wetting agents. These not only reduce the amount of water required for wetting the roads, but also have slight binding properties. Another approach to dust control involves the application of organic or synthetic compounds that physically bind the dust particles together. The disadvantage of paving/tarring, infrequent watering and chemical mitigation measures is their inability to prevent material spillage from being re-entrained. In these instances, removal of spillage by sweepers/vacuum in combination with a dust palliative is more effective for dust control (Thompson & Visser, 2000).

A decrease of 50-80% can be achieved by surface treatments (US EPA, 2013). Field testing of emissions from controlled unpaved roads has shown that dust suppressants can provide a PM_{10} control efficiency of about 80% when applied at regular intervals (US EPA, 1995). A mitigation efficiency of 80% was assumed for the mitigated scenario in the modelling. A mitigation efficiency of 92% was assumed for the tarred road scenario. This is the maximum mitigation efficiency for tar or bitumen emulsions immediately after application (Thompson & Visser, 2007). It must be noted that this mitigation efficiency would only be possible if accompanied by regular sweeping or vacuuming and covering of the load in the haul trucks.

The modelling results indicate that it is essential for the mine access haul road to be tarred. Although the section of public road earmarked for upgrade (See Figure 1) was not included in the modelling, extrapolation from the modelling results indicates that the residential areas to the north of this road will experience health impacts unless this road is tarred.

17.2 Processing plant mitigation measures

The moisture content of the material processed can have a substantial effect on emissions. Surface wetness causes fine particles to agglomerate on, or to adhere to, the faces of larger chunks of ore, 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 (US EPA, 1995). For the mitigated scenario in the modelling, it was assumed that secondary and tertiary crushing and screening is controlled by wet suppression with a 50% efficiency (NPi, 2012).

17.3 Additional PM mitigation measures

Additional control measures which should be adopted to reduce the potential for fugitive dust emissions at the mine are presented in Table 7.

Table 7: Additional dust control measures which should be implemented (U.S. EPA, 1995).

Activity	Recommended Control Measure(s)
Materials handling (soil, waste rock, ore)	Mass transfer reduction: every time material is moved PM emissions are increased. Therefore, for example, the use of temporary storage piles should be avoided.
	Drop height reduction: PM emissions are increased by an increase in drop height. For example, in the design of the conveyor transfer points this factor should be kept in mind. It is also a factor to be considered in the design of the tripper

Activity	Recommended Control Measure(s)
	conveyor planned for the stacking of material to stockpiles (Kimopax, 2018).
	Wind speed reduction through wind breaks and source enclosures. For example, at the processing plant, the feasibility of positioning a barrier to shield the crushing and screening areas as well as the stockpiles from the dominant wind directions should be considered. This would mean building an enclosure on the southerly to westerly sides to reduce emissions in the directions of greatest concern for impact.
	Wet suppression.
Vehicle entrainment from unpaved roads	Reduction of unnecessary traffic.
	Strict speed control.
Open areas – wind erosion	From the time an area is disturbed until new vegetation emerges, all disturbed areas are subject to wind erosion. Vegetation should be planted on all soil stockpiles and berms. Disturbed soil should be compacted and stabilised by chemicals or vegetation.
	Reduction of frequency of disturbance.
Conveyors	Covering of conveyors and wet suppression/enclosure of all transfer points.

18 Air Quality Monitoring Programme

In order to accurately assess the air quality impacts of particulate emissions from the proposed Matai Mining Project, particularly with regard to the health implications for residents in the surrounding areas, continuous $PM_{2.5}$ and PM_{10} monitoring must be undertaken. For this purpose, continuous ambient air quality monitoring analysers must be located on the south-western side of Sefikile. This air quality monitoring should be implemented as far prior to the start of the construction phase of the mine as possible and must include both the summer and winter seasons. This development of a baseline will make it possible to more accurately evaluate the mine's actual contribution to ambient concentrations of PM.

Meteorological stations (co-located with the continuous PM monitoring) would need to be erected for the life of the mine to measure (at minimum) wind speed and wind direction, but preferably also temperature, humidity, barometric pressure and rainfall.

It is also recommended that a continuous dustfall monitoring programme be established. The position of the samplers should be re-assessed annually as mining progresses. The samplers must be operated in accordance with the National Dust Control Regulations (Government Notice No. R827, 2013). The dustfall monitoring is purely to monitor the effectiveness of mitigation measures and may not be used to replace the continuous $PM_{2.5}$ and PM_{10} monitoring above.

As part of this monitoring programme, monthly reports must be produced with recommendations to management with regard to the effectiveness of the mitigation methods being applied. If the number of exceedances measured at any monitoring site is higher than that allowed by the NAAQS (Table 1) or the National Dust Control Regulations (Table 2), the mine must take urgent measures to further mitigate emissions until ambient air quality concentrations or dustfall rates are brought back into line with the National Standards and Regulations.

19 Conclusions and Recommendations

An air quality impact assessment was undertaken for the proposed Matai Mining Project. $PM_{2.5}$ and PM_{10} represent the main criteria pollutants associated with open pit mining and crushing and screening operations. Three scenarios were selected for modelling – an uncontrolled scenario; a scenario taking into account emission reductions possible by implementing mitigation measures on all haul roads, conveyor transfer points and the processing plant; and a scenario with the added mitigation measure of tarring the off-site access road.

It is important to note that the proposed Matai Mining Project falls within the declared Waterberg-Bojanala Priority Area (WBPA) for Air Quality. Furthermore, the proximity of the proposed mining area to the Union South Mine is of concern because of the cumulative effect on ambient concentrations from emissions of particulate matter from the two mines.

The modelling results indicate that uncontrolled emissions will result in exceedances of the NAAQS over the Sefikile and Mantserre residential areas as well as over the southern parts of the Union South Mine. Even with maximum efficiency mitigation measures in place on both the haul roads and the processing plant, exceedances of the $PM_{2.5}$ 24-hour standards may be expected over the southern areas of the Union South Mine. Considering that the emissions from the Union South Mine and from the proposed Matai Mining project will be cumulative, stringent mitigation measures must be applied at all times to reduce emissions and to keep the impact of the mine to a minimum. This must include:

- Using the best possible mitigation methods on the crushing and screening activities at the processing plant.
- Wet suppression on the ROM and product stockpiles.
- Tarring and sweeping/vacuuming of the access haul road.

- Tarring of the road earmarked for upgrade (See Figure 1).
- Efficient, regular wet suppression or chemical suppression of all unpaved haul roads, including roads to the backfill areas in the pits.
- Wet suppression or enclosure of all conveyor transfer points.
- Covering of all conveyors.
- Reducing the number of transfer points through careful planning and design, because each time the ore is dropped onto a stockpile, emissions are generated. For example, when the crushing and screening plant is in operation, the ore from the mine conveyor should bypass the ROM plant feed stockpile into the plant for screening and crushing, thus reducing handling of ore.

Furthermore, a comprehensive, continuous air quality monitoring programme must be implemented in order to ensure that the above mitigation measures are applied at all times to keep emissions within the NAAQS in residential areas.

As the proposed Matai Mining Project is still in the planning phase, many of the parameters required for the modelling were unavailable. Average values from the literature were used for many of the parameters, and in some cases, conservative estimates and 'worst-case' values were used in the model. Whilst care has been taken to assess the potential air pollution impact from the proposed mining, more accurate input data may result in different conclusions.

The impact on the environment surrounding the proposed mine is summarised in the impact assessment table below (Table 8).

Table 8: Air Quality Impact Assessment Matrix before and after mitigation (See Impact Assessment Methodology in Appendix A).

Impact Assessment Matrix Matai Mining Project		
Impact Description	Mining activities cause the emission of particulate matter into the air, thus increasing existing ambient air concentrations of criteria pollutants (both PM_{10} and $PM_{2.5}$) at receptors.	
Acceptable rating level	**PM_{10}** • 24-hour Average Concentrations: National Ambient Air Quality Standard of 75µg/m³ • Annual Average Concentrations: National Ambient Air Quality Standard of 40µg/m³ **$PM_{2.5}$** • 24-hour Average Concentrations: National Ambient Air Quality Standard of 40µg/m³ • Annual Average Concentrations: National Ambient Air Quality Standard of 20µg/m³	
Activity	**Before Mitigation**	**After Mitigation** **(Tarring of the access road, and mitigation measures implemented on all unpaved haul roads, conveyor transfer points and on crushing and screening**

		activities at the processing plant)
Magnitude	**Major negative:** Worst-case conditions may lead to the 24-hour NAAQS being exceeded over the residential areas of Mantserre, Sefikile and the Union South Mine. This is a health risk to people living in those areas.	**Moderate negative:** Even with mitigation measures in place, worst-case conditions may lead to the NAAQS being exceeded over the Union South Mine. Because of the proximity of Sefikile to both mines, cumulative concentrations may lead to exceedances of the NAAQS over some of the residential areas.
Duration	**Long Term:** There is a possibility of the ambient air concentrations exceeding the NAAQS for the duration of mining activities taking place (more than 5 years).	**Long Term:** There is a possibility of the ambient air concentrations exceeding the NAAQS for the duration of mining activities taking place (more than 5 years).
Spatial Scale	**Local:** Worst-case conditions may lead to the NAAQS being exceeded up to 7.6 km from the mining activities.	**Local:** With mitigation measures in place, worst-case conditions may lead to the NAAQS being exceeded up to 4.8 km from the mining activities.
Consequence	**High**	**Medium**
Probability	**Definite:** There are areas of Sefikile that are predicted to exceed the annual average NAAQS (No exceedances are permissible).	**Possible: Although the residential** areas of Sefikile are not predicted to exceed the annual average NAAQS, cumulative ambient concentrations may still lead to exceedances.

Significance of Air Quality Impact	**High**	**Medium**
Mitigation	Modelled: Tarring and sweeping/ vacuuming on the access haul road. Either chemical or wet suppression of unpaved haul roads. Mitigation of both crushing and screening at the processing plant. Covering of conveyors and mitigation of conveyor transfer points. Recommended: Wet suppression on all ROM and product stockpiles.	
Cumulative Impact	Due to the close proximity of the proposed Matai Mining Project to the Union South Mine, there will be a cumulative effect of the combined emissions on the residential areas of Sefikile, Union South Mine and possibly Mantserre.	

20 References

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Appendix A: Methodology used in determining the significance of environmental impacts

The impact significance rating process serves two purposes: firstly, it helps to highlight the critical impacts requiring consideration in the management and approval process; secondly, it shows the primary impact characteristics, as defined below, used to evaluate impact significance.

The impact significance rating system is presented in **Table 9** and involves three parts:

Part A: Define impact consequence using the three primary impact characteristics of magnitude, spatial scale/ population and duration;

Part B: Use the matrix to determine a rating for impact consequence based on the definitions identified in Part A; and

Part C: Use the matrix to determine the impact significance rating, which is a function of the impact consequence rating (from **Part B**) and the probability of occurrence.

Table 9: Significance Rating Methodology

PART A: DEFINING CONSEQUENCE IN TERMS OF MAGNITUDE, DURATION AND SPATIAL SCALE ***Use these definitions to define the consequence in Part B***		
Impact characteristics	**Definition**	**Criteria**
MAGNITUDE	Major -	Substantial deterioration or harm to receptors; receiving environment has an inherent value to stakeholders; receptors of impact are of conservation importance; or identified threshold often exceeded
	Moderate -	Moderate/measurable deterioration or harm to receptors; receiving environment moderately sensitive; or identified threshold occasionally exceeded
	Minor -	Minor deterioration (nuisance or minor deterioration) or harm to receptors; change to receiving environment not measurable; or identified threshold never exceeded
	Minor +	Minor improvement; change not measurable; or threshold

		never exceeded
	Moderate +	Moderate improvement; within or better than the threshold; or no observed reaction
	Major +	Substantial improvement; within or better than the threshold; or favourable publicity
SPATIAL SCALE OR POPULATION	Site or local	Site specific or confined to the immediate project area
	Regional	May be defined in various ways, e.g. cadastral, catchment, topographic
	National/ International	Nationally or beyond
DURATION	Short term	Up to 18 months.
	Medium term	18 months to 5 years
	Long term	Longer than 5 years

PART B: DETERMINING CONSEQUENCE RATING

Rate consequence based on definition of magnitude, spatial extent and duration

			SPATIAL SCALE/ POPULATION		
			Site or Local	**Regional**	**National/ international**
MAGNITUDE					
Minor	**DURATION**	**Long term**	Medium	Medium	High
		Medium term	Low	Low	Medium
		Short term	Low	Low	Medium
Moderate	**DURATION**	**Long term**	Medium	High	High
		Medium term	Medium	Medium	High

		Short term	Low	Medium	Medium
Major	**DURATION**	**Long term**	High	High	High
		Medium term	Medium	Medium	High
		Short term	Medium	Medium	High
PART C: DETERMINING SIGNIFICANCE RATING ***Rate significance based on consequence and probability***					
			CONSEQUENCE		
			Low	**Medium**	**High**
PROBABILITY (of exposure to impacts)		**Definite**	Medium	Medium	High
		Possible	Low	Medium	High
		Unlikely	Low	Low	Medium

Appendix B: Electronic files submitted with the report

AERMET input files

AERMOD.AERSFC.DAT

AERMOD.FSL

AERMOD.IN1

AERMOD.IN2

AERMOD.IN3

AERMET output files

AERMOD.OU1

AERMOD.OU2

AERMOD.OU3

AERMOD.PFL

AERMOD.SFC

AERMOD input files

AERMOD.PFL

AERMOD.SFC

Matai_PM2.5_Mitigated Tarred Off-site.txt

Matai_PM2.5_Mitigated.txt

Matai_PM2.5_Uncontrolled.txt

Matai_PM10_Mitigated Tarred off-site.txt

Matai_PM10_Mitigated.txt

Matai_PM10_Uncontrolled.txt

AERMOD output files

Matai_PM2.5_Mitigated Tarred Off-site.out

Matai_PM2.5_Mitigated. out

Matai_PM2.5_Uncontrolled. out

Matai_PM10_Mitigated Tarred off-site. out

Matai_PM10_Mitigated. out

Matai_PM10_Uncontrolled. out

AERMOD plot files

PM2.5Mit24hrMataiH5H.plt

PM2.5MitAnnualMatai.plt

PM2.5Tar24hrMataiH5H.plt

PM2.5TarAnnualMatai.plt

PM2.5Unc24hrMataiH5H.plt

PM2.5UncAnnualMatai.plt

PM10Mit24hrMataiH5H.plt

PM10MitPeriodMatai.plt

PM10Tar24hrMataiH5H.plt

PM10TarPeriodMatai.plt

PM10Unc24hrMataiH5H.plt

PM10UncPeriodMatai.plt

Appendix C: Possible impacts of mine dust on agriculture

In 2012, a desktop study was undertaken to assess the potential impact of dust on agriculture from a proposed mine in Mpumalanga, South Africa (Stevens, 2012). It was found that dust is composed predominantly of carbon and is not toxic to vegetation. Similarly, road dust is 'inert' and not toxic to vegetation. Effects of dust deposition on plants, other than toxicity, were also considered in the study. Direct effects at the leaf and plant level include the blockage of stomata; alteration of energy exchange and light absorption which leads to reduced photosynthesis; changes in transpiration; and reduced growth and production. Indirect effects include deposition to the soil which may ultimately influence growth; reduced effectiveness of sprays (e.g. herbicides, insecticides) therefore an increase in incidence of pests; hindrance to pollination which results in yield loss; and exacerbation of secondary stresses (e.g. drought, insects and pathogens) (Doley, 2006; Farmer, 1993; Grantz, Garner, & Johnson, 2003; Prajapati, Ecological effect of airborne particulate matter on plants, 2012; Seyyednejad, Niknejad, & Koochak, 2011).

Unlike in the health sector, it is the coarser particles that have an effect on vegetation. The greatest impacts will, therefore, be seen in the areas close to surface mining activities and within a 300m wide corridor from the centre of unpaved roads (Greening, 2011; McCrea, 1984) where most of the total suspended particles (TSP) will be deposited.

It is, however, not only the rate of dust deposition that will determine whether plants are affected by dust. Leaf orientation, leaf morphology, leaf age, leaf wettability (Beckett, Freer-Smith, & Taylor, 2000; Prajapati & Tripathi, 2008) and environmental conditions such as wind and rain (Raupach, Woods, Dorr, Leys, & Cleugh, 2001) affect the dust loading of the leaves and therefore also influence whether vegetation will be affected by dust deposition. Xiong-Wen (2001) found that the low dust carrying-capacity of maize makes it a suitable crop to grow in frequent dust storm areas. According to Stevens (2012), there was no specific information on the dust loading capacity of soybean or apple leaves, therefore, these plants may be more at risk because of their leaf structures.

According to Stevens (2012), there is very little experimental evidence for the impacts of dust on pastures and livestock, and it is difficult to link possible impacts directly to road or mine dust. Dust can cause respiratory and other health problems in animals as in humans for example, ovine pneumonia and pinkeye. However, it is difficult to link this directly to road or mine dust as there are other sources of dust (livestock themselves) on these farms. McCrea (1984) concludes that it is most unlikely that road dust (ingested with normal pasture feed) has any physiological effect on animal growth and development. It is suggested that game animals avoid grazing on dusty grass alongside a road and prefer grass some distance away (Greening, 2011). The reduced pasture yields and reluctance of livestock to eat contaminated grass could contribute to a 1% decrease in lambing rate and a reduced milk fat yield (McCrea, 1984).

In conclusion, data suggests that there may be some limited impacts on the vegetation and livestock in the areas surrounding the mining activities and the haul roads of the proposed Matai Mining Project, but quantification of the impacts would require further research