Air Quality Impact Assessment for the Proposed West Wits Mining Project

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

Report Compiled by:

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Report Details

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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 environmental impact practitioner and the consultant for delivery of specialised services as stipulated in the terms of reference.
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Revision Record

Revision Number	Date	Reason for Revision
Draft	February 2019	For client review
Revision 1	May 2019	Addressed client comments
Revision 2	May 2019	Addressed client comments

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NEMA Regulations (2014) (as amended) - Appendix 6	Relevant section in report
Details of the specialist who prepared the report	Section 1.3
The expertise of that person to compile a specialist report including a curriculum vitae	Section 1.3 and Appendix B
A declaration that the person is independent in a form as may be specified by the competent authority	Report details (Executive Summary) and Section 1.3
An indication of the scope of, and the purpose for which, the report was prepared	Section 1.2
An indication of the quality and age of base data used for the specialist report	Section 3.3
A description of existing impacts on the site, cumulative impacts of the proposed development and levels of acceptable change	Section 3.3 and Section 4.2
The duration, date and season of the site investigation and the relevance of the season to the outcome of the assessment	Section 3.3
A description of the methodology adopted in preparing the report or carrying out the specialised process inclusive of equipment and modelling used	Section 1.6
Details of an assessment of the specific identified sensitivity of the site related to the proposed activity or activities and its associated structures and infrastructure inclusive of a site plan identifying site alternative	Section 4
An identification of any areas to be avoided, including buffers	Not applicable
A map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers;	Section 1
A description of any assumptions made and any uncertainties or gaps in knowledge;	Section 1.7
A description of the findings and potential implications of such findings	Section 4.2

NEMA Regulations (2014) (as amended) - Appendix 6	Relevant section in report
on the impact of the proposed activity or activities	
Any mitigation measures for inclusion in the EMPr	Section 5
Any conditions for inclusion in the environmental authorisation	No comments received.
Any monitoring requirements for inclusion in the EMPr or environmental authorisation	Section 5
A reasoned opinion as to whether the proposed activity or portions thereof should be authorised and regarding the acceptability of the proposed activity or activities	Section 7
If the opinion is that the proposed activity or portions thereof should be authorised, any avoidance, management and mitigation measures that should be included in the EMPr, and where applicable, the closure plan	Section 5
A description of any consultation process that was undertaken during the course of preparing the specialist report	Not applicable.
A summary and copies of any comments received during any consultation process and where applicable all responses thereto	**Not applicable.**
Any other information requested by the competent authority.	Not applicable.

EXECUTIVE SUMMARY

West Wits Mining MLI (Pty) Ltd (West Wits) is applying for a mining right for the West Wits Mining Project in the area located to the south of Roodepoort and to the north of Soweto in the City of Johannesburg Metropolitan Municipality in Gauteng. The project would involve the development of five open pit mining areas (Mona Lisa Bird Reef Pit, Roodepoort Main Reef Pit, Rugby Club Main Reef Pit, 11 Shaft Main Reef Pit and Kimberley Reef East Pit) and the refurbishment of two existing infrastructure complexes (Bird Reef Central Infrastructure Complex and Kimberley Reef East Infrastructure Complex) to access the existing underground mine workings.

Modern mining methods and equipment for rock breaking will be employed to minimise the impact on nearby communities. The project would include the establishment of run of mine (ROM) stockpiles, topsoil stockpiles and waste rock dumps (WRDs) as well as supporting infrastructure including material storage and handling facilities, general and hazardous waste management facilities, sewage management facilities, water management infrastructure, communication and lighting facilities, centralised and satellite offices, workshops, washbays, stores, change houses, lamprooms, vent fans and security facilities.

Primary mineral processing will take place on site, where ore will be crushed prior to transportation offsite. All run-of mine material will be transported to an existing processing plant off-site for concentrating of minerals. The expected life of mine for the open pit operations is three to five years and 20 years for the Kimberley East underground workings and 10 years for the Bird Reef Central underground operations. The pits would be mined in a phased approach with each pit taking between six and 16 months to be mined and rehabilitated.

Airshed Planning Professionals (Pty) Ltd (Airshed) was appointed by SLR Consulting (South Africa) (Pty) Ltd to undertake an air quality specialist study for the proposed project as part of the Environmental Impact Assessment (EIA) process. This report outlines the findings of the air quality specialist study for inclusion in the EIA. Determination of the air quality impacts of the West Wits operations included:

- The assessment of site-specific atmospheric dispersion potential;
- The identification of existing sources of emissions in the area;
- The identification of the potential receptors within the vicinity of the proposed project sites;
- The characterisation of ambient air quality in the region based on observational data recorded to date (where available);
- The legislative and regulatory context, including South African National Ambient Air Quality Standards and National Dust Control Regulations;
- Identification of the potential impacts from proposed West Wits Mining Project operations on air quality that could affect environmental and/or human health.
- Quantification of expected emissions to atmosphere from the proposed West Wits Mining Project operations using available information and internationally published emission factors;
- Preparation of topographical, meteorological, land use, source, building and emissions data required for input to the dispersion model;
- Application of an approved atmospheric dispersion model and simulation of incremental and cumulative air pollutant concentrations of the identified pollutants occurring as a result of the proposed operations;
- Conducting of an air quality impact assessment including:
    - compliance evaluation of emissions and air pollutant concentrations based on South African National Ambient Air Quality Standards and National Dust Control Regulations;
    - analysis of the potential for local air quality impacts given potential receptor locations;
- Compilation of a specialist air quality impact assessment report.

The main findings from the baseline assessment are as follows:

- The flow field is dominated by winds from the north-north-east. During day-time conditions, winds from the north increase in frequency, with winds from the north-north-east sector increasing at night.
- Existing sources of emissions in the study area include vehicle exhaust and entrainment on paved and unpaved roads, household fuel burning, biomass burning (veld fires), industrial activities, mining operations and wind erosion from exposed areas and tailings storage facilities. High dust fallout rates recorded at all current sampling locations during the windy spring months from September to November indicates that wind erosion is likely a significant source of dust emissions in the study area.

The main findings from the impact assessment are as follows:

The main sources of dust emissions from the opencast mining operations are likely to be materials handling of ROM and waste rock in the pit and of waste rock at the WRD and vehicle entrainment emissions from haul trucks and other mobile equipment.

The main sources of dust emissions from the underground mining operations are the ventilation shafts and the aboveground handling of ROM.

With no mitigation measures applied, simulated highest daily PM_{10} concentrations exceed the National Ambient Air Quality Standards (NAAQS) at the closest potential receptor locations to the east, north and south for four of the open cast operations (the exception being the Mona Lisa pit). With simple mitigation measures such as wet suppression of dust at material handling points and regular water sprays on haul roads, simulated incremental PM_{10} concentrations due to the opencast mining operations would be in compliance with the SA NAAQS at all potential receptor locations (with the exception of Daily PM_{10} concentrations at the buildings to the south of Rugby Club and to the east of 11-Shaft. It is estimated that approximately 22 potential residential receptors are located to the east of 11 shaft and approximately 18 potential residential receptors to the south of Rugby Club.

Even with no mitigation measures applied simulated $PM_{2.5}$, NO_2, SO_2, and CO concentrations are in compliance with the SA NAAQS for all averaging periods and simulated highest monthly dust fallout rates are in compliance with the SA National Dust Control Regulations (NDCR) residential limit at all potential receptor locations and in compliance with the SA NDCR non-residential limit at all off-site areas.

Simulated incremental PM_{10} concentrations during the underground phase of the West Wits Mining Project exceed the SA NAAQS in the immediate vicinity of the infrastructure complexes (due to the handling of ROM), but are in compliance with the SA NAAQS at all potential receptor locations.

With no mitigation measures applied the incremental impact of the opencast phase of the West Wits Mining Project on the receiving environment is expected to be MEDIUM. With 50% mitigation of material handling emissions (achievable with the mitigation measures recommended below) and 30% mitigation of vehicle entrained dust from unpaved roads, the incremental impact of the opencast operations is expected to be LOW. The cumulative impact during the mining phase (with mitigation measures applied) is expected to be MEDIUM, but the short life of the open cast operations means that long term impacts (annual average pollutant concentrations) are unlikely to exceed the SA NAAQS. The impact of the underground operations on ambient air quality is considered LOW.

Based on the findings above the following recommendations are made:

It is recommended that:

- Best practice mitigation measures ("as far as reasonably possible, of any air pollution that may occur." – as per the requirements of the City of Johannesburg Metropolitan Municipality By-Laws) should be implemented for both the mining and rehabilitation phases of the opencast operations.
- A complaints register should be kept on-site once operations commence. Staff and the neighbouring communities should be encouraged to report all air quality related problems. Frequent community liaison meetings should be held with the neighbouring communities to address air quality related concerns.
- Wet suppression techniques should be used to control dust emissions, especially in areas where dry material is handled or stockpiled.
- Exposed soils and other erodible materials should be re-vegetated or covered promptly.
- New areas should be cleared and opened-up only when absolutely necessary.
- Surfaces should be re-vegetated or otherwise rendered non-dust forming when inactive.
- Storage for dusty materials should be enclosed or operated with efficient dust suppressing measures.
- Loading, transfer, and discharge of materials should take place with a minimum height of fall, and be shielded against the wind, and the use of dust suppression spray systems should be considered.
- Vehicles should be fitted with catalytic converters and low sulfur fuel should be used to minimise NO_2 and SO_2 impacts.
- Vehicle idle times should be kept to a minimum to minimise CO, NO_2, SO_2, diesel particulate and greenhouse gas emissions.
- Strict speed limits (as low as practically feasible, a maximum of 40km/hr, but preferably 20km/hr) should be imposed on all unpaved roads to reduce entrained emissions and fuel consumption rates.
- The vehicle fleet should be regularly serviced and maintained to minimise CO, NO_2, SO_2, diesel particulate and greenhouse gas emissions.
- Older vehicles in the current fleet should be replaced with newer, more fuel-efficient alternatives where feasible.
- Best practice mitigation measures (wind breaks, wet suppression, minimised drop heights) should be implemented on ROM handling operations during the underground phase of the West Wits Mining Project.
- PM_{10} monitoring is recommended for the duration of the mining and rehabilitation phases. The recommended location for PM_{10} monitoring is at the residential areas to the north or east of each the opencast mining operations (except Mona Lisa, which has no nearby receptors). The recommend location for sampling within these residential areas would be at a suitable location on the southern or western boundary of the residential area (i.e. closest to the opencast mining operations).
- It is recommended that PM_{10} concentrations be sampled prior to the construction phase of each of the open cast operations to assess baseline PM_{10} concentrations without the open cast operations active. PM_{10} sampling should continue throughout the life of each of the open cast operations to determine the impact of the operations on the receiving environment.
- If PM_{10} concentrations are found to be in exceedance of the NAAQS at the closest potential receptor locations additional dust suppression measures should be investigated.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS AND SYMBOLS

APCS	Air Pollution Control System
AQA	Air Quality Act
CEPA	Canadian Environmental Protection Agency
CO	Carbon monoxide
CO_2	Carbon dioxide
DEA	Department of Environmental Affairs (previously known as the Department of Environmental Affairs and Tourism-DEAT)
EIP	Environmental Impact Practitioner
EIR	Environmental Impact Report
g	Gram
HC	Hydro carbon
LMo	Monin-Obukhov length
m	Metre
m^2	Square metres
m^3	Cubic metres
mg	Milligram
NAAQS	National Ambient Air Quality Standards
NDCR	National Dust Control Regulations
NOAEL	No adverse effect levels
NO_x	Oxides of nitrogen
NO_2	Nitrogen dioxide
O_3	Ozone
Pb	Lead
PM	Particulate matter
PM_{10}	Particulate matter with an aerodynamic diameter of less than 10μm
$PM_{2.5}$	Particulate matter with an aerodynamic diameter of less than 2.5μm
ROM	Run of mine
SA	South Africa
SANS	South African National Standard
SO_2	Sulfur dioxide
t/a	Tonnes per annum
TSP	Total suspended particulates
µ	Micro
US-EPA	United States Environmental Protection Agency
WRD	Waste Rock Dump
WRF	Weather Research and Forecasting Model

Air Quality Impact Assessment Report for West Wits Mining Project

1 Introduction

West Wits Mining MLI (Pty) Ltd (West Wits) is applying for a mining right in the area located to the south of Roodepoort and to the north of Soweto in the City of Johannesburg Metropolitan Municipality in Gauteng. The proposed project would involve the development of five open pit mining areas (Mona Lisa Bird Reef Pit, Roodepoort Main Reef Pit, Rugby Club Main Reef Pit, 11 Shaft Main Reef Pit and Kimberley Reef East Pit) and the refurbishment of two existing infrastructure complexes (Bird Reef Central Infrastructure Complex and Kimberley Reef East Infrastructure Complex) to access the existing underground mine workings.

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1.1 Terms of Reference

The air quality characterisation includes:

- The assessment of site-specific atmospheric dispersion potential;
- The identification of existing sources of emissions in the area;
- The identification of the potential receptors within the vicinity of the proposed project site;
- The characterisation of ambient air quality in the region based on observational data recorded to date (if available);
- The legislative and regulatory context, including national ambient air quality standards;
- Identification of the potential impacts from proposed operations on air quality that could affect environmental and/or human health.
- Quantification of expected emissions to atmosphere from the West Wits Mining Project operations using available information and internationally published emission factors.
- Preparation of topographical, meteorological, land use, source, building and emissions data required for input to the dispersion model;

- Application of an approved atmospheric dispersion model and simulation of incremental and cumulative air pollutant concentrations of the identified pollutants occurring as a result of West Wits Mining Project operations;
- Conducting of an air quality impact assessment including:
    - compliance evaluation of emissions and air pollutant concentrations based on South African National Ambient Air Quality Standards and National Dust Control Regulations;
    - analysis of the potential for local air quality impacts given potential receptor locations;
- Compilation of a specialist air quality impact assessment report.

1.2 Assumptions and Limitations

In interpreting the study findings, it is important to note the assumptions and limitations of the assessment. The most important assumptions and limitations of the air quality impact assessment are summarised as follows:

- Information required to calculate emissions from fugitive dust sources for mining operations (throughputs, operating hours, equipment type) was provided by the Environmental Assessment Practitioner (EAP). It was assumed that this information is correct.
- Due to the absence of locally generated emission factors, use was made of the comprehensive set of emission factors published by the US Environmental Protection Agency (US-EPA) in its AP-42 document Compilation of Air Pollution Emission Factors as well as the Australian National Pollutant Inventory (NPI) emission estimation documents. These emissions factors are based on Australian and US conditions and due to no availability of South African conditions these are regarded to be the best estimates.
- It is assumed that the air coming from the vent shafts will comply with the SA Mine Health and Safety Act limits. This assumption is conservative, because if the ventilation system for West Wits Mining Project underground operations is well designed, underground particulate concentrations should be well below the exposure limits and consequently concentrations at the point of emissions will be well below the limit as well.
- Due to the absence of measured on-site meteorological data, use was made of Weather Research and Forecasting Model (WRF) modelled meteorological data for the period 2015 to 2017.
- No site-specific data was available for unpaved roads and the silt content was assumed to be 8%, the average for gold mines as published by the United States Environmental Protection Agency (US EPA).
- No on-site particle size distributions for wind erodible materials were available at this stage and particle size distributions and moisture content from waste rock dumps at other gold mines in South Africa were used.
- The mitigated scenario assumed 50% control efficiency on material handling operations and the crusher, achievable by reducing drop height, use of wind breaks and keeping material being handled moist.
- The mitigated scenario assumed 30% control efficiency of vehicle entrainment emissions from haul roads, achievable with regular water sprays.
- In the estimation of particulate emissions and the simulation of patterns of dispersion, a distinction is made between Total Suspended Particulates (TSP) and inhalable particulates (PM_{10}, which is particulate matter with an aerodynamic diameter of less than 10 µm). Whereas TSP is of interest due to its implications in terms of nuisance dust impacts, the PM_{10} fraction is taken into account to determine the potential for human health risks.
- There will always be some error in any geophysical model, but it is desirable to structure the model in such a way to minimise the total error. A model represents the most likely outcome of an ensemble of experimental results. The total uncertainty can be thought of as the sum of three components: the uncertainty due to errors in the model physics; the uncertainty due to data errors; and the uncertainty due to stochastic processes (turbulence) in the atmosphere.

1.3 Outline of Report

The regulatory requirements are discussed in Section 2. A description of the receiving environment is provided in Section 3 followed by an emissions inventory of expected emissions from the West Wits operations in Section 4. Section 5 comprises a discussion regarding the choice of dispersion model as well as the dispersion modelling results. A summary of the significance of impacts from the West Wits operations is given in Section 6.

2 Regulatory Requirements and Assessment Criteria

The environmental regulations and guidelines governing the emissions and impact of the proposed project need to be considered prior to potential impacts and potential receptors being identified.

Air quality guidelines and standards are fundamental to effective air quality management, providing the link between the source of atmospheric emissions and the user of that air at the downstream receptor site. The ambient air quality standards are intended to indicate safe daily exposure levels for the majority of the population, including the very young and the elderly, throughout an individual's lifetime. Air quality guidelines and standards are normally given for specific averaging periods. These averaging periods refer to the time-span over which the air concentration of the pollutant was monitored at a location. Generally, five averaging periods are applicable, namely an instantaneous peak, 1-hour average, 24-hour average, 1-month average, and annual average.

2.1 National Ambient Air Quality Standards

National Ambient Air Quality Standards (NAAQS) are available for inhalable particulate matter less than 2.5 µm in diameter ($PM_{2.5}$) gazetted on 29 June 2012 (no. 35463), inhalable particulate matter less than 10 µm in diameter (PM_{10}), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), ozone (O_3), carbon monoxide (CO), lead (Pb) and benzene gazetted on 24 December 2009. The NAAQS are provided in Table 2-1 with the pollutants of concern for the proposed project provided in bold text.

Table 2-1: South African National Ambient Air Quality Standards

Substance	Molecular formula / notation	Averaging period	Concentration limit (µg/m³)	Frequency of exceedance	Compliance date
Sulfur dioxide	SO_2	10 minutes	500	526	Immediate
		1 hour	350	88	Immediate
		24 hours	125	4	Immediate
		1 year	50	0	Immediate
Nitrogen dioxide	NO_2	1 hour	200	88	Immediate
		1 year	40	0	Immediate
Particulate matter	**PM_{10}**	**24 hour**	**75**	**4**	**Immediate**
		1 year	**40**	**0**	**Immediate**
Fine particulate matter	**$PM_{2.5}$**	**24 hour**	**40**	**4**	**1 Jan 2016 – 31 Dec 2029**
			25	**4**	**1 Jan 2030**
		1 year	**20**	**0**	**1 Jan 2016 – 31 Dec 2029**
			15	**0**	**1 Jan 2030**
Ozone	O_3	8 hours (running)	120	11	Immediate
Benzene	C_6H_6	1 year	5	0	1 Jan 2015
Lead	Pb	1 year	0.5	0	Immediate
Carbon monoxide	CO	1 hour	30 000	88	Immediate
		8 hour (calculated on 1 hour averages)	10 000	11	Immediate

2.2 National Regulations for Dust Deposition

South Africa's Draft National Dust Control Regulations were published on the 27 May 2011 with the dust fallout standards passed and subsequently published on the 1st of November 2013 (Government Gazette No. 36974). These are called the National Dust Control Regulations (NDCR). The purpose of the regulations is to prescribe general measures for the control of dust in all areas including residential and light commercial areas. Acceptable dustfall rates according to the regulation are summarised in Table 2-2.

Table 2-2: Acceptable dustfall rates

Restriction Area	Dustfall rate (D) (mg m^{-2} day^{-1}, 30-day average)	Permitted frequency of exceeding dust fall rate
Residential	D < 600	Two within a year, not sequential months.
Non-residential	600 < D < 1 200	Two within a year, not sequential months

The regulation also specifies that the method to be used for measuring dustfall and the guideline for locating sampling points shall be ASTM D1739 (1970), or equivalent method approved by any internationally recognized body. It is important to note that dustfall is assessed for nuisance impact and not inhalation health impact.

2.3 Reporting Requirements

Mines are classified under Group C as per Annexure A of the National Atmospheric Emission Reporting Regulations (GNR 283 of NEM:AQA (gazetted on 2 April 2015 – Government Gazette No 38633). As per this regulation, any person that holds a mining right or permit needs to annually submit emission reports in the format required by the National Atmospheric Emissions Inventory System (NAEIS).

2.4 Effect of Dust on Vegetation, Animals and Susceptible Human Receptors

2.4.1 Effects of Particular Matter on Vegetation

Since plants are constantly exposed to air, they are the primary receptors for both gaseous and particulate pollutants of the atmosphere. In terrestrial plant species, the enormous foliar surface area acts as a natural sink for pollutants especially the particulate ones. Vegetation is an effective indicator of the overall impact of air pollution particularly in context of Particulate matter (PM) (Rai, 2016).

There are two main types of direct injury that PM pollution can cause on plants: acute and chronic injury. Acute injury results from exposure to a high concentration of gas for a relatively short period and is manifested by clear visible symptoms on the foliage, often in the form of necrotic lesions. While this type of injury is very easy to detect (although not necessarily to diagnose), chronic injury is subtler: it results from prolonged exposure to lower gas concentrations and takes the form of growth and/or yield reductions, often with no clear visible symptoms. Plants that are constantly exposed to environmental pollutants absorb, accumulate and integrate these pollutants into their systems. It reported that depending on their sensitivity level, plants show visible changes which would include alteration in the biochemical processes or accumulation of certain metabolites (Rai, 2016). Pollutants can cause leaf injury, stomatal damage (Ricks and Williams, 1974, Hirano et al., 1995; Naidoo and Chirkoot; 2004; Harmens et al., 2005), premature senescence, decrease photosynthetic activity, disturb membrane permeability (Ernst, 1981; Naidoo and Chirkoot, 2004; Harmens et al., 2005) and reduce growth and yield in sensitive plant species. The long term, low-concentration exposures of air pollution produces harmful impacts on plant leaves without visible injury. Several studies have been conducted to assess the effects of pollution on different aspects of plant life such as overall growth and development, foliar morphology, anatomy, and bio chemical changes (Rai, 2016).

Plant leaves are the primary receptors for both gaseous and PM pollutants of the atmosphere. Before these pollutants enter the leaf tissue, they interact with foliar surface and modify its configuration. Dust deposition on leaf surface, consisting of ultra-fine and coarse particles, showed reduction in plant growth through its effect on leaf gas exchange, flowering and reproduction of plants, number of leaves and leaf area, one of the most common driving variables in growth analyses. Reduction in leaf area and leaf number may be due to decreased leaf production rate and enhanced senescence (Rai, 2016).

The chemical composition of the dust particles can also affect exposed plant tissue 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 accumulate on vegetation surfaces and if it does, what are the factors influencing the rate of deposition (ii) Once the dust has been deposited, what is the impact of the dust on the vegetation? Regarding the first question, there is adequate evidence that dust does accumulate on all types of vegetation. Any type of vegetation causes a change in the local wind fields, increasing turbulence and enhancing the collection efficiency. Vegetation structure alters the rate of dust deposition such that the larger the “collecting elements” (branches and leaves), the lower the impaction efficiency per element. Therefore, for the same volume of tree/shrub canopy, finer leaves will have better collection efficiencies. However, the roughness of the leaves themselves, in particularly the presence of hairs on the leaves and stems, plays a significant role, with venous surfaces increasing deposition of 1-5 µm particles by up to seven-times compared to smooth surfaces. Collection efficiency rises rapidly with particle size; wind tunnel studies show a relationship of deposition velocity on the fourth power of particle size for moderate wind speeds (Tiwary and Colls, 2010). Wind tunnel studies also show that windbreaks or “shelter belts” of three rows of trees have a decrease of between 35 and 56% of the downwind mass transport of inorganic particles.

After deposition onto vegetation, the effect of particulate matter depends on the composition of the dust. South African ambient standards are set in terms of $PM_{2.5}$ and PM_{10} (particulate matter smaller than 2.5 µm and 10 µm aerodynamic diameter) but 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, sulfate and nitrate; whereas the latter often consists of primary particles as a result of abrasion, crushing, soil disturbances and wind erosion (Grantz et al., 2003). Sulfate is however often hygroscopic and may exist in significant fractions in coarse PM. This has been shown at the Elandsfontein Eskom air quality monitoring station where the PM_{10} has been shown to vary between 15% (winter) and 49% (spring) sulfate (Alade, 2010). Grantz et al. (op. cit.) however indicate that sulfate is much less phototoxic than gaseous sulfur dioxide and that “it is unusual for injurious levels of particular sulfate to be deposited upon vegetation”.

According to the Canadian Environmental Protection Agency (CEPA), generally 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. 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/m²/day. Little direct evidence of the effects of dust-fall on South African vegetation, including crops, exists.

2.4.2 Effects of Particulate Matter on Animals

As presented by the Canadian Environmental Protection Agency (CEPA, 1998) studies using experimental animals have not provided convincing evidence of particle toxicity at ambient levels. Acute exposures (4-6 hour single exposures) of laboratory animals to a variety of types of particles, almost always at concentrations well above those occurring in the environment have been shown to cause:

- decreases in ventilatory lung function;
- changes in mucociliary clearance of particles from the lower respiratory tract (front line of defence in the conducting airways);
- increased number of alveolar macrophages and polymorphonuclear leukocytes in the alveoli (primary line of defence of the alveolar region against inhaled particles);
- alterations in immunologic responses (particle composition a factor, since particles with known cytotoxic properties, such as metals, affect the immune system to a significantly greater degree);
- changes in airway defence mechanisms against microbial infections (appears to be related to particle composition and not strictly a particle effect);
- increase or decrease in the ability of macrophages to phagocytize particles (also related to particle composition);
- a range of histologic, cellular and biochemical disturbances, including the production of proinflammatory cytokines and other mediators by the lungs alveolar macrophages (may be related to particle size, with greater effects occurring with ultrafine particles);
- increased electrocardiographic abnormalities (an indication of cardiovascular disturbance); and
- increased mortality.

Bronchial hypersensitivity to non-specific stimuli, and increased morbidity and mortality from cardio-respiratory symptoms, are most likely to occur in animals with pre-existing cardio-respiratory diseases. Sub-chronic and chronic exposure tests involved repeated exposures for at least half the lifetime of the test species. Particle mass concentrations to which test animals were exposed were very high (> 1 mg m^{-3}), greatly exceeding levels reported in the ambient environment. Exposure resulted in significant compromises in various lung functions similar to those seen in the acute studies, but including also:

- reductions in lung clearance;
- induction of histopathologic and cytologic changes (regardless of particle types, mass, concentration, duration of exposure or species examined);
- development of chronic alveolitis and fibrosis; and
- development of lung cancer (a particle and/or chemical effect).

The epidemiological finding of an association between 24-hour ambient particle levels below 100 µg/m^3 and mortality has not been substantiated by animal studies as far as PM_{10} and $PM_{2.5}$ are concerned. At ambient concentrations, none of the other particle types and sizes used in animal inhalation studies result in acute effects, including high mortality, with exception of ultrafine particles (0.1 µm). The lowest concentration of $PM_{2.5}$ reported that caused acute death in rats with acute pulmonary inflammation or chronic bronchitis was 250 g/m³ (3 days, 6 hour day-1), using continuous exposure to concentrated ambient particles.

Most of the literature regarding air quality impacts on 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 recently focussed on the control of air pollution from feed yards and dairies, primarily regulating coarse particulate matter. However, the link between particulates and public health is considered to be understudied (Sneeringer, 2009).

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 authors highlighted the general lack of information on the health effects and productivity-problems of air contaminants on cattle and other livestock. Ammonia and hydrogen sulfide 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. Holland et al., (2002) found that the fine inhalable particulate fraction is mainly derived from dried faecal dust.

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 (Davidson et al., 2005). Most studies concurred that the main implication of dusty environments is the stress caused to animals which is detrimental to their general 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. the South African Standards and SANS limit values.

2.4.3 Effect of Particulate Matter on Susceptible Human Receptors

The impact of particles on human health is largely depended on (i) particle characteristics, particularly particle size and chemical composition, and (ii) the duration, frequency and magnitude of exposure. The potential of particles to be inhaled and deposited in the lung is a function of the aerodynamic characteristics of particles in flow streams. The aerodynamic properties of particles are related to their size, shape and density. The deposition of particles in different regions of the respiratory system depends on their size.

The nasal openings permit very large dust particles to enter the nasal region, along with much finer airborne particulates. These larger particles are deposited in the nasal region by impaction on the hairs of the nose or at the bends of the nasal passages. The smaller particles (PM_{10}) pass through the nasal region and are deposited in the tracheobronchial and pulmonary regions. Then particles are removed by impacting with the wall of the bronchi when they are unable to follow the gaseous streamline flow through subsequent bifurcations of the bronchial tree. As the airflow decreases near the terminal bronchi, the smallest particles are removed by Brownian motion, which pushes them to the alveolar membrane (CEPA, 1998; Dockery and Pope, 1994).

The air quality guidelines for particulates are given for various particle size fractions, including TSP, thoracic particulates or PM_{10}, and respirable particulates or $PM_{2.5}$. Although TSP is defined as all particulates with an aerodynamic diameter of less than 100 µm, and effective upper limit of 30 µm aerodynamic diameter is frequently assigned. The PM_{10} and $PM_{2.5}$ are of concern due to their health impact potentials. As indicated previously, such fine particles are deposited in, and damage the lower airways and gas-exchanging portions of the lung.

The World Health Organization states that the evidence on airborne particulates and public health consistently shows adverse health effects at exposures experienced by urban populations throughout the world. The range of effects is broad, affecting the respiratory and cardiovascular systems and extending from children to adults including large susceptible groups within the general population. Long-term exposure to particulate matter has been found to have adverse effects on human respiratory health (Abbey et al., 1995). Respiratory symptoms in children resident in an industrialised city were initially found not to be associated with long-term exposure to particulate matter; however non-asthmatic symptoms and hospitalizations did increase with increased total suspended particulate concentrations (Hruba et al., 2001). Subsequently, epidemiological evidence shows adverse effects of particles after both short-term and long-term exposures. Current scientific evidence indicates that guidelines cannot be proposed that will lead to complete protection against adverse health effects as thresholds (or no adverse effect levels (NOAEL) have not been identified.

Many scientific studies have linked inhaled particulate matter to a series of significant health problems, including:

- Aggravated asthma and associated hospitalisation or emergence department admission, even for coarse particulate ($PM_{2.5}$ to PM_{10}) (Keet et al 2017);
- Hospital admissions for respiratory and cardiovascular diseases associated with fine particulate ($PM_{2.5}$) exposure, even at levels consistently below limit values (Makar et al 2017)
- Kidney, bladder and colorectal cancer (Turner et al 2017)
- Ischaemic heart disease (Lim et al 2015)
- Increases in respiratory symptoms like coughing and difficult or painful breathing;
- Chronic bronchitis;
- Decreased lung function; and,
- Premature death.

PM_{10} is the standard measure of particulate air pollution used worldwide and studies suggest that asthma symptoms can be worsened by increases in the levels of PM_{10}, which is a complex mixture of particle types. PM_{10} has many components and there is no general agreement regarding which component(s) could exacerbate asthma. However, pro-inflammatory effects of transition metals, hydrocarbons, ultrafine particles (due to combustion processes) and endotoxins - all present to varying degrees in PM_{10} - could be important.

Exposure to motor traffic emissions can have a significant effect on respiratory function in children and adults. Studies show that children living near heavily travelled roadways have significantly higher rates of wheezing and diagnosed asthma.

2.5 Regulations regarding Air Dispersion Modelling

Air dispersion modelling provides a cost-effective means for assessing the impact of air emission sources, the major focus of which is to determine compliance with the relevant ambient air quality standards. Regulations regarding Air Dispersion Modelling were promulgated in Government Gazette No. 37804 vol. 589; 11 July 2014, (DEA, 2014) and recommend a suite of dispersion models to be applied for regulatory practices as well as guidance on modelling input requirements, protocols and procedures to be followed. The Regulations regarding Air Dispersion Modelling are applicable –

(a) in the development of an air quality management plan, as contemplated in Chapter 3 of the Air Quality Act (AQA);
(b) in the development of a priority area air quality management plan, as contemplated in section 19 of the AQA;
(c) in the development of an atmospheric impact report, as contemplated in section 30 of the AQA; and,
(d) in the development of a specialist air quality impact assessment study, as contemplated in Chapter 5 of the AQA.

The Regulations have been applied to the development of this report. The first step in the dispersion modelling exercise requires a clear objective of the modelling exercise and thereby gives direction to the choice of the dispersion model most suited for the purpose. Chapter 2 of the Regulations present the typical levels of assessments, technical summaries of the prescribed models (SCREEN3, AERSCREEN, AERMOD, SCIPUFF, and CALPUFF) and good practice steps to be taken for modelling applications. The proposed operation falls under a Level 2 assessment – described as follows;

- The distribution of pollutants concentrations and depositions are required in time and space.
- Pollutant dispersion can be reasonably treated by a straight-line, steady-state, Gaussian plume model with first order chemical transformation. The model specifically to be used in the air quality impact assessment of the proposed operation is AERMOD.
- Emissions are from sources where the greatest impacts are in the order of a few kilometres (less than 50 km) downwind.

Dispersion modelling provides a versatile means of assessing various emission options for the management of emissions from existing or proposed installations. Chapter 3 of the Regulations prescribe the source data input to be used in the models. Dispersion modelling can typically be used in the:

- Apportionment of individual sources for installations with multiple sources. In this way, the individual contribution of each source to the maximum ambient predicted concentration can be determined. This may be extended to the study of cumulative impact assessments where modelling can be used to model numerous installations and to investigate the impact of individual installations and sources on the maximum ambient pollutant concentrations.
- Analysis of ground level concentration changes as a result of different release conditions (e.g. by changing stack heights, diameters and operating conditions such as exit gas velocity and temperatures).
- Assessment of variable emissions as a result of process variations, start-up, shut-down or abnormal operations.
- Specification and planning of ambient air monitoring programs which, in addition to the location of potential receptors, are often based on the prediction of air quality hotspots.

The above options can be used to determine the most cost-effective strategy for compliance with the NAAQS. Dispersion models are particularly useful under circumstances where the maximum ambient concentration approaches the ambient air quality limit value and provide a means for establishing the preferred combination of mitigation measures that may be required including:

- Stack height increases;
- Reduction in pollutant emissions through the use of air pollution control systems (APCS) or process variations;
- Switching from continuous to non-continuous process operations or from full to partial load.

Chapter 4 of the Regulations prescribe meteorological data input from onsite observations to simulated meteorological data. The chapter also gives information on how missing data and calm conditions are to be treated in modelling applications. Meteorology is fundamental for the dispersion of pollutants because it is the primary factor determining the diluting effect of the atmosphere. Therefore, it is important that meteorology is carefully considered when modelling.

Topography is also an important geophysical parameter. The presence of terrain can lead to significantly higher ambient concentrations than would occur in the absence of the terrain feature. In particular, where there is a significant relative difference in elevation between the source and off-site receptors large ground level concentrations can result. Thus the accurate determination of terrain elevations in air dispersion models is very important.

The modelling domain would normally be decided on the expected zone of influence; the latter extent being defined by the predicted ground level concentrations from initial model runs. The modelling domain must include all areas where the ground level concentration is significant when compared to the air quality limit value (or other guideline). Air dispersion models require a receptor grid at which ground-level concentrations can be calculated. The receptor grid size should include the entire modelling domain to ensure that the maximum ground-level concentration is captured and the grid resolution (distance between grid points) sufficiently small to ensure that areas of maximum impact are adequately covered. No receptors however should be located within the property line as health and safety legislation (rather than ambient air quality standards) is applicable within the site.

Chapter 5 provides general guidance on geophysical data, model domain and coordinates system required in dispersion modelling, whereas Chapter 6 elaborates more on these parameters as well as the inclusion of background air concentration data. The chapter also provides guidance on the treatment of NO_2 formation from NO_x emissions, chemical transformation of sulfur dioxide into sulfates and deposition processes.

Chapter 7 of the Regulations outline how the plan of study and modelling assessment reports are to be presented to authorities.

2.6 Vaal Triangle Priority Area

The proposed West Wits surface operations fall just outside the northern boundary of the Vaal Triangle Airshed Priority Area (VTAPA) (Figure 2-1). The Vaal Triangle Airshed was declared the first priority area by the minister on 21 April 2006. New developments in the VTAPA which are associated with atmospheric emissions and hence the potential for contributing to air pollutant concentrations are being subject to intense scrutiny by national air pollution control officers. Emphasis is being placed on ensuring that best practice control measures are being proposed for implementation and that the development will not substantially add to the existing air pollution burden in the region.

Objectives to minimise both gaseous and particulate emissions from mining activities in the VTAPA, as stated in the VTAPA Air Quality Management Plan (Government Gazette No 32263 Published on 28 May 2009) include:

- Good materials handling practices,
- Controlled crushing and screening, and
- Best practice techniques to minimise emissions from waste dumps, stockpiles and dust entrainment along haul roads.

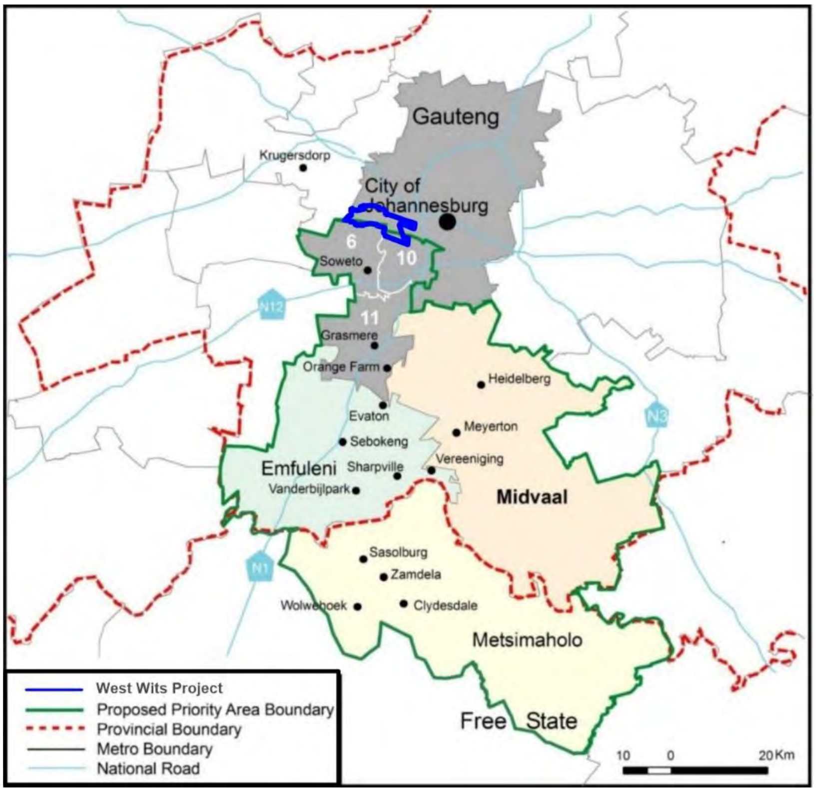


Figure 2-1: Boundaries of the Vaal Triangle Airshed Priority Area, as declared on 21 April 2006

2.7 City of Johannesburg Metropolitan Municipality Air Pollution Control By-Laws

The proposed West Wits operations fall wholly under the City of Johannesburg Metropolitan Municipality and has to comply with the Air Pollution Control By-Laws of the municipality. These by-laws include:

- The mitigation, as far as reasonably possible, of any air pollution that may occur.
- The restriction of open burning of any biomass or other fuel in the open air without utilising fuel-burning equipment except for any recreational outdoor activity or domestic purpose.
- The prohibition on the operation of any diesel fuel vehicle emitting dark smoke (with a density of 60 Hartridge smoke unites or more) on any public road.
- Prohibits the creation of nuisance dust from a property.

2.8 Air Quality Offset Guidelines

The Department of Environmental Affairs published the Air Quality Offsets Guidelines on 16 March 2016 (Government Gazette No 39833). Offsets provide one of the measures to counterbalance the negative environmental impacts that are unavoidable within reasonable boundaries. Offsets provide the opportunity to remedy the impacts of pollutions where it cannot be completely avoided or minimised further. Offsets focus primarily on air pollutants whose ambient air quality standards are being exceeded or likely to be exceeded in a region. Air quality offsets are recommended in the following circumstances:

- During an application for postponement of compliance timeframes,

- During an application for the variation of a licence, and
- During an application of an atmospheric emissions licence in areas where the NAAQS are being or likely to be exceeded.

Affected communities need to be consulted in relation to proposed offsets prior to it being adopted.

2.9 Greenhouse Gas Emissions

The Department of Environmental Affairs has published the Declaration of Greenhouse Gases as Priority Air Pollutants and the National Pollution Prevention Plans Regulations on 21 July 2017 (Government Gazette No 40996), as well as the National Greenhouse Gas Emission Reporting Regulations on 3 April 2017 (Government Gazette No 40762).

As part of these regulations, certain industries are required to submit Pollution Prevention Plans to the Minister, but gold mining is not included in the list of industries.

Furthermore, as part of the National Greenhouse Gas Emission Reporting Regulations, any person in control on conducting an activity with a capacity equal or above the threshold indicated as per Annexure 1 of these Regulations needs to submit a Greenhouse Gas Emissions Inventory to the competent authority annually.

Although Mining and Quarrying is listed in Annexure A under category 1A2i, a threshold of 10MW(th) is applicable to this category. Based on the total fuel consumption of all stationary and mobile equipment at the proposed West Wits operations, the combined thermal power of all equipment (mobile and stationary) will fall below the 10MW threshold. Therefore the proposed West Wits operations need not report on greenhouse gas emissions as stipulated in the National Greenhouse Gas Emission Reporting Regulations.

3 Receiving Environment

3.1 Site Description

Potential receptors in the vicinity of the West Wits operations include the residential areas located around the proposed open pit mining operations (Figure 3-1) and the proposed infrastructure complexes (**Figure** 3**-**2). For the purposes of this assessment all residences within these areas were considered as potential receptors. The topography of the study area is shown in Figure 3-2.

3.2 Climate and Atmospheric Dispersion Potential

Meteorological mechanisms direct the dispersion, transformation and eventual removal of pollutants from the atmosphere. The extent to which pollution will accumulate or disperse in the atmosphere is dependent on the degree of thermal and mechanical turbulence within the earth's boundary layer. This dispersion comprises vertical and horizontal components of motion. The stability of the atmosphere and the depth of the surface-mixing layer define the vertical component. The horizontal dispersion of pollution in the boundary layer is primarily a function of the wind field. The wind speed determines both the distance of downwind transport and the rate of dilution as a result of plume 'stretching'. The generation of mechanical turbulence is similarly a function of the wind speed, in combination with the surface roughness. The wind direction, and the variability in wind direction, determines the general path pollutants will follow, and the extent of crosswind spreading. The pollution concentration levels therefore fluctuate in response to changes in atmospheric stability, to concurrent variations in the mixing depth, and to shifts in the wind field (Tiwary and Colls, 2010).

The spatial variations, and diurnal and seasonal changes, in the wind field and stability regime are functions of atmospheric processes operating at various temporal and spatial scales (Goldreich and Tyson, 1988). The atmospheric processes at macro- and meso-scales need therefore be taken into account in order to accurately parameterise the atmospheric dispersion potential of a particular area. A qualitative description of the synoptic systems determining the macro-ventilation potential of the region may be provided based on the review of pertinent literature. These meso-scale systems may be investigated through the analysis of meteorological data observed for the region.

Meteorological information was sourced from WRF modelled data for the period 2015 to 2017.

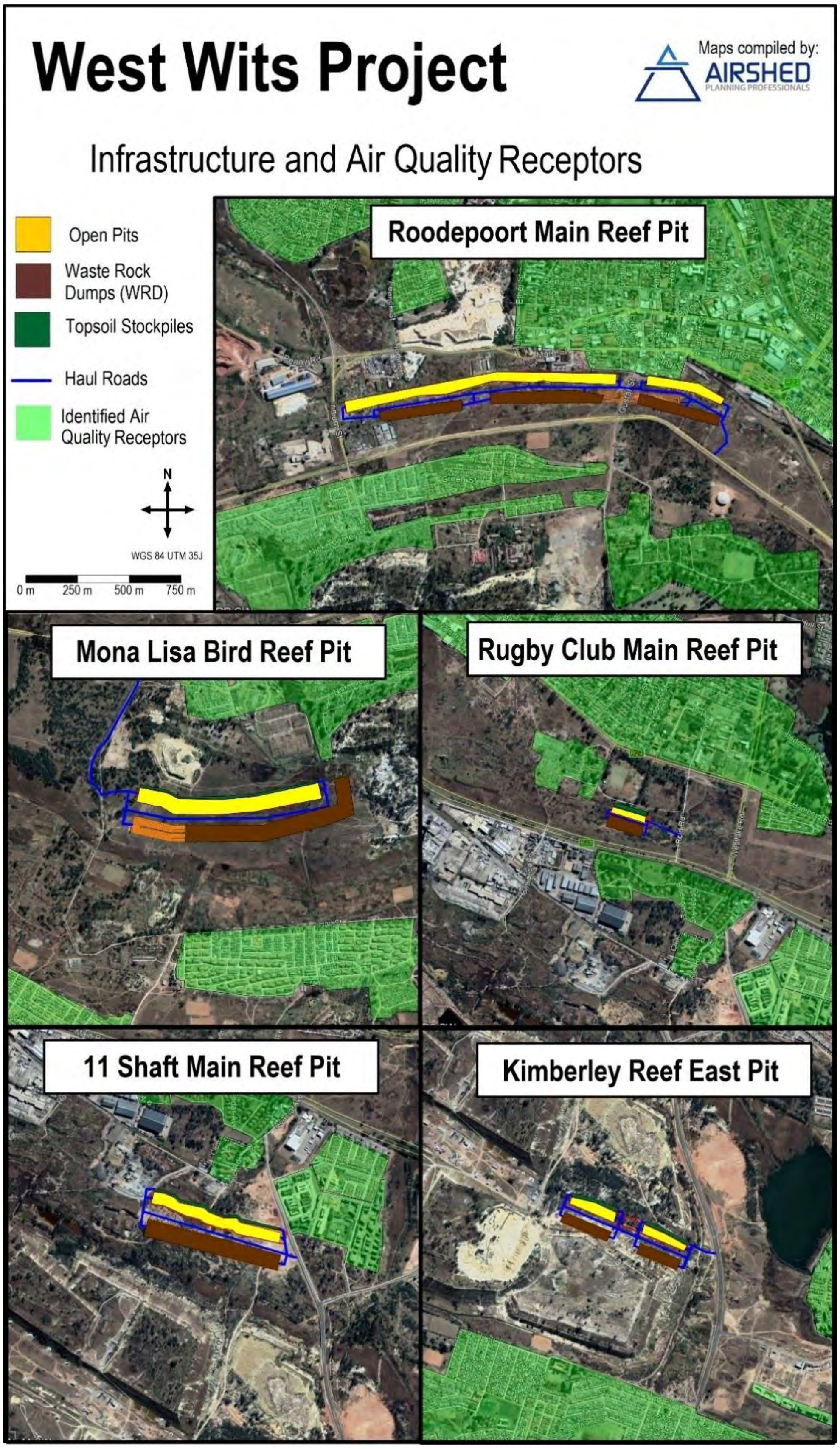


Figure 3-1: Location of potential receptors in relation to the project

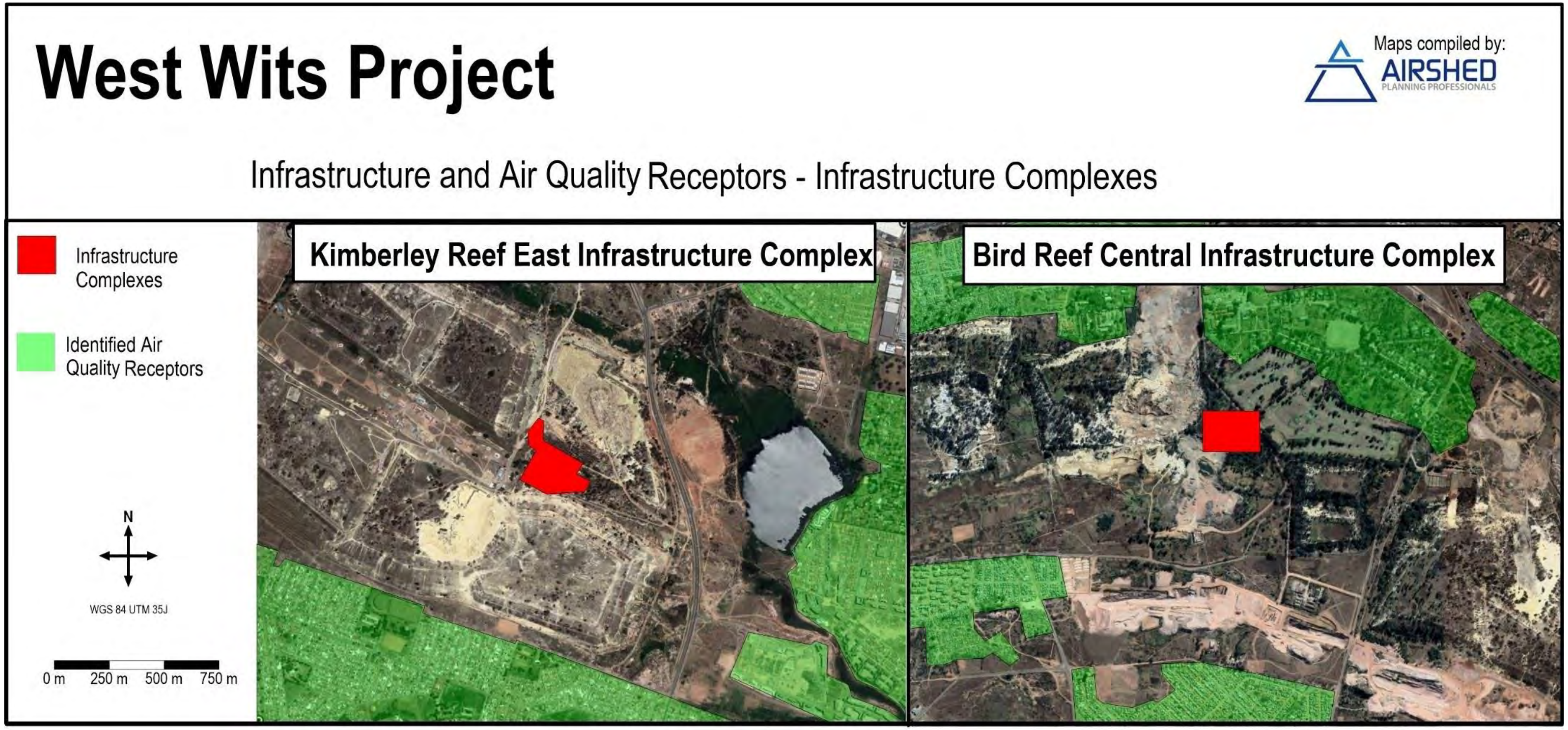


Figure 3-2: Location of potential receptors in relation to the project

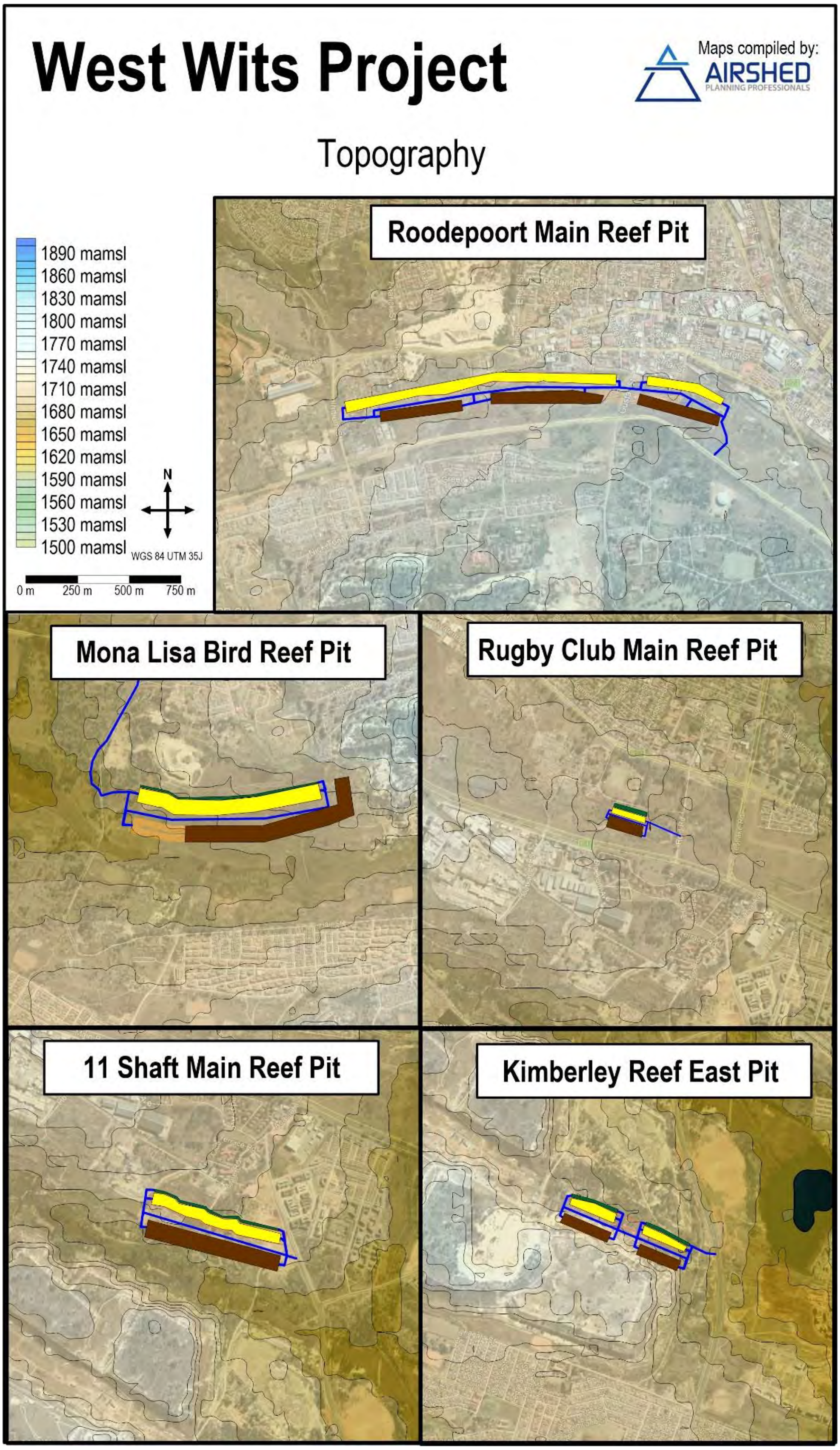


Figure 3-3: Topography of the study area

3.2.1 Local Wind Field

The vertical dispersion of pollution is largely a function of the wind field. The wind speed determines both the distance of downward transport and the rate of dilution of pollutants. The generation of mechanical turbulence is similarly a function of the wind speed, in combination with the surface roughness (Tiwary and Colls, 2010).

The 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 4 and 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 field and diurnal variability in the wind field are shown in Figure 3-4, while the seasonal variations are shown in Figure 3-5. The wind regime for the area is dominated by north-north-easterly flow fields. The northerly wind flow is more dominant during day-time conditions, with north-north-easterly wind flow more dominant during the night. Calm conditions occurred 2 % of the period summarised.

During the summer and spring months, wind from the north sector dominates, with stronger winds of more than 6 m/s occurring. Infrequent winds occur from the southern sector. During autumn, the winds increase in frequency from the southern sector. Winter months reflect an increase in flow from the south.

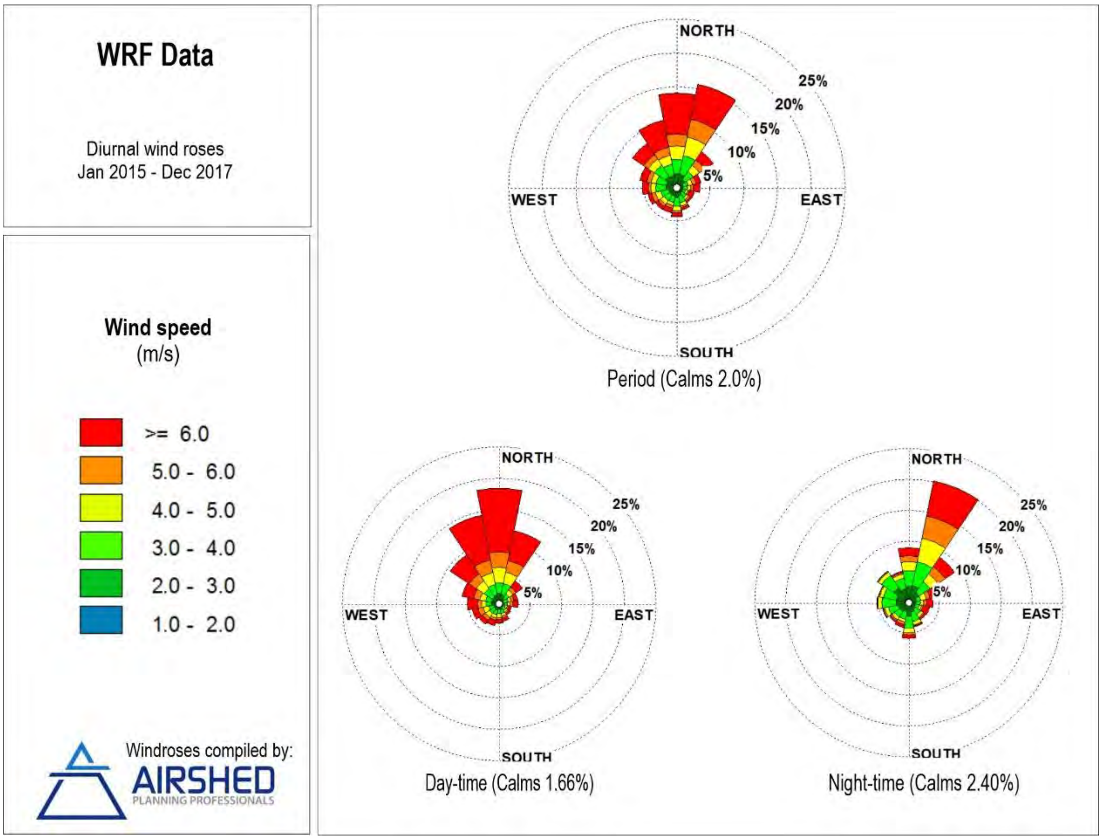


Figure 3-4: Period, day-, and night-time wind roses (WRF data, January 2015 to December 2017)

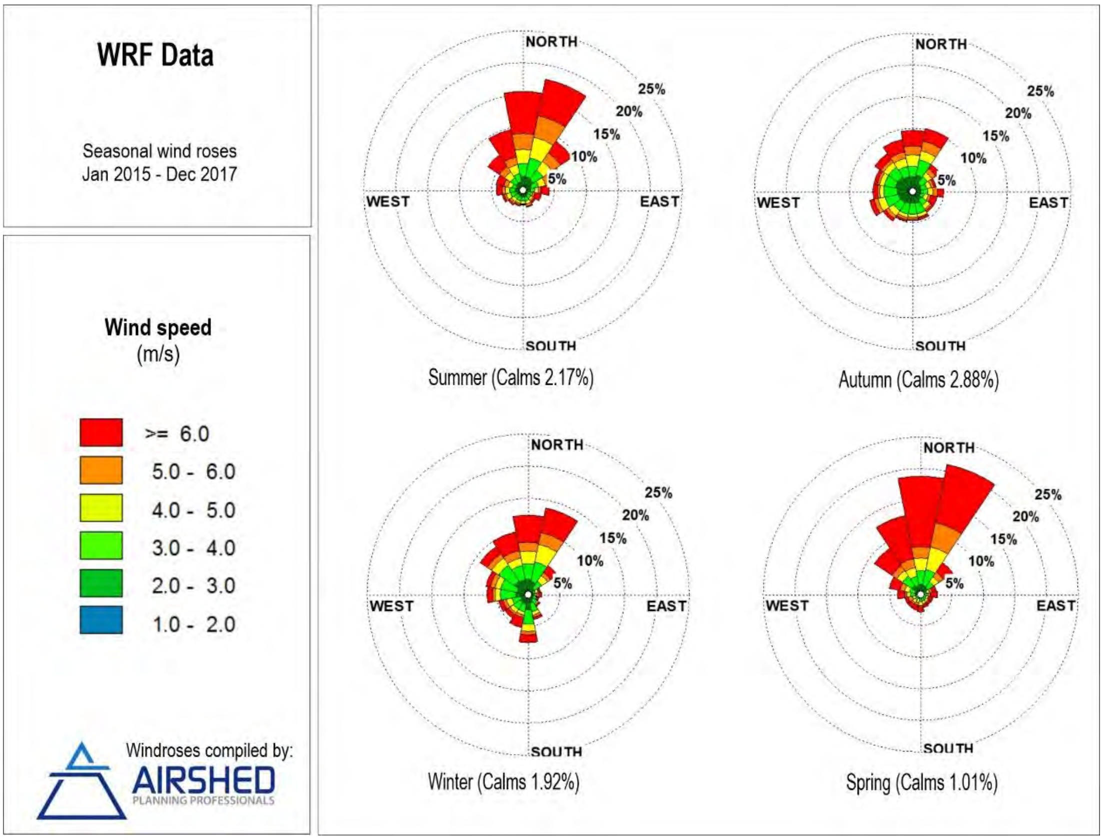


Figure 3-5: Seasonal wind roses (WRF data, January 2015 to December 2017)

3.2.2 *Ambient Temperature*

Air temperature is important, both for determining the effect of plume buoyancy (the larger the temperature difference between the emission plume and the ambient air, the higher the plume is able to rise), and determining the development of the mixing and inversion layers.

Monthly mean, maximum and minimum temperatures are given in Table 3-1. Diurnal temperature variability is presented in Figure 3-5. Temperatures ranged between 2.7°C and 32.9°C. During the day, temperatures increase to reach a maximum at about 15:00 in the late afternoon. Ambient air temperature decreases to reach a minimum at between 06:00 and 07:00.

Table 3-1: Monthly temperature summary (WRF data, January 2015 to December 2017)

Monthly Minimum, Maximum and Average Temperatures (°C)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Minimum	13.7	14.1	12.3	9.7	6.5	5.3	2.7	5.8	7.0	7.7	9.1	10.9
Average	21.7	22.0	21.1	18.4	15.2	12.7	12.1	14.5	16.9	18.9	20.5	22.1
Maximum	31.1	32.5	30.8	29.1	25.3	23.1	22.8	26.7	27.8	31.1	31.9	32.9

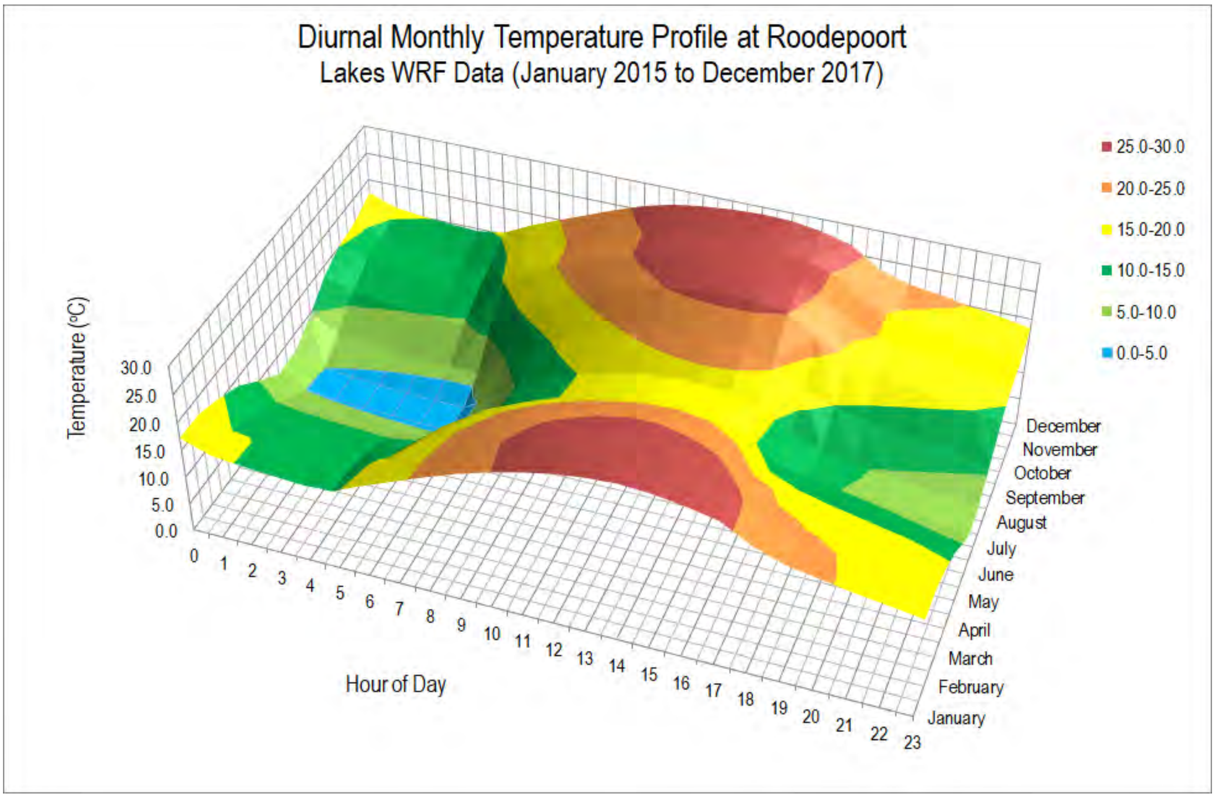
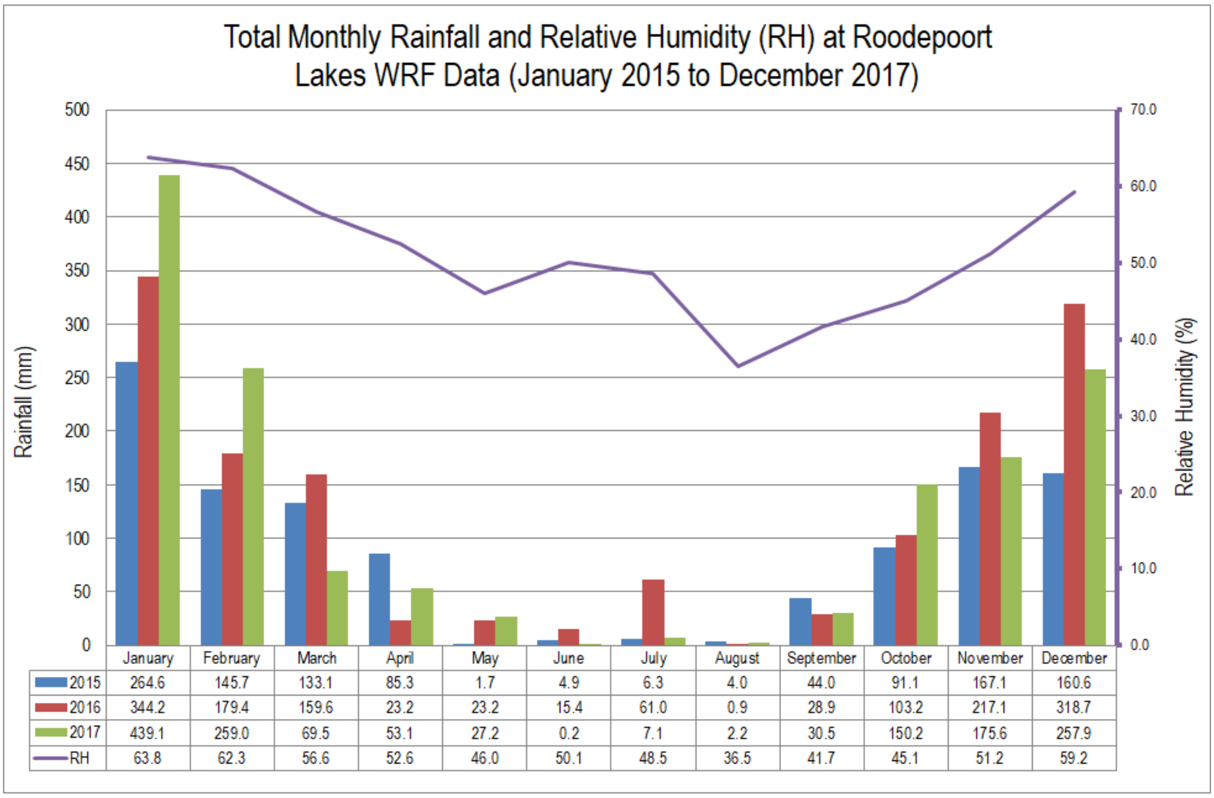


Figure 3-6: Diurnal temperature profile (WRF data, January 2015 to December 2017)

3.2.3 Precipitation

Precipitation represents an effective removal mechanism of atmospheric pollutants. Precipitation reduces wind erosion potential by increasing the moisture content of materials. Rain-days are defined as days experiencing 0.1 mm or more rainfall. The rainfall provided by the WRF data set for the period 2015 to 2017 ranged between 1 108 and 1 474 mm per year.



	January	February	March	April	May	June	July	August	September	October	November	December
2015	264.6	145.7	133.1	85.3	1.7	4.9	6.3	4.0	44.0	91.1	167.1	160.6
2016	344.2	179.4	159.6	23.2	23.2	15.4	61.0	0.9	28.9	103.2	217.1	318.7
2017	439.1	259.0	69.5	53.1	27.2	0.2	7.1	2.2	30.5	150.2	175.6	257.9
RH	63.8	62.3	56.6	52.6	46.0	50.1	48.5	36.5	41.7	45.1	51.2	59.2

Figure 3-7: Monthly rainfall as obtained from the WRF data for the area (2015-2017)

3.2.4 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 (LMo) 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 the 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 less dilution potential. During windy and/or cloudy conditions, the atmosphere is normally neutral. For low level releases, the highest ground level concentrations would occur during weak wind speeds and stable (night-time) atmospheric conditions.

3.3 Ambient Air Quality within the Region

Sampling results from a dustfall monitoring network currently operated to the south and southwest of the West Wits study area was made available for inclusion in the air quality study. The sampling locations with available data for 2017, as provided by the operator of the dust fallout network, are shown in Figure 3-8. Dustfall for the period 2017 is provided in Table 3-2.

In accordance with the NDCR the dustfall limits (600 mg/m²/day for residential areas and 1 200 mg/m²/day for non-residential areas) allows for two exceedances in a year, not sequential months. The NDCR for non-residential areas are exceeded Modise, Maswanganyi and George Thengwani and for residential areas are exceeded at Moreroa and Yvonne Meno during the period 2017. The high variability between dust fallout rates at each sampling location indicates that dust fallout at each location is likely mainly influenced by localised sources. High dust fallout rates at all current sampling locations during the windy spring months from September to November indicates that wind erosion is likely a significant source of dust emissions in the study area.

Table 3-2: Available dust fallout data in the study area for the period 2017

Sampling Site	Sampling month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Modise	424	573	182	233	97	447	997	543	6492	5327	4588	2029
Mashilane	123	214	111	108								
Moreroa	366	211	277	292	227	410	211	247	3308	1114	1640	730
Maswanganyi	195	340	295	175	193	376		266	2495	2792	2172	1843
George Thengwani	482	342	185	238	551	373	442	356	6193	3243	1888	1118
Yvonne Meno	167	342	147	109	383	196	332	269	1681	803	952	202
Anna Doornkop	204	324	246	217	259	198	66	63		675	378	327

Figure 3-8: Current dust fallout sampling locations with available results for 2017.

3.4 Existing Sources of Emissions near the Proposed Project

The sources of SO_2 and oxides of nitrogen (NO_x) that occur in the region include blasting operations at mines, veld burning, vehicle exhaust emissions, industrial activities and household fuel burning.

Various local and far-a-field sources are expected to contribute to the suspended fine particulate concentrations (which would include PM_{10} and $PM_{2.5}$) in the region. Local sources include wind erosion from exposed areas (including tailings storage facilities), fugitive dust from agricultural and mining operations, vehicle entrainment from roadways and veld burning and industrial activities in Roodepoort and Chamdor. Long-range transport of particulates, emitted from remote tall stacks and from large-scale biomass burning in countries to the north of South Africa, has been found to contribute significantly to background fine particulate concentrations over the interior (Andreae, et al., 1996) (Garstang, et al., 1996) (Piketh, et al., 1996).

3.4.1 Materials handling

Materials handling operations associated with mining activities in the area include the transfer of material by means of tipping, loading and off-loading of trucks. The quantity of dust that will be generated from such loading and off-loading operations will depend on various climatic parameters, such as wind speed and precipitation, in addition to non-climatic parameters such as the nature (i.e. moisture content) and volume of the material handled.

3.4.2 Household Fuel Burning

Despite the intensive national electrification program a large number of households continue to burn fuel to meet all or a portion of their energy requirements. The main fuels with air pollution potentials used by households within the study region are coal, wood and paraffin.

Coal burning emits a large amount of gaseous and particulate pollutants including sulfur dioxide, heavy metals, total and respirable particulates including heavy metals and inorganic ash, carbon monoxide, polycyclic aromatic hydrocarbons, and benzo(a)pyrene. Polyaromatic hydrocarbons are recognised as carcinogens. Pollutants arising due to the combustion of wood include respirable particulates, nitrogen dioxide, carbon monoxide, polycyclic aromatic hydrocarbons, particulate benzo(a)pyrene and formaldehyde. The main pollutants emitted from the combustion of paraffin are NO_2, particulates carbon monoxide and polycyclic aromatic hydrocarbons.

3.4.3 Biomass Burning

The biomass burning includes the burning of evergreen and deciduous forests, woodlands, grasslands, and agricultural lands. Within the project vicinity, crop-residue burning and wild fires (locally known as veld fires) may represent significant sources of combustion-related emissions.

The biomass burning is an incomplete combustion process, with carbon monoxide, methane and nitrogen dioxide gases being emitted. Approximately 40% of the nitrogen in biomass is emitted as nitrogen, 10% is left in the ashes, and it may be assumed that 20% of the nitrogen is emitted as higher molecular weight nitrogen compounds (Held et al, 1996). 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 proposed mining activity, long-range transported emissions from this source can be expected to impact on the air quality between the windier months August to October. 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.

3.4.4 Vehicle Exhaust 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, those pollutants formed in the atmosphere as a result of chemical reactions, such as hydrolysis, oxidation, or photochemical reactions. The significant primary pollutants emitted by motor vehicles include carbon dioxide (CO_2), CO, hydrocarbon compounds (HC), SO_2, oxides of nitrogen (NO_x) and PM. Secondary pollutants include NO_2, photochemical oxidants (e.g. ozone), HC, sulfur acid, sulfates, nitric acid and nitrate aerosols.

3.4.5 Other Fugitive Dust Sources

Fugitive dust emissions may occur as a result of vehicle entrained dust from local paved and unpaved roads, wind erosion from open areas and dust generated by agricultural activities (e.g. tilling) and mining. 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.

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, its erosion potential has to be restored; that is, the wind shear at the surface must exceed the gravitational and cohesive forces acting upon them, called the threshold friction velocity. Every time a surface is disturbed, its erosion potential is restored (US EPA, 2004). Erodible surfaces may occur as a result of agriculture and/or grazing activities.

3.5 Identification of Potential Receptors in the Area

The NAAQS (detailed in Section 2.1) are based on human exposure to specific criteria pollutants and as such, potential receptors were identified where the public is likely to be exposed (as indicated in Figure 3-1). Potential impacts from the proposed project will be assessed at these potential receptors and screened against NAAQS.

4 Emissions Inventory

Emission sources due to the proposed West Wits Mining Project operations include:

- Fugitive dust emissions from rock breaking and loading of run-of-mine (ROM) and waste rock in the open pits.
- Fugitive dust emissions from crushing of ROM in the open pits.
- Fugitive dust emissions from dozers and graders.
- Fugitive dust emissions from unloading of waste rock at the waste rock dumps (WRD).
- Material handling emissions and wind erosion emissions from the ROM stockpiles.
- Vehicle entrained emissions from the haul roads used to transport waste rock to the WRD and to transport ROM off-site.
- Wind erosion from exposed areas and stockpiles.
- Vehicle exhaust emissions from the on-site vehicle fleet.
- Fugitive dust emissions from material handling of underground ROM (no underground waste rock will be transported to the surface).
- Ventilation shaft emissions from the underground operations.

Emissions from the West Wits opencast mining operations were calculated using emissions factors published by the US EPA AP42 Section 13.2.4 (Aggregate Handling and Storage Piles) and Section 13.2.2 (Unpaved Roads), and the Australian NPi Emission Estimation Technique Manuals for Combustion Engines (Version 3.0) and Mining (Version 3.1). Mining at the West Wits open cast operations would take place from 6:00 to 18:00 on Mondays to Fridays and 6:00 to 14:00 on Saturdays. A summary of the extent and mining rates of each of the opencast operations is given in Table 4-1.

Table 4-1: Details of mining operations

Pit Name	Kimberley East	11 Shaft	Rugby Club	Mona Lisa	Roodepoort
Size of Mining Area	~9.2 ha	~15 ha	~2.6 ha	~20 ha	~26.5 ha
Mining Rate	15000 t/month	15000 t/month	15000 t/month	15000 t/month	15000 t/month
Pit Depth	20 to 30 m	20 to 30 m	7 to 10 m	20 to 30 m	7 to 10 m
Mining Duration	~ 5 months	~ 8 months	~ 3 months	~ 3 months	~ 12 months
Temporary waste rock volume	503 000 m³	1 013 000 m³	260 000 m³	296 000 m³	1 103 000 m³

Estimated fugitive dust and vehicle exhaust emissions from the proposed opencast operations is shown in Table 4-2 and Table 4-3 respectively. Because the mining rate in tonnes/month is the same for each of the pits, mining emissions from each of the pits are expected to be similar, with vehicle entrainment and exhaust emissions dependent on the distance travelled by vehicles on-site.

It is assumed that the air coming from the vent shafts will comply with the SA Mine Health and Safety Act limits. This assumption is conservative, because if the ventilation system for West Wits underground operations is well designed, underground particulate concentrations should be well below the exposure limits and consequently concentrations at the point of emissions will be well below the limit as well. The limit provided by the Act is 2 mg/m³ $PM_{2.5}$ (respirable dust) and 10 mg/m³ for other inhalable particulates (PM_{10}). The volumetric flow rate from the ventilation shafts is expected to be 60m³/s while the diameter of the ventilation shafts will be approximately 2.5 m. Particulate and gaseous emissions from the underground ventilation shafts will be highly variable and will depend on the design of the ventilation shafts and the level of underground activity at any given time. At the concentrations of gaseous pollutants present in the ventilated air, it is unlikely that gaseous emissions from ventilation shafts will have a significant impact on ambient air quality in the study area.

As with any construction activities, construction at the infrastructure complexes is expected to result in dust fallout in the immediate vicinity of the infrastructure complexes. Dust emissions during the construction phase are expected to vary substantially from day to day depending on the activities. Dust fallout impacts during the construction phase are expected to be short term and restricted to the immediate vicinity of the construction activities. The footprints of the infrastructure complexes are ~2.19 ha and ~3.5 ha for the Bird Reef Central and Kimberley Reef East complexes respectively.

Table 4-2: Estimated fugitive dust emissions for the proposed West Wits opencast operations (for each of the opencast operations)

Fugitive Emission Source	Emissions Rate		
	TSP	PM_{10}	$PM_{2.5}$
In pit emissions - Rock breaking and loading to trucks (kg/hr)	21.5	10.1	1.0
Haul of waste to WRD (kg/kilometre travelled)	0.786	0.079	0.008
Haul of ROM (inside the study area only) (kg/kilometre travelled)	0.832	0.083	0.008
Unloading of waste rock at WRD (kg/hr)	8.3	2.9	0.3
ROM Crushing (kg/hr)	0.6	0.1	0.0
Wind erosion from stockpiles (kg/hr)	2.2	1.1	0.1
Dozing (kg/hr)	17.0	8.0	0.8
Grading (kg/hr)	1.0	0.5	0.0

Table 4-3: Estimated vehicle exhaust emissions for the proposed West Wits opencast operations

Vehicle Type	Number of Vehicles	Diesel Consumption per vehicle (l/h)	Gaseous Emissions (kg/hr)				
			CO	NO_x	Diesel PM_{10}	SO_2	CO_2
50 Tonne Excavator	2	36	0.69	2.38	0.22	0.01	95.0
30 Tonne ADT	4	17	0.99	2.32	0.14	0.01	44.9
Water truck	1	7	0.10	0.24	0.01	0.00	18.5
Dozer	1	17	0.26	0.60	0.03	0.00	44.9
Grader	1	8	0.05	0.25	0.02	0.00	21.1

Table 4-4: Emission estimation techniques and activity data

Source Group	Emission Estimation Technique	Input Parameters/Notes
Materials Handling	US EPA emission factor equation (US EPA, 2006a) $$EF = k \cdot 0.0016 \cdot \left(\frac{U}{2.3}\right)^{1.3} \cdot \left(\frac{M}{2}\right)^{-1.4}$$ Where EF is the emission factor in kg/tonne material handled k is the particle size multiplier (k_{TSP} – 0.74, k_{PM10} – 0.35, $k_{PM2.5}$ – 0.053) U is the average wind speed in m/s M is the material moisture content in %	• 60 tonnes/hour ROM handled. • 780 tonnes/hour waste rock handled • Rock breaker on ROM and waste rock. • In-pit loading of ROM to haul trucks • In-pit loading of waste rock to haul trucks • Unloading of waste rock to the WRD An average **wind speed of 3.207 m/s** was determined from the MM5 data set **Hours of operation:** 68 hours per week. **Mitigation:** None
Crushing and Screening	US EPA emission factor equation USA EPA AP42 (2004) for primary crushing TSP – 0.01 kg/tonne PM_{10} – 0.004 kg/tonne	Crushing rate: 64 tonnes/hour **Hours of operation:** 68 hours per week.
Vehicle Entrained Dust from Unpaved Roads	US EPA emission factor equation (US EPA, 2006b) $$EF = k \cdot \left(\frac{s}{12}\right)^{a} \cdot \left(\frac{W}{3}\right)^{b} \cdot e$$ Where EF is the emission factor in g/vehicle kilometre travelled (VKT) k is the particle size multiplier (k_{TSP} – 4.9, k_{PM10} – 1.5, $k_{PM2.5}$ – 0.15) s is the road surface material silt content in % W is the average weight vehicles in tonnes a is an empirical constant (a_{TSP} – 0.7, a_{PM10} – 0.9, $a_{PM2.5}$ – 0.9) b is an empirical constant (b_{TSP} – 0.45, b_{PM10} – 0.45, $b_{PM2.5}$ – 0.45) e is the metric converter of 281.9 (1 lb/VMT = 281.9 g/VKT)	Transport activities include the transport of ROM from the pit off-site and transporting waste rock to the WRD **Haul roads**, truck capacity 34 tonnes for ROM and 30 tonnes for waste rock **Surface silt content of 8.4 %** (US EPA, 2006b) was applied in calculations for all unpaved roads **Hours of operation:** 68 hours per week. **Mitigation:** Water Sprays
Vehicle Exhaust Emissions	NPI Combustion Engines V3 (ADE, 2008)	As per Table 4-3. **Hours of operation:** 68 hours per week. **Mitigation:** None
Wind Erosion	Australian NPI Emission Factor for Mining. Wind erosion from active stockpiles = 0.04 kg/ha/h for TSP and 0.02 kg/ha/hr for PM_{10}	

5 Dispersion Model Selection and Results

Use was made of the US EPA AERMOD atmospheric dispersion modelling suite for the simulation of ambient air pollutant concentrations and dust fallout rates. AERMOD is a Gaussian plume model best used for near-field applications where the steady-state meteorology assumption is most likely to apply. The model was 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). Model details and domain parameters are summarised in Table 5-1 and Table 5-2 below.

Table 5-1: Model details

Pollutants	Model Version	Executable
PM_{10}, $PM_{2.5}$, dust fallout SO_2, NO_2, diesel particulates and CO	AERMOD 7.2.5	EPA 09292

Table 5-2: Simulation domain

Simulation domain	Details
South-western corner of simulation domain	580 721 m; 7 098 663 m
Domain size	12 x 9.5 km
Projection	Grid: UTM Zone 35J, Datum: WGS 84
Resolution	50 m

Dispersion modelling simulations were undertaken to determine highest hourly, highest daily and annual average ground level concentrations for each of the pollutants considered for the operational phase. Averaging periods were selected to facilitate the comparison of simulated pollutant concentrations to the SA NAAQS.

Ambient air quality criteria apply to areas where the Occupational Health and Safety regulations do not apply, which are generally outside the property or lease area. Ambient air quality criteria are therefore not occupational health indicators but applicable to areas where the general public has access. For this assessment the ambient criteria were assumed to be applicable for all areas outside the area actively being mined at any given time.

Simulated maximum concentrations at any potential receptor location are shown in Table 5-3. The figure number for the isopleth plots of pollutants of concern is also shown in Table 5-3. With no mitigation measures applied simulated highest daily PM_{10} concentrations exceed the NAAQS at the closest potential receptor locations to the east, north and south of each of the pits (except Mona Lisa). With simple mitigation measures such as wet suppression of dust at material handling points and regular water sprays on haul roads, simulated incremental PM_{10} concentrations due to the open pit mining operations are in compliance with the SA NAAQS at all potential receptor locations (with the exception of Daily PM_{10} concentrations at the buildings to the south of Rugby Club and to the east of 11-Shaft. It is estimated that approximately 22 residential receptors are located to the east of 11 shaft and approximately 18 residential receptors to the south of Rugby Club. Simulated $PM_{2.5}$, NO_2, SO_2, and CO concentrations are in compliance with the SA NAAQS for all averaging periods and simulated highest monthly dust fallout rates are in compliance with the SA NDCR residential limit at all potential receptor locations and in compliance with the SA NDCR non-residential limit at all off-site areas.

Highest daily and annual average PM_{10} concentrations as a result of aboveground ROM handling and ventilation shaft emissions during the underground phase of the operations are shown in Figure 5-7 and Figure 5-8. Simulated incremental PM_{10} concentrations during the underground phase of the West Wits Mining Project exceed the SA NAAQS in the immediate vicinity of the underground infrastructure complexes, but are in compliance with the SA NAAQS at all potential receptor locations.

Table 5-3: Dispersion modelling results – open pit operations

Pollutant	Scenario	Averaging Period	Isopleth Plot	Limit Value (µg/m³)	Simulated Maximum Concentration at Potential Receptor Locations (µg/m³)				
					Roodepoort	Mona Lisa	Rugby Club	11 Shaft	Kimberley East
PM_{10}	Unmitigated	24-hour	Figure 5-1	75	99	54	115	260	40
		1-year	Not Shown	40	33	14	63	82	7
	Mitigated	24-hour	Figure 5-2	75	51	29	91	150	23
		1-year	Figure 5-3	40	14	6	27	35	3
$PM_{2.5}$	Mitigated	24-hour	Figure 5-4	40	5	3	10	20	1
		1-year	Figure 5-5	20	1.3	0.6	3.2	5	0.3
NO_2	Unmitigated	1-hour	Not shown	200	37	21	67	110	17
		1-year	Not shown	40	7.5	3.2	14.4	18.7	1.6
SO_2	Unmitigated	1-hour	Not shown	350	0.1	0.1	0.2	0.4	0.1
		24-hour	Not shown	125	0.1	0.0	0.1	0.2	0.0
		1-year	Not shown	50	0.03	0.01	0.05	0.07	0.01
CO	Unmitigated	1-hour	Not shown	30 000	19	8	36	47	4
Diesel Particulates	Unmitigated	1-hour	Not shown		2.7	1.5	4.9	8.0	1.2
		24-hour	Not shown		2.0	1.2	3.6	6.0	0.9
		1-year	Not shown		0.6	0.2	1.1	1.4	0.1
Dust Fallout	Mitigated	1-month	Figure 5-6	600	90	50	200	250	20

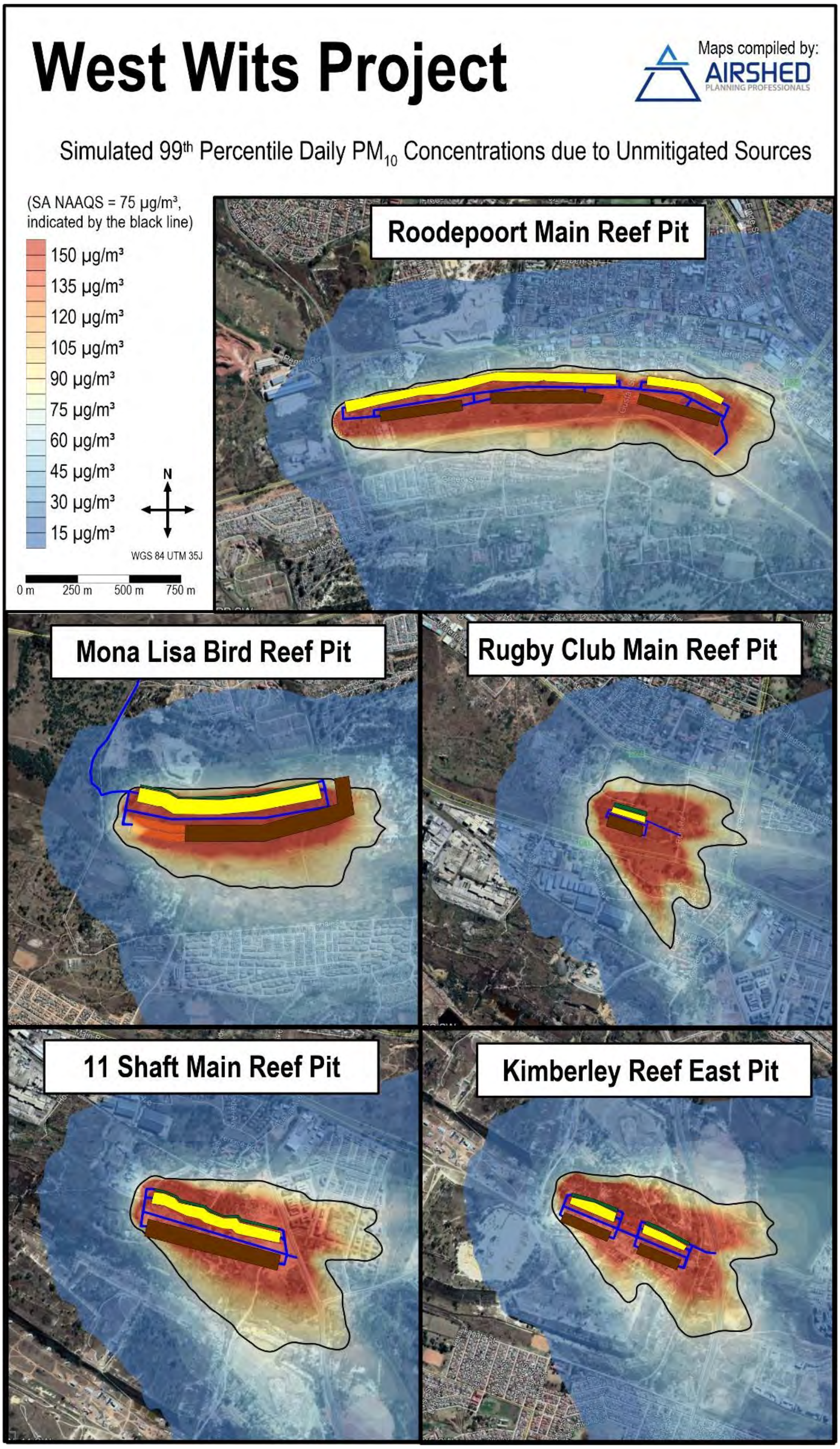


Figure 5-1: Simulated incremental unmitigated 99th percentile (4th highest) daily PM_{10} concentrations due to unmitigated West Wits open pit operations

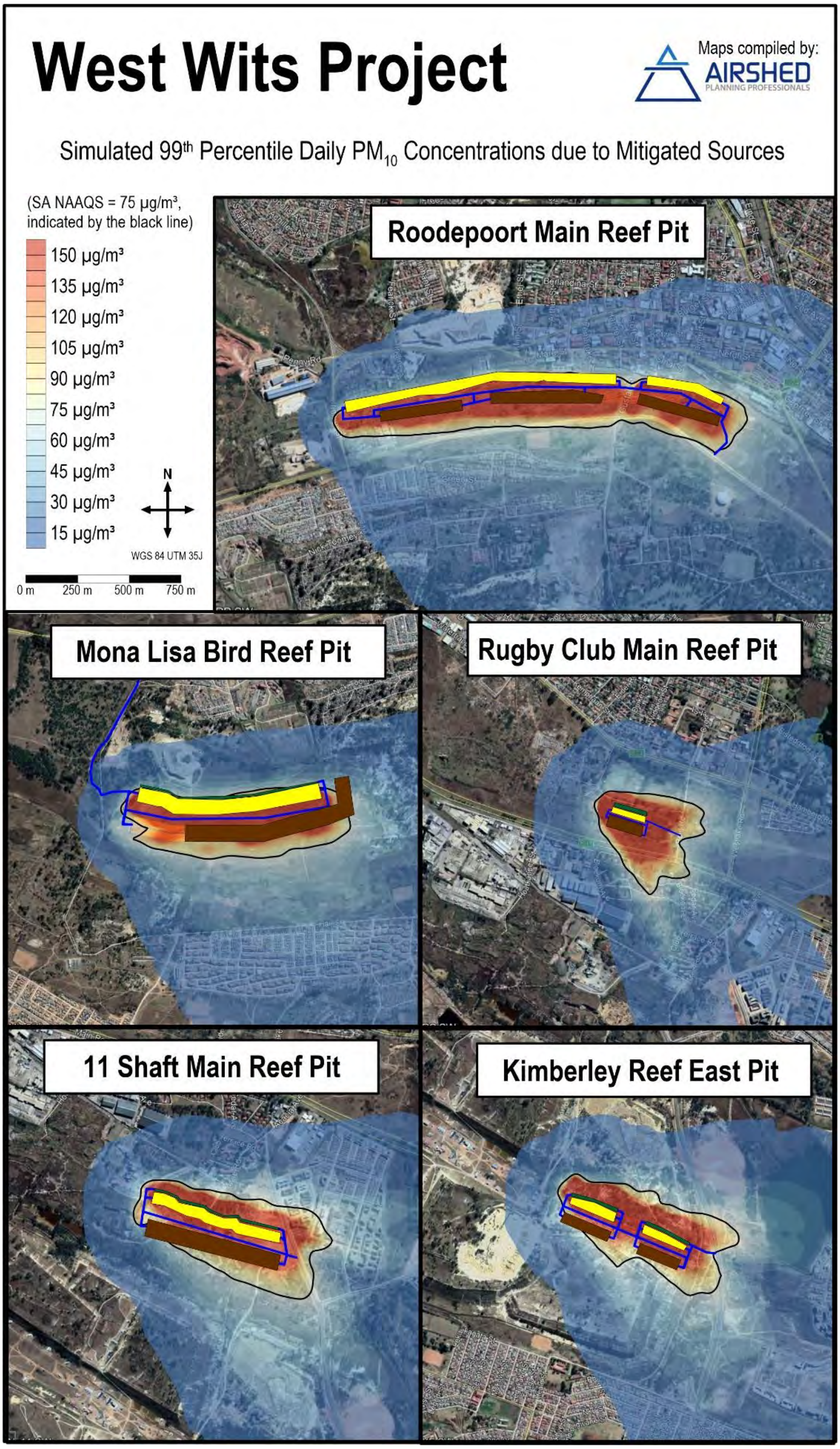


Figure 5-2: Simulated incremental mitigated 99th percentile (4th highest) daily PM_{10} concentrations due to mitigated West Wits open pit operations

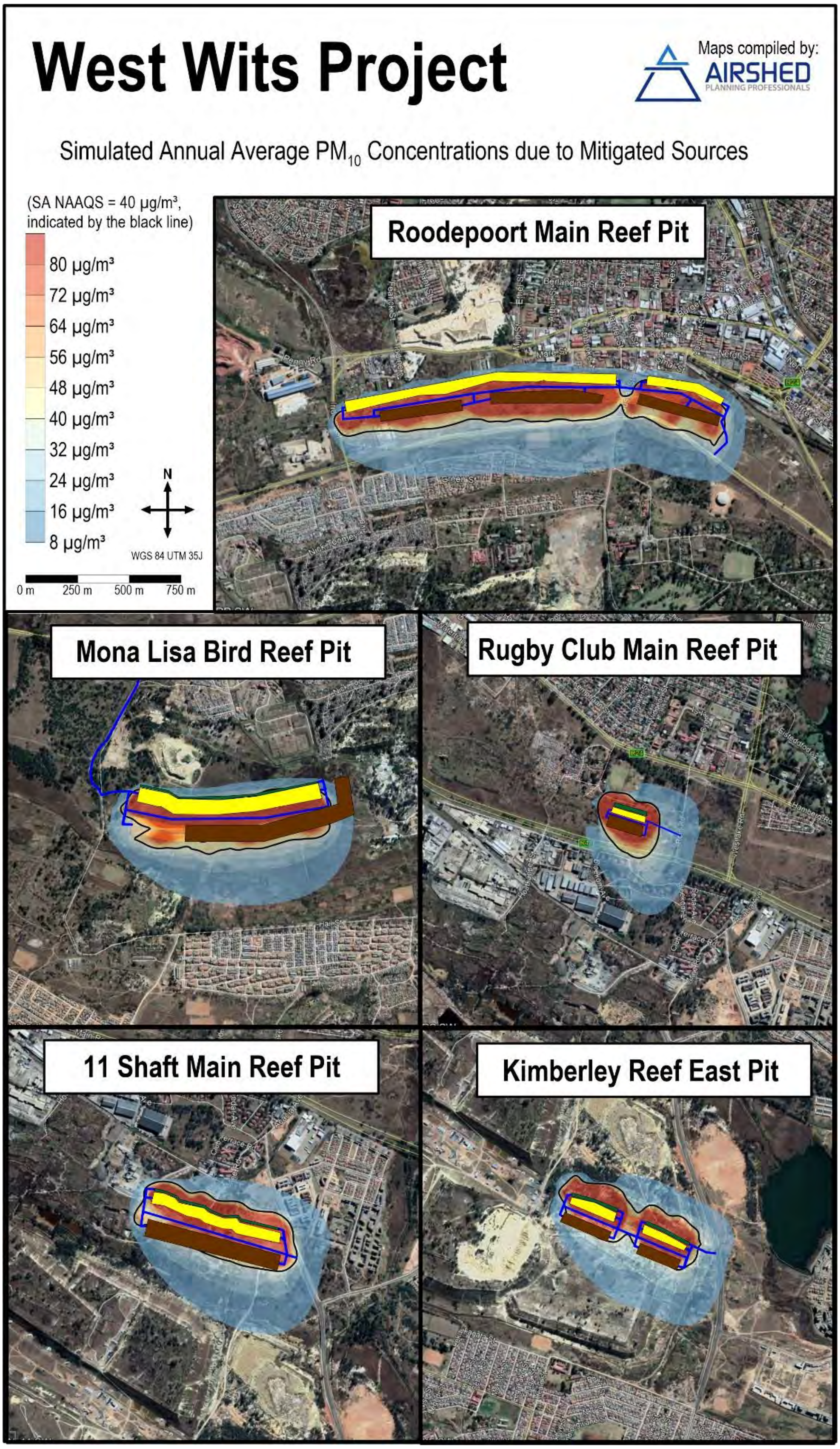


Figure 5-3: Simulated incremental mitigated annual average PM_{10} concentrations due to West Wits open pit operations

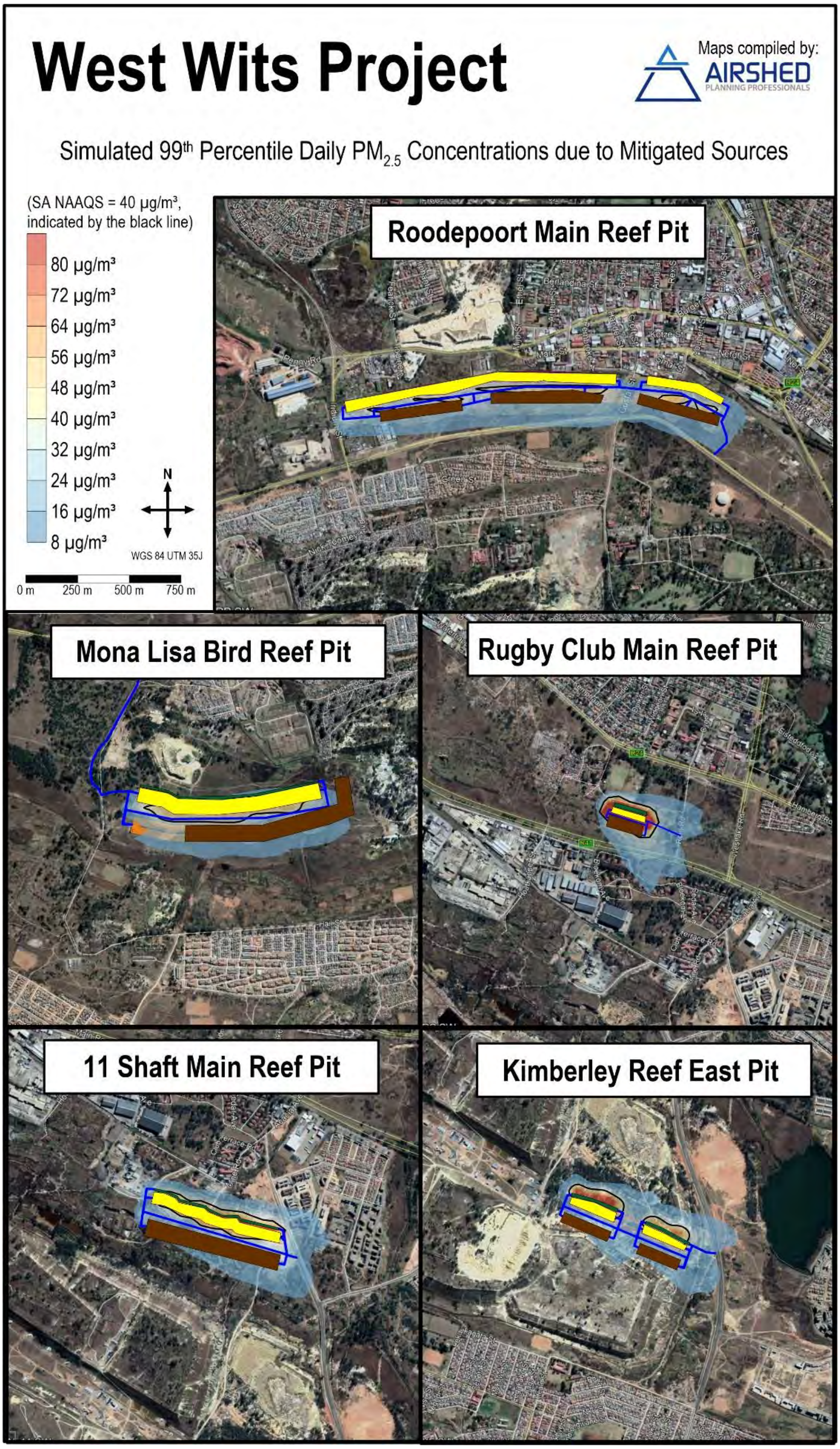


Figure 5-4: Simulated incremental mitigated 99th percentile (4th highest) daily $PM_{2.5}$ concentrations due to West Wits open pit operations

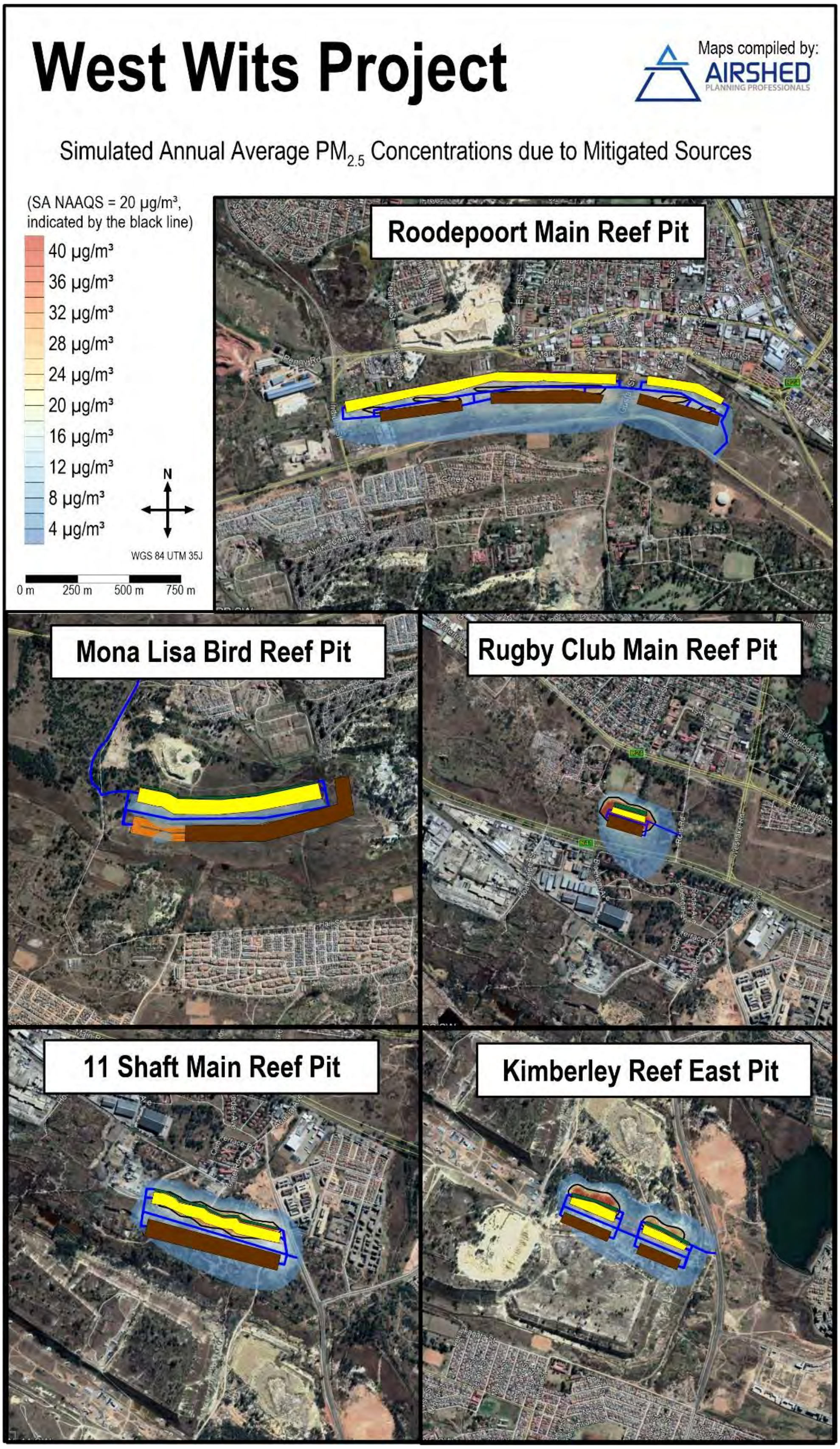


Figure 5-5: Simulated incremental mitigated annual average $PM_{2.5}$ concentrations due to West Wits open pit operations

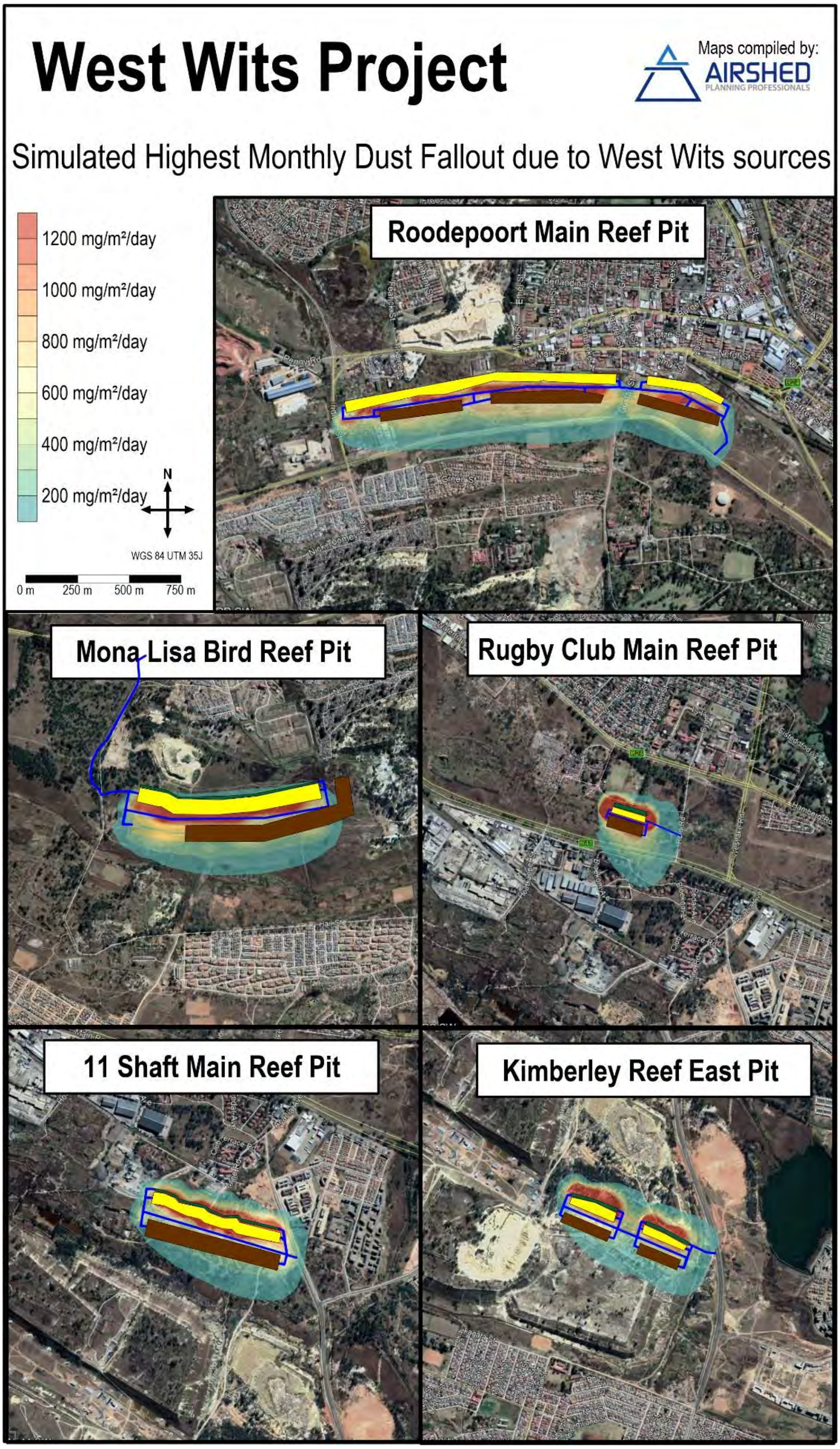


Figure 5-6: Simulated incremental mitigated highest monthly dust fallout rates due to West Wits open pit operations

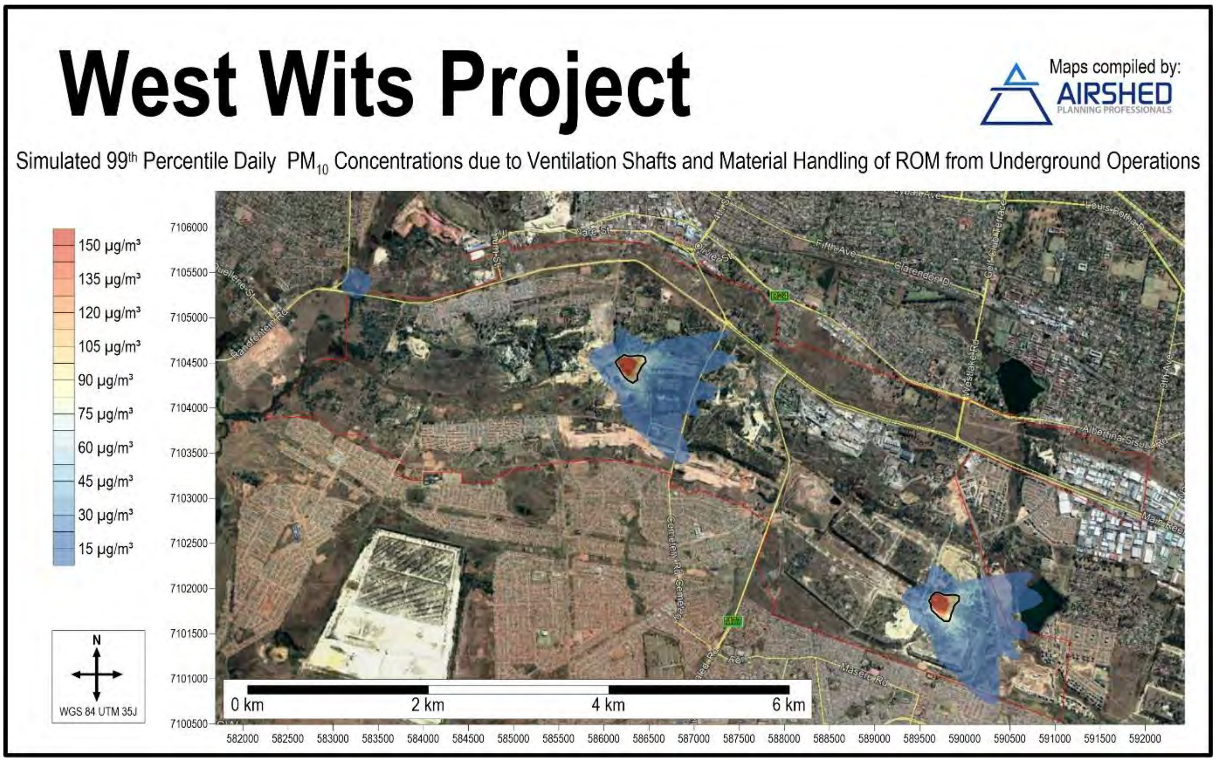


Figure 5-7: Simulated incremental highest daily PM_{10} concentrations due to West Wits underground operations

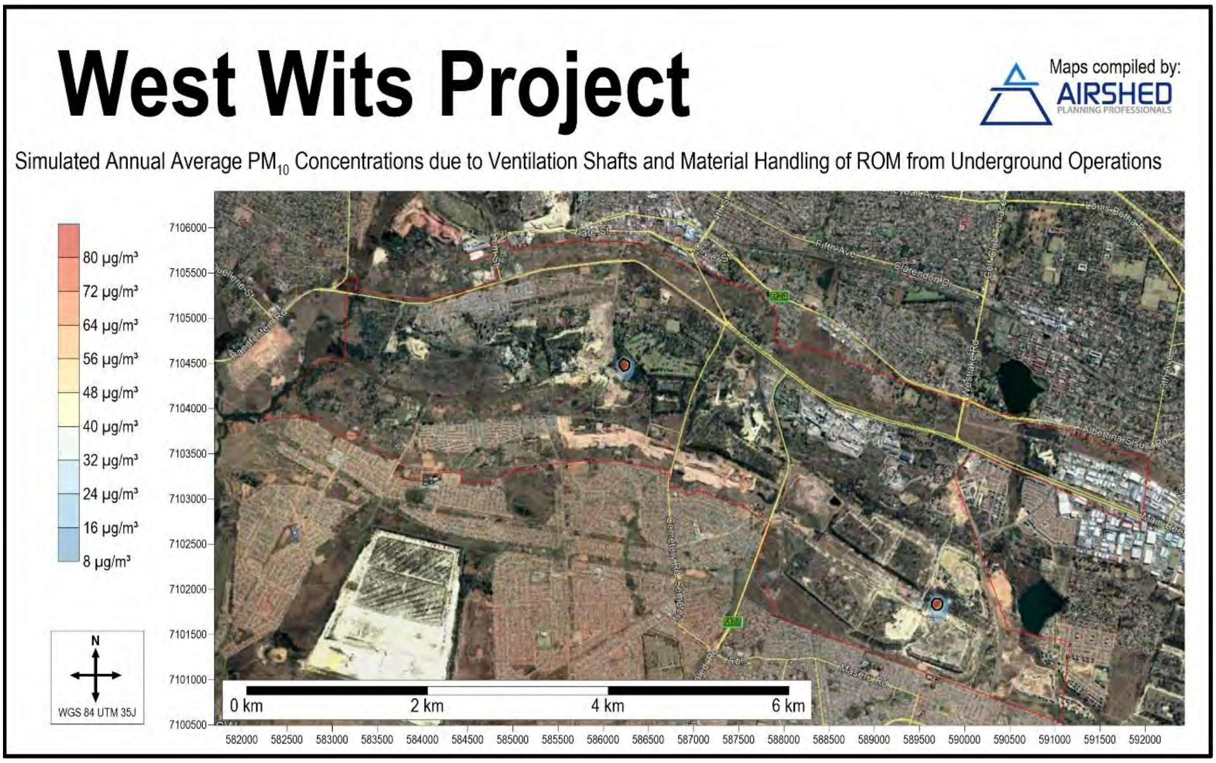


Figure 5-8: Simulated incremental annual average PM_{10} concentrations due to West Wits underground operations

6 Impact Significance Rating

Based on the findings presented in the previous sections, the impact significance of air quality impacts on the surrounding environment for the phases of the West Wits Mining Project are shown in Table 6-1.

Table 6-1: Impact Significance Statement

Project Activity	Impact		Probability	Consequence				Significance Rating
Opencast mining operations, haulage and decommissioning	Phase of Project	Construction, Operational, Decommissioning & Post-Closure – Opencast operations	Frequency of Impact	Severity	Spatial Scale	Duration	Consequence	Significance Rating
	Impact Classification	Direct Impact	Without Mitigation					
	Resulting Impact from Activity	Impact of inhalable particulate concentrations at potential receptor locations	M	M-	M	L	M	Medium
			With Mitigation					
			M	M-	L	L	L	Low
		Impact of inhalable gaseous concentrations and dust fallout at potential receptor locations	Without Mitigation					
			M	L-	L	L	L	Low
			With Mitigation					
			M	L-	L	L	L	Low
Underground mining operations, ventilation shafts and aboveground material handling	Impact Classification	Direct Impact	Without Mitigation					
	Resulting Impact from Activity	Impact of inhalable particulate concentrations at potential receptor locations	M	L-	L	L	L	Low
		Impact of inhalable gaseous concentrations and dust fallout at potential receptor locations	M	L-	L	L	L	Low

7 Conclusions

The main findings from the baseline assessment are as follows:

- The flow field is dominated by winds from the north-north-east. During day-time conditions, winds from the north increase in frequency, with winds from the north-north-east sector increasing at night.
- Existing sources of emissions in the study area include vehicle exhaust and entrainment on paved and unpaved roads, household fuel burning, biomass burning (veld fires), industrial activities, mining operations and wind erosion from exposed areas and tailings storage facilities. High dust fallout rates recorded at all current sampling locations during the windy spring months from September to November indicates that wind erosion is likely a significant source of dust emissions in the study area.

The main findings from the impact assessment are as follows:

- The main sources of dust emissions from the opencast mining operations are likely to be materials handling of ROM and waste rock in the pit and of waste rock at the WRD and vehicle entrainment emissions from haul trucks and other mobile equipment.
- The main sources of dust emissions from the underground mining operations are the ventilation shafts and the aboveground handling of ROM.
- With no mitigation measures applied, simulated highest daily PM_{10} concentrations exceed the NAAQS at the closest potential receptor locations to the east, north and south for four of the open cast operations (the exception being the Mona Lisa pit which has no nearby receptors). With simple mitigation measures such as wet suppression of dust at material handling points and regular water sprays on haul roads, simulated incremental PM_{10} concentrations due to the opencast mining operations would be in compliance with the SA NAAQS at all potential receptor locations (with the exception of Daily PM_{10} concentrations at the buildings to the south of Rugby Club and to the east of 11-Shaft. It is estimated that approximately 22 residential receptors are located to the east of 11 shaft and approximately 18 residential receptors to the south of Rugby Club.
- Even with no mitigation measures applied simulated $PM_{2.5}$, NO_2, SO_2, and CO concentrations are in compliance with the SA NAAQS for all averaging periods and simulated highest monthly dust fallout rates are in compliance with the SA NDCR residential limit at all potential receptor locations and in compliance with the SA NDCR non-residential limit at all off-site areas.
- With no mitigation measures applied the incremental impact of the opencast phase of the West Wits Mining Project on the receiving environment is expected to be MEDIUM. With 50% mitigation of material handling emissions (achievable with the mitigation measures recommended below) and 30% mitigation of vehicle entrained dust from unpaved roads, the incremental impact of the opencast operations is expected to be LOW. The cumulative impact during the mining phase (with mitigation measures applied) is expected to be MEDIUM, but the short life of the open cast operations means that long term impacts (annual average pollutant concentrations) are unlikely to exceed the SA NAAQS.
- The impact of the underground operations on ambient air quality is considered LOW.
- Simulated incremental PM_{10} concentrations during the underground phase of the West Wits Mining Project exceed the SA NAAQS in the immediate vicinity of the infrastructure complexes (due to the handling of ROM), but are in compliance with the SA NAAQS at all potential receptor locations.

Based on the findings above the following recommendations are made:

It is recommended that:

- Best practice mitigation measures (as far as reasonably possible – as per the requirements of the City of Johannesburg Metropolitan Municipality By-Laws) should be implemented for both the mining and rehabilitation phases of the opencast operations.
- A complaints register should be kept on-site once operations commence and staff and the neighbouring communities should be encouraged to report all air quality related problems. Frequent community liaison meetings should be held with the neighbouring communities to address air quality related concerns;
- Wet suppression techniques should be used to control dust emissions, especially in areas where dry material is handled or stockpiled.
- Exposed soils and other erodible materials should be re-vegetated or covered promptly;
- New areas should be cleared and opened-up only when absolutely necessary;
- Surfaces should be re-vegetated or otherwise rendered non-dust forming when inactive;
- Storage for dusty materials should be enclosed or operated with efficient dust suppressing measures;
- Loading, transfer, and discharge of materials should take place with a minimum height of fall, and be shielded against the wind, and the use of dust suppression spray systems should be considered;
- Vehicles should be fitted with catalytic converters and low sulfur fuel should be used to minimise NO_2 and SO_2 impacts.
- Vehicle idle times should be kept to a minimum to minimise CO, NO_2, SO_2, diesel particulate and greenhouse gas emissions.
- Strict speed limits (as low as practically feasible, a maximum of 40km/hr, but preferably 20km/hr) should be imposed on all unpaved roads to reduce entrained emissions and fuel consumption rates.
- The vehicle fleet should be regularly serviced and maintained to minimise CO, NO_2, SO_2, diesel particulate and greenhouse gas emissions.
- Older vehicles in the current fleet should be replaced with newer, more fuel-efficient alternatives where feasible.
- Best practice mitigation measures (wind breaks, wet suppression, minimised drop heights) should be implemented on ROM handling operations during the underground phase of the West Wits Mining Project.
- PM_{10} monitoring is recommended for the duration of the mining and rehabilitation phases. The recommended location for PM_{10} monitoring is at the residential areas to the north or east of each the opencast mining operations (except Mona Lisa, which has no nearby receptors). The recommended location for sampling within these residential areas would be at a suitable location on the southern or western boundary of the residential area (i.e. closest to the opencast mining operations).
- It is recommended that PM_{10} concentrations be sampled prior to the construction phase of each of the open cast operations to assess baseline PM_{10} concentrations without the open cast operations active. PM_{10} sampling should continue throughout the life of each of the open cast operations to determine the impact of the operations on the receiving environment.
- If PM_{10} concentrations are found to be in exceedance of the NAAQS at the closest receptor locations additional dust suppression measures should be investigated.

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9 APPENDIX A

CURRICULUM VITAE

Name	Nick Brian Grobler
Date of Birth	14 August 1986
Nationality	South African
Employer	Airshed Planning Professionals (Pty) Ltd
Position	Senior Air Quality Specialist
Profession	Chemical Engineer employed as an Air Quality Specialist
Years with Firm	6 Years

Membership of Professional Societies

- Institution of Chemical Engineers (IChemE) – Associate Member – 2014 to present.
- Golden Key International Honour Society - 2011 to present.

Experience

- Emissions inventory compilation
- Meteorological, topographical and land use data processing and preparation
- Dispersion modelling experienced in SCREEN, AERMOD, ADMS, CALPUFF and HAWK dispersion models.
- Impact and compliance assessment
- Air quality and dust management plan preparation
- Air quality monitoring program design and implementation
- Air quality monitoring set-up, training and processing of: dust fallout, PM_{10}, $PM_{2.5}$, SO_2, NO_2, H_2S, O_3, NH_3, HCl, VOCs, BTEX, CO, CO_2, CH_4, PAHs as well as meteorological station setup
- Environmental noise monitoring
- Atmospheric emission license application
- Industry sectors in which experience have been gained with specific reference to air quality include:
    - Opencast and underground mining of: copper, platinum, chrome, gold, iron, coal, limestone, potash, lead and zinc.
    - Production of: copper, platinum, gold, base metals, iron, coal, heavy mineral sands, vanadium, solder, lime, gypsum, asphalt, acetylene, vegetable oil, fertilizer, wood pulp, cement, oil recycling, tyre pyrolysis as well as meat processing and rendering at abattoirs and animal waste incineration.

Software Proficiency

- Atmospheric Dispersion Models: AERMOD, ISC, CALPUFF, ADMS (United Kingdom), HAWK, TANKS
- Other: Golden Software Surfer, Lakes Environmental WRPlot, MS Word, MS Excel, MS PowerPoint, Adobe Dreamweaver

Education

- BEng (Chemical Engineering) University of Pretoria – Completed in 2009
- BEng (Hons) (Environmental Engineering) University of Pretoria – Completed in 2010

Courses Completed

- Spreadsheets as an Engineering Tool, Presented by the University of Pretoria, RSA (September 2012)

Courses Presented

- NWU Centre for Environmental Management Essential Air Quality Management Course

Countries of Work Experience

South Africa, Zimbabwe, Namibia, Mozambique, Zambia, Democratic Republic of Congo, Republic of Congo, Ghana, Mali, Guinea, Saudi Arabia

Languages

Language	Proficiency
English	Full proficiency
Afrikaans	Full proficiency