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SEATON THOMSON AND ASSOCIATES CC

BASELINE ASSESSMENT AND HEALTH RISK ASSESSMENT REPORT – PROPOSED RESIDENTIAL DEVELOPMENT ON VARIOUS PORTIONS OF THE FARM ROOIKOPPIES 297-JQ

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EXECUTIVE SUMMARY

Rayten Engineering Solutions (Pty) Ltd was appointed by Seaton Thomson and Associates cc to compile an Air Quality Baseline Assessment for the proposed residential development on various portions of the Farm Rooikoppies 297-JQ, Rustenburg, North-West Province.

The baseline air quality assessment was undertaken through a review of meteorological monitoring data, available air quality monitoring data, air quality legislation and the identification of nearby existing emissions sources surrounding the project site. Comparison of ambient air pollutant concentrations, using available ambient air quality data, is made with the South African National Ambient Air Quality Standards where applicable. As part of the baseline assessment, a basic health risk assessment report was also compiled and can be found under Appendix A.

The land use immediately surrounding the proposed residential development consists predominantly of cultivated land, subsistence farming and mining. Mining activities are predominant in all directions surrounding the proposed site. The closest mines being located approximately 250 m to the east and 100 m to the south of the proposed development. Urban smallholdings are found to the north-west and south-east of the development. Decreasing elevation can be noticed from surrounding mines towards the proposed residential development. Exposure to relatively high pollutant concentrations in this area is therefore likely.

The towns of Marikana and Wonderkop are located approximately <1 km north-west and 4.9 km north-east of the proposed development, respectively. The towns of Lapologang and Mooinooi are situated 4 km south-west and 5.5 km south-east of the proposed development, respectively. The area is classified as rural in nature. The town of Elandsdrift is found approx. 5.6 km east of the proposed development.

There was no air quality monitoring station close to the proposed development (that could be determined) to present background concentrations for SO_2, NO_2, CO, PM_{10} and $PM_{2.5}$ concentrations. However, there was background data available for dust-fall rates as well as passive sampling taking place at a neighbouring mine. Background air quality data was obtained from an Air Quality Impact Assessment (AQIA) undertaken in 2014 by Airshed Planning Professionals (Pty) Ltd.

Dust-fall rates for buckets located in non-residential areas range from 74 – 1 060 mg/m^2/day for the period. There were no exceedances of the non-residential standard of 1 200 mg/m^2/day, during the period August 2018 – August 2019. Higher dust-fall rates are recorded at site D14, located approximately 0.6km south of the proposed development.

Dust-fall rates for buckets located in residential areas range from 20 – 1 010 mg/m^2/day for the period. There were 5 exceedances of the residential standard during the period August 2018 – August 2019. A total of three exceedances were recorded during December 2018 at sites, D09, D13 and D19. These stations are located approximately 3.25 km south, 1.72 km west and 2.95 km south-east, respectively from the proposed development. Two exceedances were recorded in 2019, with D19 exceeding in January 2019 and D12, situated approximately 1.79 km south west of the proposed development, exceeding in June 2019 (Figure 5-9).

The NAAQS annual average guideline for SO_2 is 19 ppb. Results for SO_2 during the period August 2018 – July 2019 ranged from <0.4 – 3.91 ppb. There were no exceedances recorded of the annual average during the monitoring period provided.

The NAAQS annual average standard for NO_2 is 21 ppb. Monitoring results for NO_2 during the period August 2018 – July 2019 ranged from 0.35 – 13.17 ppb. There were no exceedances recorded of the annual average during the monitoring period provided.

An AQIA was undertaken in 2014 for a mine and chrome sand drying plant located near to the proposed residential development site (approximately 100m south of the mine). The dispersion modelling results given in the AQIA report are used to provide an indication of background particulate matter, SO_2, NO_x and CO concentrations at the proposed residential development site.

The predicted annual average PM_{10} concentrations and the frequency of exceedances of the daily standard during the operational phase of the mine were modelled. The results were presented for a mitigated scenario. The annual standard of 40 µg/m^3 is not expected to exceed outside of the mine boundary. Daily exceedances of the standard (75 µg/m^3) however occur slightly outside of the mine boundary, towards the west and north (Airshed, 2014).

The predicted annual average $PM_{2.5}$ concentrations and the frequency of exceedances of the daily standard during the operational phase of a nearby mine were modelled. The results are for a partially mitigated scenario. In this scenario, the annual standard of 20 µg/m^3 (at the time of the report being compiled, the standard was 25 µg/m^3) is predicted to exceed, up to 4 km, outside the north boundary of the mine (Airshed, 2014). Due to the decrease in the annual standard, this distance is likely to increase.

Daily exceedances of the current standard (40 µg/m^3) (at the time of the report being compiled, the standard was 65 µg/m^3) are predicted to occur between 5 km to 6 km outside the north boundary of the mine (Airshed, 2014). Due to the decrease in the annual standard, this distance is likely to increase.

The predicted annual average $PM_{2.5}$ concentrations and the frequency of exceedances of the daily standard during the operational phase of a nearby mine were modelled. The predicted results show that exceedances of the standard 20 µg/m^3 (at the time of the report being compiled, the standard was 25 µg/m^3) occurs within the mine boundary (Airshed, 2014). However, due to the decrease in the annual standard, this distance is likely to increase. Further, there were no daily exceedances predicted, although this may now change as the daily standard has since decreased from 65 µg/m^3 to 40 µg/m^3.

Emissions of CO, NO_x and SO_2 from the chrome drying plant were considerably low, and the model predicted no exceedances of the relevant NAAQS.

It is important to understand the current situation regarding PM_{10} and $PM_{2.5}$ emissions in South Africa, and how likely these emissions are to occur in and around the proposed residential development. The proposed residential development on various portions of the Farm Rooikoppies 297-JQ will be situated close to numerous mines, the closest being to the east (approximetaly 250 m) and south (approximately 100 m). The proposed development will also be in close proximity to agricultural activities. These factors will contribute to PM_{10} and $PM_{2.5}$ emissions in the area.

The frequency of south-easterly and east-south-east winds that blow along the axis of the development would serve to combine emissions from the surrounding pollution sources, namely; mining areas, vehicle dust entrainment from unpaved roads, potential biomass burning and

agricultural activities, industrial activities and residential fuel burning activities. Exposure to high concentrations of emissions could occur.

In conclusion, the pollutants of concern in the area are PM_{10} and $PM_{2.5}$, due to the distance of predicted exceedances depicted in the AQIA compiled by Airshed in 2014. Daily exceedances of PM_{10} occur outside the mine boundary, while annual exceedance and daily exceedances of $PM_{2.5}$ also occur up to 6 km north of the plant boundary. Due to the close proximity of the proposed development to the mine boundary (approximately 100 m) exposure to high levels of PM_{10} and $PM_{2.5}$ could occur, as the exceedances are predicted to occur over the area where the proposed residential development is situated.

Recommendations based on the above results include:

- The proposed development should be moved to a location approximately 6 km north-east or approximately 5 km south of the proposed location. Based on the prevalent wind direction, and the position of surrounding mines and agricultural activities these locations are the most suitable.

- In the case where relocation cannot be attained, include a climate control system with a filter as part of the building design. This would not only ensure air circulation but will reduce the build-up of dust particles within the home.

- Include a barrier of trees surrounding the east and south of proposed residential development. Higher trees can act as porous bodies which influence local dispersion of pollution and aid the deposition and removal of airborne pollutants.

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LIST OF ABBREVIATIONS

AEL	Atmospheric Emissions License
AQMP	Air Quality Management Plan
CH_4	Methane
CO	Carbon Monoxide
CO_2	Carbon Dioxide
$CO_{2\text{-eq}}$	Carbon dioxide equivalent
DEA	Department of Environmental Affairs
DEFF	Department of Environment, Forestry and Fisheries
GHG	Greenhouse gas
GMT	Greenwich Meridian Time
HFC	Hydrofluorocarbons
NAEIS	National Atmospheric Emissions Inventory System
NEMA	National Environmental Management Act
NEM:AQA	National Environmental Management Air Quality Act
NO_2	Nitrogen Dioxide
NO_x	Nitrogen Oxides
N_2O	Nitrous Oxide
Mtpa	Million tonnes per annum
O_3	Ozone
PFC	Perfluorocarbons
PM_{10}	Particulate Matter, aerodynamic diameter equal to or size less than 10µm
$PM_{2.5}$	Particulate Matter, aerodynamic diameter size equal to or less than 2.5µm
SAAQIS	South African Air Quality Information System
SAWS	South African Weather Service
SF_6	Sulphur hexafluoride
SO_2	Sulphur Dioxide
WBPA	Waterberg-Bojanala Priority Area

1. INTRODUCTION

Rayten Engineering Solutions (Pty) Ltd was appointed by Seaton Thomson and Associates cc to compile an Air Quality Baseline Assessment and a Health Risk Impact Assessment for the proposed residential development, located on various Portions of the Farm Rooikoppies 297-JQ, Rustenburg, North-West Province. The farm is bordered by mines to the north-east and south.

The baseline air quality assessment was undertaken through a review of meteorological monitoring data, available air quality monitoring data, air quality legislation and the identification of nearby existing emissions sources surrounding the project site. As part of the baseline assessment, a basic health risk impact assessment report was also conducted and is included in Appendix A.

1.1. Brief Project Description

It is proposed that various portions of the Farm Rooikoppies 297JQ will be used to develop a low- and low-medium income community in Rustenburg, North-West Province. The developers, Homes 2000, hope to develop RDP and GAP housing on the allocated farm portions.

The focus of this study is to assess the ambient air quality in the surrounding area by providing an overview of the prevailing meteorological conditions, reviewing of air quality monitoring data (Wonderkop Station), reviewing the applicable air quality legislation and management plans, thereby identifying nearby existing sources of emissions surrounding the development site.

1.2. Terms of Reference

The scope of work for the Air Quality Baseline Assessment is as follows:

- A review of the study site and activities;
- An overview of the prevailing meteorological conditions in the area which influence the dilution and dispersion of pollutants in the atmosphere;
- The identification of existing sources of emissions surrounding the project site;
- Characterisation of the ambient air quality within the area using available air quality monitoring data;
- A review of the current South African legislative and regulatory requirements for air quality;
- Basic health risk assessment.

1.3. Outline of Report

An overview of the site location including surrounding land use is given in **Section 2**. National Ambient Air Quality Standards and dust control regulations are discussed in **Section 3**. The human health impacts of the criteria air pollutants are described in **Section 4**. The local meteorological conditions and surrounding emission sources are provided in **Section 5**. **Section 6** presents the likely air quality situation in the area and provided the concentrations of the pollutants using available air quality data.

2. SITE CHARACTERISTICS

2.1. Site Location

The proposed residential development is located on various Portions of the Farm Rooikoppies 297-JQ, within the Rustenburg local municipality, North-west Province (Figure 2-1).

2.2. Surrounding Land Use

The land use (Figure 2-2) immediately surrounding the proposed residential development consists predominantly of cultivated land, subsistence farming and mining. Naturally vegetated areas and urban informal settlements are also observed. Mining activities are predominant in all directions surrounding the proposed site. The closest mines being located to the east (approximately 250 m) and south (approximately 100 m) of the proposed development. Urban smallholdings are found to the north-west and south-east of the development.

The towns of Marikana and Wonderkop are located approximately <1 km north-west and 4.9 km north-east of the proposed development, respectively. The towns of Lapologang and Mooinooi are situated 4 km south-west and 5.5 km south-east of the proposed development, respectively. The area is classified as rural in nature. The town of Elandsdrift is found approx. 5.6 km east of the proposed development.

2.3. Topography

The topography surrounding the proposed residential development is shown in Figure 2-3. Surrounding elevations range from 934 – 1 860 m above sea level. The project site is situated approximately 1 160 m above sea level; with increasing elevation towards the south, south-east and south-west. Decreasing elevation can be noticed from surrounding mines towards the proposed residential development.

2.4. Sensitive Receptors

Residential areas, including educational facilities, health care facilities and old age homes, surrounding the project site, within a 10 km radius of the proposed residential development are given in Figure 2-4 below.

Figure 2-1: Site locality for the proposed residential development on various Portions on Farm Rooikoppies 297-JQ.

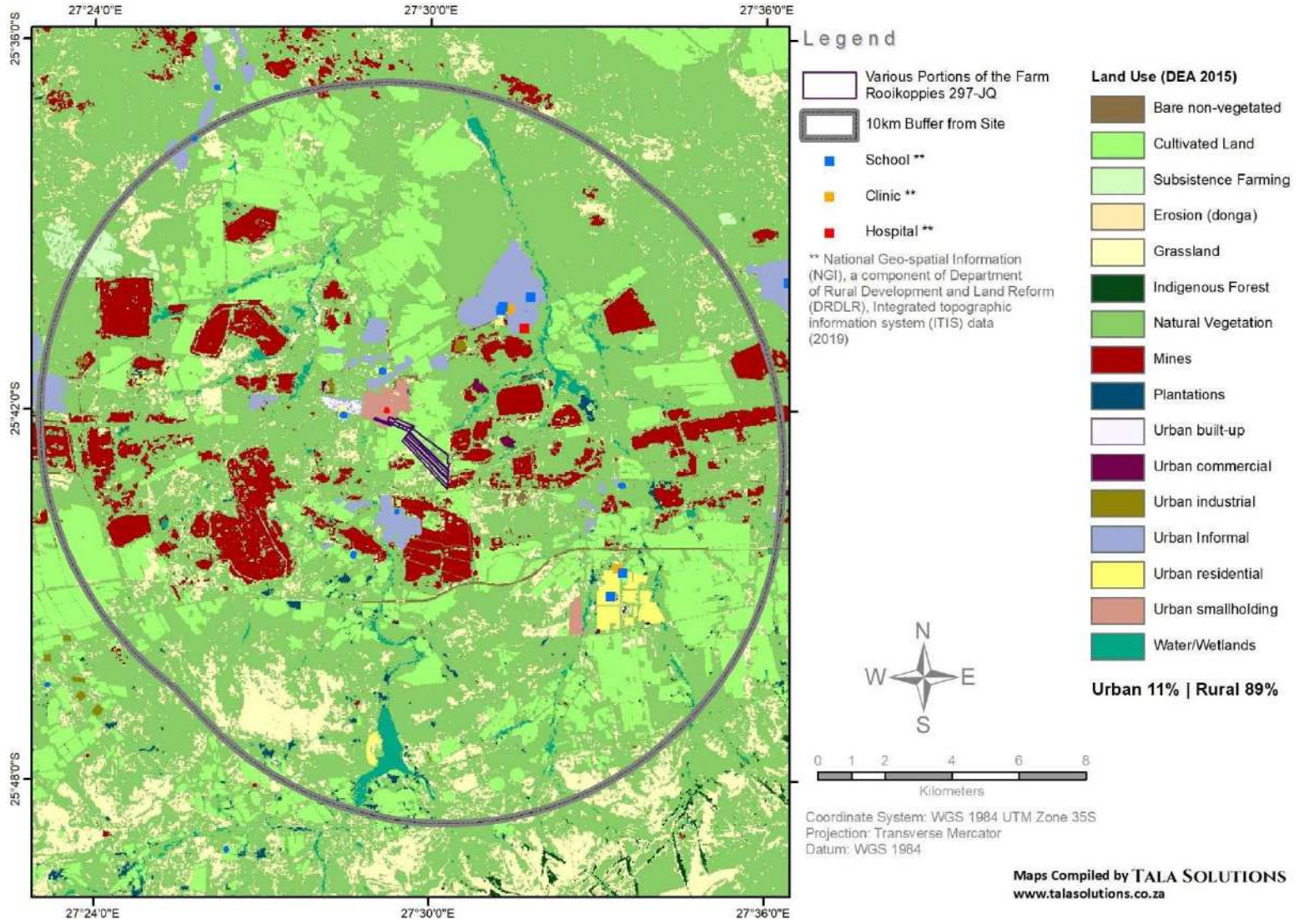


Figure 2-2: Land use surrounding the proposed residential development on various Portions on Farm Rooikoppies 297-JQ.

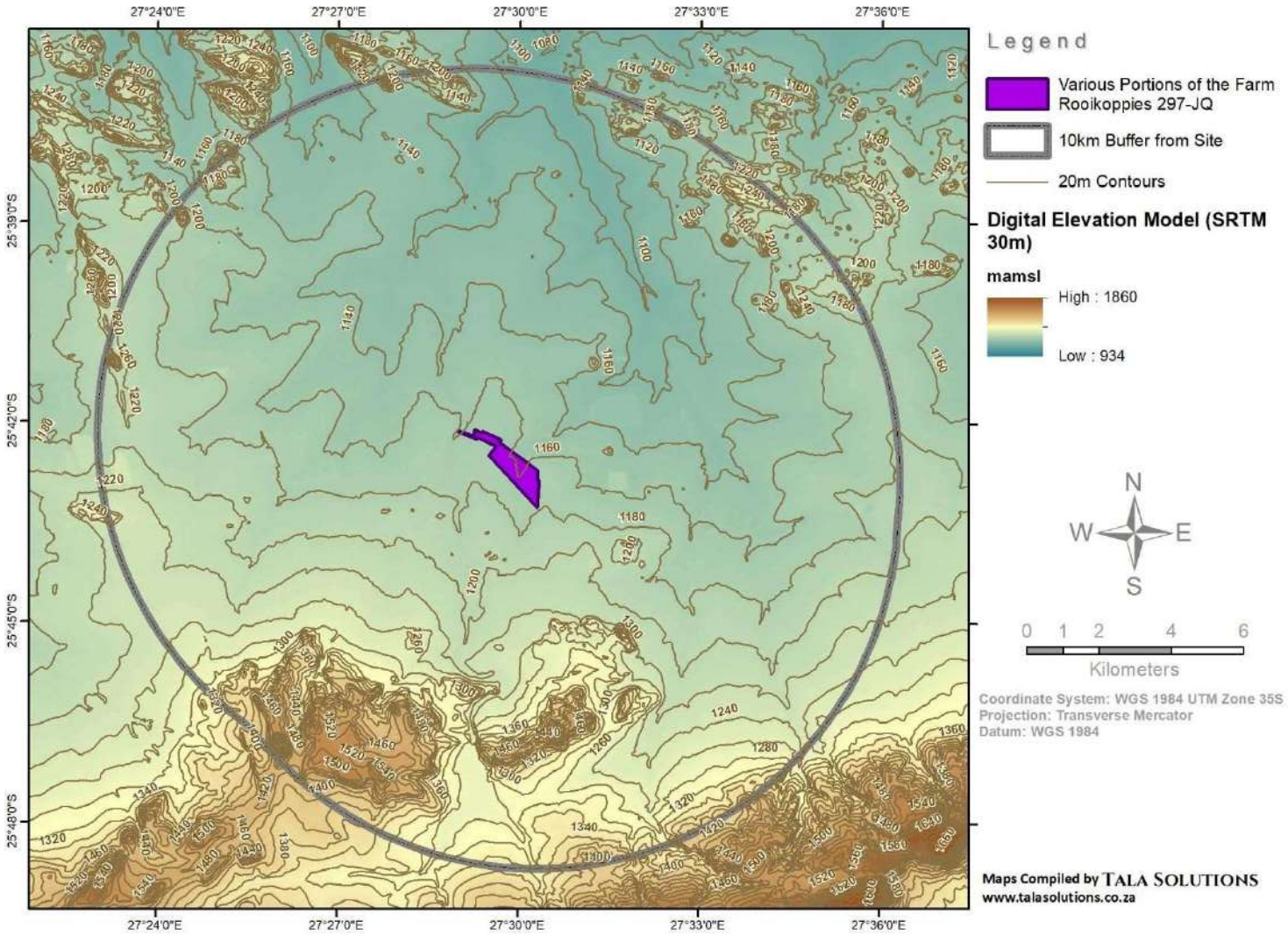


Figure 2-3: Topography surrounding the proposed residential development on various Portions on Farm Rooikoppies 297-JQ.

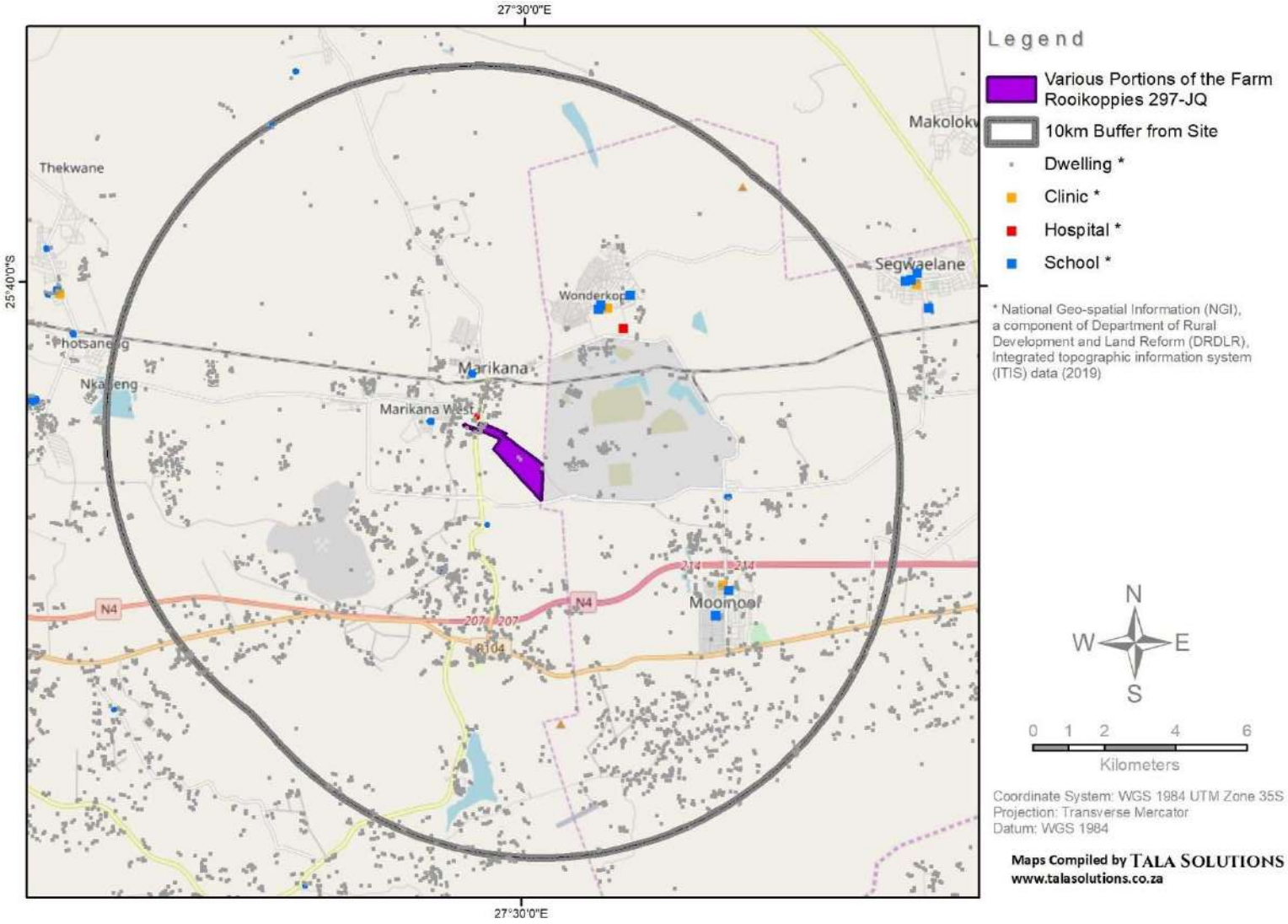


Figure 2-4: Residential areas surrounding the proposed residential development on various Portions on Farm Rooikoppies 297-JQ.

3. LEGISLATION, POLICIES AND GUIDELINES

3.1. National Environmental Management: Air Quality Act

The NEM: AQA, has shifted the approach of air quality management from source-based control to receptor-based control. The main objectives of the Act are to;

- protect the environment by providing reasonable measures for—
  - i. the protection and enhancement of the quality of air in the Republic;
  - ii. the prevention of air pollution and ecological degradation; and
  - iii. securing ecologically sustainable development while promoting justifiable economic and social development; and
- generally, to give effect to section 24(b) of the Constitution in order to enhance the quality of ambient air for the sake of securing an environment that is not harmful to the health and wellbeing of people.

The Act makes provisions for the setting and formulation of National Ambient Air Quality Standards for "substances or mixtures of substances which present a threat to health, well-being or the environment". More stringent standards can be established at the provincial and local levels.

The control and management of emissions in the NEM: AQA relates to the listing of activities that are sources of emissions and the issuing of Atmospheric Emission Licences (AEL). Listed activities are defined as activities which "result in atmospheric emissions and are regarded as having a significant detrimental effect on the environment, including human health". Listed activities have been identified by the Minister of the Department of Environmental Affairs (DEA), now known as the Department of Environment, Forestry and Fisheries (DEFF), and atmospheric emission standards have been established for each of these activities. These listed activities now require an AEL to operate. The issuing of AELs for listed activities is the responsibility of the Metropolitan and District Municipalities, with the exception of those associated within mining.

In addition, the Minister may declare any substance contributing to air pollution as a priority pollutant. Any industries or industrial sectors that emit these priority pollutants will be required to implement a Pollution Prevention Plan. Municipalities are required to "designate an air quality officer to be responsible for co-ordinating matters pertaining to air quality management in the Municipality". The appointed Air Quality Officer is responsible for the issuing of AELs.

3.2. Listed Activities and Minimum Emission Standards

The NEM: AQA requires all persons undertaking listed activities in terms of Section 21 of the Act to obtain an AEL. The listed activities and associated minimum emission standards were issued by the DEA (now known as DEFF) on 31 March 2010 (Government Gazette No. 33064 of 31 March 2010) and were amended in:

- 2013 (Government Gazette No. 37054 of 22 November 2013)
- 2015 (Government Gazette No. 38863 of 12 June 2015)
- 2018 (Government Gazette No.41650 of 25 May 2018; Government Gazette No.42013 of 31 October 2018)

- 2019 (Government Gazette No.42472 of 22 May 2019)

The Proposed Residential Development on Various Portions of the Farm Rooikoppies 297-JQ does not trigger any of the S21 listed activities based on their current and proposed operations.

South Africa launched an online National reporting system, referred to as the National Atmospheric Emissions Inventory System (NAEIS). The NEM:AQA requires all emission source groups identified in terms of the National Atmospheric Emission Reporting Regulations (Government Gazette No. 38633 of 02 April 2015), to register and report emissions on the NAEIS.

3.3. Ambient Air Quality Standards

National Ambient Air Quality Standards, including permitted frequencies of exceedance and compliance timeframes, were issued by the Minister of Water and Environmental Affairs on 24 December 2009 (Table 3-1). National standards for $PM_{2.5}$ were established by the Minister of Water and Environmental Affairs on 29 June 2012.

Table 3-1: National Ambient Air Quality Standards for Criteria Pollutants.

POLLUTANT	AVERAGING PERIOD	CONCENTRATION (µg/m³)	FREQUENCY OF EXCEEDANCE (3)
Sulphur dioxide (SO_2)	10 minutes	500 (191)	526
	1 hour	350 (134)	88
	24 hours	125 (48)	4
	1 year	50 (19)	0
Nitrogen dioxide (NO_2)	1 hour	200 (106)	88
	1 year	40 (21)	0
Particulate Matter (PM_{10})	24 hours	75	4
	1 year	40	0
Particulate Matter ($PM_{2.5}$)	24 hours	40(1) 25(2)	0
	1 year	20(1) 15(2)	0
Ozone (O_3)	8 hours (running)	120 (61)	11
Benzene (C_6H_6)	1 year	5 (1.6)	0
Lead (Pb)	1 year	0.5	0
Carbon monoxide (CO)	1 hour	30 000 (26 000)	88
	8 hours (calculated on 1 hourly averages)	10 000 (8 700)	11

Notes:

*Values indicated in blue are expressed in part per billion (ppb)

(1) Compliance required by 1 January 2016 – 31 December 2029.

(2) Compliance required by 1 January 2030.

(3) Frequency of exceedance refers to the number of times an exceedance is allowed within a calendar year.

3.4. Dust Deposition Standards

The DEA (now known as DEFF) issued National Dust Control Regulations on 1 November 2013 (Table 3-2). The purpose of the regulations is to prescribe general measures for the control of dust in all areas. The regulations prohibit activities which give rise to dust in such quantities and concentrations that the dust fall at the boundary or beyond the boundary of the premises where it originates exceeds:

a) 600 mg/m^2/day averaged over 30 days in residential areas measured using reference method ASTM D1739.
b) 1 200 mg/m^2/day averaged over 30 days in non-residential areas measured using reference method ASTM D1739.

Updated draft National Dust Control Regulations were published on 25 May 2018. The regulations prescribe the method that should be used for undertaking dust-fall monitoring, which includes the use of dust bucket stations with a wind shield.

Table 3-2: South African National Dust Control Regulations.

RESTRICTION AREAS	DUST FALL RATE (D) (1)	REQUENCY OF EXCEEDANCE
Residential Areas	D < 600 mg/m^2/day	Two within a year, no two sequential months (2)
Non-residential areas	600 < D < 1200 mg/m^2/day	Two within a year, no two sequential months (2)

Notes:
(1) Averaged over 1 month (30± 2-day average) (mg/m^2/day)
(2) Per dust-fall monitoring site.

Any person who has exceeded the dust-fall standard must, within three months after submission of a dust-fall monitoring report, develop and submit a dust management plan to the air quality officer for approval. The dust management plan must:

a) Identify all possible sources of dust within the affected site;
b) Detail the best practicable measures to be undertaken to mitigate dust emissions;
c) Develop an implementation schedule;
d) Identify the line management responsible for implementation;
e) Incorporate the dust-fall monitoring plan;
f) Establish a register for recording all complaints received by the person regarding dust fall, and for recording follow up actions and responses to the complainants.

The dust management plan must be implemented within a month of the date of approval. An implementation progress report must be submitted to the air quality officer at agreed time intervals.

3.5. GHG Emissions

On 14 March 2014, the following six greenhouse gases were declared as priority air pollutants in South Africa:

- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous Oxide (N_2O)
- Hydrofluorocarbons (HFCs)
- Perfluorocarbons (PFCs)
- Sulphur hexafluoride (SF_6)

National GHG Emission Reporting Regulations (Government Gazette No. 40762 of 3 April 2017), were published by the DEA (now known as DEFF). A person identified as a Category A data provider in terms Annexure 1 of these regulations, must register their facilities by filling in the form under Annexure 2 of these regulations and must submit a GHG emissions inventory and activity data in the required format given under Annexure 3 of these regulations on an annual basis. All data must be provided annually, by the 31 March of the following year. Data providers are required to register on the NAEIS and report on their direct GHG emissions on an annual basis and comply with the reporting requirements as detailed in the National GHG Emission Reporting Regulations.

National Pollution Prevention Plan Regulations (Gazette No. 40996) were published on 21 July 2017 by the DEA (now known as DEFF). A Pollution Prevention Plan will be required should the development do the following:

a) Undertake any of the following activities identified in Annexure A of the National GHG Emission Reporting Regulations (Government Gazette No. 40762 of 3 April 2017), which involves the direct emission of GHG more than 0.1 Megatonnes (Mt) annually measured as carbon dioxide equivalents ($CO_{2\text{-}eq}$); or
b) Undertake any of the following activities identified in Annexure A of the National Pollution Prevention Plan Regulations (Gazette No. 40996 of 21 July 2017) as a primary activity, which involves the direct emission of GHG more than 0.1 Megatonnes (Mt) annually measured as carbon dioxide equivalents ($CO_{2\text{-}eq}$);

Annexure A activities in terms of the National Pollution Prevention Plan Regulations include:

• Coal mining • Production and /or refining of crude oil • Production and/or processing of natural gas • Production of liquid fuels from coal or gas • Cement production • Glass production • Ammonia production	• Carbon black production • Iron & steel production • Ferro-alloys production • Aluminium production • Polymers production • Pulp and paper production • Electricity production • Nitric acid production

3.6. Carbon Tax Act

The Carbon Tax Act No. 15 of 2019 was promulgated on the 23 May 2019 and is implemented using a phased approach, allowing emitters time to transition to cleaner and more efficient technologies resulting in lower GHG emissions. Phase One is effective from 1 June 2019 to 31 December 2022.

Any person, company or entity who undertakes an activity (above a certain threshold) and is responsible for the release of GHG emissions is required to report on their emissions to the DEA by the 31 March each year and pay tax on those emissions by July each year.

The tax rate is R120 per tonnes of $CO_{2\text{-eq}}$ (carbon dioxide equivalent) emitted by the generation facility or entity for the relevant reporting period. The carbon tax rate will increase by CPI + 2% during the first phase and thereafter by CPI. However, there are tax-free allowances that apply that can make the overall effective tax rate much lower between R6 and R48 per tonnes of $CO_{2\text{-eq}}$ emitted. Tax free allowances are capped at 95% and include:

- A basic tax-free allowance of 60% during Phase One (until December 2022).
- An additional tax-free allowance of 10% for process emissions.
- An additional tax-free allowance of 10% for fugitive emissions.
- An additional tax-free allowance of up to a maximum of 10% for trade exposed sectors.
- An additional tax-free performance allowance of 5% based on performance against intensity benchmarks.
- An additional tax-free allowance of 5% for companies who participate in the carbon budget system.
- An additional tax-free carbon offset allowance of 5% or 10%.

3.7. Waterberg – Bojanala Priority Area Air Quality Management Plan and Threat Assessment

The Waterberg-Bojanala Priority Area (WBPA) was declared by the Minister of the Department of Environmental Affairs (now known as DEFF) on 15 June 2012 and includes the Bojanala Platinum District Municipality. The area was declared a priority area due to the number of coal reserves that are currently unexploited, but energy-based developments in the future pose a threat to the current ambient air quality. Therefore, air quality management planning was undertaken. The Bojanala Platinum District Municipality comprises of five local municipalities, three of which fall within the priority area. Rustenburg local municipality is one of the three. (DEA, 2015)

In order to meet the requirements of the NEM: AQA, an Air Quality Management Plan (AQMP) was compiled for the Waterberg-Bojanala Priority Area in 2015 and provides a management tool that can be used and implemented by departments and industry to ensure effective air quality management within the area. Emitters within the WBPA include (DEA, 2015):

- Residential fuel burning;
- Mining;
- Transport;

- Biomass burning;
- Waste management; and
- Listed activities.

An emission inventory was undertaken using AELs provided by the local municipalities in the area. In terms of the AQMP, an implementation plan was put forward in order to achieve compliance with the AQMP (DEA, 2015). Refer to Table 3-1 below for the list of goals noted to achieve compliance.

Table 3-3: Overall Objectives of the Waterberg-Bojanala Priority Area Air Quality Management Plan (DEA, 2015)

Overall objective of the Waterberg-Bojanala Priority Area (WBPA) Air Quality Management Plan (AQMP)		
Goal 1	**Cooperative governance in the WBPA promotes the implementation of the AQMP.**	This goal aims to address the shortcomings in cooperative governance by ensuring the appropriate structures and mechanisms are in place at the respective levels of governance for effective implementation of the AQMP.
Goal 2	**Air quality management in the WBPA is supported by effective systems and tools.**	The goal aims to improve the systems and tools required for effective air quality management in the WBPA, including emission inventories, ambient monitoring and modelling, and enforcement.
Goal 3	**Ambient concentrations of air pollutants comply with the NAAQS in the WBPA as a result of emission reductions.**	This goal focuses on emission control and reduction across all sectors to ensure that there is compliance with the NAAQS in the WBPA.
Goal 4	**Air quality decision making in the WBPA is informed by sound research.**	This goal aims to ensure appropriate research establishes the health baseline, which improves the Threat Assessment and prioritises emission reduction interventions to inform air quality management and planning in the WBPA.
Goal 5	**Knowledge and the understanding of air quality amongst stakeholders in the WBPA is enhanced.**	This goal aims to improve the communication and current levels of knowledge of air quality amongst stakeholders in the WBPA.

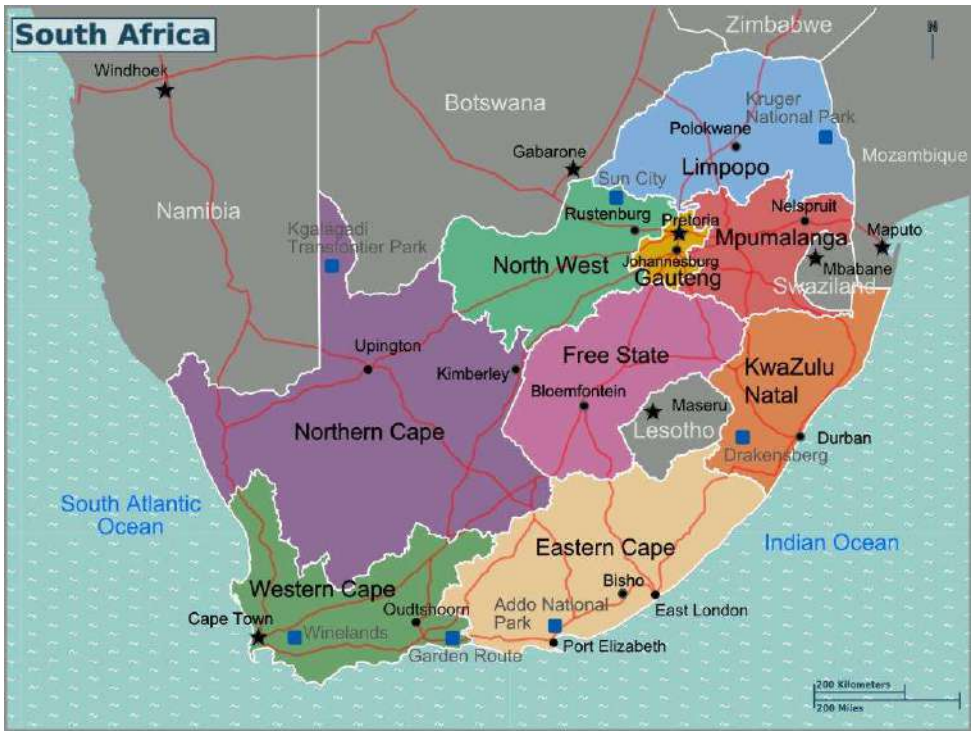


Figure 3-1: Position of Rustenburg within South Africa
(Source: https://za.pinterest.com/pin/421016265140394199/?nic=1)

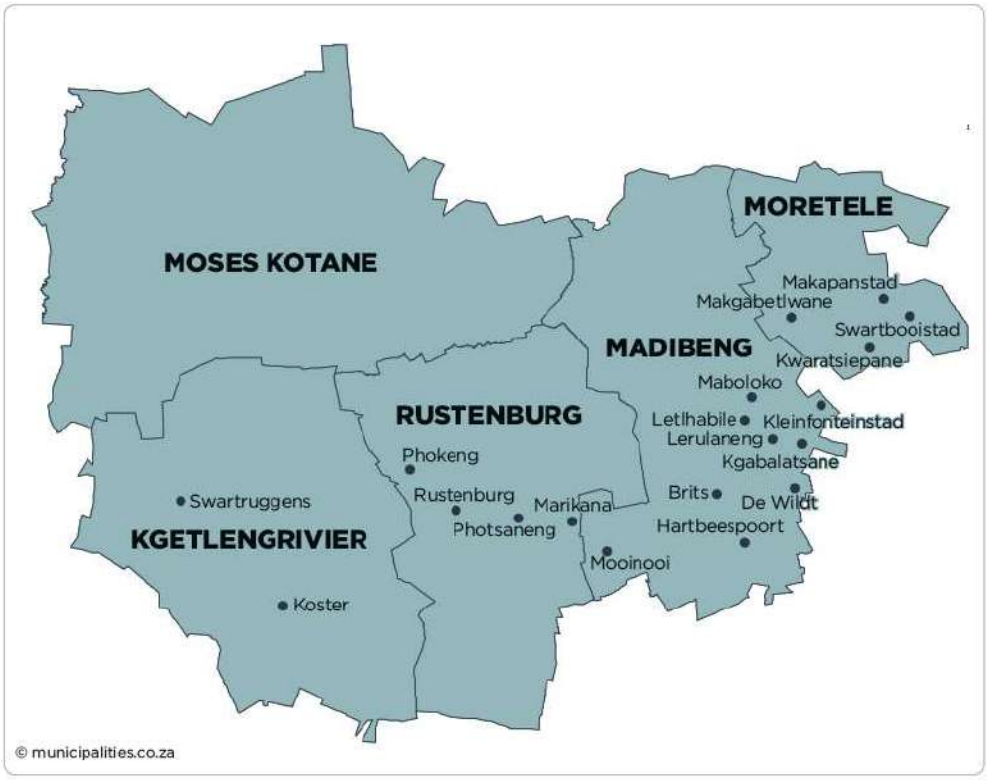


Figure 3-2: Areas within the Rustenburg Local Municipality
(Source: https://municipalities.co.za/map/1191/rustenburg-local-municipality)

Figure 3-3: Waterberg- Bojanala Priority Area (Source: DEA, 2015)

4. HUMAN HEALTH EFFECTS

4.1. Dust Fallout (TSP)

Dust-fall are particles with an aerodynamic diameter greater than 20µm that have been entrained into the air by a physical process such as wind, movement of vehicles, stack emissions and from fugitive dust. These particles are generally too heavy to remain in suspension in the air for any period of time and fall out of the air over a relatively short distance depending on a combination of various factors such as particle size, density, temperature (of the air and particle), emission velocity or method, ambient wind speed and humidity. These particles are therefore commonly known as “dust-fall”. Particulates in this range are generally classified as a nuisance dust and can cause physical damage to property and physical irritation to plants, animals and humans.

4.2. Particulates (PM_{10} & $PM_{2.5}$)

Particles can be classified by their aerodynamic properties into coarse particles, PM_{10} (particulate matter with an aerodynamic diameter equal to or less than 10 µm) and fine particles, $PM_{2.5}$ (particulate matter with an aerodynamic diameter equal to or less than 2.5 µm). The fine particles mostly contain secondary formed aerosols such as sulphates and nitrates, combustion particles and re-condensed organic and metal vapours. The coarse particles mostly contain earth crust materials and fugitive dust from roads and industries (Harrison and van Grieken, 1998) (Fenger, 2002).

In terms of health impacts, particulate air pollution is associated with effects on the respiratory system (WHO, 2000). When looking at human health particle size is an important factor to consider because it controls where in the respiratory system a given particle will be deposited. Fine particles are thought to be more damaging to human health than coarse particles as larger particles do not penetrate deep into the lungs compared to smaller particles. Larger particles are deposited into the extra thoracic part of the respiratory tract while smaller particles are deposited into smaller airways that lead to the respiratory bronchioles (WHO, 2000).

Recent studies suggest that short-term exposure to particulate matter leads to adverse health effects, even at low concentrations of exposure (below 100 µg/m^3). Morbidity effects associated with short-term exposure to particulates include increases in lower respiratory symptoms, medication use and small reductions in lung function. Long-term exposure to low concentrations (~10 µg/m^3) of particulates is associated with mortality and other chronic effects such as increased rates of bronchitis and reduced lung function (WHO, 2000). Those most at risk include the elderly, individuals with pre-existing heart or lung disease, asthmatics and children.

4.3. Lead (Pb)

Lead is a naturally occurring substance in the Earth's crust, although the majority of lead found on the surface is due to anthropogenic causes such as mining, refining, petrol constituents, jewellery making, etc. (WHO, 2010). Lead enters the bloodstream of human beings via food and water consumption, and inhalation of, dust, paint odours and industrial smog.

Long-term exposure to lead can increase health risk vulnerability, especially in children and elderly people. Typically, anyone who is exposed to lead may experience symptoms such as persistent fatigue, insomnia, poor muscle coordination, irritability, nerve damage hearing and vision impairment (Wani et al., 2015).

4.4. Carbon Monoxide (CO)

Carbon monoxide (CO) is a tasteless, odourless and colourless gas which has a low solubility in water. In the human body, after reaching the lungs it diffuses rapidly across the alveolar and capillary membranes and binds reversibly with the haem proteins. Approximately 80 - 90% of CO binds to haemoglobin to form carboxyhaemoglobin. This causes a reduction in the oxygen-carrying capacity of the blood which leads to hypoxia as the body is starved of oxygen. Severe hypoxia due to acute poisoning results in headaches, nausea and vomiting, muscular weakness, loss of consciousness, shortness of breath and finally death, depending on the concentration and time of exposure. Poisoning may cause both reversible, short-lasting neurological deficits and severe, often delayed, neurological

damage. Neurobehavioral effects include impaired co-ordination, tracking, driving ability, vigilance and cognitive ability (WHO, 2000).

4.5. Sulphur Dioxide (SO_2)

SO_2 is classified as a criteria air pollutant in terms of the South African National Environmental Management: Air Quality Act (No. 39 of 2004). Studies suggest that over 85% of SO_2 originates from human activities, particularly the combustion of sulphur-containing fuels at various industrial facilities and power plants (EPA, 2017).

SO_2 is a colourless gas that has a pungent odour and can have negative effects on human health when inhaled (Brauer *et al.*, 2002). Being soluble, SO_2 be harmful to the human respiratory system because it can be readily absorbed in the mucous membranes of the nose and upper respiratory tract, causing difficulties in breathing in both children and the elderly (EPA, 2017). Exposure to SO_2 and sulphur containing compounds may cause irritation of the eyes, nose, and throat and lung air ways. Common symptoms of exposure include a reflex cough and a tight chest (www.mfe.govt.nz, 2013).

Effects of short-term exposure to SO_2 are short-lived, with lung function reverting back to the normal state within a few minutes to hours (WHO, 2000). However, long-term exposure to SO_2 may exacerbate respiratory symptoms such as wheezing, and coughing in adults, and reduce lung function in children in some cases, particularly when SO_2 exposure occurs in the presence of other chemical compounds such as sulphates. Recent studies on health impacts have demonstrated that vehicle and industrial SO_2 emissions released into the air can affect mortality (total, cardiovascular and respiratory), even at low concentrations. (WHO, 2000).

4.6. Nitrogen Dioxide (NO_2)

NO_2 is a red-brown gas which is mainly released during combustion processes from mobile sources (vehicles) and stationary sources (factories, refineries, power stations, etc). In urban environments vehicle emissions account for the majority of NO_2 released into the atmosphere. (Kamarehie *et al.*, 2017).

NO_2 is a highly reactive gas with strong oxidizing properties and contributes significantly to formation of ground level ozone and brown haze (pollution smog). Furthermore, when NO_2 is emitted into the atmosphere, it can easily react with water to form nitric acid which can in turn, result in acid rain. In this respect, exposure to elevated levels of NO_2 may cause eye, mucus membrane and respiratory infections because NO_2 is highly reactive with water. Studies indicate that prolonged exposure to NO_2 can cause respiratory infections and permanent lung damage (EPA, 2017).

NO_2 can be absorbed into the mucus membrane of the respiratory tract. The most impact on human health occurs at the section (in the human body) between the conducting airway and the gas exchange region of the lungs. The impact of NO_2 on the upper airways is less because of the aqueous nature of the airways – NO_2 is not very soluble in aqueous surfaces. Exposure to NO_2 may additionally increase the risk of respiratory infections, increase airway resistance in asthmatics, and decrease pulmonary function (Kamarehie *et al.,*2017).

Pulmonary function in adults that have been exposed to NO_2 (>200 µg/m^3) for short periods may be altered; pronounced decreases in pulmonary function may be experienced when exposure to NO_2

concentrations above 500µg/m^3 occurs (WHO, 2005). Long-term epidemiological studies have been conducted to determine the link between indoor use of gas cooking appliances and health effects. These studies have shown that children aged 5 – 12 years may be at higher risk of respiratory symptoms and diseases when exposed to elevated NO_2 concentrations from the cooking appliances. Similar but increased and prolonged health impacts may be noticed in children that have been exposed to outdoor ambient NO_2 over long periods (WHO, 2000).

4.7. Ozone (O_3)

Ozone, also listed as a criteria pollutant in South Africa, is a naturally occurring colourless pollutant that can also be emitted directly into the air from industrial fossil fuels and combustion processes. Ozone is formed in the troposphere through complex chemical reactions between volatile organic compounds (VOCs) and oxides of nitrogen (NO_X) in the presence of sunlight. This implies that meteorological factors influence ozone formation (EPA, 2017).

At ground level, ozone can be harmful, and may cause negative health impacts in individuals who are at high risk of exposure. According to Bell (2014), short term exposure to ozone can have detrimental effects on the pulmonary and respiratory systems in human beings. When inhaled by children, the elderly, those who are actively outdoors, and asthmatics, may all be at high risk of pulmonary and respiratory irritations. Additional side- effects of exposure to ozone include shortness of breath, inflamed airways, and chronic obstructive pulmonary disease (COPD) (Karthik *et al.,* 2017).

4.8. Benzene

Benzene is the only Volatile Organic Compound (VOC) is listed as a criteria pollutant in South Africa due to its carcinogenic properties. Bridges et al., (2000) and Vrijheid (2000) argue that carcinogenic chemicals or gases must not have standard threshold limits as they may be harmful to human health even in small concentrations. This suggests that people who are exposed to carcinogenic agents irrespective of the concentration, are at some level of risk to adverse health effects.

Exposure to VOCs via inhalation can cause a variety of health effects depending on the concentration and type of VOC a person is exposed to and the duration of exposure. In general exposure to elevated levels of VOCs over a short duration can potentially cause skin, eyes, nose and throat irritations, headaches, drowsiness, nausea and vomiting. Exposure to low levels of VOCs over a longer duration period may potentially cause cancer, kidney and liver damage, chromosomal aberrations, and blood disease (Duarte-Davidson et al., 2001).

5. BASELINE ASSESSMENT

5.1. Meteorological Overview

Meteorological processes will determine the dispersion and dilution potential of pollutants emitted into the atmosphere. The vertical dispersion of pollution is governed by the stability of the atmosphere as well as the depth of the surface mixing layer. Horizontal dispersion of pollution is defined by dominant wind fields. Therefore, meteorological parameters including temperature, precipitation, wind speed and wind direction are of significance as they will influence the degree to which pollution will accumulate or disperse in the atmosphere.

The Wonderkop Weather Station situated at the Marikana mining operations is the nearest weather station to the proposed development. The station is located within 5 km north-east of the proposed residential development. Meteorological data, including wind speed, wind direction, rainfall, temperature, and relative humidity, were obtained from the Wonderkop Weather Station for the period January 2016 to December 2018.

5.1.1 Local Wind Field

Figure 5-1 below provides the period wind rose plot for the proposed residential development for the period January 2016 to December 2018. The predominant wind directions for the period are observed from the south-east (~14.6% of the time), east-south-east (~8.9%) and east (~8.5%). Wind speeds for the three-year period were generally moderate to fast with calm conditions, defined as wind speeds less than 1 m/s, observed for 18.65 % of the time.

The morning (AM) and evening (PM) period wind rose plots for the period January 2016 to December 2018 are given in Figure 5-2 below and shows a slight diurnal variation in the wind field data. During the morning (AM) period, high frequency winds are observed from the south-east and east-south-east; as opposed to the evening (PM) period, where winds are predominantly observed from the south-east and north-west.

Seasonal variation in winds at the proposed residential development is shown in Figure 5-3 below. There is a slight variation in the wind field over the different seasons. During summer, prevailing easterly, and east-south-easterly winds were observed; while during spring, autumn and winter, south-easterly and east-south-easterly winds prevail. Wind speeds were generally moderate to low during all seasons; which could subsequently facilitate the transport of emissions from pollution sources surrounding the proposed development.

Based on the prevailing wind fields for the period, emissions from surrounding sources are likely transported towards the north-westerly and west-north-western regions. The proposed development is surrounded by mining activities and is downwind from cultivated land activities and urban informal areas. Moderate to fast wind speeds observed may result in effective dispersion and dilution of emissions. However, moderate to fast wind speeds may also facilitate dust emissions from open storage piles, tailings facilities and exposed areas surrounding the development. Removal of pollutants via wet depositional processes would be evident during the spring and summer seasons, thus lower ambient concentrations of pollutants (particularly dust) are expected during these seasons. Elevated levels of pollutants would be expected during the autumn and winter seasons due to reduced wet depositional process. Higher ambient concentrations of pollutants would also be evident during the autumn and winter seasons due to reduced vertical dispersion of pollutants as a result of the winter inversion layers.

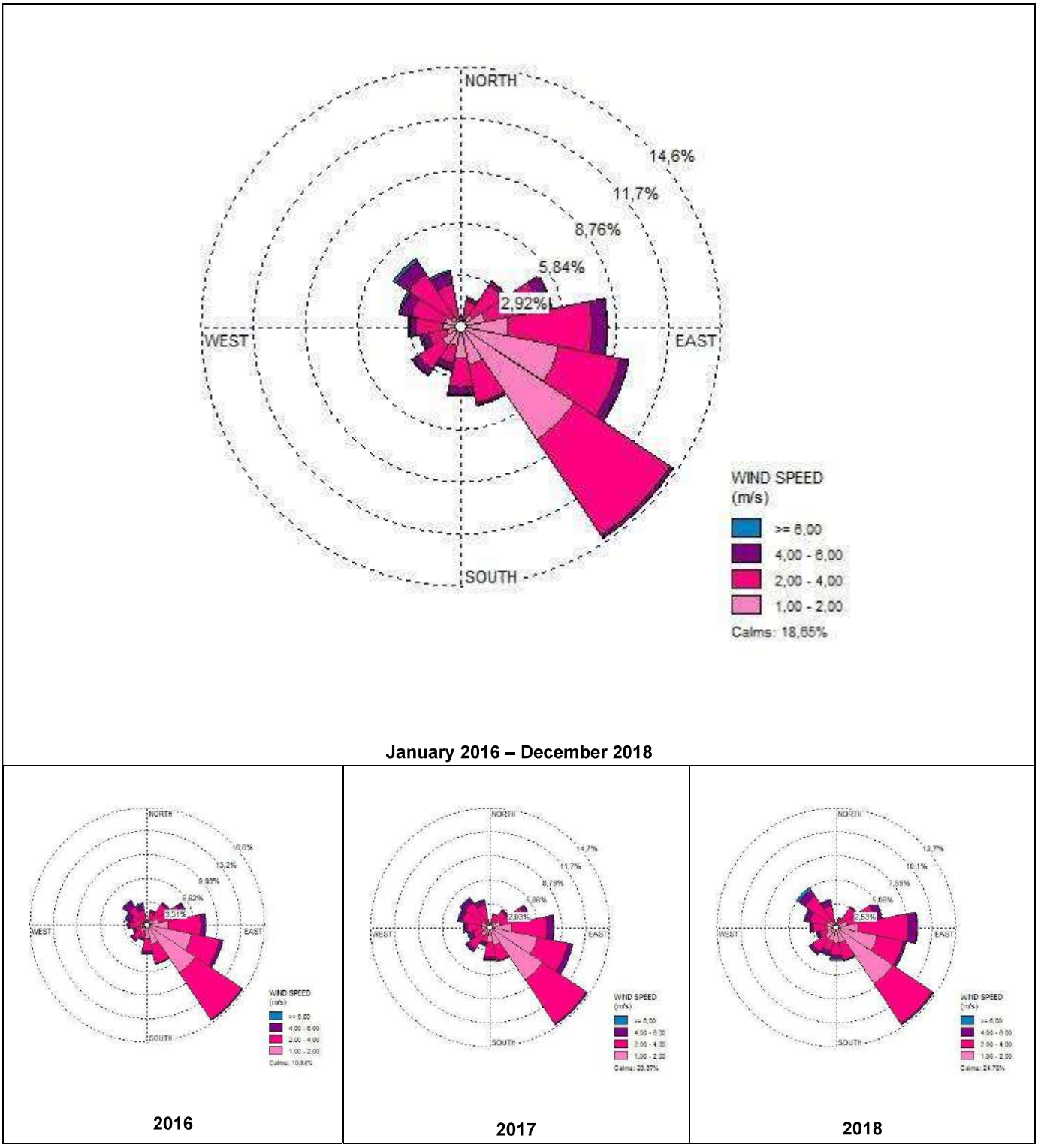
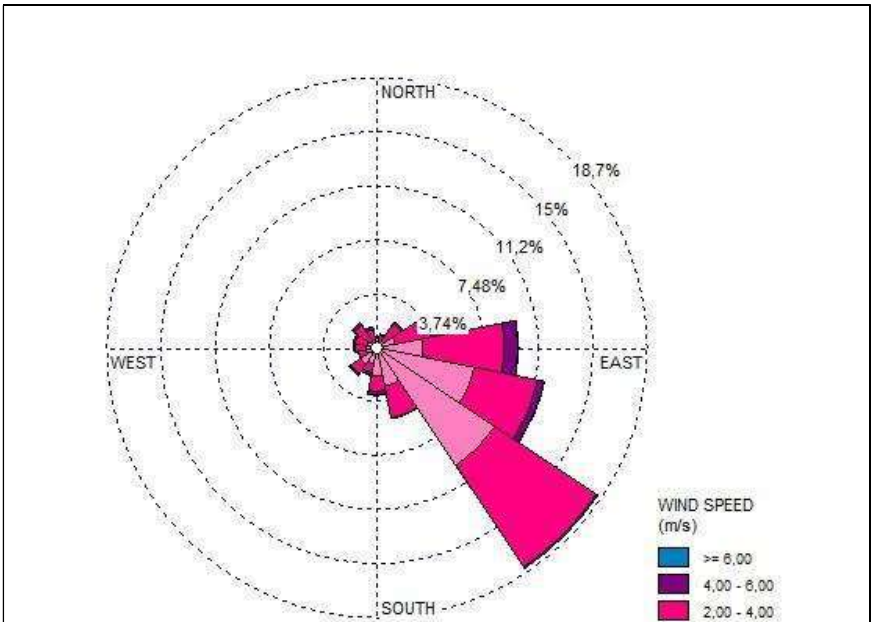
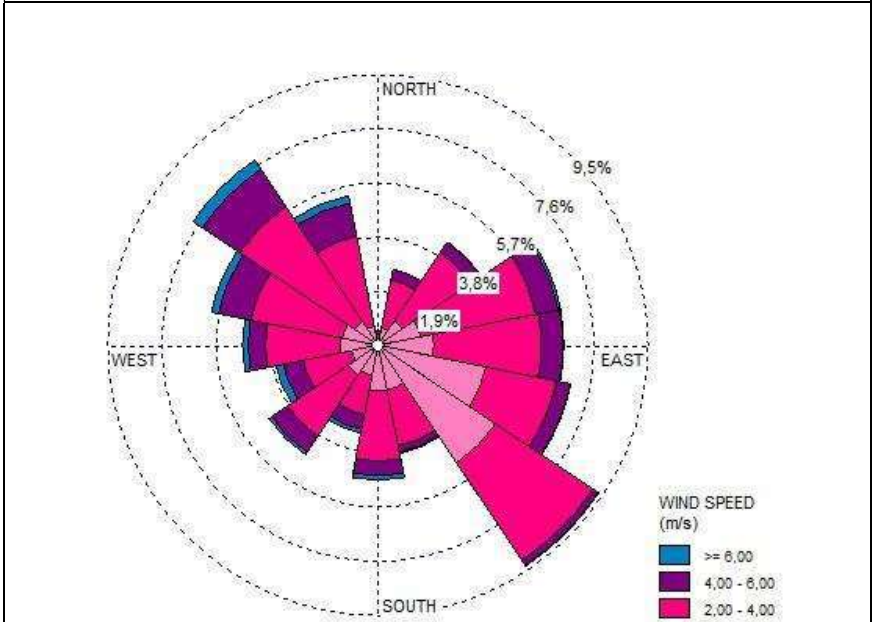


Figure 5-1: Period Wind Rose Plots for the proposed residential development on various portions of Farm Rooikoppies 297-JQ for the period January 2016 - December 2018.



Morning (AM) (00:00 – 12:00)



Evening (PM) (12:00 – 23:00)

Figure 5-2: Morning (AM) (00:00 - 12:00) and Evening (PM) (12:00 - 23:00) Period Wind Rose Plots for proposed residential development on various Portions of Farm Rooikoppies 297-JQ for the Period January 2016 - December 2018.

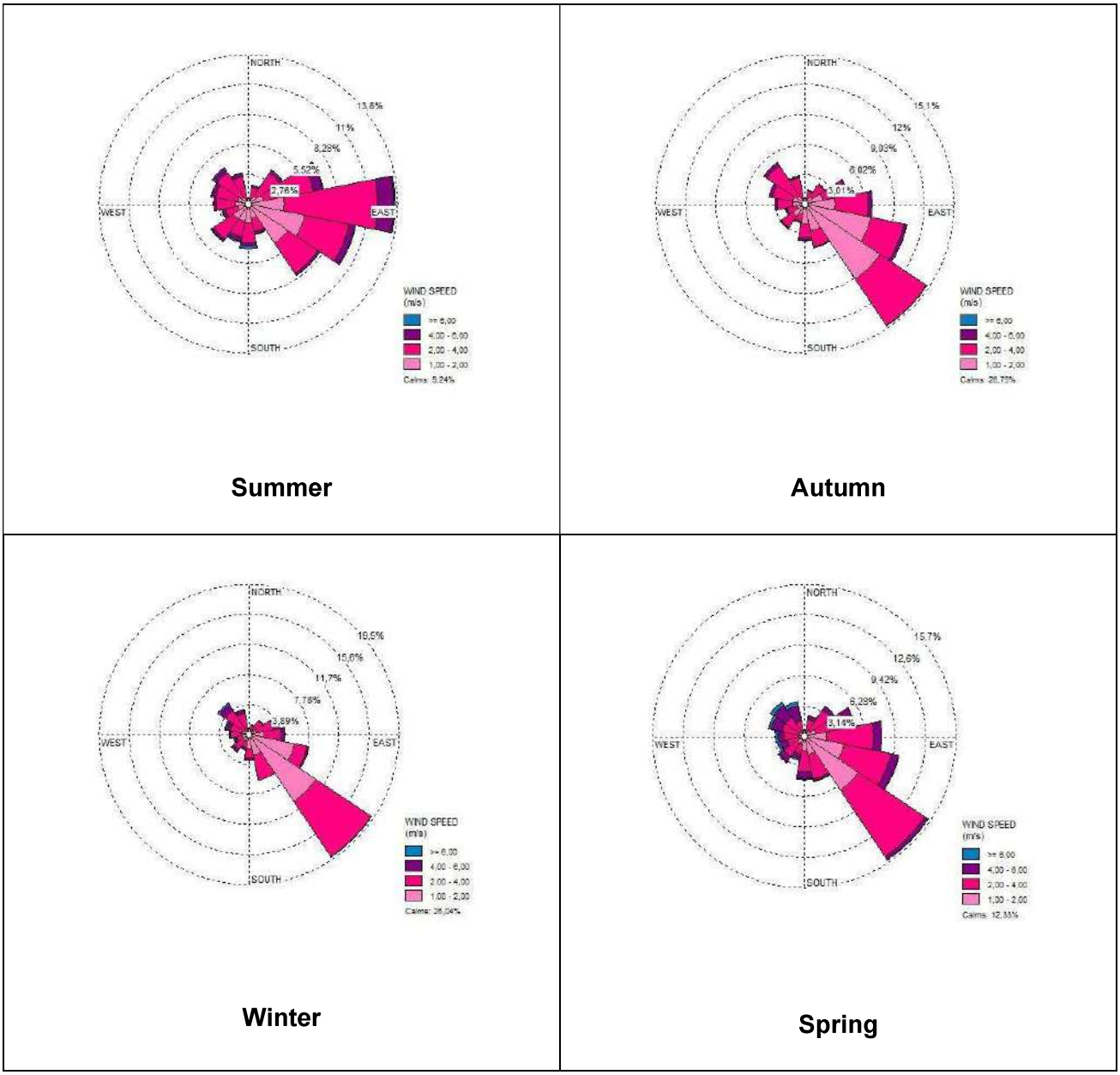


Figure 5-3: Seasonal Variation of Winds for the proposed residential development on various Portions of Farm Rooikoppies 297-JQ for the Period January 2016 - December 2018.

5.1.2 Temperature and Relative Humidity

Temperature affects the formation, action and interactions of pollutants in various ways. Temperature provides an indication of the rate of development and dissipation of the mixing layer, which is largely controlled by surface inversions. Surface temperature inversions play a major role in air quality, especially during the winter months when these inversions are the strongest. Higher ambient temperatures will facilitate the dispersion of air pollutants which can result in lower ambient concentrations.

Chemical reaction rates also tend to increase with temperature and the warmer the air, the more water it can hold and therefore the higher the humidity. When relative humidity exceeds 70%, light scattering

by suspended particles begins to increase, as a function of increased water uptake by the particles. This results in decreased visibility due to the resultant haze. Many pollutants may also dissolve in water to form acids.

The Rustenburg District Municipality generally experiences a mild, generally mild and temperate climate. Most rainfall is experienced during the spring and summer months, with little to no rain experienced during the autumn and winter months. Monthly average temperatures and relative humidity profiles at the project site for the period January 2016 to December 2018 are presented in Figure 5-4 below. Average monthly temperatures range from 13.4 ºC – 24.7 ºC (Table 5-1). Highest temperatures are observed during the spring, summer and autumn months (September – April) and minimum temperatures are observed during the winter months (May – August). Relative humidity is higher in summer (December - February) and during Autumn (i.e. March – April).

Table 5-1: Hourly Minimum, Maximum and Monthly Average Temperatures for January 2016 - December 2018.

MINIMUM, MAXIMUM AND MONTHLY AVERAGE TEMPERATURES (ºC)												
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Minimum	12,5	16,3	11,2	8,6	4,9	0,4	1,1	1,9	3,4	8,4	9,1	13,5
Maximum	41,6	36,9	33,8	33,8	27,6	26,1	26,3	30,3	36,0	38,4	36,9	38,0
Average	24,7	24,4	22,7	20,1	16,1	13,6	13,4	16,7	21,5	22,7	22,9	24,1

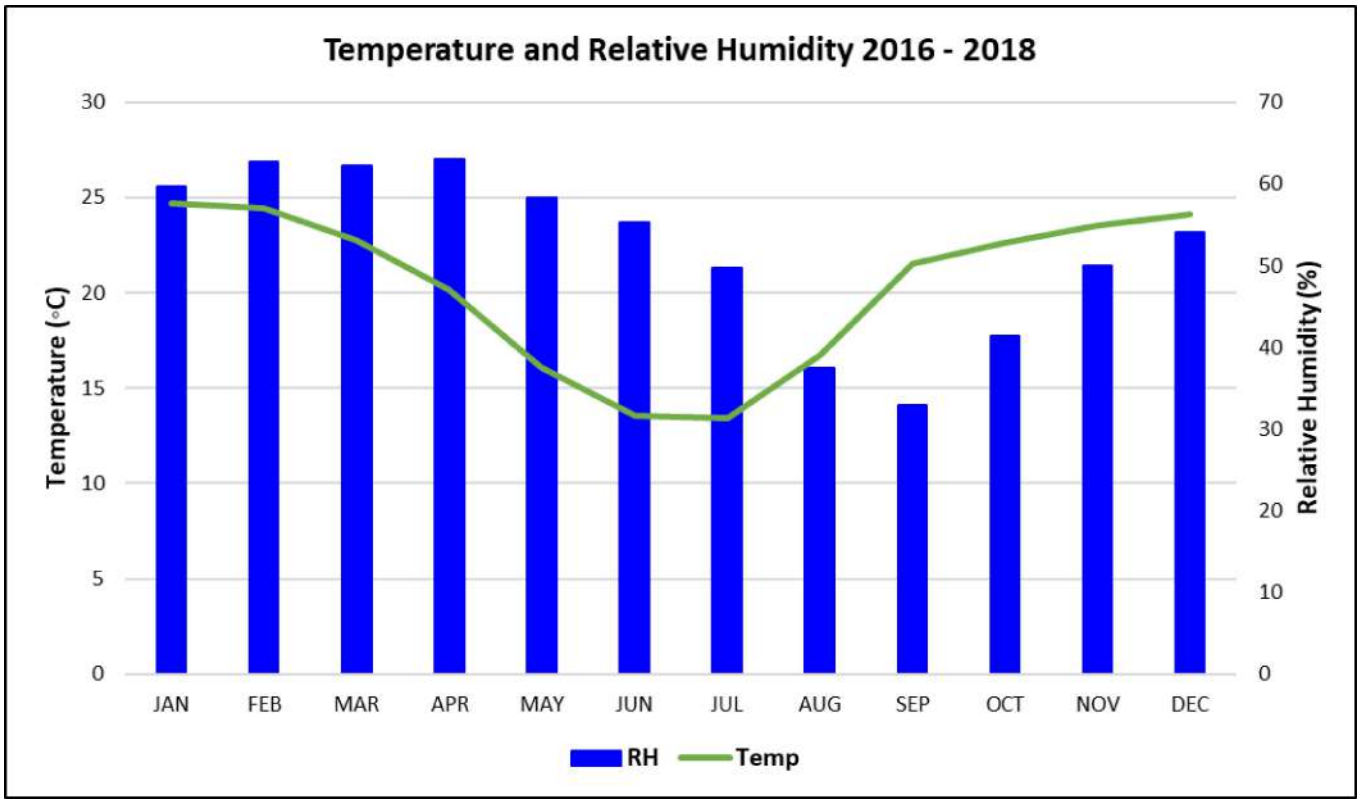


Figure 5-4: Monthly Average Temperature and Relative Humidity profiles for the proposed residential development on various Portions of Farm Rooikoppies 297-JQ for January 2016 - December 2018.

5.1.3 Precipitation

Precipitation has an overall dilution effect and cleanses the air by washing out particles suspended in the atmosphere. Monthly total rainfall for the period January 2016 to December 2018 is presented in Figure 5-5. The area receives most of its rainfall during the spring, summer and early autumn seasons during the months October - March. Little to no rainfall is observed during the mid-autumn and winter seasons from April to August (Table 5-2). Removal of particulates via wet depositional processes would be evident during the warmer (wet) seasons thus lower ambient concentrations of particulates could be expected during these seasons. Over the remainder of the year higher ambient concentrations of particulates could be expected.

Table 5-2: Total Monthly Rainfall for January 2016 - December 2018.

TOTAL MONTHLY RAINFALL (mm)												
YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
2016	48,38	11,97	39,10	2,63	11,87	4,00	1,20	0,00	0,43	7,89	15,20	25,26
2017	58,18	23,69	0,23	1,53	3,05	0,00	1,00	0,00	1,03	10,57	20,97	16,52
2018	6,42	5,52	18,93	15,11	1,80	0,43	2,20	0,00	2,17	7,70	2,26	13,62

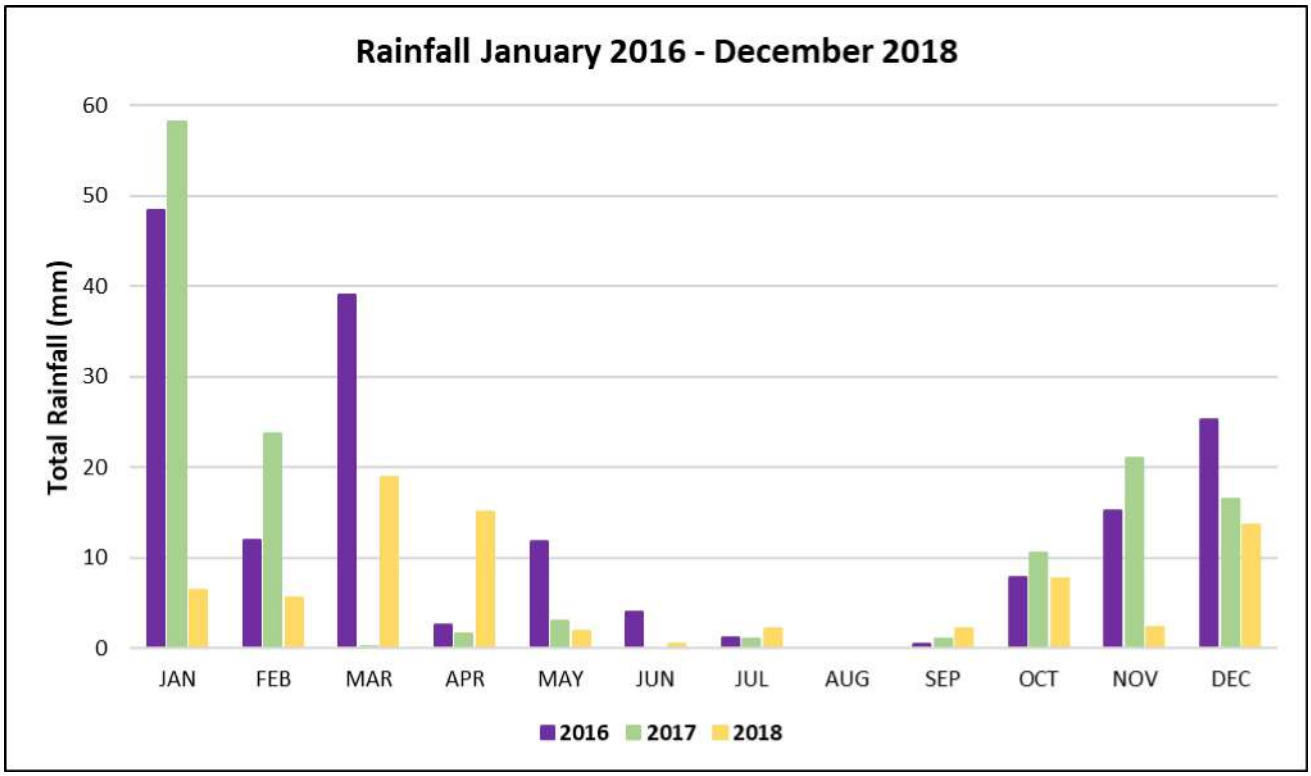


Figure 5-5: Total Monthly and Average Rainfall (mm) for the proposed residential development on various Portions of Farm Rooikoppies 297-JQ for the period January 2016 - December 2018.

5.2. Surrounding Sources of Air Pollution

Existing sources of emissions are all contributing to air pollution and air pollutant concentrations within the area. The existing key sources of air pollution surrounding the proposed residential development were identified during a desktop exercise and include (Figure 5-6 to Figure 5-8):

- Mining activity (surrounding the proposed development, excl. northerly);
- Vehicle exhaust emissions and vehicle dust entrainment on unpaved roads (surrounding areas);
- Agricultural activity and potential biomass burning (surrounding areas);
- Domestic fuel burning for cooking and heating purposes in surrounding township/informal settlements (south-west, north-west and north-east of the proposed development);
- Wind erosion from exposed areas (east, north-west and north of the proposed area).

Forestry and industrial areas were identified as additional sources of air pollution but to a smaller extent. Forestry activity occurs over small areas to the east and south-west of the proposed development. Industrial areas are found to the north-west and north-east of the proposed development.

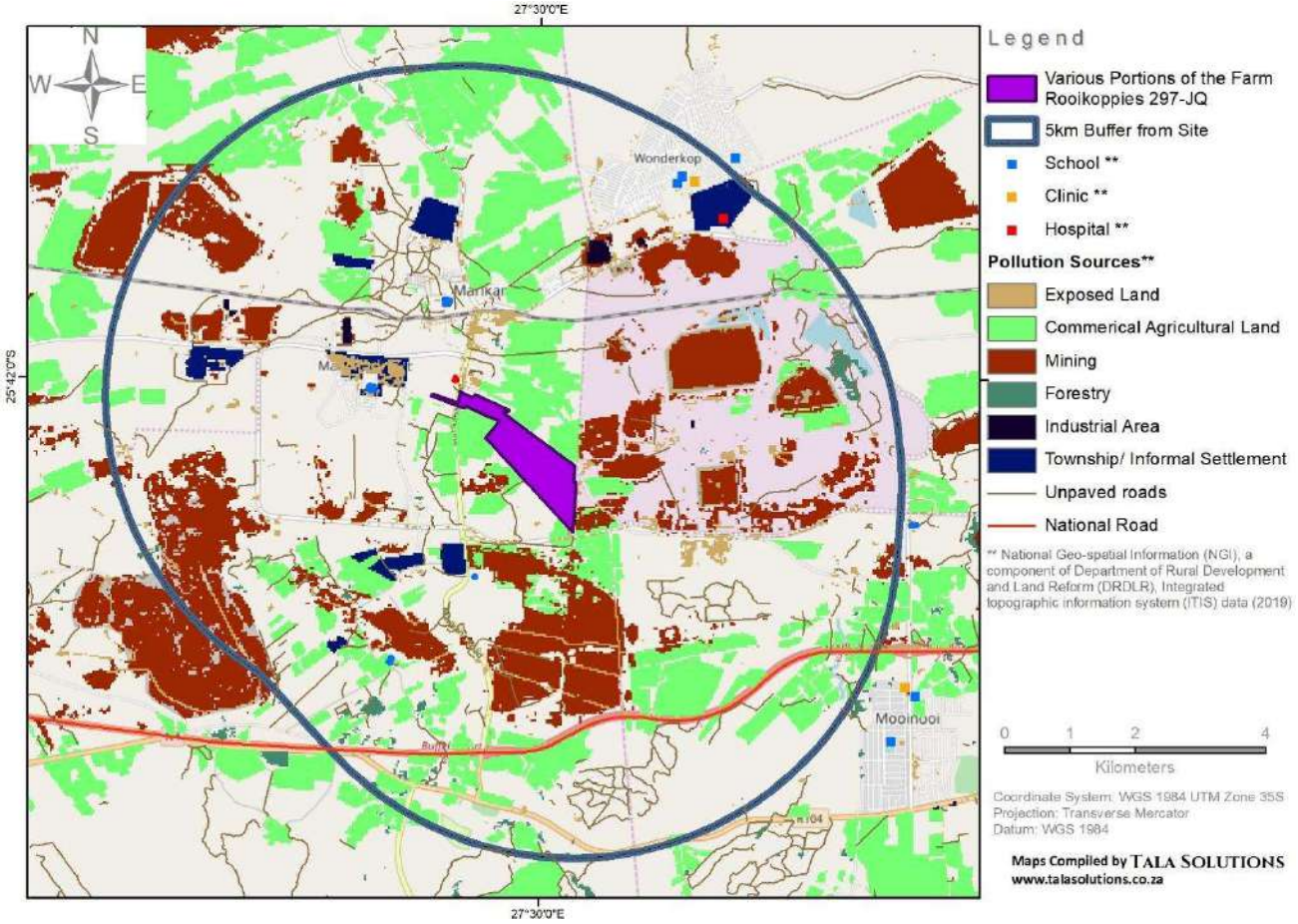


Figure 5-6: Identified surrounding emission sources within 5km of the proposed residential development on various Portions of the Farm Rooikoppies 297-JQ.

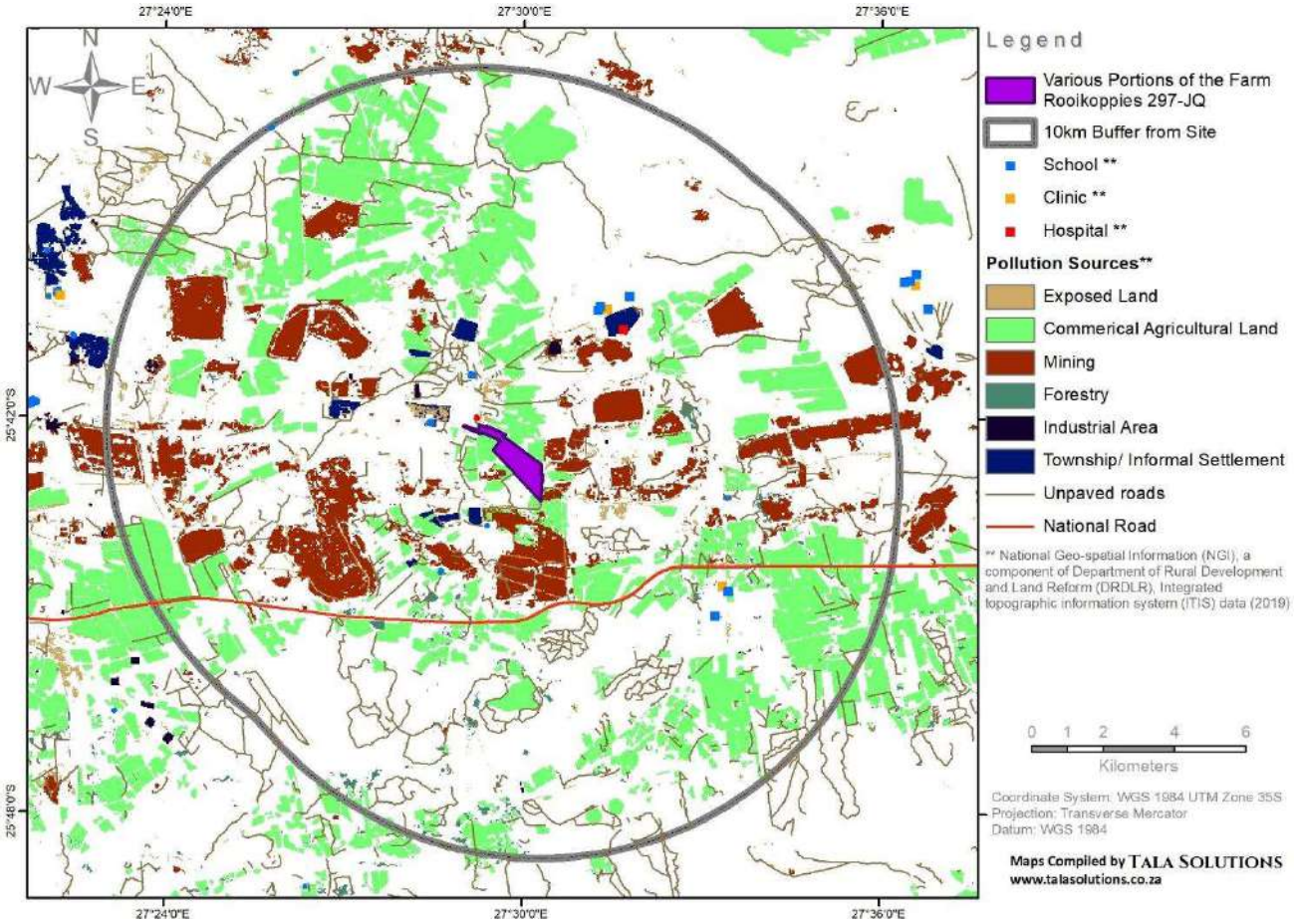


Figure 5-7: Identified surrounding emission sources within 10km of the proposed residential development on various Portions of the Farm Rooikoppies 297-JQ.

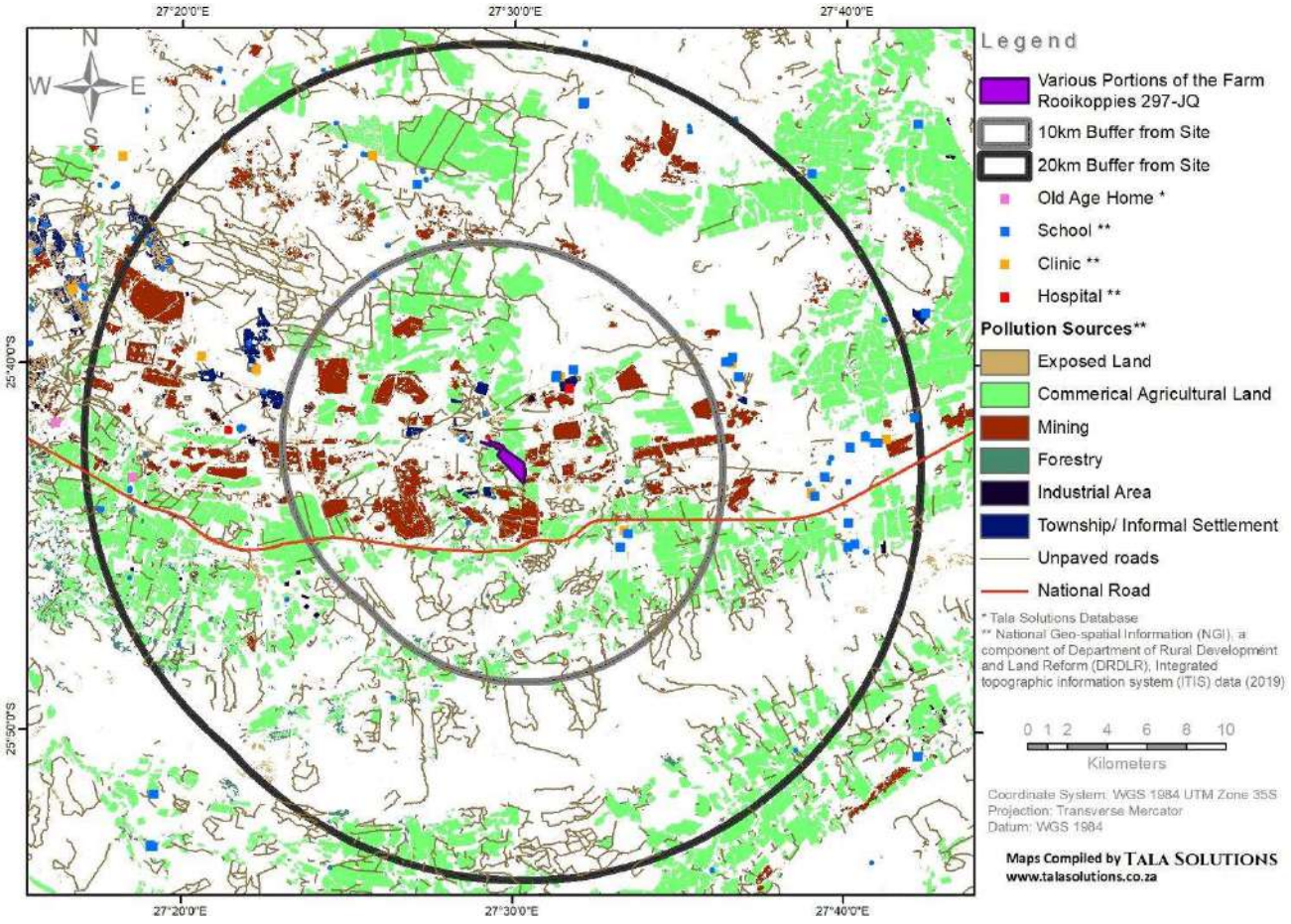


Figure 5-8: Identified surrounding emission sources within 20km of the proposed residential development on various Portions of the Farm Rooikoppies 297-JQ.

5.2.1. Mining Activity

There are existing mining operations and stockpiles surrounding the site, particularly to the east, north-east, south and south-west of the proposed development. The following activities are key sources of emissions associated with mines:

- Material handling, storage and processing;
- Crushing and screening;
- Combustion processes (e.g. gas, diesel & oil combustion);
- Processing plant operations and associated combustion processes;
- Blasting and drilling;
- Excavation, bull dozing, grading;
- Removal of material (e.g. topsoil, overburden, ore);
- Wind erosion from exposed areas (e.g. opencast areas, stockpiles and storage piles);
- Conveying of material (material transfer);
- Vehicle dust entrainment due to truck hauling activities on unpaved roads; and
- Truck and mining equipment exhaust emissions.

Mining activity taking place near to the proposed residential development is a key source of dust in the area.

5.2.2. Vehicle Exhaust Emissions and Vehicle Dust Entrainment on Unpaved Roads

The proposed residential development is located in close proximity to the towns of Marikana and Wonderkop where motor vehicle activity is prominent, and mining activities. There are numerous unpaved roads surrounding the proposed development. The N4 freeway is found south of the proposed development. Vehicle activity is associated with emissions of SO_2, NO_x, CO, PM, VOCs and Pb. Vehicle emissions will vary depending on the distance travelled, the speed of travel, the type of fuel used, the model/age of the engine and the type of emission control technology used by the car.

Vehicles that have lower fuel combustion efficiency (generally older models and less well-maintained vehicles) are associated with higher emissions. Lower exhaust emissions will result in a more consistent travelling speed and a shorter distance of travel. Hauling trucks, forklifts and front-end loaders used in mining, industrial and manufacturing plants can be a source of both exhaust emissions and fugitive emissions from vehicle dust entrainment from material spills.

There are also commercial agricultural land and informal settlements located in close proximity to the project site. Vehicle dust entrainment on unpaved roads that may occur within these areas can also be a source of dust in the area.

5.2.3. Agricultural activity and potential biomass burning

There are several commercial agricultural areas surrounding the project site. Emissions from agricultural activities are difficult to control due to the seasonality of emissions and the large surface area producing emissions. Expected emissions resulting from agricultural activities include particulates associated with wind erosion and burning of crop residue, chemicals associated with crop spraying and odiferous emissions resulting from manure, fertilizer and crop residue. Dust associated with agricultural practices may contain seeds, pollen and plant tissue, as well as agrochemicals, such as pesticides. The application of pesticides during temperature inversions increases the drift of the spray and the area of impact.

Dust entrainment from farming vehicles travelling on gravel roads may also cause increased particulates in an area. Dust from traffic on gravel roads increases with higher vehicle speeds, more vehicles and lower moisture conditions. The seasonal burning of the veld from July to September for field clearing in preparation for planting is also a source of smoke. The nature of the activity has a potential impact on air quality in the area.

5.2.4 Township/informal settlements

The burning of domestic fuels for heating and cooking purposes is likely to occur in some of the surrounding informal residential areas surrounding the project area. Even in electrified areas, households make use of domestic fuels due to high electricity costs and the traditional use of such fuels.

Pollutants released from these fuels include PM_{10}, CO, NO_2, SO_2, inhalable particulates and polycyclic aromatic hydrocarbons. Particulates are the dominant pollutant emitted from the burning of wood. Smoke from wood burning contains respirable particles that are small enough in diameter to enter

and deposit in the lungs. These particles comprise a mixture of inorganic and organic substances including aromatic hydrocarbon compounds, trace metals, nitrates and sulphates. Polycyclic aromatic hydrocarbons are produced as a result of incomplete combustion and are potentially carcinogenic in wood smoke. The main pollutants emitted from the combustion of paraffin are NO_2, particulates, CO and polycyclic aromatic hydrocarbons.

Domestic fuel burning shows a characteristic diurnal and seasonal signature. Periods of elevated domestic fuel burning, and hence emissions, occurs in the early morning and evening for space heating and cooking purposes. During the winter months, an increase in domestic fuel burning is recorded as the demand for space heating and cooking increases with the declining temperature.

5.2.5. Wind erosion from exposed areas

There are open exposed areas such as bare soil, eroded natural land, etc. and tailings facilities surrounding the proposed dvelopment site which represent a source of dust in the area. Dust emissions due to the erosion of exposed areas occur when the threshold wind speed is exceeded. The threshold wind speed is dependent on the erosion potential of the exposed surface, which is expressed in terms of the availability of erodible material per unit area (mass/area). Any factor which binds the erodible material or otherwise reduces the availability of erodible material on the surface thus decreases the erosion potential of the surface. Studies have shown that when the threshold wind speeds are exceeded, particulate emission rates tend to decay rapidly due to the reduced availability of erodible material.

5.3. Baseline Air Quality Concentrations

Existing sources of emissions (please refer to **section 5.2** above) are all contributing to air pollution and air pollutant concentrations within the area. Air quality monitoring data is needed to assess the quality of the air that people residing in the proposed housing development site will potentially be exposed to. Air quality data is usually obtained from permanent ambient air quality monitoring stations and dust fallout networks operated within close proximity to the project site. The data provides an indication of the baseline air quality situation (i.e. quality of air). Ambient air quality standards have been developed for eight criteria air pollutants in South Africa (Table 3-1). These pollutants are considered to be harmful to human health (please refer to **Section 4**). People who are exposed to pollutant concentrations that frequently exceed the acceptable National Ambient Air Quality Standards, are considered to be vulnerable to potential health risks. South Africa has also developed Dust Control Regulations which provide acceptable dust fallout limits for residential and non-residential areas (Table 3-2). High dust fallout rates can act as a nuisance and damage property or crops and can also create irritation of the skin, eyes, nose and throat of people.

Air pollutant concentrations will vary for different areas due to the changes in the emission sources (i.e. type, characteristics and quantity), meteorology (i.e. wind speed, wind direction, temperature, etc.) and topography (i.e. terrain). Therefore, the air quality monitoring data, that is used to represent the air quality situation at a particular site, needs to be obtained from a sampling site that is operated in close proximity or even at the study site itself. This is often a significant limitation in baseline air quality studies; as in many cases, not all of the pollutants of concern are measured and for the

pollutants that are measured, there is often a high percentage of missing or inaccurate data. Furthermore, the instruments and equipment used to monitor air pollutants is very expensive and sophisticated, thus making it difficult for monitoring to be undertaken.

An existing air quality situation is usually evaluated using available monitoring data from permanent ambient air quality monitoring stations and dust-fall networks operated near the proposed residential development. There was no air quality monitoring station close to the proposed development (that could be determined) to present background concentrations for SO_2, NO_2, CO, PM_{10} and $PM_{2.5}$ concentrations. However, there was background data available for dust-fall rates as well as passive sampling taking place at a neighbouring mine, which are given below in sections 5.3.1. and 5.3.2, respectively. Background air quality data was obtained from an AQIA undertaken in 2014 by Airshed Planning Professionals (Pty) Ltd. The background information from this study is provided in section 5.3.3 below.

5.3.1. Baseline Dust Fallout Rates

Dust-fall monitoring is conducted at fourteen (14) sites around the neighbouring mine operations, see Figure 5-9 below. Dust bucket locations are classified as both residential and non-residential, see Table 5-3 below for classification and respective standards. Dust-fall rates for the period August 2018 – August 2019 are presented in Figure 5-10 and Figure 5-11 below.

Table 5-3: Classification of dust fallout buckets

Dust Bucket Number	Site Classification	Dust fallout standard (mg/m^2/day)
D01	Non-Residential	1 200
D02	Residential	600
D03	Residential	600
D04	Non-Residential	1 200
D05	Non-Residential	1 200
D06	Non-Residential	1 200
D08	Residential	600
D09	Residential	600
D11	Residential	600
D12	Residential	600
D13	Residential	600
D14	Non-Residential	1 200
D19	Residential	600
Dkiep1	Residential	600

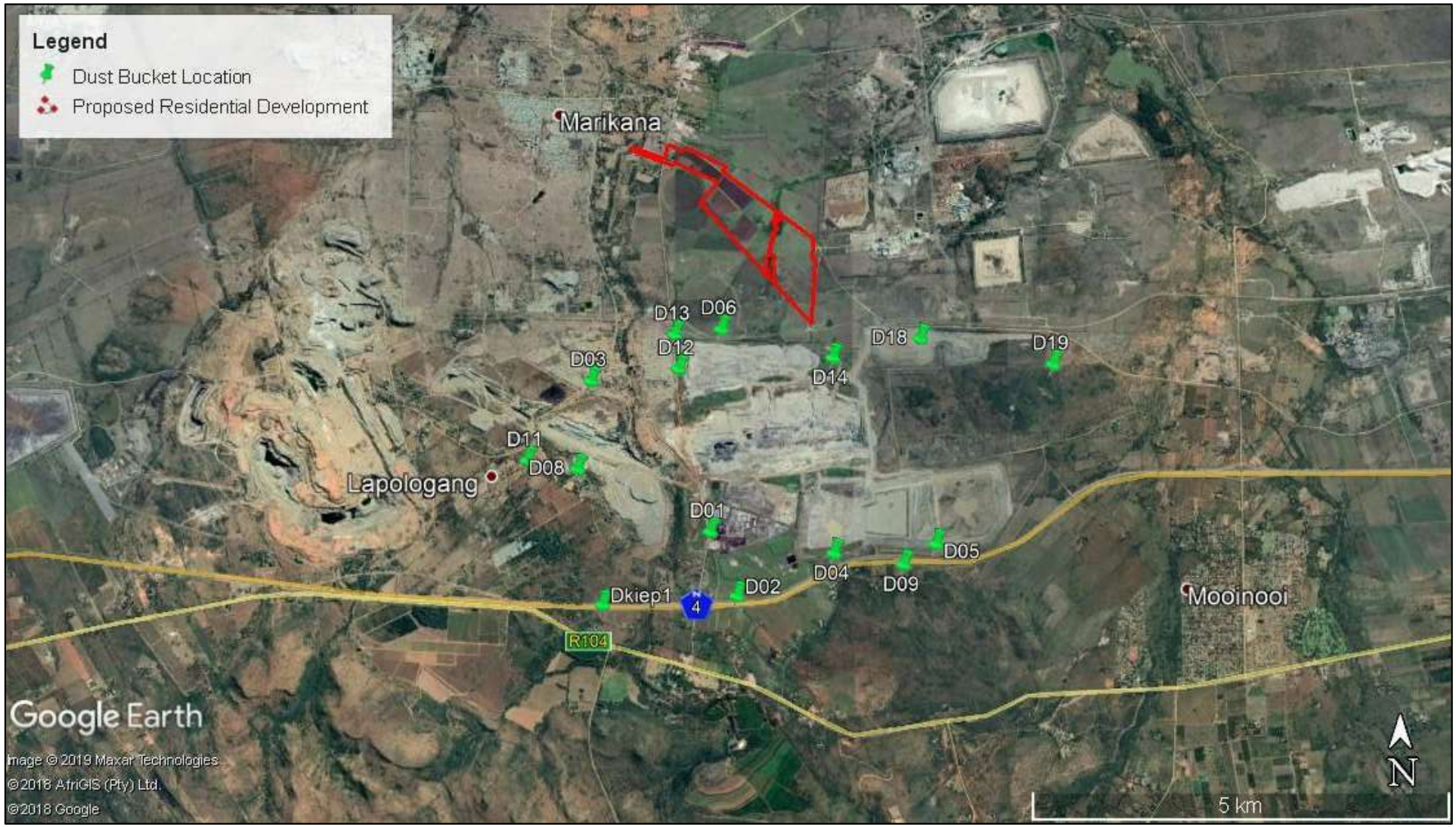


Figure 5-9: Location of dust fallout buckets in relation to the proposed residential development on various Portions of the Farm Rooikoppies 297-JQ

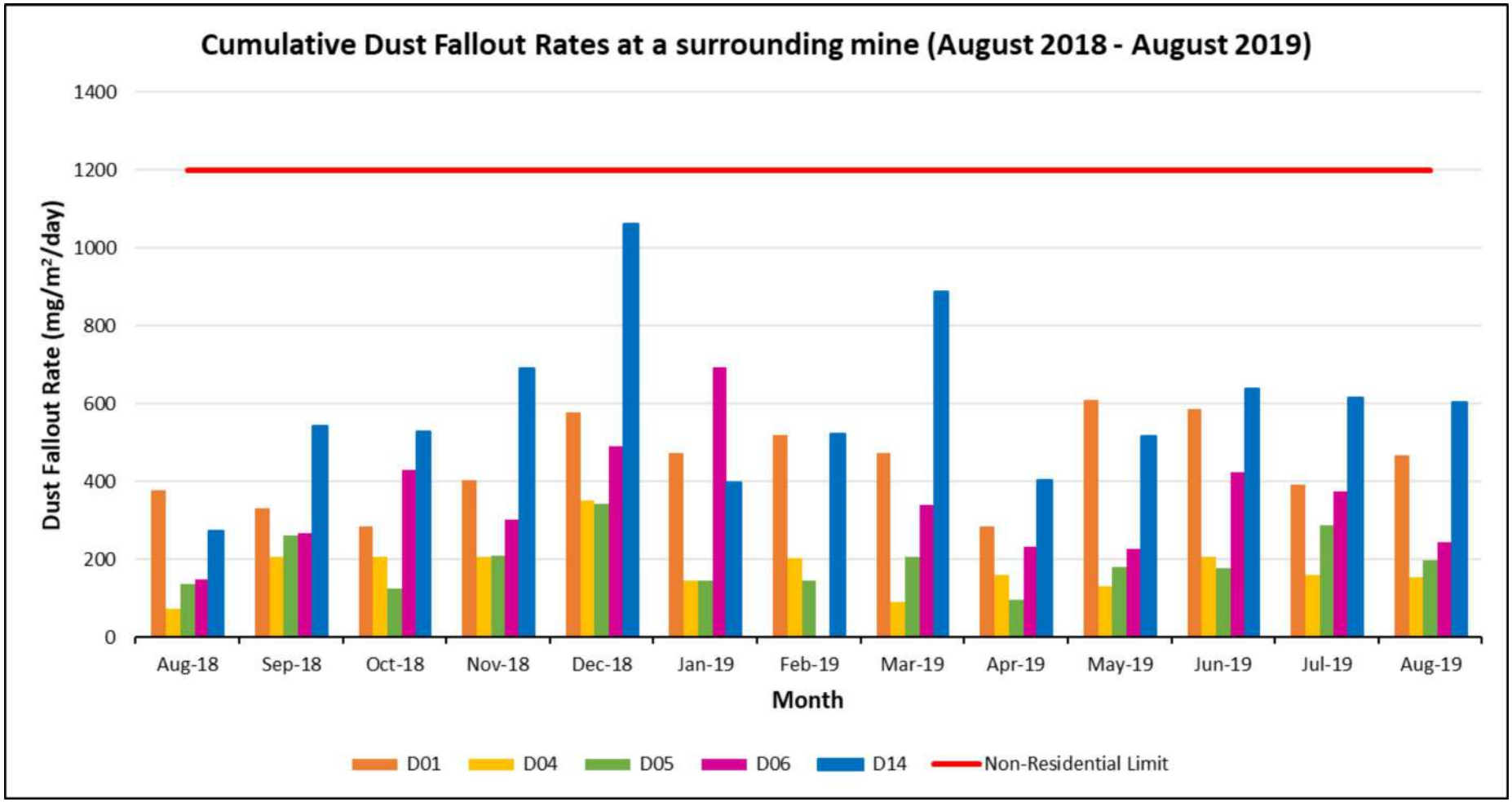


Figure 5-10: Non-residential dust fallout rates at a surrounding mine for the period August 2018 – August 2019

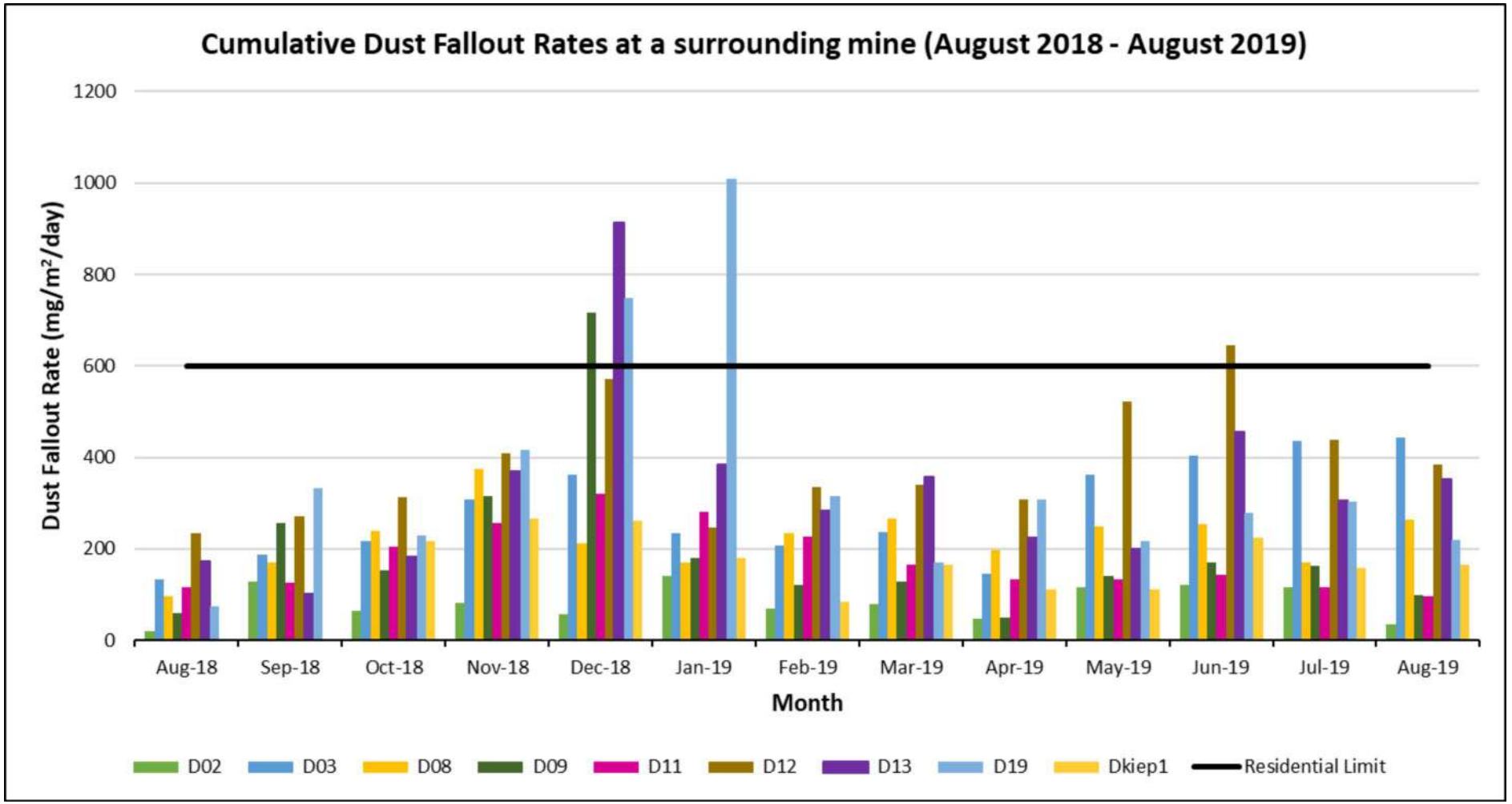


Figure 5-11: Residential dust fallout rates at a surrounding mine for the period August 2018 – August 2019

5.3.2. *Passive Sampling*

Passive sampling for SO_2 and NO_2 is conducted at three (3) sites around the neighbouring mine operations using Radiello passive samplers, see Table 5-4 and Figure 5-12 below. Passive samples were exposed for one month, where gases are adsorbed onto the relevant cartridge.

Table 5-4: Site locations of passive samplers

Site Code	Co-Ordinates	Description
PS01	25°44'14" S; 27°28'12" E	Lapologang Village
PS02	25°44'54" S; 27°30'55" E	Glenross Farmhouse
PS03	25°45'07" S 27°27'44" E	Swanepoel

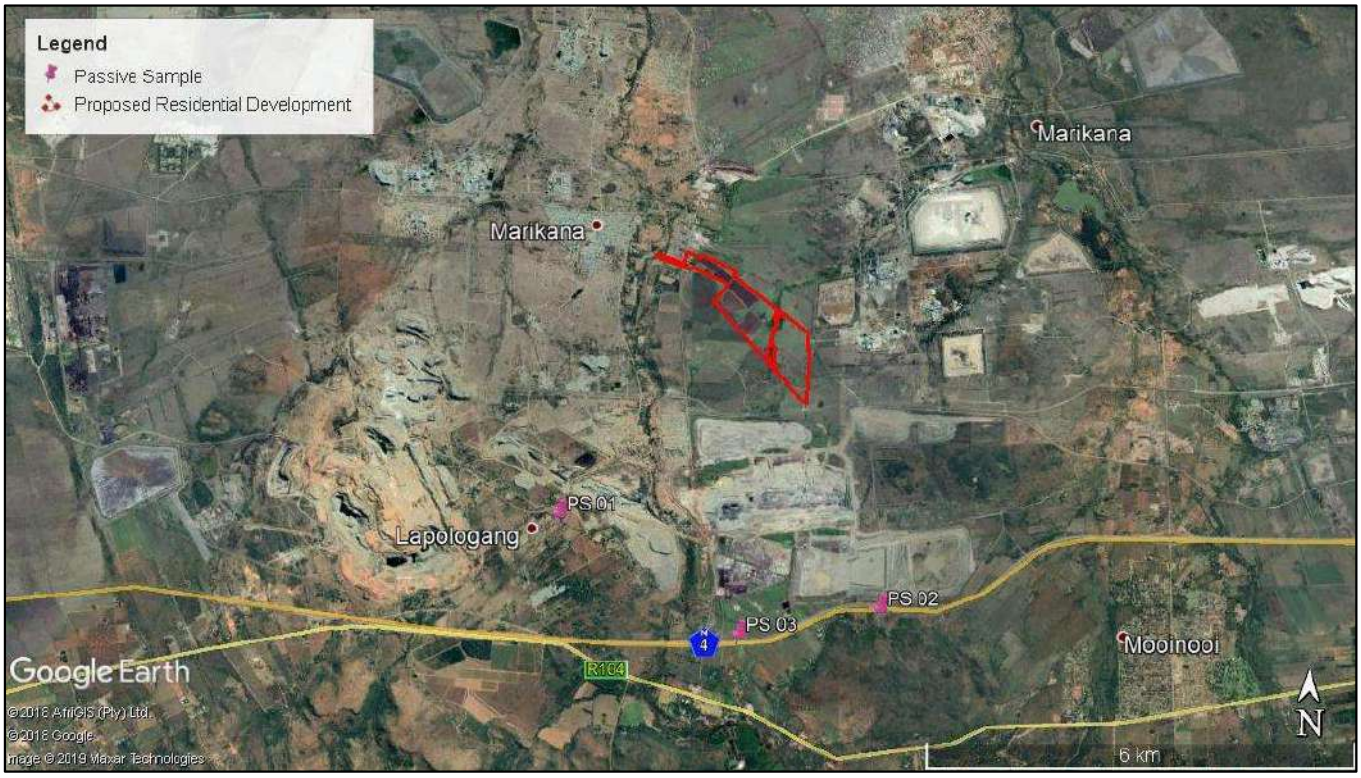


Figure 5-12: Location of passive samples in relation to the proposed residential development on various Portions of the Farm Rooikoppies 297-JQ

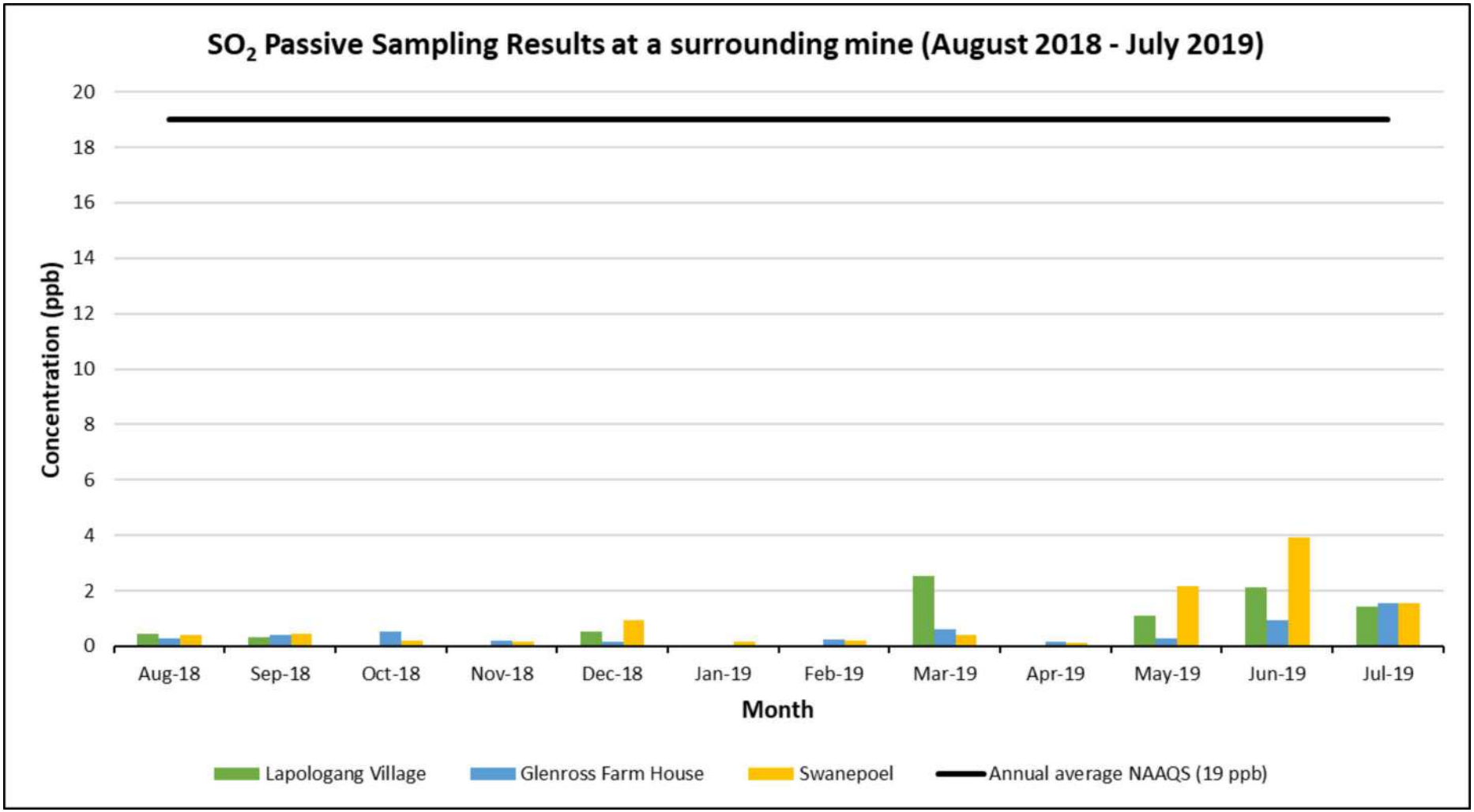


Figure 5-13: SO_2 passive results at a surrounding mine for the period August 2018 – July 2019

Notes: October 2018 and November 2018 - Passive sample found on the ground
February 2019 – Passive sample was missing

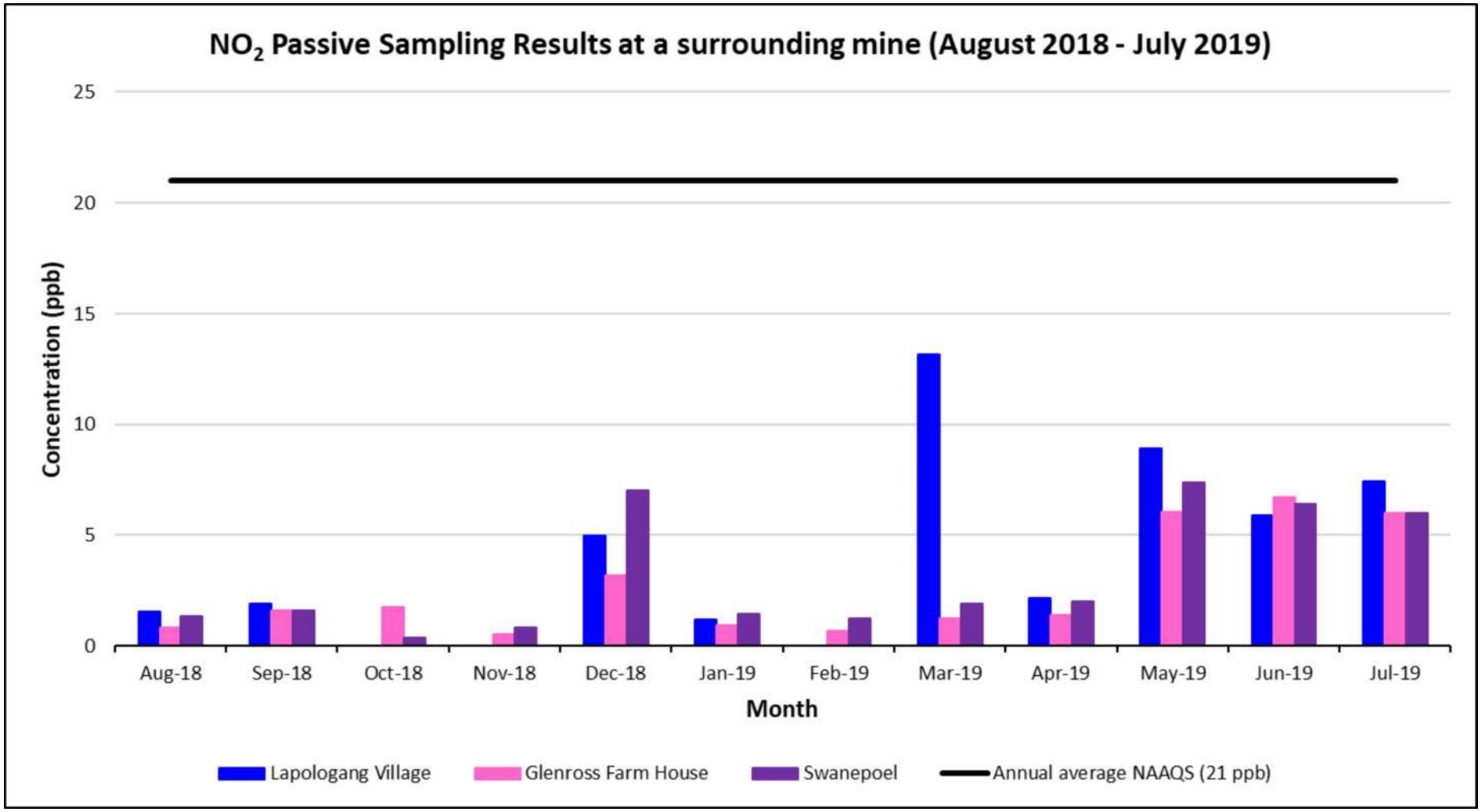


Figure 5-14: NO_2 passive results at a surrounding mine for the period August 2018 – July 2019

Notes: October 2018 and November 2018 - Passive sample found on the ground
February 2019 – Passive sample was missing

5.3.3. Modelled Emissions

Airshed Planning Professionals (Pty) Ltd undertook an AQIA at Tharisa Minerals in 2014. Tharisa Minerals is situated approximately 100m south of the proposed residential development. Figure 5-15 to Figure 5-24 provide modelled results for the operational phase of the mine. Pollutants covered include PM_{10}, $PM_{2.5}$, CO, NO_x and SO_2.The dispersion modelling results given in the AQIA report can provide an indication of the baseline air quality in the surrounding areas.

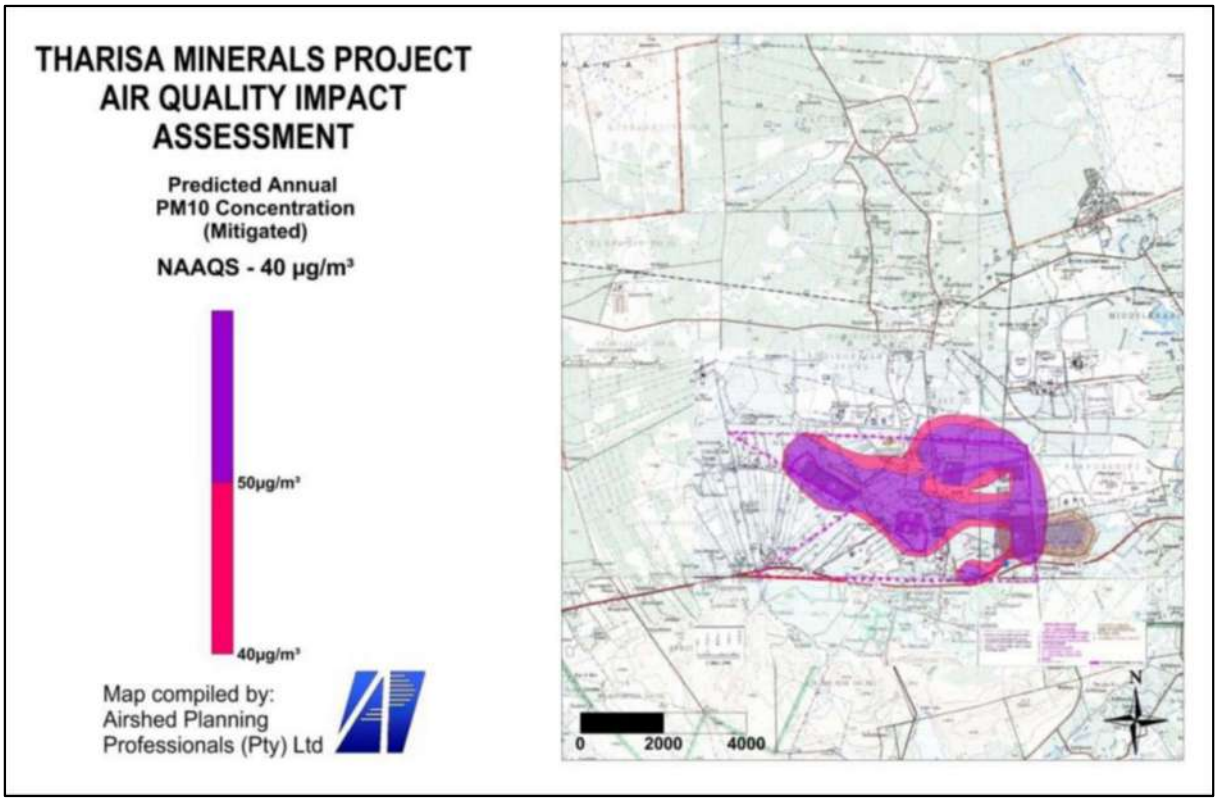


Figure 5-15: Predicted PM_{10} annual average incremental concentrations for Tharisa Minerals – Mitigated Scenario (Source: Airshed, 2014).

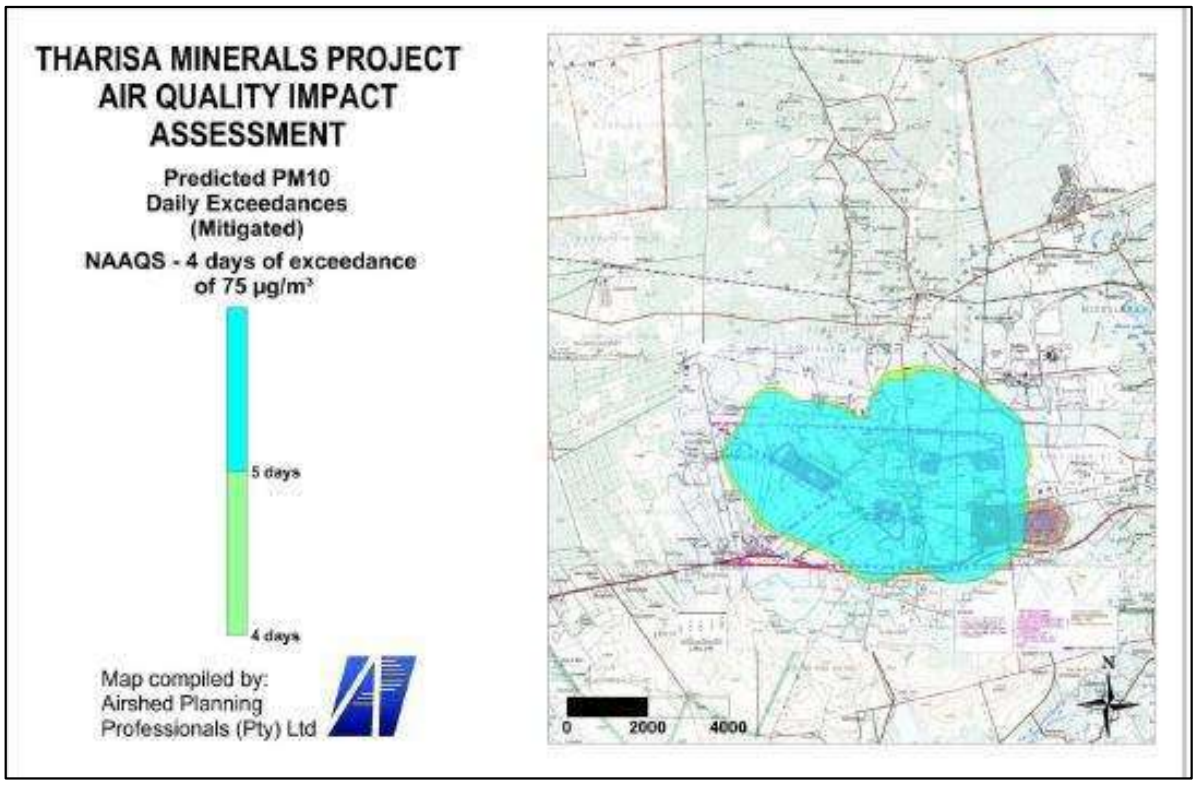


Figure 5-16: Predicted PM_{10} daily exceedances for Tharisa Minerals – Mitigated Scenario (Source: Airshed 2014).

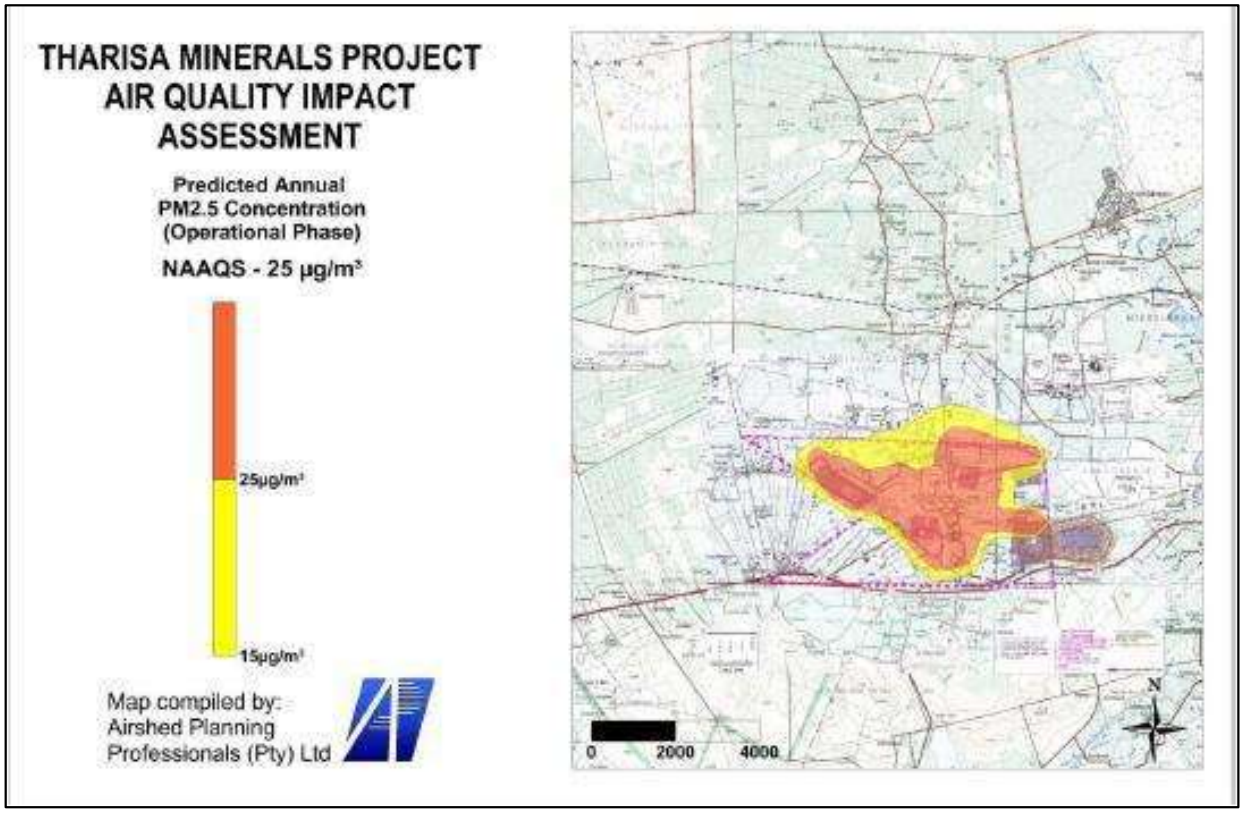


Figure 5-17: Predicted $PM_{2.5}$ annual average incremental concentrations for Tharisa Minerals – Partially Mitigated Scenario (Source: Airshed, 2014).

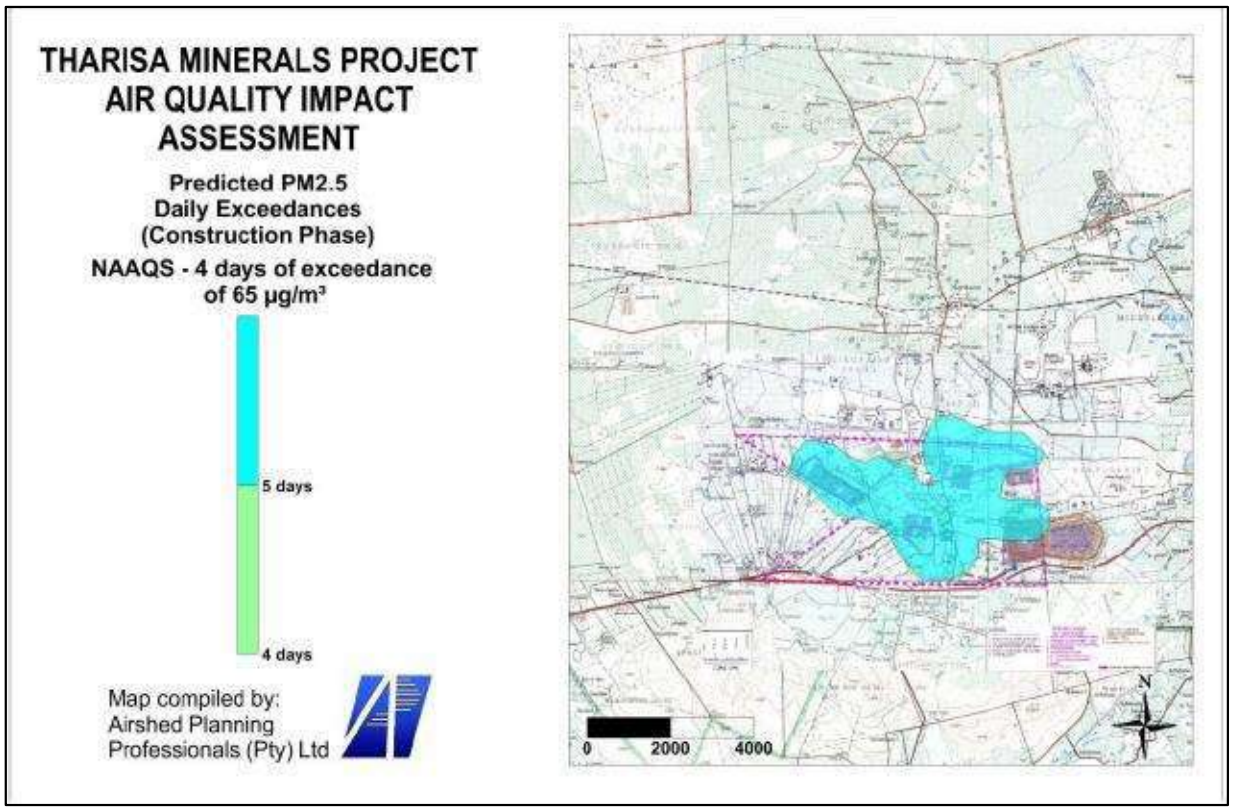


Figure 5-18: Predicted $PM_{2.5}$ daily exceedances for Tharisa Minerals – Partially Mitigated Scenario (Source: Airshed 2014).

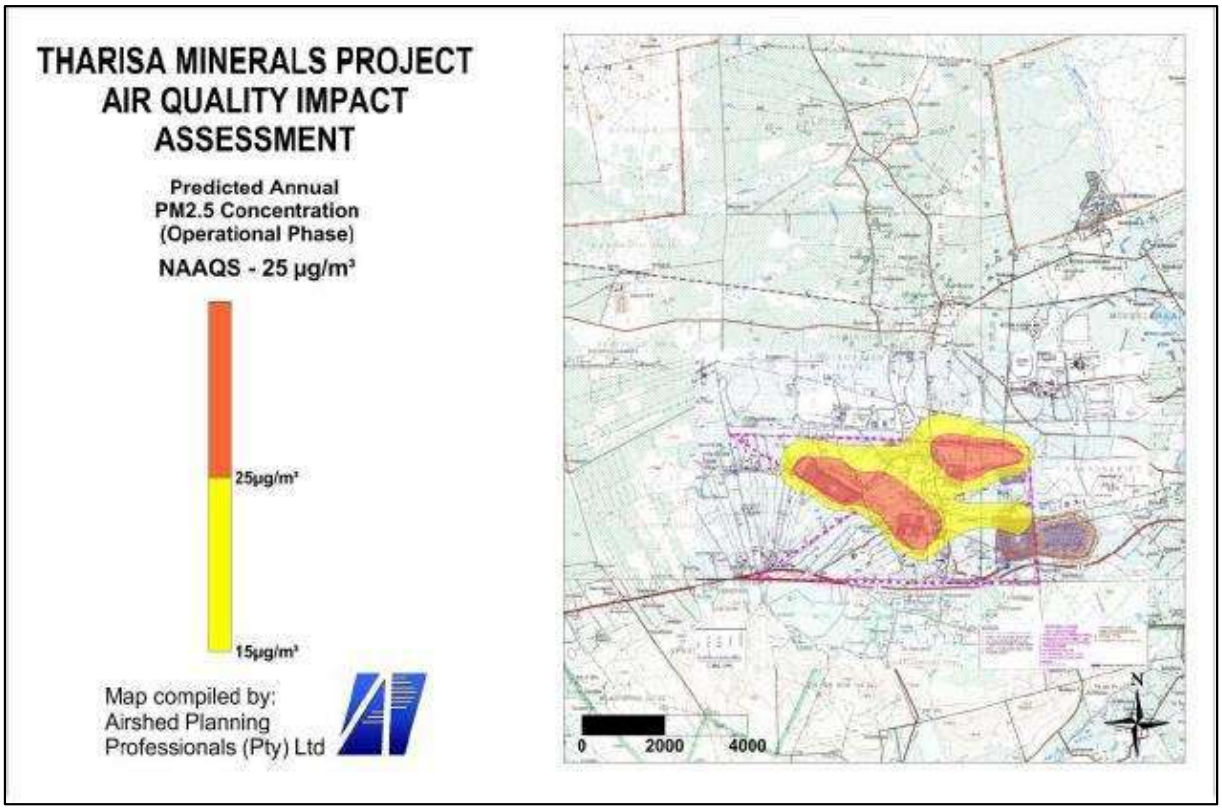


Figure 5-19: Predicted $PM_{2.5}$ annual average incremental concentrations for Tharisa Minerals – Mitigated Scenario (Source: Airshed, 2014).

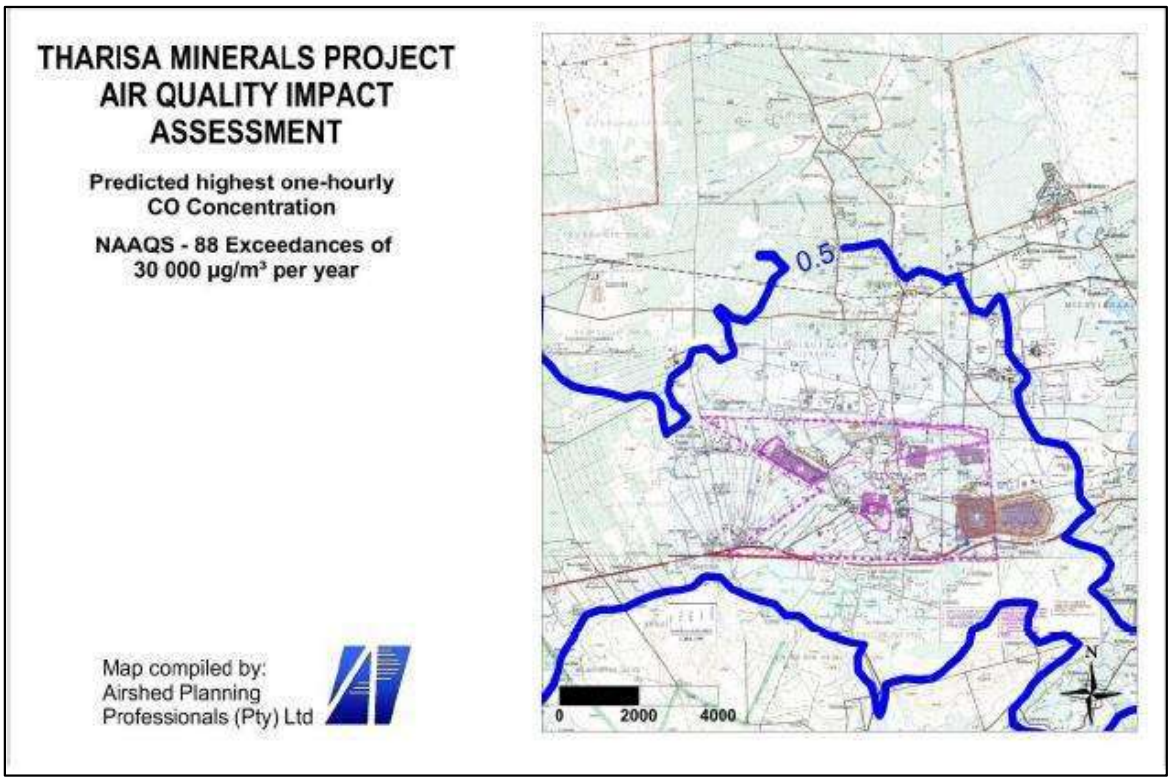


Figure 5-20: Predicted CO maximum one-hour incremental concentrations at Tharisa Minerals chrome sand drying plant) (Source: Airshed, 2014).

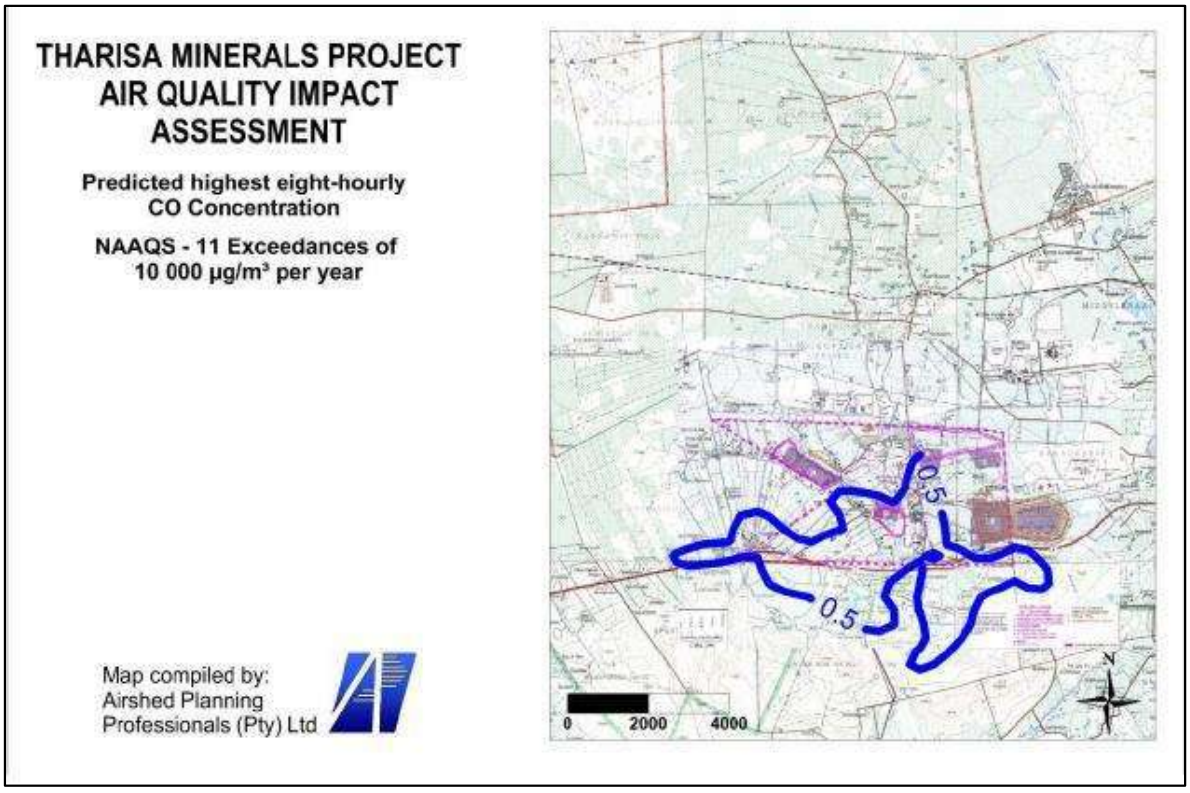


Figure 5-21: Predicted CO maximum eight-hour incremental concentrations at Tharisa Minerals chrome sand drying plant) (Source: Airshed, 2014).

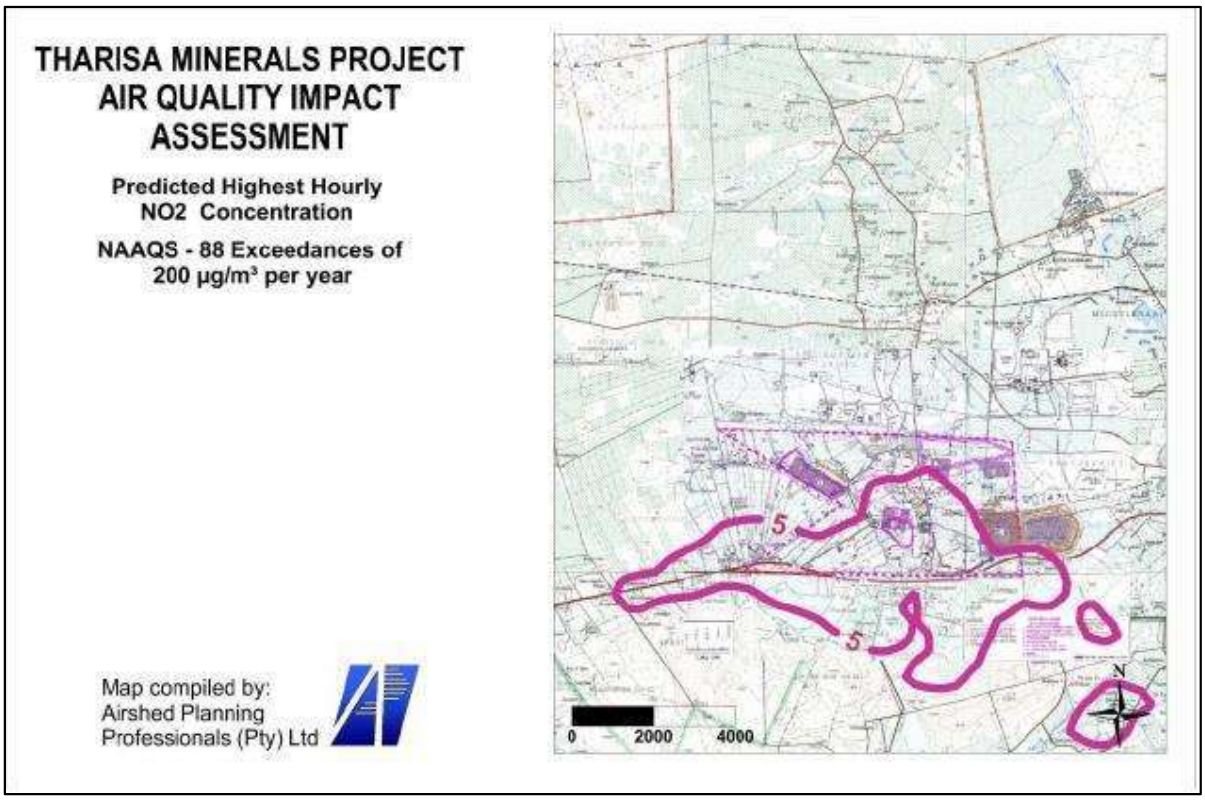


Figure 5-22: Predicted NO_2 maximum one-hour incremental concentrations at Tharisa Minerals chrome sand drying plant) (Source: Airshed, 2014).

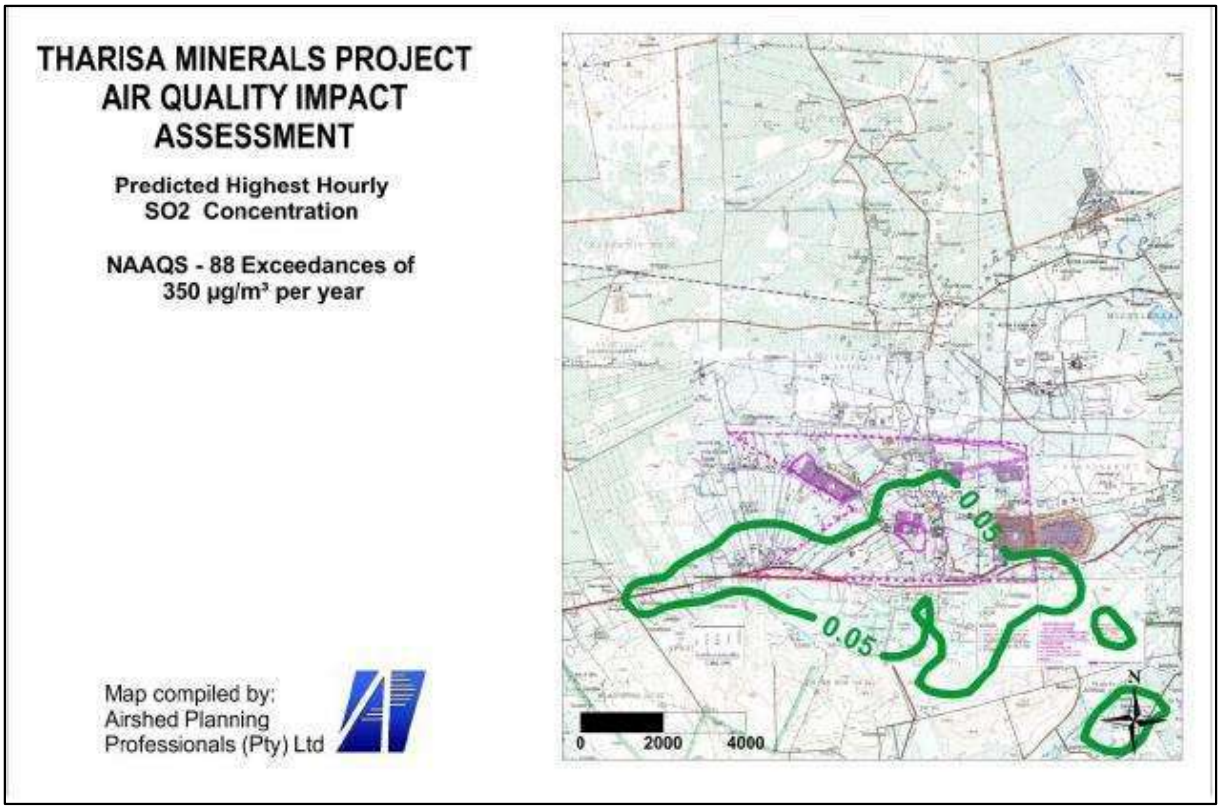


Figure 5-23: Predicted SO_2 maximum one-hour incremental concentrations at Tharisa Minerals chrome sand drying plant) (Source: Airshed, 2014).

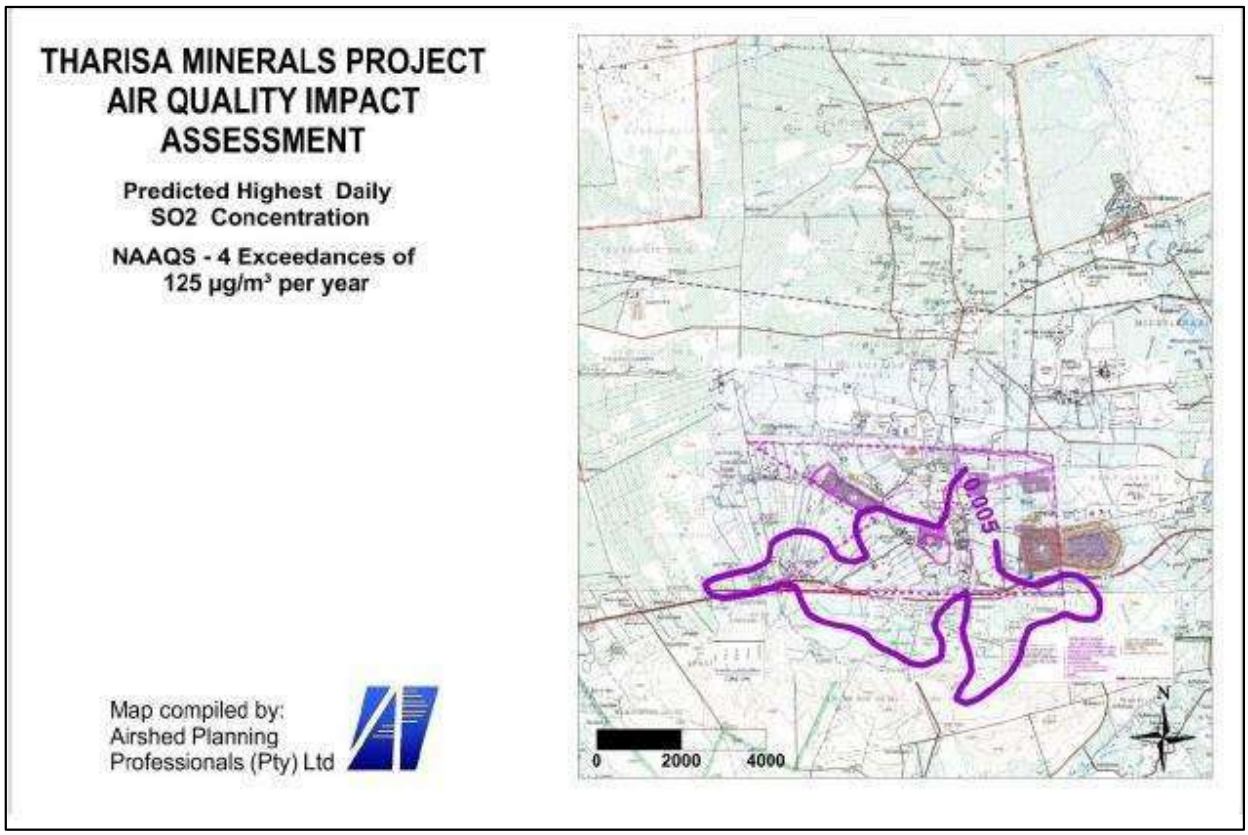


Figure 5-24: Predicted SO_2 maximum daily incremental concentrations at Tharisa Minerals chrome sand drying plant) (Source: Airshed, 2014).

6. RESULTS AND DISCUSSION

6.1. Dust Fallout Rates

Dust-fall rates for buckets located in non-residential areas range from 74 – 1 060 mg/m^2/day for the period. There were no exceedances of the non-residential standard of 1 200 mg/m^2/day, during the period August 2018 – August 2019. Higher dust-fall rates are recorded at site D14, located approximately 0.6km south of the proposed development.

Dust-fall rates for buckets located in residential areas range from 20 – 1 010 mg/m^2/day for the period. There were 5 exceedances of the residential standard during the period August 2018 – August 2019.A total of three exceedances were recorded during December 2018 at sites, D09, D13 and D19. These stations are located approximately 3.25 km south, 1.72 km west and 2.95 km south-east, respectively from the proposed development. Two exceedances were recorded in 2019, with D19 exceeding in January 2019 and D12, situated approximately 1.79 km south west of the proposed development, exceeding in June 2019 (Figure 5-9).

6.2. Passive Sampling

Passive sampling was conducted at three sites surrounding a neighbouring mine to detect ambient concentrations of SO_2 and NO_2. Results are provided in Figure 5-13 and Figure 5-14 for the monitoring period August 2018 – July 2019. Results were compared to the annual average, so that an indication of high concentrations in the area could be provided. Passive samples for October 2018 and November 2018 could not be analysed due to contamination. The passive sample for February 2019 was missing.

The NAAQS annual average guideline for SO_2 is 19 ppb. Results for SO_2 during the period August 2018 – July 2019 ranged from <0.4 – 3.91 ppb. There were no exceedances recorded of the annual average during the monitoring period provided.

The NAAQS annual average standard for NO_2 is 21 ppb. Monitoring results for NO_2 during the period August 2018 – July 2019 ranged from 0.35 – 13.17 ppb. There were There were no exceedances recorded of the annual average during the monitoring period provided.

6.3. Modelled Emissions

Figure 5-15 and Figure 5-16 depicts the annual average PM_{10} concentrations and the frequency of exceedances of the daily standard during the operational phase of the mine. The modelled results present a mitigated scenario. The annual standard of 40 µg/m^3 is not expected to exceed outside of the mine boundary. Daily exceedances of the standard (75 µg/m^3) however occur slightly outside of the mine boundary, towards the west and north (Airshed, 2014).

Figure 5-17 and Figure 5-18 presents the annual average $PM_{2.5}$ concentrations and the frequency of exceedances of the daily standard during the operational phase of the mine. The results are for a partially mitigated scenario. In this scenario, the annual standard of 20 µg/m^3 (at the time of the report being compiled, the standard was 25 µg/m^3) is predicted to exceed, up to 4 km, outside the north boundary of the mine (Airshed, 2014). Due to the decrease in the annual standard, this distance is likely to increase.

Daily exceedances of the current standard (40 µg/m^3) (at the time of the report being compiled, the standard was 65 µg/m^3) are predicted to occur between 5 km to 6 km outside the north boundary of the mine (Airshed, 2014). Due to the decrease in the annual standard, this distance is likely to increase.

Figure 5-19 presents the annual average $PM_{2.5}$ concentrations during the operational phase of the mine. The results are for a mitigated scenario. The predicted results show that exceedances of the standard 20 µg/m^3 (at the time of the report being compiled, the standard was 25 µg/m^3) occurs within the mine boundary (Airshed, 2014). However, due to the decrease in the annual standard, this distance is likely to increase. Further, there were no daily exceedances predicted, although this may now change as the daily standard has since decreased from 65 µg/m^3 to 40 µg/m^3. Exceedances for PM_{10} & $PM_{2.5}$ overlap the area where the proposed residential development will be situated.

Figure 5-20 and Figure 5-21 depicts the maximum hourly and eight-hourly average concentrations for CO from the chrome sand drying plant. The standards for CO are 30 000 µg/m^3 (hourly) and 10 000 µg/m^3 (eight-hourly). The predicted results show no exceedances of either standard (Airshed, 2014).

Figure 5-22 presents the maximum hourly concentrations of NO_x from the chrome sand drying plant. There were no exceedances predicted, as emissions were considerably low. Figure 5-23 and Figure 5-24 depicts maximum hourly and daily SO_2 concentrations, respectively. Emissions of SO_2 from the chrome sand drying plant were significantly low, therefore no exceedances predicted (Airshed, 2014).

7. LIMITATIONS

The following key limitations of the study are given below:

- The closest air quality monitoring station with accessible ambient data was situated > 20 km away from the site of the proposed development, in Rustenburg. Therefore, there was no recent ambient air quality data available to provide accurate background data for this study.

- The AQIA undertaken by Airshed Planning Professionals (Pty) Ltd for a neighbouring mine, was compiled in 2014. The five-year gap in reporting could have resulted in a change in operating conditions at the mine.

- The pollutant concentrations in the ambient air could only be assessed based on the data that is available from the AQIA.

- Dust fallout reports were not provided for a full calendar year to be compared to the National Dust Control Regulations.

- Passive sampling reports were not provided for a full calendar year to be compared to the NAAQS.

- Passive sampling sites were not representative of all boundaries of the neighbouring mine; therefore, results are not a true reflection of concentrations to the north of the mine.

8. RECOMMENDATIONS

The direct and indirect effects of air pollution have an impact across South Africa, with the majority of emissions resulting from industrial emissions, domestic use of wood, coal and paraffin, vehicle exhaust emissions, biomass burning and energy production (DEA, 2016). Based on the results discussed above, the pollutants of concern are PM_{10} and $PM_{2.5}$.

The ambient concentrations of PM_{10} and $PM_{2.5}$ from the surrounding sources represent a concern for human health and environmental nuisance, due to daily and annual exceedances depicted in the AQIA report, suggesting that people residing in the area north of the mine could potentially be exposed to future high concentrations (based on the acceptable applicable limits for these criteria pollutants). The current location is within 100 m north of the boundary of a neighbouring mine.

Due to the proposed residential development being predominantly surrounded by mining activity (quarries, tailings, etc.), and commercial agricultural activities (biomass burning), which are considered key sources of particulate matter, people residing in this area may likely be exposed to above standard concentrations of both PM_{10} and $PM_{2.5}$ on a regular basis.

Recommendations based on the above results include:

- The proposed development should be moved to a location approximately 6 km north-east or approximately 5 km south of the proposed location. Based on the prevalent wind direction, and the position of surrounding mines and agricultural activities these locations are the most suitable.

- In the case where relocation cannot be attained, the design of the building should include a climate control system with a filter. This would not only ensure air circulation but will reduce the build-up of dust particles within the home.

- Include a barrier of trees surrounding the east and south of proposed residential development. Higher trees can act as porous bodies which influence local dispersion of pollution and aid the deposition and removal of airborne pollutants.

9. CONCLUSION

Rayten Engineering Solutions (Pty) Ltd was appointed by Seaton Thomson and Associates cc to compile an Air Quality Baseline Assessment for the proposed residential development on various portions of the Farm Rooikoppies 297-JQ, Rustenburg, North-West Province.

The baseline air quality assessment was undertaken through a review of meteorological monitoring data, available air quality monitoring data, air quality legislation and the identification of nearby existing emissions sources surrounding the project site. Comparison of ambient air pollutant concentrations, using available ambient air quality data, is made with the South African National Ambient Air Quality Standards where applicable. As part of the baseline assessment, a basic health risk assessment report was also compiled and can be found under Appendix A.

The land use immediately surrounding the proposed residential development consists predominantly of cultivated land, subsistence farming and mining. Mining activities are predominant in all directions surrounding the proposed site. The closest mines being located approximately 250 m to the east and 100 m to the south of the proposed development. Urban smallholdings are found to the north-west and south-east of the development. Decreasing elevation can be noticed from surrounding mines towards the proposed residential development. Exposure to relatively high pollutant concentrations in this area is therefore likely.

The towns of Marikana and Wonderkop are located approximately <1 km north-west and 4.9 km north-east of the proposed development, respectively. The towns of Lapologang and Mooinooi are situated 4 km south-west and 5.5 km south-east of the proposed development, respectively. The area is classified as rural in nature. The town of Elandsdrift is found approx. 5.6 km east of the proposed development.

There was no air quality monitoring station close to the proposed development (that could be determined) to present background concentrations for SO_2, NO_2, CO, PM_{10} and $PM_{2.5}$ concentrations. However, there was background data available for dust-fall rates as well as passive sampling taking

place at a neighbouring mine. Background air quality data was obtained from an Air Quality Impact Assessment (AQIA) undertaken in 2014 by Airshed Planning Professionals (Pty) Ltd.

Dust-fall rates for buckets located in non-residential areas range from 74 – 1 060 mg/m^2/day for the period. There were no exceedances of the non-residential standard of 1 200 mg/m^2/day, during the period August 2018 – August 2019. Higher dust-fall rates are recorded at site D14, located approximately 0.6km south of the proposed development.

Dust-fall rates for buckets located in residential areas range from 20 – 1 010 mg/m^2/day for the period. There were 5 exceedances of the residential standard during the period August 2018 – August 2019. A total of three exceedances were recorded during December 2018 at sites, D09, D13 and D19. These stations are located approximately 3.25 km south, 1.72 km west and 2.95 km south-east, respectively from the proposed development. Two exceedances were recorded in 2019, with D19 exceeding in January 2019 and D12, situated approximately 1.79 km south west of the proposed development, exceeding in June 2019 (Figure 5-9).

The NAAQS annual average guideline for SO_2 is 19 ppb. Results for SO_2 during the period August 2018 – July 2019 ranged from <0.4 – 3.91 ppb. There were no exceedances recorded of the annual average during the monitoring period provided.

The NAAQS annual average standard for NO_2 is 21 ppb. Monitoring results for NO_2 during the period August 2018 – July 2019 ranged from 0.35 – 13.17 ppb. There were no exceedances recorded of the annual average during the monitoring period provided.

An AQIA was undertaken in 2014 for a mine and chrome sand drying plant located near to the proposed residential development site (approximately 100m south of the mine). The dispersion modelling results given in the AQIA report are used to provide an indication of background particulate matter, SO_2, NO_x and CO concentrations at the proposed residential development site.

The predicted annual average PM_{10} concentrations and the frequency of exceedances of the daily standard during the operational phase of the mine were modelled. The results were presented for a mitigated scenario. The annual standard of 40 µg/m^3 is not expected to exceed outside of the mine boundary. Daily exceedances of the standard (75 µg/m^3) however occur slightly outside of the mine boundary, towards the west and north (Airshed, 2014).

The predicted annual average $PM_{2.5}$ concentrations and the frequency of exceedances of the daily standard during the operational phase of a nearby mine were modelled. The results are for a partially mitigated scenario. In this scenario, the annual standard of 20 µg/m^3 (at the time of the report being compiled, the standard was 25 µg/m^3) is predicted to exceed, up to 4 km, outside the north boundary of the mine (Airshed, 2014). Due to the decrease in the annual standard, this distance is likely to increase.

Daily exceedances of the current standard (40 µg/m^3) (at the time of the report being compiled, the standard was 65 µg/m^3) are predicted to occur between 5 km to 6 km outside the north boundary of the mine (Airshed, 2014). Due to the decrease in the annual standard, this distance is likely to increase.

The predicted annual average $PM_{2.5}$ concentrations and the frequency of exceedances of the daily standard during the operational phase of a nearby mine were modelled. The predicted results show that exceedances of the standard 20 µg/m^3 (at the time of the report being compiled, the standard

was 25 µg/m^3) occurs within the mine boundary (Airshed, 2014). However, due to the decrease in the annual standard, this distance is likely to increase. Further, there were no daily exceedances predicted, although this may now change as the daily standard has since decreased from 65 µg/m^3 to 40 µg/m^3.

Emissions of CO, NO_x and SO_2 from the chrome drying plant were considerably low, and the model predicted no exceedances of the relevant NAAQS.

It is important to understand the current situation regarding PM_{10} and $PM_{2.5}$ emissions in South Africa, and how likely these emissions are to occur in and around the proposed residential development. The proposed residential development on various portions of the Farm Rooikoppies 297-JQ will be situated close to numerous mines, the closest being to the east (approximetaly 250 m) and south (approximately 100 m). The proposed development will also be in close proximity to agricultural activities. These factors will contribute to PM_{10} and $PM_{2.5}$ emissions in the area.

The frequency of south-easterly and east-south-east winds that blow along the axis of the development would serve to combine emissions from the surrounding pollution sources, namely; mining areas, vehicle dust entrainment from unpaved roads, potential biomass burning and agricultural activities, industrial activities and residential fuel burning activities. Exposure to high concentrations of emissions could occur.

In conclusion, the pollutants of concern in the area are PM_{10} and $PM_{2.5}$, due to the distance of predicted exceedances depicted in the AQIA compiled by Airshed in 2014. Daily exceedances of PM_{10} occur outside the mine boundary, while annual exceedance and daily exceedances of $PM_{2.5}$ also occur up to 6 km north of the plant boundary. Due to the close proximity of the proposed development to the mine boundary (approximately 100 m) exposure to high levels of PM_{10} and $PM_{2.5}$ could occur, as the exceedances are predicted to occur over the area where the proposed residential development is situated.

Recommendations based on the above results include:

- The proposed development should be moved to a location approximately 6 km north-east or approximately 5 km south of the proposed location. Based on the prevalent wind direction, and the position of surrounding mines and agricultural activities these locations are the most suitable.

- In the case where relocation cannot be attained, include a climate control system with a filter as part of the building design. This would not only ensure air circulation but will reduce the build-up of dust particles within the home.

- Include a barrier of trees surrounding the east and south of proposed residential development. Higher trees can act as porous bodies which influence local dispersion of pollution and aid the deposition and removal of airborne pollutants.

10. REFERENCES

- Airshed Planning Professionals (Pty) Ltd (2014) Air Quality Impact Assessment for a chrome sand drying plant, changes to the tailings dam design and other operational and surface infrastructure changes at Tharisa Minerals. Report No. APP/12/SLR04, pages 5-21 to 5-33.
- Bell, M.L., Zanobett, A & Dominic, F. 2014. Who is more affected by the ozone pollution? A systematic review and meta-analysis, vol.180, no.1, pp. 15-28.
- Brauer, M., Henderson, S., Kirkham, T., Lee, K.S., Rich, K., and Teschke, K. 2002: Review of the Health Risks Associated with Nitrogen Dioxide and Sulfur Dioxide in Indoor Air, University of British Columbia School of Occupational and Environmental Hygiene, Report to Health Canada, 31
- Bridges, O., Bridges, J.W. and Potter, J.F., 2000: A generic comparison of the airborne risks to human health from landfill and incinerator disposal of MSW, The Environmentalist, 20, 325-334.
- Department of Environmental Affairs (DEA), 2004: National Environmental Management: Air Quality Act 39 of 2004, GNR 163, South Africa
- Department of Environmental Affairs (DEA), 2009: National Ambient Air Quality Standards, GNR 1210, South Africa
- Department of Environmental Affairs (DEA), 2010: Commencement of certain sections of the National Environmental Management: Air Quality Act,2004, South Africa
- Department of Environmental Affairs (DEA), 2013: National Environmental Management: Air Quality Act 39 of 2004: National Dust Control Regulations, Department of Environmental Affairs, report No. 827, Government Printer, Pretoria
- Department of Environmental Affairs (DEA), 2013: List of activities which result in atmospheric emissions which have or may have a significant detrimental effect on the environment, including health, social conditions, economic conditions, ecological conditions or cultural heritage, GN 893, South Africa
- Department of Environmental Affairs (DEA), 2014: Declaration of Greenhouse Gases as Priority Air Pollutants, GNR 172, South Africa
- Department of Environmental Affairs (DEA), 2015: National Atmospheric Emission Reporting Regulations, GNR 283, South Africa
- Department of Environmental Affairs (DEA), Waterberg-Bojanala Priority Area Air Quality
- Management Plan and Threat Assessment, June 2015.
- Department of Environmental Affairs (DEA), 2016: 2nd South Africa Environment Outlook. A report on the state of the environment., South Africa
- Department of Environmental Affairs (DEA), 2017: National Pollution Prevention Plans Regulations, GNR 712, South Africa

- Department of Environmental Affairs (DEA), 2019: Carbon Tax Act, South Africa
- Duarte-Davidson, R., Courage, C., Rushton, L. and Levy, L., 2001: Benzene in the environment: an assessment of the potential risks to the health of the population, Occupational Environment Medical, 58, 2-13.
- EPA's 2017 Environmental Report [online] Available: https://www.epa.gov/roe/ [2017, Jan 19].
- Fenger, J., 2002: Urban air quality, In J. Austin, P. Brimblecombe and W. Sturges (eds), Air pollution science for the 21st century, Elsevier, Oxford.
- Harrison, R.M. and R.E. van Grieken, 1998: *Atmospheric Aerosols*. John Wiley: Great Britain.
- Gauteng Department of Agriculture and Rural Development (GDARD), 2009: Gauteng Province Air Quality Management Plan, South Africa
- Ghorani-Azam, A., Riahi-Zanjani, B. & Balali-Mood, M. (2016). Effects of air pollution on human health and practical measures for prevention in Iran. *Journal of Research in Medical Sciences,* 21, 65.
- Guillerm, N. & Cesari, G. (2015). Fighting ambient air pollution and its impact on health: from human rights to the right to a clean environment. *The International Journal of Tuberculosis and Lung Disease,* Volume 19 (8), pp. 887-897 (11).
- Kamarehie B, Ghaderpoori M., Jafari A, Karami M., Mohammadi A., Azarshab K.H. 2017, Quantification of health effects related to SO_2 and NO_2 pollutants using Air quality model. J Adv. Environ Health Res, Vol.1, no 5, pp. 44-50.
- Karthik, B.L., Sujith, B., Rizwan, A.S., & Sehgal. M. 2017. Characteristics of the ozone pollution and its health effects in india.vol.7, no.1, pp.56-60.
- USEPA (2018). Risk and Exposure Assessment for the Review of the Primary National Ambient Air Quality Standard for Sulfur Oxides. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Health and Environmental Impacts Division, Research Triangle Park, NC.

  Available at: https://www.epa.gov/sites/production/files/2018-05/documents/primary_so2_naaqs_-_final_rea_-_may_2018.pdf
- Wani, A.L., Ara, A & Usmani, J. 2015. Lead Toxicity: A review. 2, no.2, pp. 55-64 Available [online] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4961898/ Accessed: [2018, Aug 14].
- Warburton, D.E.R., Bredin, S.S.D., Shellington, E.M., Cole, C., de Faye, A., Harris, J., Kim, D.D. & Abelsohn, A. (2019). A Systematic Review of the Short-Term Health Effects of Air Pollution in Persons Living with Coronary Heart Disease. *Journal of Clinical Medicine,* 8 (2), 274.
- World Health Organization, WHO Air Quality Guidelines for Europe, 2nd edition, WHO Regional Office for Europe, 2000, Copenhagen, Denmark (WHO Regional Publications, European Series, No 91).

  https://nerc.ukri.org/planetearth/stories/561 (Accessed 24 July 2019).

- World Health Organization (WHO), 2010: Preventing Disease Through Healthy Environments - Exposure to Lead: A Major Public Health Concern
- World Health Organization, 2019. Ambient Air Pollution: Health Impacts. https://www.who.int/airpollution/ambient/health-impacts/en/ WHO (2019). Accessed: 22 March 2019.
- World Health Organization, 2019. Ambient Air Pollution: Pollutants. https://www.who.int/airpollution/ambient/pollutants/en/ WHO (2019). Accessed: 22 March 2019.

APPENDIX A
HEALTH RISK IMPACT ASSESSMENT

Environmental Consultants

Health Risk Assessment for The Proposed Residential Development on Various Portions of The Farm Rooikoppies 297-JQ

Seaton Thomson and Associates Cc

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Cell: +27827672786; Fax: 0865314434

PROJECT DETAILS

Project Name	Environmental Authorisation for The Proposed Residential Development on Various Portions of The Farm Rooikoppies 297-JQ
Client:	Esimeme Projects (Pty) Ltd, on behalf of Seaton Thomson and Associates Cc
Project Number	ESI03
Report Title	Health Risk Assessment for The Proposed Residential Development on Various Portions of The Farm Rooikoppies 297-JQ
Date Submitted	October 2019
Authors	Vumile Dlamini-Ribeiro

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Specialist Declaration of Independence

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I Vumile Dlamini-Ribeiro, as duly authorised representative of Niara Environmental Consultants (Pty) Ltd., hereby confirm my independence and declare that I:

- I act as the independent specialist in this application;
- I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant;
- I declare that there are no circumstances that may compromise my objectivity in performing such work;
- I have expertise in conducting the specialist report relevant to this application, including knowledge of the Act, regulations and any guidelines that have relevance to the proposed activity;
- I will comply with the Act, regulations and all other applicable legislation;
- I have no, and will not engage in, conflicting interests in the undertaking of the activity;
- I undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing any decision to be taken with respect to the application by the competent authority; and the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority;
- all the particulars furnished by me in this form are true and correct; and
- I realise that a false declaration is an offence in terms of Regulation 71 and is punishable in terms of Section 24F of the Act.

Signature of the Specialist:	V. Dlamini
Designation:	Environmental Health Consultant
Qualifications:	Post Graduate Degree (Hons): BSoc Sci Environmental Analysis and Management
Name of company:	Niara Environmental Consultants (Pty) Ltd
Experience (years):	Twelve (12)
Date:	October 2019

Executive Summary

Human health, the environment and development are intricately linked in that a negative impact in any one sphere would impact negatively on the remaining two spheres. For example, insufficient development of proper sanitation facilities would lead to unhygienic and unhealthy living conditions for humans as well as impact on the environment by causing pollution to water resources.

According to a study conducted by Rayten Engineering Solutions (Pty) Ltd (2019), the frequency of south-easterly and east-south-east winds that blow along the axis of the proposed development would serve to combine emissions from the surrounding pollution sources, such as mining areas, vehicle dust entrainment from unpaved roads, potential biomass burning and agricultural activities, industrial activities and residential fuel burning activities. Exposure to high concentrations of emissions could occur.

Air quality impacts from existing neighbouring mines have been found to be significant and that the developer needs to find a better suited site for residential development. Adequate mitigation measures from the mines' side may reduce the significance of some negative impacts although not always to acceptable levels, while positive health effects can be created through the implementation of associated enhancement measures. The developer would have no control over recommended mitigation measures which need to be implemented by surrounding mining operations, to manage the impacts.

It is recommended that the proposed residential development is either relocated to an alternative area greater than 5km away from the Tharisa Mine, and other mines, or that the proposed land use for the development footprint is re-assessed and other possible land uses such as industrial/ manufacturing use be assessed. Only then should the proposed development be allowed to proceed on the assumption that the environmental, social and health management commitments are adhered to

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Table of Acronyms and Abbreviations

AIDS	Acquired Immunodeficiency Syndrome
APPA	Atmospheric Pollution Prevention Act (Act no. 45 of 1965)
AQIA	Air Quality Impact Assessment
ARI	Acute Respiratory Infection
cHIA	Community Health Impact Assessment
DEA	Department of Environmental Affairs
DEFF	Department of Environment Forestry and Fisheries
DG	Director General
DoH	Department of Health
EIA	Environmental Impact Assessment
EMP	Environmental Management Programs
HRA	Health Risk Assessment
HIV	Human Immunodeficiency Virus
HRA	Health Risk Assessment
IFC	International Finance Corporation
MDR-TB	Multi-drug Resistant Tuberculosis
NAAQS	National Ambient Air Quality Standards
NEM: AQA	Environmental Management: Air Quality Act, 2004 (Act No. 39 of 2004)
NEMA	National Environmental Management Act, 1998 (Act 107 of 1998)
NHA	National Health Act, 2003 (Act No. 61 of 2003)
NIHL	Noise-Induced Hearing Loss
STIs	Sexually Transmitted Infections
TB	Tuberculosis
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
VOCs	Volatile Organic Compounds
WHO	World Health Organization

1. Introduction

Currently, the most pressing public health problems in many countries, such as asthma, depression, diabetes, and obesity, are linked to/ influenced by the places where people live, work, and play. Policy decisions that affect housing quality, affordability, and location as well as neighbourhood characteristics can influence whether these places are supportive of, or are detrimental to community health and well-being and can play important roles in reducing or even preventing disease (Bravemen, *et al*., 2015).

Niara Environmental Consultants (Pty) Ltd was appointed by Esimeme Projects (Pty) Ltd to undertake a Health Risk Assessment (HRA) for the proposed residential development on various portions of the Farm Rooikoppies 297JQ in Rustenburg, North-West Province.

1.1. Project Description

Homes 2000 proposes to develop a low- and low-medium income residential development (RDP and GAP housing) on various portions of the Farm Rooikoppies 297JQ in Rustenburg, North-West Province. The intention is to create a housing opportunity for the local people of Marikana as well as to deal with the housing needs and housing delivery.

1.2. Project Location

The towns of Marikana and Wonderkop are located approximately <1 km north-west and 4.9 km north-east of the proposed development, respectively. The towns of Lapologang and Mooinooi are situated 4 km south-west and 5.5 km south-east of the proposed development, respectively. The area is classified as rural in nature. The town of Elandsdrift is found approx. 5.6 km east of the proposed development. Exposure to relatively high pollutant concentrations in this area is therefore likely (Rayten, 2019).

1.3. Objective of the Specialist Study

The over-riding objective of a Health Risk Assessment (HRA) is to maximise health gain and reduce health inequalities. The overarching aim of the HRA was to provide decision-makers with a set of recommendations on health issues associated with the proximity of existing mining operations in relation to the proposed residential development t so that health objectives may be considered at the same level as socio-economic and environmental objectives.

The objectives were:

- To predict the likely impacts the nearby mining operations may have on the health of the potential inhabitants of the proposed residential development; and

- To formulate mitigation measures to avoid or ameliorate negative community health impacts and to enhance positive ones.

1.4. Details and Expertise of Specialist

Vumile Dlamini-Ribeiro is currently the Director of Environmental Management Services at Niara Environmental Consultants (Pty) Ltd. Vumile has 12 years of professional experience in Environmental Assessment and Management. Her roles include the operational management responsibilities of Niara Environmental Consultants, project management, report writing, client liaison, as well as business development.

Having worked for a multi-disciplinary advisory firms and environmental consultancies, Vumile has a competent understanding of the work effort and cross collaboration required for a successful multidisciplinary organisation. Vumile has been involved in a number of Environmental Impact Assessments and has a particular interest in health impacts assessments, water resource management, mining, energy and stakeholder engagement. Vumile has considerable experience across a range of community health and environmental sciences and has worked in South Africa, Mozambique, Sierra Leone and Liberia and is familiar with Regulatory Environmental Legislation in other parts of Africa.

Vumile is very well versed in the IFC Environmental and Social Performance Standards (including IFC PS 2012) and the associated Equator Principles, which have informed the approach and standard for a number of ESIA processes that she has been involved in. Vumile is skilled at organising and driving effective project teams at a scale relevant to the project's requirements. She has technical experience and is able to quickly identify the most pertinent issues of a particular project whilst focussing on driving project success by rigorously implementing project management tools.

Vumile has experience ranging over several aspects of social research, including the planning and execution of social surveys, participatory rural appraisal, sustainable livelihoods assessments, data management and statistical analysis, capturing and management of spatial data, stakeholder identification and community facilitation. She has acted as project manager and/or task leader on a number of social impact studies in Africa. Social impact studies included both mining development and linear projects.

2. South African Legislation Pertaining to Health

No new health-related primary legislation has been enacted since the 2015 amendment to the Medicines and Related Substances Act. Two Bills tabled in 2017 are still in the process of being legislated, while two Private Member's Bills have been ruled as undesirable and will therefore not be legislated. A further Private Member's Bill has been published for comment. Three draft Bills have been published for comment, dealing with tobacco control, the National Health Insurance Fund, and proposed amendments to medical schemes legislation. Other public

health-oriented targets have included the proposal to raise the age limit for alcohol consumption from 18 to 21 years, and the tax on sugar-sweetened beverages. Although the Minister's preference for inclusion of the new restrictions in the proposed Liquor Amendment Bill has been reported, this Bill has yet to be published for comment or tabled in Parliament. Only a minor change to the labelling requirement for alcoholic beverages has been issued, as a regulation in terms of the Foodstuffs, Cosmetics and Disinfectants Act (Gray *et al.*, 2018).

2.1. Constitution of the Republic of South Africa (Act 108 of 1996)

The over-arching legislation is the Constitution of South Africa (Act 108 of 1996) (the Constitution), in particular Section 24, which places people and their needs at the forefront of environmental management. The Constitution provides a right to "an environment that is not harmful to [human] health or well-being" and to have the environment protected, for the benefit of present and future generations, through reasonable legislative measures. These measures include the prevention of pollution and ecological degradation, the promotion of conservation, the securing of ecologically sustainable development and the utilisation of natural resources while promoting justifiable economic and social development.

2.2. The National Health Act (Act 61 of 2003)

The National Health Act, 2003 (Act No. 61 of 2003) (NHA) provides a framework for a structured uniform health system in South Africa, taking into account the obligations with regard to health services imposed on the national, provincial and local governments by the Constitution and other laws. Any activity that gives rise to offensive/injurious conditions or is dangerous to health (e.g. accumulation of refuse) may have a negative impact on health and thus warrants being assessed in the EHIA (DOH, 2010). The Director General (DG) should issue and promote adherence to, norms and standards on health matters, including conditions that constitute a health hazard and facilitate the provision of indoor and outdoor environmental pollution control services. The Act also provides for environmental health investigations in Section 88.

2.3. National Ambient Air Quality Standards

The Department of Environmental Affairs (DEA), now known as the Department of Environment, Forestry and Fisheries (DEFF), issued ambient air quality guidelines for several criteria pollutants, including particulates, sulphur dioxide, oxides of nitrogen, lead, ozone and carbon monoxide. The National Environmental Management: Air Quality Act, 2004 (Act No. 39 of 2004) (NEM:AQA) adopted these guidelines as National Ambient Air Quality Standards (NAAQS). On 2 June 2006, the Minister of Environmental Affairs and Tourism announced his intention of setting new ambient air quality standards in terms of Section 9(1)(a) and (b) of the NEM:AQA. The proposed new standards were published for public comment in the Government Gazette of 9 June 2006. Since then, updated draft National standards with allowable frequencies of exceedance and compliance timeframes have been proposed.

The prevailing legislation in the Republic of South Africa with regards to air quality is the NEM: AQA. The NEM: AQA serves to repeal the Atmospheric Pollution Prevention Act (Act no. 45 of 1965) (APPA).

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

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

Guidelines provide a basis for protecting public health from adverse effects of air pollution and for eliminating, or reducing to a minimum, those contaminants of air that are known or likely to be hazardous to human health and well-being (WHO, 2000). Once the guidelines are adopted as standards, they become legally enforceable. These standards prescribe the allowable ambient concentrations of pollutants which are not to be exceeded during a specified time period in a defined area. If the air quality guidelines/standards are exceeded, the ambient air quality is poor and the potential for health effects is greatest.

Air quality legislation comprises primary standards which protect human health and secondary standards which protect property, vegetation, climate and aesthetic values. The development of new industries that increase air pollution through the emission of gases in the atmosphere should be managed. It should, however, be noted that no Air Quality Impact Assessment, inclusive of dispersion modelling was conducted at the time of this study.

2.4. National Environmental Management Act, 1998 (Act No. 107 of 1998), as amended

The National Environmental Management Act (NEMA) provides the legislative framework for Integrated Environmental Management (IEM) in South Africa. Section 24 provides that all activities that may significantly affect the environment and require authorisation by law must be assessed prior to approval. NEMA also provides for co-operative environmental governance by establishing principles for decision-making on matters affecting the environment, institutions that will promote co-operative governance and procedures for co-ordinating environmental functions exercised by organs of the State and to provide for matters connected therewith. Section 2 of NEMA establishes a set of principles that apply to the activities of all organs of state that may significantly affect the environment.

These include the following:

- Development must be sustainable;
- Pollution must be avoided or minimised and remedied;

- Waste must be avoided or minimised, reused or recycled;
- Negative impacts must be minimised; and
- Responsibility for the environmental health and safety consequences of a policy, project, product or service exists throughout its life cycle.

These principles are taken into consideration when a government department exercises its powers, for example during the granting of permits and the enforcement of existing legislation or conditions of approval.

Section 28(1) of NEMA states that "every person who causes, has caused or may cause significant pollution or degradation of the environment must take reasonable measures to prevent such pollution or degradation from occurring, continuing or recurring". If such pollution cannot be prevented, then appropriate measures must be taken to minimise or rectify such pollution. These measures may include:

- Assessing the impact on the environment;
- Informing and educating employees about the environmental risks of their work and ways of minimising these risks;
- Ceasing, modifying or controlling actions which cause pollution/degradation;
- Containing pollutants or preventing movement of pollutants;
- Eliminating the source of pollution; and
- Remedying the impacts of the pollution.

The authorities may direct an industry to rectify or remedy a potential or actual pollution problem. If such a directive is not complied with, the authorities may undertake the work and recover the costs from the responsible industry.

2.5. Other Relevant Legislation

Acts and Regulations pertaining to health and environmental, and health in particular, are indicated in Table 2-1

Table 2-1: Acts and Regulations relevant to Health and Environmental Health

National legislation	Relevance to Health
Atmospheric Pollution Prevention Act (Act 45 of 1965)	Hazardous substances associated with air pollution affect human health. This Act has identified some of the activities for which authorization for emissions is required from the DEA (DOH, 2010).
National Environmental Management: Waste Act (Act 59 of 2008)	The objectives of this Act are to protect health, well-being and the environment; to ensure that people are aware of the impact of waste on their health, well-being and the environment; to provide for compliance with

National legislation	Relevance to Health
	the measures set out in the Act and to give effect to Section 24 of the Constitution to secure an environment that is not harmful to health and well-being (DOH, 2010).
National Water Act (Act 36 of 1998)	The quality of water in domestic water sources impacts on human health. The Act provides for the protection of water quality for the benefit of human health and aquatic ecosystems through the concept of the reserve determination process (DOH, 2010).
Water Services Act (No. 108 of 1998)	Water services (water supply services and sanitation services) may impact on human health. Water service providers have an important role to play in this regard. Proposed activities may involve industrial use of water, which is covered under Section 7 of this Act (DOH, 2010)

3. Impact Assessment Methodology

Five factors need to be considered when assessing the significance of community health impacts, namely:

- Relationship of the impact to **temporal** scales (duration) - the temporal scale defines the significance of the impact at various time scales, as an indication of the duration of the impact.
- Relationship of the impact to **spatial** scales - the spatial scale defines the physical extent of the impact.
- The severity of the impact - the **severity/beneficial** scale is used to scientifically evaluate how severe negative impacts would be, or how beneficial positive impacts would be on a particular affected system (for ecological impacts) or a particular affected party.
- The severity of impacts can be evaluated with and without mitigation to demonstrate how serious the impact is when it is not allayed. The word 'mitigation' means not just 'compensation', but includes concepts of containment and remedy. For beneficial impacts, optimization means anything that can enhance the benefits. However, mitigation or optimization must be practical, technically feasible and economically viable.
- The **likelihood** of the impact occurring - the likelihood of impacts taking place as a result of Project actions differs between potential impacts. There is no doubt that some impacts would occur (e.g. loss of vegetation), but other impacts are not as likely to occur (e.g. vehicle accident), and may or may not result from the proposed development. Although some impacts may have a severe effect, the likelihood of them occurring may affect their overall significance.

Each criterion is ranked with scores assigned as presented in Table 3-1 to determine the overall **significance** of an activity. The criterion is then considered in two categories, viz. effect of the activity and the likelihood of the impact. The total scores recorded for the consequence and likelihood are then read off the matrix presented in Table 3-2, to determine the overall significance of the impact. The overall significance is either negative or positive.

The ***environmental significance*** scale is an attempt to evaluate the importance of a particular impact. This evaluation needs to be undertaken in the relevant context, as an impact can either be ecological or social, or both. The evaluation of the significance of an impact relies heavily on the values of the person making the judgment. For this reason, impacts of a social nature in particular need to reflect the values of the affected society.

3.1. Prioritisation of Impacts

The evaluation of the impacts, as described above is used to prioritise which impacts require mitigation measures.

Negative impacts that are ranked as being of "**VERY HIGH**" and "**HIGH**" significance will need to be investigated further to determine how the impact can be minimised or what alternative activities or mitigation measures can be implemented. These impacts may also assist decision makers i.e. numerous **HIGH** negative impacts may bring about a negative decision.

For impacts identified as having a negative impact of "**MODERATE**" significance, it is standard practice to investigate alternate activities and/or mitigation measures. The most effective and practical mitigations measures will then be proposed.

For impacts ranked as "**LOW**" significance, no investigations or alternatives will be considered. Possible management measures should be investigated to ensure that the impacts remain of low significance.

Table 3-1: Ranking of Evaluation Criteria

EFFECT	**Temporal Scale (Duration)**			**Score**
	Short term	Less than 5 years		1
	Medium term	Between 5-20 years		2
	Long term	Between 20 and 40 years (a generation) and from a human perspective also permanent		3
	Permanent	Over 40 years and resulting in a permanent and lasting change that will always be there		4
	Spatial Scale			
	Localised	At localised scale and a few hectares in extent		1
	Study Area	The proposed site and its immediate environs		2
	Regional	District and Provincial level		3
	National	Country		3
	International	Internationally		4
	Severity	**Severity**	**Benefit**	
	Slight	Slight impacts on the affected system(s) or party(ies)	Slightly beneficial to the affected system(s) and party(ies)	1
	Moderate	Moderate impacts on the affected system(s) or party(ies)	Moderately beneficial to the affected system(s) and party(ies)	2
	Severe/ Beneficial	Severe impacts on the affected system(s) or party(ies)	A substantial benefit to the affected system(s) and party(ies)	4
	Very Severe/ Beneficial	Very severe change to the affected system(s) or party(ies)	A very substantial benefit to the affected system(s) and party(ies)	8
LIKELIHOOD	**Likelihood**			
	Unlikely	The likelihood of these impacts occurring is slight		1
	May Occur	The likelihood of these impacts occurring is possible		2
	Probable	The likelihood of these impacts occurring is probable		3
	Definite	The likelihood is that this impact will definitely occur		4

* In certain cases, it may not be possible to determine the severity of an impact thus it may be determined: Don't know/can't know

Table 3-2: Matrix used to determine the overall significance of the impact based on the likelihood and effect of the impact

Likelihood		Effect													
		3	4	5	6	7	8	9	10	11	12	13	14	15	16
	1	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	2	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	3	6	7	8	9	10	11	12	13	14	15	16	17	18	19
	4	7	8	9	10	11	12	13	14	15	16	17	18	19	20

Table 3-3: Description of Environmental Significance Ratings and associated range of scores

Significance Rating	Description	Positive	Negative
Low	An acceptable impact for which mitigation is desirable but not essential. The impact by itself is insufficient even in combination with other low impacts to prevent the development being approved. These impacts will result in either positive or negative medium to short term effects on the social and/or natural environment.	4-7	4-7
Moderate	An important impact which requires mitigation. The impact is insufficient by itself to prevent the implementation of the Project but which in conjunction with other impacts may prevent its implementation. These impacts will usually result in either a positive or negative medium to long-term effect on the social and/or natural environment.	8-11	8-11
High	A serious impact, if not mitigated, may prevent the implementation of the Project (if it is a negative impact). These impacts would be considered by society as constituting a major and usually a long-term change to the (natural &/or social) environment and result in severe effects or beneficial effects.	12-15	12-15
Very High	A very serious impact which, if negative, may be sufficient by itself to prevent implementation of the Project. The impact may result in permanent change. Very often these impacts cannot be mitigated and usually result in very severe effects, or very beneficial effects.	16-20	16-20

4. Country Health Profile: South Africa

South Africa is a dynamic and complex country. A middle-income nation that has dedicated substantial resources to health and human capital investments, South Africa has a progressive Constitution that guarantees the right to health care and a vibrant civil society.

Life expectancy has increased due to innovations and rapid scale-up of HIV/AIDs and Tuberculosis (TB) treatment and care, and expanded access to immunizations. Life expectancy which incorporates the impact of AIDS increased from 52.1 years in 2005 to 61.2 years in 2014 (Statistics South Africa, 2014). The estimated national HIV prevalence among the general population aged 15 – 49 years has remained 17.3% since 2005 (Department of Health Strategic Plan 2014/15-2018/9). Two in three TB patients also are HIV positive. South Africa has one of

the highest TB incidence rates in the world (834 per 100,000 populations). The treatment success rate for new and relapse cases registered in 2013 is 78% (Global TB Report 2015).

South Africa also contributes about 10.4% of the global burden of reported Multi-drug Resistant Tuberculosis (MDR-TB) initiated on treatment. A National DRTB Survey to ascertain the burden of DR-TB was made available in the first quarter of 2016. Diagnosis and management of drug resistant cases account for nearly half of the TB budget and treatment success rates are 49% for MDR-TB and 20% for XDR-TB (Global TB Report, 2015).

Progress in maternal and child health has been hindered by the HIV and tuberculosis epidemics and the performance of the health system. Efforts to accelerate prevention interventions are underway, including the prevention of maternal to child transmission of HIV. Important reductions have occurred in under five and neonatal mortality (42 and 14 per 1000 live births (2013/14)), although these rates are higher in comparison with other countries of similar socioeconomic status. Maternal mortality ratios remain high, estimated at 269 deaths per 100 000 live births. Immunization remains critical to improving child health. The government currently has eleven antigens on its national immunization schedule, including rotavirus and Pneumococcal Conjugate Vaccine, which has markedly reduced child morbidity and mortality. A national HPV campaign was launched in March 2014.

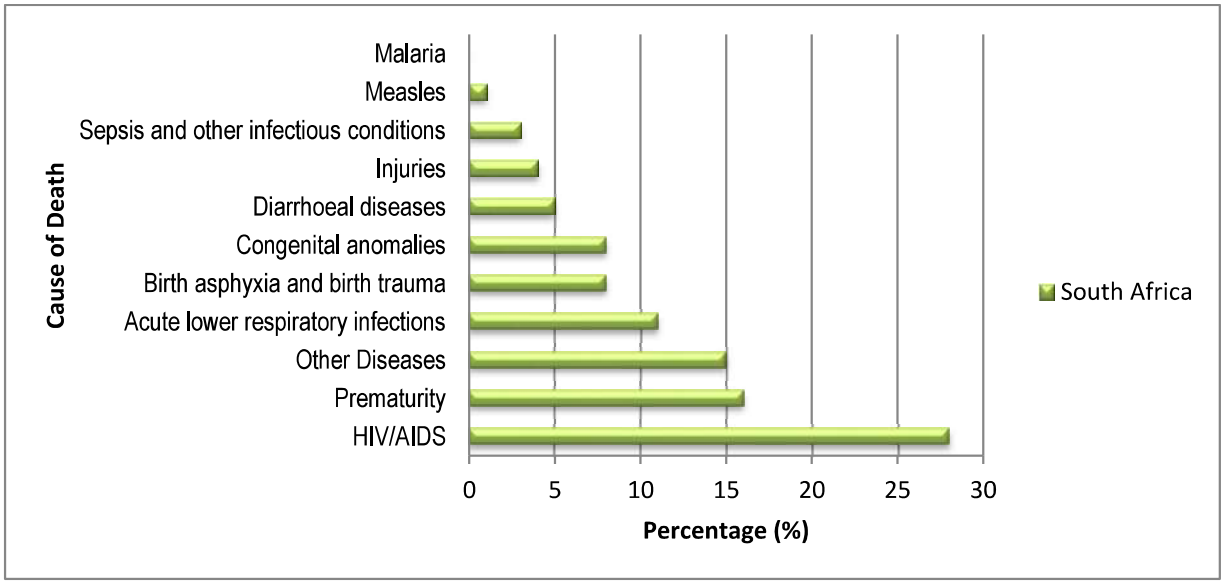


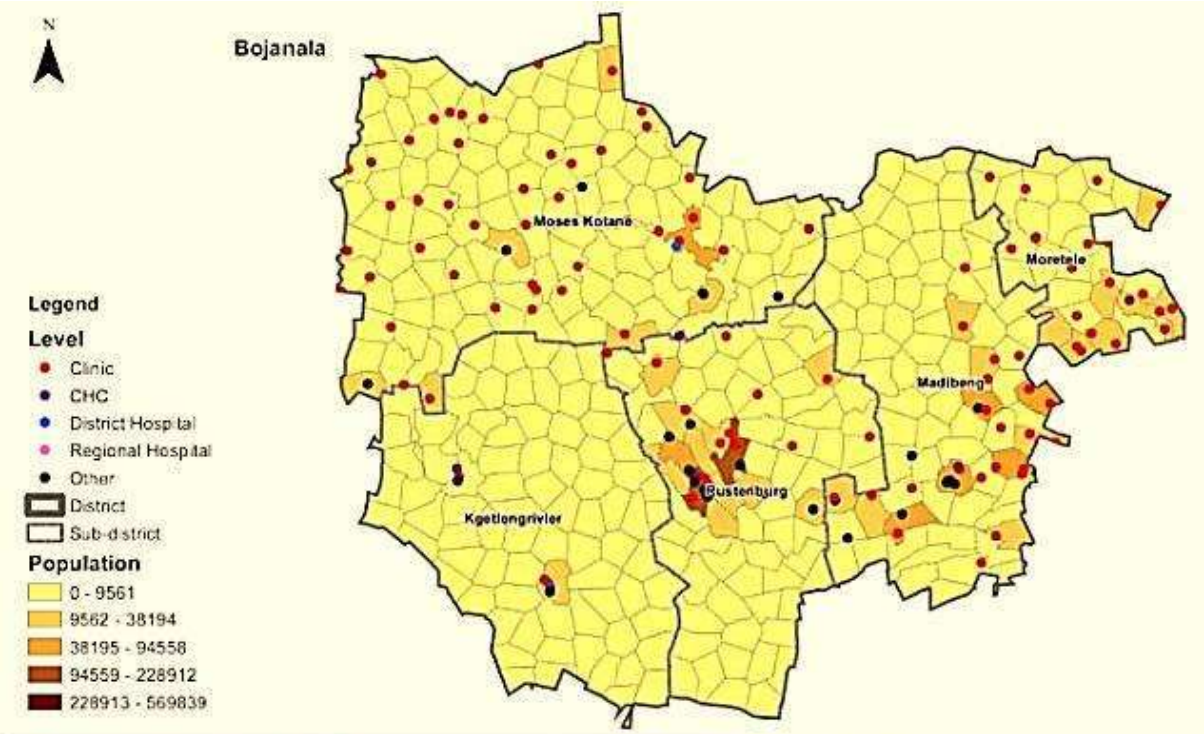
Figure 4-1: Distribution of causes of death among children aged under 5, % of totals in RSA

Approximately two in five deaths are attributable to non-communicable diseases. Some 40% of mortality from non-communicable conditions among men occurred before the age of 60 years which is therefore considered premature. Second to non-communicable conditions is the burden of mortality and disability from violence and injuries. A rapid increase in motor vehicles has led to increases in road traffic accidents that now account for more than one-quarter of deaths due to injuries. For nearly two decades, tobacco-use declined because of strong legislation and policies to control tobacco consumption. The WHO FCTC was ratified in 2005. However, smoking

rates are among the highest in the continent (21.5% in 2014). Harmful alcohol consumption is the third most important risk factor contributing to non-communicable diseases, injuries, and communicable diseases. Alcohol use is a major underlying factor in injuries and road traffic accidents. Patterns of harmful use exist among those who drink. Harmful and excessive alcohol consumption also contributes to non-communicable conditions and can also accelerate the progression of infectious diseases.

5. District Health Profile: Bojanala District Municipality

Bojanala District is situated in North West Province and comprises five health sub-districts, namely Kgetlengrivier, Madibeng, Moses Kotane, Moretele and Rustenburg. The district has a population of 1 665 222, with a population density of 90.8 persons per km^2 and falls in the mid socio-economic quintile, Quintile 3. Estimated medical scheme coverage is 14. 6%.



a Statistics South Africa. Census 2011 Municipal fact sheet. Report No. 03-01-58. Pretoria: Statistics SA; 2012.

Figure 5-1: Population distribution sub-district boundaries and health facility locations

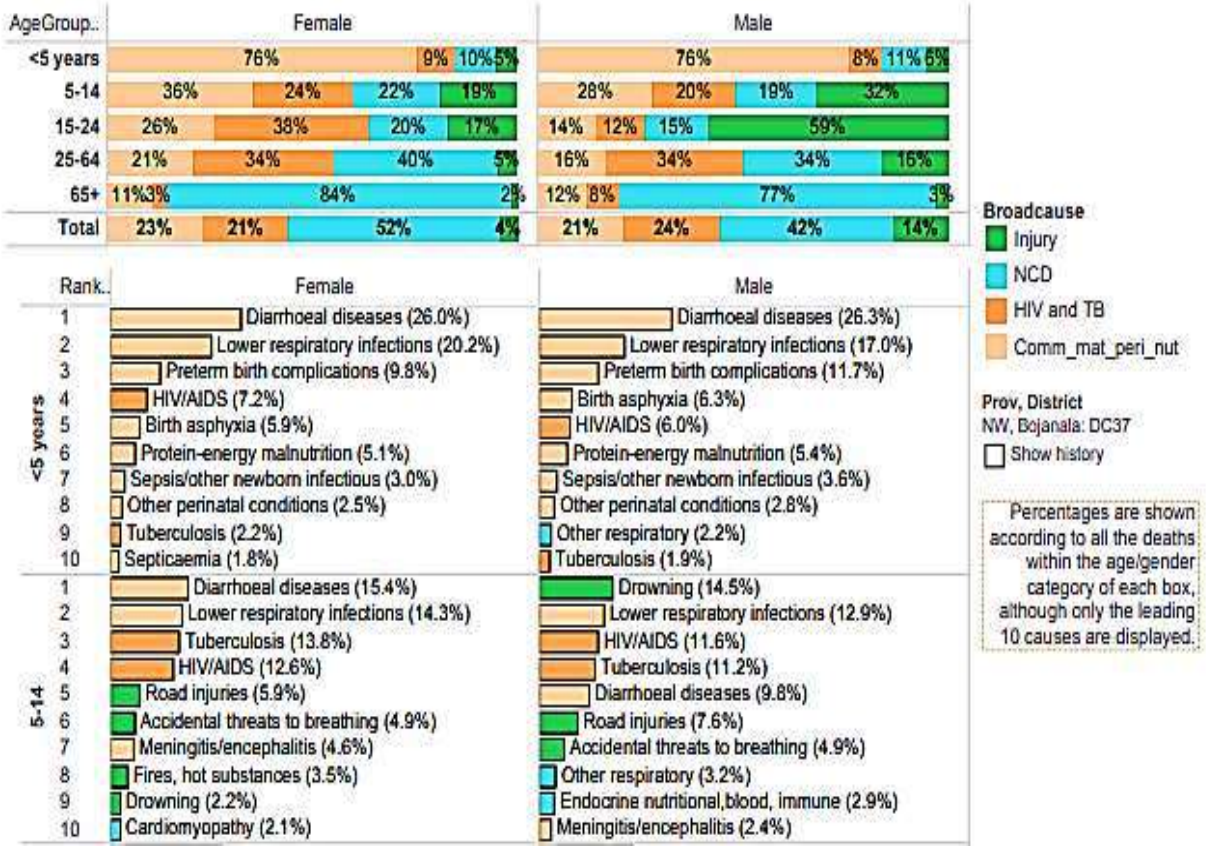
Table 5-1: Number of facilities by level, 2016/17

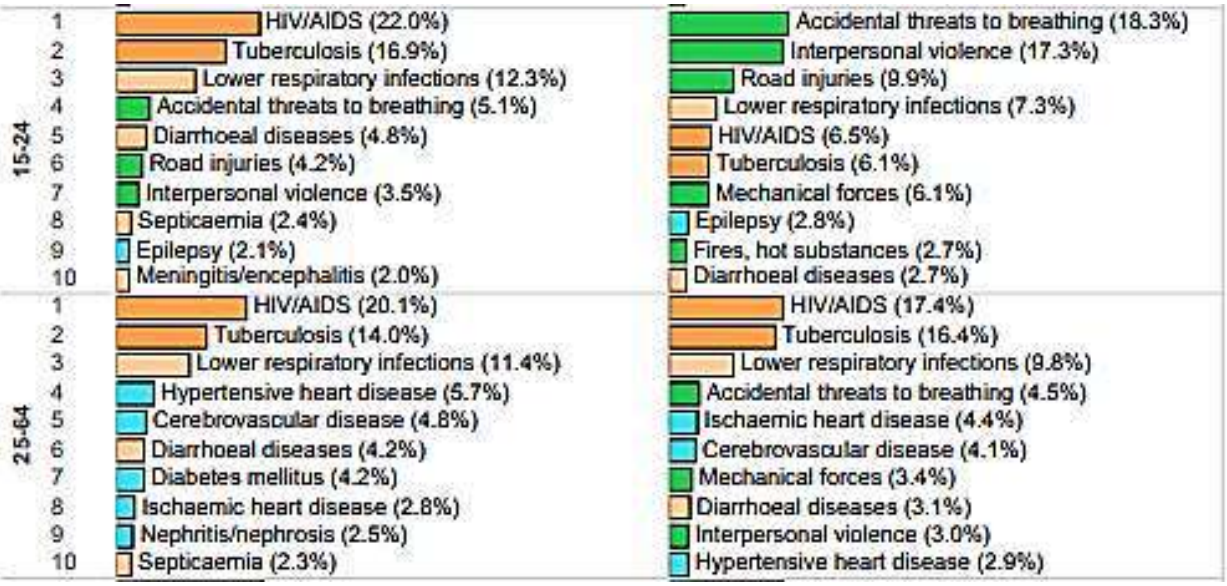
	Ward based outreach teams	Clinic	CHC	District Hospital	Regional Hospital	Central/ Tertiary Hospitals	Other Hospitals
Kgetleng Rivier SD	6	3	1	1	0	0	0
Madibeng SD	33	22	2	1	0	0	1
Moretele SD	30	22	0	0	0	0	0
Moses Kotane SD	34	47	3	1	0	0	0
Rustenburg SD	30	21	3	0	0	1	6
Bojanala	133	115	9	3	0	1	7

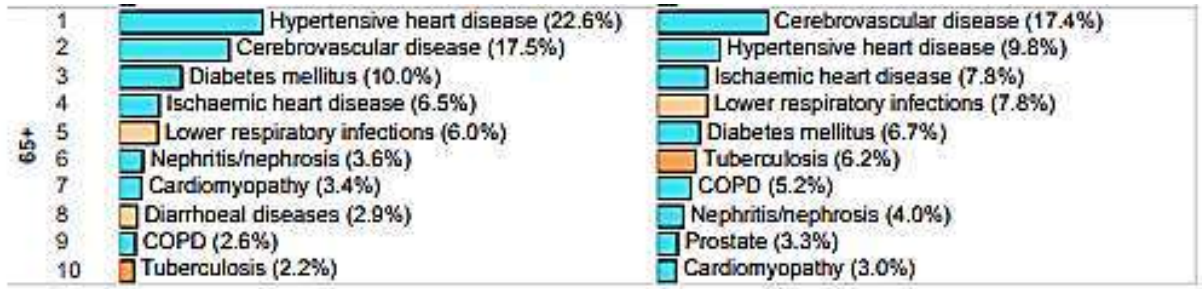
Source: DHIS.

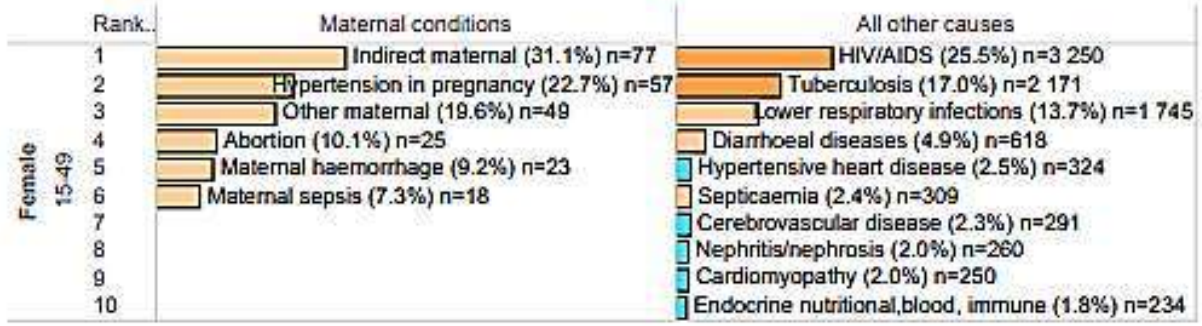
5.1 Burden of Disease Profile

For the percentage of deaths by broad cause, deaths are classified into four groups namely: (i) injuries; (ii) non-communicable diseases; (iii) HIV and TB; and (iv) communicable diseases together with maternal perinatal and nutritional conditions. Data are given by gender and age group for the period 2010–2015. The second part of the graph shows the 10 leading single causes of death within each age group (both genders) for 2010–2015 combined.









6. Baseline Status

Rayten was appointed by Seaton Thomson and Associates cc to compile an Air Quality Baseline Assessment for the proposed residential development. The following section describes the baseline health status in the proposed residential development area. The information presented in this section has been taken from the above mentioned 2019 Rayten Baseline study as well as other specialist studies undertaken for Tharisa Mine.

6.1 Surface Water

In 2014, SLR Consulting (Africa) (Pty) Ltd (SLR), formerly Metago, were commissioned to prepare Hydrology Assessment for a Chrome Sand Drying Plant, changes to the Tailings Dam Design and other Operational and Surface Infrastructure changes at Tharisa Mine.

SLR noted the following local hydrology in the vicinity of Tharisa Mine (and by extension, the proposed Rooikoppies residential development area):

- Sterkstroom – a perennial watercourse which flows from the Buffelspoort Dam, south of the N4;
- Unnamed tributaries of the Brakspruit – two non-perennial watercourses which flow to the north to separate confluences with the Brakspruit;
- Western unnamed tributaries of the Maretlwane – two non-perennial watercourses which flow to the north then north-east to a confluence with the Maretlwane;
- Eastern unnamed tributaries of the Maretlwane – two non-perennial watercourses which to the north then north-east to a confluence with the Maretlwane tributaries; and
- Unnamed of the Elandsdriftspruit – a non-perennial tributary which flows north then east through the far eastern part of the mine.

Water from the Sterkstroom is used for domestic purposes such as washing and bathing, livestock watering and for agricultural purposes.

During 2014 sampling rounds, the following parameters were found in higher concentrations:

- Elevated nitrate:

All samples with high nitrate concentrations should be checked for bacteriological contamination. This has acute health effects (SANS Drinking water standards). A source of nitrate in natural water results from the oxidation of plant and animal debris and of animal and human excrement. Several reviews of epidemiological studies have been published, none with compelling/ convincing evidence of an association between gastric cancer and the consumption of drinking-water high in nitrates. Studies that have assessed the effect of nitrate from sources other than vegetables, such as the concentration in drinking water or occupational exposure to nitrate dusts, have not shown a protective effect against gastric cancer risk. For other types of cancer, there are no adequate data with which to establish any association with nitrite or nitrate intake (Gangolli et al., 1994; Möller, 1995; FAO/WHO, 1996). Congenital malformations have been related to high nitrate levels in drinking-water in Australia; however, these observations were not confirmed. Other studies also failed to demonstrate a relationship between congenital malformations and nitrate intake (WHO, 1985b; ECETOC, 1988; Manassaram et al., 2007).

- Elevated dissolved salts:

Elevated dissolved salts results in drinking water developing a slightly saltier taste but should not pose a significant health risk to the general population. There could be impacts for those who need to limit their daily salt intake (for example, severely hypertensive, diabetic and renal dialysis patients). Calcium and magnesium, two minerals commonly found in Total Dissolved Solids (TDS) , can cause water hardness, scale formation, and staining (Hassinger *et al.*, 1994).

- High Total Suspended Solids (TSS):

TSS are solids in water that can be trapped by a filter. TSS can include a wide variety of material, such as silt, decaying plant and animal matter, industrial wastes, and sewage. This could suggest coliforms (e.g. Fecal coliforms, Escherichia coli) are present in the water. Coliforms are bacteria that are always present in the digestive tracts of animals, including humans, and are found in their wastes. They are also found in plant and soil material. The most basic test for bacterial contamination of a water supply is the test for total coliform bacteria. Total coliform counts give a general indication of the sanitary condition of a water supply.

The health effects of exposure to disease-causing bacteria, viruses, and parasites in drinking water are varied. The most common symptoms of waterborne illness include nausea, vomiting, and diarrhoea. Infants, the elderly, and those with compromised immune systems may suffer more severe effects. In extreme cases some pathogens may infect the lungs, skin, eyes, nervous system, kidneys, or liver and the effects may be more severe, chronic, or even fatal (Brunswick, year unknown).

- Low pH (acidic):

The pH of water is a measure of the acid–base equilibrium and, in most natural waters, is controlled by the carbon dioxide–bicarbonate–carbonate equilibrium system. The pH is of major importance in determining the corrosivity of water -the lower the pH, the higher the level of corrosion (Rose, 1986). Elevated levels of metal contaminants found in acidic water can cause plenty of health issues that could prove fatal or debilitating for children and individuals with compromised immunity. Eye irritation, exacerbation of skin disorders, vomiting, diarrhoea, kidney disease, liver disease, stomach cramps, and nausea are among the leading health issues caused by the consumption of acidic water (WHO, 2002).On the opposite end of the scale, pH values below 4 also cause irritation due to the corrosive effects of low pH levels. WHO warns that extreme pH levels can worsen existing skin conditions.

Other than the unpleasant aspect of foul-tasting water, low pH values generally have few negative health effects. Acidic drinking water can cause serious problems, however, through the leaching of heavy metals from plumbing systems. These toxic metals can include substances such as lead. Lead exposure can lead to a host of neurological and reproductive problems, such as seizures, hearing loss and miscarriages. Ingestion of lead-tainted water is one-way adults can become exposed to this toxin.

Leaching of heavy metals causes a domino effect that can impact the gastrointestinal system. Overexposure to zinc from corroded pipes can cause nausea, vomiting or diarrhoea. Over ingestion of copper results in similar symptoms. These effects are not limited to heavy metals; high pH levels lead to similar ailments in sensitive individuals.

- Elevated turbidity:

Turbidity is a measure of the cloudiness of water- the cloudier the water, the greater the turbidity. Turbidity in water is caused by suspended matter such as clay, silt, and organic matter (see TSS above) and by plankton and other microscopic organisms that interfere with the passage of light through the water (American Public Health Association, 1998). Turbidity is closely related to TSS, but also includes plankton and other organisms. Turbidity itself is not a major health concern, but high turbidity can interfere with disinfection and provide a medium for microbial growth. It also may indicate the presence of microbes in the water.

- Elevated ammonium:

Elevated levels of ammonium in water is an important indicator of faecal pollution (International Organization for Standardization, 1986). No proposed health impacts for humans, but toxic for aquatic life.

- Faecal coliforms exceeded the guideline limit:

If faecal coliforms exceed the guideline limit for irrigation at and of the sampling points, as well as the guideline limit for livestock watering: Faecal coliforms are bacterial indicators of faecal pollution from humans and warm-blooded animals. They are primarily used to indicate the presence of bacterial pathogens such as Salmonella spp., Shigella spp. Vibrio cholerae, Campylobacter jejuni, Campylobacter coli, Yersinia enterocolitica and pathogenic E. coli. The most basic test for bacterial contamination of a water supply is the test for total coliform bacteria. Total coliform counts give a general indication of the sanitary condition of a water supply.

- Total coliforms include bacteria that are found in the soil, in water that has been influenced by surface water, and in human or animal waste.
- Fecal coliforms are the group of the total coliforms that are considered to be present specifically in the gut and feces of warm-blooded animals. Because the origins of fecal coliforms are more specific than the origins of the more general total coliform group of bacteria, fecal coliforms are considered a more accurate indication of animal or human waste than the total coliforms.
- Escherichia coli (E. coli) is the major species in the fecal coliform group. Of the five general groups of bacteria that comprise the total coliforms, only E. coli is generally not found growing and reproducing in the environment. Consequently, E. coli is considered to be the species of coliform bacteria that is the best indicator of faecal pollution and the possible presence of pathogens.

In general, increased levels of faecal coliforms provide a warning of failure in water treatment, a break in the integrity of the distribution system, possible contamination with pathogens. When levels are high there may be an elevated risk of waterborne gastroenteritis. As suggested in the Surface Water Report, the presence of faecal coliform in aquatic environments may indicate that the water has been contaminated with the faecal material of humans or other animals. Faecal coliform bacteria can enter rivers through direct discharge of waste from mammals and birds, from agricultural and storm runoff, and from human sewage (Doyle, 2006).

The health effects of exposure to disease-causing bacteria, viruses, and parasites in drinking water area varied. The most common symptoms of waterborne illness include nausea, vomiting, and diarrhoea. Infants, the elderly, and those with compromised immune systems may suffer more severe effects. In extreme cases some pathogens may infect the lungs, skin, eyes, nervous system, kidneys, or liver and the effects may be more severe, chronic, or even fatal (Brunswick, year unknown).

Elevated manganese is also likely to be from sewage from the nearby settlements.

Other points to note are:

- Both calcium and magnesium are essential to human health. Inadequate intake of either nutrient can impair health. Recommended daily intakes of each element have been set at national and international levels.
- The palatability of drinking- water has been rated by panels of tasters in relation to its TDS level as follows: excellent, less than 300 mg/litre; good, between 300 and 600 mg/litre; fair, between 600 and 900 mg/litre; poor, between 900 and 1200 mg/litre; and unacceptable, greater than 1200 mg/litre. TDS is classified under the secondary standards, which are based on aesthetic factors such as colour and staining properties of water rather than potentially harmful health effects. The standard in drinking water for TDS is 500 milligrams per liter (mg/l).
- The more dissolved solids in the water, the higher the hardness of the water/ the level of total dissolved solids in drinking water affect the taste of the water. Higher levels of TDS can make water taste bitter, salty or brackish. However, levels of total dissolved solids affect animals much more than humans.

6.2 Air Quality Findings

Heavy construction is a source of dust emissions that may have a substantial temporary impact on local air quality. Building and road construction are two examples of construction activities with high emissions potential. However, dust emissions often vary substantially from day to day, depending on the level of activity, the specific operations, and the prevailing meteorological conditions.

As mentioned above, Rayten was appointed by Seaton Thomson and Associates cc to compile an Air Quality Baseline Assessment for the proposed residential development. According to Rayten, existing sources of

emissions are all contributing to air pollution and air pollutant concentrations within the area. The existing key sources of air pollution surrounding the proposed residential development were identified during a desktop exercise and include:

- Mining activity (surrounding the proposed development, excl. northerly);
- Vehicle exhaust emissions and vehicle dust entrainment on unpaved roads (surrounding areas); and
- Agricultural activity and potential biomass burning (surrounding areas).
- Township/informal settlements (south-west, north-west and north-east of the proposed development)
- Exposed areas (east, north-west and north of the proposed area)

Forestry and industrial areas were identified as additional sources of air pollution but to a smaller extent. Forestry activity occurs over small areas to the east and south-west of the proposed development. Industrial areas are found to the north-west and north-east of the proposed development.

6.3 Noise

Noise is also a factor to consider and the health impacts of noise are well described at both a physical and psycho-social level in the Noise Impact Assessment. Noise and vibration are noted as potential environmental risks due to the nature of the Project's operations. The WHO published a set of guidelines relating to community noise, including potential sources, quantification and potential effects (WHO 1999). Potential health effects identified include hearing loss or loss of hearing sensitivity, sleep disturbance, cardiovascular and physiological effects, mental health effects and behavioural effects, including poor performance by school children (Stansfield and Matheson 2003, WHO 1999, Health Evidence Bulletins 1999). Environmental noise has also been found to be responsible for interference with communication, cognitive performance and annoyance (Stansfield and Matheson 2003, WHO 1999). Stansfield and Matheson (2003) concluded that the effects of environmental noise are strongest for categories linked to quality of life (or the wider determinants of health in the context of human health) as opposed to illness (or bio physical factors).

From an occupational health perspective, noise-induced hearing loss (NIHL) begins gradually and progressively gets worse. Problems with this disease include loss of the ability to communicate and reduced response to environmental and occupational noise and danger. In the mining environment, the effects of NIHL can be deadly in specific work situations. Bise (2001) listed several factors that influence occupational hearing loss. These factors include the following:

- Age of employee.
- Pre-employment hearing impairment.
- Diseases of the ear.
- Sound pressure level of the noise.

- Length of daily exposure.
- Duration of employment.
- Ambient conditions of the workplace.
- Employee lifestyle outside the workplace.

The physical effect of hearing loss and impairment due to noise exposure is not a community health risk but will certainly be an important workplace occupational health consideration. The noise levels required to induce hearing loss only occur at levels above 85 dB(A) which would be intolerable for any community. Noise annoyance can however lead to stress-related impacts on health and general well-being and may also have an influence on mood, performance, fatigue and cognition. Sleep can be disturbed by noise levels as low as 35 dB(A).

7. Housing and Community Health

Housing quality, affordability, location, and surrounding social and community attributes are important to human health.

Housing quality: Housing that is safe, dry, clean, maintained, adequately ventilated, and free from pests and contaminants, such as lead, radon, and carbon monoxide, can reduce the incidence of negative health outcomes such as injuries, asthma, cancer, neurotoxicity, cardiovascular disease, and poor mental health.

Housing community: Neighbourhoods free from segregation and concentrated poverty, and in which residents have close and supporting relationships with one another, can improve physical and mental health by reducing stress and exposure to violence and crime as well as improving school performance and civic engagement.

Housing location: Easy access to public transportation, parks and recreation, quality schools, good jobs, healthy foods, and medical care can help reduce the incidence of chronic disease, injury, respiratory disease, mortality, and poor mental health.

Housing affordability: Affordable housing enables people to pay for other basic needs such as utilities, food, and medical care, which can reduce the incidence of negative health outcomes such as malnutrition, diabetes, anxiety, and depression.

8. Potential Health Impacts

The ultimate goal of a HRA is to identify whether there are potential health impacts and communicate these impacts to decision makers during the planning and permitting process. Health impacts are:

- Changes in health outcomes or determinants, not general changes in environmental conditions;

- Specific health outcomes or determinants, not general statements about health status; and
- Quantifiable, whenever possible.

All communities have existing health problems and health assets. Similarly, all development projects have the potential to generate positive and negative health and well-being impacts. It is within this wider context that the community health impacts of mining projects should be considered. Both positive and negative impacts occur because a project has the potential to change the economic, social, sanitary and natural environments within which communities live and work. Good design and management can help to maximize the positive health and safety impacts and avoid or minimize the negative ones.

A health impact is a positive or negative change in a specific health outcome or health determinant.

This section provides an analysis of the potential impacts associated with the existing, surrounding mining operations may have on the proposed residential development and has included the analysis of potential negative impacts and their mitigation measures. This is based on the evidence presented to the Specialist by Rayten and information obtained from the other available specialist studies conducted for Tharisa Mine.

The key health impacts and needs have been described in the EHA framework. Project-specific determinants and comments will be described so as to inform the impact assessment.

8.1 Soil-, Water- and Waste-related Diseases

Mining projects can potentially change these exposures by adding or removing substances in the air, water and/or soil. Some of the substances that may be added can remain in the environment and/or the food chain for decades after the closure of a project (e.g. mercury, pesticides), and therefore may have transgenerational health impacts[1].

8.1.1 Water and Sanitation

Access to clean water and good sanitation are a fundamental determinant of health and can be positively or negatively affected by mining and metals projects. Projects can be heavy users of local water and can also release materials into existing water sources.

The proposed residential development may also play a role in availability of water due to increased demand, which may ultimately negatively affect water quality. Water-borne diseases such as diarrhoea are currently not very common but where it occurs, are linked to contaminated water and poor sanitary conditions. Water-washed diseases such as eye and skin infections may become common. These are linked to poor hygiene.

[1] According to the International Council on Mining and Metals (ICMM), Transgenerational impacts are those impacts which can affect future generations i.e. they lead to ill health in children and grandchildren even after a particular project has closed.

Mining poses a significant threat to the integrity of aquifers, which may be hydrologically connected to other groundwater-dependent ecosystems including farm dams, bores and rivers. Water from mines must be disposed of and waste material is often held within the surface lease of a mine, introducing a risk of contamination of human food sources. Pollution of the environment can also occur through windblown dust during transportation, where the ore is washed.

Although water is an essential requirement in the mine for various purposes, the use of it has the potential to affect the quality of surrounding resources. All mines are, therefore, required to contain, recycle and re-use dirty water within their operational systems, to avoid discharging contaminated water into the natural environment. Water contamination may occur as a result of runoff from contaminated surfaces and from any dirty water discharges including treated sewage effluent within the mine into the water course in proximity to the site. The inhabitants of the proposed development will need to be educated about these risks and potential health impacts.

8.1.2 Impact Evaluation

The table below considers the scale of the specific predicted impacts related to EHA #5 by presenting the impact evaluation ratings for the three project phases.

Table 8-1: Impact Evaluation

Soil, Water and Waste-Related Diseases					
	Effect			Risk or Likelihood	Overall Significance
	Temporal Scale	Spatial Scale	Severity of Impact		
Operational Phase					
Without Mitigation	Long Term (3)	Study Level (2)	Severe (4)	Probable (3)	MODERATE – (11)
With Mitigation	Long Term (3)	Study Level (2)	Moderate (2)	May Occur (2)	MODERATE – (9)

8.2 Exposure to Potentially Hazardous Materials, Noise and Malodours

Mining activities are predominant in all directions surrounding the proposed site. The closest mines being located to the east and south of the proposed development. Local communities may already be exposed to low background levels of potentially hazardous materials (e.g. dust, particulate matter, possible heavy metals) that can be associated with health problems such as respiratory illnesses, skin diseases, organ damage, circulatory problems, birth defects, cancers and neurological disorders.

The negative health effects of ore mining in the Project Region are wide-ranging though not extensively documented. Many health effects can be directly correlated with toxic agents released into the soil, air, and

groundwater by mining activity, but are also related to the social environment of North West Province, including limited economic opportunities.

Exposures and environmental health determinants as a result of the neighbouring mines will be covered in a number of specialist reports. These include air quality, water, noise and soil studies. Air quality and odours have been addressed in detail in the Air Quality Report.

8.2.1 Solid Waste (General and Hazardous)

Waste streams likely to be produced during the construction phase will include both general (non-hazardous) and hazardous wastes and are expected to be similar in composition to the non-process wastes or co-products produced during the operational phase. The domestic waste stream will be comprised predominantly of non-hazardous waste types including paper, plastic, cloth and some food waste. In addition, relatively insignificant quantities of hazardous wastes may be included in this waste stream, including batteries, empty containers for cleaning chemicals, fluorescent light tubes, pesticide aerosol cans etc.

Waste storage drums that have industrial residues may adversely impact household water and food supplies, because these containers are often prized as inexpensive storage devices. The construction and rehabilitation activities will also result in the generation of hazardous wastes including chemicals associated with machine and vehicle maintenance, oily rags and filters, empty containers for hazardous chemicals (paints, solvents, lubricants, herbicides, pesticides / herbicides) and electrical and electronic equipment.

The uncontrolled storage of solid waste, in particular food waste, can attract vermin and pests including rodents, birds and flies. These vermin / pests may pose a nuisance to PACs closest to the site and may act as vectors for disease. The uncontrolled storage of solid waste can result in the release of unpleasant odours which may be regarded as a nuisance to adjacent land-users, particularly that downwind of the material. Odorous compounds are also released from relatively well-managed solid waste disposal facilities. The presence of large quantities of litter around the facility or at the proposed landfill may constitute a visual impact to employees and local communities.

8.2.2 Volatile Organic Compounds

Volatile Organic Compounds (VOCs) are compounds that have a high vapour pressure at ordinary, room-temperature conditions. It is noted that some organic compounds have little or no known direct human health effects, while others are extremely toxic and/or carcinogenic. Breathing VOCs can irritate the eyes, nose and throat, can cause difficulty breathing and nausea, and can damage the central nervous system as well as other organs. Some VOCs can cause cancer. The USEPA has classified benzene as a Group A, known human carcinogen. Increased incidence of leukaemia (cancer of the tissues that form white blood cells) has been observed in humans occupationally exposed to benzene. The USEPA has derived a range of inhalation cancer unit risk estimates for

benzene. The value at the high end of the range was used in this assessment. Chronic (long-term) inhalation exposure has caused various disorders in the blood, including reduced numbers of red blood cells and aplastic anaemia, in occupationally exposed humans. Reproductive effects have been reported in women exposed by inhalation to high levels of benzene, and adverse effects on the developing foetus have been observed in animal tests (USEPA, 2001).

The USEPA calculated a range of 2.2x10-5 to 7.8x10-6 as the increase in the lifetime cancer risk to an individual who is continuously exposed to 1 µg/m3 of benzene in the air over his or her lifetime. EPA estimates that, if an individual were to continuously breathe air containing benzene at an average of 0.13 to 0.45 µg/m3 over his or her entire lifetime, that person would have no more than a 1 in a million increased chance of developing cancer as a direct result (USEPA, 2001).

Chronic inhalation of certain levels of benzene causes disorders in the blood of humans. Benzene specifically affects bone marrow (the tissues that produce blood cells). Aplastic anaemia, excessive bleeding, and damage to the immune system (by changes in blood levels of antibodies and loss of white blood cells) may develop. In animals, chronic inhalation and oral exposure to benzene produce the same effects as seen in humans. Reproductive effects have been reported for women exposed by inhalation to high levels, and adverse effects on the developing foetus have been observed in animal tests (USEPA, 2001).

Benzene is the only VOC for which a National ambient air quality standard has been established. An annual average standard of 10 µg/m3 and 5 µg/m3, respectively, has been established for current and future compliance (1 Jan 2015).

In summary, health effects may include:

- Eye, nose and throat irritation
- Headaches, loss of coordination and nausea
- Damage to liver, kidney and central nervous system
- Some organics can cause cancer in animals, some are suspected or known to cause cancer in humans.

Key signs or symptoms associated with exposure to VOCs include:

- conjunctival irritation
- nose and throat discomfort
- headache
- allergic skin reaction
- dyspnea
- declines in serum cholinesterase levels
- nausea
- emesis
- epistaxis
- fatigue
- dizziness

8.2.3 Particulate Matter

Numerous epidemiological studies have linked levels of ambient particulate matter (PM) with a variety of human health problems, such as silicosis, pneumoconiosis and increased risk of TB, lung cancer, scleroderma, and systemic lupus erythematosus. Specifically, exposure to gold mine dust, that is, rich in silica, has been linked to the development of chronic bronchitis, emphysema, and air flow obstruction. (Oguntoke *et al.*, 2013)

Mine dump facilities are major generators of wind-blown dust and one of the main sources of air pollution with potential adverse health implications for nearby communities. The perennial dust issue is brought to the surrounding residents as a result of dying vegetation and currently, reworking of old mine dumps to the for residual gold content by illegal miners, referred to as 'zama-zamas'. Fine dust particles are dispersed into the atmosphere and are distributed/ transported across vast distances. Research studies have shown that mine dumps are the perpetual contributors to the ambient particulate matter (PM) loading of the surrounding atmosphere (Shima, 2008).

Research has linked PM with serious adverse health effects and different types of respiratory and cardiovascular diseases. Exposure to ambient PM can cause premature mortality, chronic cough, wheeze, chronic bronchitis, pneumonia, emphysema, asthma, decreased lung function, chronic obstructive pulmonary diseases, lung fibroids, lung cancer and myocardial infarction. The elemental composition, size, shape, specific surface area and surface charge may also determine cellular toxicity. Particle size determines deposition patterns in the respiratory tract, and consequently the extent of toxicity. The transport and deposition of PM into respiratory system can be divided into four different categories, namely:

- Impact mechanism in the nasopharyngeal region by particles between 5 and 30 µm
- Sedimentation mechanism in the tracheobronchial region by particles between 1 and 5 µm
- Interception mechanism in the alveolar region by particles < 1 µm or ≤ 2.5 µm
- Diffusion mechanism for particles < 0.5 µm

Smaller particles are more toxic since they may infiltrate further into the respiratory system.

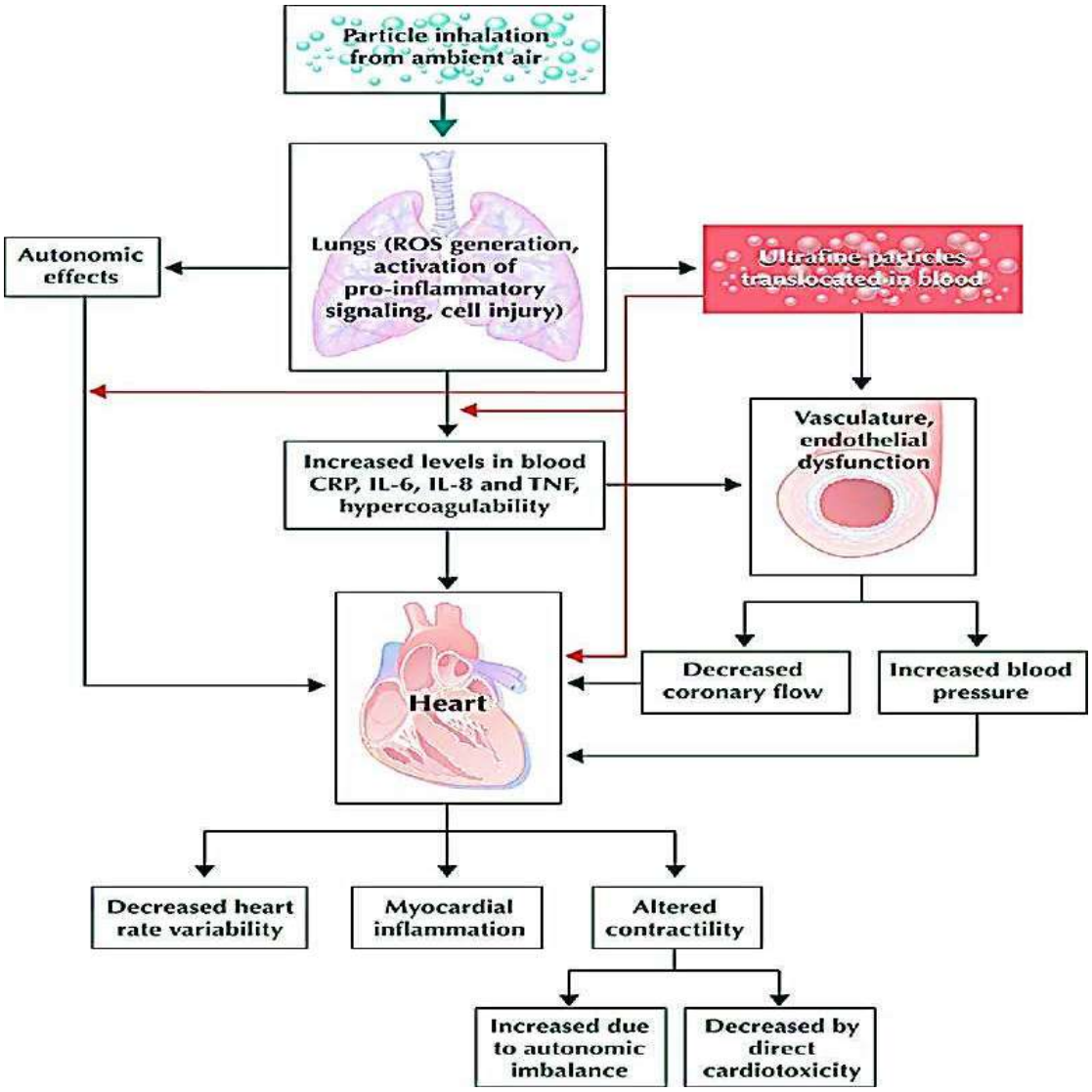


Figure 8-1: Pathophysiological mechanism of lung and circulation – mediated cardiovascular toxicity of particulate air pollutants (Simkhovich, 2008)

The construction of the housing development itself and roads will be a source of dust emissions that may have a considerable though temporary impact on air quality in the development area and surrounds. Vehicles travelling to and from the mine also have the potential to cause significant instantaneous emissions from exposed areas of tailings material. However, it was assumed that (other than haul vehicles on the sand dumps) the total amount of traffic and hence the total emissions from this source would be insignificant.

8.2.4 Dust Fallout

According to Rayten (2019), dust-fall rates for buckets located in non-residential areas range from 74 – 1 060 mg/m2/day for the period. There were no exceedances of the non-residential standard of 1 200 mg/m2/day, during the period August 2018 – August 2019. Higher dust-fall rates are recorded at site D14, located approximately 0.6km south of the proposed development. Dust-fall rates for buckets located in residential areas range from 20 –

1 010 mg/m2/day for the period. There were 5 exceedances of the residential standard during the period August 2018 – August 2019.A total of three exceedances were recorded during December 2018 at sites, D09, D13 and D19. These stations are located approximately 3.25 km south, 1.72 km west and 2.95 km south-east, respectively from the proposed development. Two exceedances were recorded in 2019, with D19 exceeding in January 2019 and D12, situated approximately 1.79 km south west of the proposed development, exceeding in June 2019.

Dust from mining operations located close to residential developments in general would be blown into the communities affecting their health and this can have serious long-term consequences (Abdul-Wahab and Marikar 2012, Castillo et al. 2013). Contaminants are usually associated with the finer particles (< 2µm in diameter). These particles can travel long distances and cause health problems to people as they penetrate through the respiratory system (Csavina et al. 2012).

Dust suppression is crucial in the mining industry as dust affects not only the health and safety of mine workers, but that of surrounding communities as well. The surroundings mining operations are accountable under the dust regulations for the dust emissions. Mining operations are required to comply with the National Dust Control Regulation Act and the National Environmental Management: Air Quality Act, 2004 (Act No. 39 of 2004), which make provision for dust-control management or air-quality control. These Regulations ensure that mines comply to protect their employees and contractors, as well as communities neighbouring their operations in terms of health and safety, as dust emission is an air pollutant.

The mines taking accountability over their sites by implementing dust suppression measures such as wetting roads, vegetating certain sections, works in favour of the mine surrounding communities as dispersion of dust is reduced/ minimised.

8.2.5 Diesel Particulate Matter

Diesel particulate emissions are of special concern, particularly the size fraction up to 2.5 microns, known as $PM_{2.5}$. This size of particle is able to be respired deep into the lungs. $PM_{2.5}$ from all sources has been implicated in numerous diseases ranging from cardiopulmonary disease to cognitive decline to cancer.

The deleterious impact on human health is incontrovertible (WA DOE 2008, California Air Resources Board 1998). Diesel engines are of particular concern as sources of particulate matter, as they typically produce $PM_{2.5}$ at a rate about twenty times greater than from gasoline (petrol) engines (WA DOE 2008, California Air Resources Board 1998).

8.2.5.1 Health Impacts of DPM: Cancer

Studies show an association between exposure to diesel exhaust and lung cancer (Bhatia, 1998), as well as cancers of the bladder and soft tissues (Guo et al., 2004). Several extensive and detailed reviews have been

conducted on the body of literature relating long-term exposure to diesel exhaust particles and lung cancer (California EPA, 1998; USEPA, 2002; Cohen and Nikula, 1999). In addition, over forty studies conducted among those populations exposed to diesel exhaust have found increased rates of lung cancer associated with diesel exhaust particles exposure (as cited in Cohen and Nikula, 1999). Occupational studies conducted in railroad workers and truck drivers have consistently found increased lung cancer risk, even after adjusting for comorbidities such as smoking (Bofetta, 2001). The impact of DPM on cancer risk must be considered in the decision-making process for the proposed residential development.

8.2.5.2 Health Impacts of DPM: Cardiac and Pulmonary

Although cancer risk is understandably of great concern to the public, cardiac and respiratory effects of diesel exposure have an even larger public health impact because they cause death and illness for a greater number of people. DPM can exacerbate asthma and emphysema, induce heart attacks and strokes, and has been associated with congenital heart abnormalities. According to a landmark study by Pope et al (2002), each 10 ug/m3 increase in DPM was associated with a 6% increase in cardiopulmonary mortality. In a follow-up to this study, Pope et al (2004) demonstrated that their previously observed increase in cardiopulmonary mortality was largely driven by increases in cardiovascular, as opposed to pulmonary mortality. In this follow-up study, a 10 ug/m3 increase in PM2.5 was associated with a 12% increase in mortality due to 'all cardiovascular disease plus diabetes' and an 18% increase in mortality due to 'ischemic heart disease'. Further epidemiological investigations have revealed that these estimates are likely largely underestimating the effect of $PM_{2.5}$ due to inadequate exposure characterization. Published in the New England Journal of Medicine, Miller et al. (2007) utilized a novel exposure characterization method and reported from the Women's Health Study that a 10 ug/m3 increase in $PM_{2.5}$ was associated with a 76% increase in death due to cardiovascular disease.

It is well understood that ambient air pollution and fine ambient particulate matter strongly contribute to disease burden and death, but it has been less clear as to how much an individual's living proximity to a major roadway or direct $PM_{2.5}$ source influences health risks. An individual's exposure to $PM_{2.5}$ is dependent on where he/she lives and works and that this strongly influences health outcomes. Van Hee et al. (2009) demonstrated that living close to a major roadway was a strongly associated with left ventricular hypertrophy, an important marker of cardiovascular disease and a strong predictor of heart failure and mortality. Additional work by this group has demonstrated an individual's exposure to PM2.5 impairs how well blood vessels dilate and how well the heart functions, providing a basis for our understanding of previously observed increases in mortality (Van Hee et al. 2011, Krishnan et al. 2012).

There are very specific physiological effects with DPM exposure. A recent study by Cosselman et al (2012) showed that diesel exhaust exposure, to healthy human volunteers, rapidly increases systolic blood pressure (SBP). In their study, SBP increased within 15 minutes of being exposed to dilute diesel exhaust and reached a maximum

increase in SBP within one hour. Additional work utilising controlled diesel exhaust exposures to human volunteers has revealed that these acute exposures results in impairment in blood vessel function and alters blood coagulability[2], both of which are extremely deleterious effects and increase the risk of acute cardiovascular events such as heart attack and stroke (Mills et al. 2005, 2007, and Törnqvist et al. 2007). Fitting with these findings, epidemiological investigations have consistently demonstrated that acute increases in $PM_{2.5}$ result in an increased risk of heart attack (Peters et al. 2001).

In addition to cardiovascular risk, cerebrovascular effects and risk of stroke associated with $PM_{2.5}$ exposure has been investigated. Research published in the Archives of Internal Medicine (2012) examines, for the first time, the risk of acute, short term exposures to $PM_{2.5}$ as a key factor in triggering stroke, often within hours of exposure.

8.2.6 Noise

Exposures and environmental health determinants as a result of the project will be covered in a number of specialist reports. These include air quality, water, noise and soil studies. There was no large industrial activity in the area.

Noise is also a factor to consider and the health impacts of noise are well described at both a physical and psycho-social level in the Noise Impact Assessment. Noise and vibration are noted as potential environmental risks due to the nature of the Project's operations. The project's activities that are likely to cause noise include:

- Single impulse noises such as blasting;
- Continuous noise from operations such as conveyors, crushers and processing plants; and
- Intermittent noises from activities like traffic, rail and/or construction.

Noise at the plant site will need to be managed with worker health and safety requirements and also based on the WHO and IFC guidelines to reduce ambient noise that may affect surrounding communities. The recommended maximum limits for noise exposure in communities as a result of an operation are 55 dB(A) during the day and 45 dB(A) at night. These have been addressed in the relevant specialist report.

The physical effect of hearing loss and impairment due to noise exposure is not a community health risk but will certainly be an important workplace occupational health consideration. The noise levels required to induce hearing loss only occur at levels above 85 dB(A) which would be intolerable for any community. Noise annoyance can however lead to stress-related impacts on health and general well-being and may also have an influence on mood, performance, fatigue and cognition. Sleep can be disturbed by noise levels as low as 35 dB(A).

[2] Coagulation (also known as clotting) is the process by which blood changes from a liquid to a gel, forming a blood clot. It potentially results in haemostasis, the cessation of blood loss from a damaged vessel, followed by repair.

8.2.6.1 Exposure to Noxious Fumes

Explosives used in the mining environment are required to be oxygen balanced. Oxygen balance refers to the stoichiometry of the chemical reaction and the nature of gases produced from the detonation of the explosives. The creation of poisonous fumes such as nitrous oxides and carbon monoxide are particular undesirable. These fumes present themselves as red brown cloud after the blast has detonated. It has been reported that 10 ppm to 20 ppm can be mildly irritating. Exposure to 150 ppm or more (no time period given) has been reported to cause death from pulmonary oedema. It has been predicted that 50% lethality would occur following exposure to 174 ppm for 1 hour. Anybody exposed must be taken to hospital for proper treatment.

Fumes, vapours, and gases are usually invisible. The effects of a toxic chemical on your body may be either acute or chronic. Acute (short-term) effects show up immediately or soon after exposure to the chemical. They may be minor, like nose or throat irritation, or they could be serious, like eye damage or passing out from chemical vapours. What all these effects have in common is that they happen right away. Chronic (long-term) effects may take years to show up. They are usually caused by regular exposure to a harmful substance over a long period of time. These effects are usually permanent. Factors contributing to undesirable fumes are typically: poor quality control on explosive manufacture, damage to explosive, lack of confinement, insufficient charge diameter, excessive sleep time, water in blast holes, incorrect product used or product not loaded properly and specific types of rock/geology can also contribute to fumes.

Symptoms and health effects of breathing carbon monoxide (CO), which has been identified by Rayten as one of the criteria pollutants can cause headache, dizziness, vomiting, and nausea. If CO levels are high enough, you may become unconscious or die. Exposure to moderate and high levels of CO over long periods of time has also been linked with increased risk of heart disease. People who survive severe CO poisoning may suffer long-term health problems. Nitrous oxide is a gas with several legitimate uses, but when inhaled it can make people feel euphoric and relaxed. This happy feeling has led to it being nicknamed 'laughing gas'. Some people also experience hallucinations. However, there is a risk of death as a lack of oxygen can occur when using nitrous oxide.

8.2.7 Impact Evaluation

The table below considers the scale of the specific predicted impacts related to EHA #8 by presenting the impact evaluation ratings for the three Project phases (overall potentially hazardous materials, noise and malodours).

Table 8-2: Impact Evaluation

Exposure to Potentially Hazardous Materials, Noise and Malodours					
	Effect			Risk or Likelihood	Overall Significance
	Temporal Scale	Spatial Scale	Severity of Impact		
Operational Phase					
Without Mitigation	Long Term (3)	Regional (3)	Moderate (2)	Probable (3)	HIGH – (11)
With Mitigation	Long Term (3)	Study Level (2)	Moderate (2)	Probable (3)	MODERATE – (10)

9. Cumulative Impacts[3]

Cumulative impacts are contextual and encompass a broad spectrum of impacts at different spatial and temporal scales (IFC, 2013) i.e. cumulative impacts can result from individually minor but collectively significant activities taking place over a period of time (Dutta, *et al*., 2012). These are not new types of impacts but recognition that impacts from individual projects and activities can combine together in time and space. In some cases, cumulative impacts occur because a series of projects of the same type are being developed. In other cases, cumulative impacts occur from the combined effects over a given resource of a mix of different types of projects, for example, the development of a mine site, access roads, transmission lines, and other adjacent land uses.

The following cumulative impacts are expected:

- An influx of people -i.e. extended family members of those who will be moving into the proposed residential developments to seek jobs may lead to increased pressure on infrastructure and services and an increase in social pathologies. While the potential impacts linked to influx can have negative consequences, this is a common and anticipated phenomenon that cannot be a reason for preventing further development;
- Direct nuisance factors from surroundings mines; namely, noise, air pollution, traffic and visual disturbances could further impact negatively on the sense of place for some receptors as well as the inhabitants of the proposed development. Implementation of suitable mitigation need to be proposed by the relevant specialist to reduce and manage these (already existing) nuisance factors;
- The other mines may contribute to the pollutant load on surface water systems. These changes may be substantial, affecting the regional water quality, though some mitigation is possible with practicable management systems. Changes in surface water quality impacts on the health various surface water users –drinking and recreational users. The assumption is that the proposed residential will not place

[3] The impacts which combine from different projects and which result in significance change, which is larger than the sum of all the impacts.

pressures on existing sanitation and water supply systems expected the anticipated increase in population in the area as this will be planned for and necessary capacities increased to accommodate the population growth.

- Ground water extraction at other mines may affect groundwater availability in the area. The change may be substantial, extend regionally, affect many people, and may be cumulative in nature causing an overall shortage of drinking water as majority of the healthcare facilities and settlements depend on borehole water.
- With regards to noise and vibration, some of the surrounding settlements s will be exposed to noise from the operations of various machines on the mines and trucks on the road. Extraction and transport operations of other mines will affect some of the receptors the proposed development would fall into this group. Though blasting will be carried out at other mines, the effects are not synergistic. With modern blasting technologies, the effects are likely to be small, localised, easy to mitigate, and non-cumulative.
- Changes in income level; education; health care; change in existing cultural pattern; alteration of location or distribution of human population in the area; change in housing.
- Potential health hazards; risk of accidents from explosion, release of oil, radioactive materials, toxic substances etc.

10. Conclusion and Recommendations

In conclusion, Seaton Thomson and Associates Cc needs to consider the existing health needs of the proposed development area/ footprint as these existing health concerns and needs are present regardless of the proposed residential development and represent the current health status of the area. The proposed residential development must consider the future health impacts that surrounding mines may exert on homeowners and residents.

The author recommends that a comprehensive community Health Impact Assessment (cHIA) must be undertaken for the proposed development. An attempt must be made to give a comprehensive outlook of the baseline health status of the proposed Project site (where possible) and also to understand and prioritise future Project health impacts, based on the available evidence from the surrounding mines. Mitigation and management measures must be recommended and it is advised that these measures are incorporated into the overall environmental and social management plan for the proposed Project as well as the neighbouring mines.

It is the author's opinion that air quality impacts from existing neighbouring mines have been found to be significant and that the developer needs to find a better suited site for residential development. Adequate mitigation measures from the mines' side may reduce the significance of some negative impacts although not always to acceptable levels, while positive health effects can be created through the implementation of associated enhancement measures. The developer would have no control over recommended mitigation measures which need to be implemented by surrounding mining operations, to manage the impacts.

It is recommended that the proposed residential development is either relocated to an alternative area greater than 5km away from the Tharisa Mine, and other mines, or that the proposed land use for the development footprint is re-assessed and other possible avenues such as industrial/ manufacturing use be assessed. Only then should the proposed development be allowed to proceed on the assumption that the environmental, social and health management commitments are adhered to.

11. References

Bhatia R, Lopipero P, Smith AH. 1998. Diesel exhaust exposure and lung cancer. Epidemiology 9(1): 84-91.

Bradshaw, D., Groenewald, P., Laubscher, R., Nannan, N., Nojilana, B., Norman, R., Pieterse, D., Schneider, M. 2003. "Initial estimates from the south African national burden of disease study, 2000." MRC Policy Brief, No.1. March. Obtained 29 July, 2004 from <http://www.mrc.ac.za/policybriefs/initialestimates.pdf>.

Bradshaw, D., Nannan, N., Laubscher, R., Groenewald, P., Joubert, J., Nojilana, B., Pieterse, D. & Schneider, M. 2004. South African National Burden of Disease Study 2000: Estimates of provincial mortality.

California Air Resources Board. Findings of the Scientific Review Panel on the Report on Diesel Exhaust (as adopted at the Panel's April 22, 1998 meeting) http://www.arb.ca.gov/toxics/dieseltac/de-fnds.htm

California Environmental Protection Agency. Part B: Health Risk Assessment for Diesel Exhaust. For the Proposed Identification of Diesel Exhaust as a Toxic Air Contaminant. California Environmental Protection Agency, Office of Environmental Health Hazard Assessment, Air Toxicology and Epidemiology Section, Oakland. May 1998

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

Cosselman K, Kaufman JA. 2012. Blood Pressure Response to Controlled Diesel Exhaust Exposure in Humans. Hypertension. March 19 2012.

Day, C., Monticelli, F., Barron, P., Haynes, R., Smith, J., Sello, E. & Editors. 2010. The District Health Barometer 2008/09.

DEAT. 2005 Government Gazette, National Environmental Management Air Quality Act, 2004. No. 28899.

Dockery, D. et al. 1993. An association between air pollution and mortality in six U.S. cities. New Engl J Med 329(24): 1753-1759.

Dockery, D.W., Pope, C.A., Xu, X., Spengler, J.D., Ware, J.H., Fay, M.E. Ferris, B.G., Speizer, F.E., (1993). An Association between Air Pollution and Mortality in Six U.S. Cities The New England Journal of Medicine, 329, 1753-1759.

Gauderman, W. et al. 2004. The effect of air pollution on lung development from 10 to 18 years of age. New Engl J Med 351(11): 1057-1067 Gaudermann, W.J. et al. 2005. Childhood asthma and exposure to traffic and nitrogen dioxide. Epidemiology 16(6): 1-.

Ghio, A. J et al. 2000. Concentrated ambient air particles induce mild pulmonary inflammation in healthy human volunteers. Am J Respir Crit Care Med 162: 981-2000.

Gray A, Vawda Y. Health policy and legislation. In Padarath A, King J, English R, editors. South African Health Review 2014/2015. Durban: Health Systems Trust; 2015.

Health Canada. (1998). National Ambient, Air Quality Objectives for Particulate Matter. Report by the CEPA/FPAC Working Group on Air Quality Objectives and Guidelines.

Health Canada. (1999). Priority Substances List. Assessment Report – Respirable Particulate Matter less than or equal to 10 Microns. Draft Report, 1999.

ICMM. Good practice guidance on health impact assessment. International Council on Minerals and Metals. London, U.K.; 2010 http://www.icmm.com/page/35457/good-practice-guidance-on-health-impact-assessment

IFC. Introduction to health impact assessment. International Finance Corporation; 2009 http://www.ifc.org/ifcext/sustainability.nsf/Content/Publications_GoodPractice_HealthAssessment

John, J., Matooane M., Oosthuizen, R., Binedell M. (2006). Vulnerability to air pollution exposure: who is more at risk? Report No: CSIR/NRE/PW/IR/2006/0040/A. Pretoria: CSIR.

Jorgensen H. Hygiene in mines. In: Rogan JM, ed. Medicine in the Mining Industries. London: William Heinemann Medical, 1972; 333–343.

Kappos, A.D., Bruckmann, P., Eikmann, T., Englert, N., Heinrich, U., Hōppe, P., Koch, E., Krause, G.H.M., Kreyling, W.G., Rauchfuss, K., Rombout, P.,Schuiz-Kemp, V., Thiel, W.R., Wichmann, H.E. 2004. Health effects of particles in ambient air. Int. J. Hyg. Environ. Health, 207:399-407.

Krishnan, R. M. et al. Vascular Responses to Long- and Short-Term Exposure to Fine Particulate Matter: The MESA Air (Multi-Ethnic Study of Atherosclerosis and Air Pollution). Journal of the American College of Cardiology, doi:10.1016/j.jacc.2012.08.973 (2012).

Lin, S. et al. 2002. Childhood asthma hospitalization and residential exposure to state route traffic. Environ Res Sect A 88:73-81.

Miller, K. A. et al. Long-term exposure to air pollution and incidence of cardiovascular events in women. NEJM 356, 447-458 (2007).

Mills, N.L. et al. 2007. Ischemic and thrombotic effects of dilute diesel-exhaust inhalation in men with coronary heart disease. NEJM (357(11): 1075-.

Minister of Health. Foodstuffs, Cosmetics and Disinfectants Act: Regulations: Health messages on container labels of alcoholic beverages: Amendment. Government Notice No. 1458, Government Gazette No. 41350, 22 December 2017. URL: https://www.gov.za/sites/default/files/41350_gon1458.pdf

Minister of Health. National Health Act: National Health Insurance Policy: Towards universal health coverage. Government Notice No. 627, Government Gazette No.40955, 30 June 2017. URL: https://www.gov.za/sites/default/files/40955_gon627.pdf

Peters, A., Dockery, D. W., Muller, J. E. & Mittleman, M. A. Increased particulate air pollution and the triggering of myocardial infarction. Circulation 103, 2810- 2815 (2001).

Pope, C. A and Dockery, D. W, 1992. Acute health effects of PM10 pollution on symptomatic and asymptomatic children. American review of respiratory disease, 145:1123–1128.

Pope, C. A. and Kanner, R. E, 1993. Acute effects of PM 10 pollution on pulmonary function of smokers with mild to moderate chronic obstructive pulmonary disease. American review of respiratory disease, 147:1336–1340.

Pope, C. A. et al. Cardiovascular mortality and long-term exposure to particulate air pollution: epidemiological evidence of general pathophysiological pathways of disease. Circulation 109, 71-77 (2004).

Pope, C. A. III et al. 1995. Particulate air pollution as a predictor of mortality in a prospective study of U.S. adults. Am J Respir Crit Care Med 151: 669-674.

Pope, C. A. III et al. 2002 Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. JAMA 287: 1132-1141.

Schwartz, J,1993. Particulate Air Pollution and Chronic Respiratory Disease, Environmental Research, 62(1): 7-13.

South Africa, 2013: National Environmental Management: Air Quality Act 39 of 2004: National Dust Control Regulations, Department of Environmental Affairs, report No. 827, Government Printer, Pretoria.

United States Environmental Protection Agency., 1995: Emission factors & AP 42, Compilation of Air Pollution Emission Factors, 5th Edition, Volume 1. Available from: http://www.epa.gov/ttnchie1/ap42

WHO. 2006. World Health Organization. Country Health System Fact Sheet 2006 South Africa. World Health Statistics 2006. Available: http://www.who.int/whosis/en/ [Accessed March 2015].

WHO. Health Impact Assessment. 2010 April 13, 2011]; Available from: http://www.who.int/hia/policy/en/.

WHO/ECHP. Gotheburg consensus paper. Health impact assessment: Main concepts and suggested approach. 1999 September 2009]; Available from: http://www.euro.who.int/document/PAE/Gothenburgpaper.pdf.

World Health Organization, WHO Air Quality Guidelines for Europe, 2nd edition, WHO Regional Office for Europe, 2000, Copenhagen, Denmark (WHO Regional Publications, European Series, No 91)