DIGBY WELLS ENVIRONMENTAL

Environmental Impact Assessment for Syferfontein underground operations

Air Quality Report

Project Number:

SAS1744

Prepared for:

SASOL MINING (PTY) LTD

October 2014

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Report Type:	**Air Quality Report**
Project Name:	**Environmental Impact Assessment for Syferfontein underground operations**
Project Code:	**SAS1744**

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EXECUTIVE SUMMARY

An underground coal mine, Syferfontein block 4 is being proposed by Sasol Pty Ltd in the Mpumalanga Province. The proposed coal mine is in close proximity to Kinross. Land use currently is agriculture.

Sasol Pty Ltd is required to obtain environmental authorisation for its development of an extension of Syferfontein colliery and has appointed Digby Wells and Associates (South Africa) (Pty) Ltd (Digby Wells) to undertake an air quality impact assessment of the underground coal mine.

To determine the current air quality conditions, modelled meteorological data for the period January 2009 to December 2011 was utilised. This data was obtained for a point close to the proposed Syferfontein block 4 coal mine site (26.403822 S, 29.131606 E).

From this modelled data, the predominant wind direction is from the north northwest, north and northwest. Less frequent winds (under 3% of the time) were coming from the southwest, west and west southwest. Calm conditions (wind speeds < 0.5 m/s) occurred for 8.8% of the time.

The average monthly maximum temperatures range from 21.3°C in January to 7.5°C in July, with monthly minima ranging from 19.9°C in December to 6.6°C in July. Annual mean temperature for Syferfontein is given as 14.5°C. The monthly maximum relative humidity remains above 60% for the whole year and ranges from 82% in winter (July) to 64% in spring (November).

The air quality monitoring data for 2011 and 2012 from Sasol Club was used as the background information for the Syferfontein Block 4. Sasol Club is located approximately 9 km south east of the proposed operations. The following parameters were discussed in the report: $PM_{2.5}$, PM_{10}, O_3, CO, SO_2 and NO_2. The main pollutant of concern envisaged for the proposed Syferfontein Block 4 is particulate matter (PM_{10} and $PM_{2.5}$). Data from the ambient monitoring stations show that $PM_{2.5}$, PM_{10} were below the recommended daily standard of 65 µg/m^3 and 120 µg/m^3 respectively. There were days when the O_3 levels exceeded the 8 hourly limits of 61 ppb. The concentrations of CO measured were generally below the 8 hourly limit of 8.7 ppm. The standard of 48 ppb was exceeded once in 2011. Several exceedances were experienced in 2011 for NO_2 while levels were below the standard in 2012.

The Syferfontein dust monitoring network operated by Digby Wells Environmental collected dust deposition data for the period April – September 2013. Deposition rates measured were below the residential limit of 600 mg/m^2/day except for the month of September - were SYFER2 (1 798 mg/m2/day), SYFER4 (1 095 mg/m2/day), SYFER5 (955 mg/m2/day) and SYFER6 (745 mg/m2/day). Deposition rates at SYFER 2 exceeded the non-residential limit of 1 200 mg/m2/day.

For the Syferfontein extension, the monitoring period covered the months of March 2014 – May 2014. Deposition rates measured were all within the residential limit of 600 $mg/m^2/day$, except in April with SYF EXT 2 (654 $mg/m^2/day$) and SYF EXT 4 (752 $mg/m^2/day$) exceeding the residential limit respectively. In May only SYF EXT 2 and SYF 5 did not exceed the residential limit. There was no violation of the permissible frequency of exceedance. According to the standard, *the margin of tolerance is two times within a year or if the limit is exceeded, it must not be two sequential months*.

The US-EPA in its AP-42 document and the Australian National Pollutant Inventory Emission Estimation Technique Manuals was utilised in quantifying potential emissions from the proposed underground operations. The following pollutants were assessed; PM_{10}, $PM_{2.5}$, SO_2, and NO_2. Emission factors generated served as input data into AERMOD dispersion modelling, which was used to determine the extent of pollution plume. The modelled scenario is inclusive of emissions from the vent shaft, with the mine operating for 20 hours per day and 284 days per annum.

Pollutant levels were assessed at the mine boundary - South West, South and West, with predicted concentrations of SO_2, NO_2, PM_{10} and $PM_{2.5}$ all within the recommended standards.

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LIST OF ABBREVIATIONS

AEL	Atmospheric Emission Licence
ASTM	American Society for Testing and Materials
AQG	Air Quality Guidelines
AWS	Automatic Weather Station
CO	Carbon monoxide
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
GN	Government Notice
mamsl	metres above mean sea level
MM5	Mesoscale model - Fifth generation
MPRDA	Minerals and Petroleum Resources Development Act
NEM:AQA	The National Environmental Management: Air Quality Act
NFAQM	National Framework for Air Quality Management
NO_2	Nitrogen dioxide
PM_{10}	Particulate Matter less than 10 microns in diameter
$PM_{2.5}$	Particulate Matter less than 2.5 microns in diameter
PSU/NCAR	Pennsylvania State University / National Center for Atmospheric Research
SANS	South African National Standards
SO_2	Sulphur dioxide
TSP	Total Suspended Particulates

1 Introduction

An underground coal mining operation is being proposed by Sasol Pty Ltd in the Mpumalanga Province. The proposed Syferfontein block 4 Coal Mine will be covering an area of approximately 5,200 hectares, and is in close proximity to Kinross. The current land use in the area is agricultural.

Sasol Pty Ltd is required to obtain environmental authorisation for its development of an extension of Syferfontein colliery in Mpumalanga Province and has appointed Digby Wells Environmental, South Africa (Pty) Ltd (Digby Wells) to undertake an Air Quality Impact Assessment (AQIA) of the Underground Coal Mine near Kinross. The AQIA study will establish the baseline air quality and climatic conditions of the proposed project area.

The project aims to determine ambient air quality and climate, followed by the development of an air emission inventory that will take into account all the relevant sources of air pollution and associated air emissions. Potential emissions from the mine will be modelled to determine the implications of the proposed mining on ambient pollutant loading. . Literature review of the health implications associated with the identified pollutants will be conducted. Lastly, recommendations, mitigation and management measures will be provided in order to ameliorate the identified potential impacts

2 Methodology

2.1 Terms of Reference for air quality study

This AQIA report aims to investigate the baseline climate and air quality conditions coupled with an assessment of the potential atmospheric impacts that the proposed mining development will have on the surrounding environment.

2.1.1 Terms of reference for air quality impact assessment:

- Baseline assessment;
  - Baseline air quality
  - Baseline climate
- Emissions inventory;
- Dispersion modelling;
- Impact assessment;
- Set up a dust fallout monitoring network and compilation of quarterly reports; and
- Air quality monitoring programme.

3 BRIEF PROJECT DESCRIPTION

3.1 Location of Site

The proposed Syferfontein coal mine will be located in the Govan Mbeki Local Municipality (see Plan 1), which is located in the Gert Sibande District Municipality, in Mpumalanga Province.

The surrounding settlements are:

- Kinross - approximately 6 km south west;
- Evander - approximately 9 km south
- Secunda approximately - 14 km south east.

3.2 Project Description

Project proposes to extend the Syferfontein colliery to the adjacent Block 4 situated in the North West of the Syferfontein reserves. Underground coal mining method will be employed in in order to access the reserve. The coal ore will be supplied to the Sasol Synfuels plant in Secunda.

4 Status of current environment

4.1 Physical Features and Characteristics

4.1.1 Topography

The topographical model indicates that the elevation of the project area ranges from approximately 1680 to 1580 metres above mean sea level (mamsl) from the south to a northerly direction. The northern section and some parts of the eastern boundary of the project site are situated at an elevation of approximately 1580 mamsl, while the southern boundary is situated at an elevation of 1680 mamsl. Therefore, the elevation increases when moving from the north towards the southern parts of the project area. The project area is situated on a slightly high-lying area surrounded by mildly undulating topography. The predominant land use type in the area is agricultural, with crop farming and animal husbandry spread across the area.

4.2 Climate and Meteorological Overview

4.2.1 Air Quality

Ambient air quality in this region of South Africa is strongly influenced by regional atmospheric movements, together with local climatic and meteorological conditions. The most important of these atmospheric movement routes are the direct transport towards the Indian Ocean and the recirculation over the sub-continents.

Mpumalanga Province experiences a wide range of both natural and anthropogenic sources of air pollution ranging from power generation to veld fires, mining activities, industrial processes, agriculture, paper and pulp processing, vehicle use and domestic use of fossil fuels. Different pollutants are associated with each of the above activities, ranging from volatile organic compounds to heavy metals to particulate matter, dust and odours. Mpumalanga experiences distinct weather patterns in summer and winter that affect the dispersal of pollutants in the atmosphere. In summer, unstable atmospheric conditions result in mixing of the atmosphere and rapid dispersion of pollutants. In contrast, winter is characterised by atmospheric stability caused by a persistent high pressure system over South Africa. This dominant high pressure system results in subsidence, causing clear skies and a pronounced temperature inversion over the Highveld central plateau area. This inversion layer traps the pollutants in the lower atmosphere, which results in reduced dispersion and a poorer ambient air quality. Preston-Whyte and Tyson (1988) describe the atmospheric conditions in the winter months as highly unfavourable for the dispersion of atmospheric pollutants.

Precipitation reduces erosion potential by increasing the moisture content of materials. This represents an effective mechanism for removal of atmospheric pollutants and is therefore considered during air pollution studies. Rain-days are defined as days experiencing 0.1 mm or more rainfall.

Site specific MM5 modelled meteorological data set for full three calendar years (2009 – 2011) was obtained from the Lakes Environmental in Canada to determine local prevailing weather conditions. This dataset consists of surface data, as well as upper air meteorological data that is required to run the dispersion model. It is necessary if site specific upper air meteorological data is not available. The Pennsylvania State University / National Center for Atmospheric Research (PSU/NCAR) meso-scale model (known as MM5) is a limited-area, non-hydrostatic, terrain-following sigma-coordinate model designed to simulate or predict meso-scale atmospheric circulation.

This data has been tested extensively and has been found to be extremely accurate. Modelled meteorological data for the period January 2009 to December 2011 was obtained for a point close to the proposed Syferfontein block 4 Coal Mine site (26.403822 S, 29.131606 E). Data availability was 100%.

Generally, a data set of greater than 90% (Taken to be the same as that stipulated for pollutant data availability (SANS, 2005) is required in order for that month/year to be considered representative of the assessed area (SANS, 2005).

Dispersion of atmospheric pollutants is a function of the prevailing wind characteristics at any site. The vertical dispersion of pollution is largely a function of the wind field. The wind speed determines both the distance of downward transport and the rate of dilution of pollutants. The generation of mechanical turbulence is similarly a function of the wind speed, in combination with the surface roughness.

The amount of particulate matter generated by wind is highly dependent upon the wind speed. Below the wind speed threshold for a specific particle type, no particulate matter is liberated, while above the threshold, particulate matter liberation tends to increase with the wind speed. The amount of particulate matter generated by wind is also dependent on the material's surface properties. This includes whether the material is crusted, the amount of non-erodible particles and the particle size distribution of the material.

Wind roses comprise 16 spokes which represent the directions from which winds blew during the period. The colours reflect the different categories of wind speeds. The dotted circles provide information regarding the frequency of occurrence of wind speed and direction categories. The figure given at the bottom of the legend described the frequency with which calms occurred, i.e. periods during which the wind speed was below 0.5 m/s.

The spatial and annual variability in the wind field for the Syferfontein modelled data is clearly evident in Figure 4-1. The predominant wind direction is from the north-north west, north and north-west, with frequent winds also occurring from the east, east north east and north-north east. Over the three year period, frequency of occurrence was 10.8% from the north-north westerly sector, 10.2% from the north and 9.9% from the northwest sector. Less frequent winds (under 3% of the time) were coming from the south west, west and west south west. Calm conditions (wind speeds < 0.5 m/s) occurred for 8.76% of the time. Wind class frequency distribution per sector is given in

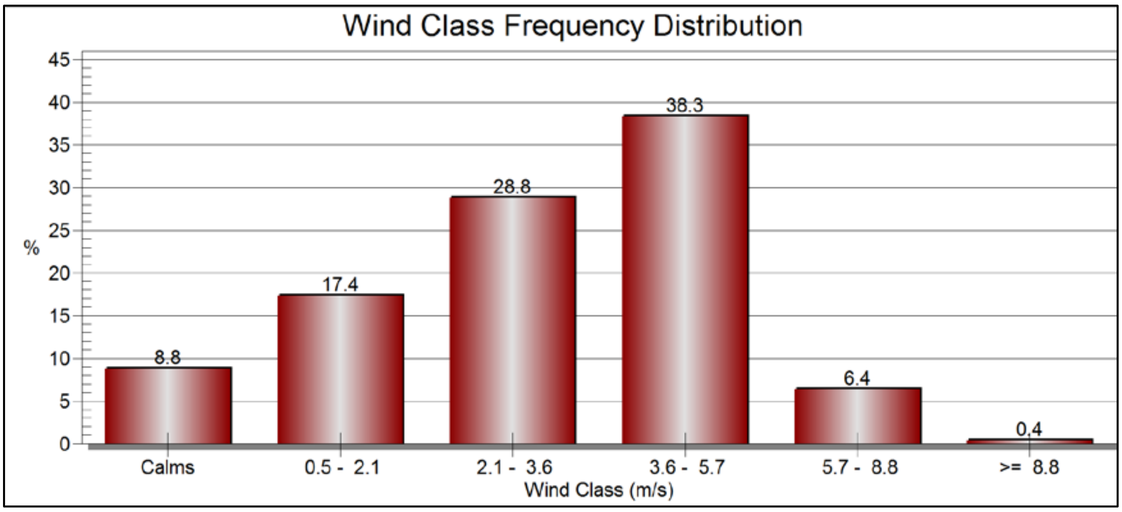

Figure 4-4 and Table 4-1.

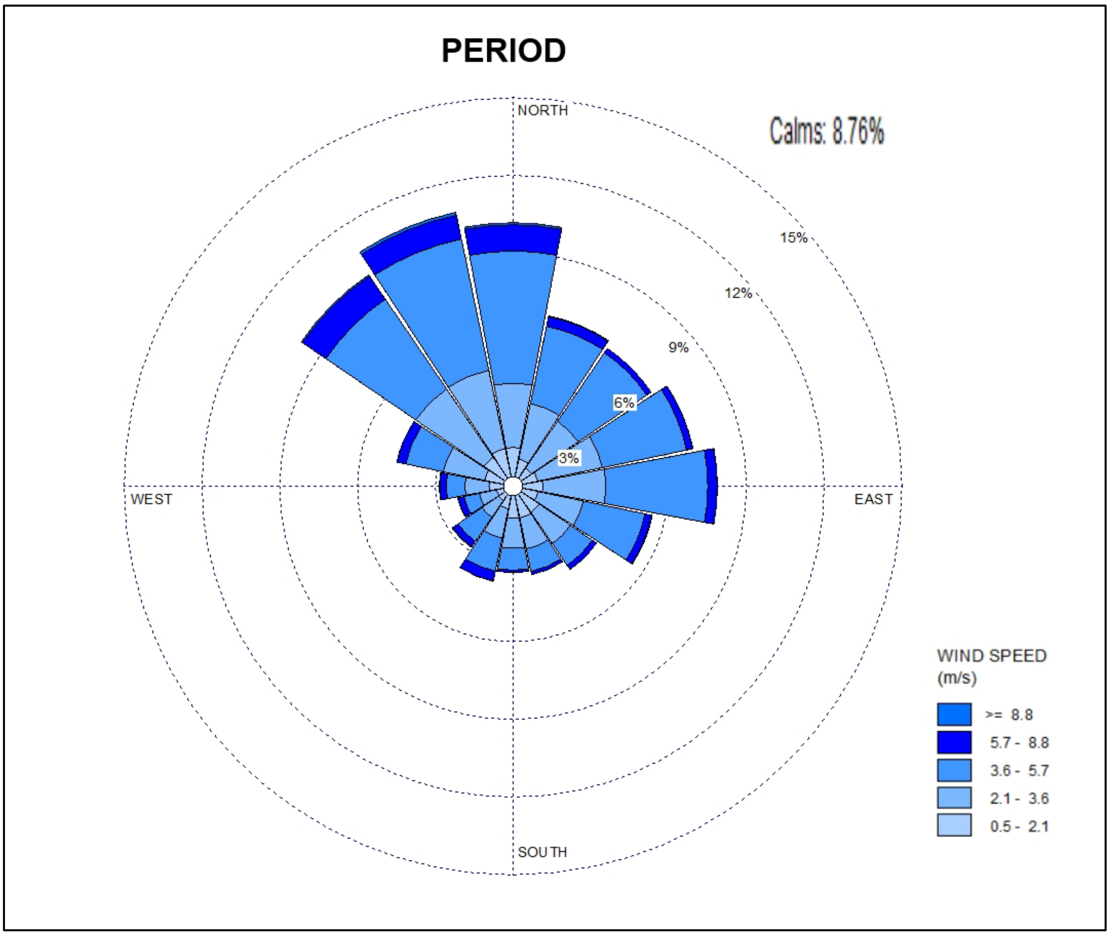

Figure 4-1: Period surface wind rose for Syferfontein modelled data, 01 January 2009 – 31 December 2011

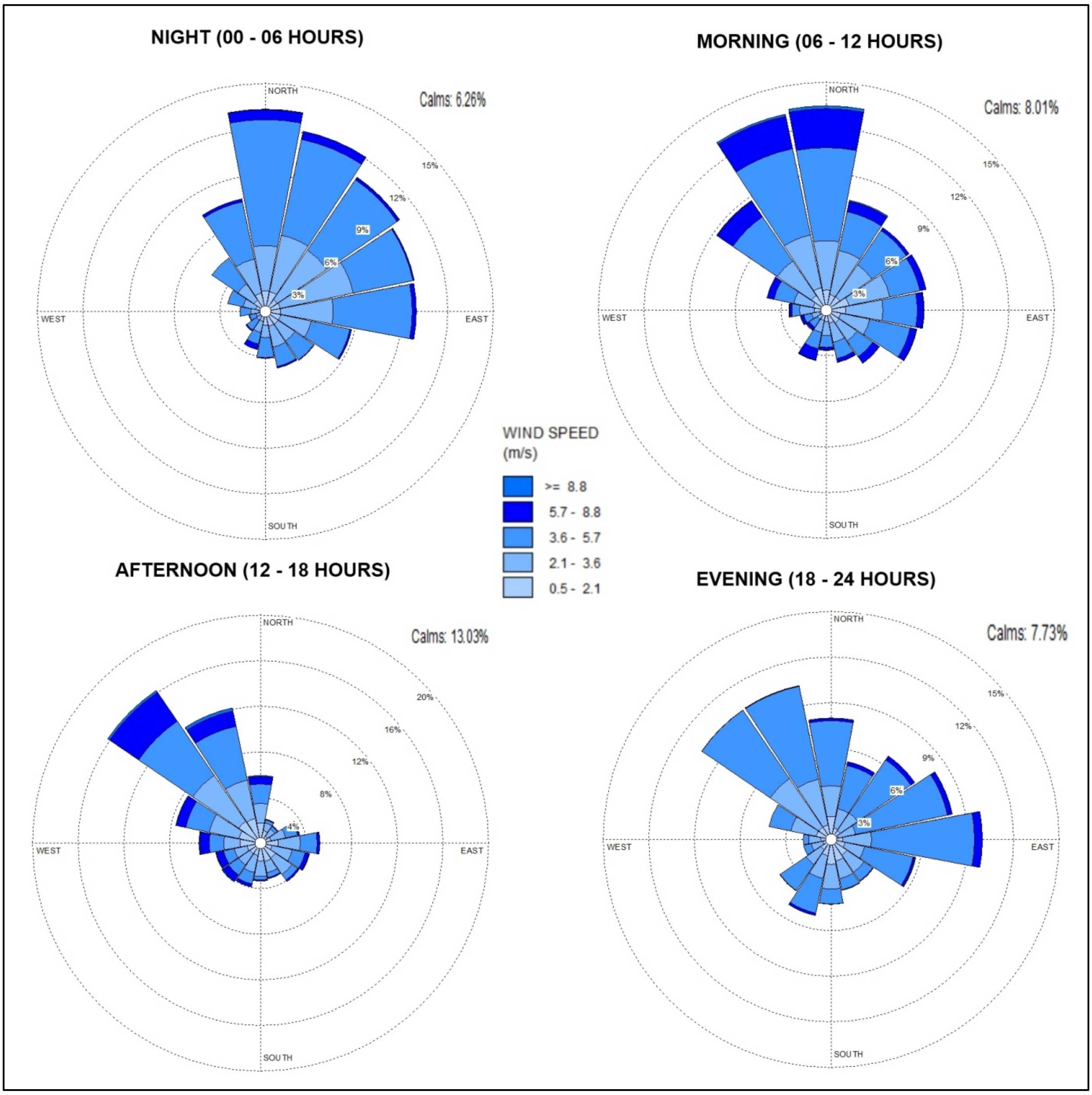

Figure 4-2: Diurnal variation of winds between Night time 00:00 – 06:00 (top left), Morning 06:00 – 12:00 (top right), Afternoon 12:00 – 18:00 (bottom left) and Evening 18:00 – 24:00 (bottom right) (modelled data 01 January 2009 – 31 December 2011)

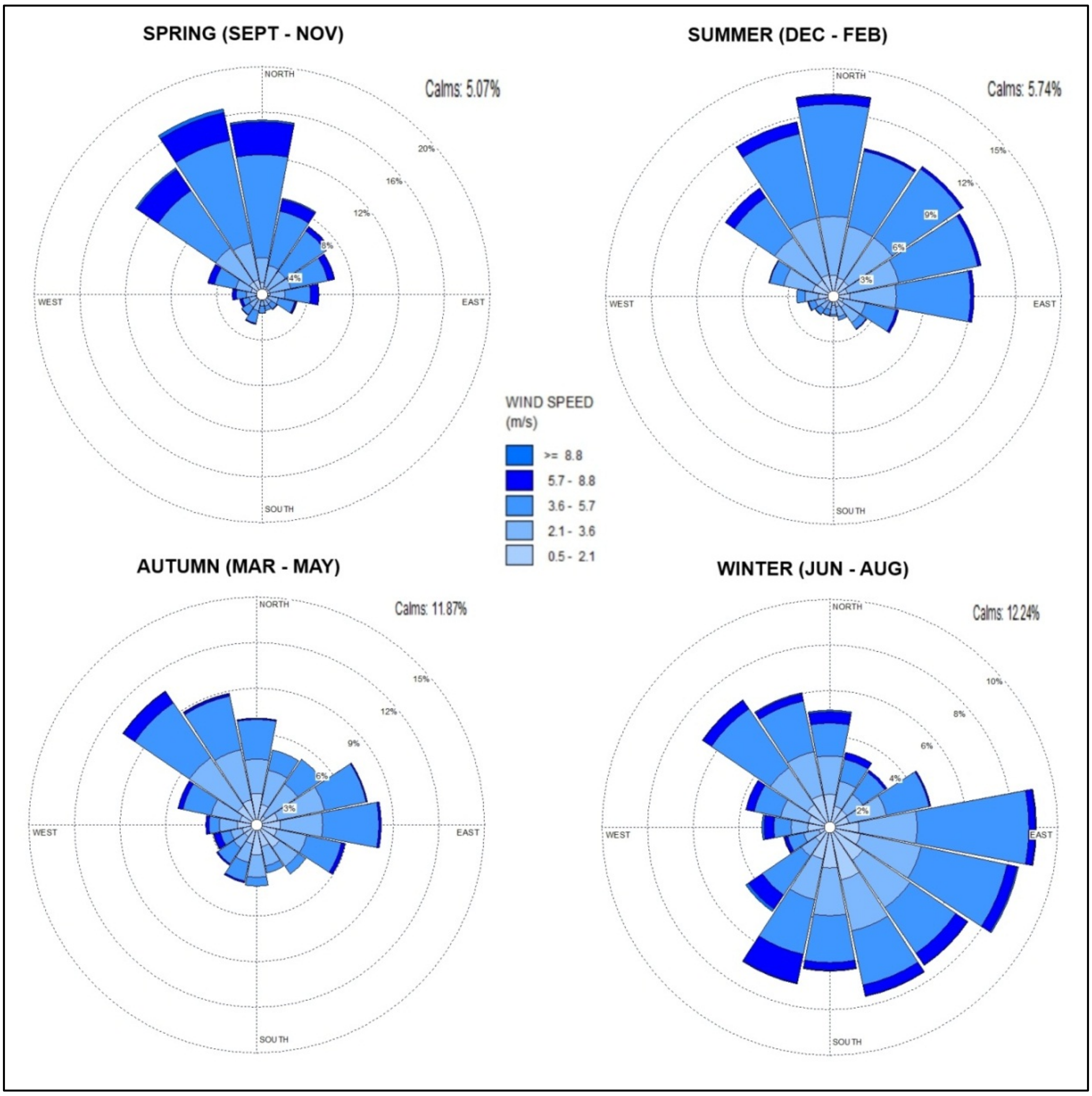

Figure 4-3: Seasonal variation of winds in spring (September – November) (top left), summer (December - February) (top right), autumn (March – May) (bottom left) and winter (June – August) (bottom right) (modelled data 01 January 2009 – 31 December 2011)

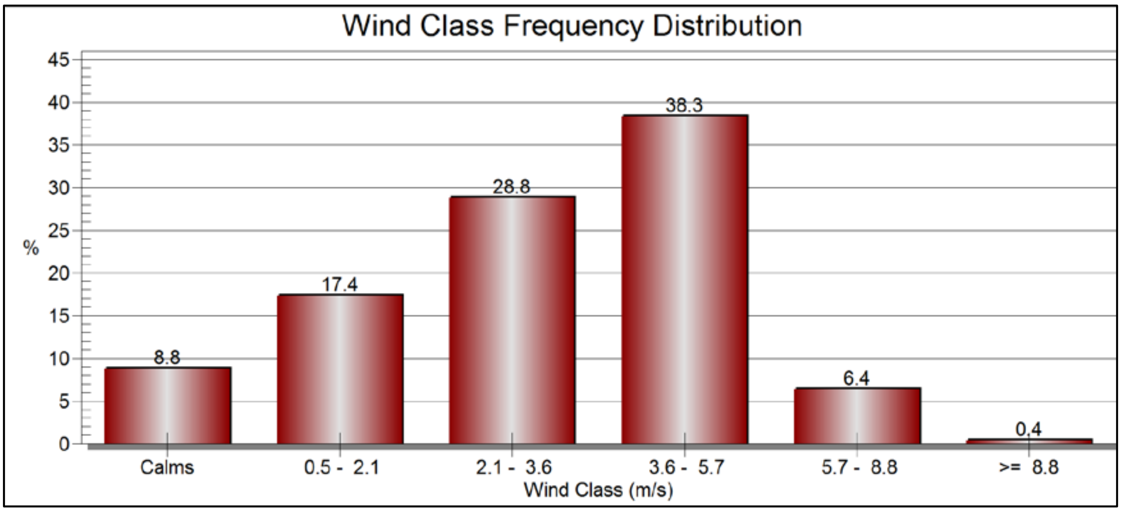

Figure 4-4: Wind Class Frequency Distribution for Syferfontein modelled data, 01 January 2009 – 31 December 2011

Table 4-1: Wind Class Frequency Distribution per Direction for Syferfontein modelled data, 01 January 2009 – 31 December 2011

	Directions	**Wind classes (m/s)**					
		0.5 - 2.1	**2.1 - 3.6**	**3.6 - 5.7**	**5.7 - 8.8**	**>= 8.8**	**Total (%)**
1	N	1.50	2.48	5.08	1.02	0.08	10.15
2	NNE	1.08	2.18	3.04	0.38	0.03	6.71
3	NE	0.86	2.17	3.20	0.20	0.00	6.43
4	ENE	0.98	2.53	3.31	0.25	0.00	7.07
5	E	1.15	2.43	3.92	0.36	0.01	7.86
6	ESE	1.00	1.77	2.43	0.26	0.03	5.48
7	SE	1.22	1.45	1.02	0.19	0.00	3.89
8	SSE	1.24	1.22	0.89	0.13	0.00	3.48
9	S	1.22	1.17	0.84	0.09	0.01	3.33
10	SSW	0.89	1.15	1.30	0.39	0.01	3.74
11	SW	0.67	0.78	1.13	0.24	0.03	2.85
12	WSW	0.65	0.68	0.61	0.23	0.02	2.18
13	W	0.93	0.92	0.72	0.25	0.02	2.85
14	WNW	1.12	1.62	1.48	0.34	0.00	4.57
15	NW	1.35	3.19	4.18	1.09	0.06	9.87
16	NNW	1.49	3.08	5.16	0.95	0.10	10.78
	Sub-Total	17.35	28.81	38.30	6.38	0.40	91.24
	Calms						8.76
	Missing/Incomplete						0.00
	Total						100.00

4.2.2 Temperature

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

South African Weather Service does not have an Automatic Weather Station (AWS) within the reasonable distance from the proposed Syferfontein coal mine site that would give representative and accurate climate data, so the use was made of modelled data and trends were observed analysing the three years available (2009-2011).

Three-year average monthly maximum, mean and minimum temperatures for Syferfontein are given in Table 4-2. The average monthly maximum temperatures range from 21.3°C in January to 7.5°C in July, with monthly minima ranging from 19.9°C in December to 6.6°C in July. Annual mean temperature for Syferfontein is given as 14.5°C.

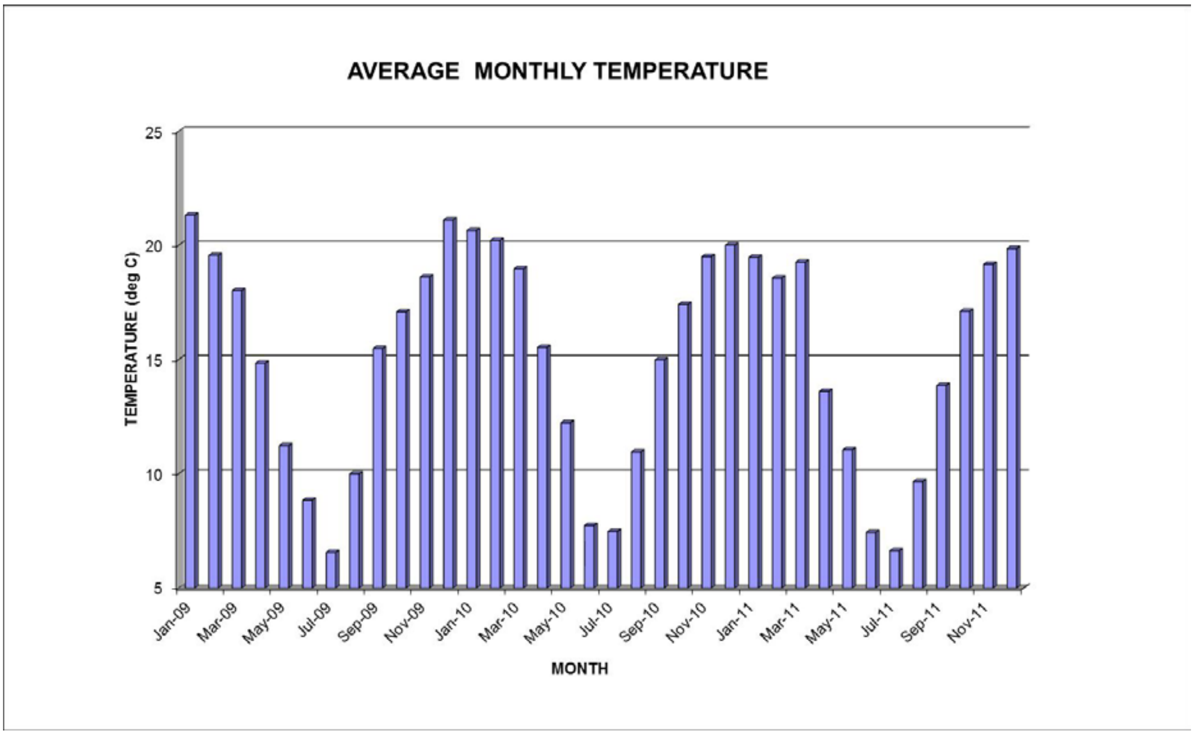

Figure 4-5: Average monthly temperature derived from the Syferfontein modelled data (2009 - 2011)

Table 4-2: Average monthly minimum, maximum and mean temperature values derived from the Syferfontein modelled data (2009 - 2011)

Temperature (deg °C)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Monthly Max.	21.3	20.2	19.3	15.5	12.2	8.8	7.5	11.0	15.5	17.4	19.5	21.1	15.8
Monthly Min.	19.5	18.6	18.0	13.6	11.1	7.4	6.6	9.7	13.9	17.1	18.6	19.9	14.5

Temperature (deg °C)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Monthly Mean	20.5	19.5	11.5	14.7	11.5	8.0	6.9	10.2	14.8	17.2	19.1	20.3	14.5

4.2.3 Relative Humidity

The data in Table 4-3 is representative of the relative humidity for the Syferfontein area. The annual maximum, minimum and mean relative humidity is given as 73%, 68% and 71% respectively. The monthly maximum relative humidity remains above 60% for the whole year and ranges from 82% in winter (July) to 64% in spring (November). The monthly minimum relative humidity on the other hand is less than 75% throughout the year, with the highest minimum (73%) occurring in June and the lowest (62%) occurring in November and December.

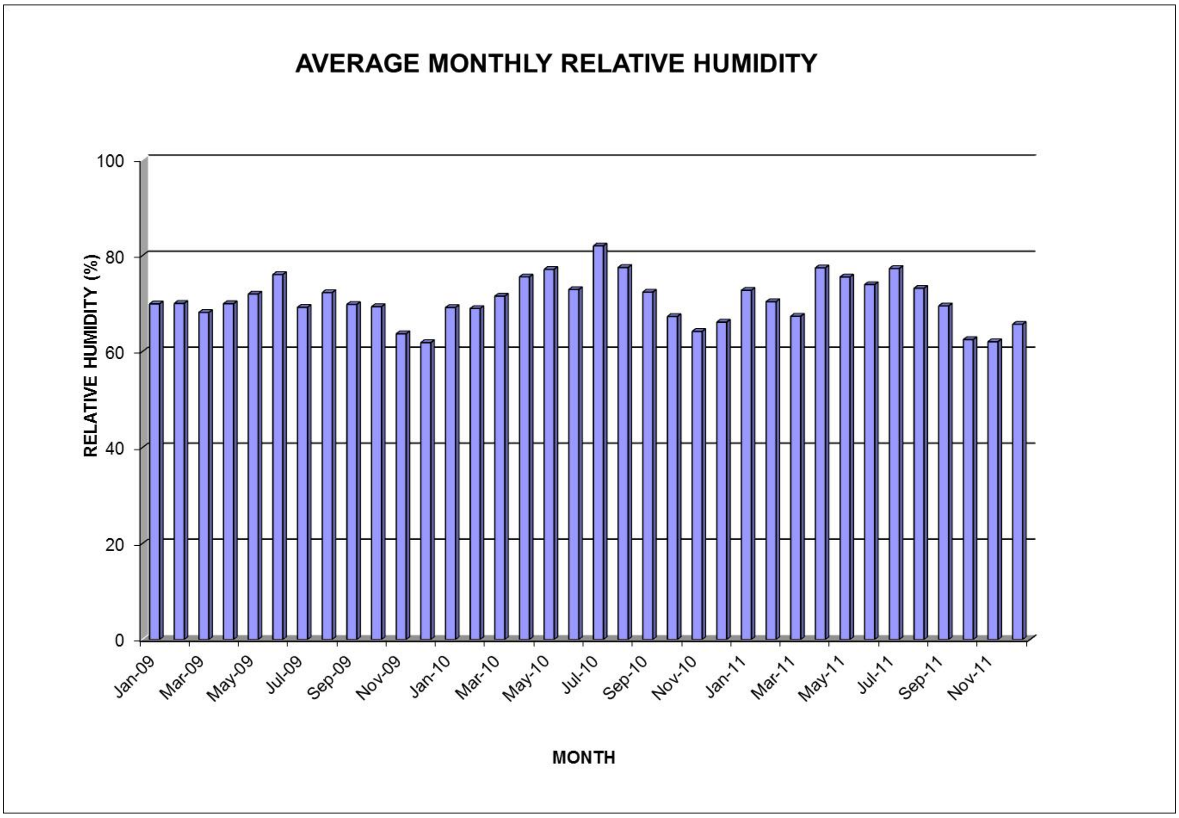

Figure 4-6: Average Monthly Relative Humidity derived from the Syferfontein modelled data (2009-2011)

Table 4-3: Average Monthly Relative Humidity derived from the Syferfontein modelled data (2009-2011)

Relative Humidity (%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Monthly Max.	73	70	72	77	77	76	82	78	72	69	64	66	73

Monthly Min.	69	69	67	70	72	73	69	72	70	63	62	62	68
Monthly Mean	71	70	75	74	75	74	76	74	71	66	63	65	71

4.2.4 Precipitation

As shown in Table 4-4 below, the three year (2009-2011) annual total rainfall maximum and average for the Syferfontein site are 988 mm and 683 mm respectively. The highest total monthly precipitation (210 mm) was observed in January. The rate decreases down to 9 mm in June. The maximum total rainfall and averages observed for each month over the three year period under survey are depicted in Figure 4-7 below.

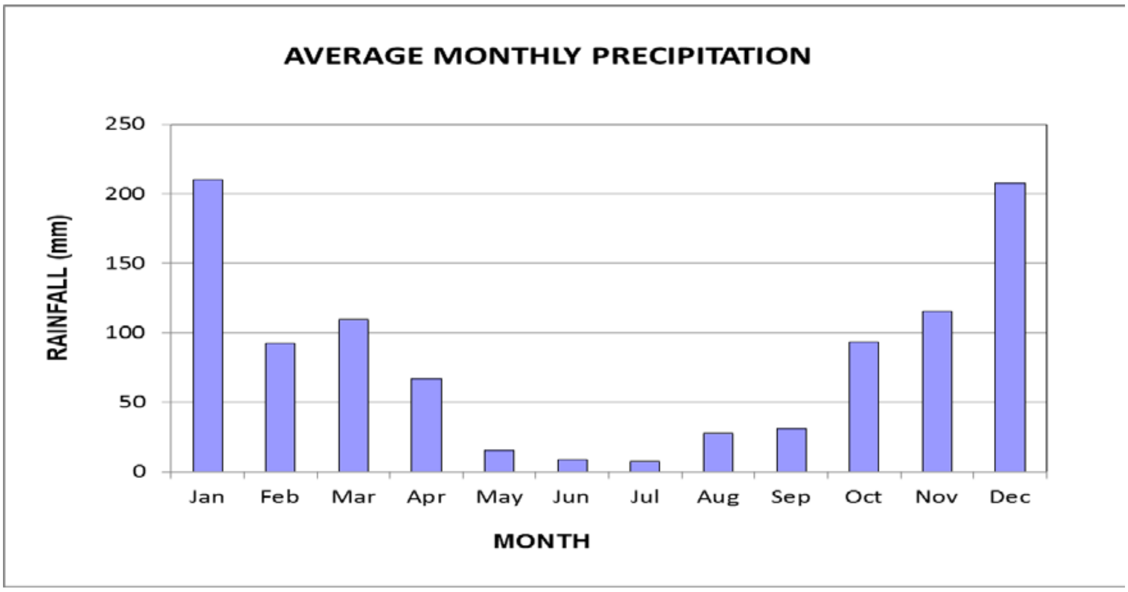

Figure 4-7: Average Monthly Precipitation derived from the Syferfontein modelled data (2009-2011)

Table 4-4: Average Monthly Precipitation derived from the Syferfontein modelled data (2009-2011)

Precipitation (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
Total Monthly Rainfall (Max).	210	92	110	67	16	9	8	28	31	93	116	208	988
Average Total Monthly Rainfall	158	77	13	42	13	3	3	10	23	64	110	167	683

4.2.5 Ambient air quality assessment

The air quality assessment from Sasol Club was used to assess scenario for the Syferfontein Block 4. Sasol club is located approximately 9 km south east of the proposed operations. The main pollutant anticipated from the operation of the proposed Syferfontein

Block 4 Coal Mine is particulate matter. However, concentration of gaseous pollutants measured at Sasol Club ambient monitoring stations are discussed in this report.

Figure 4-8 shows the 24 hour average for $PM_{2.5}$, this is one of the significant parameters that will be affected by the proposed Syferfontein Block 4 operations. $PM_{2.5}$ for Sasol club is below the standard of 65 µg/m^3.The highest levels of $PM_{2.5}$ were attained in February and the rest of the monitoting period were within the range of 30 µg/m^3.

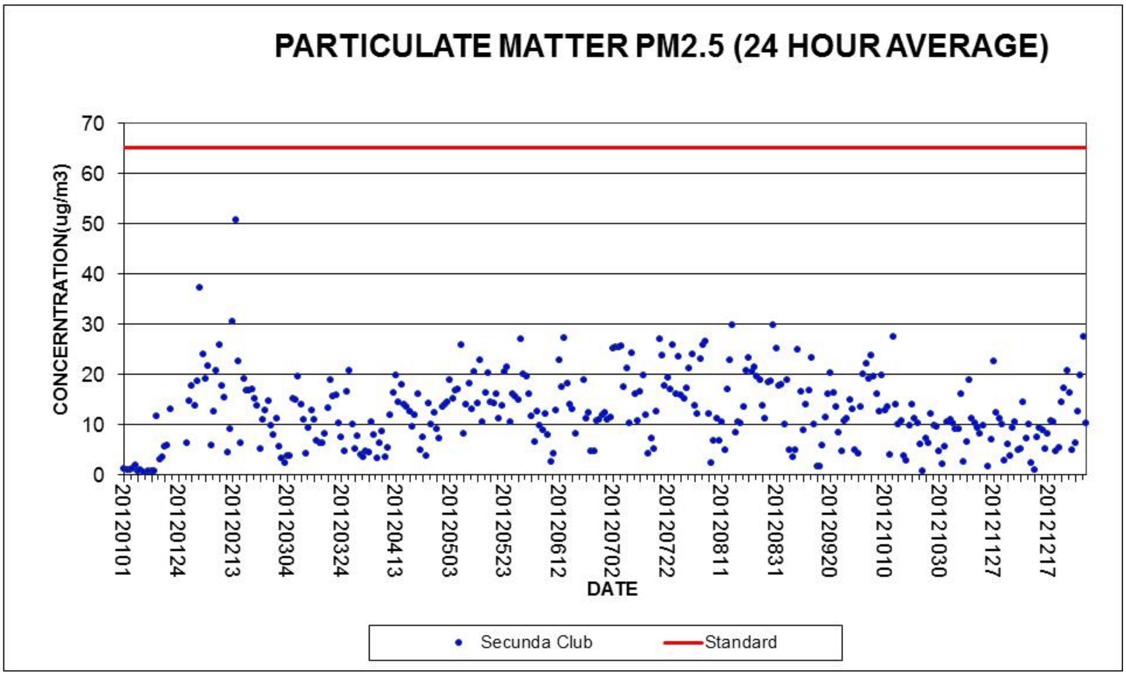

Figure 4-8: 24 hour $PM_{2.5}$ 2012 (Sasol, 2013)

Figure 4-9 and Figure 4-10 shows the PM_{10} levels for 2011 and 2012. The PM_{10} measured was below the daily limit of 120 µg/m^3. Higher levels of PM_{10} were observed from August to October which are the windy months.

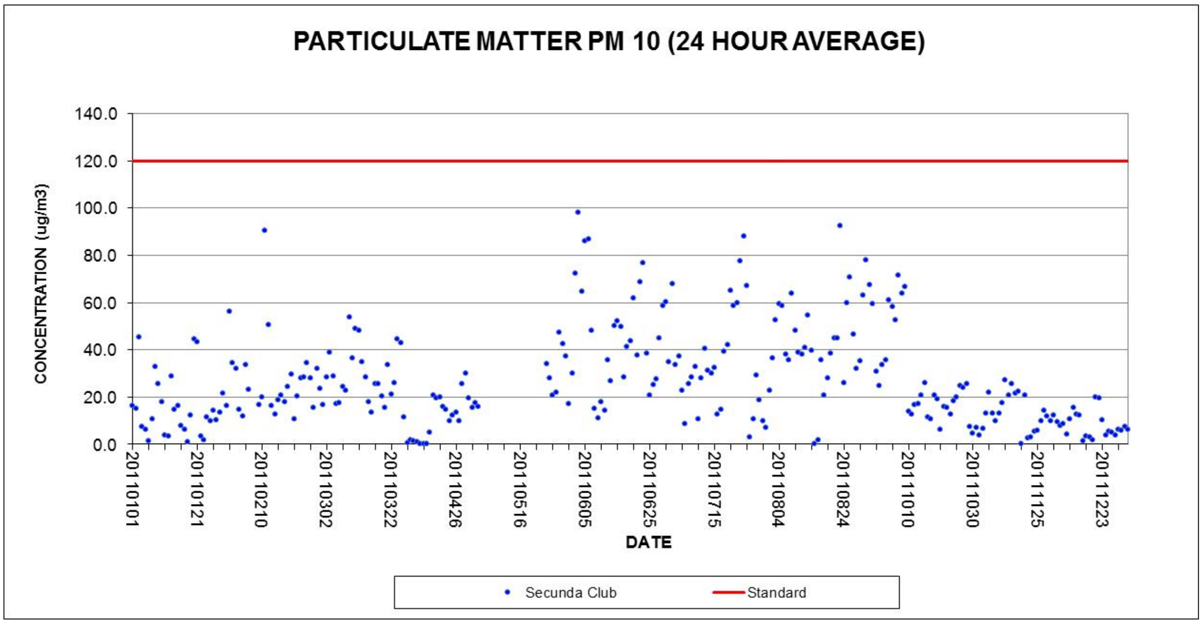

Figure 4-9: 24 hour PM_{10} 2011 (Sasol, 2013)

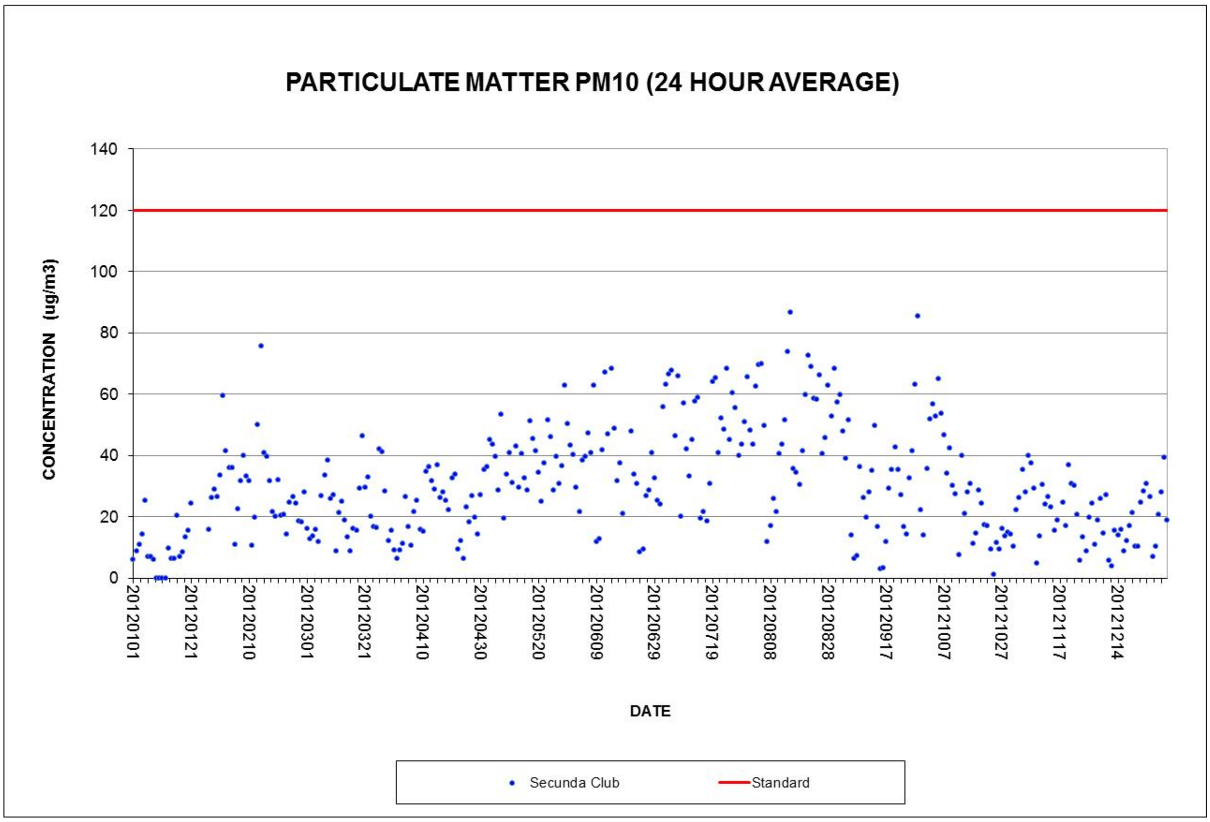

Figure 4-10: 24 hour PM_{10} 2012 (Sasol, 2013)

The 8 hourly averages for ozone are given in Figure 4-11 .The standard of 61 ppb is exceeded in the first two weeks of February 2012. Other exceedances were observed in April, then August to December.

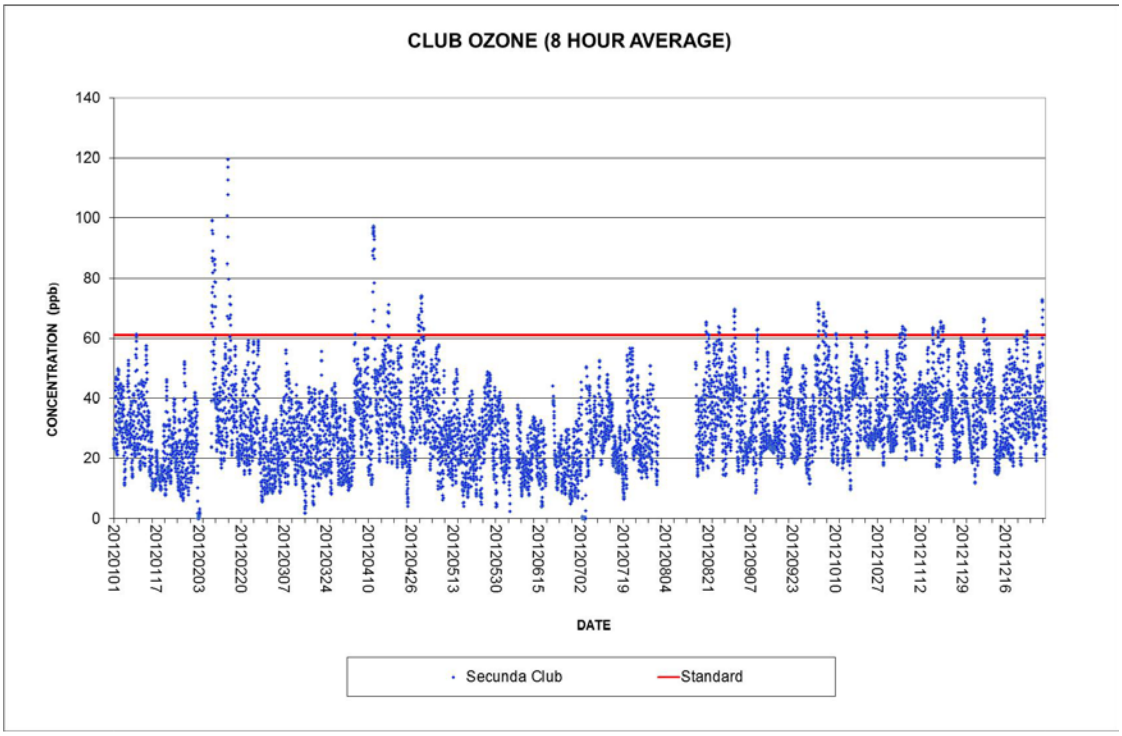

Figure 4-11: Ozone 8 hourly average 2012 (Sasol, 2013)

The levels of carbon monoxide measured at the ambient monitoring station for 2011 are below the 8-hourly standard of 8.7 ppm. The highest level was attained in May and no data was recorded during the last week of May until the end of August.

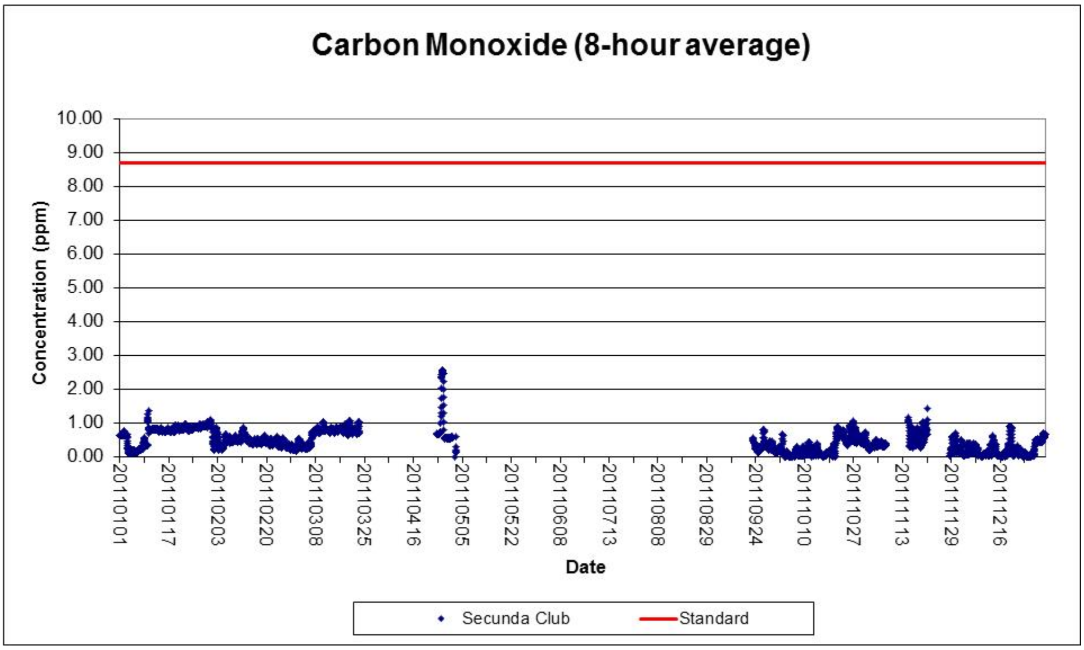

Figure 4-12: Carbon monoxide 8 hourly average 2011 (Sasol, 2013)

The levels of carbon monoxide for 2012 are below the standard of 8.7 ppm. The highest level was attained in the windy months of August Figure 4-13 and the lowest 8 hourly average was recorded in December.

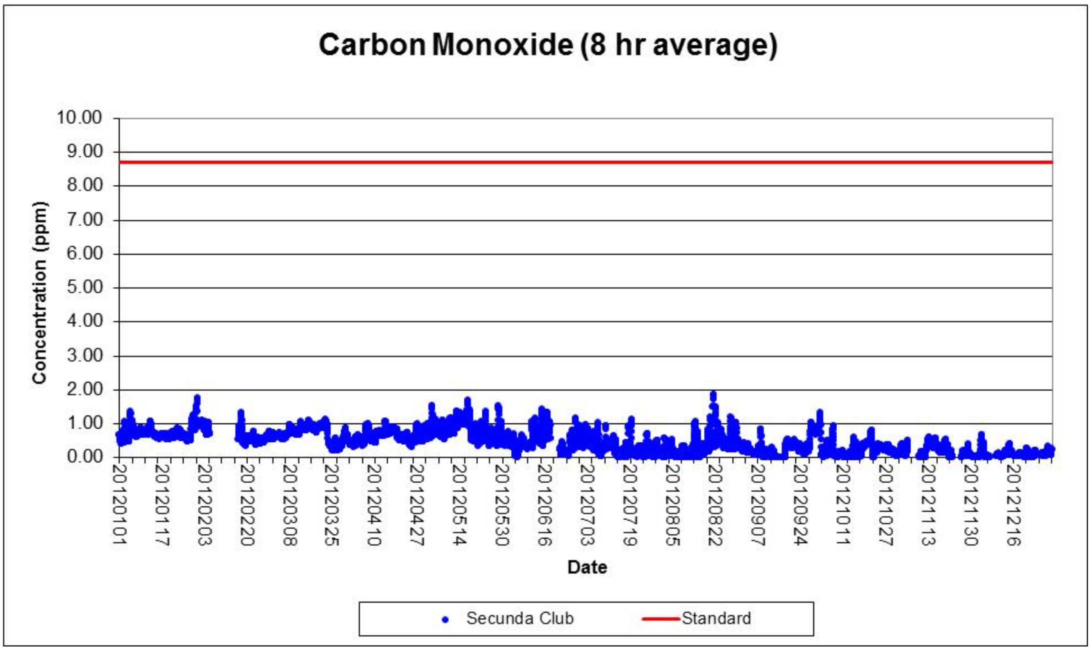

Figure 4-13: Carbon monoxide 8 hourly average 2012 (Sasol, 2013)

Figure 4-14 and Figure 4-15 show the levels of SO_2 for Sasol Club for 2011 and 2012 respectively. During the monitoring period, the levels of SO_2 measured were below the standard of 48 ppb except for February 2011. The month of August experienced higher levels of SO_2.

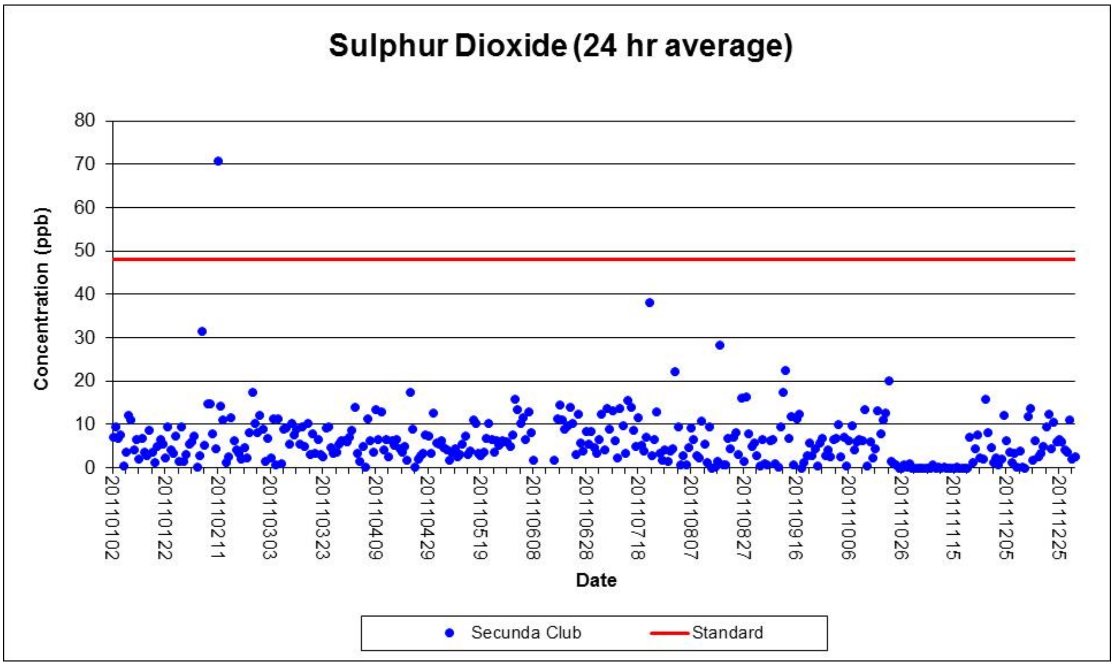

Figure 4-14 Sulphur dioxide 24 hour average 2011 (Sasol, 2013)

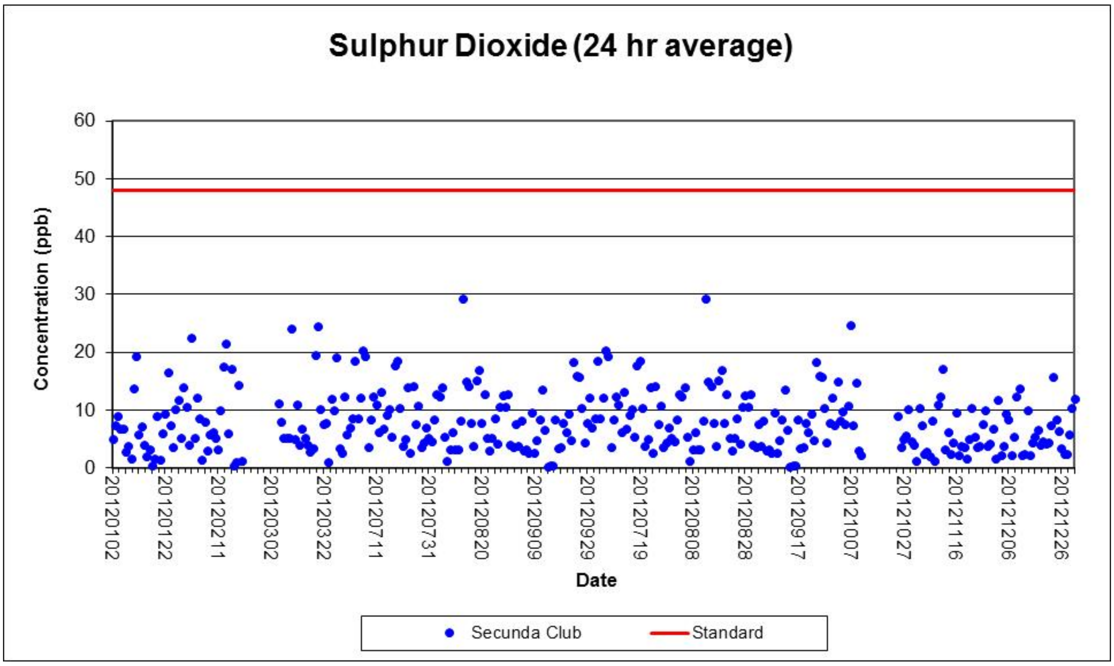

Figure 4-15: Sulphur dioxide 24 hour averages 2012 (Sasol, 2013)

Figure 4-16 and Figure 4-17 the levels of NO_2 for Sasol Club for 2011 and 2012. 2011 experienced more exceedances. The 1-hourly concentration of NO_2 for 2012 were within the standard the recommended standard of 106 ppb, with the highest level of NO_2 experienced in February.

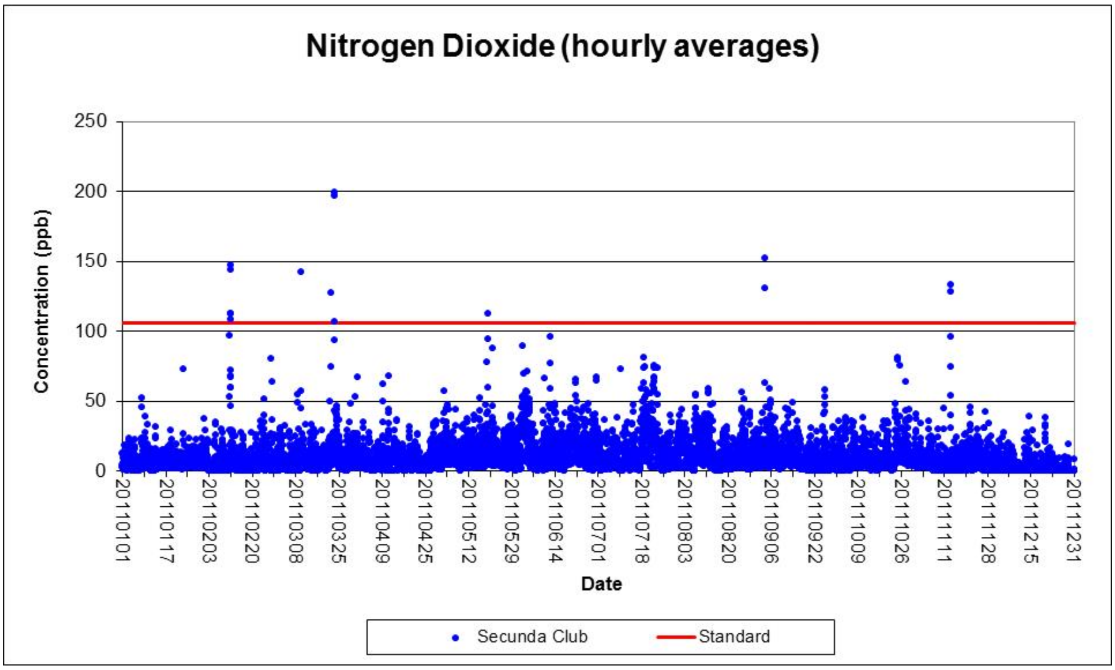

Figure 4-16: Nitrogen dioxide 24 hourly averages 2011 (Sasol, 2013)

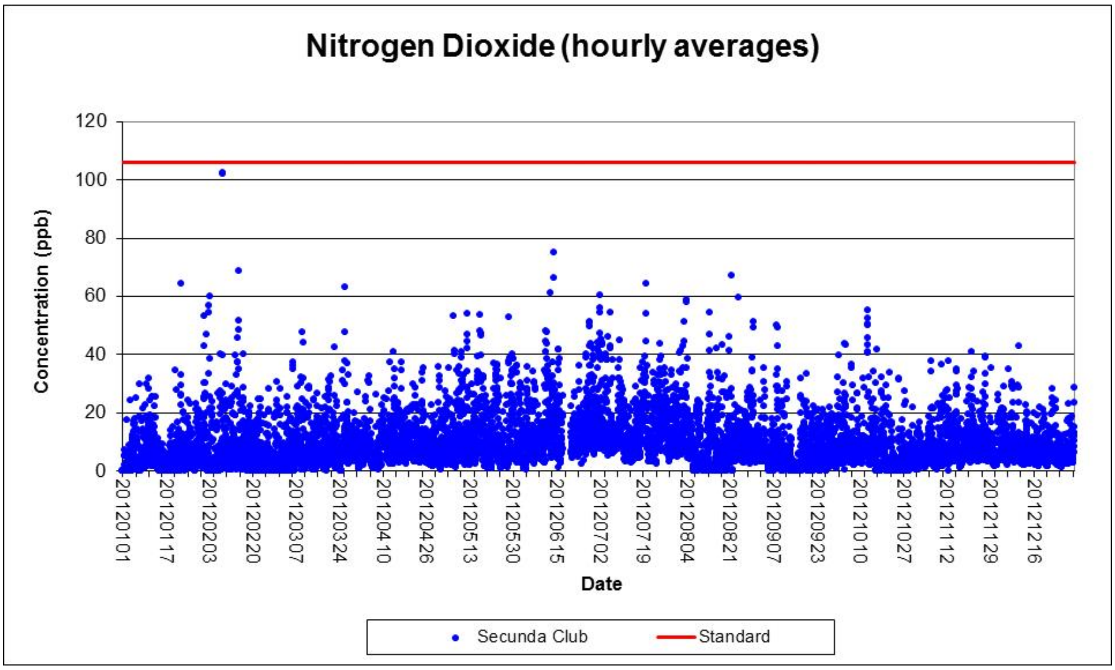

Figure 4-17: Nitrogen dioxide 24 hourly averages 2012 (Sasol, 2013)

4.2.6 Boundary Layer Properties and Atmospheric Stability

The region of the atmosphere governing transport and dispersion of the majority of the pollutants is the planetary boundary layer. This layer is defined as the layer where the wind structure is influenced by the surface of the earth.

The height of the planetary boundary layer varies with the atmospheric stability and this is important for the concentrations of pollutants in the air because the majority of the pollutant mass typically is confined within this layer. During night-time when conditions in most cases are stable, the planetary boundary layer is shallow, down to 20-50 metres and the surface concentration of pollutants can therefore be quite high, especially close to emission sources that are active during the night. Under unstable conditions the planetary boundary layer can be as high as 2 kilometres and pollutants are in this case distributed in the air column mainly by convective turbulence. In the vicinity of the top of the boundary layer, the horizontal winds are typically stronger and the pollutants that end up at these higher levels may be transported far away from the emission sources. In neutral conditions emitted pollutants are quickly mixed in the air by mechanical turbulence and the surface concentration is not particularly high. During neutral conditions the strong horizontal wind speeds can transport pollutants across large distances.

The atmospheric conditions may be divided into three broad classes in terms of stability: neutral, stable and unstable conditions. These major three categories are characterised by the following:

- *Neutral* conditions where the temperature is homogeneous throughout the boundary layer. This situation typically occurs in the transition from day to night and is characterised by strong winds and clouds and large amounts of mechanical turbulence.

- *Stable* conditions where the temperature is lowest close to the surface and increases towards the top of the boundary layer. This situation typically occurs during night-time or in winter situations and is characterised by little turbulence and a strong stratification of the planetary boundary layer which is quite shallow. This class can be further divided into stable and very stable classes.
- *Unstable* conditions where the temperature of the air closest to the surface is higher than the temperature of the air above it. This situation typically occurs during daytime at summer when the sun is shining and it is characterised by large amounts of convective turbulence usually resulting in the formation of cumulus clouds during the day. This class can be further divided into very unstable, moderately unstable and unstable classes.

The refined classes of atmospheric stability classes are further defined in the Table 4-5 and Table 4-6.

Table 4-5: Atmospheric Stability Classes

Designation	Stability Class	Atmospheric Condition
A	Very unstable	Calm wind, clear skies, hot daytime conditions
B	Moderately unstable	Clear skies, daytime conditions
C	Unstable	Moderate wind, slightly overcast daytime conditions
D	Neutral	High winds or cloudy days and nights
E	Stable	Moderate wind, slightly overcast night-time conditions
F	Very stable	Low winds, clear skies, cold night-time conditions

Table 4-6: Meteorological conditions that define the Pasquill stability classes

Surface wind speed	Daytime incoming solar radiation			Night time cloud cover	
m/s	Strong	Moderate	Slight	> 50%	< 50%
< 2	A	A – B	B	E	F
2 – 3	A – B	B	C	E	F
3 – 5	B	B – C	C	D	E
5 – 6	C	C – D	D	D	D
> 6	C	D	D	D	D

*Note: Class D applies to heavily overcast skies, at any wind speed day or night.

5 Legal context

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 wellbeing World Health Organization (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.

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

According to the Act, the then Department of Environment Affairs and Tourism (now the Department of Environmental Affairs) (DEA), the provincial environmental departments and local authorities (district and local municipalities) are separately and jointly responsible for the implementation and enforcement of various aspects of NEM: AQA. Each of these spheres of government is obliged to appoint an air quality officer and to co-operate with each other and co-ordinate their activities through mechanisms provided for in the National Environment Management Act, 1998 (Act 107 of 1998) (NEMA).

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.

Amongst other things, it is intended that the setting of norms and standards will achieve the following:

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

Section 24 in Chapter 2 (Bill of Rights) of Constitution of the Republic of South Africa, 1996 dealing with the Environment states that:

Everyone has the right:

- to an environment that is not harmful to their health or well-being; and
- to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that –
  - prevent pollution and ecological degradation;
  - promote conservation; and
  - secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development.

It is this constitutional imperative that underpins the environmental protection laws such as NEM: AQA.

A fundamental aspect of the new approach to the air quality regulation, as reflected in the NEM: AQA, is the establishment of National Ambient Air Quality Standards (NAAQS). These standards provide the goals for air quality management plans and also provide the benchmark by which the effectiveness of these management plans is measured. The NEM: AQA provides for the identification of priority pollutants and the setting of ambient standards with respect to these pollutants.

The Act ensures that air quality planning is integrated with existing activities. The implications of this are that plans that are required in terms of the NEMA must incorporate consideration of air quality. In addition, Integrated Development Plans (IDP's) developed by local and district municipalities, also have to take air quality into account.

The Act describes various regulatory tools that should be developed to ensure the implementation and enforcement of air quality management plans. These include:

- *Priority Areas*, which are air pollution 'hot spots';

- *Listed Activities and Minimum Emission Standards*[1], under Section 21 of the AQA which are 'problem' processes that require an Atmospheric Emission Licence (AEL) in order to operate;
- *Controlled Emitters*, which includes the setting of emission standards for 'classes' of emitters, such as motor vehicles, incinerators, etc., as well as controlled fuels;
- Control of Dust;
- Control of Noise; and
- Control of Odours.

In order to facilitate implementation of and compliance with the NEM: AQA, the Act provides for government to turn down AEL Licence applications from applicants who have a problematic record of air quality management practices. It also provides for government to demand that 'problem' industries appoint qualified air quality practitioners.

The Act also deals with South Africa's international obligations in terms of air quality management. Provision is made for the control of processes impacting on South Africa's neighbours and the global atmosphere in general, as well as trans-boundary air pollution.

The Act further regulates the establishment of the National Framework for Air Quality Management (NFAQM). The Framework was published in September 2007 and under its provisions is due for the review this year (2012).

The Act as a whole is defined by the adoption of a comprehensive approach to the management of offences and penalties, which includes the provision of transitional arrangements. The Act provides for flexibility and proactive approach, so that permissible emission limits can be amended on a progressive basis in order to achieve set air quality standards. As a consequence, the NEM: AQA came into full effect only on 1 April 2010. Certain sections of the Act came into force on 11 September 2005, but the Minister excluded other sections until such time as local authorities had the capacity and skills to deal with the implementation of the legislation. Significantly, many of the excluded sections related to listed activities and licensing of listed activities. The excluded sections were brought into effect on the 31 March 2010, and the old Atmospheric Pollution Prevention Act (APPA) of 1965 was fully repealed on the same date.

The Act also required the Minister or the Member of Executive Council (MEC) to identify and publish activities which result in atmospheric emissions that require an Atmospheric Emission Licence before they can operate. 1 April 2010 also marked the date when the new list of activities requiring Atmospheric Emissions Licenses to operate was promulgated and,

[1] Minimum Emission Standards are the highest emission standards at which a Listed Activity will be allowed to operate under normal working conditions. If a definition of the process operated on the plant is matching the process description under established Listed Activities, the plant operates a Listed Activity and it must then be in possession of an Atmospheric Emission Licence indicating the specific Listed Activity(s) operated on the facility. Not only must the plant be in possession of an Atmospheric Emission Licence, it must also comply with the conditions within the licence to comply with NEM:AQA.

with this, the levelling of the atmospheric emission “playing field” through the setting of minimum emissions standards for all these listed activities was implemented.

Government Notice 248 (GN248:2010) established and identified activities which result in atmospheric emissions for which an Atmospheric Emission Licence must be obtained before operation can take place.

GN248:2010 lists the ten main categories, each with its associated subcategories (more detailed description of the exact activities and minimum emission standards), for which an Atmospheric Emission Licence needs to be obtained. The main categories include:

- Combustion Installations
- Petroleum Industry
- Carbonization and Coal Gasification
- Metallurgical Industry
- Mineral Processing, Storage and Handling
- Organic Chemicals Industry
- Inorganic Chemicals Industry
- Disposal of Hazardous and General Waste
- Pulp and Paper Manufacturing Activities
- Animal Matter Processing.

The Notice further states that the minimum emission standards will be applicable to both permanently operating plants and for experimental (pilot) plants with a design capacity equivalent to the one of a listed activity. Minimum standards are applicable under normal working conditions, and any normal start-ups, maintenance, upset and shut-down conditions that exceed a period of 48 hours will be subject to Section 30 of the AQA, which deals with control of emergency accidents. Upset conditions means any temporary failure of air pollution control equipment or failure of a process to operate in a normal or usual manner that leads to an emission standard being exceeded.

Any new plant must comply with the new plant minimum emission standards as contained in Part 3 of the Notice (which gives detailed account of minimum emission standards) on the date of publication of the notice, which was 31 March 2010.

Department of Environmental Affairs (DEA) has established the National Ambient Air Quality Standards for the criteria pollutants in the Government Notice - GN1210:2009 (Table 5-1).

Table 5-1 gives an overview of the established NAAQS, as well reference methods and compliance dates for criteria pollutants.

Table 5-1: National Ambient Air Quality Standards as of 24 December 2009

National Ambient Air Quality Standard for Sulphur Dioxide (SO_2)				
AVERAGING PERIOD	LIMIT VALUE ($\mu g/m^3$)	LIMIT VALUE (ppb)	FREQUENCY OF EXCEEDANCE	COMPLIANCE DATE
10 Minutes	500	191	526	Immediate
1 hour	350	134	88	Immediate
24 hours	125	48	4	Immediate
1 year	50	19	0	Immediate
The reference method for the analysis of SO_2 shall be ISO 6767.				

National Ambient Air Quality Standard for Nitrogen Dioxide (NO_2)				
AVERAGING PERIOD	LIMIT VALUE ($\mu g/m^3$)	LIMIT VALUE (ppb)	FREQUENCY OF EXCEEDANCE	COMPLIANCE DATE
1 hour	200	106	88	Immediate
1 year	40	21	0	Immediate
The reference method for the analysis of NO_2 shall be ISO 7996.				

National Ambient Air Quality Standard for Particulate Matter (PM_{10})			
AVERAGING PERIOD	LIMIT VALUE ($\mu g/m^3$)	FREQUENCY OF EXCEEDANCE	COMPLIANCE DATE
24 hour	120	4	Immediate – 31 December 2014
24 hour	75	4	1 January 2015
1 year	50	0	Immediate – 31 December 2014
1 year	40	0	1 January 2015
The reference method for the determination of the PM_{10} fraction of suspended particulate matter shall be EN 12341.			

National Ambient Air Quality Standard for Ozone (O_3)				
AVERAGING PERIOD	LIMIT VALUE ($\mu g/m^3$)	LIMIT VALUE (ppb)	FREQUENCY OF EXCEEDANCE	COMPLIANCE DATE
8 hours (running)	120	61	11	Immediate
The reference method for the analysis of ozone shall be the UV photometric method as described in SANS 13964.				
National Ambient Air Quality Standard for Benzene (C_6H_6)				
AVERAGING PERIOD	LIMIT VALUE ($\mu g/m^3$)	LIMIT VALUE (ppb)	FREQUENCY OF EXCEEDANCE	COMPLIANCE DATE
1 year	10	3.2	0	Immediate – 31 December 2014
1 year	5	1.6	0	1 January 2015
The reference methods for the sampling and analysis of benzene shall either be EPA				

compendium method TO-14 A or method TO-17.

National Ambient Air Quality Standard for Lead (Pb)				
AVERAGING PERIOD	LIMIT VALUE ($\mu g/m^3$)	LIMIT VALUE (ppb)	FREQUENCY OF EXCEEDANCE	COMPLIANCE DATE
1 year	0.5		0	Immediate
The reference method for the analysis of lead shall be ISO 9855.				

National Ambient Air Quality Standard for Carbon Monoxide (CO)				
AVERAGING PERIOD	LIMIT VALUE (mg/m^3)	LIMIT VALUE (ppm)	FREQUENCY OF EXCEEDANCE	COMPLIANCE DATE
1 hour	30	26	88	Immediate
8 hour (calculated on 1 hourly averages)	10	8.7	11	Immediate
The reference method for analysis of CO shall be ISO 4224.				

The Minister of Water and Environmental Affairs, in terms of section 9 (1) of the NEM: AQA established the National Ambient Air Quality Standard for particulate matter of aerodynamic diameter less than 2.5 micron metre ($PM_{2.5}$), published in GN R 486 in GG 35463 of 29 June 2012.

Table 5-2: National Ambient Air Quality Standard for Particulate Matter PM2.5

National Ambient Air Quality Standard for Particulate Matter ($PM_{2.5}$)			
AVERAGING PERIOD	CONCENTRATION	FREQUENCY OF EXCEEDANCE	COMPLIANCE DATE
24 hours	65 $\mu g/m^3$	4	Immediate – 31 December 2015
24 hours	40 $\mu g/m^3$	4	1 January 2016 – 31 December 2029
24 hours	25 $\mu g/m^3$	4	1 January 2030
1 year	25 $\mu g/m^3$	0	Immediate – 31 December 2015
1 year	20 $\mu g/m^3$	0	1 January 2016 – 31 December 2029
1 year	15 $\mu g/m^3$	0	1 January 2030
The reference method for the determination of the $PM_{2.5}$ fraction of suspended particulate matter shall be EN 14907.			

The DEA has also published the Draft National Dust Control Regulations in May 2011 (GN309:2011). These regulations relate to dust fall monitoring and ambient dust monitoring and propose dust fall limits at the boundary or beyond the boundary of premises for residential and light commercial areas, as well as areas other than residential and light commercial.

The proposed limits are as follows:

- 600 mg/m^2/day averaged over 30 days in residential and light commercial areas measured using reference method ASTM D1739-98 (2010); or
- 1200 mg/m^2/day averaged over 30 days in areas other than residential and light commercial areas measured using reference method ASTM D1739-98 (2010).

6 HEALTH EFFECTS OF THE IDENTIFIED POLLUTANTS

6.1 Particulates

The main pollutant of concern identified as a result of the construction and operational phases of the mining development will be the particulate matter, whether in the form of total suspended particulates (TSP), PM_{10} or $PM_{2.5}$.

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

In terms of health effects, particulate air pollution is associated with complaints of the respiratory system (WHO, 2000). Particle size is important for health because it controls where in the respiratory system a given particle deposits. Fine particles are thought to be more damaging to human health than coarse particles as larger particles are less respirable in that they do not penetrate deep into the lungs compared to smaller particles (Manahan, 1991). Larger particles are deposited into the extrathoracic part of the respiratory tract while smaller particles are deposited into the smaller airways leading to the respiratory bronchioles (WHO, 2000).

Particulate matter (PM) is a type of air pollution that is present wherever people live. It is generated mainly by human activities: transport, energy production, domestic fuel combustion and by a wide range of industries. There is no evidence of a safe level of exposure or a threshold below which no adverse health effects occur.

The range of adverse health effects of PM is broad, involving respiratory and cardiovascular systems in children and adults. Both short- and long-term exposures lead to adverse health effects. Very young children, probably including unborn babies, are particularly sensitive to the adverse effects of PM. The evidence is sufficient to infer a causal relationship between exposure to PM and deaths from respiratory diseases in the post-neonatal period. Adverse effects of PM on lung development include reversible deficits of lung function as well as chronically reduced lung growth rate and long-term lung function deficit. The available evidence is also sufficient to assume a causal relationship between exposure to PM and aggravation of asthma, as well as cough and bronchitis symptoms. Daily mortality and hospital admissions have been linked with short term variation of PM levels. Increased mortality from cardiovascular and respiratory diseases and from lung cancer has been observed in residents of more polluted areas.

Based on the existing evidence of adverse health effects at low levels of exposure, WHO revised the Air Quality Guidelines (AQG) for PM in 2005. For $PM_{2.5}$, the new AQG values are 10 µg/m^3 for the annual average and 25 µg/m^3 for the 24-hour mean (not to be exceeded for more than 3 days/year). The corresponding guidelines for PM_{10} were set as 20 µg/m^3 and 50 µg/m^3.

Ambient PM_{10} concentrations are a good approximation of population exposure to PM from outdoor sources. Numerous epidemiological studies conducted in Europe and in other parts of the world have shown adverse health effects of exposure to PM_{10} and $PM_{2.5}$ at concentrations that are currently observed in Europe and the rest of the world. WHO estimated that approximately 700 annual deaths from acute respiratory infections in children aged 0–4 years could be attributed to PM_{10} exposure in the WHO European Region in the late 1990s alone. Population health effects of exposure to PM in adults are dominated by mortality associated with long-time exposure to fine PM ($PM_{2.5}$). Short-term and long-term health effects associated with exposure to particulate matter are presented in Table 6-1.

6.1.1 Short-term exposure

Recent studies suggest that short-term exposure to particulate matter is associated with health effects, even at low concentrations of exposure. Various studies undertaken during the 1980s and early 1990s have looked at the relationship between daily fluctuations in particulate matter and mortality at low levels of exposure. Pope *et al* (1992) studied daily mortality in relation to PM10 concentrations in Utah Valley during the period 1985 - 1989. A maximum daily average concentration of 365 µg/m^3 was recorded with effects on mortality observed at concentrations of < 100 µg/m^3. The increase in total daily mortality was 13% per 100 µg/m^3 increase in the 24 hour average. Studies by Schwartz (1993) in Birmingham recorded daily concentrations of 163 µg/m^3 and noted that an increase in daily mortality was experienced with an increase in PM_{10} concentrations. Relative risks for chronic lung disease and cardiovascular deaths were higher than deaths from other causes.

However, in the past, daily particulate concentrations were in the range 100 – 1000 µg/m^3 whereas in more recent times, daily concentrations are between 10 – 100 µg/m^3. Overall, exposure-response can be described as curvilinear, with small absolute changes in exposure at the low end of the curve having similar effects on mortality to large absolute changes at the high end (WHO, 2000).

Morbidity effects associated with short-term exposure to particulates include increases in lower respiratory symptoms, medication use and small reductions in lung function. Pope and Dockery (1992) studied panels of children in Utah Valley in winter during the period 1990 – 1991. Daily PM10 concentrations ranged between 7 – 251 µg/m^3. Peak Expiratory Flow (PEF) was decreased and respiratory symptoms increased when PM10 concentrations increased. Pope and Kanner (1993) utilised lung function data obtained from smokers with mild to moderate chronic obstructive pulmonary disease in Salt Lake City. The estimated effect was a 2% decline in FEV_1 (Forced Expiratory Volume over one second) for each 100 µg/m^3 increase in the daily PM_{10} average.

6.1.2 Long-term exposure

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). The short term and long term effects associated with particulate matter are depicted in Table 6-1.

Studies have indicated an association between lung function and chronic respiratory disease and airborne particles. Older studies by Chestnut *et al* (1991) found that FVC (Forced Vital Capacity) decreases with increasing annual average particulate levels with an apparent threshold at 60 µg/m^3. Using chronic respiratory disease data, Schwartz (1993) determined that the risk of chronic bronchitis increased with increasing particulate concentrations, with no apparent threshold.

Few studies have been undertaken documenting the morbidity effects of long-term exposure to particulates. Recently, the Harvard Six Cities Study showed increased respiratory illness rates among children exposed to increasing particulate, sulphate and hydrogen ion concentrations. Relative risk estimates suggest an 11% increase in cough and bronchitis rates for each 10 µg/m^3 increase in annual average particulate concentrations.

Table 6-1: Short-term and long-term health effects associated with exposure to PM (after WHO, 2004)

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

8 EMISSIONS INVENTORY METHODOLOGY AND RESULTS

Establishment of an emissions inventory forms the basis for any air quality impact assessment. Air pollution emissions may typically be obtained using actual sampling at the point of emission, or estimating it from mass and energy balances or emission factors which have been established at other, similar operations. The method adopted here is the latter. Emission factors published by the US-EPA in its AP-42 document Compilation of Air Pollution Emission Factors and Australian National Pollutant Inventory Emission Estimation Technique Manuals (Common Wealth Australia 2012).

There are various sources of emissions anticipated from the proposed underground coal mine. Typical emissions from the coal mine include:

- Inhalable particulates, with aerodynamic diameters less than or equal to 10 micron (PM_{10}) and $PM_{2.5}$ from all mining sources;
- Sulphur dioxide (SO_2) from the vent shaft;
- Oxides of nitrogen (NO_X) from the vent shaft; and
- Carbon monoxide (CO) from the vent shaft

An emissions inventory was established comprising emissions for the different activities associated with the underground Syferfontein operations. The establishment of this emissions inventory is necessary to provide the source and emissions data required as input to the dispersion model simulations.

8.1 Predictive Emission Factors

An emission factor is a representative value that attempts to relate an activity associated with the release of a pollutant to the quantity of that pollutant released into the atmosphere. Emission factors and emission inventories are fundamental tools for air quality management. The emission factors are frequently the best or only method available for estimating emissions produced by varying sources. Emission estimates are important, amongst others, for developing emission control strategies; determining applicability of permitting and control programmes; and ascertaining the effects of sources and appropriate mitigation measures.

In order to determine the significance of the potential for impacts, it is necessary to quantify atmospheric emissions and predicted airborne pollutant concentrations occurring as a result of each emission source. Empirically derived *predictive emission factor equations* are available for the quantification of TSP, PM_{10} and $PM_{2.5}$, for sources such as aeolian erosion from open areas.

The State Pollution Control Commission of New South Wales, Australia (SPCC, 1983) published a number of emission factors i.e. the average value for wind erosion from open areas is 0.4 kg/ha/h (3,504 kg/ha/year). It is suggested that this value be adopted as a default in the absence of other information. The same applies to all other activities with inadequate information to assess associated pollution load.

AP-42 (USEPA, 1998) states that 50% of the TSP is emitted as PM_{10}. Therefore, the default emission factor for PM_{10} is 0.2 kg/ha/h.

Default values:

$$EF_{TSP\,(kg/ha/hr)} = 0.4\ kg/ha/hr$$

$$EF_{PM_{10}\,(kg/ha/hr)} = 0.2\ kg/ha/hr$$

For the fine dust component of particulate emissions from industrial wind erosion, a $PM_{2.5}/PM_{10}$ ratio of 0.15 is recommended. Industrial wind erosion is associated with crushed aggregate materials, such as coal or metallic ore piles. Examples would include open storage piles at mining operations (USEPA, 2006). A pit retention factor of 50% for TSP and 5% for PM_{10} was applied to the pit.

Significant emissions can arise due to the mechanical disturbance of granular material from open areas and storage piles. Parameters which have the potential to impact on the rate of emission of fugitive dust include the extent of surface compaction, moisture content, ground cover, the shape of the storage pile, particle size distribution, wind speed and precipitation. Any factor that binds the erodible material, or otherwise reduces the availability of erodible material on the surface, decreases the erosion potential of the fugitive source. High moisture content, whether due to precipitation or deliberate wetting, promotes the aggregation and cementation of fines to the surfaces of larger particles, thus decreasing the potential for dust emissions. Surface compaction and ground cover similarly reduces the potential for dust generation. The shape of a storage pile influences the potential for dust emissions through the alteration of the airflow field. The particle size distribution of the material on the disposal site is important since it determines the rate of entrainment of material from the surface, the nature of dispersion of the dust plume, and the rate of deposition which may be anticipated.

Dust emissions due to the erosion of open storage piles and exposed areas occur when the threshold wind speed is exceeded (Cowherd *et al.*, 1988; USEPA, 1995). The threshold wind speed is dependent on the erosion potential of the exposed surface, which is expressed in terms of the availability of erodible material per unit area (mass/area). 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 (Cowherd *et al.*, 1988).

Fugitive dust generation resulting from wind erosion under high winds (i.e. > 5.4 m/s) is directly proportional to the elevated dust levels. Wind speeds stronger than 5.4 m/s and occur in the area some 6.4% of the time (Figure 4-4). An average wind speed of 3.2 m/s was calculated from the Syferfontein modelled data.

9 RESULTS AND DISCUSSION

9.1 Baseline Characterisation

In terms of dust fallout, Syferfontein operated a network of 13 single buckets as shown in Figure 9-1. Seven of these dustfall monitoring units were for the Syferfontein (SYFER 1 – 7) and 6 dust fallout units for the Syferfontein extension (SYF EXT).

9.1.1 Dust Deposition

The dust fallout for Syferfontein was assessed for a six months period from April to September 2013. The results are shown in Table 9-1 and the results from the Syferfontein extension March to May 2014 are shown in Table 9-2

9.1.1.1 Syferfontein April – September 2013

In April, all single bucket monitoring units SYFER1 – SYFER 7 recorded levels that fell below the residential threshold (600 mg/m^2/day). However these buckets were exposed for 33 days, which is one day more than the standard (30±2 days) set out in the SANS 1137:2012 based on the ASTM D1739-98 (2010).

In May and June, all the dust fallout units recorded levels that fell below the residential threshold (600 mg/m^2/day). In June, no data was recorded on the monitoring unit SYFER 6 (there was no access to site). In July, all single bucket monitoring units SYFER1 – SYFER 7 recorded levels that fell below the residential threshold (600 mg/m^2/day). SYFER06 was exposed for 59 days as access to site in June was not obtained. The single bucket monitoring units recorded levels that fell below the residential threshold (600 mg/m^2/day) recommended by the new dust regulation (NCDR, 2013). The buckets were exposed for 33 days exceeding the standard (30±2 days).

In September 2013, SYFER2 (1 798 mg/m^2/day), SYFER4 (1 095 mg/m^2/day), SYFER5 (955 mg/m^2/day) and SYFER6 (745 mg/m^2/day) all recorded, dust deposition rates above the recommended standard. SYFER 2 exceeded the non-residential limit of 1 200 mg/m^2/day.

9.1.1.2 Syferfontein Extension March – May 2014

For the Syferfontein extension dust fallout units, all the buckets where within the residential limit of 600 mg/m^2/day, except SYF EXT 2 654 mg/m^2/day) and SYF EXT 4 (752 mg/m^2/day) exceeded the residential limit in April. . In May only SYF EXT 2 and SYF 5 did not exceed the residential limit, the other sites were all above the recommended limit. Hence, SYF EXT 4 was in violation of the permissible frequency of exceedance. According to the standard, *the margin of tolerance is two times within a year or if the limit is exceeded, it must not be two sequential months*.

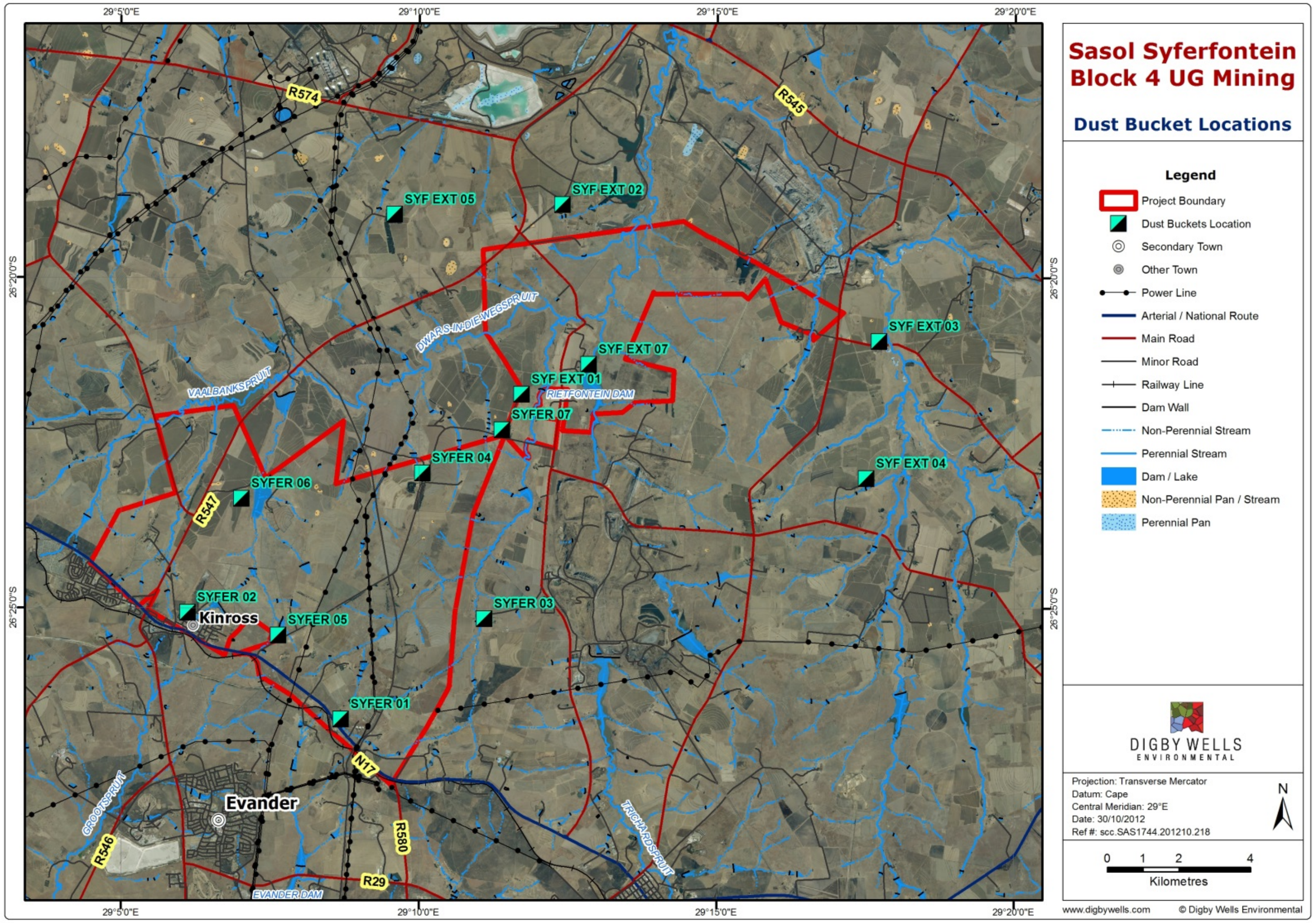

Figure 9-1: Position of the single dust fallout units buckets for Syferfontein and Syferfontein Extension

Table 9-1: Syferfontein dust fallout results April – September 2013

Dust levels measured in $mg/m^2/day$						
	Apr-13	**May-13**	**Jun-13**	**Jul-13**	**Aug-13**	**Sep-13**
SYFER 1	256*	56	202	52	239*	538
SYFER 2	241*	364	236	126	313*	**1 798**
SYFER 3	236*	280	52	80	190*	302
SYFER 4	256*	338	95	84	78*	**1 095**
SYFER 5	66*	209	91	121	272*	**955**
SYFER 6	210*	452	-	134^	111*	**745**
SYFER 7	216*	133	209	120	425*	**567**

*buckets were exposed for 33 days: ^ bucket exposed for 59 days

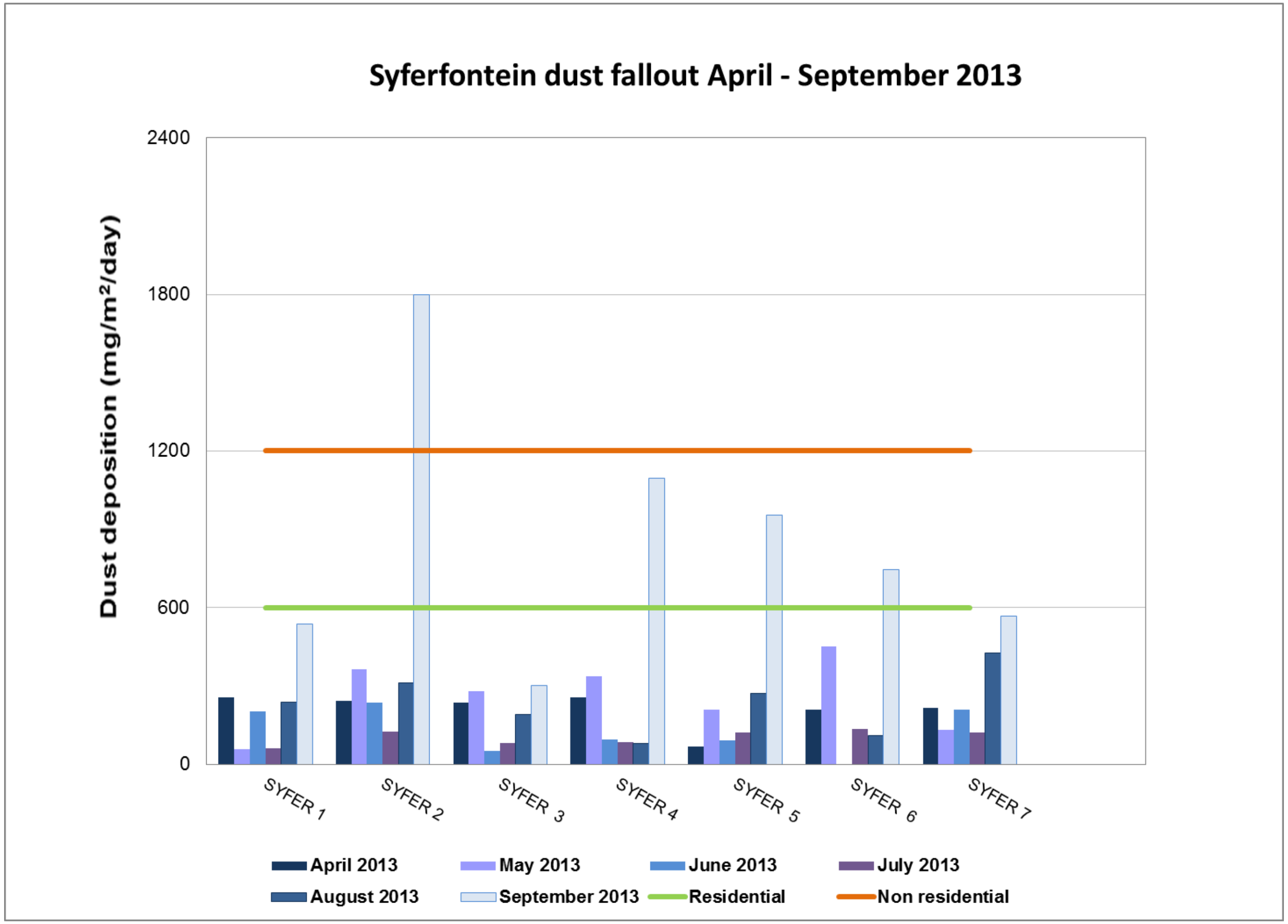

Figure 9-2: Syferfontein dust fallout April - September 2013

Table 9-2: Syferfontein extension dust fallout results March – May 2014

	March-14	April-14	May-14
SYF EXT 1	570	490	**815**
SYF EXT 2	515	**654**	557
SYF EXT 3	578	595	**707**
SYF EXT 4	378	**752**	**1 114**
SYF EXT 5	280	475	446
SYF EXT 7	530	552	**810**

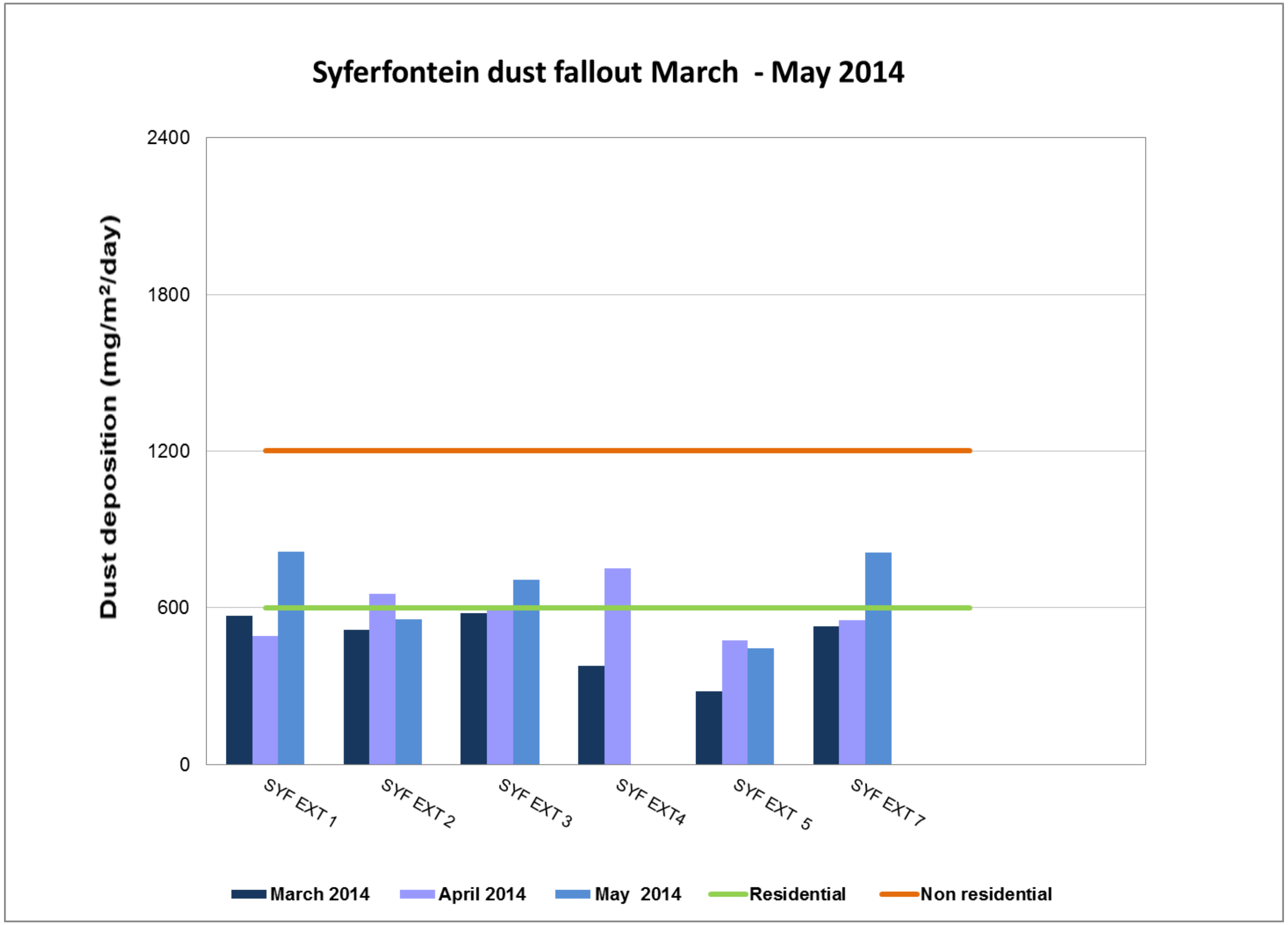

Figure 9-3: Syferfontein Extension dust fallout March – May 2014

9.2 Dispersion Model Methodology and Scenario

The modelled scenario in this project has a vent shaft only It is assumed the mine's operations are 20 hours per day and 284 days a year. The pollutants modelled were SO_2, NO_2, PM_{10} and $PM_{2.5}$

Dispersion models are used to predict the ambient concentration in the air of pollutants emitted to the atmosphere from a variety of processes (South African National Standards - SANS 1929:2011). Dispersion models compute ambient concentrations as a function of source configurations, emission strengths and meteorological characteristics, thus providing a useful tool to ascertain the spatial and temporal patterns in the ground level concentrations arising from the emissions of various sources. Increasing reliance has been placed on concentration estimates from models as the primary basis for environmental and health impact assessments, risk assessments and emission control requirements. It is therefore important to carefully select a dispersion model for the purpose.

All emission scenarios have been simulated using the USA Environmental Protection Agency's Preferred/Recommended Models: AERMOD modelling system (as of December 9, 2006, AERMOD is fully promulgated as a replacement to ISC3 model).

The AERMOD modelling system incorporates air dispersion based on planetary boundary layer turbulence structure and scaling concepts, including treatment of both surface and elevated sources, and both simple and complex terrain.

There are two input data processors that are regulatory components of the AERMOD modelling system: AERMET, a meteorological data pre-processor that incorporates air dispersion based on planetary boundary layer turbulence structure and scaling concepts, and AERMAP, a terrain data pre-processor that incorporates complex terrain using USGS Digital Elevation Data. Other non-regulatory components of this system include: AERSCREEN, a screening version of AERMOD; AERSURFACE, a surface characteristics pre-processor, and BPIPPRIME, a multi-building dimensions program incorporating the GEP technical procedures for PRIME applications.

AERMOD model is capable of providing ground level concentration estimates of various averaging times, for any number of meteorological and emission source configurations (point, area and volume sources for gaseous or particulate emissions), as well dust deposition estimates.

The effect of complex terrain is modelled by changing the plume trajectory and dispersion to account for disturbances in the air flow due to the terrain. This may increase or decrease the concentrations calculated. The influence of the terrain will vary with the source height and position and the local meteorology. The terrain used in the model is elevated.

9.3 Modelled domain

A rectangular receptor grid of 20 km x 20 km was utilised as the modelling domain. The multi-tier grid mesh was utilised. Multi-tier grid combines coarse and fine grids to ensure that maximum impacts from sources are captured. Table 9-3 shows the grid spacing utilised for the dispersion modelling at Grootegeluk.

Table 9-3: Grid spacing for receptor grids at Syferfontein Underground Operations.

Tier	Distance from centre (m)	Tier spacing (m)
1	1000	100
2	5000	250
3	10000	500

A total of 3 281 grid points were generated. Each of the grid points has x and y (Cartesian co-ordinates) values in metres. Terrain effects were imported from NASA Shuttle Radar Topography Mission (SRTM3) global database with ~90 m accuracy and processed by the AERMAP module of AERMOD.

This receptor grid has been chosen to include the nearest sensitive receptors (these are mainly surrounding farms and residential dwellings and provide an indication of the extent of any air pollution impacts. The 24-hour and annual averaging times have been used for consistency. The modelling has been performed using the meteorological data discussed in previous section and the gaseous, particulate and deposition emissions calculations explained in the emissions inventory section.

Table 9-4 gives an overview of meteorological parameters and basic setup options for the AERMOD model runs.

Table 9-4: Summary of meteorological and AERMET parameters used for Grootegeluk

Years of analysis	Jan 2011 to Dec 2013
Centre of analysis	26.403822 S, 29.131606E
Meteorological grid domain	12 km (east-west) x 12 km (south-north)
Meteorological grid cell resolution	12 km x 12 km
Station Base Elevation	1602 mamsl
MM5-Processed Grid Cell (Grid Cell Centre)	26.403822 S, 29.131606E
Anemometer Height	13 m
Surface meteorological stations	1 site at the Syferfontein underground operations using data generated by AERMET

Upper air meteorological stations	1 site at the Syferfontein underground operations using data generated by AERMET
Simulation length	26280 hours (Jan 2011 to Dec 2013)
Sectors	The surrounding area land use type was considered to be *grassland and residential*
Albedo	0.29 (generated with the AERMOD Model – when the land use types are specified)
Surface Roughness	0.04025
Bowen Ratio	0.925
Terrain Option	Elevated (The regional setting showed some ridges in the area)

9.3.1 Sensitive receptors

Discrete receptors were identified as the houses located around and within the 20km by 20km dispersion modelling domain (Table 9-5). These were categorised as sensitive receptors prone to be impacted by air emissions from the mine operations. The level of exposure to each of the pollutants is dependent on the proximity of the receptors to the mine operations and the wind direction.

Table 9-5: Sensitive receptor locations

Receptor description	Receptor number for air quality modelling	UTM Easting coordinate (m)	UTM Northing coordinate (m)
Kinross	1	706891.81	7077164.63
Evander	2	710290.75	7070349.80

9.3.2 Source data requirements

The infrastructure layout utilised during the dispersion model was provided by the client. AERMOD can model area, volume and point sources. Input into the dispersion model includes prepared meteorological data, source data, information on the nature of the receptor grid and emissions input data. Model inputs were verified before the model was executed.

9.4 Assessment of Impacts

The AERMOD model predicts the one-hour average concentration at each receptor specified, for each hour of the year's meteorological data. The highest ground level concentration is established for each hour and is referred to as the peak hourly concentration.

The daily values option controls the output options for tables of concurrent values summarised by receptor for each day processed. For each averaging period for which the daily values option is selected, the model will print in the main output file the concurrent averages for all receptors for each day of data processed. Results are output for each source group.

In general, the distributions of concentrations follow closely the main wind directions (wind roses generated for the site Numerical values of maximum depend on the emission rate and the meteorological data used. Simulations were undertaken to determine concentrations of SO_2, NO_2 particulate matter with a particle size of less than 10 microns (µm) in size (PM_{10}), particle size of less than 2.5 microns (µm) in size ($PM_{2.5}$) for Syferfontein underground operations.

9.4.1 Isopleth Plots and Evaluation of Modelling Results

A summary of isopleth plots generated in the current section are presented in Table 9-6.

Table 9-6: Evaluation of results at the mine boundary during the operational phase (concentrations at the SW, S and W boundary are presented in the table below).

Pollutant	Averaging period	Guideline (µg/m³)	Syferfontein	Figure
	Unmitigated concentrations			
SO_2	1 hour	350[(1)]	54[a],7[b],7[c]	9-4
	24 hours	125[(1)]	4.E-03[a], 8.E-04[b], 4.E-04 [c]	9-5
	1 year	50[(1)]	9.E-05[a], 7.E-05[b], 4.E-05 [c]	9-6
NO_2	1 hour	200[(1)]	51[a],7[b],5[c]	9-7
	1 year	40[(1)]	6.E-02[a], 4.E-02[b], 2.E-02 [c]	9-8
PM_{10}	24 Hours	120[(1)] 75 [(2)]	82a,9[b],52 [c]	9-9
	1 Year	50[(1)] 40[(2)]	10[a],2[b],6 [c]	9-10

$PM_{2.5}$	24 Hours	65[3] 40[4]	12[a],1[b],8 c	9-11
	1 Year	25[3] 20[4]	2[a],0.2[b],1 [c]	9-12
[a]SW Boundary – 716823.78: 7073983.49 [b]S Boundary - 715205.49: 7071355.76 [c]W Boundary – 706923.67: 7077765.45				

(1) South African- Current National Ambient Air Quality Standards (NAAQS)
(2) South African- Future (from 1 January 2015) National Ambient Air Quality Standards (NAAQS)
(3) South African- Proposed current National Ambient Air Quality Standards (NAAQS)
(4) South African- Proposed future (from 1 January 2016) National Ambient Air Quality Standards (NAAQS)
(5) South African- National Ambient Air Quality Standards (NAAQS) – National Dust Control Regulation 2013

9.4.2 SO_2 predicted impacts

The predicted highest 1-hour concentrations for SO_2 generated from the operation of the Syferfontein underground mine are shown in Figure 9-4 . The highest predicted 1-hour ground level concentration of SO_2 is 54 µg/m³ at the south west mine boundary (716823.78: 7073983.49), 7.2 µg/m³ at the south mine boundary (715205.49: 7071355.76) and 6.9 µg/m³ at the west mine boundary (706923.67: 7077765.45) (Table 9-6). These coordinates were selected as they are locations facing the predominant wind direction for the Syferfontein area (Figure 4-1). The predicted SO_2 concentration at the mine boundary do not exceed the current ambient air quality standard of 350 µg/m³. The concentrations reported from the vent shaft emissions did not consider mitigation measures. Ambient levels at Kinross and Evander are approximately 10 µg/m³ (Table 9-7).

The highest predicted 24 hour ground level concentration of SO_2 is shown in Figure 9-5. Ambient concentrations of 0.04 µg/m³ at the south west mine boundary (716823.78: 7073983.49), 0.0008 µg/m³ at the south mine boundary (715205.49: 7071355.76) and 0.0004 µg/m³ at the west mine boundary (706923.67: 7077765.45) are reported (Table 9-7). The predicted SO_2 concentration at the mine boundary do not exceed the current ambient air quality standard of 125 µg/m³.

The highest predicted annual ground level concentration of SO_2 is depicted (Figure 9-6). Concentration of 9.E-05 µg/m³ was predicted at the south west mine boundary (716823.78: 7073983.49), 7.E-05 µg/m³ at the south mine boundary (715205.49: 7071355.76) and 4.E-05 µg/m³ at the west mine boundary (706923.67: 7077765.45) respectively (Figure 9-6). The concentrations at the nearest sensitive receptors are presented in Table 9-7. The predicted SO_2 concentration at the mine boundary is within the recommended ambient air quality standard of 50 µg/m³.

It should be noted that isopleth plots reflecting daily averaging periods contain only the highest predicted ground level concentrations for that averaging period, over the entire period for which simulations were undertaken. These isopleths are likely ambient air quality burden the proposed expansion activities would have on surrounding environment. *It is therefore possible that even though a high daily concentration is predicted to occur at certain locations, that this may only be true for one day during the entire period.*

Table 9-7 : Predicted SO_2 concentrations at sensitive receptors

Receptor modelled	1 hour SO_2 concentrations (µg/m^3)	24 hour SO_2 concentrations (µg/m^3)	Annual SO_2 concentrations (µg/m^3)
Kinross	10	6.E-04	2.E-05
Evander	10	5.6.E-04	2.E-05

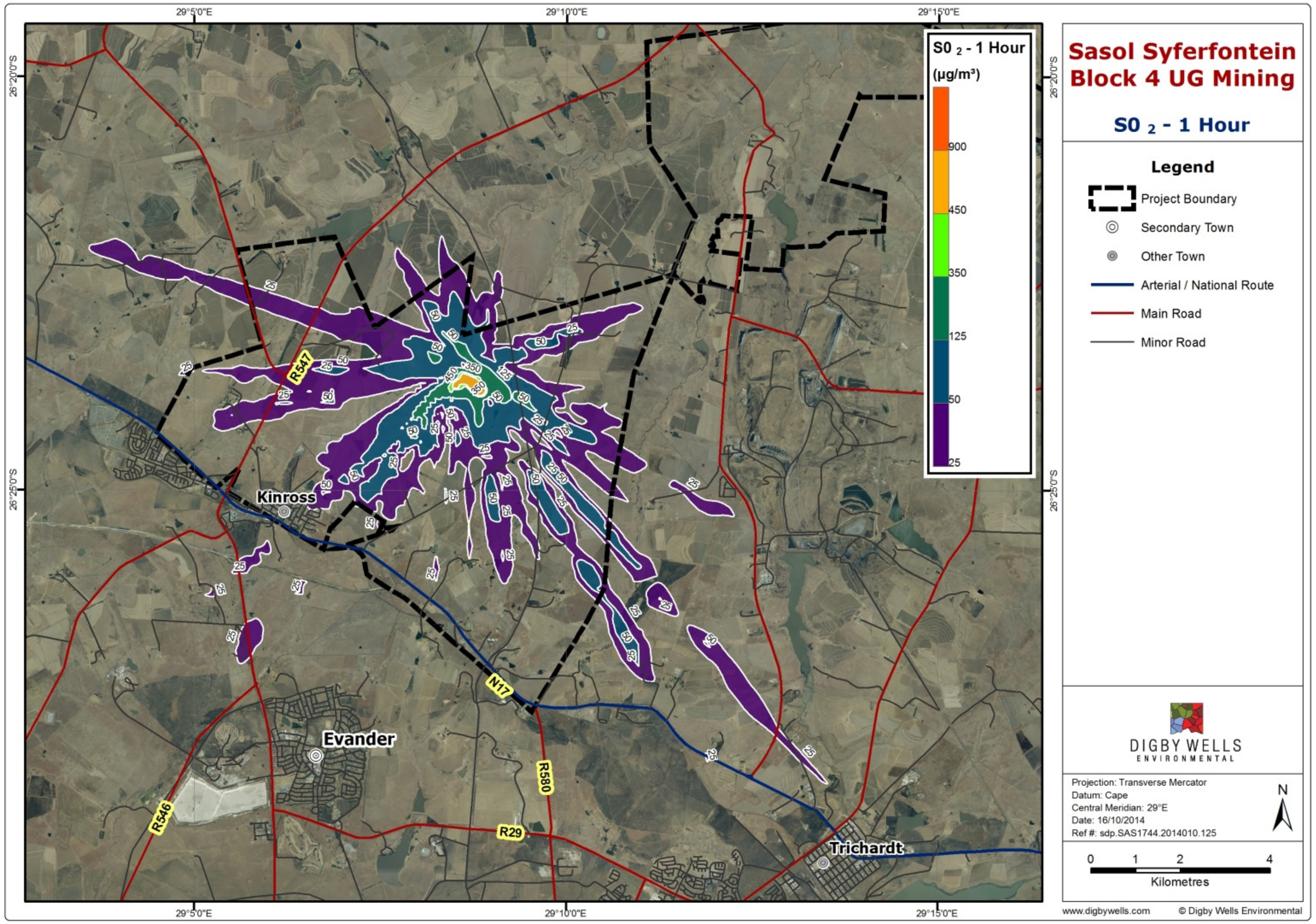

Figure 9-4: Predicted 4th highest (99th percentile) 1 hour average SO_2 concentrations (µg/m³) due to the Syferfontein underground activities. (Syferfontein boundary highlighted in black)

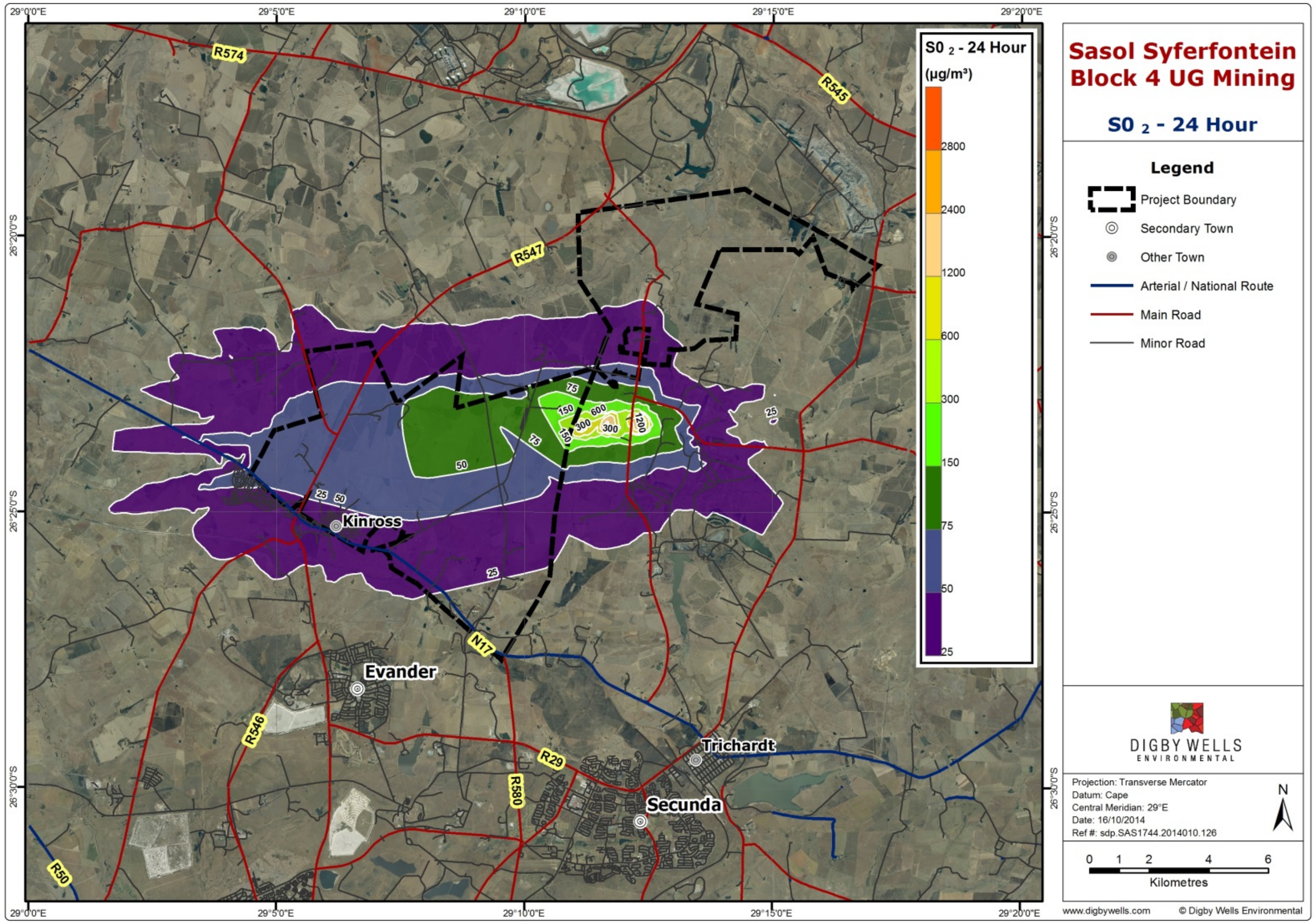

Figure 9-5: Predicted 4th highest (99th percentile) 24 hour average SO_2 concentrations (µg/m^3) due to the Syferfontein underground activities. (Syferfontein boundary highlighted in black)

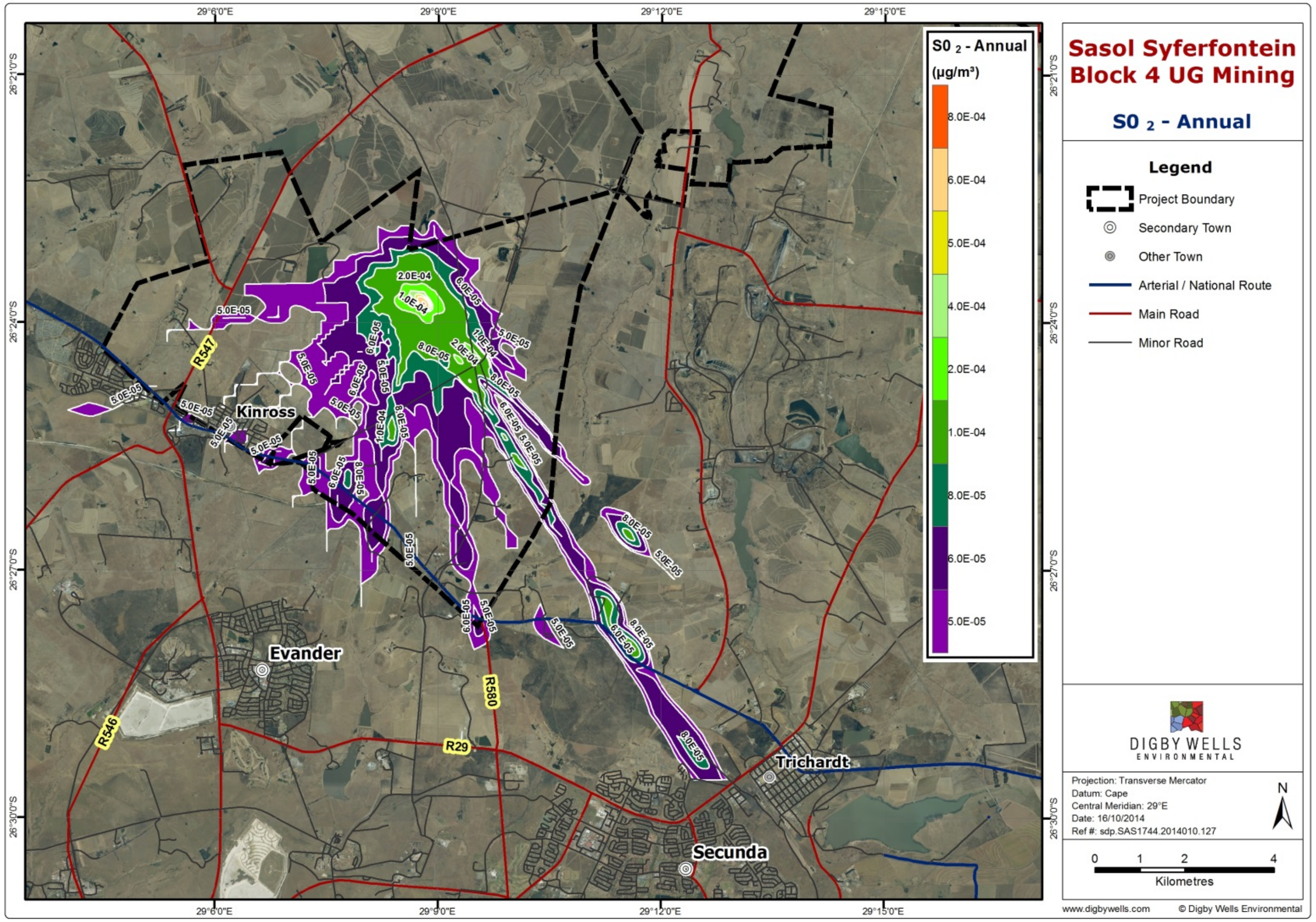

Figure 9-6: Predicted 1st highest (100th percentile) annual average SO_2 concentrations (µg/m^3) due to the Syferfontein underground activities. (Syferfontein boundary highlighted in black)

9.4.3 NO_2 predicted impacts

The predicted highest NO_2 concentrations attributed to the operation of the proposed Syferfontein underground mine are shown in Figure 9-7 and Figure 9-8. The highest predicted 1-hour ground level concentration of NO_2 is 61 µg/m³ at the south west mine boundary (716823.78: 7073983.49), 8.4 µg/m³ at the south mine boundary (715205.49: 7071355.76) and 48.6 µg/m³ at the west mine boundary (706923.67: 7077765.45). The predicted NO_2 concentrations at the mine boundary do not exceed the regulatory limit value of 200 µg/m³. This isopleth plot predicted plant boundary daily values from the vent shaft emissions without mitigation measures. Ambient concentration of ~25 µg/m³ is predicted for Kinross and Evander respectively (Table 9-8).

The highest predicted annual ground level concentration of NO_2 of 6.E-02 µg/m³ is reported at the south west mine boundary (716823.78: 7073983.49), 4.E-02 µg/m³ at the south mine boundary (715205.49: 7071355.76) and 2.E-02 µg/m³ at the west mine boundary (706923.67: 7077765.45) (Table 9-8). The predicted NO_2 concentration at the mine boundary do not exceed the current ambient air quality standard of 40 µg/m³.

It should be noted that isopleth plots reflecting daily averaging periods contain only the highest predicted ground level concentrations for that averaging period, over the entire period for which simulations were undertaken. These isopleths are likely ambient air quality burden the proposed expansion activities would have on surrounding environment. *It is therefore possible that even though a high daily concentration is predicted to occur at certain locations, that this may only be true for one day during the entire period.*

Table 9-8: Predicted NO_2 concentrations at sensitive receptors

Receptor modelled	1 hour NO_2 concentrations (µg/m³)	Annual NO_2 concentrations (µg/m³)
Kinross	25	0.02
Evander	25	0.01

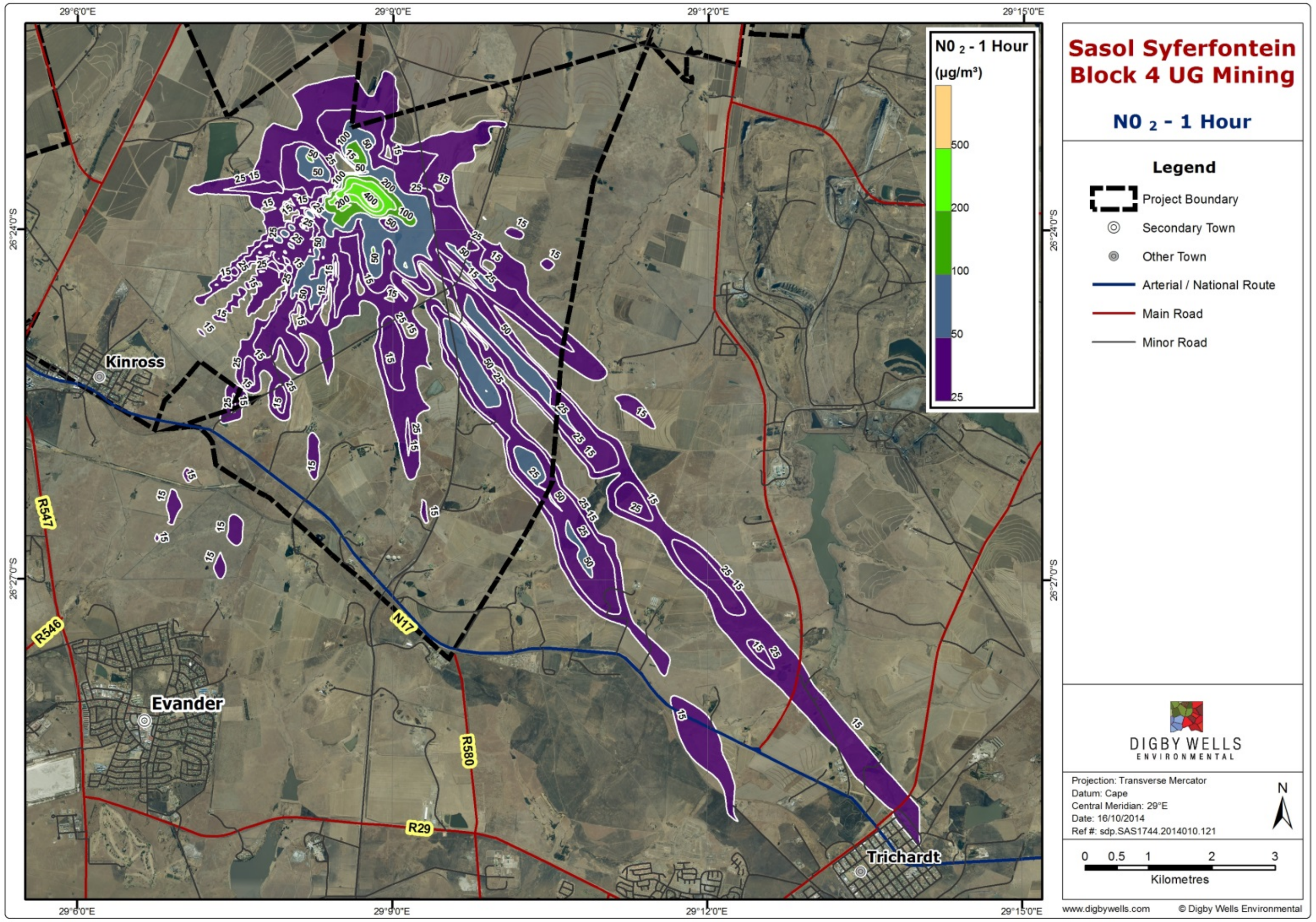

Figure 9-7: Predicted 4th highest (99th percentile) 1 hour average NO_2 concentrations (µg/m³) due to the Syferfontein underground activities. (Syferfontein boundary highlighted in black)

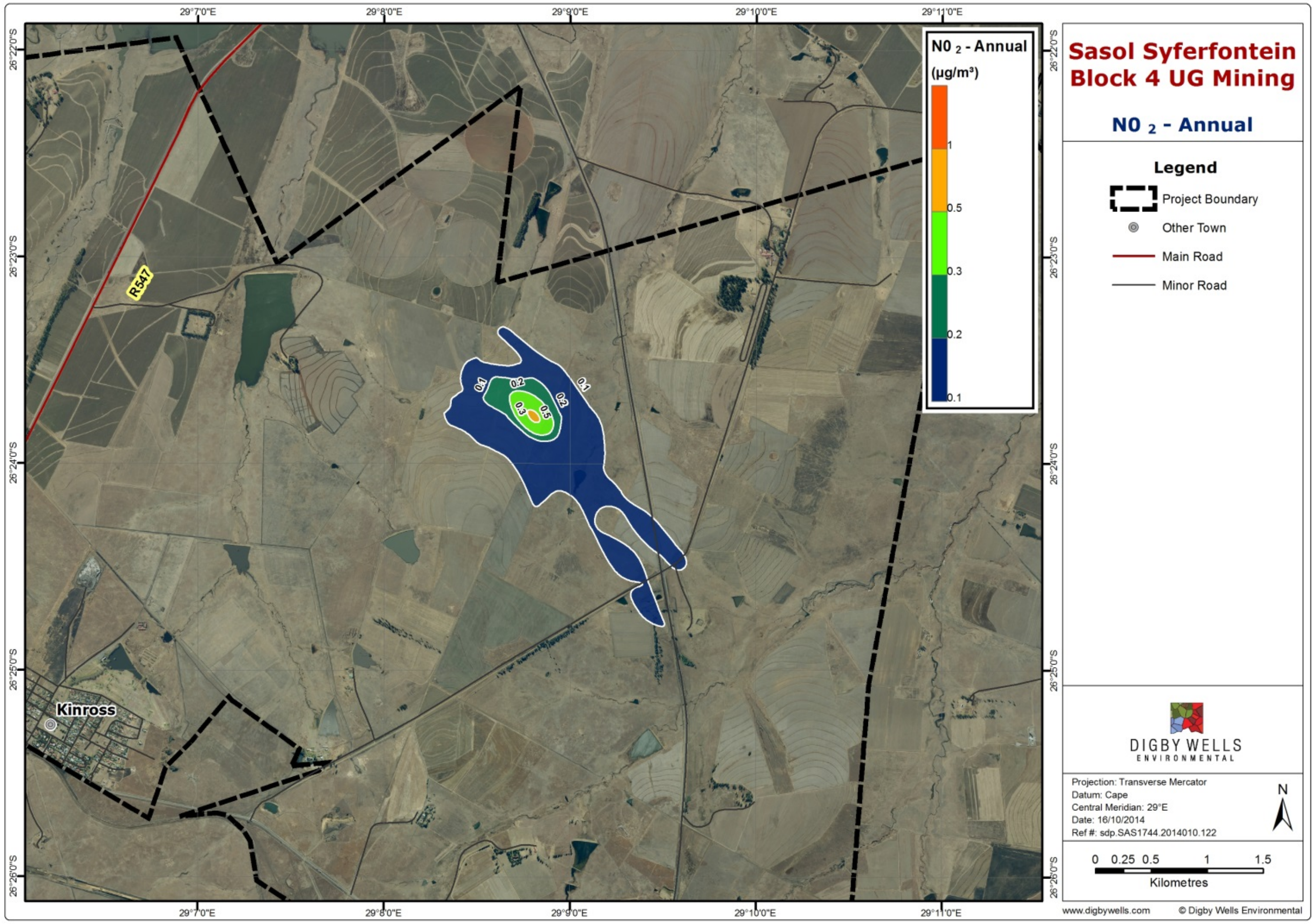

Figure 9-8: Predicted 1st highest (100th percentile) annual average NO_2 concentrations (µg/m^3) due to the Syferfontein underground activities. (Syferfontein boundary highlighted in black)

9.4.4 PM_{10} predicted impacts

The isopleth plot of predicted highest daily concentration of PM_{10} generated by the Syferfontein underground operations are shown in Figure 9-9 . A daily highest predicted 24-hour ground level concentration of PM_{10} is 0.1 µg/m³ at the south west mine boundary (716823.78: 7073983.49), 0.02 µg/m³ at the south mine boundary (715205.49: 7071355.76) and 0.01 µg/m³ at the west mine boundary (706923.67: 7077765.45). The predicted PM_{10} concentration at the mine boundary do not exceed the current ambient air quality standard of 120 µg/m³ and the future limit of 75 µg/m³ which comes into effect 1 January 2015.. Ambient levels at Kinross and Evander are 0.001 (Table 9-9).

The highest predicted annual ground level concentration of PM_{10} is depicted in Figure 9-10. Concentrations of 0.0023 µg/m³ at the south west mine boundary (716823.78: 7073983.49), 0.0017 µg/m³ at the south mine boundary (715205.49: 7071355.76) and 0.001 µg/m³ at the west mine boundary (706923.67: 7077765.45) are reported (Table 9-8). The predicted PM_{10} concentrations at the mine boundary do not exceed the current ambient air quality standard of 50 µg/m³ and the future limit of 40 µg/m³ which comes into effect 1 January 2015. Ambient levels at Kinross and Evander of 0.0009 and 0.0005 µg/m³ are reported (Table 9-9).

Table 9-9: Predicted PM_{10} concentrations at sensitive receptors

Receptor modelled	24 hour PM_{10} concentrations (µg/m³)	Annual PM_{10} concentrations (µg/m³)
Kinross	0.01	0.0009
Evander	0.01	0.0005

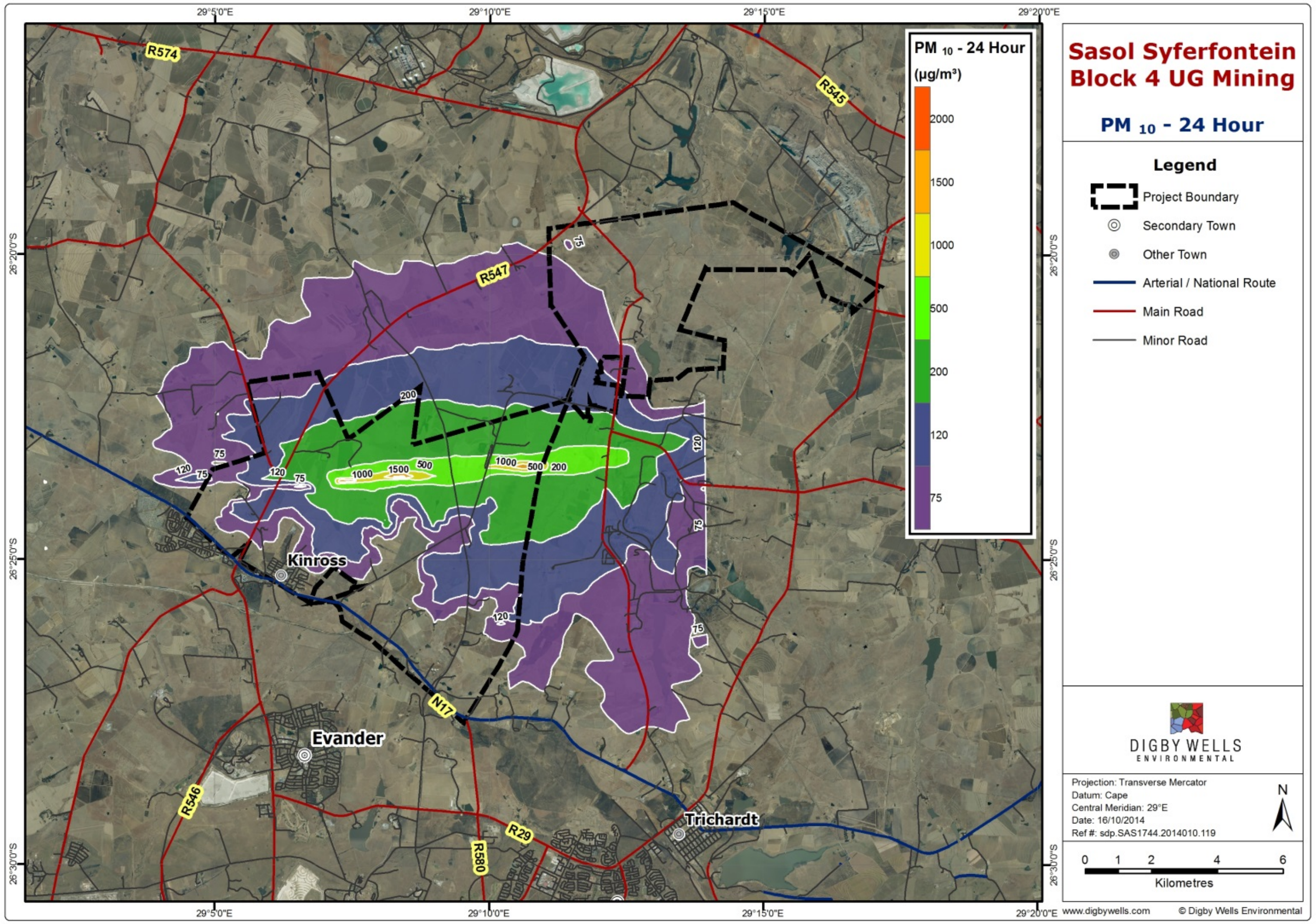

Figure 9-9: Predicted 4th highest (99th percentile) 24hour average PM_{10} concentrations (µg/m³) due to the Syferfontein underground activities. (Syferfontein boundary highlighted in black)

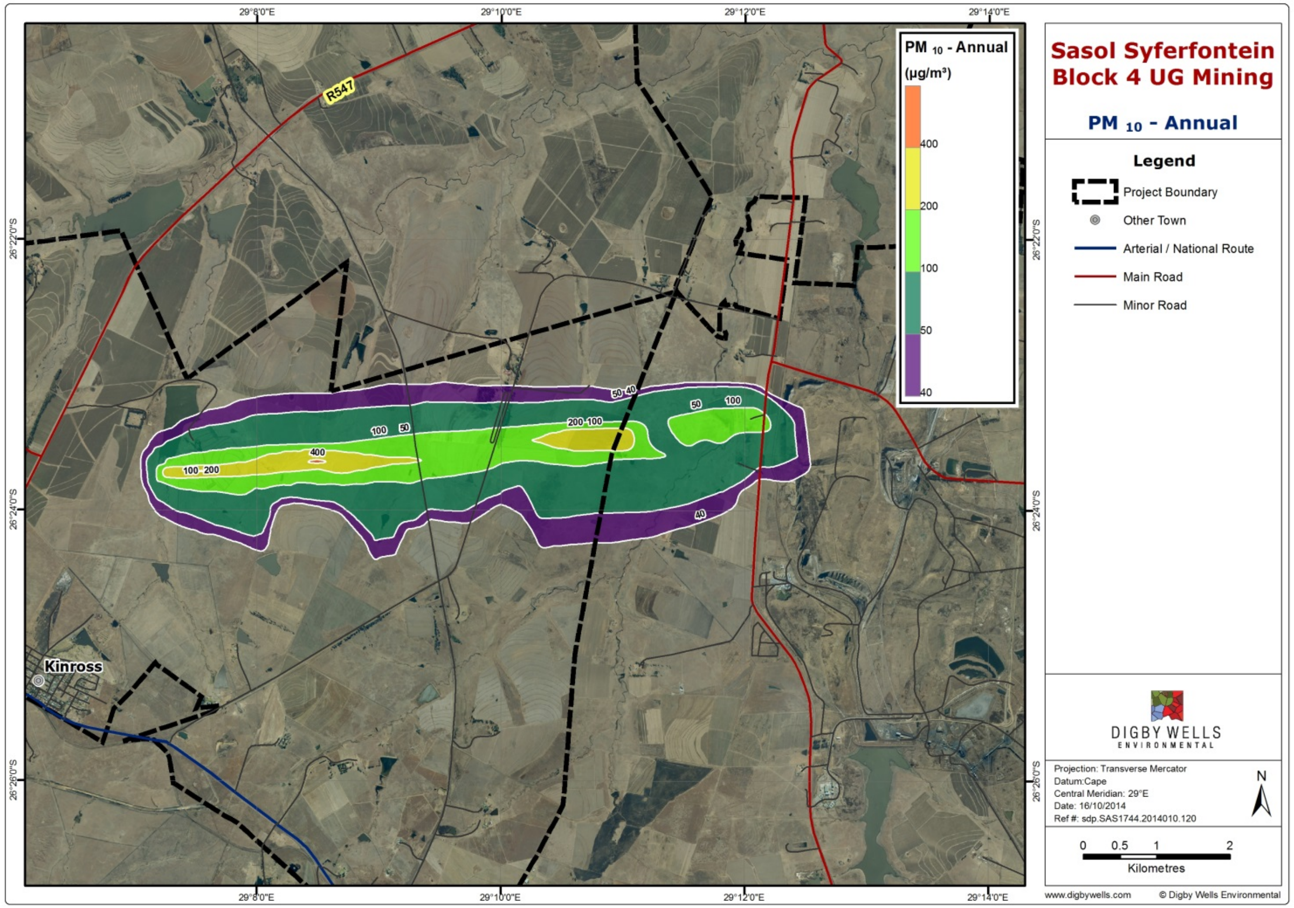

Figure 9-10: Predicted 1st highest (100th percentile) annual average PM_{10} concentrations (µg/m³) due to the Syferfontein underground activities. (Syferfontein boundary highlighted in black)

9.4.5 $PM_{2.5}$ Predicted impacts

The isopleth plot of predicted highest daily values for $PM_{2.5}$ generated attributed to the proposed operation of the Syferfontein underground mine are shown in Figure 9-11 and Figure 9-12. A daily highest predicted 24 hour ground level concentration of $PM_{2.5}$ is 0.1 µg/m³ at the south west mine boundary (716823.78: 7073983.49), 0.02 µg/m³ at the south mine boundary (715205.49: 7071355.76) and 0.01 µg/m³ at the west mine boundary (706923.67: 7077765.45). The predicted PM_{10} concentrations at the mine boundary do not exceed the current ambient air quality standard of 65 µg/m³ and the future limit of 40 µg/m³ which comes into effect 1 January 2016. Ambient levels of 0.03 and ~0.002 µg/m³ are reported for Kinross and Evander respectively (Table 9-10).

The highest predicted annual ground level concentration of 0.0022 µg/m³ at the south west mine boundary (716823.78: 7073983.49), 0.0016 µg/m³ at the south mine boundary (715205.49: 7071355.76) and 0.0010 µg/m³ at the west mine boundary (706923.67: 7077765.45) (Table 9-6). The predicted $PM_{2.5}$ concentrations at the mine boundary do not exceed the current ambient air quality standard of 25 µg/m³ and the future limit of 20 µg/m³ which comes into effect 1 January 2016. Ambient levels reported for Kinross and Evander reached 0.001 and 0.005 µg/m³ respectively (Table 9-10).

Table 9-10: Predicted $PM_{2.5}$ concentrations at sensitive receptors

Receptor modelled	24 hour $PM_{2.5}$ concentrations (µg/m³)	Annual $PM_{2.5}$ concentrations (µg/m³)
Kinross	0.03	0.001
Evander	0.002	0.005

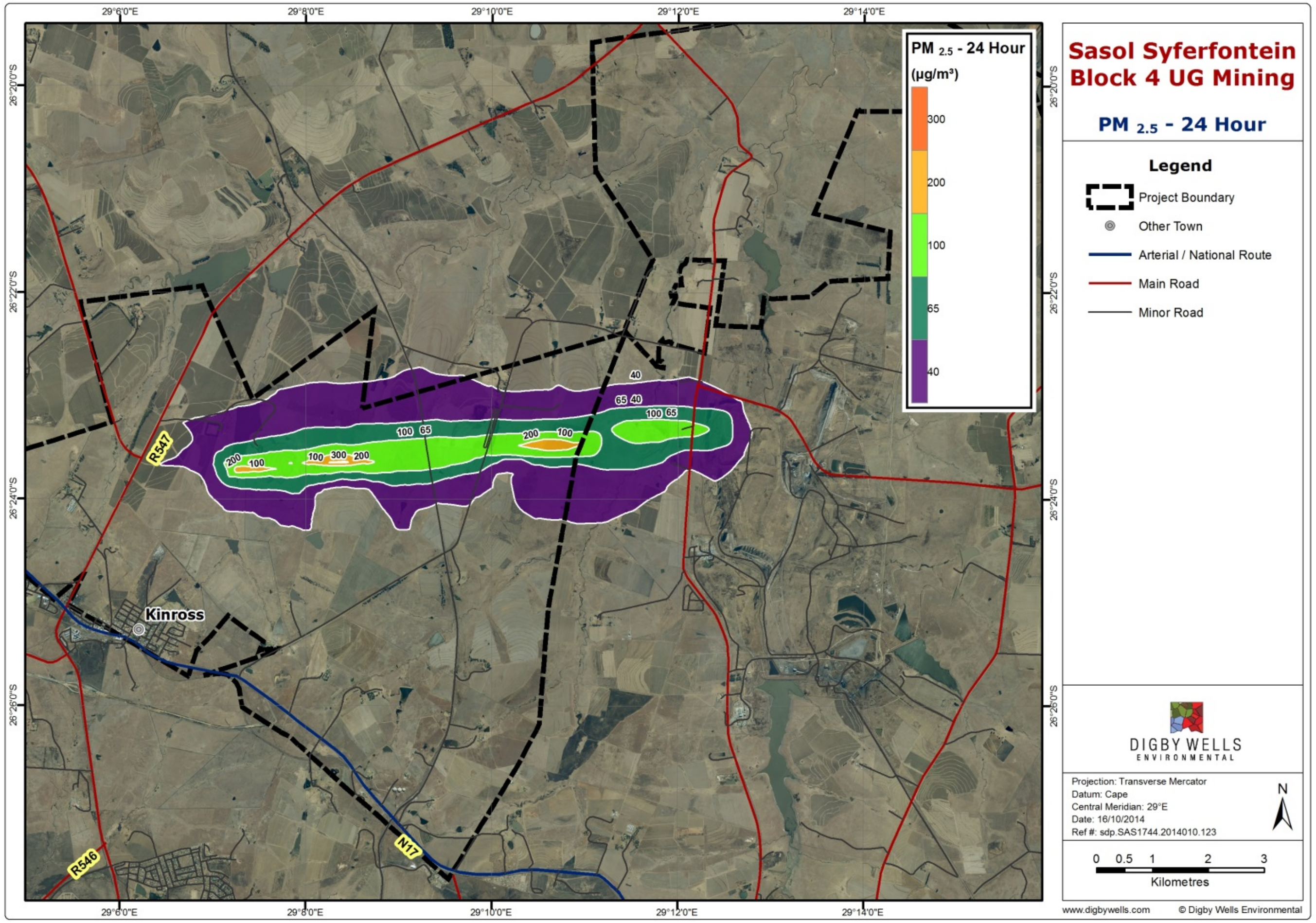

Figure 9-11: Predicted 4th highest (99th percentile) 24hour average $PM_{2.5}$ concentrations (µg/m^3) due to the Syferfontein underground activities. (Syferfontein boundary highlighted in black)

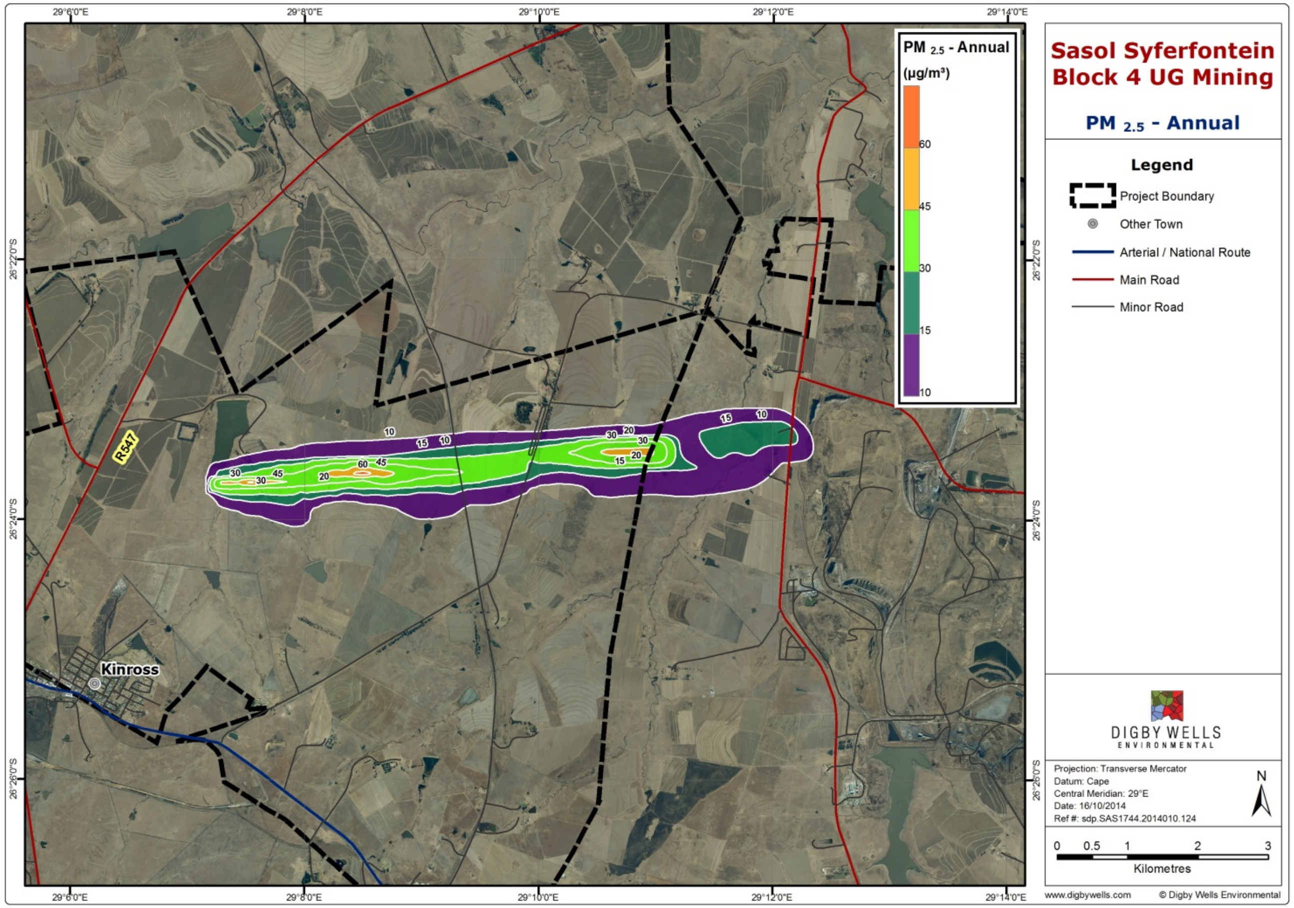

Figure 9-12: Predicted 1st highest (100th percentile) annual average $PM_{2.5}$ concentrations ($\mu g/m^3$) due to the Syferfontein underground activities. (Syferfontein boundary highlighted in black)

10 IMPACT ASSESSMENT

10.1 Air Quality Assessment

Projects of this nature will generally present a number of air pollution sources that can have a negative impact on ambient air quality both within and for downwind communities/land uses if mitigation measures are not implemented.

10.2 IMPACT ASSESSMENT METHODOLOGY

The descriptions and scales of the terms used to define the impact significance and the Impact significance matrix are provided in Table 10-1 and Table 10-2 respectively. Impact significance classification is depicted in Table 10-3. The list of activities used for the Syferfontein activities is given in Table 10-4.

The method provides an indication in relative terms of the significance of potential impact on the atmospheric environment.

The system is based on ordinal data where a number is used to represent a category. Ordinal data allows for an increase or decrease in the scoring to provide a relative indication which cannot be interpreted on a linear scale.

The methodology determines the environmental significance using the following equation:

Significance of environmental impact = Consequence X Probability

The consequence of an impact can be derived from the following factors:

- Spatial extent;
- Duration of impact; and
- Severity / magnitude

Duration is defined by how long the impact may be prevalent and spatial scale is the physical area which could be affected by an impact. The severity of an impact relates to how severe the impact will be. The overall probability of the impact can be determined, and is related to the likelihood of such an impact occurring.

Table 10-2, and then the overall consequence is determined by adding the individual scores.

Environmental impacts are obtained by multiplying the consequence of the impact with the probability of occurrence, as follows:

Significance = Consequence x Probability

Where

Consequence = Severity (1-7) + Extent (1-7) + Duration (1-7)

And

Probability = Likelihood of an impact occurring (1-7)

The maximum score that can be obtained is 147 significance points.

The impact rating process is designed to provide a numerical rating (scores from 1 to 7) of the various environmental impacts identified for various project activities. The matrix calculates the rating out of 147. The significance of an impact is then determined and categorised into one of four categories (Table 10-3). The assessment is done for all activities that were predicted to have an air quality impact.

Environmental impacts are rated as Major, Moderate, Minor and Negligible based on the significance scoring

More than 108 points indicate Major environmental significance;

- Between 73 and 108 points indicate Moderate environmental significance;
- Between 33 and 73 points indicate Minor environmental significance; and
- Less than 33 points indicate Negligible environmental significance.

Table 10-1: Descriptions and scales of the terms used to define the impact significance.

Rating	Severity	Spatial scale	Duration	Probability
7	Very significant impact on the environment. Irreparable damage to highly valued species, habitat or eco system. Persistent severe damage.	International The effect will occur across international borders	Permanent: No Mitigation No mitigation measures of natural process will reduce the impact after implementation.	Certain/ Definite. The impact will occur regardless of the implementation of any preventative or corrective actions.

Rating	Severity	Spatial scale	Duration	Probability
6	Significant impact on highly valued species, habitat or ecosystem.	National Will affect the entire country	Permanent: Mitigation Mitigation measures of natural process will reduce the impact.	Almost certain/Highly probable It is most likely that the impact will occur.
5	Very serious, long-term environmental impairment of ecosystem function that may take several years to rehabilitate	Province/ Region Will affect the entire province or region	Project Life The impact will cease after the operational life span of the project.	Likely The impact may occur.
4	Serious medium term environmental effects. Environmental damage can be reversed in less than a year	Municipal Area Will affect the whole municipal area	Long term 6-15 years	Probable Has occurred here or elsewhere and could therefore occur.
3	Moderate, short-term effects but not affecting ecosystem function. Rehabilitation requires intervention of external specialists and can be done in less than a month.	Local Local extending only as far as the development site area	Medium term 1-5 years	Unlikely Has not happened yet but could happen once in the lifetime of the project, therefore there is a possibility that the impact will occur.

Rating	Severity	Spatial scale	Duration	Probability
2	Minor effects on biological or physical environment. Environmental damage can be rehabilitated internally with/ without help of external consultants.	Limited Limited to the site and its immediate surroundings	Short term Less than 1 year	Rare/ improbable Conceivable, but only in extreme circumstances and/ or has not happened during lifetime of the project but has happened elsewhere. The possibility of the impact materialising is very low as a result of design, historic experience or implementation of adequate mitigation measures
1	Limited damage to minimal area of low significance, (e.g. ad hoc spills within plant area). Will have no impact on the environment.	Very limited Limited to specific isolated parts of the site.	Immediate Less than 1 month	Highly unlikely/None Expected never to happen.

Table 10-2: Impact significance matrix as a product of Consequence and Probability.

Significance

Consequence (severity + scale + duration)

Probability / Likelihood		1	3	5	7	9	11	15	18	21
	1	1	3	5	7	9	11	15	18	21
	2	2	6	10	14	18	22	30	36	42
	3	3	9	15	21	27	33	45	54	63
	4	4	12	20	28	36	44	60	72	84
	5	5	15	25	35	45	55	75	90	105
	6	6	18	30	42	54	66	90	107	126
	7	7	21	35	49	63	77	105	126	147

Table 10-3: Impact significance classification based on the Significance scoring.

Significance		
High (Major)	**108- 147**	
Medium-High (Moderate)	**73 - 107**	
Medium-Low (Minor)	**36 - 72**	
Low (Negligible)	**0 - 35**	

Table 10-4: Activity List.

Activity No.	**Activity**
Construction phase	
1	Construction of underground structures - incline
2	Transportation of materials & workers on site
Operational Phase	
4	Underground bord and pillar mining method.
Decommissioning phase	
8	Decommissioning of underground mine.

10.3 Construction Phase

10.3.1 Impact: Construction of underground structures - incline

Criteria	**Details / Discussion**				
Description of impact	Construction of the incline shaft results in the production of fugitive dust, PM_{10}, $PM_{2.5}$.(dust with a size less than 10 micron, and dust with a size less than 2.5 micron giving rise to health impacts). This activity will be short-term, localised, and will have low impacts on the atmospheric environment seizing after the construction activities.				
Mitigation required	Limiting construction activities during the windy months of August, September and October as dust levels will increase.				
Parameters	*Spatial*	*Duration*	*Severity*	*Probability*	*Significant rating*
Pre-Mitigation	Limited - 2	Short term - 2	Medium – 3	Highly probable- 6	Minor 42
Post-Mitigation	Limited - 2	Short term - 2	Short term - 2	Probable - 4	Low - 24

10.3.2 Impact: Transportation of materials & workers on site

Criteria	**Details / Discussion**				
Description of impact	During this activity, there is transportation of the workers and materials onsite. This leads to the production of fugitive dust (containing TSP (total suspended particulate, giving rise to nuisance impacts as fallout dust), as well as PM_{10} and $PM_{2.5}$ (dust with a size less than 10 micron, and dust with a size less than 2.5 micron giving rise to health impacts).				
Mitigation required	In order to mitigate the impacts of the activity, reduced vehicle speed, drop heights of loose and erodible materials should be minimised. Roads utilised when transporting the workers needs to be watered constantly.				
Parameters	*Spatial*	*Duration*	*Severity*	*Probability*	*Significant rating*
Pre-Mitigation	Limited - 2	Short term - 2	Low – 2	Certain / Definite- 7	Minor 42
Post-Mitigation	Limited - 2	Short term - 2	Short term - 2	Probable - 4	Low - 24

10.4 Operational Phase

10.4.1 Impact: Underground bord and pillar mining method.

Criteria	**Details / Discussion**				
Description of impact	To remove of the ore, the bord and pillar method will be used. This activity includes drilling and blasting the hard overburden. Drilling is an intermittent exercise that emits fugitive dust.				
Mitigation required	When blasting, it is advised to wet the proposed blasting area through the use of water cartridges alongside the explosives. The blast area needs to be minimised				
Parameters	*Spatial*	*Duration*	*Severity*	*Probability*	*Significant rating*
Pre-Mitigation	Limited - 2	Project Life - 5	Medium - 3	Likely - 5	Medium - Low-50
Post-Mitigation	Limited - 2	Project Life - 5	Short term - 2	Probable – 4	Medium - Low - 36

11 MONITORING PROGRAMME

11.1 Dust Monitoring Programme

Syferfontein should continue the current dust monitoring programme throughout the life of mine in order to amass historical dust deposition data that will feed into management practices aimed at reducing impacts from the construction, operation and closure phases of the project

As the area exposed is directly proportional to the amount of dust generated and transported, it is advised that construction activities be limited during the windy periods of August, September and October. If construction has to be done during this period, it is advised to disturb a small area at a time.

In order to determine the wind speed for each particular day, a wind anemometer installed on site should be utilised. Wind speeds are recorded daily and when it exceeds 5.4 m/s (the threshold for transporting particles) extra dust control measures need to be carried out.

12 RECOMMENDATIONS AND KNOWLEDGE GAPS

Based on the results presented in the report, the following are the recommendations:

- Ensure that ambient concentrations of pollutant during the operational phase of the expansion activities comply with all relevant statutory standards, and that air quality impacts on surrounding sensitive receptors are minimised.

- The concentrations at the mine boundary are to be minimised to ensure compliance.

The knowledge gaps in this assessment include the fact that a lot of assumptions were made including the specifications of the vent shaft used, amongst others.

13 CONCLUSION

The predominant winds are blowing from the north northwest, north and northwest in that order. Less frequent winds (under 3% of the time) were coming from the southwest, west and west southwest. Calm conditions (wind speeds < 0.5 m/s) occurred for 8.8% of the time.

The average monthly maximum temperatures range from 21.3°C in January to 7.5°C in July, with monthly minima ranging from 19.9°C in December to 6.6°C in July. Annual mean temperature for Syferfontein is given as 14.5°C. The monthly maximum relative humidity remains above 60% for the whole year and ranges from 82% in winter (July) to 64% in spring (November).

The air quality data obtained from Sasol Club was used to assess background conditions at the proposed Syferfontein Block 4 mining area. The concentrations of $PM_{2.5}$, and PM_{10} measured at the Sasol Club were below the standard of 65 µg/m^3 and 120 µg/m^3 respectively. Several exceedances of the 8 hourly limits of 61 ppb limit were measured for the ambient O_3 concentrations. . CO was generally below the 8 hourly targets of 8.7 ppm for the period under survey. The target for the 8 hourly averages of 48 ppb was exceeded once in 2011. Exceedances were experienced in 2011 for NO_2, while ambient levels were below the standard in 2012.

The dust deposition rate during the period April – September 2013 at the Syferfontein sites were below the residential limit of 600 mg/m2/day except for the month of September when deposition rates were exceeded at: SYFER2, SYFER4, SYFER5 and SYFER6 with 1 798 mg/m^2/day, 1 095 mg/m2/day, 955 mg/m2/day and 745 mg/m2/day respectively. SYFER 2 exceeded the non-residential limit of 1 200 mg/m2/day.

Also, deposition rates at the Syferfontein extension dust monitoring sites were all within the residential limit of 600 mg/m^2/day, except for SYF EXT 2 and SYF EXT 4 (April) that recorded exceedances of 654 mg/m^2/day and 752 mg/m^2/day respectively. In May, SYF EXT 2 and SYF 5 did not exceed the residential limit. However, there was no violation of the permissible frequency of exceedance. According to the standard, *the margin of tolerance is two times within a year or if the limit is exceeded, it must not be two sequential months*.

The pollutants assessment in this study: SO_2, NO_2, PM_{10}, and $PM_{2.5}$ were all with the recommended standards at the project boundary, hence will not posed adverse impacts on neighbouring residential settlements.

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Appendix A: Plans

Appendix B: Appendix Title

Appendix C: Appendix Title