APPENDIX I: AIR QUALITY STUDY

Air Quality Specialist Impact Assessment Report for the proposed Commissiekraal Coal Mine

Project done on behalf of **SLR Consulting Africa (Pty) Ltd**

Project Compiled by:
N Gresse

Project Manager:
H Liebenberg-Enslin

Report No: 13SLR02 Final | **Date:** October 2015

Address: 480 Smuts Drive, Halfway Gardens | **Postal:** P O Box 5260, Halfway House, 1685
Tel: +27 (0)11 805 1940 | **Fax:** +27 (0)11 805 7010

www.airshed.co.za

Report Details

Reviewed by	13SLR02
Status	Final
Report Title	Air Quality Specialist Impact Assessment Report for the proposed Commissiekraal Coal Mine
Date	October 2015
Client	SLR Consulting Africa (Pty) Ltd
Prepared by	Natasha Gresse, BSc Hons. (Meteorology) (University of Pretoria)
Reviewed by	Hanlie Liebenberg-Enslin, PhD (University of Johannesburg) Terri Bird, PhD (University of the Witwatersrand)
Notice	Airshed Planning Professionals (Pty) Ltd is a consulting company located in Midrand, South Africa, specialising in all aspects of air quality, ranging from nearby neighbourhood concerns to regional air pollution impacts as well as noise impact assessments. The company originated in 1990 as Environmental Management Services, which amalgamated with its sister company, Matrix Environmental Consultants, in 2003.
Declaration	Airshed is an independent consulting firm with no interest in the project other than to fulfil the contract between the client and the consultant for delivery of specialised services as stipulated in the terms of reference.
Copyright Warning	Unless otherwise noted, the copyright in all text and other matter (including the manner of presentation) is the exclusive property of Airshed Planning Professionals (Pty) Ltd. It is a criminal offence to reproduce and/or use, without written consent, any matter, technical procedure and/or technique contained in this document.

Natasha Shackleton (neé Gresse) (Senior Air Quality Consultant) - Report writing (Air Quality Report)

Natasha holds a BSc Honours degree in Meteorology and a BSc degree from the University of Pretoria and is currently employed at Airshed Planning Professionals. Natasha's main focus is air quality impact studies. She has been an Air Quality Consultant for approximately four years and as such has been focused primarily on air quality management and impact assessment. Natasha has worked on air quality impact assessments and management plans in South Africa, Botswana, Burkina Faso, Mozambique, Zimbabwe, Zambia, Namibia and Madagascar.

Revision Record

Revision Number	Date	Reason for Revision
Draft	June 2015	For Client Review
Final	October 2015	Updated with Client comments

Abbreviations

AERMIC	AMS/EPA Regulatory Model Improvement Committee
Airshed	Airshed Planning Professionals (Pty) Ltd
AMS	American Meteorological Society
AQG(s)	Air Quality Guideline(s)
AQSR(s)	Air Quality Sensitive Receptor(s)
ASG	Atmospheric Studies Group
ASTM	American Society for Testing and Materials
CALEPA	California Environmental Protection Agency
CCM	Commissiekraal Coal Mine
CE	Control Efficiency
CPVs	Cancer Potency Values
DEA	Department of Environmental Affairs
DEAT	Department of Environmental Affairs and Tourism
EETMs	Emission Estimation Technique Manuals
EMS	Environmental Management Systems
FEL(s)	Front End Loader(s)
FOE	Frequency of Exceedence
GLC(s)	Ground Level Concentration(s)
GLCC	Global Land Cover Characterisation
I&APs	Interested and Affected Parties
IRIS	Integrated Risk Information System
LPG	Liquefied Petroleum Gas
mamsl	Meters above mean sea level
MEI	Maximally Exposed Individual
MM5	Fifth-Generation Penn State/NCAR Mesoscale Model
NAAQS	National Ambient Air Quality Standard(s)
NCAR	National Center for Atmospheric Research
NDCR(s)	National Dust Control Regulation(s)
NEM:AQA	National Environmental Management: Air Quality Act 2004
NPI	National Pollutant Inventory
PM	Particulate Matter
RELs	Reference Exposure Levels
RfC(s)	Reference Concentration(s)
RoM	Run of Mine
SA	South African
SABS	South African Bureau of Standards
SLR	SLR Consulting Africa (Pty) Ltd
SP(s)	Stockpile(s)

SRTM	Shuttle Radar Topography Mission
TCEQ	Texas Commission on Environmental Quality
Tholie Logistics	Tholie Logistics (Pty) Ltd
TSP	Total Suspended Particulates
URFs	Unit Risk Factors
US EPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VKT	Vehicle Kilometers Travelled
WHO	World Health Organisation

Glossary

Air pollution[a]	The presence of substances in the atmosphere, particularly those that do not occur naturally
Dispersion[a]	The spreading of atmospheric constituents, such as air pollutants
Dust[a]	Solid materials suspended in the atmosphere in the form of small irregular particles, many of which are microscopic in size
Instability[a]	A property of the steady state of a system such that certain disturbances or perturbations introduced into the steady state will increase in magnitude, the maximum perturbation amplitude always remaining larger than the initial amplitude
Mechanical mixing[a]	Any mixing process that utilizes the kinetic energy of relative fluid motion
Oxides of nitrogen (NO_x)	The sum of nitrogen oxide (NO) and nitrogen dioxide (NO_2) expressed as nitrogen dioxide (NO_2)
Particulate matter (PM)	Total particulate matter, that is solid matter contained in the gas stream in the solid state as well as insoluble and soluble solid matter contained in entrained droplets in the gas stream
$PM_{2.5}$	Particulate Matter with an aerodynamic diameter of less than 2.5 µm
PM_{10}	Particulate Matter with an aerodynamic diameter of less than 10 µm
Stability[a]	The characteristic of a system if sufficiently small disturbances have only small effects, either decreasing in amplitude or oscillating periodically; it is asymptotically stable if the effect of small disturbances vanishes for long time periods

Notes:

(a) Definition from American Meteorological Society's glossary of meteorology (AMS, 2014)

Symbols and Units

°C	Degree Celsius
C	Carbon
CH_4	Methane
C_6H_6	Benzene
CO	Carbon monoxide
CO_2	Carbon dioxide
DPM	Diesel particulate matter
g	Gram(s)
g/VKT	Grams per vehicle kilometre travelled
HC(s)	Hydrocarbon(s)
H_2S	Hydrogen sulfide
kg	Kilograms
1 kilogram	1 000 grams
kg/kWh	Kilogram(s) per kilowatt hour
km	Kilometre(s)
1 kilometre	1 000 metres
kW	Kilowatt
1 kilowatt	1 000 watts
m	Meter(s)
m^2	Square meter(s)
m/s	Meters per second
µg	Microgram
1 microgram	$1x10^{-6}$ grams
$µg/m^3$	Micrograms per square meter
mg	Milligram
1 milligram	0.001 grams
$mg/m^2/day$	Milligrams per square meter per day
Mg	Megagram
1 Mg	1 000 000 grams
m^2	Square meter
mm	Millimetres
1 millimetre	0.001 metres
Mtpa	Megatonnes per annum
1 Mtpa	1 000 000 tonnes
N_2	Nitrogen
N_2O	Nitrous oxide
NO	Nitrogen oxide
NO_2	Nitrogen dioxide
NO_x	Oxides of nitrogen

O_3	Ozone
PAH(s)	Polycyclic aromatic hydrocarbon(s)
Pb	Lead
$PM_{2.5}$	Inhalable particulate matter
PM_{10}	Thoracic particulate matter
SO_2	Sulphur dioxide
tpa	Tonnes per annum
1 tonne	1 000 000 grams
VOC(s)	Volatile organic compound(s)

Executive Summary

Tholie Logistics (Pty) Ltd (Tholie Logistics) proposes to develop a new underground coal mine and related surface infrastructure to support a mining operation on the farm Commissiekraal 90HT. The mine will be located approximately 28 km north of Utrecht in the eMadlangeni Local Municipality and the Amajuba District Municipality, KwaZulu-Natal Province, South Africa. Airshed Planning Professionals (Pty) Ltd (Airshed) was appointed SLR Consulting Africa (Pty) Ltd (SLR) to conduct an air specialist study for the proposed Commissiekraal Coal Mine (CCM). The main objective of the air quality study was to determine potential air quality related impacts associated with the proposed CCM on the surrounding environment and human health.

Apart from reviewing interested and/or affected party (I&AP) comments received by the environmental impact assessment (EIA) consultant during the EIA process, no other consultation with the public was part of the air quality study.

As is typical of an air quality impact assessment, the study included: a **review** of proposed project activities in order to identify sources of emissions and associated pollutants emitted; a study of **regulatory requirements and health thresholds** for identified key pollutants; a study of the **receiving environment** in the vicinity of the project; the compilation of a comprehensive **emissions inventory** for the operational phase of the project, **atmospheric dispersion modelling** to simulate ambient air pollutant concentrations and dustfall rates as a result of the CCM, a **screening** assessment to determine compliance with air quality criteria; and the compilation of a **comprehensive air quality specialist report** detailing the study approach, limitations, assumption, results and recommendations of mitigation and management of air quality impacts.

Pollutants included in the assessment are particulate matter (PM), diesel particulate matter (DPM), carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2) and volatile organic compounds (VOCs). Impacts associated with emissions were quantified, taking into account: unmitigated operations; mitigation measures that form part of the CCM design; as well as additional mitigation.

The main conclusion is that the proposed CCM operations are likely to result in exceedances of the National Ambient Air Quality Standards (NAAQS) for $PM_{2.5}$, PM_{10} and the National Dust Control Regulations (NDCRs) for dustfall at sensitive receptors located near the mine boundary. There is the possibility of exceedences outside the project area (boundary) and at sensitive receptors on a cumulative (baseline and incremental) basis. Water sprays on unpaved roads, at crushers, screens, product materials handling points and the product stockpile, are still unlikely to result in compliance to national standards and regulations at sensitive receptors. If hooding with fabric filters is applied to crushers and screens instead of water sprays there are likely to be exceedences of the standards and regulations only at the on-site receptor but not off-site.

The environmental significance of the project operations is high without mitigation applied, medium-high with design and medium with additional mitigation applied

Recommendations include:

- Water sprays on unpaved road surfaces should achieve at least 75% control efficiency (CE);
- Water sprays at product materials handling points and product stockpile to achieve 50% CE;
- Hooding with fabric filters at crusher and screen (to achieve up to 83% CE);
- Dustfall; ambient PM_{10} and $PM_{2.5}$ sampling.

Table of Contents

List of Tables

List of Figures

Air Quality Specialist Impact Assessment Report for the proposed Commissiekraal Coal Mine

1 INTRODUCTION

Tholie Logistics (Pty) Ltd (Tholie Logistics) proposes to develop a new underground coal mine and related surface infrastructure to support a mining operation on the farm Commissiekraal 90HT. The mine will be located approximately 28 km north of Utrecht in the eMadlangeni Local Municipality and the Amajuba District Municipality, KwaZulu-Natal Province, South Africa (Figure 1-1).

Airshed Planning Professionals (Pty) Ltd (Airshed) was appointed SLR Consulting Africa (Pty) Ltd (SLR) to conduct an air specialist study for the proposed Commissiekraal Coal Mine (CCM). The main objective of the air quality study was to determine potential air quality related impacts associated with the proposed CCM on the surrounding environment and human health.

1.1 Consultation Process

Apart from reviewing interested and/or affected party (I&AP) comments received by the environmental impact assessment (EIA) consultant during the EIA process, no other consultation with the public was part of the air quality study.

1.2 Scope of Work

As is typical of an air quality impact assessment, the following tasks were included in the study:

- A **review** of proposed project activities in order to identify sources of emission and associated pollutants emitted.
- A study of **regulatory requirements and health thresholds** for identified key pollutants against which compliance would be assessed and health risks screened.
- A study of the **receiving environment** in the vicinity of the project; including:
    - The identification of potential air quality sensitive receptors (AQSRs);
    - A study of the atmospheric dispersion potential of the area taking into consideration local meteorology, land-use and topography; and
    - The analysis of all available ambient air quality information/data to determine pre-development ambient pollutant levels and dustfall rates.
- The compilation of a comprehensive **emissions inventory** which included:
    - Fugitive dust emissions from construction phase, operational phase and decommissioning phase activities;
    - Combustion emissions (particulate matter (PM) and gaseous pollutants) during the operational phase;
- **Atmospheric dispersion modelling** to simulate ambient air pollutant concentrations and dustfall rates as a result of the project.
- A **screening** assessment to determine:
    - Compliance of criteria pollutants with ambient air quality standards;
    - Potential health risks as a result of exposure to non-criteria pollutants; and
    - Nuisance dustfall

- The compilation of a comprehensive air quality specialist report detailing the study approach, limitations, assumption, results and recommendations of mitigation and management of air quality impacts.

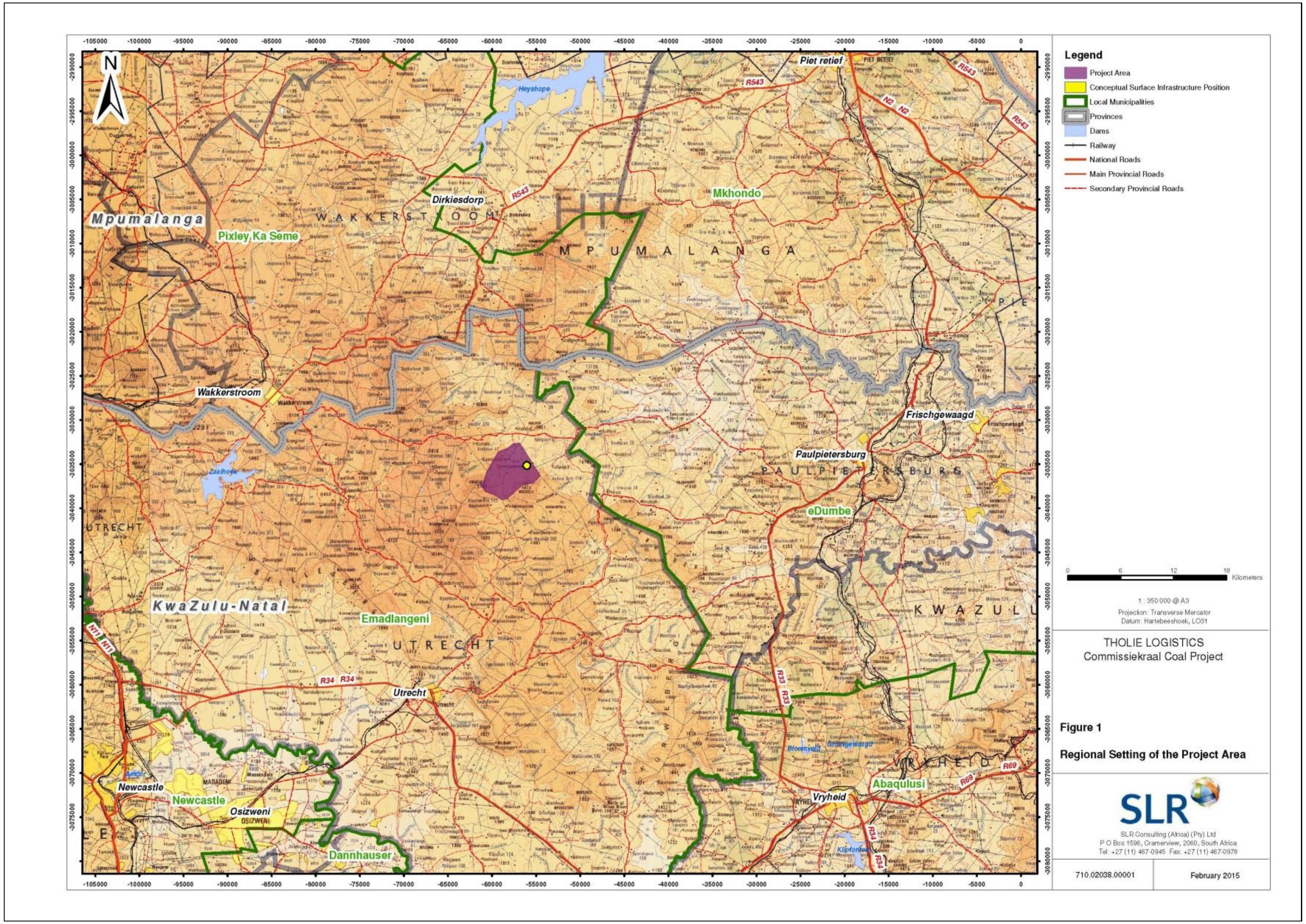

Figure 1-1: Regional setting of project area

1.3 Description of Project Activities from an Air Quality Perspective

The local setting of the CCM is shown in Figure 1-2 and the surface infrastructure layout is shown in Figure 1-3.

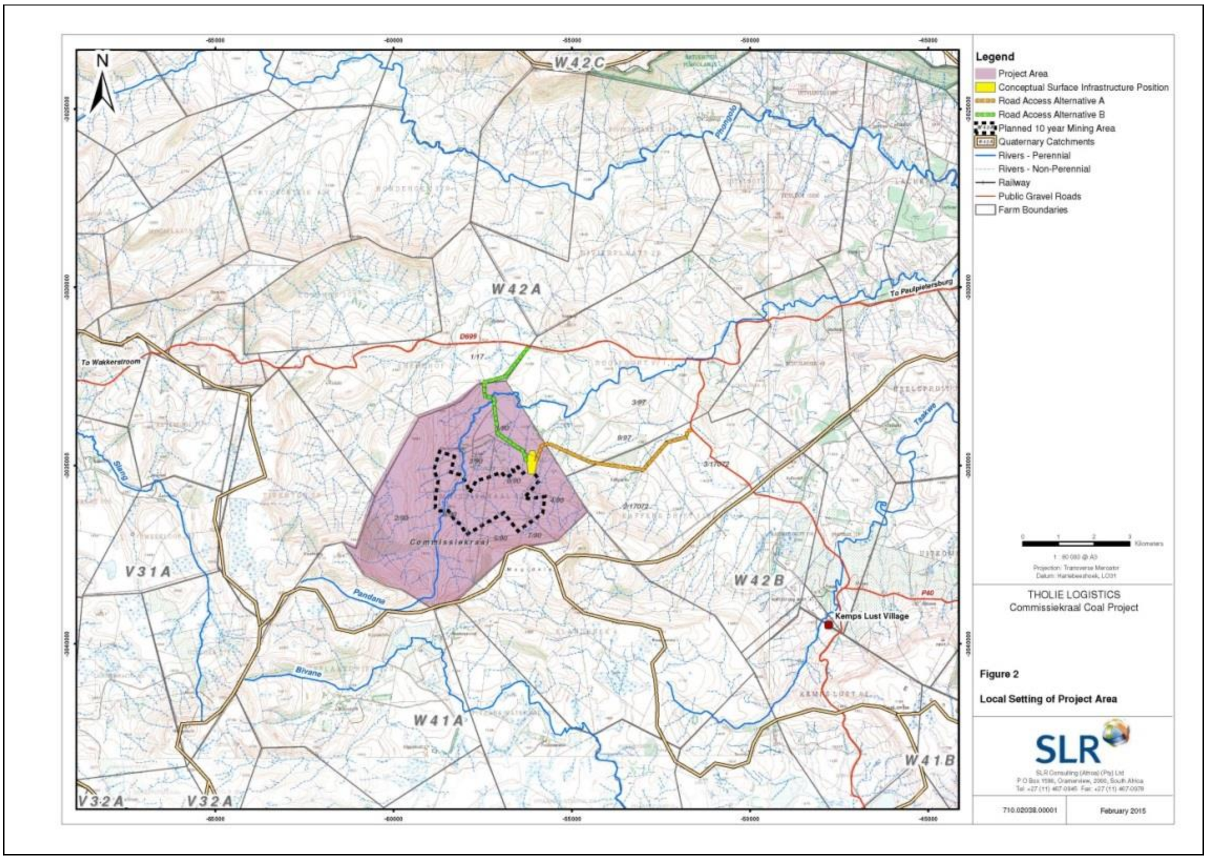

Figure 1-2: Local setting of project area

The CCM will consist of an underground mine and a mobile crushing and screening plant. The project includes the mining, handling and transportation of run of mine (RoM) coal, crushing and screening of RoM coal and transportation of the product along unpaved roads to final customer or a regional railway siding.

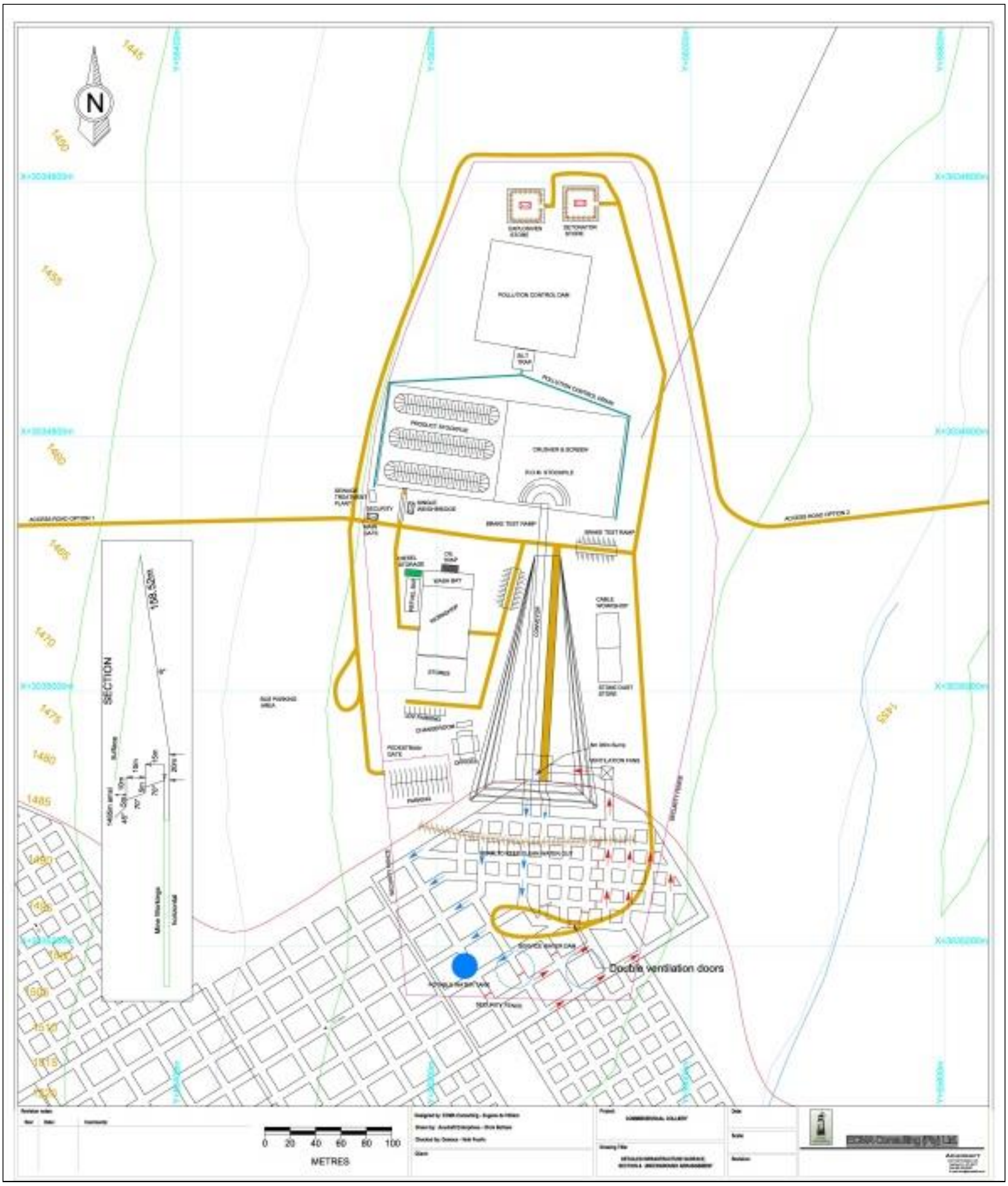

Figure 1-3: CCM surface infrastructure layout

The underground mining broadly encompasses the following processes that may result in atmospheric emissions through the ventilation shaft:

- drilling and blasting of coal;
- coal handling and transportation;

The surface operations broadly encompass the following processes that may result in atmospheric emissions:

- RoM coal stockpiling and handling at the surface;

- crushing and screening of coal;
- product handling and transportation; and
- wind erosion of stockpiles.

The potential air emissions that may result from the operations are dependent on the nature of the source material itself (Table 1-1 and Table 1-2).

Table 1-1: Air emissions and pollutants associated with the underground mining

Details	Activities	Pollutants
Ventilation shaft	Drilling and blasting operations	Mainly total suspended particulates (TSP), particulate matter with an aerodynamic diameter of less than 10 µm (PM_{10}) and particulate matter with an aerodynamic diameter of less than 2.5 µm ($PM_{2.5}$), but blasting emissions including oxides of nitrogen (NO_x), carbon dioxide (CO_2), carbon monoxide (CO), sulphur dioxide (SO_2), methane (CH_4), hydrogen sulphide (H_2S) and particulates
	Transportation of coal underground - wheel entrainment and exhaust gas	Mainly TSP, PM_{10} and $PM_{2.5}$, but vehicle tailpipe emissions including NO_x, CO_2, CO, SO_2, CH_4, nitrous oxide (N_2O), volatile organic compounds (VOCs) and particulates
	Materials handling operations	TSP, PM_{10} and $PM_{2.5}$

Table 1-2: Air emissions and pollutants associated with surface operations

Details	Activities	Pollutants
Coal at shaft decline	Conveyer transfer operations	TSP, PM_{10} and $PM_{2.5}$
Coal transfer at the RoM stockpile	Offloading and reclaiming Wheel entrainment and exhaust gas	Mainly TSP, PM_{10} and $PM_{2.5}$, but vehicle tailpipe emissions including NO_x, CO_2, CO, SO_2, CH_4, N_2O, VOCs and particulates
Coal storage	Wind erosion	TSP, PM_{10} and $PM_{2.5}$
Crushers and screens	Primary crushing and screening	TSP, PM_{10} and $PM_{2.5}$
Product storage	Stacking and reclaiming Wind erosion	TSP, PM_{10} and $PM_{2.5}$
Product loading and transport	Tipping operations Wheel entrainment and exhaust gas	Mainly TSP, PM_{10} and $PM_{2.5}$, but vehicle tailpipe emissions including NO_x, CO_2, CO, SO_2, CH_4, N_2O, VOCs and particulates

1.4 Approach and Methodology

The approach to, and methodology followed in the completion of tasks as part of the scope of work are discussed in this section.

1.4.1 Project Information and Activity Review

All project/process related information referred to in this study was provided by SLR.

1.4.2 The Identification of Regulatory Requirements and Health Thresholds

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

- South African National Ambient Air Quality Standards (SA NAAQS) as set out in the National Environmental Management: Air Quality Act (Act No. 39 of 2004) (NEM:AQA) and South African National Dust Control Regulations (SA NDCR); and,
- Health risk screening levels for non-criteria pollutants published by the various internationally recognised regulatory authorities.

1.4.3 Study of the Receiving Environment

Physical environmental parameters that influence the dispersion of pollutants in the atmosphere include terrain, land cover and meteorology. Existing pre-development ambient air quality in the study area is also considered. Readily available terrain and land cover data was obtained from the Atmospheric Studies Group (ASG) via the United States Geological Survey (USGS) web site (ASG, 2011). Use was made of Shuttle Radar Topography Mission (SRTM) (90 m, 3 arc-sec) data and Global Land Cover Characterisation (GLCC) data for Africa.

An understanding of the atmospheric dispersion potential of the area is essential to an air quality impact assessment. In the absence of on-site meteorological data (which is required for atmospheric dispersion modelling), use was made of simulated data for a period between 2012 and 2014. The MM5 (short for Fifth-Generation Penn State/NCAR Mesoscale Model) is a regional mesoscale model used for creating weather forecasts and climate projections. It is a community model maintained by Penn State University and the National Centre for Atmospheric Research (NCAR).

1.4.4 Determining the Impact of the Project on the Receiving Environment

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

In the simulation of ambient air pollutant concentrations and dustfall rates use was made of the US EPA AERMOD atmospheric dispersion modelling suite. AERMOD is a Gaussian plume model best used for near-field applications where the steady-state meteorology assumption is most likely to apply. AERMOD is a model developed with the support of the AMS/EPA Regulatory Model Improvement Committee (AERMIC), whose objective has been to include state-of the-art science in regulatory models (Hanna, Egan, Purdum, & Wagler, 1999). AERMOD is a dispersion modelling system with three components, namely: AERMOD (AERMIC dispersion model), AERMAP (AERMOD terrain pre-processor), and AERMET (AERMOD meteorological pre-processor).

1.4.5 Compliance Assessment and Health Risk Screening

Compliance was assessed by comparing simulated ambient criteria pollutant concentrations (CO, NO_2, $PM_{2.5}$, PM_{10} and SO_2) and dustfall rates to selected ambient air quality and dustfall criteria. Health risk screening was done through the comparison of simulated non-criteria pollutant concentrations (diesel particulate matter (DPM) and VOCs) to selected inhalation screening levels.

1.4.6 The Development of an Air Quality Management Plan

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

1.5 Assumptions, Exclusions and Limitations

A number of assumptions had to be made resulting in certain limitations associated with the results. The most important assumptions and limitations of the air quality impact assessment are:

- This study only considered atmospheric emissions and impacts associated with CCM, and not any other operations that may be located within the area.
- No site specific particle size fraction, moisture or silt content data were available for various sources and use was made of US EPA default values and values from similar operations in South Africa.
- Only routine emissions for the proposed operations were simulated. All other operations will be continuous.
- Dispersion models do not contain all the features of a real environmental system but contain the feature of interest for the management issue or scientific problem to be solved (MFE, 2001). Gaussian plume models are generally regarded to have an uncertainty range between -50% to 200%. It has generally been found that the accuracy of off-the-shelf dispersion models improve with increased averaging periods. The accurate prediction of instantaneous peaks are the most difficult and are normally performed with more complicated dispersion models specifically fine-tuned and validated for the location. The duration of these short-term, peak concentrations are often only for a few minutes and on-site meteorological data are then essential.
- AERMOD cannot compute real time processes; average process throughputs were therefore used, even though the nature of operations may change over the life of operations.
- Gaseous emissions would result from vehicles, and underground blasting. Emission rates for combustion sources are dependent on the amount of fuel used and for the vehicle emissions the type and size of vehicles used. Only the total fuel use was available and thus only vehicle exhaust emissions were estimated and simulated. It was assumed that 80% of the fuel will be used for underground operations and 20% for the surface operations. Gaseous emissions from blasting are expected to have less of an impact than the vehicle exhaust due to the infrequency of blasting operations.
- Gaseous emissions from construction, decommissioning, closure and post-closure are expected to be minimal compared to particulate emissions from operations associated with these phases.
- Nitrogen monoxide (NO) is rapidly converted in the atmosphere into the much more toxic nitrogen dioxide (NO_2). The rate of this conversion process is determined by the rate of the physical processes of dispersion and mixing of the plume and the chemical reaction rates as well as the local atmospheric ozone concentration.
- The estimation of greenhouse gases did not form part of the scope of this study.
- The construction, decommissioning and closure phases are assessed qualitatively.
- It was assumed that all processing operations will have ceased by the closure phase. The potential for impacts during this phase will depend on the extent of rehabilitation efforts during closure and on features which will remain. Information regarding the extent of rehabilitation procedures were limited and therefore not included in the emissions inventory or the dispersion modelling.

2 Regulatory Requirements and Assessment Criteria

2.1 Ambient Air Quality Standards for Criteria Pollutants

2.1.1 SA National Ambient Air Quality Standards

The South African Bureau of Standards (SABS) was engaged to assist the Department of Environmental Affairs (DEA, then known as the Department of Environmental Affairs and Tourism or DEAT) in the facilitation of the development of ambient air quality standards. This included the establishment of a technical committee to oversee the development of standards. Standards were determined based on international best practice for PM_{10}, $PM_{2.5}$, dustfall, SO_2, NO_2, ozone (O_3), CO, lead (Pb) and benzene (C_6H_6).

The final revised SA NAAQS were published in the Government Gazette on 24 of December 2009 (DEA, 2009) and included a margin of tolerance (i.e. frequency of exceedance) and implementation timelines linked to it. SA NAAQS for $PM_{2.5}$ were published on 29 July 2012 (DEA, 2012). SA NAAQS referred to in this study are also given in Table 2-1.

Table 2-1: National Ambient Air Quality Standards for criteria pollutants

Pollutant	Averaging Period	Limit Values	Frequency of Exceedance	Compliance Date
		Concentration (µg/m³)	Occurrences per Year	
CO	1 hour	30 000	88	Immediate
NO_2	1 hour	200	88	Immediate
	1 year	40	n/a	Immediate
$PM_{2.5}$	24 hour	60	4	Immediate – 31 December 2015
	24 hour	40	4	1 January 2016 – 31 December 2029
	24 hour	25	4	1 January 2030(b)
	1 year	25	n/a	Immediate – 31 December 2015
	1 year	20	n/a	1 January 2016 – 31 December 2029
	1 year	15	n/a	1 January 2030(b)
PM_{10}	24 hour	75	4	1 January 2015
	1 year	40	n/a	1 January 2015
SO_2	1 hour	350	88	Immediate
	24 hour	125	4	Immediate
	1 year	50	n/a	Immediate
O_3	8 hours	120	11	Immediate
C_6H_6	1 year	5	n/a	1 January 2015

Notes:

(a) n/a – not applicable

(b) included as operations will likely continue beyond January 2030

2.2 Inhalation Health Criteria and Unit Risk Factors for Non-criteria Pollutants

The potential for health impacts associated with non-criteria pollutants emitted from mobile diesel combustion sources are assessed according to guidelines published by the following institutions:

- WHO air quality guidelines (AQGs) and cancer unit risk factors (URFs);
- Inhalation reference concentrations (RfCs) and URFs published by the US EPA Integrated Risk Information System (IRIS)
- Reference Exposure Levels (RELs) and Cancer Potency Values (CPVs) published by the California Environmental Protection Agency (CALEPA)
- The Texas Commission on Environmental Quality (TCEQ)

Chronic inhalation criteria and URFs/CPVs for pollutants considered in the study are summarised in Table 2-2. Increased lifetime cancer risk is calculated by applying the unit risk factors to predicted long term (annual average) pollutant concentrations.

Table 2-2: Chronic and acute inhalation screening criteria and cancer unit risk factors

Pollutant	Chronic Screening Criteria ($\mu g/m^3$)	Acute Screening Criteria ($\mu g/m^3$)	Inhalation URF/CPV $(\mu g/m^3)^{-1}$
Diesel Exhaust as diesel particulate matter (DPM)	5 (US EPA IRIS)	Not Specified	$3x10^{-04}$ (CALEPA)
VOC (*Diesel fuel* used as indicator)	100 (TCEQ)	Not Specified	Not Specified

The identification of an acceptable cancer risk level has been debated for many years and it possibly will still continue as societal norms and values change. Some people would easily accept higher risks than others, even if it were not within their own control; others prefer to take very low risks. An acceptable risk is a question of societal acceptance and will therefore vary from society to society. In spite of the difficulty to provide a definitive “acceptable risk level”, the estimation of a risk associated with an activity provides the means for a comparison of the activity to other everyday hazards, and therefore allowing risk-management policy decisions. Technical risk assessments seldom set the regulatory agenda because of the different ways in which the non-technical public perceives risks. Consequently, science does not directly provide an answer to the question.

Whilst it is perhaps inappropriate to make a judgment about how much risk should be acceptable, through reviewing acceptable risk levels selected by other well-known organizations, it would appear that the US EPA’s application is the most suitable, i.e. *“If the risk to the maximally exposed individual (MEI) is no more than $1x10^{-6}$, then no further action is required. If not, the MEI risk must be reduced to no more than $1x10^{-4}$, regardless of feasibility and cost, while protecting as many individuals as possible in the general population against risks exceeding $1x10^{-6}$”*.Some authorities tend to avoid the specification of a single acceptable risk level. Instead a “risk-ranking system” is preferred.

2.3 Dust Control Regulations

South Africa has published the National Dust Control Regulations in November 2013 (Government Gazette No. 36974) (DEA, 2013) with the purpose to prescribe general measures for the control of dust in all areas including residential and light commercial areas. The acceptable dustfall rates as measured using the American Society of Testing and Materials (ASTM) D1739:1970 (ASTM Standard D1739-70, 1998) or equivalent at and beyond the boundary of the premises where dust originates are given in Table 2-3. It is important to note that **dustfall is assessed for nuisance impact** and not inhalation health impact.

Table 2-3: South African National Dust Control Regulations

Restriction Area	Dustfall Rate (mg/m^2-day)	Permitted Frequency of Exceedence
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

2.4 Screening criteria for animals and vegetation

The impact of dust on vegetation and grazing quality may be a concern to I&APs. While there is little direct evidence of what the impact of dust fall on vegetation is under a South African context, a review of European studies has shown the potential for reduced growth and photosynthetic activity in sunflower and cotton plants exposed to dust fall rates greater than 400 $mg/m^2/day$ (Farmer, 1993). This is discussed in more detail in Appendix F.

3 DESCRIPTION OF THE RECEIVING/BASELINE ENVIRONMENT

3.1 Air Quality Sensitive Receptors

The CCM will be situated approximately 28 km north of the Utrecht. Current land uses within the vicinity of the CCM area are agriculture, primarily livestock grazing with minor dryland crops, forestry (remnants and naturally occurring), conservation, tourism and residential. There are a number of residences in the vicinity of the CCM site. Individual houses (private farmsteads and rural homesteads) and community structures were included in this study as AQSRs (Figure 3-1 (Table 12-1).

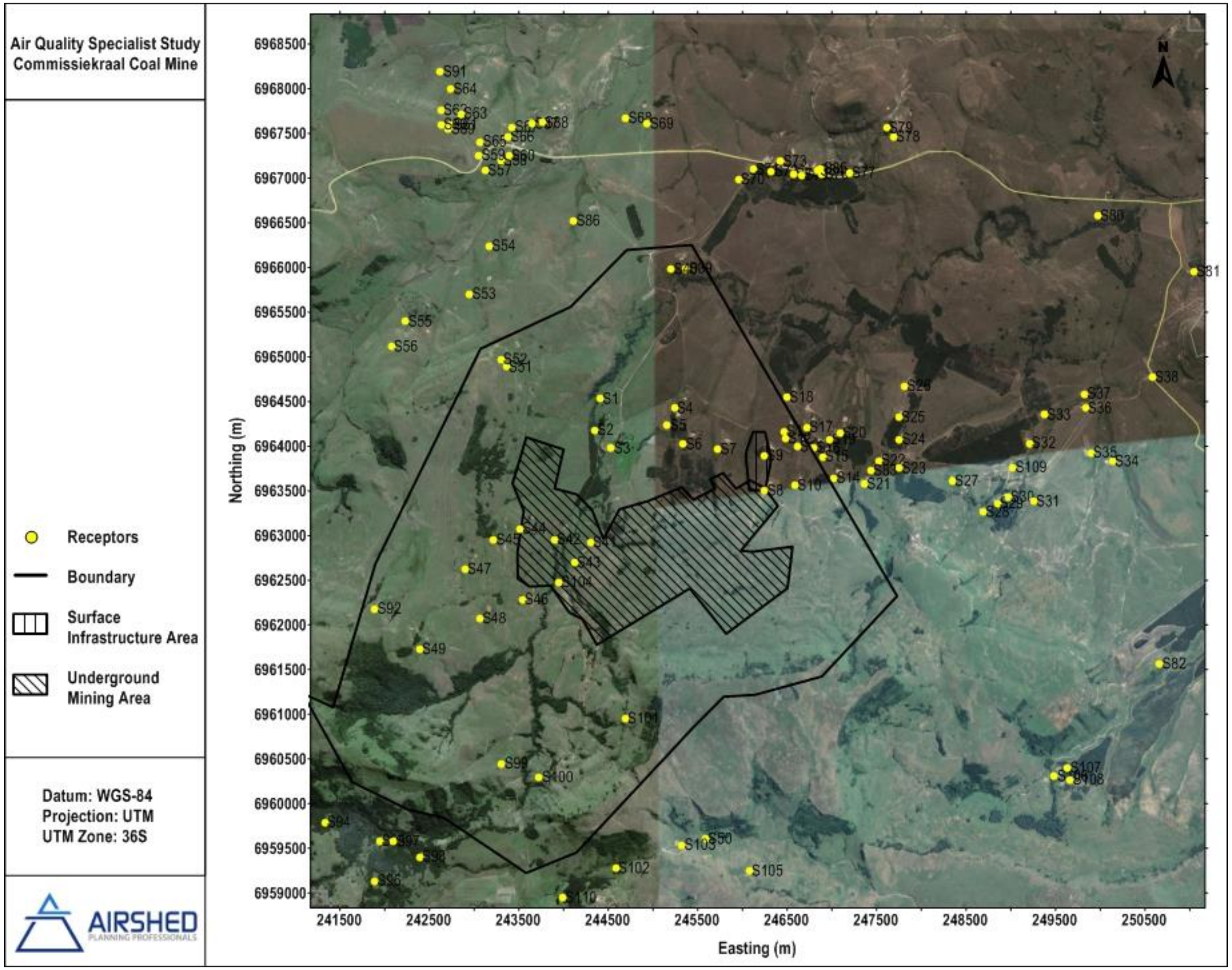

Figure 3-1: Nearby AQSRs

3.2 Atmospheric Dispersion Potential

Physical and meteorological mechanisms govern the dispersion, transformation, and eventual removal of pollutants from the atmosphere. The analysis of hourly average meteorological data is necessary to facilitate a comprehensive understanding of the dispersion potential of the site. Parameters useful in describing the dispersion and dilution potential of the site i.e. wind speed, wind direction, temperature and atmospheric stability, are subsequently discussed. In the absence of on-site meteorological data (which is required for atmospheric dispersion modelling), use was made of simulated data for a period between 2012 and 2014. The MM5 (short for Fifth-Generation Penn State/NCAR Mesoscale Model) is a regional mesoscale model used for creating weather forecasts and climate projections. It is a community model maintained by Penn State University and the National Centre for Atmospheric Research (NCAR).

3.2.1 Topography and Land-use

Terrain around the site has undulating mountains and flatter grasslands. The northern part of the farm is relatively flat and low-lying. The western, southern and eastern parts of the farm are mountainous. Topographical data was included in dispersion simulations. The terrain elevation of the study area ranges between 1 242 and 2 143 meters above mean sea level (mamsl). The topography of the study area is shown in Figure 3-2.

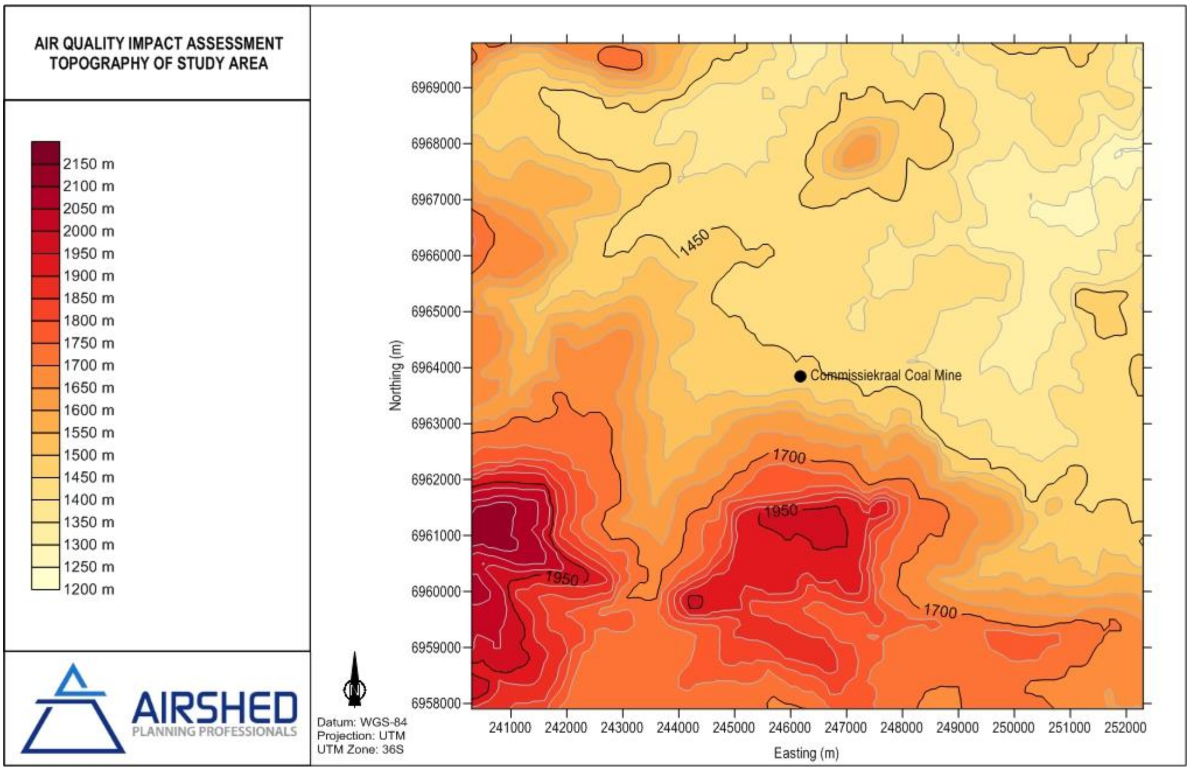

Figure 3-2: Topography of study area

3.2.2 Surface Wind Field

The wind field determines both the distance of downward transport and the rate of dilution of pollutants. The generation of mechanical turbulence is a function of the wind speed, in combination with the surface roughness. The wind field for the study area is described with the use of wind roses. Wind roses comprise 16 spokes, which represent the directions from which winds blew during a specific period. The colours used in the wind roses below, reflect the different categories of wind speeds; the yellow area, for example, representing winds in between 5 and 7.5 m/s. The dotted circles provide information regarding the frequency of occurrence of wind speed and direction categories. The frequency with which calms occurred, i.e. periods during which the wind speed was below 1 m/s are also indicated.

The period wind rose for the period January 2012 to December 2014 is shown in Figure 3-3. Day-time and night-time wind roses for the period January 2012 to December 2014 are provided in Figure 3-4. Seasonal wind roses for the period January 20121 to December 2014 are shown in Figure 3-5.

The wind field was dominated by winds from the west, east-north-east and north-east. Less frequent winds also occurred from the north-westerly and south-westerly sectors. Calm conditions occurred 4% of the time. During the day, more frequent winds at higher wind speeds occurred from the east-north-easterly and north-easterly sectors with almost 5.4% calm conditions. Night-time airflow had less frequent winds from the east-north-easterly and north-easterly sectors and at lower wind speeds with winds most frequently occurring from the westerly sectors. The percentage calm conditions decreased to 2.7%. Autumn and winter reflect the average prevailing wind direction as from the west. Summer and spring reflect the average prevailing wind direction as from the east-north-east and north-east.

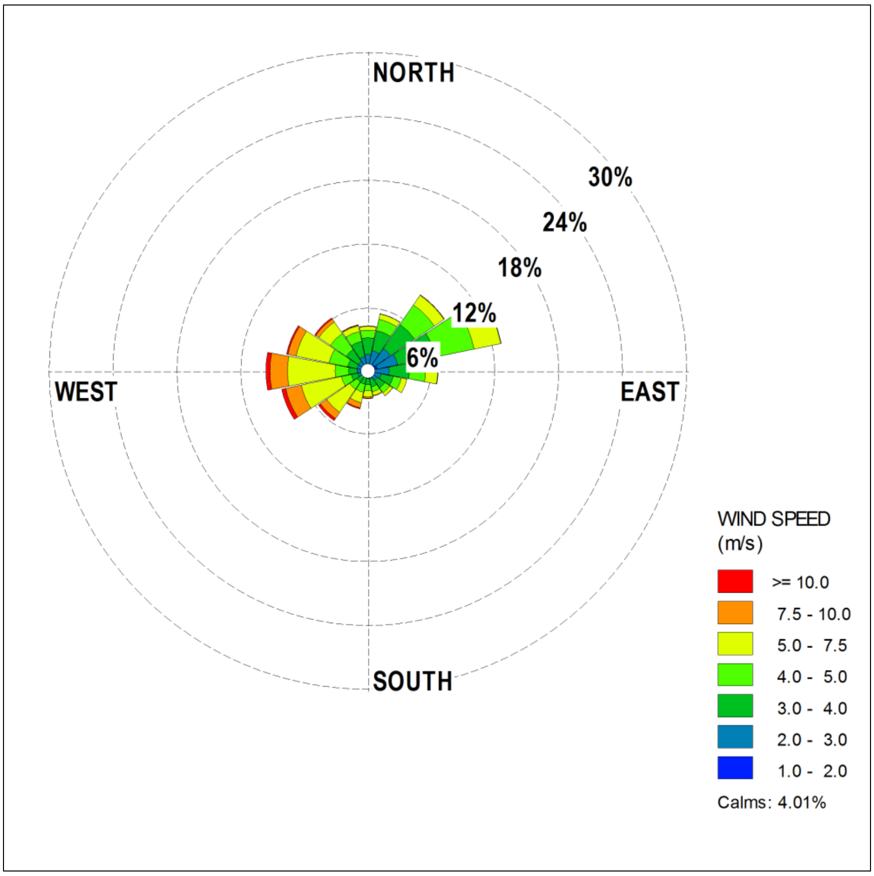

Figure 3-3: Period average wind rose (MM5 data, 2012 to 2014)

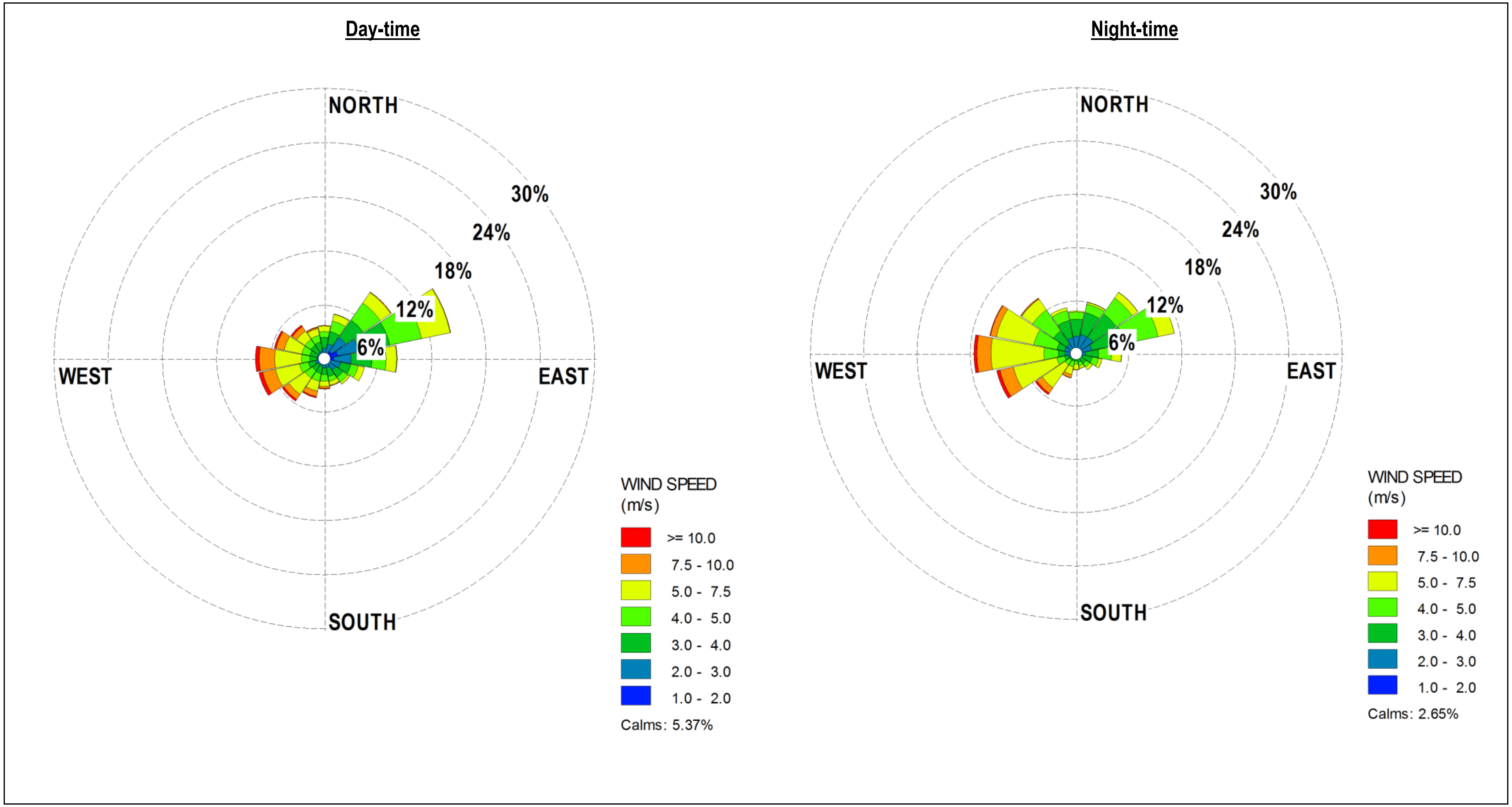

Figure 3-4: Day-time and night-time wind roses (MM5 data, 2012 to 2014)

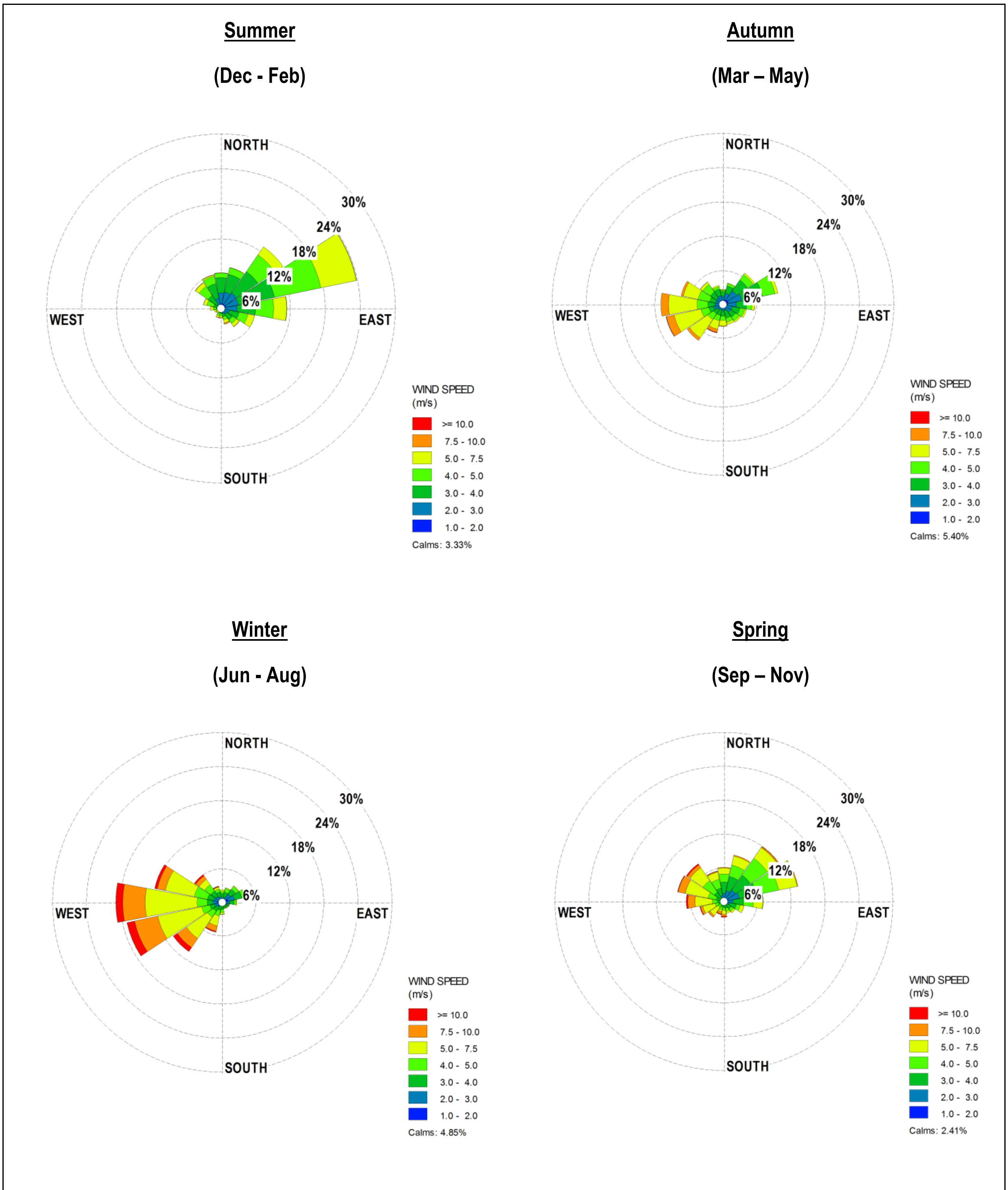

Figure 3-5: Seasonal wind roses (MM5 data, 2012 to 2014)

3.2.3 Temperature

Air temperature is important, both for determining the effect of plume buoyancy (the larger the temperature difference between the plume and the ambient air, the higher a pollution plume is able to rise), and determining the development of the mixing and inversion layers. Minimum, maximum and mean temperatures for the project area, as obtained from MM5 data, are shown in Table 3-1. Diurnal monthly average temperatures shown provided in Figure 3-6.

Maximum, minimum and average temperatures were 28°C, -1°C and 14°C, respectively. The month of July experienced lowest temperature of -1°C whereas the maximum temperature of 28°C occurred in January. Temperatures reach their minimum just before sunrise and there maximum between midday and sunset.

Table 3-1: Minimum, maximum and average temperatures in °C (MM5 data, 2011 to 2013)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Minimum	11	10	9	4	3	0	-1	0	2	4	5	9
Average	18	18	17	14	12	10	9	11	14	14	17	17
Maximum	28	28	26	26	24	19	19	23	25	26	28	28

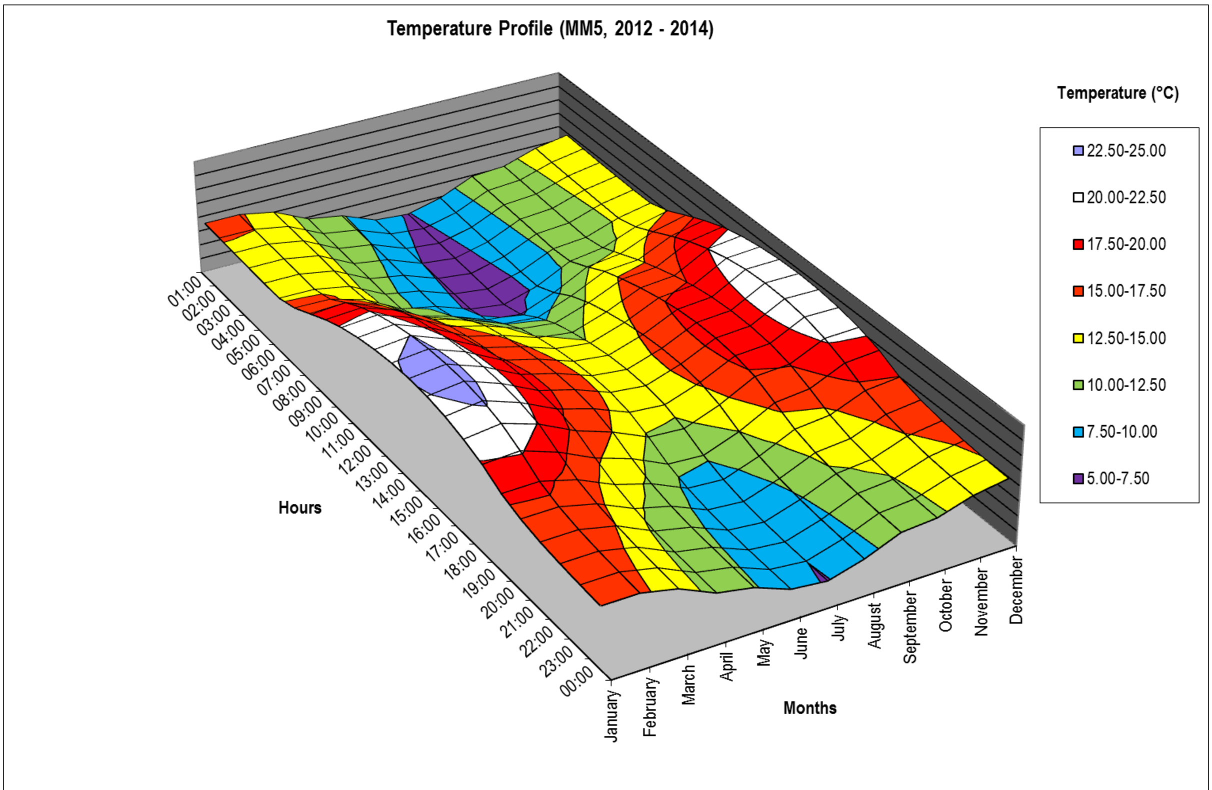

Figure 3-6: Diurnal monthly average temperature profile (MM5 data, 2012 to 2014)

3.2.4 Rainfall

Rainfall represents an effective removal mechanism of atmospheric pollutants and is therefore frequently considered during air pollution studies. Rain typically occurs primarily as storms and individual rainfall events can be intense. This creates an uneven rainfall distribution over the wet season (November to April). Dust is generated by strong winds that sometimes accompany these storms. This dust generally occurs in areas with dry soils and sparse vegetation. This area has a unimodal rainfall pattern with a rainy season starting in November and ending in April, with maximum monthly rainfalls occurring from December to March. The largest amount of rain falls during January (Table 3-2).

Table 3-2: Monthly rainfall for CCM (MM5 data, 2011 to 2013)

Monthly Rainfall (mm/hr)											
Jan	Feb	March	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
665.3	157.2	16.7	39.8	12.1	18.2	17.1	18.7	3.3	66.2	96.9	136.1

3.2.5 Atmospheric Stability and Mixing Depth

The new generation air dispersion models differ from the models traditionally used in a number of aspects, the most important of which are the description of atmospheric stability as a continuum rather than discrete classes. The atmospheric boundary layer properties are therefore described by two parameters; the boundary layer depth and the Monin-Obukhov length, rather than in terms of the single parameter Pasquill Class.

The Monin-Obukhov length (L_{Mo}) provides a measure of the importance of buoyancy generated by the heating of the ground and mechanical mixing generated by the frictional effect of the earth's surface. Physically, it can be thought of as representing the depth of the boundary layer within which mechanical mixing is the dominant form of turbulence generation (CERC, 2004). The atmospheric boundary layer constitutes the first few hundred metres of the atmosphere. During daytime, the atmospheric boundary layer is characterised by thermal turbulence due to the heating of the earth's surface. Night-times are characterised by weak vertical mixing and the predominance of a stable layer. These conditions are normally associated with low wind speeds and lower dilution potential.

Diurnal variation in atmospheric stability, as calculated from on-site data, and described by the inverse Monin-Obukhov length and the boundary layer depth is provided in Figure 3-7. The highest concentrations for ground level, or near-ground level releases from non-wind dependent sources would occur during weak wind speeds and stable (night-time) atmospheric conditions.

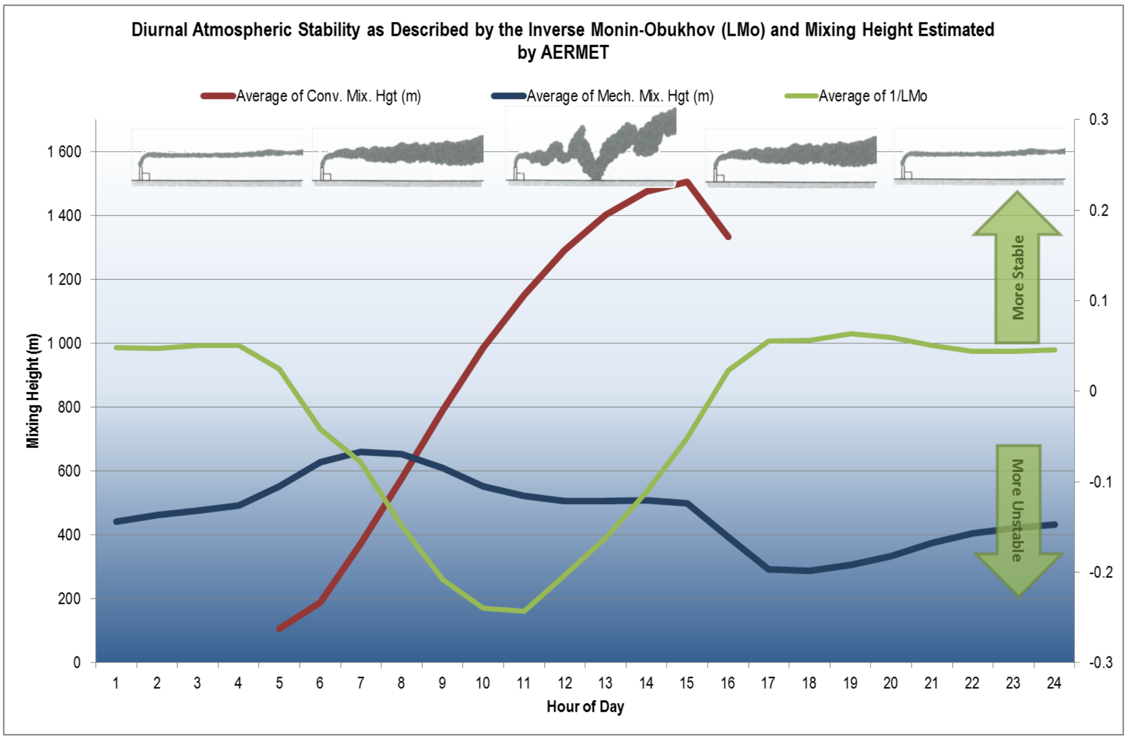

Figure 3-7: Diurnal atmospheric stability (MM5 Data, 2011 - 2013)

3.3 Existing Sources of Air Pollution in the Area

Land use in the region includes agriculture, primary livestock grazing with minor dryland crops, forestry, conservation, tourism and residential. Expected sources of atmospheric emissions include:

- Miscellaneous fugitive dust sources including vehicle entrainment on roads and wind-blown dust from open areas;
- Gaseous and particulate emissions from vehicle exhaust emissions;
- Gaseous and particulate emissions from household fuel burning;
- Gaseous and particulate emissions from biomass burning (e.g. wild fires); and
- Gaseous and particulate emissions from agriculture.

3.3.1 Miscellaneous Fugitive Dust Sources

Fugitive dust emissions may occur as a result of vehicle entrained dust from local paved and unpaved roads, and wind erosion from open or sparsely vegetated areas. The extent of particulate emissions from the main roads will depend on the number of vehicles using the roads and on the silt loading on the roadways. The extent, nature and duration of road-use activity and the moisture and silt content of soils are required to be known in order to quantify fugitive emissions from this source. The quantity of wind-blown dust is similarly a function of the wind speed, the extent of exposed areas and the moisture and silt content of such areas

3.3.2 Vehicle Tailpipe Emissions

Air pollution from vehicle emissions may be grouped into primary and secondary pollutants. Primary pollutants are those emitted directly into the atmosphere, and secondary are pollutants formed in the atmosphere as a result of chemical reactions, such as hydrolysis, oxidation, or photochemical reactions. The significant primary pollutants emitted by vehicles include CO_2, CO, hydrocarbons (HCs), SO_2, NO_x, DPM and Pb. Secondary pollutants include: NO_2, photochemical oxidants (e.g. ozone), HCs, sulphur acids, sulphates, nitric acid, nitric acid and nitrate aerosols. Hydrocarbons emitted include benzene, 1.2-butadiene, aldehydes and polycyclic aromatic hydrocarbons (PAH). Benzene represents an aromatic HC present in petrol, with 85% to 90% of benzene emissions emanating from the exhaust and the remainder from evaporative losses. Vehicle tailpipe emissions are localised sources and unlikely to impact far-field.

3.3.3 Household Fuel Burning

Energy use within the residential sector is given as falling within three main categories, viz.: (i) traditional - consisting of wood, dung and bagasse, (ii) transitional - consisting of coal, paraffin and liquefied petroleum gas (LPG), and (iii) modern - consisting of electricity and, increasingly, renewable energy. The typical universal trend is given as being from (i) through (ii) to (iii).

3.3.4 Biomass Burning

Biomass burning includes the burning of evergreen and deciduous forests, woodlands, grasslands, and agricultural lands. Within the project vicinity fires may therefore represent a source of combustion-related emissions.

Biomass burning is an incomplete combustion process, with CO, methane and NO_2 gases being emitted. Approximately 40% of the nitrogen in biomass is emitted as nitrogen (N_2), 10% is left is the ashes, and it may be assumed that 20% of the nitrogen is emitted as higher molecular weight nitrogen compounds. The visibility of the smoke plumes is attributed to the aerosol (particulate matter) content. In addition to the impact of biomass burning within the vicinity of the project, long-range transported emissions from this source can further be expected to impact on the air quality. It is impossible to control this source of atmospheric pollution loading; however, it should be noted as part of the background or baseline condition before considering the impacts of other local sources.

3.3.5 Agriculture

Agriculture is a land-use within the area surrounding the site. Particulate matter is the main pollutant of concern from agricultural activities as particulate emissions are derived from windblown dust, burning crop residue, and dust entrainment as a result of vehicles travelling along dirt roads. In addition, pollen grains, mould spores and plant and insect parts from agricultural activities all contribute to the particulate load. Should chemicals be used for crop spraying, they would typically result in odiferous emissions. Crop residue burning is an additional source of particulate emissions and other toxins.

3.4 Status Quo Ambient Air Quality

No ambient air quality data was available to establish baseline/pre-development pollutant concentrations and dustfall rates. Baseline/pre-development pollutant concentrations and dustfall rates are expected to be low due to the remoteness of the project area and the lack of large scale agricultural, mining and industrial activities.

4 Impact of CCM on the Receiving Environment

4.1 Atmospheric Emissions

4.1.1 Construction Phase

The construction operations will include construction of the stockpile footprints, haul roads, conveyors, boxcut and surface support infrastructure. The construction operations will not occur concurrently with mining operations. Construction operations are planned to take place for 6 months.

Specific activities likely to result in air emissions are listed in Table 4-1.

Table 4-1: Typical fugitive dust impacts and associated activities during construction of the CCM's infrastructure

Impact	Source	Activity
TSP, PM_{10} and $PM_{2.5}$	Dust generation from earthworks	Drilling and blasting activities to establish boxcut
		Clearing and grubbing and bulldozing activities
		Soil excavation
		Stockpiling of topsoil and other material
		Disposal and treatment of contaminated soil
	Dust generation from site development	Clearing of vegetation and topsoil
	Vehicle entrained dust	Construction and use of new on-site roads, clearing of areas
		Operation and movement of construction vehicles and machinery
Gases and particles	Vehicle and construction equipment activity	Tailpipe emissions from vehicles and construction equipment such as graders, scrapers and dozers

These activities normally comprise a series of different operations including land clearing, topsoil removal, road grading, material loading and hauling, stockpiling, grading, bulldozing, compaction, (etc.). Each of these operations has their own duration and potential for dust generation. It is anticipated that the extent of dust emissions would vary substantially from day to day depending on the level of activity, the specific operations, and the prevailing meteorological conditions. This is in contrast to most other fugitive dust sources where emissions are either relatively steady or follow a discernible annual cycle.

Due to the lack of detailed information, emissions from the construction activities were estimated on an area wide basis. This approach estimates construction emissions for the entire affected area in the absence of detailed construction plans for the project.

In the quantification of releases from the construction phase, use is made of emission factors published by the US EPA (US EPA, 1996). The approximate emission factors for construction activity operations are given as:

$$E_{TSP} = 2.69 \text{ Mg/hectare/month of activity}$$

This emission factor is most applicable to construction operations with (i) medium activity levels, (ii) moderate silt contents, and (iii) semi-arid climates and applies to TSP. Thus, it will result in conservatively high estimates when applied to PM_{10}. Also, because the derivation of the factor assumes that construction activity occurs 30 days per month, it is regarded as conservatively high for TSP as well (US EPA, 1995). The emission factor does not provide an indication of which type of activity during construction would result in the highest impacts. The calculated emissions from construction activities are shown in Table 4-2 and are based on the entire surface infrastructure area. As fuel use or detailed fleet information was not available for the construction phase, vehicle exhaust emissions resulting in gaseous emissions could not be calculated. It is expected that the gaseous emissions will be slight compared to particulate emissions.

Mitigation measures to consider during the construction phase include water sprays on all cleared and graded areas; ensure the distances between the topsoil removal and topsoil stockpiles are kept at a minimum and topsoil stockpiles vegetated. The recommended mitigation measures are provided in Section 5. The calculated mitigated emissions from construction activities are based on a 50% control efficiency (CE) due to the use of water sprays.

Table 4-2: Emissions from unmitigated and mitigated construction activities

Pollutant	Unmitigated (tonnes per annum (tpa))	Mitigated (tpa)
$PM_{2.5}$	21	10
PM_{10}	41	21
TSP	118	59

4.1.2 Operational Phase

The proposed mining operations at the CCM will comprise a series of different operations. The main environmental impacts associated with the surface operations are ventilation shaft, materials handling, crushing and screening, unpaved haul roads; all contribute to the dust emissions.

An emissions inventory was completed for the surface operations for one scenario. Operational phase will be when access road option 1 (Figure 1-3) is used.

Sources of atmospheric emission associated with the proposed operations at CCM are listed in Table 4-3 with relevant information as used in the emissions calculations included. The emission factors and equations are provided in Appendix A and a summary of the emission rates is provided in Table 4-4 and Table 4-5.

Emission rates were calculated for sources with given mitigation methods applied to the main sources. The mitigation measures are based on the information provided.

4.1.2.1 Underground emissions: ventilation shaft

In the estimation of ventilation emission, use was made of the South African particulate matter Occupational Exposure Limits (OEL). These were used to determine $PM_{2.5}$, PM_{10} and TSP emission rates (Appendix A). Compared to the calculated particulate emissions from underground vehicle exhausts, the emission rates for $PM_{2.5}$, PM_{10} and TSP calculated using the OELs are high; however, as a conservative approach these higher emissions rates were still used. Ventilation shaft (point source) parameters are summarized in Table 4-3. Table 4-4 and Table 4-5 summarises the emission rates from ventilation shafts.

4.1.2.2 Materials handling

The handling of ROM and coal product are potential significant sources of dust generation at the various transfer points between the decline shaft, the stockpiles and the mobile crushing and screening plant. Conveyor transfer points also constitute tipping points where dust emissions are generated. The quantity of dust generated depends on various climatic parameters, such as wind speed and precipitation, in addition to non-climatic parameters such as the nature and volume of the material handled. Fine particulates are most readily disaggregated and released to the atmosphere during the material transfer process, as a result of exposure to strong winds. Increases in the moisture content of the material being transferred will decrease the potential for dust emission, since moisture promotes the aggregation and cementation of fines to the surfaces of larger particles.

A number of transfer points were identified and summarised in Table 4-3 with the emission factors used provided in Appendix A. Table 4-4 summarises the emission rates from materials transfer points.

4.1.2.3 Crushing and screening operations

Crushing and screening operations can be a significant dust-generating source if uncontrolled. Dust fallout in the vicinity of crushers also gives rise to the potential for re-entrainment of dust by vehicles or by wind at a later date. The large percentage of fines in the deposited material enhances the potential for it to become airborne.

Primary crushing and screening will occur. Emissions factors are available for high moisture ore (moisture in excess of 4%) and low moisture ore (moisture less than 4%) (Appendix A). Moisture of ore was given as 2.75%, resulting in the application of the low moisture ore emission factors. The source parameters are listed in Table 4-3 with the emission rates summarised in Table 4-4. It was indicated that the mine will control dust from the crushing and screening through water sprays and it was assumed that at least 50% CE on crushing and screening will be achieved.

4.1.2.4 Vehicle entrainment on unpaved roads

Vehicle-entrained dust from unpaved roads is a significant source of dust, especially where there are high traffic volumes on a road and/or utilised by heavy equipment. The force of the wheels travelling on unpaved roads causes the pulverisation of surface material. Particles are lifted and dropped from the rotating wheels, and the road surface is exposed to strong air currents in turbulent shear with the surface. The turbulent wake behind the vehicle continues to act on the road surface after the vehicle has passed. The quantity of dust emissions from unpaved roads will vary linearly with the volume of traffic expected on that road.

The extent of particulate emissions from paved roads is a function of the “silt loading” present on the road surface, and to a lesser extent of the average weight of vehicles travelling on the road (Cowherd and Engelhart, 1984; US EPA, 2006a). Silt loading refers to the mass of silt-size material (i.e. equal to or less than 75 microns in diameter) per unit area of the travel surface. Silt loading is the product of the silt fraction and the total loading. The silt content was obtained from the US EPA’s manual for unpaved roads (US EPA, 2006a). The emission equation as provided in Appendix A was used to quantify emission from all unpaved roads. The information used is provided in Table 4-3.

A summary of the emission from truck activity on unpaved roads are provided in Table 4-4. It was indicated that the mine will control dust from the on-site unpaved roads through water sprays and it was assumed that at least 75% CE on all the unpaved roads will be achieved.

4.1.2.5 Windblown dust

Wind erosion is a complex process, including three different phases of particle entrainment, transport and deposition. It is primarily influenced by atmospheric conditions (e.g. wind, precipitation and temperature), soil properties (e.g. soil texture, composition and aggregation), land-surface characteristics (e.g. topography, moisture, aerodynamic roughness length, vegetation and non-erodible elements) and land-use practice (e.g. farming, grazing and mining) (Shao, 2008).

Windblown dust generates from natural and anthropogenic sources. For wind erosion to occur, the wind speed needs to exceed a certain threshold, called the threshold velocity. This relates to gravity and the inter-particle cohesion that resists removal. Surface properties such as soil texture, soil moisture and vegetation cover influence the removal potential. Conversely, the friction velocity or wind shear at the surface is related to atmospheric flow conditions and surface aerodynamic properties. Thus, for particles to become airborne the wind shear at the surface must exceed the gravitational and cohesive forces acting upon them, called the threshold friction velocity (Shao, 2008).

The proposed stockpiles are the likely sources of wind erosion. Emissions from the stockpiles are low due to the size of the material and the moisture contents. The information used is provided in Table 4-3.

A summary of the emission from wind erosion is provided in Table 4-4.

4.1.2.6 Vehicle exhausts

Emissions resulting from motor vehicles can be grouped into primary and secondary pollutants. While primary pollutants are emitted directly into the atmosphere, secondary pollutants form in the atmosphere because of chemical reactions. Significant primary pollutants emitted combustion engines include CO_2, carbon (C), SO_2, NO_x (mainly NO), particulates and lead. Secondary pollutants include NO_2, photochemical oxidants such as ozone, sulphur acids, sulphates, nitric acid, and nitrate aerosols (particulate matter). Vehicle type (i.e. model-year, fuel delivery system), fuel (i.e. oxygen content), operating (i.e. vehicle speed, load, power) and environmental parameters (i.e. altitude, humidity) influence vehicle emission rates (Onursal & Gautam, 1997). The information used is provided in Table 4-3.

A summary of the emission from vehicle exhausts is provided in Table 4-4 and Table 4-5.

4.1.2.7 Emissions inventory summary - PM emissions

Operational Phase Unmitigated

The source group contributions to total emissions are shown in Table 4-4. The most significant emissions source of $PM_{2.5}$, PM_{10} and TSP is crushing and screening, contributing 90%, 77% and 81% to the overall $PM_{2.5}$, PM_{10} and TSP emissions, respectively. The second most significant source of $PM_{2.5}$ emissions is ventilation. The second most significant source of PM_{10} and TSP emissions is vehicle entrainment on unpaved roads. The only source of DPM is vehicle exhaust emissions. The underground vehicle exhaust contributes more to DPM that the surface vehicle exhaust emissions.

Operational Phase Design mitigated

The source group contributions to total emissions are shown in Table 4-4. The most significant source of $PM_{2.5}$, PM_{10} and TSP remains to be crushing and screening emissions, however contributing slightly less to the overall emissions (86%, 75% and 84% to the overall $PM_{2.5}$, PM_{10} and TSP emissions, respectively). The second most significant source of $PM_{2.5}$ and PM_{10} emissions is ventilation. The second most significant source of TSP emissions is vehicle entrainment on unpaved roads. The only source of DPM is vehicle exhaust. The underground vehicle exhaust contributes more to DPM that the surface vehicle exhaust emissions.

Table 4-3: Activities, aspects and their associated assumptions for the proposed operations at CCM for emissions inventory calculations

Aspect	Source	Activity	Comments/Assumptions/Mitigation
Fugitive dust (TSP, PM_{10} and $PM_{2.5}$) and gases	Ventilation shaft	Underground operations	Based on 24 hours Monday to Sunday. Release height: 8 m Exit diameter: 3 m Exit temperature: 20 °C Exit velocity: 5 m/s Assumed 48 000 litres of diesel fuel used per month underground.
	Materials handling operations	Tipping coal onto conveyor at decline shaft and tipping from conveyor onto RoM stockpile RoM coal from RoM stockpile to crusher Crushed coal to product stockpile Crushed coal from product stockpile to trucks using front end loaders (FELs)	Based on 24 hours Monday to Sunday. RoM coal = 1 million tonnes per annum (Mtpa). Product = 1 Mtpa. Mitigation measures will include water sprays at product stockpiles (50% CE).
	Crushing and Screening	Primary crushing of coal Screening of coal	Based on 24 hours Monday to Sunday. RoM coal = 1 Mtpa. Moisture content = 2.75% Mitigation measures will include water sprays on crusher and screen (50% CE).
	Vehicle activity on unpaved haul roads	Transportation of product off-site Vehicle exhaust emissions from haul trucks travelling on unpaved roads	Silt content of 5.1% for all unpaved access roads. Length of access road option 1 = 312.12 m. Width of road = 10 m. 34 tonne capacity haul trucks. Assumed 12 000 litres of diesel fuel used per month at the surface. Mitigation measures will include water sprays on unpaved haul roads (assumed 75% CE).
	Wind erosion	Wind erosion at stockpiles (SPs)	Area of RoM SP: 505 m² Area of product SPs: 3 680 m² Mitigation measures will include water sprays on product stockpiles (50% CE).

Table 4-4: Summary of estimated particulate emission rates and contributions for the proposed operational phase

Source Group	PM2.5	PM10	TSP	DPM	PM2.5	PM10	TSP	DPM	Mitigation Applied
	tpa	tpa	tpa	tpa	%	%	%	%	
Unmitigated									
Ventilation shaft	2	7	7	2	4	6	2	80	None
Materials Handling	1	4	8		1	4	2		
Crushing and Screening	42	85	296		90	77	81		
Unpaved Roads	1	14	54		3	13	15		
Wind Erosion	0.003	0.02	0.02		0	0	0		
Surface Vehicle Exhaust	0.5	1	1	0.5	1	0	0	20	
Total	**47**	**110**	**365**	**2.5**	**100**	**100**	**100**	**100**	
Design Mitigated									
Ventilation shaft	2	7	7	2	8	12	4	100	None
Materials Handling	0.5	3	7		2	6	4		50% CE on product stockpile by spraying water
Crushing and Screening	21	42	148		86	75	84		50% CE at crushing and screening plant by spraying water
Unpaved Roads	0.3	3	13		1	6	8		50% CE on unpaved roads by spraying water
Wind Erosion	0.002	0.01	0.01		0	0	0		50% CE on product stockpile by spraying water
Surface Vehicle Exhaust	0.5	1	1	0.5	2	1	0	20	None
Total	**25**	**56**	**176**	**2.5**	**100**	**100**	**100**	**100**	

4.1.2.8 Emissions inventory summary - Gaseous emissions

Due to a lack of information regarding underground blasting, only gaseous emissions from vehicle exhausts could be determined (Table 4-5). The greatest contribution to CO, NO_x, SO_2 and VOC emissions are ventilation shafts (80%).

Table 4-5: Summary of estimated gaseous emission rates for the proposed operational phase

Source Group	CO	NO_x	SO_2	VOC
	tpa	tpa	tpa	tpa
Ventilation Shafts (underground vehicle exhaust)	11	26	0.014	2
Surface Vehicle Exhaust	3	6	0.003	1
Total	**14**	**32**	**0.02**	**3**

4.1.3 Decommissioning and Closure Phases

It is assumed that all operations will have ceased by the decommissioning phase. It is expected that all surface infrastructure will be demolished and removed and site access roads closed off. It is also expected that the surface will be covered with topsoil and vegetated.

The potential for air quality impacts during the decommissioning phase will depend on the extent of demolition and rehabilitation efforts during decommissioning and on features which will remain.

Aspects and activities associated with the decommissioning phase of the operations are listed in Table 4-6.

Table 4-6: Activities and aspects identified for the decommissioning phase of operations

Impact	Source	Activity
TSP, PM_{10} and $PM_{2.5}$	Topsoil stockpiles	Topsoil recovered from stockpiles for rehabilitation and re-vegetation of surroundings
	Unpaved roads	Vehicle entrainment on unpaved road surfaces during rehabilitation. Once that is done, vehicle activity should cease
Gases and particles	Vehicles	Exhaust emissions from vehicles utilised during the closure phase. Once that is done, vehicle activity should cease.

The closure phase includes the period of aftercare and maintenance after the decommissioning phase. It is when rehabilitated areas are checked and maintained. The activities that may be included are irregular and minimal vehicle entrainment on roads and vehicle exhaust emissions when the property is checked up on.

4.1.4 Post-closure Phase

No emissions due to the CCM are expected post-closure. Emissions from post-closure will be similar to the baseline assuming effective rehabilitation is achieved.

4.2 Screening of Simulated Human Health Impacts (Incremental and Cumulative)

For the assessment of the CCM operations on air quality with regards to compliance with selected critera "on-site" will refer to the area within the mine boundary. "Off-site" refers to the area outside the mine boundary (refer to an appropriate figure indicating the boundary).

4.2.1 Construction Phase

Dispersion modelling for the construction phase of the CCM was considered to be unrepresentative of the actual activities that will result in dust and gaseous emissions, due to the overly conservative emission rate calculation. It is anticipated that the various construction activities would not result in higher off-site $PM_{2.5}$, PM_{10} DPM, NO_2, CO, SO_2 and VOC ground level concentrations (GLCs) than the operational phase activities. The temporary nature of the construction activities would likely reduce the significance of the potential impacts.

4.2.2 Operational Phase

4.2.2.1 Transport Route

Only an unpaved portion of the access road to the railway siding was simulated to determine the likely GLCs and frequency of exceedence (FOE) from the centre of the road. To determine the likely GLCs due to the activities associated with the access road only a portion of the road was simulated because the GLCs are expected to be similar along the length of the road and it is unlikely that there will be CCM vehicles along the entire road length at one time. GLCs and FOE as would likely be lower for the paved portion of the road.

To determine the distance from the road edge 5 m is subtracted from the distance on the graph to take into account the portion of the road included on the graph.

Simulated annual average $PM_{2.5}$ ground level concentrations are above the NAAQS for a distance of approximately 76 m from the unmitigated road edge (Figure 4-1). The furthest distance from the unmitigated road edge that the daily $PM_{2.5}$ NAAQS is exceeded is approximately 112.5 m from the source (Figure 4-2).

Simulated annual average PM_{10} ground level concentrations are above the NAAQS for a distance of approximately 146 m from the unmitigated road edge (Figure 4-3). The furthest distance from the unmitigated road edge that the daily PM_{10} NAAQS is exceeded is approximately 210 m from the source (Figure 4-4).

There are receptors located within the exceedance area for the access road.

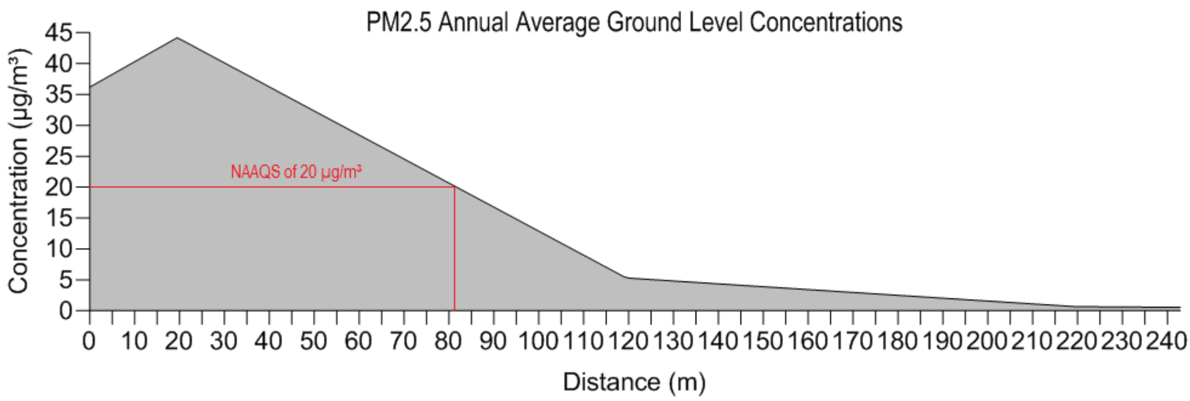

Figure 4-1: Unmitigated operational phase - $PM_{2.5}$ annual average ground level concentrations transect for the access road

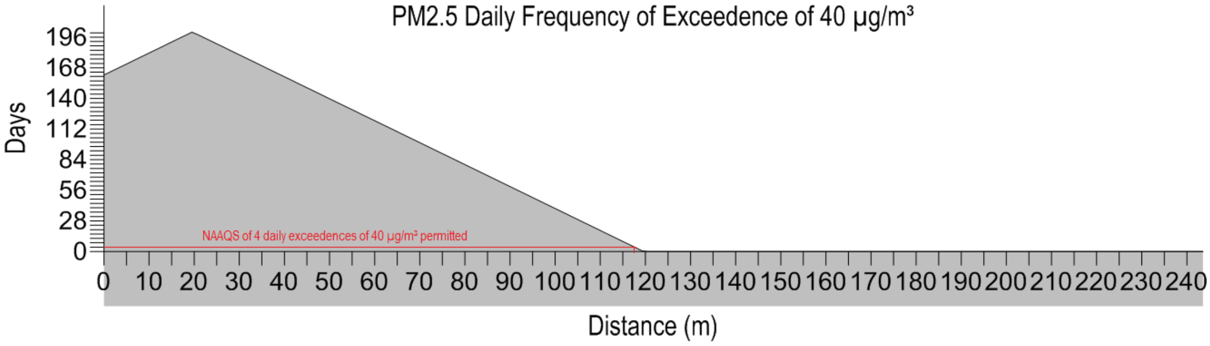

Figure 4-2: Unmitigated operational phase - Frequency of exceedance of the SA NAAQ limit of 40 µg/m³ for daily average $PM_{2.5}$ concentrations transect for the access road

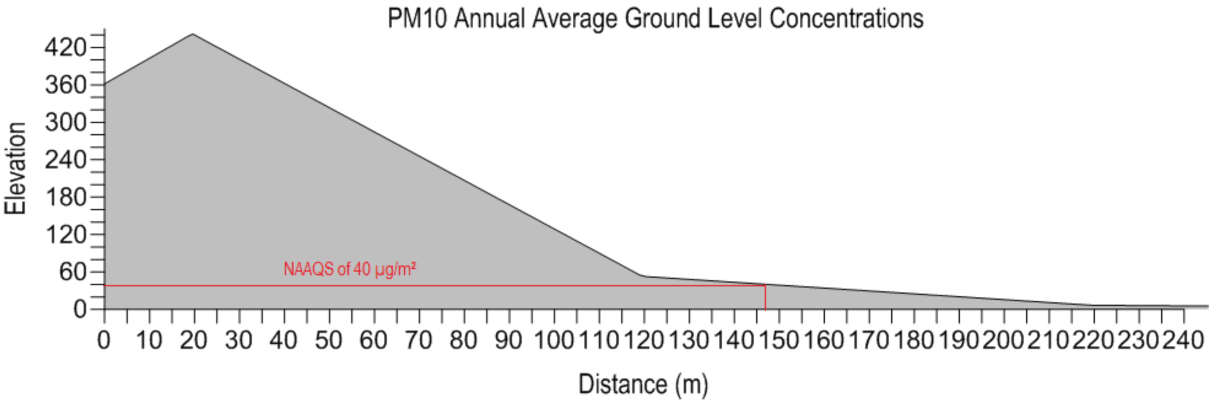

Figure 4-3: Unmitigated operational phase – PM_{10} annual average ground level concentrations transect for the access road

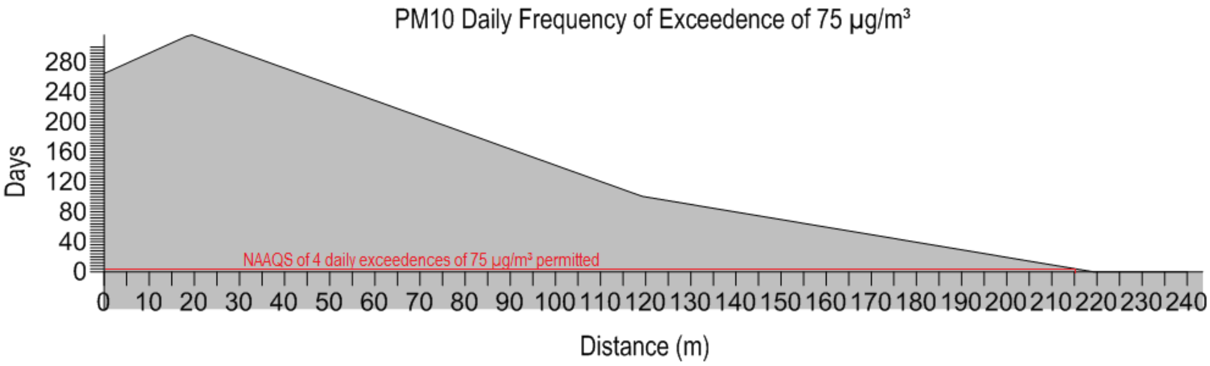

Figure 4-4: Unmitigated operational phase - Frequency of exceedance of the SA NAAQ limit of 75 µg/m³ for daily average PM_{10} concentrations transect for the access road

4.2.2.2 On-site Activities

4.2.2.2.1 $PM_{2.5}$

- Simulated ***unmitigated operational phase*** $PM_{2.5}$ daily frequency of exceedence is shown in Figure 4-5 and $PM_{2.5}$

annual GLC is shown in Figure 4-6. Over a daily average, the concentrations exceed the NAAQ limit of 40 µg/m³ for more than 4 days per year at the sensitive receptors on-site and to the east and north-east of the surface infrastructure area off-site (Figure 4-5). Over an annual average the simulated GLCs exceed the NAAQS of 20 µg/m³ at the sensitive receptors on-site but not off-site (Figure 4-6).

- Simulated ***design mitigated operational phase*** $PM_{2.5}$ daily frequency of exceedence is shown in Figure 4-7 and $PM_{2.5}$ annual GLC is shown in Figure 4-8. Over a daily average, the simulated concentrations exceed the NAAQ limit of 40 µg/m³ for more than 4 days per year at the sensitive receptors on-site (Figure 4-7). Over an annual average the simulated GLCs exceed the NAAQS of 20 µg/m³ at the sensitive receptors on-site but is not exceeded off-site (Figure 4-8).
- The main contributing source to the ***unmitigated and design mitigated*** $PM_{2.5}$ simulated concentrations are crushing and screening. The source that contributes the least to the ***unmitigated and design mitigated*** $PM_{2.5}$ simulated concentrations is vehicle exhausts.
- Due to the absence of ambient (baseline) air quality data, cumulative (ambient concentrations and future CCM GLCs) $PM_{2.5}$ concentrations could not be determined.

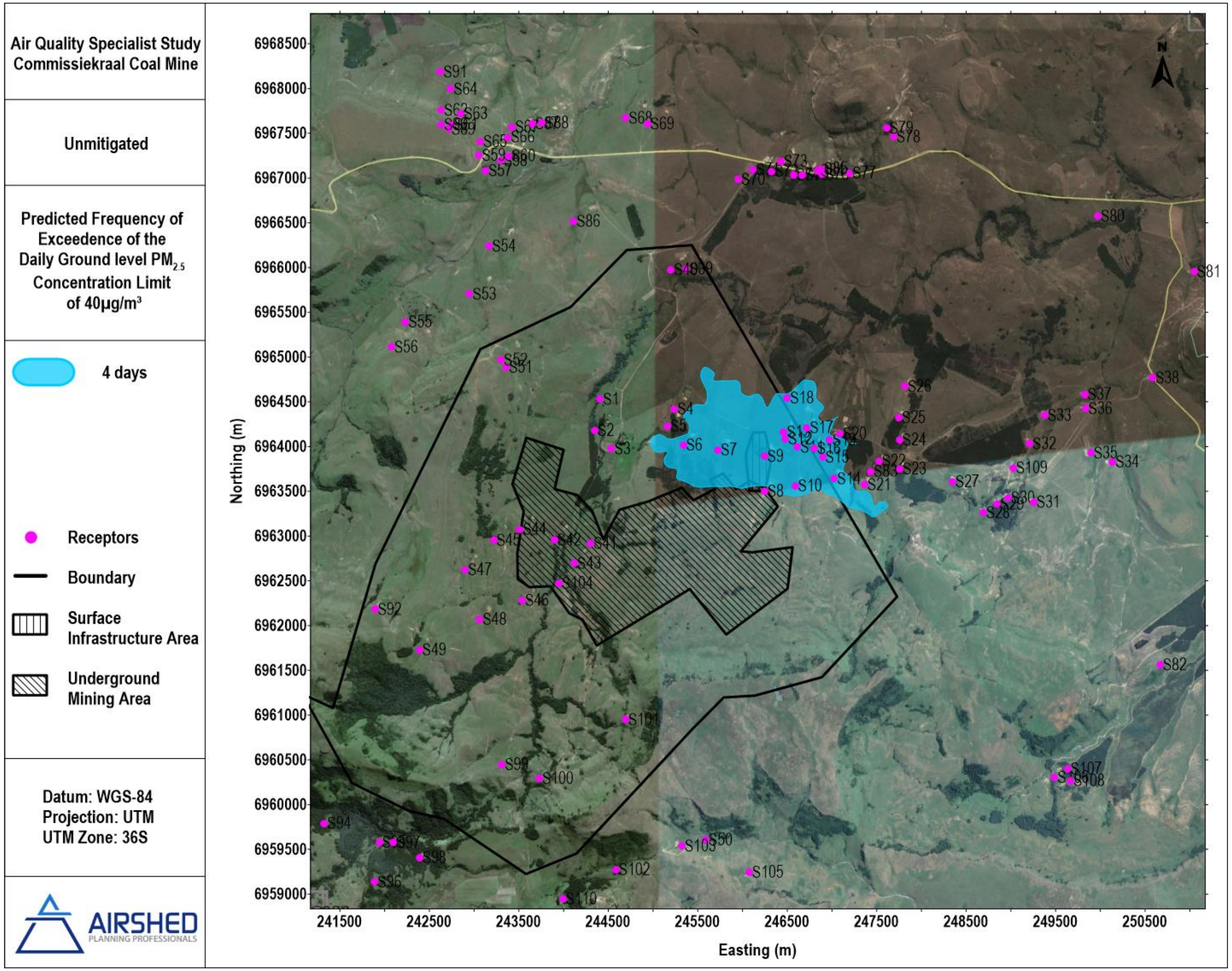

Figure 4-5: Unmitigated operational phase - Frequency of exceedance of the SA NAAQ limit of 40 µg/m³ for daily average $PM_{2.5}$ concentrations

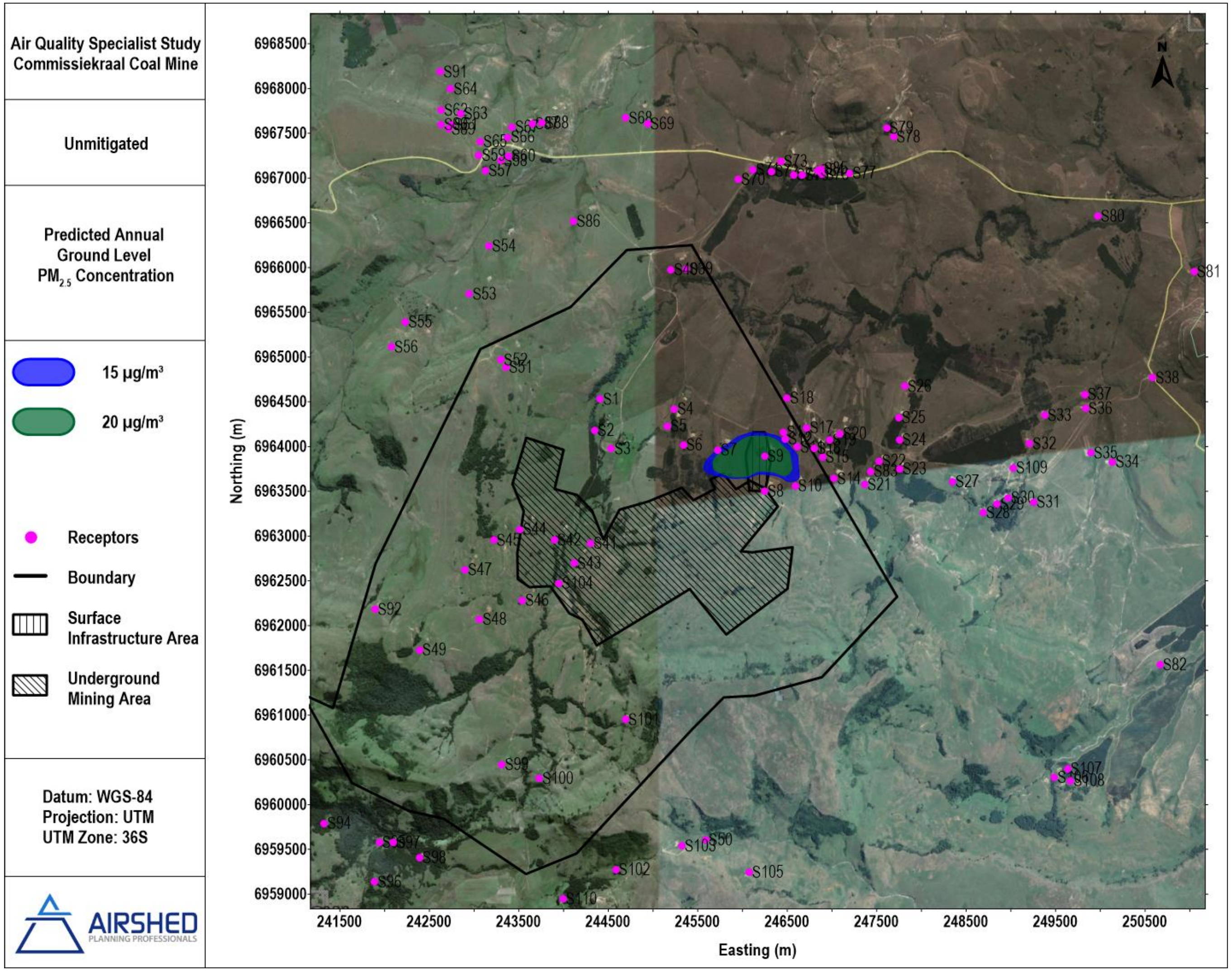

Figure 4-6: Unmitigated operational phase - Area of exceedance of the SA NAAQS for annual average $PM_{2.5}$ concentrations

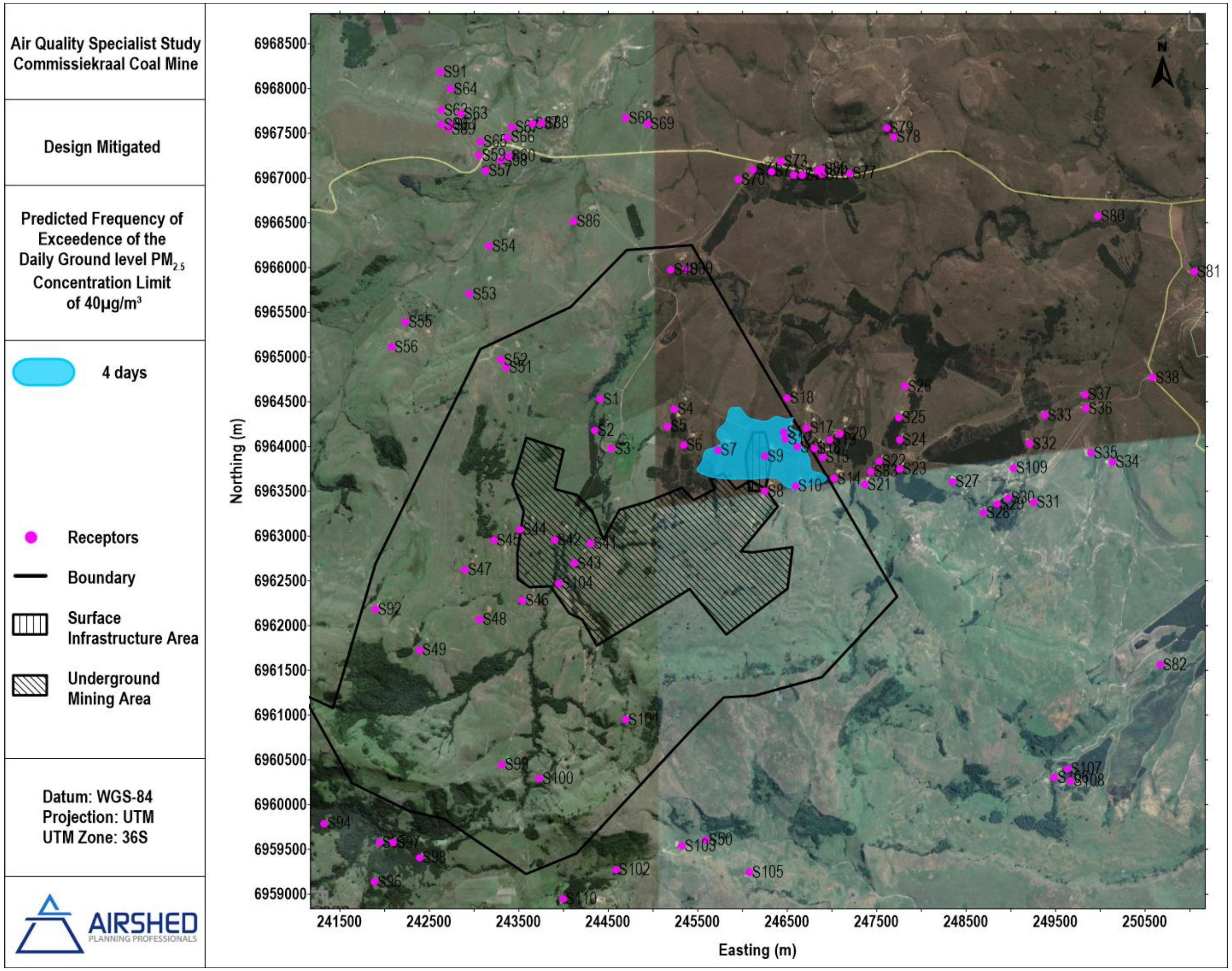

Figure 4-7: Design mitigated operational phase - Frequency of exceedance of the SA NAAQ limit of 40 µg/m³ for daily average $PM_{2.5}$ concentrations

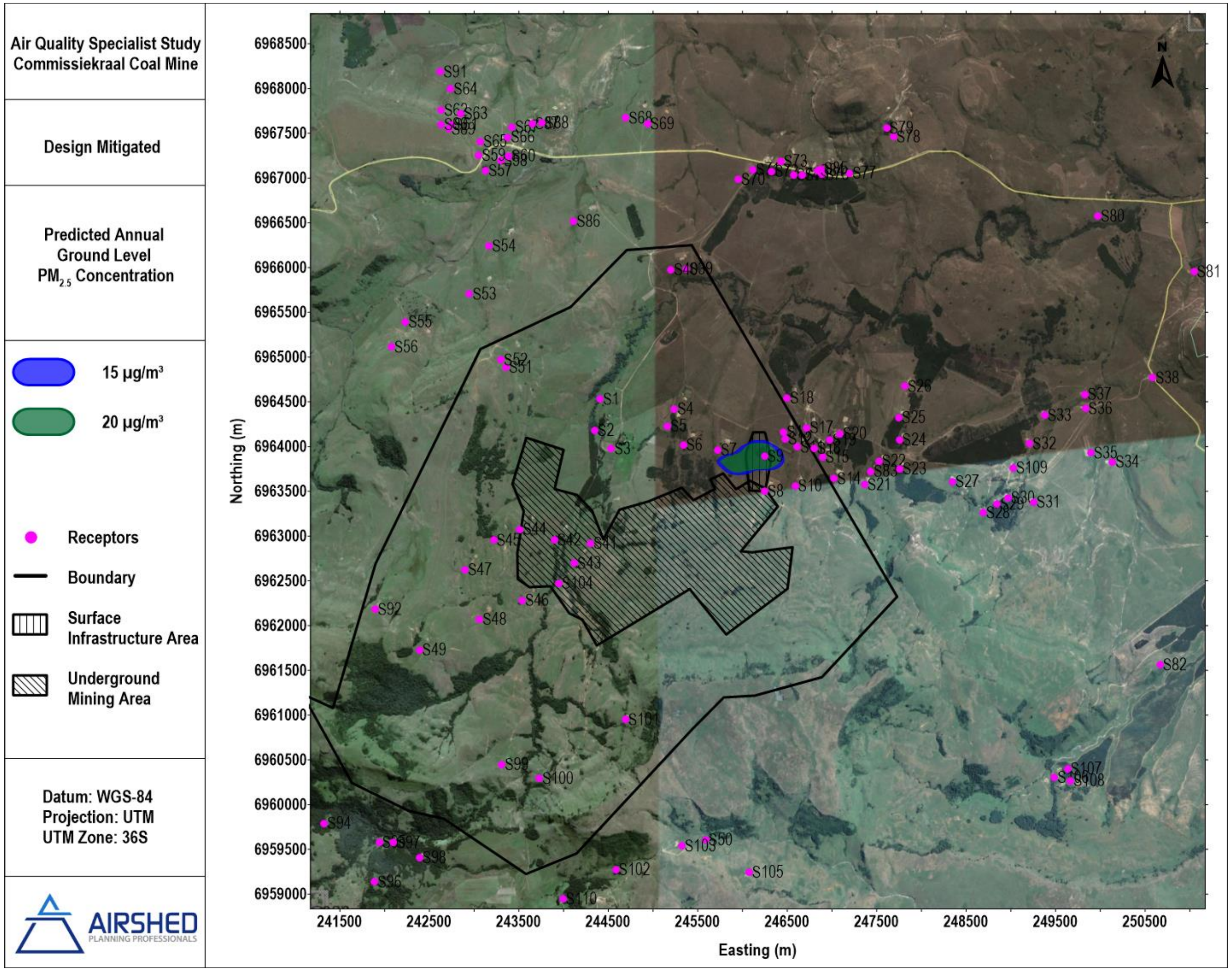

Figure 4-8: Design mitigated operational phase - Area of exceedance of the SA NAAQS for annual average $PM_{2.5}$ concentrations

4.2.2.2.2 PM_{10}

- Simulated ***unmitigated operational phase*** PM_{10} daily frequency of exceedence is shown in Figure 4-9 and PM_{10} annual GLC is shown in Figure 4-10. Over a daily average, the concentrations exceed the NAAQ limit of 75 µg/m³ for more than 4 days per year at the sensitive receptors on-site and to the east and north-east of the surface infrastructure area off-site (Figure 4-9). Over an annual average the simulated GLCs exceed the NAAQS (40 µg/m³) at the sensitive receptors on-site but not off-site (Figure 4-10).
- Simulated ***design mitigated operational phase*** PM_{10} daily frequency of exceedence is shown in Figure 4-11 and PM_{10} annual GLC is shown in Figure 4-12. Over a daily average, the concentrations exceed the NAAQ limit of 75 µg/m³ for more than 4 days per year at the sensitive receptors on-site and to the east of the surface infrastructure area off-site (Figure 4-11). Over an annual average the simulated GLCs exceed the selected criterion (40 µg/m³) at the sensitive receptors on-site but not off-site (Figure 4-12).
- The main contributing source to the ***unmitigated*** and ***design mitigated*** PM_{10} simulated concentrations are crushing and screening. The sources that contribute the least to the ***unmitigated*** and ***design mitigated*** PM_{10} simulated concentrations are vehicle exhausts.
- Due to the absence of ambient (baseline) air quality data, cumulative (ambient concentrations and future CCM GLCs) PM_{10} concentrations could not be determined.

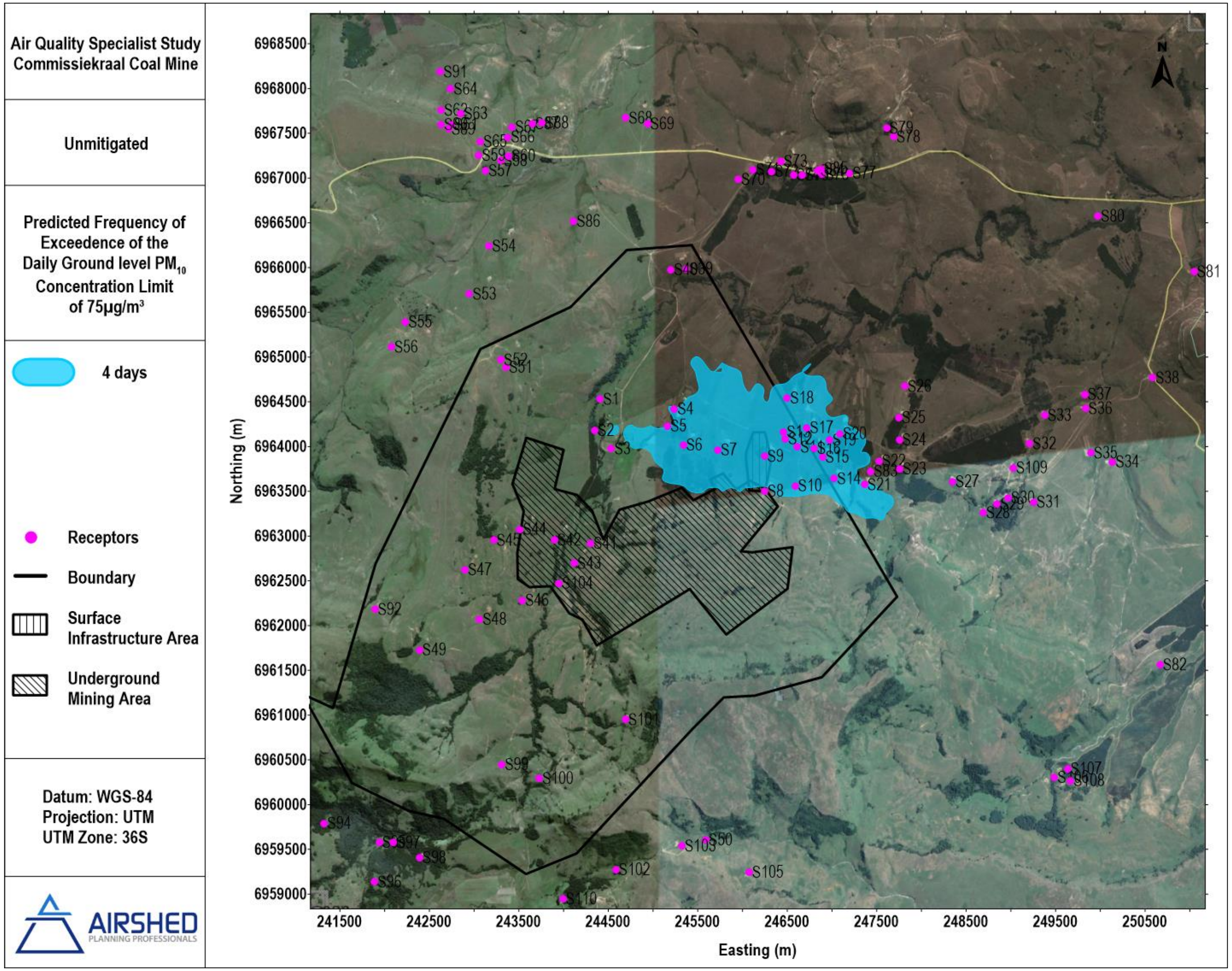

Figure 4-9: Unmitigated operational phase - Frequency of exceedance of the SA NAAQ limit of 75 µg/m³ for daily average PM_{10} concentrations

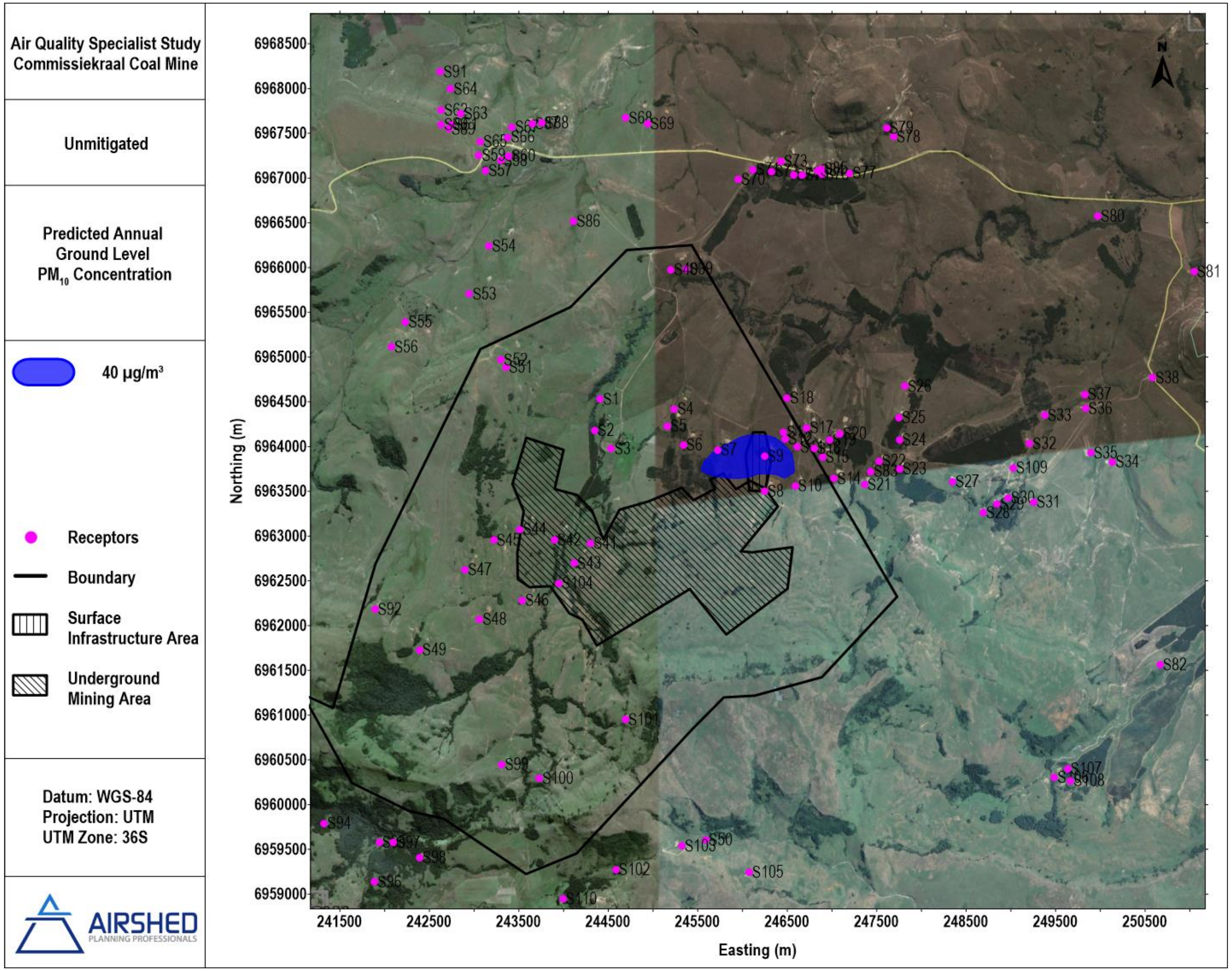

Figure 4-10: Unmitigated operational phase - Area of exceedance of the SA NAAQS for annual average PM_{10} concentrations

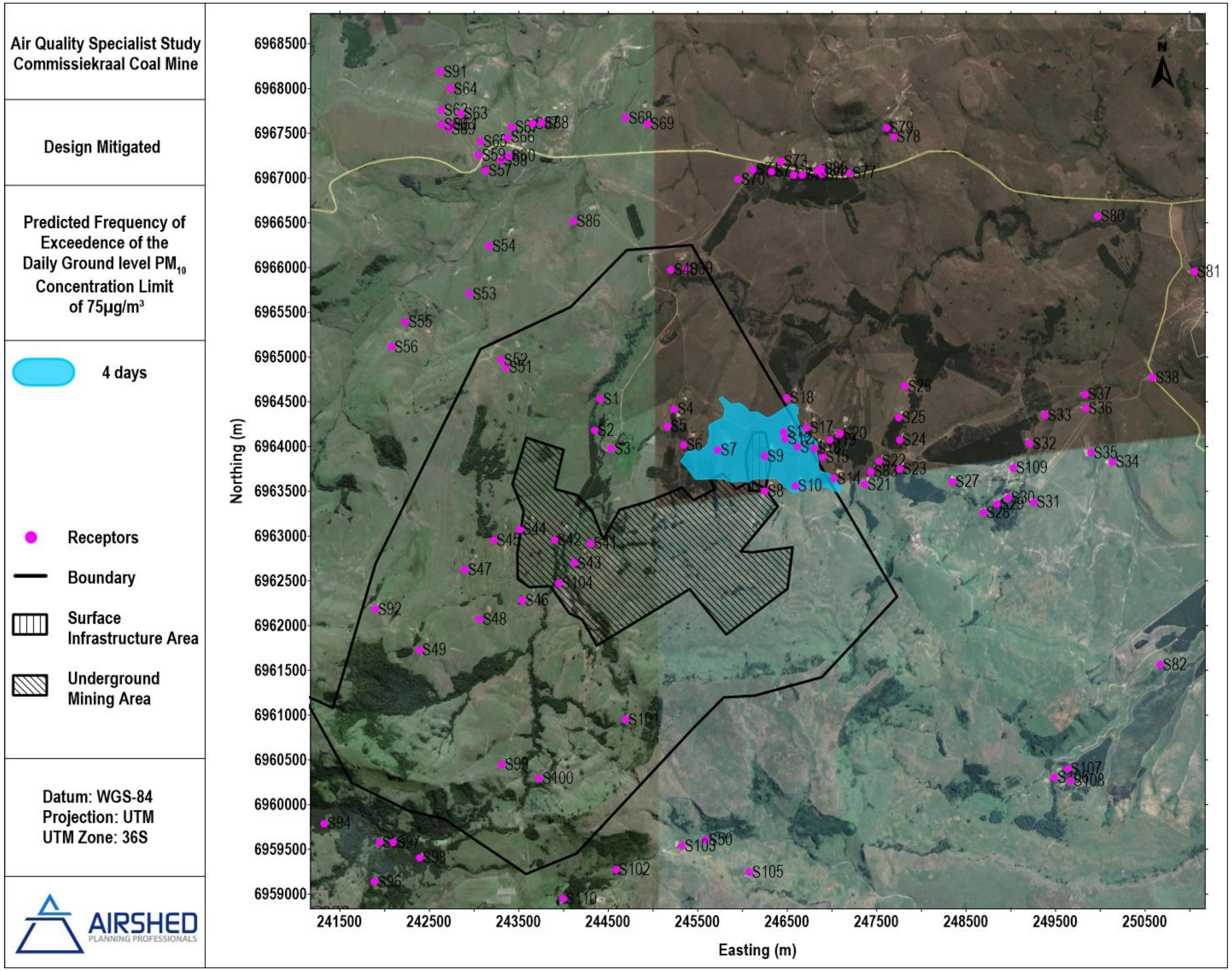

Figure 4-11: Design mitigated operational phase - Frequency of exceedance of the SA NAAQ limit of 75 µg/m³ for daily average PM_{10} concentrations

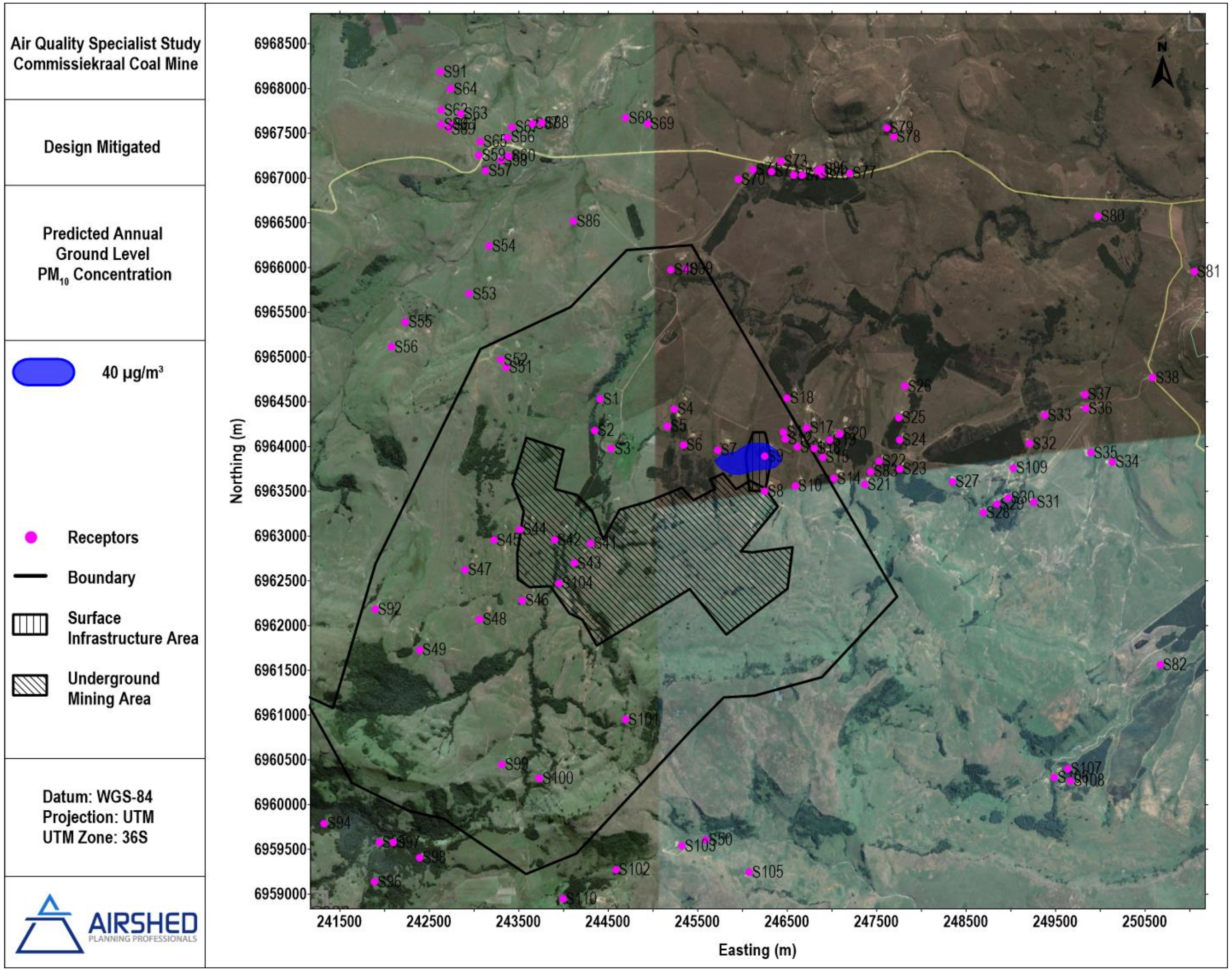

Figure 4-12: Design mitigated operational phase - Area of exceedance of the SA NAAQS for annual average PM_{10} concentrations

4.2.2.2.3 DPM

- Simulated incremental DPM concentrations as a result of vehicle exhaust emissions are low and do not exceed the selected annual evaluation criterion of 5 µg/m³. Due to the low level of impact, isopleth plots have not been prepared for DPM.
- Due to the absence of ambient (baseline) air quality data, cumulative (ambient concentrations and future CCM GLCs) DPM concentrations could not be determined.
- Increased lifetime cancer risk as a result of chronic exposure to DPM is considered 'very low' (less than 1 in 1 million) at sensitive receptors.

4.2.2.2.4 CO

- Simulated incremental CO concentrations as a result of vehicle exhaust emissions are low and do not exceed the selected evaluation criterion of 30 000 µg/m³ more than 88 hours per year. Due to the low level of impact, isopleth plots have not been prepared for CO.
- Due to the absence of ambient (baseline) air quality data, cumulative (ambient concentrations and future CCM GLCs) CO concentrations could not be determined.

4.2.2.2.5 NO_2

- Simulated incremental NO_2 concentrations as a result of vehicle exhaust emissions do not exceed the selected evaluation criteria. Due to the low level of impact, isopleth plots have not been prepared for NO_2.
- Due to the absence of ambient (baseline) air quality data, cumulative (ambient concentrations and future CCM GLCs) NO_2 concentrations could not be determined.

4.2.2.2.6 SO_2

- Simulated incremental SO_2 concentrations as a result of vehicle exhaust emissions are low and do not exceed the selected evaluation criteria. Due to the low level of impact, isopleth plots have not been prepared for SO_2.
- Due to the absence of ambient (baseline) air quality data, cumulative (ambient concentrations and future CCM GLCs) SO_2 concentrations could not be determined.

4.2.2.2.7 VOC

- Simulated incremental VOC concentrations as a result of vehicle exhaust emissions are low and do not exceed the selected annual evaluation criterion of 100 µg/m³. Due to the low level of impact, isopleth plots have not been prepared for VOCs.
- Due to the absence of ambient (baseline) air quality data, cumulative (ambient concentrations and future CCM GLCs) VOC concentrations could not be determined.

4.2.3 Decommissioning and Closure Phase

Dispersion modelling was not possible due to limited information on the decommissioning and closure schedules. It is not anticipated that the various activities for both phases would result in high off-site $PM_{2.5}$, PM_{10}, DPM, NO_2, CO, SO_2 and VOCs GLCs.

4.2.4 Post Closure Phase

No atmospheric impacts are expected from the CCM project post-closure.

4.3 Analysis of Emissions' Impact on the Environment (Dustfall) (Incremental and Cumulative)

4.3.1 Construction Phase

Dispersion modelling was regarded not representative of the actual activities that will result in dust emissions during the construction phase for the proposed CCM. It is anticipated that the various construction activities would not result in higher off-site dustfall rates than the operational phase activities. The temporary nature of the construction activities would reduce the significance of the potential impacts.

4.3.2 Operational Phase

- Simulated incremental dustfall rates are, in general, high on-site for ***unmitigated operational phase*** operations. These are above the SA NDCR of 600 mg/m²/day for residential areas at one sensitive receptor on-site but below the SA NDCR residential limit off-site (Figure 4-13).

- Simulated incremental dustfall rates are high in general on-site for ***design mitigated operational phase*** operations. These are above the SA NDCR of 600 mg/m²/day for residential areas at one sensitive receptor on-site but below the SA NDCR residential limit off-site (Figure 4-14).

- The main contributing source to the ***unmitigated and design mitigated*** simulated dustfall rates are crushing and screening. The source that contributes the least to the ***unmitigated*** and ***design mitigated*** simulated dustfall rates is vehicle exhausts.

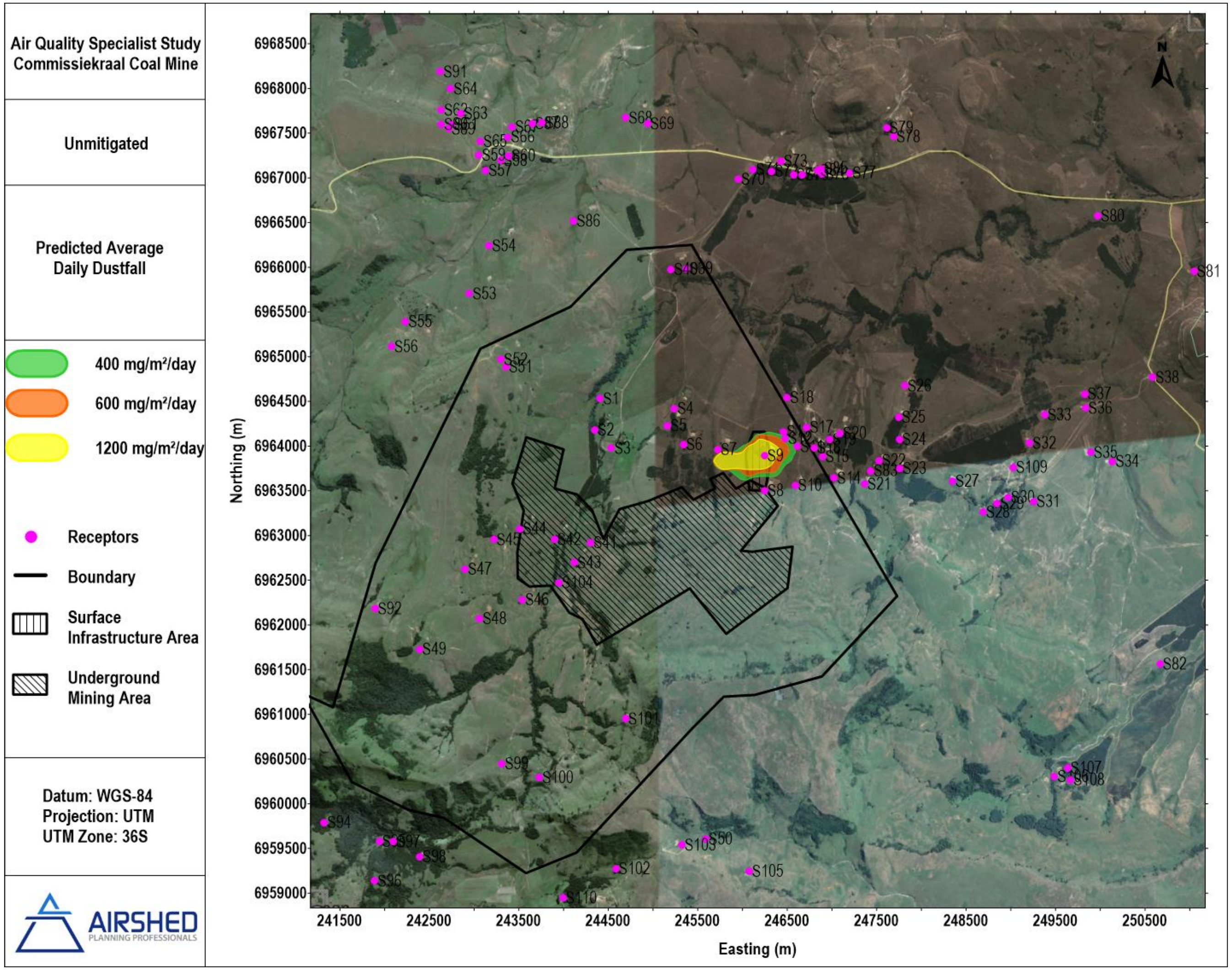

Figure 4-13: Predicted unmitigated operational phase daily dustfall rates (SA NDCR residential limit is 600 mg/m²/day)

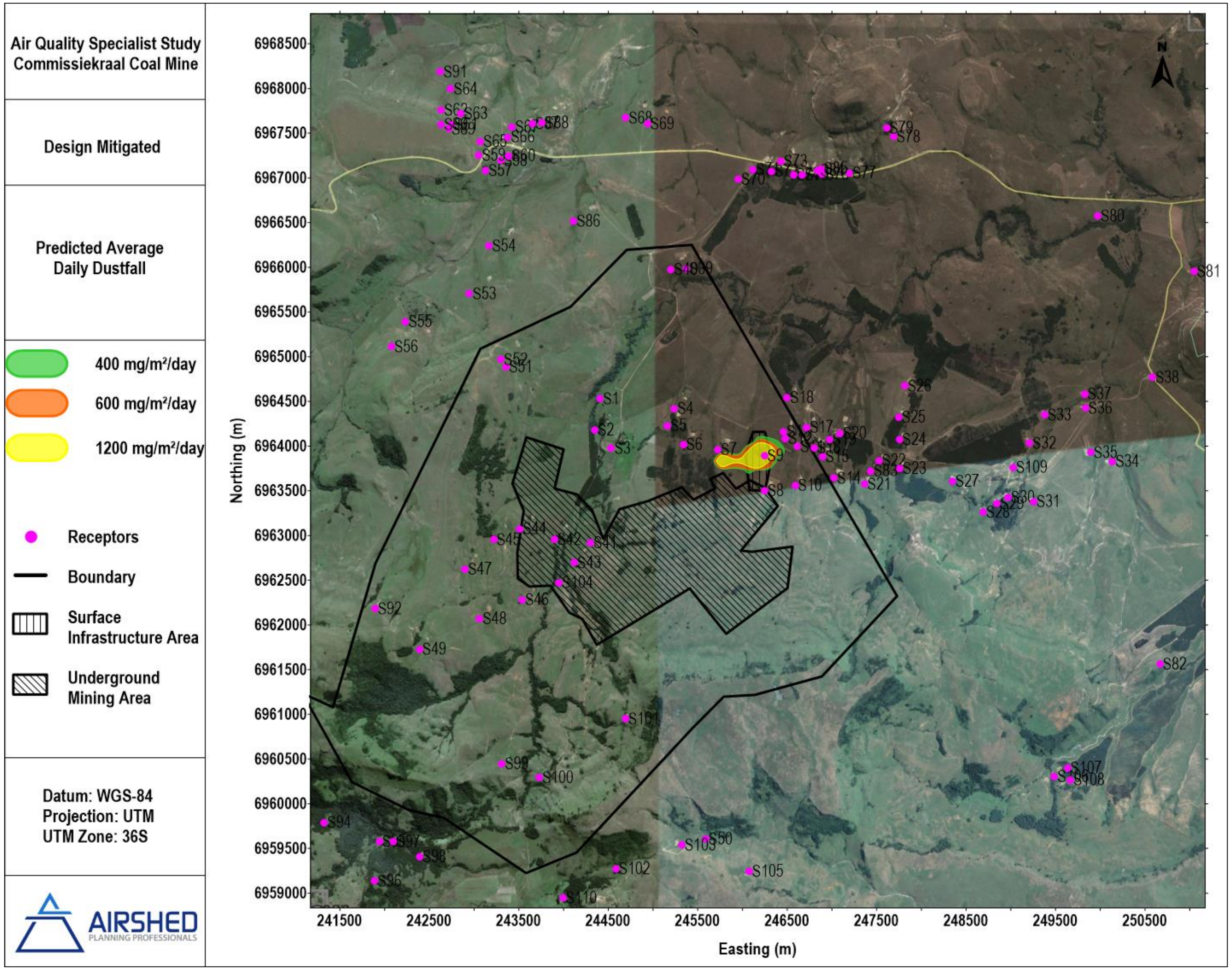

Figure 4-14: Predicted design mitigated operational phase daily dustfall rates (SA NDCR residential limit is 600 mg/m²/day)

4.3.3 *Decommissioning and Closure Phases*

Dispersion modelling was not possible due to limited information on the decommissioning and closure schedules. It is anticipated that the various decommissioning and closure activities would not result in high off-site dustfall rates.

4.3.4 *Post Closure Phase*

No dust fallout rates due to the CCM are expected post-closure.

4.4 Impact Significance Rating

The impact assessment is summarised in the subsequent tables for the different phases of the proposed CCM. Table 4-7 provides the significance rating for the construction phase with the evaluation of the operational phase provided in Table 4-8. The significance rating for the closure phase is provided in Table 4-9. The methodology is described in Appendix C.

Table 4-7: Impact assessment summary table for the construction phase for CCM

Scenario	Impact	Severity/ Nature of Impact	Duration of Impact	Spatial Scale of Impacts	Consequence	SIGNIFICANCE
Unmitigated	$PM_{2.5}$	M	M	M	M	Medium
	PM_{10}	M	M	M	M	Medium
	Dustfall	L	M	L	L	Low
Mitigated	$PM_{2.5}$	L	M	L	L	Low
	PM_{10}	L	M	L	L	Low
	Dustfall	L	M	L	L	Low

Table 4-8: Impact assessment summary table for the operational phase for CCM for the area at which exceedences occur for particulates

Scenario	Impact	Severity/ Nature of Impact	Duration of Impact	Spatial Scale of Impacts	Consequence	SIGNIFICANCE
Unmitigated	$PM_{2.5}$	H	M	M	H	High
	PM_{10}	H	M	M	H	High
	Dustfall	L	M	L	L	Low
	SO_2	L	M	L	L	Low
	NO_2	L	M	L	L	Low
	CO	L	M	L	L	Low
	DPM	L	M	L	L	Low
Design mitigated	$PM_{2.5}$	M	M	M	M	Medium
	PM_{10}	M-H	M	M	M-H	Medium – High
	Dustfall	L	M	L	L	Low

Scenario	Impact	Severity/ Nature of Impact	Duration of Impact	Spatial Scale of Impacts	Consequence	SIGNIFICANCE
	SO_2	L	M	L	L	Low
	NO_2	L	M	L	L	Low
	CO	L	M	L	L	Low
	DPM	L	M	L	L	Low

Table 4-9: Impact assessment summary table for the closure phase for CCM

Scenario	Impact	Severity/ Nature of Impact	Duration of Impact[(a)]	Spatial Scale of Impacts	Consequence	SIGNIFICANCE
Unmitigated Demolition of infrastructure	$PM_{2.5}$	M	M	L	M	Low
	PM_{10}	M	M	M-L	M	Low
	Dustfall	L	M	L	L	Low
	SO_2	L	M	L	L	Low
	NO_2	L	M	L	L	Low
	CO	L	M	L	L	Low
	DPM	L	M	L	L	Low

Notes: (a) For closure period only

5 RECOMMENDED AIR QUALITY MANAGEMENT MEASURES

It is recommended that the project proponent commit itself to air quality management planning throughout the life of the operations. This section expands on the air quality management plan for the future CCM operations.

5.1 Air Quality Management Objectives

It is recommended that air quality management planning forms part of the construction, operational phase and decommissioning of the CCM. The air quality management plan provides options on the control of dust at the main sources with the monitoring network designed as such to track the effectiveness of the mitigation measures. The sources need to be ranked according to sources strengths (emissions) and impacts. Once the main sources have been identified, target control efficiencies for each source can be defined to ensure acceptable cumulative ground level concentrations.

In the places of constant human occupation pollutant concentrations should not exceed the NAAQS and dustfall rates should be below the SA NDCR residential limit of 600 mg/m²/day.

5.2 Source Ranking

Source ranking focuses on the operational phase since the construction phase was not assessed in detail. The ranking of sources serves to confirm, and possibly revise, the current understanding of the significance of specific sources and to evaluate the emission reduction potentials required for each. Sources of emissions during the design mitigated operational phase of the proposed CCM may be ranked based on emissions and impacts.

5.2.1 Ranking of Sources by Emissions

Unmitigated

The most significant sources of $PM_{2.5}$, PM_{10} and TSP emissions are crushing and screening. The only source of DPM, NO_2, SO_2, CO and VOCs emissions is vehicle exhaust.

Design mitigated

The most significant sources of $PM_{2.5}$, PM_{10} and TSP emissions remained to be crushing and screening emissions, however at much lower rates. The only source of DPM, NO_2, SO_2, CO and VOCs is vehicle exhausts.

5.2.2 Ranking of Sources by Impact

The main contributing sources to the unmitigated and design mitigated $PM_{2.5}$ and PM_{10} simulated concentrations, and dustfall rates are crushing and screening. The source that contributes the least to the unmitigated and design mitigated $PM_{2.5}$ and PM_{10} simulated concentrations, and to dust fallout is vehicle exhausts.

5.3 Source Specific Recommended Management and Mitigation Measures

The minimum mitigation measures must be achieved; however, it is suggested that additional mitigation measures be considered to ensure compliance with NAAQSs off-site, specifically at the sensitive receptors. These mitigation measures are briefly discussed below (Table 5-1 for construction phase, Table 5-2 for operational phase and Table 5-3 for decommissioning and closure phase) (in more detail in Appendix B).

Table 5-1: Air Quality Management Plan: construction phase of the proposed CCM

Aspect	Impact	Management Actions/Objectives	Responsible Person(s)	Target Date
Land clearing activities such as bulldozing and scraping of road and blasting	PM_{10} and $PM_{2.5}$ concentrations and dustfall rates	Water sprays at area to be cleared – 50% CE can be achieved. Moist topsoil will reduce the potential for dust generation when tipped onto stockpiles – US EPA indicated a 62% reduction in dust generation by doubling the moisture content. Ensure travel distance between clearing area and topsoil piles to be at a minimum. Dustfall buckets placed around the proposed project site and at sensitive receptors (DB01 to DB05). During construction operations monthly dustfall rates should not exceed 600 mg/m²/day[a]. Dustfall buckets placed at surface infrastructure (DB06). During construction operations monthly dustfall rates should not exceed 1 200 mg/m²/day[b].	Contractor(s) CCM Environmental Manager	During construction
Road construction activities such as road grading	PM_{10} and $PM_{2.5}$ concentrations and dustfall rates	Water sprays at area to be graded – 50% CE Freshly graded areas to be kept to a minimum. Monthly dustfall rates should not exceed 600 mg/m²/day[a] at the single dustfall units DB01 to DB05. Monthly dustfall rates should not exceed 1 200 mg/m²/day[b] at the single dustfall units DB06.		
Wind erosion from exposed areas	PM_{10} and $PM_{2.5}$ concentrations and dustfall rates	Ensure exposed areas remain moist through regular water spraying during dry, windy periods. Monthly dustfall rates should not exceed 600 mg/m²/day[a] at the single dustfall units DB01 to DB05. Monthly dustfall rates should not exceed 1 200 mg/m²/day[b] at the single dustfall units DB06.		

Notes: (a) SA NDCR residential limit of 600 mg/m²/day
(b) SA NDCR non-residential limit of 1 200 mg/m²/day

Table 5-2: Air Quality Management Plan: operational phase of the proposed CCM

Aspect	Impact	Management Actions/Objectives	Responsible Person(s)	Target Date
Ventilation	PM_{10} and $PM_{2.5}$ concentrations and dustfall rates	It is recommended that ventilation emissions be monitored so that future modelling can be based on monitored data. Monthly dustfall rates should not exceed 600 mg/m²/day[(a)] at dustfall units DB01 to DB05. Monthly dustfall rates should not exceed 1 200 mg/m²/day[(b)] at dustfall unit DB06.	CCM Environmental Manager	On-going during operational phase
Vehicle activity on unpaved roads	PM_{10}, $PM_{2.5}$ concentrations and dustfall rates	A minimum mitigation measure of water sprays on unpaved roads to ensure a minimum of 75% CE (this could be achieved through a watering rate of (2 litres/m²/h). Monthly dustfall rates should not exceed 600 mg/m²/day[(a)] at dustfall units DB01 to DB05. Monthly dustfall rates should not exceed 1 200 mg/m²/day[(b)] at dustfall unit DB06.		
Materials handling	PM_{10} and $PM_{2.5}$ concentrations and dustfall rates	A minimum mitigation measure of water sprays at the product stockpile resulting in 50% CE. Monthly dustfall rates should not exceed 600 mg/m²/day[(a)] at dustfall units DB01 to DB05. Monthly dustfall rates should not exceed 1 200 mg/m²/day[(b)] at dustfall unit DB06.		
Crushing and screening	PM_{10} and $PM_{2.5}$ concentrations and dustfall rates	A minimum mitigation measure of water sprays at crushing and screening resulting in 50% CE. It is recommended that a permanent crushing and screening plant be installed where the crushers and screens have hooding with fabric filters. This can result in up to 83% CE. Monthly dustfall rates should not exceed 600 mg/m²/day[(a)] at dustfall units DB01 to DB05. Monthly dustfall rates should not exceed 1 200 mg/m²/day[(b)] at dustfall unit DB06.		
Wind erosion	PM_{10} and $PM_{2.5}$ concentrations and dustfall rates	A minimum mitigation measure of water sprays at the product stockpile resulting in a 50% CE. Monthly dustfall rates should not exceed 600 mg/m²/day[(a)] at dustfall units DB01 to DB05. Monthly dustfall rates should not exceed 1 200 mg/m²/day[(b)] at dustfall unit DB06.		
General	PM_{10} and $PM_{2.5}$ concentrations and dustfall rates	Dustfall buckets placed around the proposed project site and at sensitive receptors (DB01 to DB05). During operations monthly dustfall rates should not exceed 600 mg/m²/day[(a)]. Dustfall buckets placed at surface infrastructure (DB06). During operations monthly dustfall rates should not exceed 1 200 mg/m²/day[(b)]. $PM_{2.5}$ and PM_{10} ambient sampler with no exceedences of the selected criteria.		

Notes: (a) SA NDCR residential limit of 600 mg/m²/day.
(b) SA NDCR non-residential limit of 1 200 mg/m²/day.

Table 5-3: Air Quality Management Plan: decommissioning and closure phase (rehabilitation activities) for the proposed CCM

Aspect	Impact	Management Actions/Objectives	Responsible Person(s)	Target Date
Wind erosion from exposed areas	PM_{10} and $PM_{2.5}$ concentrations and dustfall rates	Demolition of infrastructure to have water sprays where a lot of vehicle activity is required. Ensure site is restored to pre-mining conditions.	Contractor(s) CCM Environmental Manager	Post-operational, can cease after vegetation cover is established

5.4 Performance Indicators

Increasingly environmental indicators are used in Environmental Land Use Planning and Management to simplify environmental assessments.

Indicators are defined as a single measure of a condition of an environmental element that represents the status or quality of that element. An index is a combination of a group of indicators to measure the overall status of an environmental element, and a threshold is the value of an indicator or index. For example, ambient PM_{10} concentrations monitored within a specific area will be the indicator, with the SA NAAQS being the threshold.

It is recommended that the criteria as listed in Section 2 be adopted as indicators for the proposed CCM. The relevant criteria applicable for the time period should be complied with, working toward the more stringent future limits.

5.4.1 Performance Indicators

Key performance indicators against which progress may be assessed form the basis for all effective environmental management practices. In the definition of key performance indicators careful attention is usually paid to ensure that progress towards their achievement is measurable, and that the targets set are achievable given available technology and experience.

Performance indicators are usually selected to reflect both the source of the emission directly and the impact on the receiving environment. Ensuring that no visible evidence of wind erosion exists represents an example of a source-based indicator, whereas maintaining off-site dustfall rates to below 600 mg/m^2/day represents an impact- or receptor-based performance indicator. Criteria for pollutant concentrations and dustfall rates have been published as indicated in Section 2. The adopted evaluation criteria discussed in Section 2 should not be exceeded.

5.4.2 Specification of Source Based Performance Indicators

It is recommended that dustfall rates in the immediate vicinity should be less than 1 200 mg/m^2/day for unpaved roads associated with on-site activities. This is not mandated by the NDCRs but is regarded to be good on-site management practice.

The absence of visible dust plume at all tipping points, crushers and screens would be the best indicator of effective control equipment in place. In addition, the dustfall rates in the immediate vicinity of various sources (materials handling points, unpaved roads, crushers and screens) should be less than 1 200 mg/m^2/day. Dustfall rates from all activities associated with the proposed CCM should not exceed 600 mg/m^2/day at sensitive receptors (according to the NDCRs) or off-site.

5.4.3 Receptor based Performance Indicators

Dustfall collection provides a useful and cost-effective tool to track the success of mitigation measures and overall dust generation from the proposed CCM. It is recommended that the proposed mine initiates monthly dustfall monitoring as well as ambient $PM_{2.5}$ and PM_{10} monitoring (Figure 5-1). $PM_{2.5}$ and PM_{10} sampling at the site should be conducted near the closest off-site residence (S16) (Figure 5-1).

- It is recommended that dust deposition monitoring be confined to sites within close proximity (<2 km) to the proposed operations. Monitoring should be undertaken using the American Society for Testing and Materials standard test method for the collection and analysis of dustfall (ASTM D-1739) (ASTM D1739-98, 2004). Logsheets should be kept providing information on the surrounding conditions (such as construction activities), sampling date and duration.

- $PM_{2.5}$ and PM_{10} monitoring is usually conducted every three days for 24 hours. Logsheets should be kept providing information on the surrounding conditions (such as construction activities), sampling date, duration, flow rate and filter number. This is essential for reporting on the $PM_{2.5}$ and PM_{10} concentrations.

5.4.4 Ambient Air Quality Monitoring

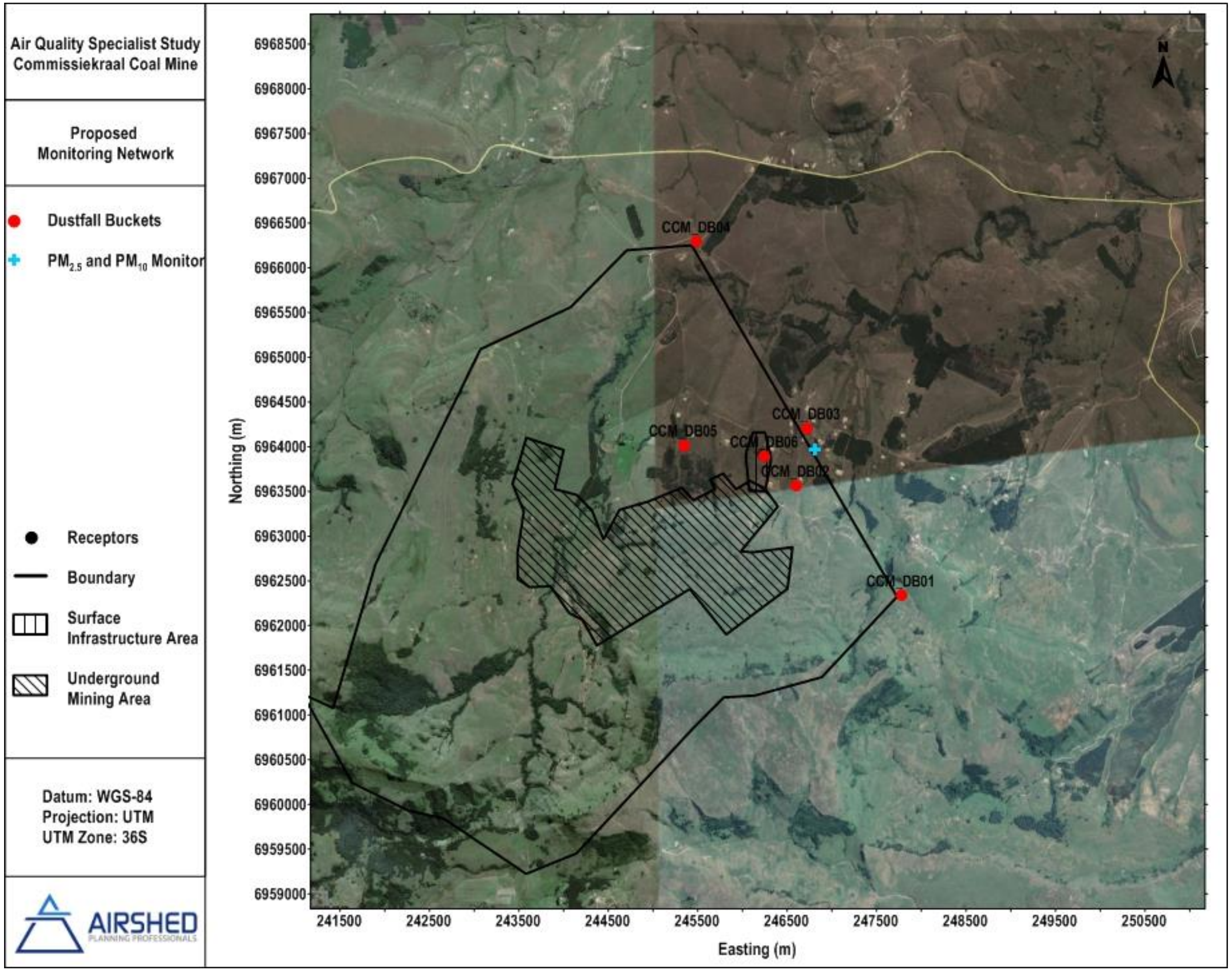

Figure 5-1: Proposed monitoring network for the proposed operations at the CCM

5.5 Record-keeping, Environmental Reporting and Community Liaison

5.5.1 Periodic Inspections and Audits

It is recommended that site inspections and progress reporting be undertaken at regular intervals (at least quarterly) during operations, with annual environmental audits being conducted. Results from site inspections and off-site monitoring efforts should be combined to determine progress against source- and receptor-based performance indicators. Progress should be reported to all interested and affected parties, including authorities and persons affected by pollution.

Corrective action or the implementation of contingency measures must be proposed to the stakeholder forum in the event that progress towards targets is indicated by the quarterly/annual reviews to be unsatisfactory.

5.5.2 Liaison Strategy for Communication with Interested and Affected Parties (I&APs)

Stakeholder forums provide possibly the most effective mechanisms for information dissemination and consultation. Forums will be held at least twice annually.

5.5.3 Management Costs

The budget should provide a clear indication of the capital and annual maintenance costs associated with dust control measures and dust monitoring plans. It may be necessary to make assumptions about the duration of aftercare prior to obtaining closure. This assumption must be made explicit so that the financial plan can be assessed within this framework.

The financial plan for air quality management and monitoring should be reviewed on an annual basis.

6 RESIDUAL AIR QUALITY IMPACTS

This section discusses the simulated results if additional mitigation measures, as recommended in Section 5, be implemented.

The selected and recommended mitigation measures and related dust control efficiencies applied to the residual modelling area listed in Table 6-1.

Table 6-1: Mitigation measures recommended and accounted for in the residual air quality impact assessment

Source	Mitigation Measure And Control Efficiencies
Vehicle activity on the unpaved roads	Regular water sprays on the unpaved roads to ensure a minimum of 75% CE
Materials transfer points	Materials handling at product stockpile to be controlled through water sprays resulting in 50% CE
Crushing and screening	Crushing and screening to be controlled through hooding with fabric filters resulting in 83% CE
Wind Erosion	Ensure product stockpile remains moist through regular water spraying during dry, windy periods (CE 50%)

6.1 Additionally Mitigated Atmospheric Emissions

Operational phase additionally mitigated

The source group contributions to total emissions are shown in Table 6-2. The most significant source of $PM_{2.5}$, PM_{10} and TSP is crushing and screening emissions contributing 68%, 50% and 64% to the overall $PM_{2.5}$, PM_{10} and TSP emissions, respectively. The second most significant source of TSP emissions is vehicle entrainment on unpaved roads. The second most significant source of $PM_{2.5}$ and PM_{10} emissions is ventilation.

Table 6-2: Summary of estimated particulate emission rates for the proposed additionally mitigated operational phase

Source Group	$PM_{2.5}$	PM_{10}	TSP	DPM	$PM_{2.5}$	PM_{10}	TSP	DPM	Additional Mitigation Measures
	tpa	tpa	tpa	tpa	%	%	%	%	
Additionally Mitigated									
Ventilation	2	7	7	2	20	24	9	80	None
Materials Handling	0.5	3	7	-	5	11	9	-	50% CE for water sprays at product stockpiles
Crushing and Screening	7	14	50	-	68	50	64	-	83% CE for hooding with fabric filters
Unpaved Roads	0.3	3	13	-	3	12	17	-	75% CE on unpaved roads by spraying additional water on roads
Wind Erosion	0.002	0.01	0.01	-	0	0	0	-	50% CE for water sprays on product stockpiles
Vehicle Exhaust	0.5	1	1	0.5	4	2	1	20	None

Source Group	$PM_{2.5}$	PM_{10}	TSP	DPM	$PM_{2.5}$	PM_{10}	TSP	DPM	Additional Mitigation Measures
	tpa	tpa	tpa	tpa	%	%	%	%	
Additionally Mitigated									
Total	**11**	**29**	**78**	**2.5**	**100**	**100**	**100**	**100**	

6.2 Screening of Simulated Additionally Mitigated Human Health Impacts

6.2.1.1 $PM_{2.5}$

- Simulated ***additionally mitigated*** $PM_{2.5}$ daily frequency of exceedence is shown in Figure 6-1 and $PM_{2.5}$ annual GLC is shown in Figure 6-2. Over a daily average, the concentrations exceeded the selected criteria of 40 µg/m³ for more than 4 days per year at one of the sensitive receptors on-site but not off-site (Figure 6-1). Over an annual average the simulated GLCs exceed the SA NAAQS at one of the sensitive receptors on-site but not off-site (Figure 6-2).
- The main contributing source to the ***additionally mitigated*** $PM_{2.5}$ simulated concentrations are still crushing and screening, but at much lower levels. The source that contributes the least to the ***additionally mitigated*** $PM_{2.5}$ simulated concentrations remains to be vehicle exhausts.

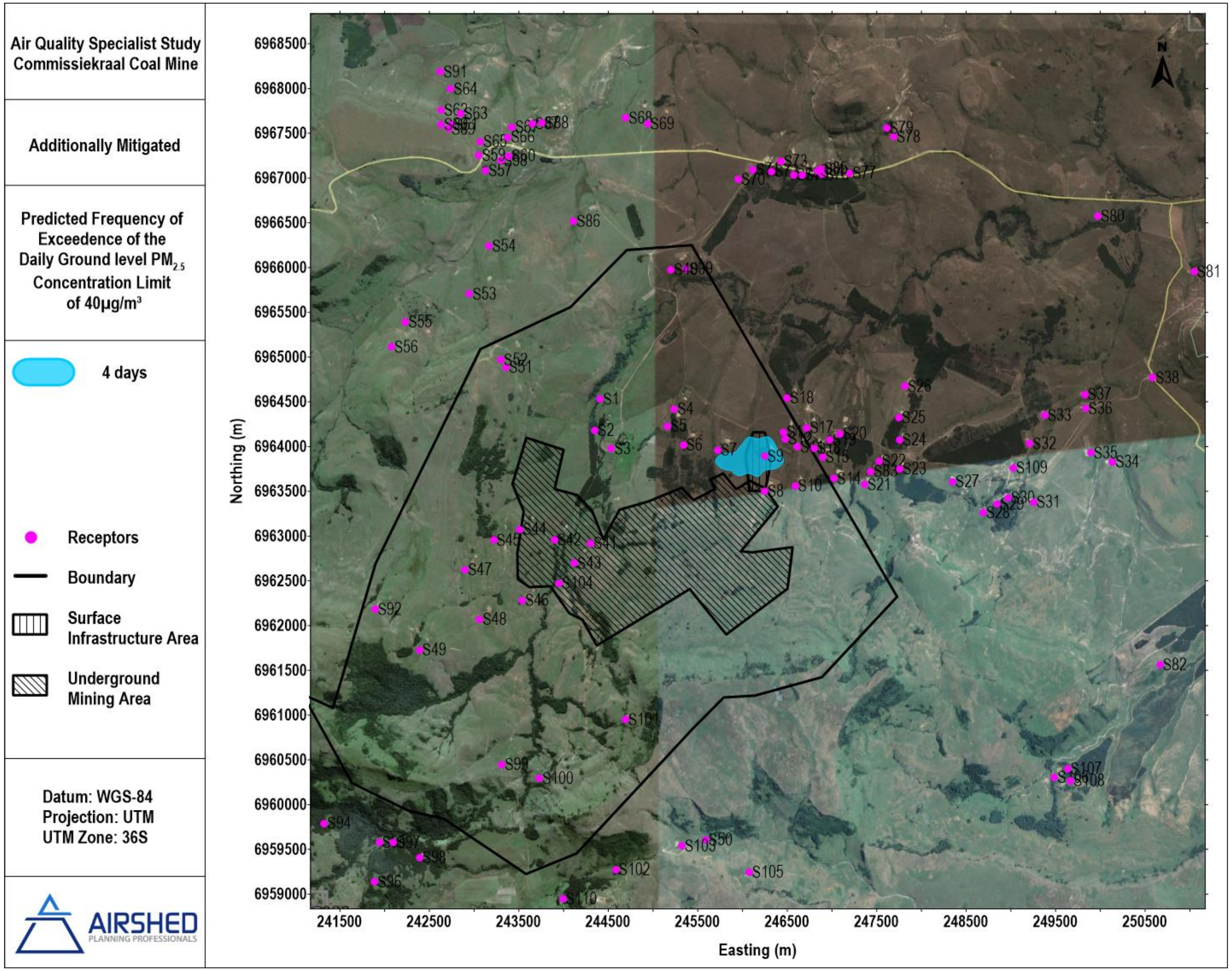

Figure 6-1: Additionally mitigated operational phase - Frequency of exceedance of the SA NAAQ limit of 40 µg/m³ for daily average $PM_{2.5}$ concentrations

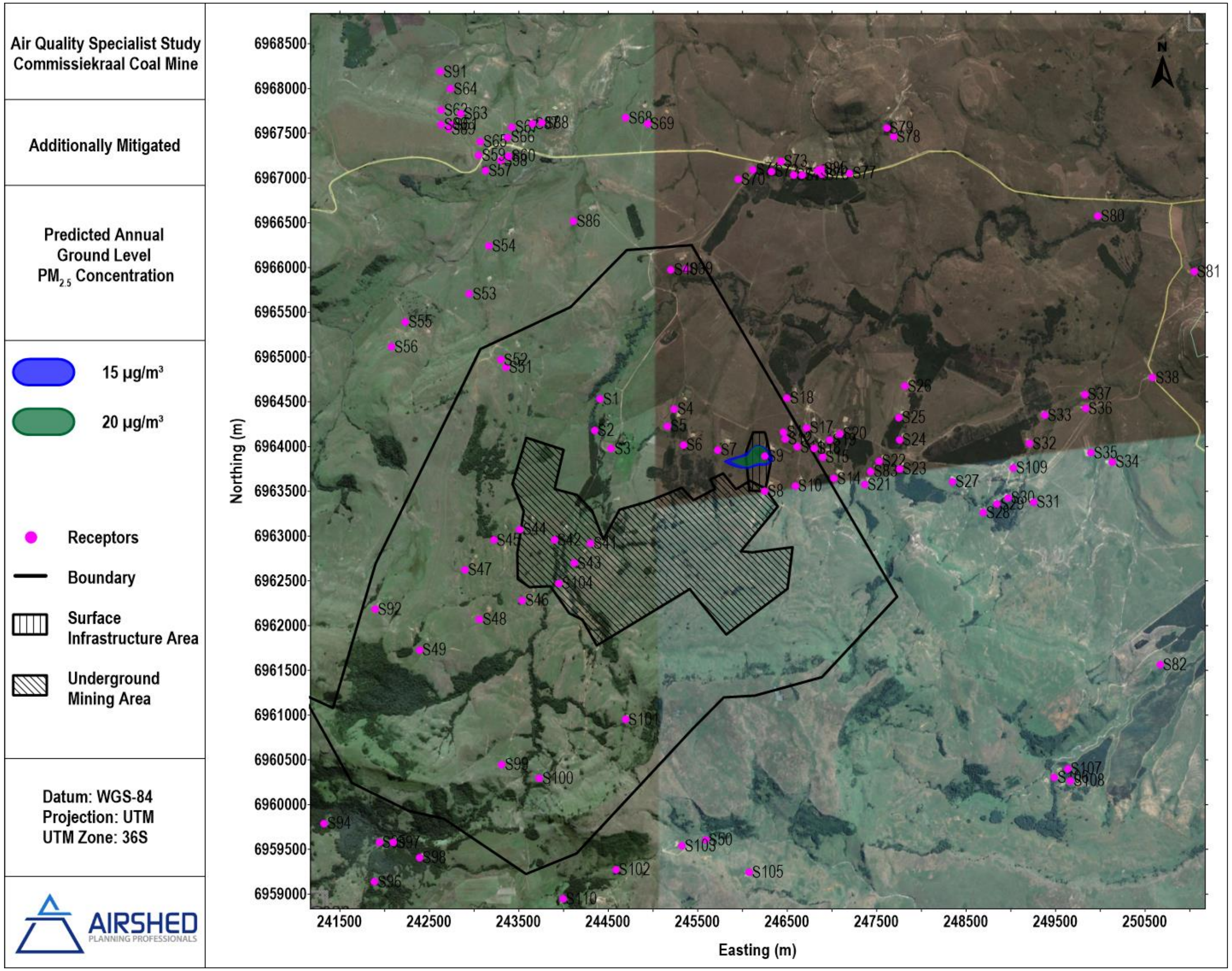

Figure 6-2: Additionally mitigated operational phase - Area of exceedance of the SA NAAQS for annual average $PM_{2.5}$ concentrations

6.2.1.2 PM_{10}

- Simulated ***additionally mitigated*** PM_{10} daily frequency of exceedence is shown in Figure 6-3 and PM_{10} annual GLCs are shown in Figure 6-4. Over a daily average, the concentrations exceed the NAAQ limit of 75 µg/m³ for more than 4 days per year at some of the sensitive receptors on-site but not for more than 4 days per year off-site (Figure 6-3). Over an annual average the simulated GLCs exceed the SA NAAQS at one of the sensitive receptors on-site but not off-site (Figure 6-4).
- The main contributing source to the ***additionally mitigated*** PM_{10} simulated concentrations continues crushing and screening, but at much lower GLCs. The source that contributes the least to the ***additionally mitigated*** PM_{10} simulated concentrations remains the vehicle exhausts.

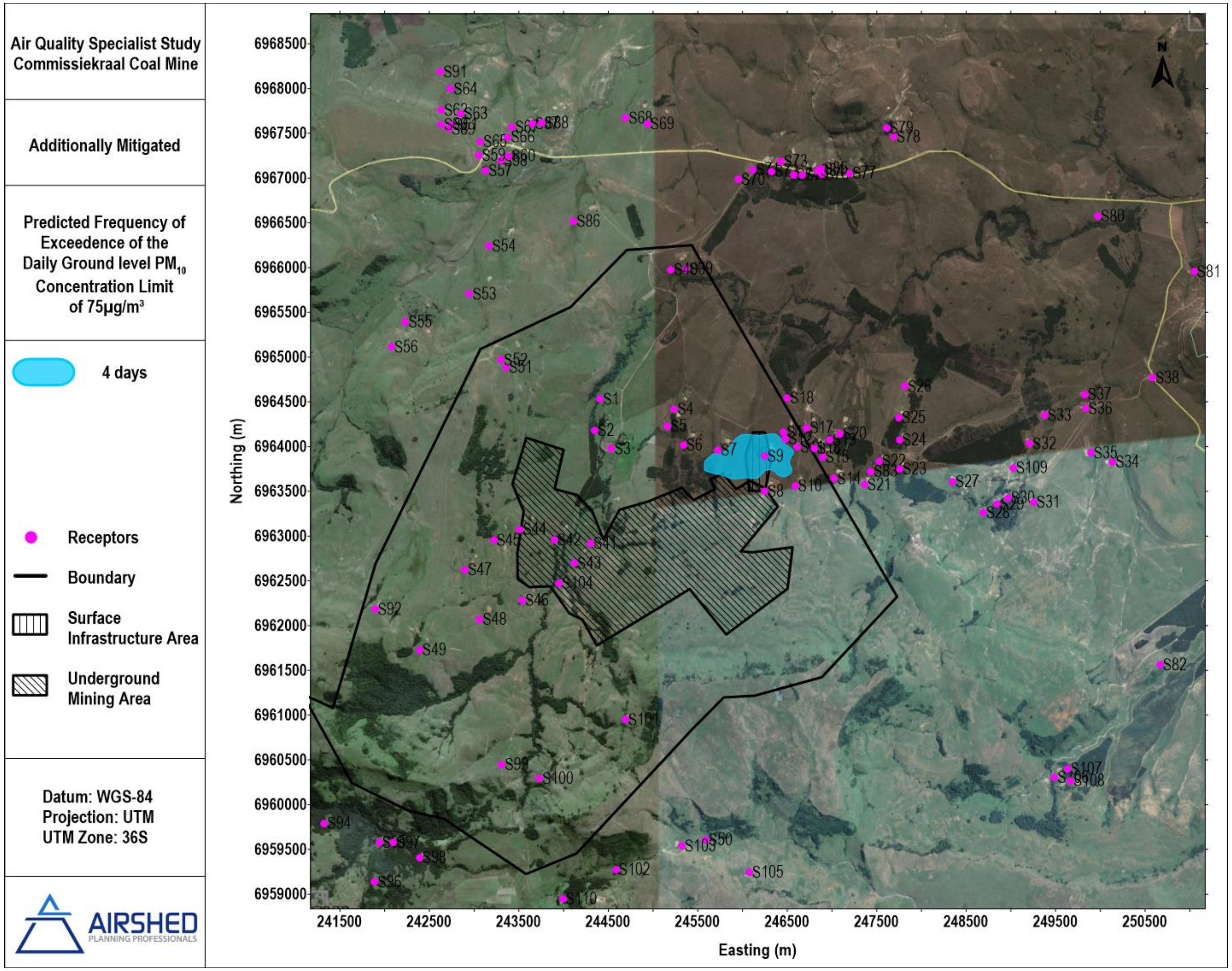

Figure 6-3: Additionally mitigated operational phase - Frequency of exceedance of the SA NAAQ limit of 75 µg/m³ for daily average PM_{10} concentrations

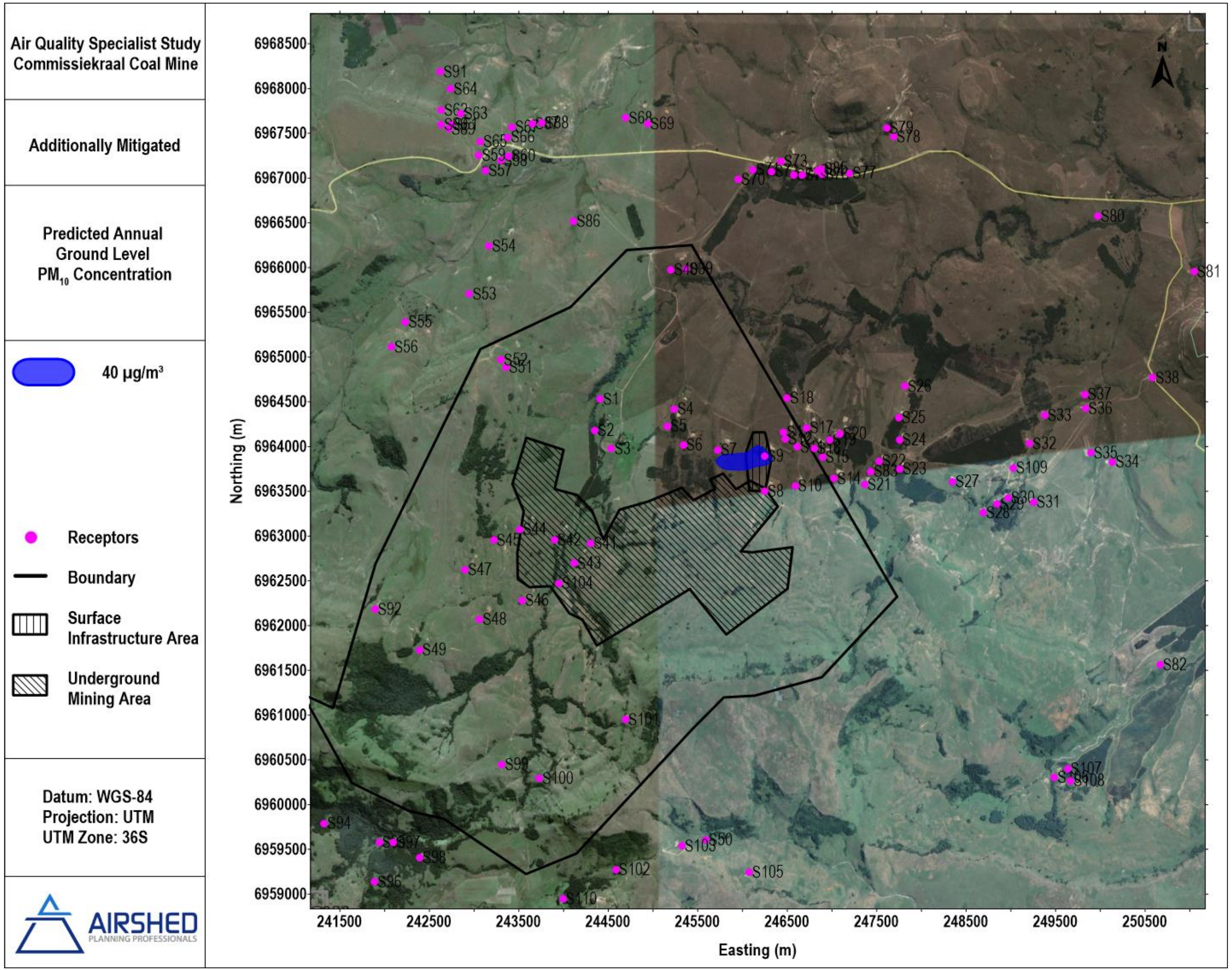

Figure 6-4: Additionally mitigated operational phase - Area of exceedance of the SA NAAQS for annual average PM_{10} concentrations

6.3 Analysis of Additionally Mitigated Emissions' Impact on the Environment (Dustfall)

- Simulated incremental dustfall rates for ***additionally mitigated operational phase*** operations are above the SA NDCR of 600 mg/m²/day for residential areas at one sensitive receptor on-site but below the SA NDCR of 600 mg/m²/day for residential areas off-site (Figure 6-5).
- The main contributing source to the ***additionally mitigated*** simulated dustfall rates remained to be crushing and screening but at much lower rates.

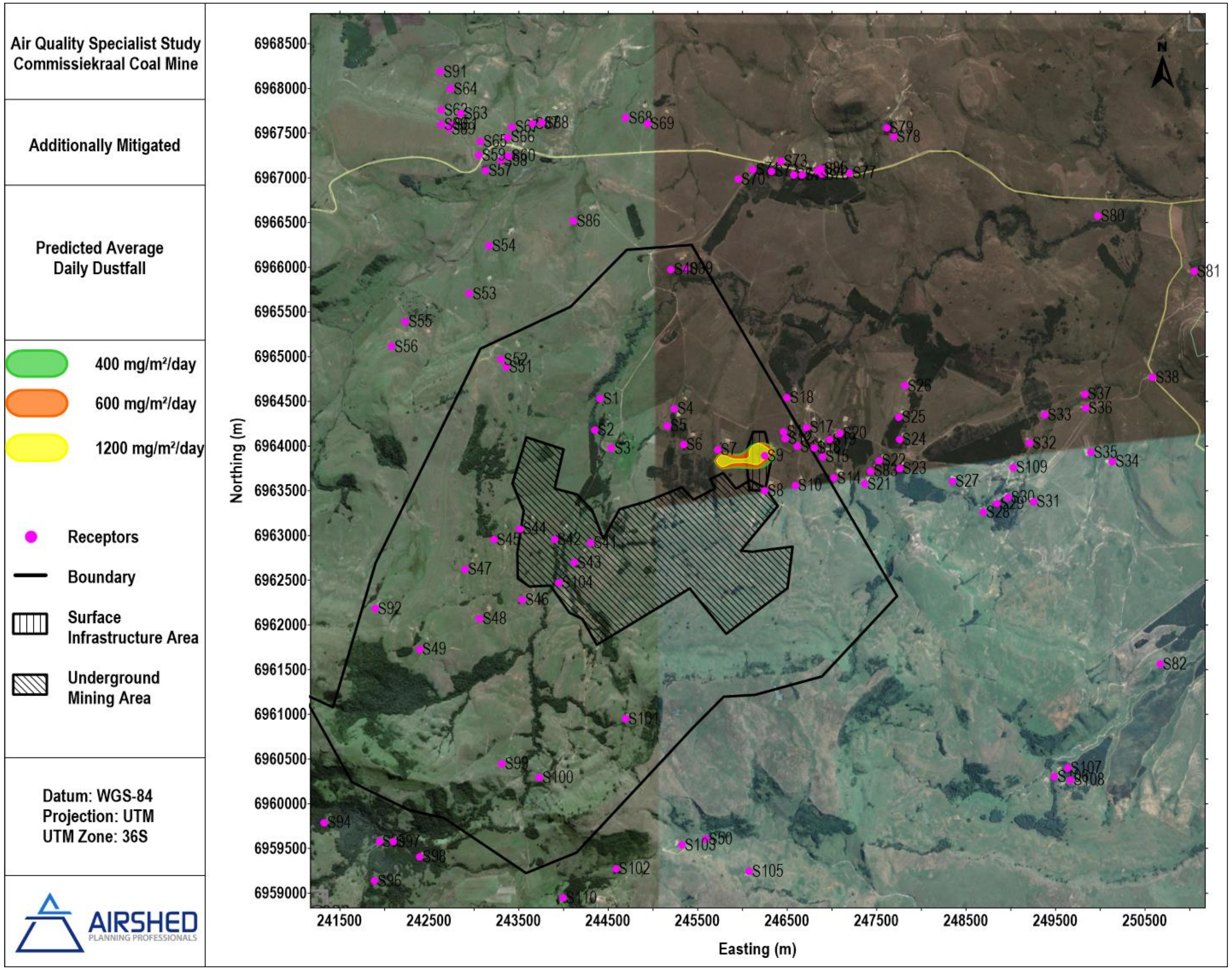

Figure 6-5: Predicted additionally mitigated operational phase daily dustfall rates (SA NDCR residential limit is 600 mg/m²/day)

6.4 Impact Significance Rating

The incremental impact's significance is described in Table 6-3.

Table 6-3: Impact assessment summary table for the operational phase for CCM

Scenario	Impact	Severity/ Nature of Impact	Duration of Impact	Spatial Scale of Impacts	Consequence	SIGNIFICANCE
Additionally mitigated	$PM_{2.5}$	M	M	L	M	Medium
	PM_{10}	M	M	L	M	Medium
	Dustfall	L	M	L	L	Low
	SO_2	L	M	L	L	Low
	NO_2	L	M	L	L	Low
	CO	L	M	L	L	Low
	DPM	L	M	L	L	Low

7 CONCLUSIONS AND RECOMMENDATIONS

7.1 Main Conclusions

The main conclusion is that the proposed CCM operations are likely to result in exceedances of the NAAQS for $PM_{2.5}$, PM_{10} and the NDCRs for dustfall at sensitive receptors located near the mine boundary. There is the possibility of exceedences outside the mine boundary and at sensitive receptors on a cumulative basis. Water sprays on unpaved roads, at crushers, screens, product materials handling points and the product stockpile, are still unlikely to result in compliance to national standards and regulations at sensitive receptors. If hooding with fabric filters is applied to crushers and screens instead of water sprays there is likely to be exceedences of the standards and regulations only at the on-site receptor but not off-site. Regarding the access road there are likely to be exceedences at sensitive receptors within 210 m from the road edge if no mitigation measures are applied to the road.

The environmental significance of the project operations is high without mitigation applied, medium-high with design mitigation and medium with additional mitigation applied. The change from high to medium environmental significance would advocate the use of additional mitigation measures. Regarding the access road the environmental significance at the sensitive receptors within 210 m from the road edge is high.

7.2 Recommendations

It is recommended that the proposed management and mitigation measures as set out in Section 5 be implemented over and above what is included as part of the CCM design. Recommendations include:

- Water sprays on unpaved road surfaces should achieve at least 75% CE;
- Water sprays at product materials handling points and product stockpile to achieve 50% CE;
- Hooding with fabric filters at crusher and screen (to achieve up to 83% CE);
- Dustfall; ambient PM_{10} and $PM_{2.5}$ sampling.

8 REFERENCES

Alade, L.O., 2010. *Characteristics of particulate matter over the South African industrialized Highveld.* Master of Science Research Report, School of Geography, Archaeology and Environmental Studies, University of the Witwatersrand, Johannesburg.

ASG, 2011. Air Quality Modelling Data Sets: The Atmospheric Studies Group at TRC. Retrieved September 11, 2011, from The Atmospheric Studies Group at TRC: http://www.src.com

AMS, 2014. Glossary of Meteorology. [Online] Available at: http://glossary.ametsoc.org/wiki/ [Accessed 2 June 2014].

ASTM Standard D1739-70, 1998. Standard Test Method for Collection and Measurement of Dustfall (Settleable Particulate Matter), ASTM International: West Conshohocken, PA, 4 pp.

ASTM Standard D1739-98, 2004. Standard test Method for Collections and Measurement of Dustfall (Settleable Particulate Matter). American Society for Testing and Materials.

Burger, L.W., Held, G. and Snow, N.H., 1997. Revised User's Manual for the Airborne Dust Dispersion Model from Area Sources (ADDAS). *Eskom TSI Report No. TRR/T97/066.*

Burger, L.W., 2010. Complexities in the estimation of emissions and impacts of wind generated fugitive dust. Proceedings of the National Association for Clean Air Conference, Polokwane 13 – 15 October 2010.

CEPA/FPAC Working Group 1998. *National Ambient Air Quality Objectives for Particulate Matter. Part 1: Science Assessment Document*, A Report by the Canadian Environmental Protection Agency (CEPA) Federal-Provincial Advisory Committee (FPAC) on Air Quality Objectives and Guidelines.

CERC, 2004. *ADMS Urban Training*. Version 2. Unit A.

Cowherd, C., and Englehart, J.; 1984. *Paved Road Particulate Emissions*, EPA-600/7-84-077, US Environmental Protection Agency, Cincinnati, OH.

Cowherd, C., Muleski, G. and Kinsey, J., 1988. *Control of Open Fugitive Dust Sources*, US Environmental Protection Agency, North Carolina.

DEA, 2009. National Environmental Management: Air Quality Act, 39 of 2004, National Ambient Air Quality Standards 1210. Government Gazette 32816. Republic of South Africa: s.n.

DEA, 2012. National Environmental Management: Air Quality Act, 39 of 2004, National Ambient Air Quality Standard for Particulate Matter with Aerodynamic Diameter less than 2.5 micron metres (PM2.5). Government Gazette 35463. Republic of South Africa: s.n.

DEA, 2013. National Environmental Management: Air Quality Act, 39 of 2004, National Dust Control Regulations. Government Gazette 36974. Republic of South Africa: s.n.

Ernst, W. 1981. Monitoring of particulate pollutants. In L. Steubing, & H.-J. Jager, *Monitoring of Air Pollutants by Plants: Methods and Problems.* The Hague: Dr W Junk Publishers.

Farmer, A.M. 1993 "The Effects of dust on vegetation-A review." *Environmental Pollution* 79: 63-75.

Grantz, D.A., Garner, J.H.B. and Johnson, D.W., 2003. Ecological effects of particulate matter. Env. Int 29 pp 213-239.

Hanna, S. R., Egan, B. A., Purdum, J. & Wagler, J., 1999. Evaluation of ISC3, AERMOD, and ADMS Dispersion Models with Observations from Five Field Sites, s.l.: s.n.

Harmens, H., Mills, G., Hayes, F., Williams, P., and De Temmerman, L., 2005. Air Pollution and Vegetation. The International Cooperative Programme on Effects of Air Pollution on Natural Vegetation and Crops Annual Report 2004/2005.

Holland R.E., Carson, T.L., and Donham, K.J., 2002. Chapter 6.2: Animal Health Effects. In: Iowa concentrated animal feeding operations air quality study. Iowa State University. http://www.deq.state.or.us/aq/dairy/docs/appendix/appendix_L.pdf#page=115. Access date: 2012-03-27.

Horzinek, M.C., and Lutz, H., 2001. Veterinary Sciences Tomorrow , http://www.vetscite.org. Access date: 2013-05-30.

Marticorena, B., and G., Bergametti, 1995: Modelling the Atmospheric Dust Cycle: 1. Design of a Soil-Derived Dust Emission Scheme. Journal of Geophysical Research, 100, 16415-16430

MFE, 2001. Good Practice Guide for Assessing and Managing the Environmental Effects of Dust Emissions, s.l.: New Zealand Ministry for the Environment.

Naidoo, G. and Chirkoot, D., 2004. The effects of coal dust on photosynthetic performance of the mangrove, Avicennia marina in Richards Bay, South Africa. Environmental Pollution 127 359–366.

NPI, 2008. Emission Estimation Technique Manual for Combustion Engines. Version 3. Australian Government Department of the Environment, Water, Heritage and the Arts.

NPI, 2012. Emission Estimation Technique Manual for Mining. Version 3.1. Australian Government Department of Sustainability, Environment, Water, Population and Communities.

Onursal, B. & Gautam, S., 1997. Vehicular Air Pollution: Experiences from Seven Latin American Urban Centers, World Bank Technical Paper No. 373, Washington DC.: World Bank.

Shao, Y., 2008. Physics and Modelling of Wind Erosion. Atmospheric and Oceanographic Science Library, 2nd Revised and Expanded Edition, Springer Science.

Spencer, S., 2001. Effects of coal dust on species composition of mosses and lichens in an arid environment. *Arid Environments* 49, 843-853.

Tiwary, A., and Colls, J., 2010. Air pollution: measurement, monitoring and mitigation. 3rd Edition ed. Oxon: Routledge.

US EPA, 1995. AP-42, 5th Edition, Volume I, Chapter 13: Miscellaneous Sources, 13.2.3 Heavy Construction Operations. [Online] Available at: http://www.epa.gov/ttn/chief/ap42/

US EPA, 1996. Compilation of Air Pollution Emission Factors (AP-42), 6th Edition, Volume 1, as contained in the AirCHIEF (AIR Clearinghouse for Inventories and Emission Factors) CD-ROM (compact disk read only memory), US Environmental Protection Agency, Research Triangle Park, North Carolina.

US EPA, 2006a. AP-42, 5th Edition, Volume I, Chapter 13: Miscellaneous Sources, 13.2.2 Unpaved Roads. [Online] Available at: http://www.epa.gov/ttn/chief/ap42/

US EPA, 2006b. AP-42, 5th Edition, Volume I, Chapter 13: Miscellaneous Sources, 13.2.5 Industrial Wind Erosion. [Online] Available at: http://www.epa.gov/ttn/chief/ap42/

9 APPENDIX A: EMISSIONS QUANTIFICATION METHODOLOGY

In the quantification of fugitive emissions such as fugitive dust releases from wind entrainment, vehicle entrainment, mining operations and materials handling it is recommended that use be made of emission factors. Given that no local emission factors are available it is proposed that reference be made to factors that are widely used internationally. The US EPA AP-42 Emission Factor Data Base is widely used for the quantification of fugitive and diffuse sources. Although this data base does not separately address processing operations it provides a comprehensive list of emission factors for use in mining and industrial processes. Separate emission factors are given for specific particle size ranges, viz. fine particulates in the inhalable range (PM_{10}) and TSP. TSP is quantified for the purpose of assessing dust nuisance impact potentials, whereas PM_{10} is of concern due to the potential for human health risks associated with this Inhalable fraction.

9.1 Fugitive Dust Emission Estimation

In the quantification of fugitive dust emissions such as materials handling operations and wind entrainment from tailings storage facilities use was primarily made of US EPA and NPI emission estimation factors and protocols.

9.1.1 *Vehicle entrained dust from unpaved roads*

Vehicle-entrained dust emissions have been found to account for a great portion of fugitive dust emissions from mining operations. The force of the wheels of vehicles travelling on the on-site unpaved roads causes the pulverisation of surface material. Particles are lifted and dropped from the rotating wheels, and the road surface is exposed to strong air currents in turbulent shear with the surface. The turbulent wake behind the vehicle continues to act on the road surface after the vehicle has passed. The quantity of dust emissions from unpaved roads varies linearly with the volume of traffic.

The unpaved road size-specific emission factor equation of the US EPA, used in the quantification of emissions, is given as follows:

$$E = k*(s/12)^{a}*(W/3)^{b}*281.9 \qquad (1)$$

where,

E	=	*emissions in g of particulates per vehicle kilometer travelled (g/VKT)*
k	=	*particle size multiplier (dimensionless);*
S	=	*silt content of road surface material (%);*
W	=	*mean vehicle weight (tonnes)*

The particle size multiplier in the equation (k) varies with aerodynamic particle size range and is given as 0.15 for $PM_{2.5}$, 1.5 for PM_{10} and 4.9 for TSP. The constants a and b are given as 0.9 and 0.45 respectively for $PM_{2.5}$, 0.9 and 0.45 respectively for PM_{10} and as 0.7 and 0.45 respectively for TSP.

9.1.2 *Materials handling*

The quantity of dust that will be generated from miscellaneous materials handling operations will depend on various climatic parameters, such as wind speed and precipitation, in addition to non-climatic parameters such as the nature and volume of the material handled. Fine particulates are most readily disaggregated and released to the atmosphere during the material transfer process, as a result of exposure to strong winds. Increases in the moisture content of the material being transferred would decrease the potential for dust emission, since moisture promotes the aggregation and cementation of fines to the surfaces of larger particles. The following US EPA AP42 predictive equation was used to estimate emissions from material transfer operations:

$$E = k*0.0016*(U/2.3)^{1.3}*(M/2)^{1.4} \qquad (2)$$

where,

E	=	*emissions in kg of particles per tonne of material transferred*
U	=	*mean wind speed (m/s)*
M	=	*material moisture content (%)*
k	=	*particle size multiplier ($k_{PM2.5}$ = 0.053; k_{PM10} = 0.35; k_{TSP} = 0.74)*

9.1.3 Crushing and screening

Crushing and screening operations can be a significant dust-generating source if uncontrolled. Dust fallout in the vicinity of crushers also give rise to the potential for re-entrainment of dust by vehicles or by wind at a later date. The large percentage of fines in the deposited material enhances the potential for it to become airborne.

Primary crushing, secondary crushing and screening will occur at the mine. Fugitive dust emissions due to the crushing and screening operations for mine were quantified using the NPI single valued emission factors for such operations. Emissions factors are provided for high moisture ore (moisture in excess of 4%) and low moisture ore (moisture less than 4%) (Table 9-1).

The crushing emission factors include emissions from the loading of crusher hoppers, crushing and unloading of crushers. The $PM_{2.5}$ emission factor is assumed to be 50% of the PM_{10} emission factor.

Table 9-1: Emission factors for metallic minerals crushing and screening

Source	Emission Factor (kg/tonne material processed)			
	Low Moisture Material[(a)]		High Moisture Material[(b)]	
	PM_{10}	TSP	PM_{10}	TSP
Primary crushing	0.02	0.2	0.004	0.01
Secondary crushing	0.04	0.6	0.012	0.03
Tertiary crushing	0.08	1.40	0.01	0.03
Screening	0.06	0.06	-	-

Notes:

(a) Moisture content of 4% or less
(b) Moisture content more than 4%

9.1.4 Ventilation

Table 9-2: SA occupational exposure limits (OEL)

SA OEL	$PM_{2.5}$	PM_{10}
mg/m³	3	10

Notes:

(a) 100% of the PM_{10} SA OEL is used for total particulates.

The SA OELs in mg/m³ were multiplied by the volumetric flow in m³/s to get the emission value in mg/s. The emission value in g/s was input into the model.

9.1.5 Wind Erosion

Wind erosion is a complex process, including three different phases of particle entrainment, transport and deposition. It is primarily influenced by atmospheric conditions (e.g. wind, precipitation and temperature), soil properties (e.g. soil texture, composition and aggregation), land-surface characteristics (e.g. topography, moisture, aerodynamic roughness length, vegetation and non-erodible elements) and land-use practice (e.g. farming, grazing and mining) (Shao, 2008).

Windblown dust generates from natural and anthropogenic sources. For wind erosion to occur, the wind speed needs to exceed a certain threshold, called the threshold velocity. This relates to gravity and the inter-particle cohesion that resists removal. Surface properties such as soil texture, soil moisture and vegetation cover influence the removal potential. Conversely, the friction velocity or wind shear at the surface, is related to atmospheric flow conditions and surface aerodynamic properties. Thus, for particles to become airborne, the wind shear at the surface must exceed the gravitational and cohesive forces acting upon them, called the threshold friction velocity (Shao, 2008).

Saltation and suspension are the two modes of airborne particles in the atmosphere. The former relates to larger sand particles that hop and can be deposited as the wind speed reduces or changes. Suspension refers to the finer dust particles that remain suspended in the atmosphere for longer and can disperse and be transported over large distances. It should be noted that wind erosion involves complex physics that is not yet fully understood (Shao, 2008).

Airshed has developed an in-house wind erosion model called ADDAS (Burger et al., 1997; Burger, 2010). This model, developed for specific use by Eskom in the quantification of fugitive emissions from its ash dumps, is based on the dust emission models proposed by Marticorena and Bergametti (1995) and more recently the one by Shao (2008). The model attempts to account for the variability in source erodibility through the parameterisation of the erosion threshold (based on the particle size distribution of the source) and the roughness length of the surface. In the quantification of wind erosion emissions, the model incorporates the calculation of two important parameters, viz. the threshold friction velocity of each particle size, and the vertically integrated horizontal dust flux, in the quantification of the vertical dust flux (i.e. the emission rate).

In the quantification of wind erodable emissions, the model incorporates the calculation of two important parameters, viz. the threshold friction velocity of each particle size, and the vertically integrated horizontal dust flux, in the quantification of the vertical dust flux (i.e. the emission rate). The equations used are as follows:

$$E_i = G_i 10^{(0.134C-6)} \qquad (3)$$

where,

$$G_i = 0.261 \frac{\rho_a}{g} U_*^3 (1+R_i)(1-R_i^2) \qquad (4)$$

$$R_i = \frac{U_{t*i}}{U_*} \qquad (5)$$

and,

E_i	=	Emission rate (size category i)
C	=	clay content (%)
ρ_a	=	air density
g	=	gravitational acceleration
U_*	=	frictional velocity
U_{t^*i}	=	threshold frictional velocity (size category i)

Dust mobilisation occurs only for wind velocities higher than a threshold value, and is not linearly dependent on the wind friction and velocity. The threshold friction velocity, defined as the minimum friction velocity required to initiate particle motion, is dependent on the size of the erodible particles and the effect of the wind shear stress on the surface. The threshold friction velocity decreases with a decrease in the particle diameter, for particles with diameters >60 µm. Particles with a diameter <60 µm result in increasingly high threshold friction velocities, due to the increasingly strong cohesion forces linking such particles to each other (Marticorena and Bergametti, 1995). The relationship between particle sizes ranging between 1 µm and 500 µm and threshold friction velocities (0.24 m/s to 3.5 m/s), estimated based on the equations proposed by Marticorena and Bergametti (1995), is illustrated in Figure 10-1.

The logarithmic wind speed profile may be used to estimate friction velocities from wind speed data recorded at a reference anemometer height of 10 m (US EPA, 2006b):

$$U^* = 0.053U_{10}^+ \qquad (6)$$

(This equation assumes a typical roughness height of 0.5 cm for open terrain, and is restricted to large relatively flat piles or exposed areas with little penetration into the surface layer.)

Equivalent friction velocity can also be calculated using a re-arrangement of the logarithmic distribution of the wind speed profile in the surface boundary (US EPA, 2006b):

$$U^* = \frac{KU_{10}}{\ln\left(\frac{Z}{Z_0}\right)} \qquad (7)$$

where,

U^*	=	friction velocity (m/s)
K	=	von Karma's constant (0.41)
Z	=	wind speed height (in this case 10 m)
Z_0	=	wind speed height (in this case 10 m)

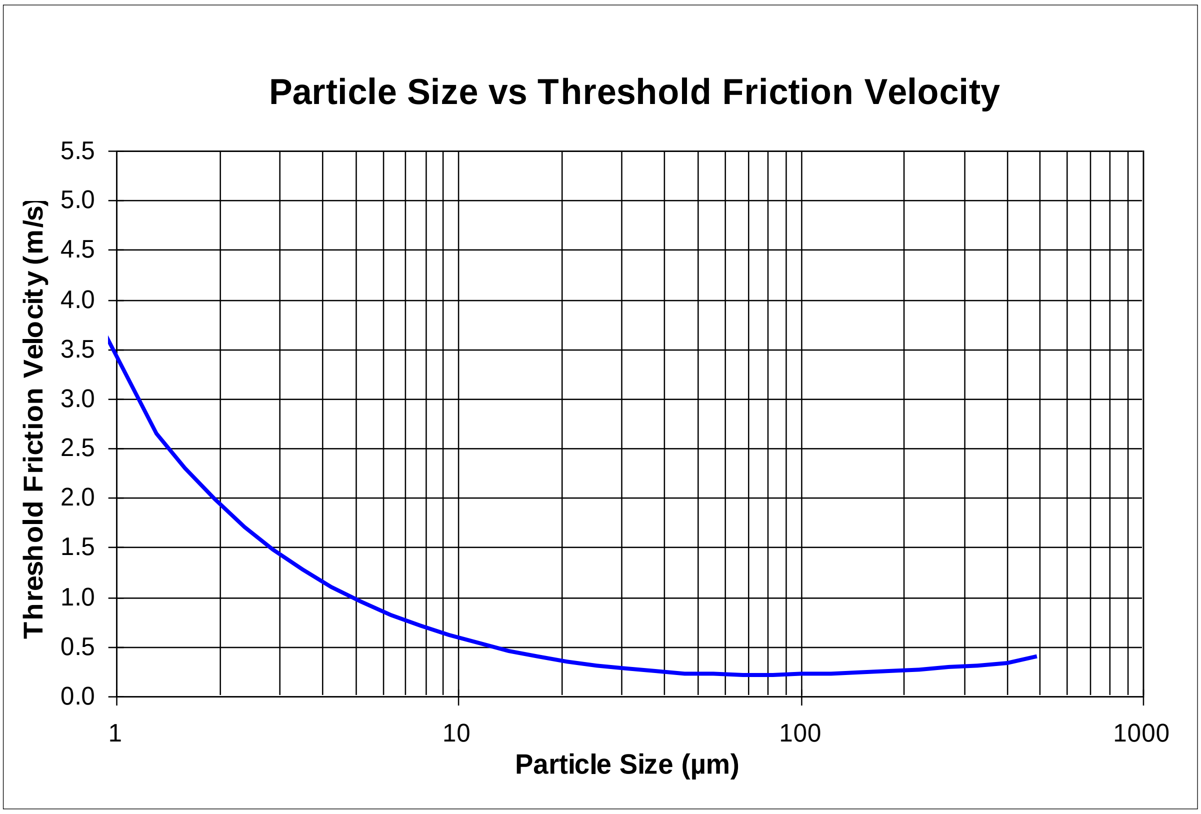

Figure 9-1: Relationship between particle sizes and threshold friction velocities using the calculation method proposed by Marticorena and Bergametti (1995).

The wind speed variation over the dump was based on the work of Cowherd et al. (1988). With the aid of physical modelling, the US EPA (2006b) has shown that the frontal face of an elevated pile (i.e. windward side) is exposed to wind speeds of the same order as the approach wind speed at the top of the pile. The ratios of surface wind speed (u_s) to approach wind speed (u_r), derived from wind tunnel studies for two representative pile shapes, are indicated in Figure 9-2 (viz. a conical pile, and an oval pile with a flat top and 37° side slope. The contours of normalised surface wind speeds are indicated for the oval, flat top pile for various pile orientations to the prevailing direction of airflow. (The higher the ratio, the greater the wind exposure potential.)

Particle size distribution data were taken from similar operations. The particle size distribution was taken into account both in the estimation of emissions and in the simulation of resultant dust fall and ambient PM_{10} concentrations.

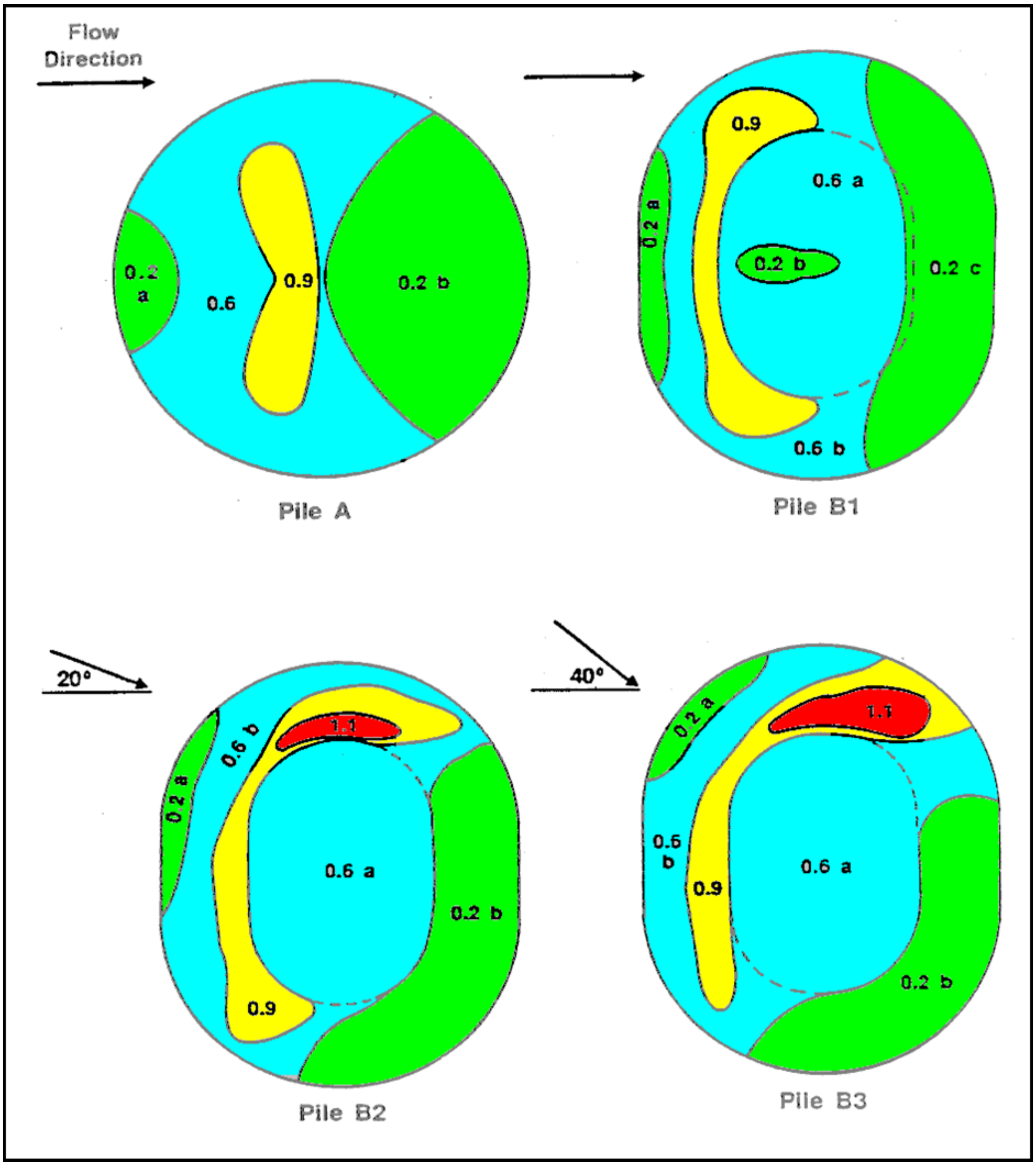

Figure 9-2: Contours of normalised surface wind speeds (i.e. surface wind speed/ approach wind speed) (after US EPA, 1996).

9.2 Vehicle Exhausts

$PM_{2.5}$, PM_{10}, CO, NO_x and SO_2 emission factors published by the NPI (NPI, 2008) for diesel vehicles are provided in Table 9-3. The diesel SO_2 emission factor is based on 10 ppm sulphur content.

Table 9-3: Vehicle exhaust emission factors

Mobile Equipment Type	Unit	$PM_{2.5}$	PM_{10}	CO	NO_x	SO_2	VOCs
Diesel Vehicle Exhaust Emissions (miscellaneous)	kg/l	$3.30x10^{-03}$	$3.60x10^{-03}$	$1.86x10^{-02}$	$4.50x10^{-02}$	$2.40x10^{-05}$	$4.20x10^{-03}$

10 APPENDIX B: DESCRIPTION OF SUITABLE ADDITIONAL POLLUTION ABATEMENT MEASURES

10.1 Crushing

The use of shrouds or enclosures for crushers can contain the dust so that a dust control system can operate more efficiently. The following measures are recommended for higher emission control effeciencies:

- A crusher feed box with a minimum number of openings should be installed;
- Rubber curtains should be used to minimize dust escape and air flow;
- The crusher should be choke fed to reduce air entrainment and dust emission; and
- Dust escape at the crusher discharge end can be minimized by properly designed and installed transfer chutes.

Dust from crushers is normally controlled by water sprays and local exhaust ventilation from the crusher enclosure. The amount of water needed to do the job is hard to specify since it depends on the type of material crushed and the degree to which water will cause downstream handling problems. If the ore is dry a starting point would be to add a water quantity equivalent to 1% of the weight of the material being crushed. The nozzle pressure of sprays should avoid stirring the dust cloud and reducing the capture efficiency of the ventilation system.

The amount of air required for dust control depends on how much the crusher can be enclosed. Enough air should be exhausted from a plenum under the crusher to produce a strong in-draught around the crusher.

Emission reductions that can typically be afforded are as follows (NPI, 2012):

- 65% for hooding with cyclones
- 75% for hooding with scrubbers
- 83% for hooding with fabric filters

11 APPENDIX C: IMPACT SIGNIFICANCE METHODOLOGY

Table 11-1: Criteria for assessment of impacts

PART A: DEFINITION AND CRITERIA*		
Definition of SIGNIFICANCE		**Significance = consequence x probability**
Definition of CONSEQUENCE		**Consequence is a function of severity, spatial extent and duration**
Criteria for ranking of the SEVERITY of environmental impacts	**H**	Substantial deterioration (death, illness or injury). Recommended level will often be violated. Vigorous community action.
	M	Moderate/ measurable deterioration (discomfort). Recommended level will occasionally be violated. Widespread complaints.
	L	Minor deterioration (nuisance or minor deterioration). Change not measurable/ will remain in the current range. Recommended level will never be violated. Sporadic complaints.
	L+	Minor improvement. Change not measurable/ will remain in the current range. Recommended level will never be violated. Sporadic complaints.
	M+	Moderate improvement. Will be within or better than the recommended level. No observed reaction.
	H+	Substantial improvement. Will be within or better than the recommended level. Favourable publicity.
Criteria for ranking the DURATION of impacts	**L**	Quickly reversible. Less than the project life. Short term
	M	Reversible over time. Life of the project. Medium term
	H	Permanent. Beyond closure. Long term.
Criteria for ranking the SPATIAL SCALE of impacts	**L**	Localised - Within the site boundary.
	M	Fairly widespread – Beyond the site boundary. Local
	H	Widespread – Far beyond site boundary. Regional/ national

PART B: DETERMINING CONSEQUENCE					
			SEVERITY = L		
DURATION	Long term	**H**	Medium	Medium	Medium
	Medium term	**M**	Low	Low	Medium
	Short term	**L**	Low	Low	Medium
			SEVERITY = M		
DURATION	Long term	**H**	Medium	High	High
	Medium term	**M**	Medium	Medium	High
	Short term	**L**	Low	Medium	Medium
			SEVERITY = H		
DURATION	Long term	**H**	High	High	High
	Medium term	**M**	Medium	Medium	High
	Short term	**L**	Medium	Medium	High
			L	**M**	**H**
			Localised Within site boundary Site	Fairly widespread Beyond site boundary Local	Widespread Far beyond site boundary Regional/ national
			SPATIAL SCALE		

PART C: DETERMINING SIGNIFICANCE					
PROBABILITY (of exposure to impacts)	Definite/ Continuous	**H**	Medium	Medium	High
	Possible/ frequent	**M**	Medium	Medium	High
	Unlikely/ seldom	**L**	Low	Low	Medium

	L	M	H
	CONSEQUENCE		

PART D: INTERPRETATION OF SIGNIFICANCE	
Significance	**Decision guideline**
High	It would influence the decision regardless of any possible mitigation.
Medium	It should have an influence on the decision unless it is mitigated.
Low	It will not have an influence on the decision.

***H = high, M= medium and L= low and + denotes a positive impact.**

12 APPENDIX D: AIR QUALITY SENSITIVE RECEPTORS' LOCATIONS

Table 12-1: Location of points of interest near CCM

ID	Latitude	Longitude
S1	-27.418737	30.414718
S2	-27.421867	30.414038
S3	-27.423752	30.415876
S4	-27.419845	30.423089
S5	-27.421554	30.422264
S6	-27.423500	30.423996
S7	-27.424080	30.427899
S8	-27.428338	30.433081
S9	-27.424811	30.433140
S10	-27.427862	30.436554
S11	-27.423964	30.436901
S12	-27.423103	30.435549
S13	-27.422413	30.435385
S14	-27.427217	30.440986
S15	-27.425019	30.439703
S16	-27.424131	30.438774
S17	-27.422033	30.438007
S18	-27.418981	30.435857
S19	-27.423323	30.440534
S20	-27.422698	30.441734
S21	-27.427896	30.444382
S22	-27.425531	30.446072
S23	-27.42637	30.448396
S24	-27.423433	30.448434
S25	-27.421212	30.448417
S26	-27.418065	30.449156
S27	-27.427772	30.454322
S28	-27.430961	30.457739
S29	-27.430119	30.459352
S30	-27.4295	30.460579
S31	-27.429979	30.463454
S32	-27.424091	30.463121
S33	-27.421285	30.464905
S34	-27.426098	30.472474

ID	Latitude	Longitude
S35	-27.425172	30.470034
S36	-27.420685	30.469541
S37	-27.419231	30.469475
S38	-27.417722	30.477174
S39	-27.405773	30.424743
S40	-27.405807	30.423044
S41	-27.433217	30.413302
S42	-27.432819	30.409204
S43	-27.435213	30.411432
S44	-27.431658	30.405352
S45	-27.432718	30.402347
S46	-27.43883	30.405437
S47	-27.435619	30.399061
S48	-27.440654	30.400607
S49	-27.443607	30.393713
S50	-27.463358	30.42562
S51	-27.41531	30.404164
S52	-27.414554	30.40359
S53	-27.40786	30.400225
S54	-27.403056	30.40255
S55	-27.410527	30.392909
S56	-27.413035	30.391248
S57	-27.39546	30.402303
S58	-27.39449	30.404048
S59	-27.393904	30.401591
S60	-27.394014	30.404958
S61	-27.390726	30.398542
S62	-27.389269	30.397431
S63	-27.389656	30.399671
S64	-27.387155	30.398579
S65	-27.392524	30.401791
S66	-27.392117	30.40493
S67	-27.391104	30.405435
S68	-27.390467	30.418277
S69	-27.391075	30.420712
S70	-27.39688	30.430853
S71 (School)	-27.395902	30.432526
S72	-27.396114	30.434617
S73	-27.395162	30.435675

ID	Latitude	Longitude
S74	-27.396516	30.437067
S75	-27.396558	30.438048
S76	-27.396541	30.440334
S77	-27.396454	30.443412
S78	-27.392907	30.448479
S79	-27.392003	30.44771
S80	-27.401316	30.471367
S81	-27.407116	30.482105
S82	-27.446644	30.47736
S83	-27.426539	30.445126
S84	-27.39614	30.439805
S85	-27.395956	30.440209
S86	-27.400738	30.412147
S87	-27.390832	30.407696
S88	-27.390754	30.408813
S89	-27.391213	30.398227
S90	-27.390715	30.397403
S91	-27.385415	30.397463
S92	-27.439441	30.388775
S93	-27.436208	30.381298
S94	-27.460864	30.382564
S95	-27.462893	30.388704
S96	-27.46689	30.388116
S97	-27.462975	30.390337
S98	-27.464547	30.393223
S99	-27.455323	30.402763
S100	-27.456806	30.406952
S101	-27.451061	30.416814
S102	-27.466149	30.415391
S103	-27.463913	30.4229
S104	-27.437176	30.409621
S105	-27.466699	30.430468
S106	-27.457775	30.465192
S107	-27.456935	30.466682
S108	-27.458128	30.466983
S109	-27.426508	30.46122
S110	-27.468994	30.409325

13 APPENDIX E: EXCEEDENCE TABLES

AQSRs at which exceedences occur are marked with a tick in the tables below.

Table 13-1: Unmitigated operational phase

Unmitigated					
Receptor	$PM_{2.5}$ Annual	$PM_{2.5}$ Daily FOE for 40 µg/m²	PM_{10} Annual	PM_{10} Daily FOE for 75 µg/m²	Dustfall
S4				✓ (4 days)	
S5				✓ (4 days)	
S6		✓ (7 days)		✓ (14 days)	
S7	✓ (15 µg/m³)	✓ (33 days)	✓ (42 µg/m³)	✓ (58 days)	
S8					
S9	✓ (112 µg/m³)	✓ (209 days)	✓ (274 µg/m³)	✓ (225 days)	✓ (16 007 mg/m²/day)
S10		✓ (33 days)		✓ (39 days)	
S11		✓ (27 days)		✓ (32 days)	
S12		✓ (22 days)		✓ (29 days)	
S13		✓ (17 days)		✓ (22 days)	
S14		✓ (11 days)		✓ (16 days)	

S15		✓ (13 days)		✓ (18 days)	
S16		✓ (15 days)		✓ (20 days)	
S17		✓ (6 days)		✓ (9 days)	
S18		✓ (4 days)		✓ (7 days)	
S19		✓ (6 days)		✓ (10 days)	
S20				✓ (5 days)	
S21				✓ (4 days)	
S22					
S83					

Table 13-2: Design mitigated operational phase

Design mitigated					
Receptor	$PM_{2.5}$ Annual	$PM_{2.5}$ Daily FOE for 40 µg/m²	PM_{10} Annual	PM_{10} Daily FOE for 75 µg/m²	Dustfall
S4					
S5					
S6					

S7		✓ (10 days)		✓ (21 days)	
S8					
S9	✓ (65 µg/m³)	✓ (165 days)	✓ (140 µg/m³)	✓ (179 days)	✓ (8 617 mg/m²/day)
S10		✓ (7 days)		✓ (13 days)	
S11		✓ (7 days)		✓ (11 days)	
S12		✓ (8 days)		✓ (10 days)	
S13		✓ (7 days)		✓ (10 days)	
S14				✓ (4 days)	
S15					
S16				✓ (4 days)	
S17					
S18					
S19					
S20					
S21					
S22					

S83					

Table 13-3: Additionally mitigated operational phase

Additionally mitigated					
Receptor	$PM_{2.5}$ Annual	$PM_{2.5}$ Daily FOE for 40 µg/m²	PM_{10} Annual	PM_{10} Daily FOE for 75 µg/m²	Dustfall
S4					
S5					
S6					
S7					
S8					
S9	✓ (26 µg/m³)	✓ (67 days)	✓ (58 µg/m³)	✓ (95 days)	✓ (3 521 mg/m²/day)
S10					
S11					
S12					
S13					

S14					
S15					
S16					
S17					
S18					
S19					
S20					
S21					
S22					
S83					

14 APPENDIX F: DUST EFFECTS ON VEGETATION AND ANIMALS

14.1 Dust Effects on Vegetation

Suspended particulate matter can produce a wide variety of effects on the physiology of vegetation that in many cases depend on the chemical composition of the particle. Heavy metals and other toxic particles have been shown to cause damage and death of some species as a result of both the phytotoxicity and the abrasive action during turbulent deposition (Harmens et al, 2005). Heavy loads of particle can also result in reduced light transmission to the chloroplasts and the occlusion of stomata (Harmens et al, 2005; Naidoo and Chirkoot, 2004), decreasing the efficiency of gaseous exchange (Harmens et al, 2005; Naidoo and Chirkoot, 2004, Ernst, 1981) and hence water loss (Harmens et al, 2005). They may also disrupt other physiological processes such as budbreak, pollination and light absorption/reflectance (Harmens et al, 2005). The chemical composition of the dust particles can also affect the plant and have indirect effects on the soil pH (Spencer, 2001).

To determine the impact of dust deposition on vegetation, two factors are of importance: (i) Does dust collect on vegetation and if it does, what are the factors influencing the rate of deposition (ii) Once the dust has deposited, what is the impact of the dust on the vegetation?

Regarding the first question, there is adequate evidence that dust does collect on all types of vegetation. Any type of vegetation causes a change in the local wind fields, with an increase in turbulence which enhances the collection efficiency. The characteristics of the vegetation influences the rate; the larger the “collecting elements” (branches and leaves), the lower the impaction efficiency per element. This would seem to indicate that, for the same volume of tree/shrub canopy, finer leaves will have a better collection efficiency. However, the roughness of the leaves themselves and particularly the presence of hairs on the leaves and stems plays a significant role, with veinous surfaces increasing deposition of 1-5 micron particles by up to seven times compared to smooth surfaces. Collection efficiency rises rapidly with particle size; for moderate wind speeds wind tunnel studies show a relationship of deposition velocity on the fourth power of particle size (Tiwary and Colls 2010). In wind tunnel studies , windbreaks or “shelter belts” of three rows of trees has shown a decrease in 35 to 56% in the downwind mass transport of inorganic particles.

On the effect of particulate matter once it is deposited on vegetation, this depends on the composition of the dust. Internationally it is recognised that there are major differences in the chemical composition of the fine PM (the fraction between 0 and 2.5 µm in aerodynamic diameter) and coarse PM (the fraction between 2.5 µm and 10 µm in aerodynamic diameter). The former is often the result of chemical reactions in the atmosphere and may have a high proportion of black carbon, sulphate and nitrate, whereas the latter often consist of primary particles resulting from abrasion, crushing, soil disturbances and wind erosion (Grantz et al. 2003). Sulphate is however often hygroscopic and may exist in significant fractions in coarse PM. Alade 2010. Grantz *et al* (*op .cit.*) do however indicate that sulphate is much less phototoxic than gaseous sulphur dioxide and that “it is unusual for injurious levels of particular sulphate to be deposited upon vegetation”.

Naidoo and Chirkoot conducted a study during the period October 2001 to April 2002 to investigate the effects of coal dust on Mangroves in the Richards Bay harbour. The investigation was conducted at two sites where 10 trees of the Mangrove species: *Avicennia Marina* were selected and mature, fully exposed, sun leaves tagged as being covered or uncovered with coal dust. From the study it was concluded that coal dust significantly reduced photosynthesis of upper and lower leaf surfaces. The reduced photosynthetic performance was expected to reduce growth and productivity. In addition, trees in close proximity to the coal stockpiles were in poorer health than those further away. Coal dust particles, which are composed predominantly of carbon were found not to be toxic to the leaves; neither wasit found that it occlude stomata as these particles were larger than fully open stomatal apertures (Naidoo and Chirkoot, 2004).

In general, according to the Canadian Environmental Protection Agency (CEPA), air pollution adversely affects plants in one of two ways. Either the quantity of output or yield is reduced or the quality of the product is lowered. The former (invisible) injury results from pollutant impacts on plant physiological or biochemical processes and can lead to significant loss of growth or yield in nutritional quality (e.g. protein content). The latter (visible) may take the form of discolouration of the leaf surface caused by internal cellular damage. Such injury can reduce the market value of agricultural crops for which visual appearance is important (e.g. lettuce and spinach). Visible injury tends to be associated with acute exposures at high pollutant concentrations whilst invisible injury is generally a consequence of chronic exposures to moderately elevated pollutant concentrations. However given the limited information available, specifically the lack of quantitative dose-effect information, it is not possible to define a Reference Level for vegetation and particulate matter (CEPA, 1998).

Exposure to a given concentration of airborne PM may therefore lead to widely differing phytotoxic responses, depending on the mix of the deposited particles. The majority of documented toxic effects indicate responses to the chemical composition of the particles. Direct effects have most often been observed around heavily industrialised point sources, but even there, effects are often associated with the chemistry of the particulate rather than with the mass of particulate.

14.2 Dust Effects on Animals

Most of the literature regarding air quality impacts and animals, specifically cattle, refers to the impacts from feedlots on the surrounding environment, hence where the feedlot is seen as the source of pollution. This mainly pertains to odours and dust generation. The US EPA has recently started to focus on the control of air pollution from feed yards and dairies, primarily regulating coarse particulate matter (Horzinek and Lutz, 2001). The National Cattle Beef Association in the USA in response has disputed this decision based on the lack of evidence on health impacts associated with coarse dust (TSP) concentrations.

A study was conducted by the State University of IOWA on the effects of air contaminants and emissions on animal health in swine facilities. Air pollutants included gases, particulates, bioaerosols, and toxic microbial by-products. The main findings were that ammonia is associated with lowered average number of pigs weaned, arthritis, porcine stress syndrome, muscle lesions, abscesses, and liver ascarid scars. Particulates are associated with the reduction in growth and turbine pathology, and bioaerosols could lower feed efficiency, decrease growth, and increase morbidity and mortality. The study concurred the lack of information on the health effects and productivity problems of air contaminants on cattle and other livestock. Ammonia and hydrogen sulphide are regarded the two most important inorganic gases affecting the respiratory system of cattle raised in confinement facilities, affecting the mucociliary transport and alveolar macrophage functions. With regard to particulates, it was found that it is the fine inhalable fraction that is mainly deriving from dried faecal dust (Holland et al., 2002). Another study conducted by DSM Nutritional Products North America indicated that calves exposed to a dust-stress environment continued to have lower serum vitamin E concentrations.

Inhalation of confinement house dust and gases produces a complex set of respiratory responses. An individual's response depends on characteristics of the inhaled components (such as composition, particle size and antigenicity) and of the individual's susceptibility, which is tempered by extant respiratory conditions. Most of the studies concurred that the main implication of dusty environments are causing animal stress which is detrimental to their health. However, no threshold levels exist to indicate at what levels these are having a negative effect. In this light it was decided to use the same screening criteria applied to human health, i.e. international standards and SA NDCR values