DIGBY WELLS
ENVIRONMENTAL

Environmental Impact Assessment for Lanxess Chrome Mine

Air Quality Impact Assessment

Project Number:

LAN3111

Prepared for:

Lanxess Chrome Mine (Pty) Ltd

March 2015

Digby Wells and Associates (South Africa) (Pty) Ltd
(Subsidiary of Digby Wells & Associates (Pty) Ltd). Co. Reg. No. 2010/008577/07. Fern Isle, Section 10, 359 Pretoria Ave Randburg Private Bag X10046, Randburg, 2125, South Africa
Tel: +27 11 789 9495, Fax: +27 11 789 9498, info@digbywells.com, www.digbywells.com

Directors: DJ Otto, GB Beringer, LF Koeslag, AJ Reynolds (Chairman) (British)*, J Leaver*, GE Trusler (C.E.O)
*Non-Executive

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Name	Responsibility	Signature	Date
Winnie Ngara	Report writer		March 2015
Matthew Ojelede	Reviewer		March 2015

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EXECUTIVE SUMMARY

Digby Wells was requested by Lanxess Mining (Pty) Ltd, hereafter (Lanxess) to conduct a suite of studies to comply with the requirements of the Minerals and Petroleum Resources Development Act, Act 28 of 2002 (MPRDA) and the Environmental Impact Assessment Regulations, 2014, promulgated in terms of Sections 24(5) and 44 of the National Environmental Management Act, 1998 (GN R982 of 4 December 2014). With Lanxess already in possession of the Environmental Impact Assessment and Environmental Management Plan (EIA/EMP), amendment to the existing approved documents to include the details of the proposed opencast mining operations as well as the extension of the underground sections (Segment 1, 2, 3 and 4) as part of a section 102 amendment was a necessity in line with the MPRDA. An Air Quality Impact Assessment (AQIA) forms an integral component of the suites of studies.

The assessment will establish the ambient air quality baseline conditions, followed by the development of an air emissions inventory that will take into account the relevant sources of air pollution and associated air emissions. Dispersion modelling will be carried out to assess pollutant dispersion and possible impacts on the ambient environment.

Lanxess falls in the Waterberg Bojanala Priority area (WBPA), which encompasses the Waterberg District in Limpopo Province and the Bojanala Platinum District in the North West. This district has several sources of pollution such as heavy industry, refinery, power station, motor vehicles, small industries and households that rely on coal for cooking and space heating).

To determine the baseline conditions, site specific (meso-scale model) MM5 modelled meteorological was utilised to determine local prevailing weather conditions. Predominant winds come from the east and east northeast respectively. Over the three year period, frequency of occurrence was 11.8% from the east, 10.5% east northeast, and 9.9% from northeast. Calm conditions (wind speeds < 0.5 m/s) occurred for 4.7% of the time. The average monthly maximum temperatures range from 13.3°C in July to 25.7°C in February, with monthly minima ranging from 12°C in July to 25.1°C in January and the maximum relative humidity of 76.4% in July and the lowest of 55.9% was achieved in November.

An emissions inventory was carried out to determine pollutants budget from various sources. These emissions were utilised to determine dispersion of the pollutants across the landscape. The following pollutants were assessed Total Suspended Particulates (TSP), particulates with aerodynamic diameter of ≤10 µm (PM_{10}), and particulates with aerodynamic diameter of ≤2.5 µm ($PM_{2.5}$) within the project boundary and at the selected sensitive receptors that surround the operations.

The 4th highest PM_{10}, 24 hour level of 191 µg/m³ was achieved within the project boundary, however all the sensitive receptors were below the 75 µg/m³ current limit. The PM_{10} annual concentration of 43 µg/m³ was predicted within the project area is above the recommended limit, however the concentrations predicted for the selected sensitive receptors were all below the limit of 40 µg/m^3.

For $PM_{2.5}$, the 4th highest $PM_{2.5}$, 24 hour level of 187 µg/m³ was achieved within the project boundary. This is almost thrice the current limit of 65 µg/m^3. The concentrations at the selected sensitive receptors were below the recommended 65 µg/m³ limit. The $PM_{2.5}$ annual level of 28 µg/m³ was experienced within the project boundary but the sensitive receptors were all below the limit.

In terms of dust deposition, the highest dust fallout level was predicted within the project boundary (2 292 mg/m²/day). The deposition rates at the selected sensitive receptors were below the 600 mg/m²/day recommended for residential areas. When the mitigation measures were implemented, the dust fallout level within the project boundary decreased to 1 604 mg/m²/day and the anticipated fallout dust at the sensitive receptors reduced further.

The predicted results are in agreement with the actual deposition rates observed in the vicinity of Lanxess operation, with 12 dust fallout monitoring sites.

The conclusion reached in this reported is informed by observed and modelled data. An air quality impact assessment study was undertaken for the proposed Lanxess opencast mining operation, the current and proposed extension of the underground operation. Pollutants assessed in the study includes: TSP (dust deposition), PM_{10} and $PM_{2.5}$. Other pollutants common to mining operation of this nature i.e. gaseous pollutant were not assessed.

The findings from this study should inform mine management on the monitoring and strict mitigation measures to ameliorate potential atmospheric impacts. Some of the numerous mitigation measures recommended are listed below:

- The area of disturbance should be kept to a minimum and no unnecessary clearing, digging or scraping must occur, especially on windy days (with wind speed ≥ 5.4 m/s).
- The drop heights when loading onto trucks and at tipping points should be minimised.
- Use of dust suppressants and binders on haul roads to reduce dust generation.
- There is need to minimise travel speed and distance. Dust generating capacity of particles less than 10 µm is contained by 58% when vehicle speed is reduced from 25 mph (40 km/h) to 15 mph (24 km/h).
- Routine maintenance and vegetation of storage facilities i.e. topsoil and overburden stockpiles are imperative throughout the lifespan of the mine to avoid exposing surfaces to wind erosion.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

Digby Wells was requested by Lanxess Mining (Pty) Ltd, hereafter (Lanxess) to carry out an Air Quality Impact Assessment (AQIA) for the proposed an expansion of their existing underground chrome operations into neighbouring portions as well as the establishment of an open pit operation within their existing mining rights area.

The assessment will establish the current ambient air quality baseline conditions, followed by the development of an air emissions inventory that will take into account the relevant sources of air pollution and associated air emissions. Dispersion modelling was carried out to assess pollutant dispersion and possible impact of the pollutants distributed across the landscape.

2 TERMS OF REFERENCE

This AQIA will form part of the compilation of various technical reports that will be included in the Environmental Impact Assessment (EIA). This study aims to investigate the implications of the proposed expansion on ambient air quality. The terms of reference for the air quality impact assessment are set out below:

- Baseline assessment;
  - Identification of sensitive receptors;
  - Assessment of available ambient air quality data;
- Impact assessment
  - Emissions inventory;
  - Development of air dispersion modelling; and
  - Impact assessment of proposed developments on surrounding airshed.

3 ASSUMPTIONS AND LIMITATIONS

Data limitations and assumptions associated with this study are listed below:

- This impact assessment is limited to particulates $PM_{2.5}$, PM_{10}, and dust fallout;
- This assessment did not include tail pipe emissions from vehicles.
- US-EPA and NPi emission factors for mining was utilised in this assessment due to the unavailability of local emission factors.

4 PROJECT AREA

4.1 Location of Site

Lanxess Chrome Mine is located 7 km east of Kroondal and 11 km south-east of Rustenburg and falls within the Rustenburg Local Municipality of the North West Province (Figure 4-1 and Figure 4-2).

The surrounding sensitive receptor (residential) areas include:

- Wigwam – approximately 9 km to the south west;
- Kroondal – approximately 5 km to the west;
- Marikana – approximately 8 km to the north east;
- Buffelspoort – approximately 9 km to the south east;
- Lapologang – approximately 6 km to the east;
- Waterkloof – approximately 5 km to the north west; and
- Nkaneng – approximately 2 km to the north of the project boundary.

4.2 Waterberg- Bojanala Priority Area (WBPA)

The Waterberg-Bojanala Priority Area (WBPA) was declared the third priority area by the Minister in terms of GNR 495 on 15 June 2012. The WBPA is comprises of the Waterberg District in Limpopo Province and the Bojanala Platinum District in the North West. The Bojanala Platinum is the largest of the four District Municipalities within the North West (C&M Consulting Engineers, 2013) Figure 4-3.

The Bojanala Platinum District covers 5 local municipalities which are Moses Kotane, Rustenburg, Madibeng, Moretele and Kgetlengrivier (C&M Consulting Engineers, 2013). This district has several sources of pollution such as heavy industry, refinery, power station, motor vehicles, small industries and households using coal for cooking and space heating.

The Waterberg district has three forms of settlements which are villages, informal settlements and farms. The mining activities are located around the periphery while tourism and game farming are located around the centre of the District. This area was considered pristine and after the virgin coal resources were identified, new developments were proposed such as Medupi power station. There are various other new power stations which are proposed in the future. There was an urgency to be proactive and to take precautionary measures prior to these developments to ensure that the ambient air quality standards are met (DEA, 2012). The current air pollution sources of concern in the Waterberg District are:

- Dust from mines, quarries, brickworks, spoil/overburden heaps and heavy vehicles using gravel roads.
- Burning of solid waste at waste disposal sites, informal waste dumps
- Tailpipe emissions especially heavy vehicles that drive through towns

- Use of biomass for cooking and space heating.

Lanxess Chrome Mine is located within the footprint demarcated as the Bojanala Priority Area.

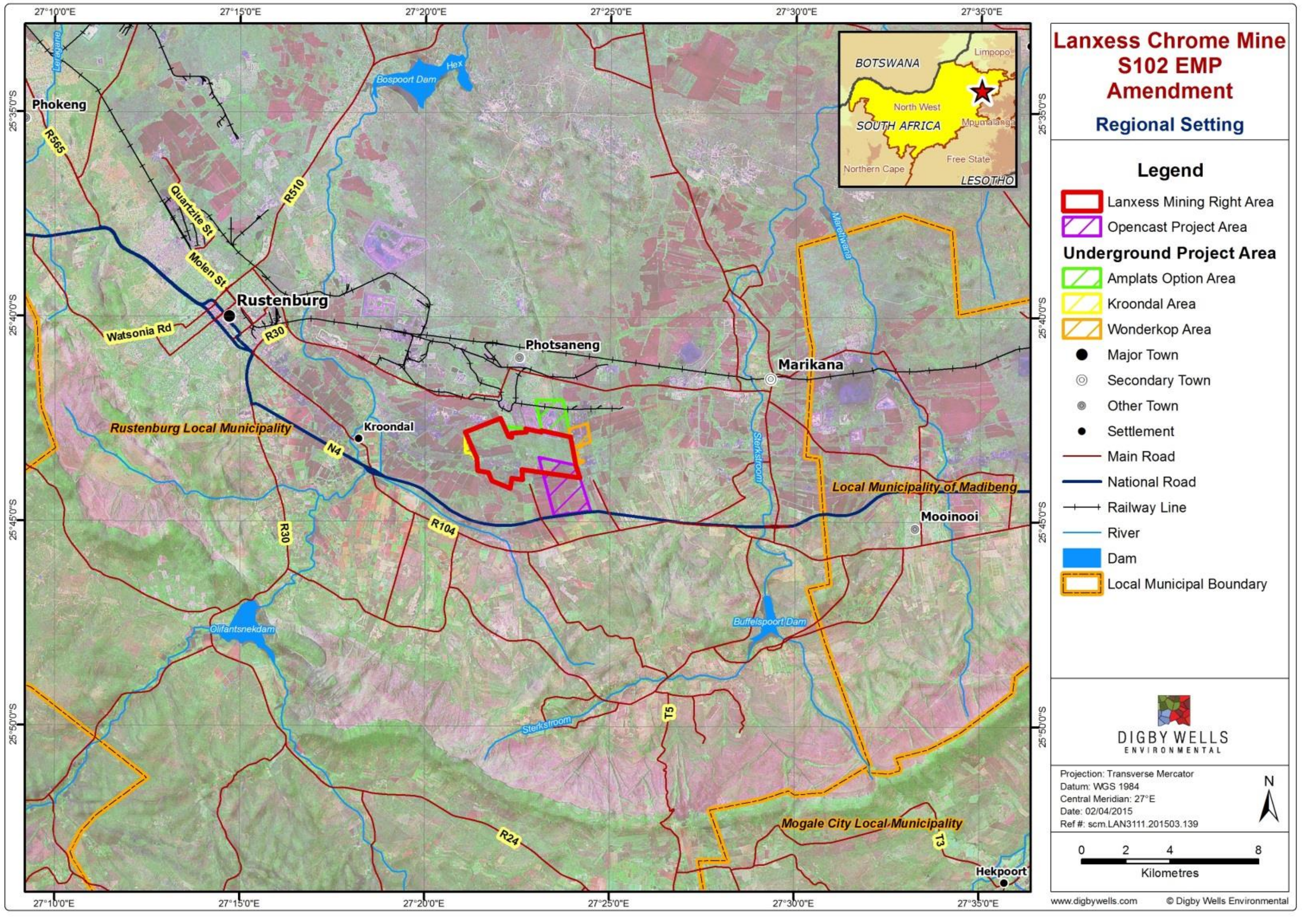

Figure 4-1: Lanxess regional setting

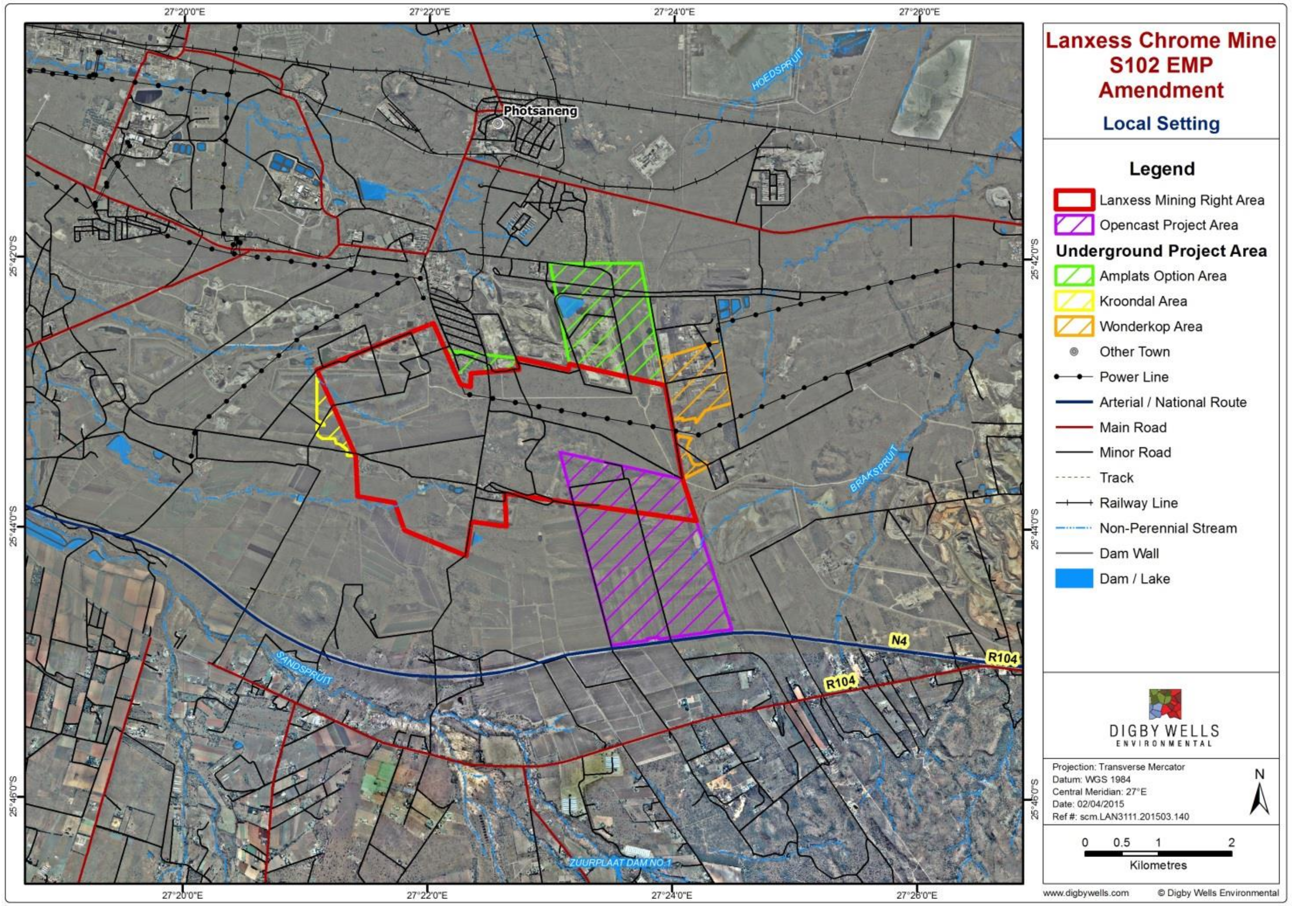

Figure 4-2: Lanxess local setting

Currently, the Department of Environmental Affairs operates four ambient monitoring stations, including the Waterberg-Bojanala Ambient Air Quality Monitoring Network. This network previously comprised of three air quality monitoring stations bought by the Department of Environmental situated in Lephalale, Thabazimbi and Mokopane. The fourth station which was recently installed in located in Brits. The following parameters are measured at each station: PM_{10}, $PM_{2.5}$, sulphur dioxide (SO_2), nitric oxide (NO), nitrogen dioxide (NO_2), nitrogen oxides (NO_x), ozone (O_3), carbon monoxide (CO), benzene (C_6H_6), toluene and xylene. In addition to the above, meteorological data for wind speed; wind direction, ambient temperature, relative humidity, rainfall, solar radiation and barometric pressure are also measured.

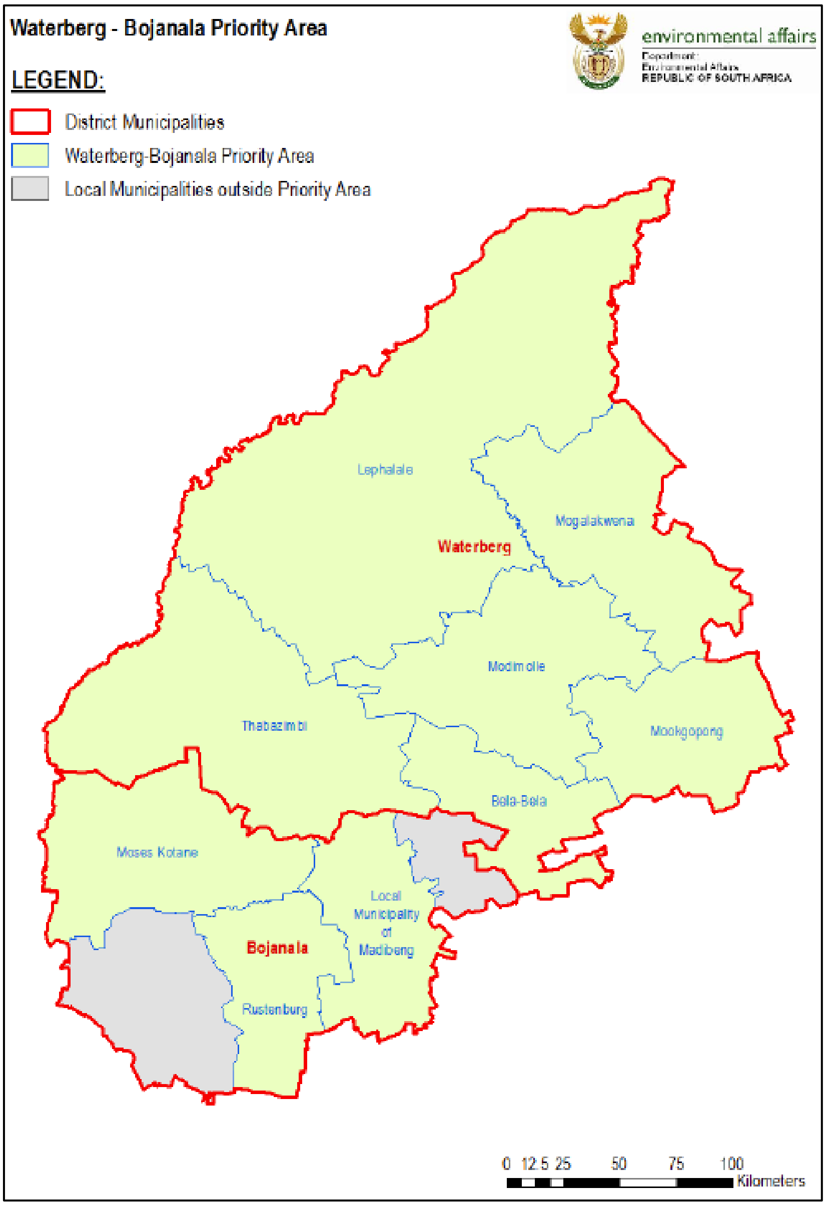

Figure 4-3: Waterberg- Bojanala Priority Area (DEA 2012)

5 REGIONAL CLIMATE AND FACTORS INFLUENCING AIR DISPERSION

5.1 Regional Climate

South Africa is located in the sub-tropics where high pressures and subsidence dominate. However, the southern part of the continent can also serve as a source of hot air that intrudes sub-tropics, and that sometimes lead to convective movement of air masses. On average, a low pressure will develop over the southern part of the continent, while the normal high pressures will remain over the surrounding oceans. These high pressures are known as Indian High Pressure Cell and Atlantic High pressure Cell. The intrusion of continents will allow for the development of circulation patterns that will draw moisture (rain) from either tropics (hot air masses over equator) or from the mid-latitude and temperate latitudes.

Southern Africa is influenced by two major high pressure cells, in addition to various circulation systems prevailing in the adjacent tropical and temperate latitudes. The mean circulation of the atmosphere over Southern Africa is anticyclonic throughout the year (except near the surface) due to the dominance of the three high pressure cells, namely South Atlantic High Pressure, off the west coast, the South Indian high pressure off the east coast and the continental high pressure over the interior.

It is these climatic conditions and circulation movements that are responsible for the distribution and dispersion of air pollutants within and around the Lanxess project area, neighbouring provinces and countries bordering South Africa.

5.2 Land Use

The major land use type in the area includes mining and agricultural activities.

5.3 Climate and Meteorological Overview

The climatic conditions in this region vary greatly from west to east. The far western region is arid encompassing the eastern sides of the Kalahari Desert. The central region is predominately semi arid while the eastern region is temperate (NWPG, 2002). 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.

The North- West province experiences warm wet summers and dry winters. Summer rainfall aids in removing pollutants through wet deposition. 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. 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 0.2 mm or more rainfall.

There are temperature seasonal and daily variations throughout the year. The daily high average temperatures of 32˚C can be experienced in January and mild to cold temperatures in winter (average daily minimum in July is 0.9 ˚C (NWPG, 2002). These vary greatly within the daily cycle and according to location, vegetation cover, wind reach, and the presence of any large water bodies. The austral winter in southern Africa is characterised by the presence of pronounced atmospheric inversion layer, which, combined with a regional high-pressure system, can trap the pollutants in the lower atmosphere in a large anti-cyclonic vortex covering the interior of southern Africa. This usually results in reduced dispersion and a poorer ambient air quality during the winter period. Preston-Whyte and Tyson (1988) describe the atmospheric conditions in the winter months as highly unfavourable for the dispersion of atmospheric pollutants.

Site specific (meso-scale model) MM5 modelled meteorological data set for full three calendar years (2011 – 2013) was obtained from Lakes Environmental Consultants 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 required if site specific surface and upper air meteorological data is not available. The Pennsylvania State University / National Center for Atmospheric Research (PSU/NCAR) MM5 is a limited-area, non-hydrostatic, terrain-following sigma-coordinate model designed to simulate or predict meso-scale atmospheric circulation (Lake Environmental Software, 2014).

This data has been tested extensively and has been found to be extremely accurate. Modelled meteorological data for the period January 2011 to December 2013 was obtained for Lanxess (25.733208 S, 27.394783 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 (Jacobson, 2005)

The amount of particulate matter (PM) generated by wind is highly dependent upon the wind speed. Below the wind speed threshold for a specific particle type, no PM is liberated, while above the threshold, PM liberation tends to increase with the wind speed. The amount of PM 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 (Fryrear *et al*., 1991)

Wind roses generally comprise of 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 top 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 Lanxess modelled data is clearly evident in Figure 5-1. The predominant wind direction is from the east and east northeast Over the three year period, frequency of occurrence was 11.8% from the east, 10.5% east north east, and 9.9% from north-easterly sector. Calm conditions (wind speeds < 0.5 m/s) occurred for 4.7% of the time. Wind class frequency distribution per sector is given in Table 5-1 and Figure 5-4.

There is some diurnal variation in the modelled meteorological data as shown in Figure 5-2. During the night, the predominant wind direction is from the east and south east, in the morning, the predominant wind direction is from the north east while during the afternoon its from the afternoon and in the evening it is from the south southeast. Calms are experienced the most during the afternoon period, 8.6%.

The wind roses for the four seasons are shown in Figure 5-3. The predominant wind direction is from the east north east, north east and south east. Summer experiences more calm periods (7.8% frequency of occurrence) which is higher than all the other seasons.

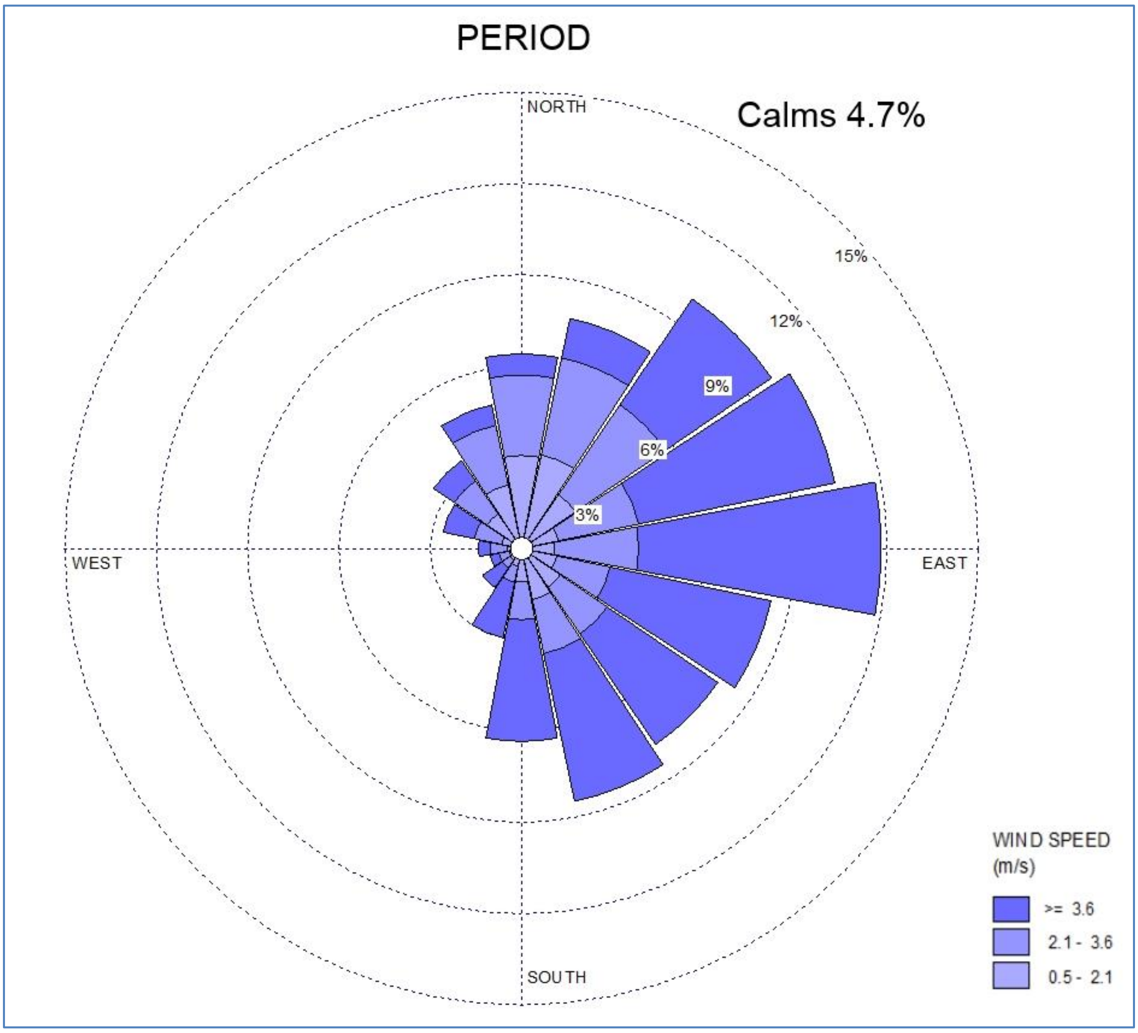

Figure 5-1: Period surface wind rose for Lanxess modelled data, 01 January 2011 - 31 December 2013 (Lakes Environmental 2014)

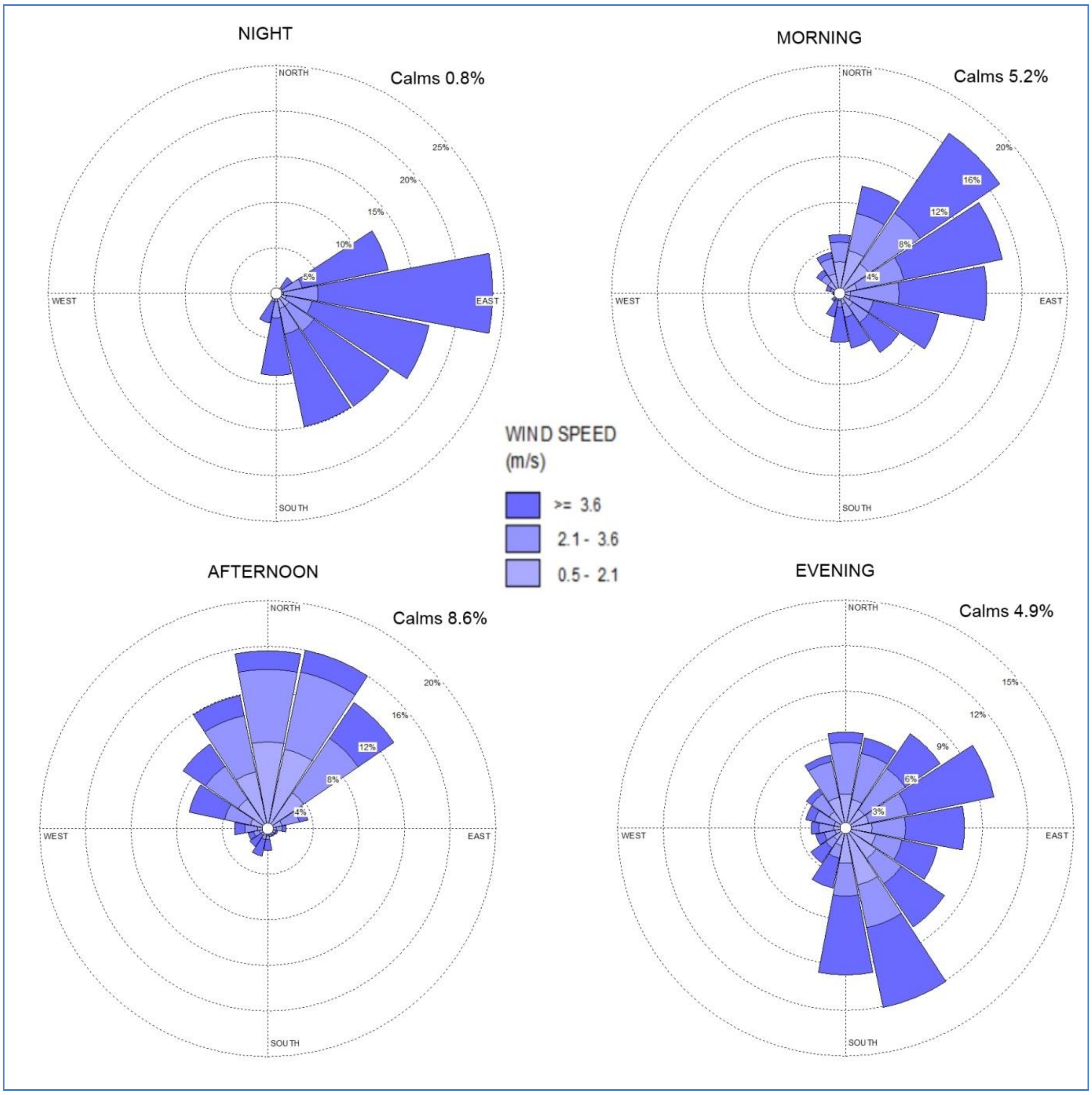

Figure 5-2: Diurnal variation of wind directions for Lanxess modelled data (01 January 2011 - 31 December 2013): Night 00:00 – 06:00 (top left), Morning 06:00 – 12:00 (top right), Afternoon 12:00 – 18:00 (bottom left) and Evening 18:00 – 23:00 (bottom right) (Lakes Environmental 2014)

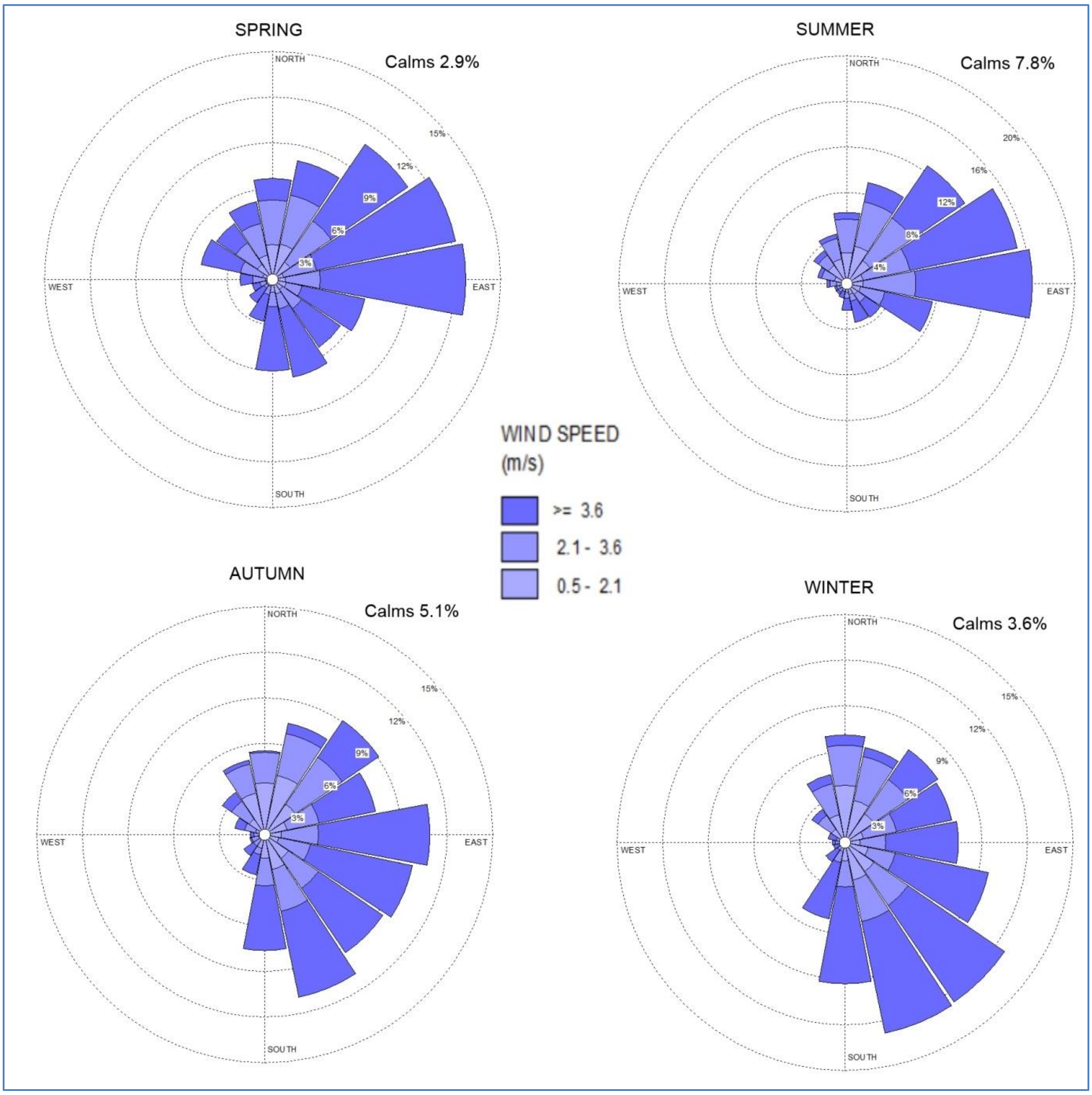

Figure 5-3: Seasonal surface wind roses for Lanxess modelled data (01 January 2011 - 31 December 2013): spring (September – November) summer (December – February); autumn (March – May); winter (June – August) and (Lakes Environmental 2014)

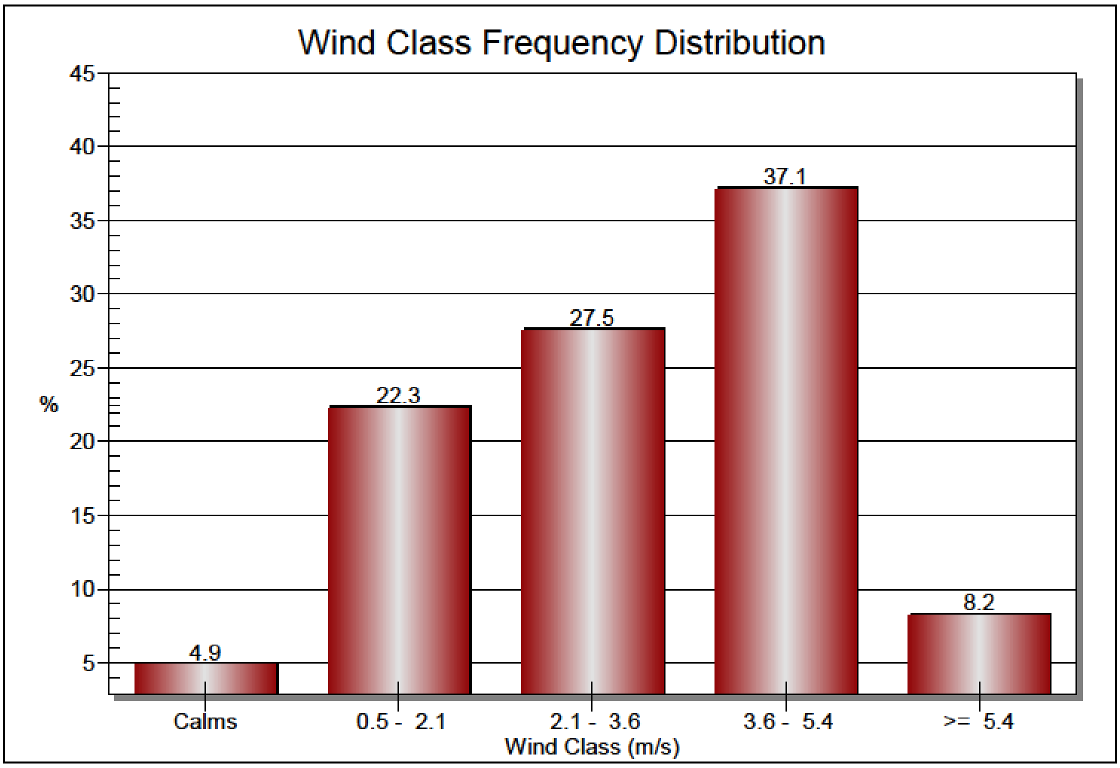

Figure 5-4: Wind Class Frequency Distribution for Lanxess modelled data (01 January 2011 - 31 December 2013 (Lakes Environmental 2014)

Table 5-1: Wind Class Frequency Distribution per Direction for Lanxess modelled data 01 January 2011 – 31 December 2013 (Lakes Environmental 2014)

	Direction	Wind classes (m/s)				
		0.5 - 2.1	2.1 - 3.6	3.6 - 5.4	>5.4	Total (%)
1	N	3.1	2.6	0.6	0.1	6.4
2	NNE	3.1	3.2	1.2	0.1	7.7
3	NE	2.1	3.6	3.2	1.0	9.9
4	ENE	1.2	2.7	5.7	0.9	10.5
5	E	1.1	2.7	7.6	0.3	11.8
6	ESE	1.2	1.8	5.1	0.3	8.3
7	SE	1.5	1.9	3.8	0.6	7.8
8	SSE	1.7	1.8	3.6	1.4	8.5
9	S	1.1	1.3	2.4	1.6	6.3
10	SSW	0.6	0.5	1.1	0.8	3.0
11	SW	0.5	0.3	0.6	0.2	1.6
12	WSW	0.4	0.3	0.2	0.1	1.1
13	W	0.5	0.5	0.3	0.1	1.4
14	WNW	0.7	0.9	0.6	0.4	2.6
15	NW	1.4	1.3	0.6	0.2	3.5
16	NNW	2.1	2.0	0.6	0.1	4.8
	Sub-Total	22.3	27.5	37.1	8.2	95.1
	Calms					4.9
	Missing/Incomplete			0.0		
	Total					100.0

5.4 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.

Three-year average maximum, minimum and mean temperatures for Lanxess area are shown in Figure 5-5 and Table 5-2. Annual mean temperature is 20.1°C. The average monthly maximum temperatures range from 13.3°C in July to 25.7°C in February, with monthly minima ranging from 12°C in July to 25.1°C in January.

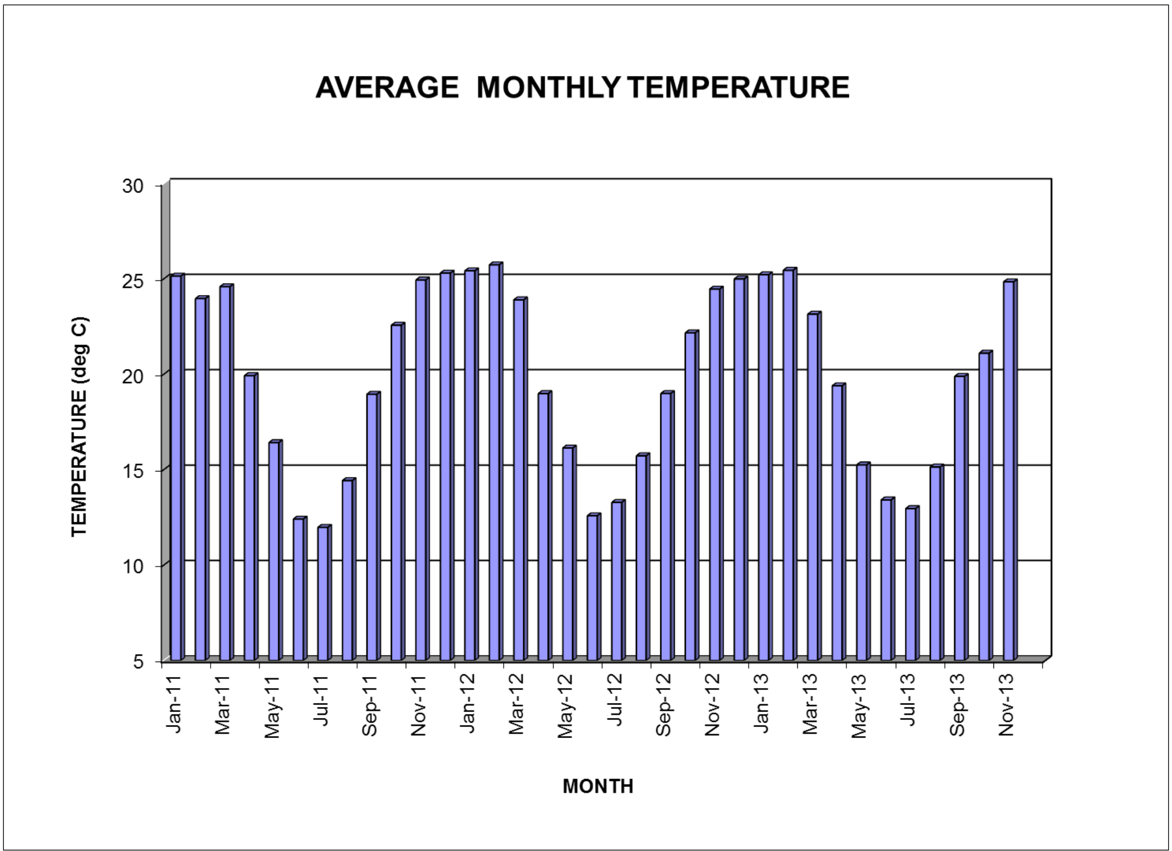

Figure 5-5: Average monthly temperature derived from the Lanxess modelled data 2011-2013 (Lakes Environmental 2014)

Table 5-2: Average Monthly temperature derived from the Laxness modelled data 2011-2013 (Lakes Environmental 2014)

Temperature (deg °C)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Monthly Max	25.4	25.7	24.6	19.9	16.4	13.4	13.3	15.7	19.9	22.6	24.9	25.3	20.60
Monthly Min	25.1	24.0	23.1	19.0	15.3	12.4	12.0	14.4	19.0	21.1	24.5	24.7	19.54
Monthly Mean	25.3	25.0	23.9	19.4	15.9	12.8	12.7	15.1	19.3	21.9	24.7	25.0	20.10

5.5 Relative Humidity

Figure 5-6 and the data in Table 5-3 depict the relative humidity for the Lanxess project area. The annual values for maximum, minimum and mean relative humidity are given as 66.4%, 62.3% and 64.2%, respectively. For the entire three years, maximum relative humidity of 76.4% in July and the lowest of 55.9% in November were observed. The highest minimum (70.6 %) was observed in June and the lowest (55.2%) in November.

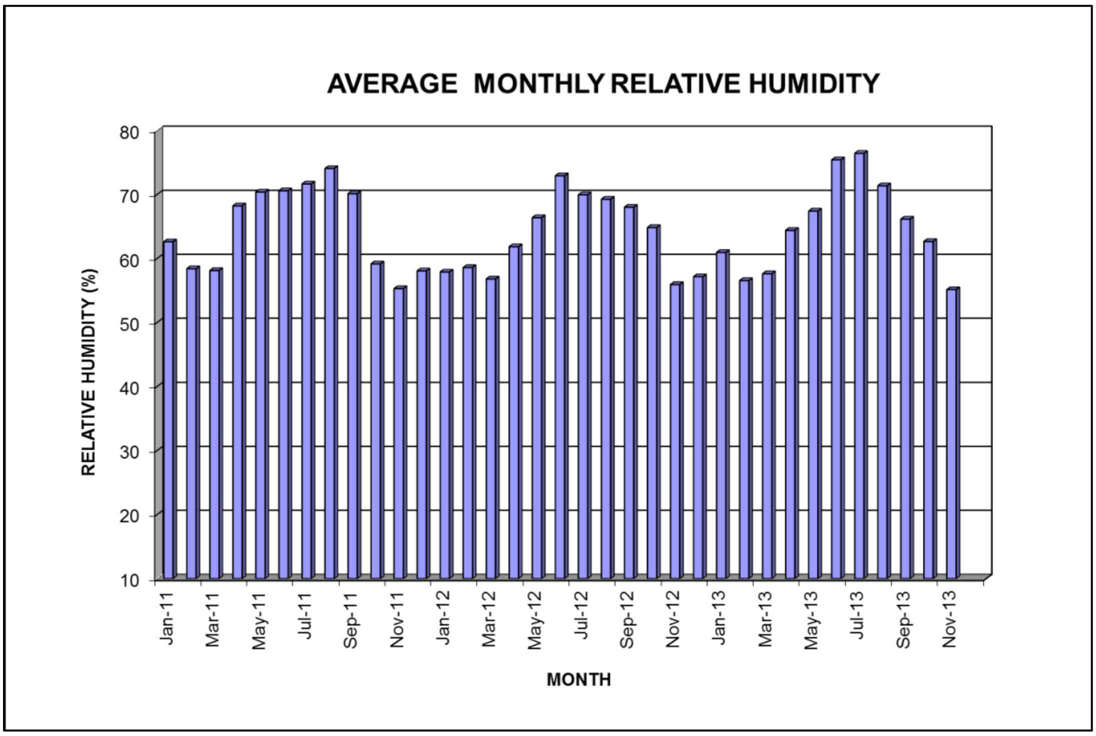

Figure 5-6: Average Monthly Relative Humidity derived from the Lanxess area modelled data 2011-2013 (Lakes Environmental 2014)

Table 5-3: Average Monthly Relative Humidity derived from the Lanxess area modelled data 2011-2013 (Lakes Environmental 2014)

Relative Humidity (%)	Jan	Fe b	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Monthly Max	62.6	58.6	58.1	68.2	70.4	75.4	76.4	74.1	70.1	64.8	55.9	62.1	66.4
Monthly Min	57.9	56.6	56.8	61.9	66.4	70.6	70.0	69.3	66.2	59.2	55.2	57.2	62.2
Monthly Mean	60.5	57.9	57.5	64.8	68.1	73.0	72.7	71.6	68.1	62.2	55.5	59.1	64.2

5.6 Rainfall

Figure 5-7 shows the total monthly rainfall (Maximum) and the average total monthly precipitation for the Lanxess area. As shown in Table 5-4, the annual total and average of

1687 and 562 mm were obtained from the modelled data respectively. The highest monthly maximum precipitation (159.5 mm) was observed in January and the lowest 0.5 mm in June.

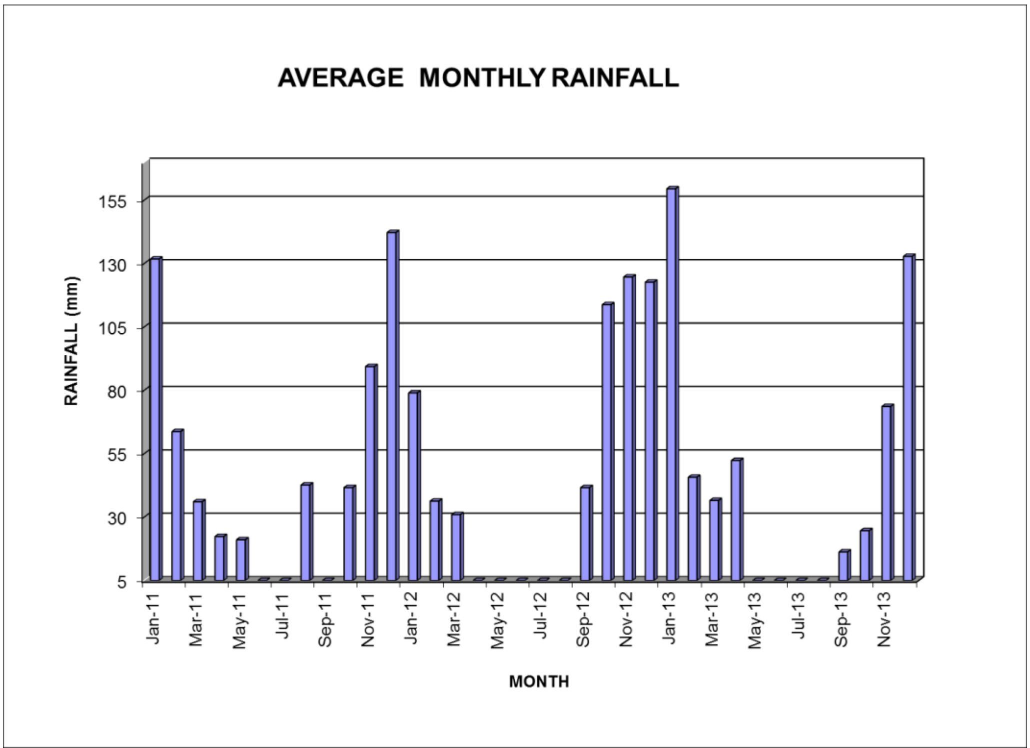

Figure 5-7: Average Monthly Precipitation derived from the Lanxess site modelled data 2011-2013 (Lakes Environmental 2014)

Table 5-4: Average Monthly Precipitation derived from the Lanxess area modelled data 2011-2013 (Lakes Environmental 2014)

Precipitation (%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
Total Monthly Rainfall (Max)	159.5	63.8	36.6	52.3	21.1	0.5	1.3	42.7	41.7	113.8	124.7	142.2	1687
Average Total Monthly Rainfall	123.4	48.6	34.5	25.0	7.3	0.3	0.5	15.2	19.5	60.0	95.9	132.6	562

6 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 repealed the Atmospheric Pollution Prevention Act (45 of 1965) (APPA).

According to NEM: AQA, 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 applications from applicants who have a problematic

[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.

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 2007 framework was amended on the 29 November 2013.

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 APPA of 1965 was fully repealed on the same date.

The NEM: AQA 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. On 31 March 2010 under GNR248 the list of activities which result in atmospheric emissions which may have a significant detrimental effect on the environment were published.1 April 2010 also marked the date when the new list of activities requiring Atmospheric Emissions Licenses to operate was promulgated and, with this, the levelling of the atmospheric emission "playing field" through the setting of minimum emissions standards for all these listed activities was implemented.

On 22 November 2013 the Minister repealed the listed activities promulgated on 31 March 2010 and introduced a new list of activities under GNR 893 promulgated on 22 November 2013. Government Notice 893 (GN893:2013) established and identified activities which result in atmospheric emissions for which an Atmospheric Emission Licence must be obtained before operation can take place.

GN893:2013 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. This list of activities has been amended and a revised version released in November of 2013.

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.

DEA has established the National Ambient Air Quality Standards for the criteria pollutants in the Government Notice - GN1210:2009 (Table 6-1).

Table 6-1 gives an overview of the established NAAQS, as well reference methods and compliance dates for criteria pollutants.

Table 6-1: 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	75	4	1 January 2015
1 year	40	0	1 January 2015
The reference method for the determination of the PM_{10} fraction of suspended particulate matter shall be EN 12341.			

National Ambient Air Quality 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	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 6-2: National Ambient Air Quality Standard for Particulate Matter $PM_{2.5}$

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.			

In line with NEM: AQA, the National Department of Environmental Affairs has published important National Dust Control Regulations in Government Notice 827 in Gazette 36974 on 1 November 2013.

Terms like target, action and alert thresholds were omitted. Another notable observation was the reduction of the permissible frequency from three to two incidences within a year. The standard actually adopted a more stringent approach than previously, and will require dedicated mitigation plans once it is in force.

The National Dust fallout standard is given in the

Table 6-3 below.

Table 6-3: Acceptable dust fall rates as measured (using ASTM D1739:1970 or equivalent) at and beyond the boundary of premises where dust originates.

Restriction Areas	Dust fall rate ($mg/m^2/day$, 30-days average)	Permitted Frequency of exceeding dust fall rate
Residential Area	D < 600	Two within a year, not sequential months
Non-Residential Area	600 < D < 1200	Two within a year, not sequential months

7 HEALTH EFFECTS OF THE IDENTIFIED POLLUTANTS

7.1 Particulates

The main pollutant of concern identified as a result of the 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).

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 its 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 7-1.

7.1.1 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 PM_{10} 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 PM_{10} concentrations ranged between 7 – 251 µg/m^3. Peak Expiratory Flow (PEF) was decreased and respiratory symptoms increased when PM_{10} 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.

7.1.2 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 7-1.

Studies have indicated an association between lung function and chronic respiratory disease and airborne particles. Older studies by Chestnut *et al* (1991) found that 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 7-1: 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 existing chrome mine, from the proposed construction, operational and decommissioning phases. Typical emissions from the chrome mine include:

- Inhalable particulates, with aerodynamic diameters less than or equal to 10 micron (PM_{10}) and $PM_{2.5}$ from all mining sources;
- TSP from all mining sources.

An emissions inventory was established comprising emissions for the different activities associated with the Lanxess operations. The establishment of this emissions inventory is necessary to provide the source and emissions data required as input to the dispersion model simulations. Emissions from the construction of the rail loop were not considered in this emission inventory as this was considered short-term and negligible.

8.1.1 Material handling operations

Material handling focuses on the loading and offloading of ore – tipping, and storage / conveyors. These emissions depend on various factors such as wind speed, wind direction and precipitation. The higher the moisture content of the material, the less fugitive dust will be released during the process. To calculate the emissions from the material handling operations, equations from USEPA AP42 and Australian NPI emission factors were utilised.

8.1.2 Vehicle activity on haul roads

For haulage of waste and ore material from the Lanxess operation, articulate vehicles i.e. 25 tonne trucks was assumed.

8.1.3 Wind erosion from ore stockpiles

Various stockpiles release dust fallout, PM_{10} and $PM_{2.5}$ and the stockpiles which were assessed during this assessment were the following:

- Waste dump;
- Tailings;
- HMS feed stockpile;
- HMS fines stockpile; and
- Metallurgical grade stockpile.

8.2 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).

It is anticipated that significant amounts of dust will be eroded from crusher under wind speeds of greater than 5.4 m/s (i.e. threshold friction velocity of 0.26 m/s). 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 of 5.4 m/s and stronger occur in the area some 4.7% of the time (Figure 5-4). An average wind speed of 3.0 m/s was calculated from the Lanxess modelled data.

9 METHODOLOGY, RESULTS AND DISCUSSION

9.1 Baseline Characterisation

The management of Lanxess have been monitoring dust deposition rates in the vicinity of its operations, with 10 monitoring sites in the network. Two additional sites were commissioned from April 2013, with the site names: new road and new offices respectively. Table 9-1, Table 9-2, Figure 9-1 and Figure 9-2 shows the dust fallout for the monitoring period November 2013 to August 2014. .

9.2 Dust deposition results

From November to January, the site labelled Magazine yard recorded deposition rates that exceeded the non-residential limit of 1200 mg/m^2/day for the 3 consecutive months thus violating the permissible frequency of exceedance of two recommended (NDCR, 2013). According to the standard, *the margin of tolerance is two times within a year or if the limit is exceeded, it must not be sequential months*. The site labelled Tailings Dam1 and Tailings Dam2 violated the permissible frequency of exceedance, with deposition rates of 1808 mg/m^2/day (November 2013) and 1508 mg/m^2/day (December 2013) and 1634 mg/m^2/day (November 2013) and 1202 mg/m^2/day (December 2013) Table 9-1. No data was recorded at the HMS plant 1 dump in January.

From February to May 2013, site labelled Tailings Dam1 and Tailings Dam2 exceeded the 1200 mg/m^2/day three month in a role (Table 9-1 and Table 9-2). In March only 4 sites did not exceed the non-residential limit and these are Bottom village, Magazine yard, HMS plant and dump 1. The newly commissioned sites new road and new office exceeded the limit (Table 9-2).

From May to August 2014, the monitoring site Magazine yard, new office and new road all recorded deposition rates in exceedance of the limit for more three consecutive months in a role. This is in violation of the recommended frequency of exceedance of two. The *margin of tolerance is two times within a year or if the limit is exceeded, it must not be two sequential months*. No data was recorded at the mine manager's village in August Table 9-2.

Table 9-1: Lanxess dust fallout results November 2013 to March 2014

Site	Site classification	Nov 13	Dec 2013	Jan 14	Feb 14	March 14
Bottom village	Non residential	946	512	847	728	898
Mine managers village	Non residential	784	574	833	1142	1876
Magazine yard	Non residential	2951	1402	2220	609	2303
Haul road	Non residential	1354	575	918	678	1363
Hostel and gravity plant	Non residential	2542	976	1054	134	1350
Tailings dam 1	Non residential	1808	1508	1043	1595	1272
Village	Non residential	446	529	894	906	2373
Tailings dam 2	Non residential	1634	1202	407	1380	2514
HMS plant and dump 1	Non residential	654	5022	0	983	1132
HMS plant and dump 2	Non residential	1208	589	83	650	1426

Table 9-2: Lanxess dust fallout results April to August 2014

Site	Site classification	April 14	May 14	June 14	July 14	Aug 14
Bottom village	Non residential	843	619	679	643	900
Mine managers village	Non residential	830	729	875	785	-
Magazine yard	Non residential	3374	2509	2214	1822	1846
Haul road	Non residential	850	821	834	830	844
Hostel and gravity plant	Non residential	998	1147	1219	652	1567
Tailings dam 1	Non residential	1420	3166	1739	935	1934
Village	Non residential	739	635	597	607	1044
Tailings dam 2	Non residential	1129	1040	913	1137	1172
HMS plant and dump 1	Non residential	663	686	544	553	746
HMS plant and dump	Non residential	1043	1041	972	782	1001
New road	Non residential	1337	1675	1648	1527	1597
New office	Non residential	1336	1344	1499	1141	1486

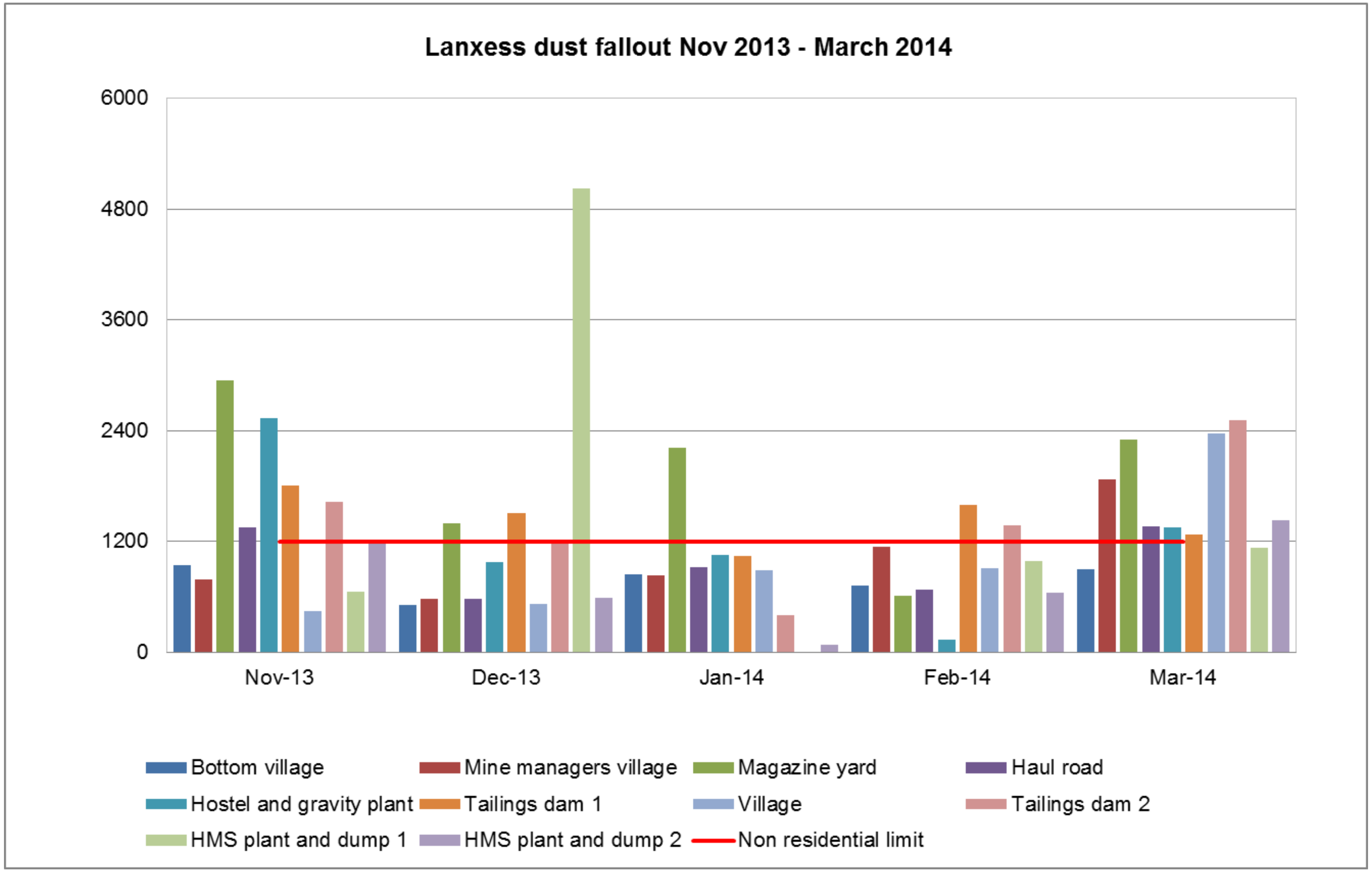

Figure 9-1: Lanxess dust fallout results November 2013 – March 2014 (Lanxess, 2015)

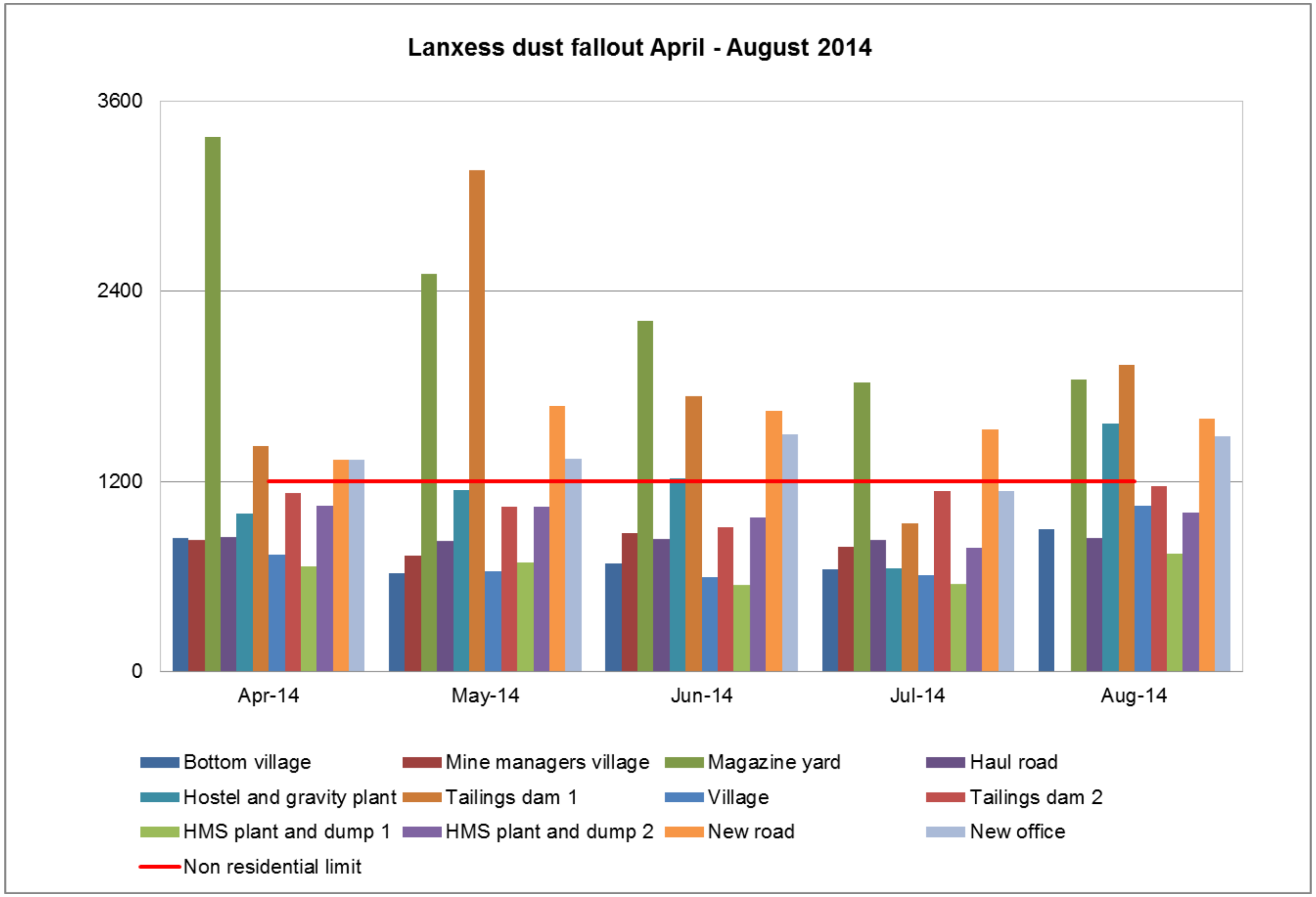

Figure 9-2: Lanxess dust fallout results April – August 2014 (Lanxess, 2015)

9.3 Dispersion Model Methodology and Scenario

The modelled scenario in this project involves the various infrastructure as shown in the infrastructure setting (Figure 9-3). It is assumed the mine's operations varies with the area with 8 hours per day for ore hauling and waste rock hauling and 16 hours for the process plant and the crusher. The pollutants modelled were PM_{10}, $PM_{2.5}$ and TSP. For TSP, two scenarios were modelled, deposition rates without mitigation and with mitigation.

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.

9.4 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 Lanxess.

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

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

A total of 15 081 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 Lanxess.

Years of analysis	Jan 2011 to Dec 2013
Centre of analysis	25.733208 S, 27.394783 E
Meteorological grid domain	12 km (east-west) x 12 km (south-north)
Meteorological grid cell resolution	12 km x 12 km
Station Base Elevation	1230 m amsl
MM5-Processed Grid Cell (Grid Cell Centre)	25.733208 S, 27.394783 E
Anemometer Height	14 m
Surface meteorological stations	1 site at the Lanxess operations using data generated by

	AERMET
Upper air meteorological stations	1 site at the Lanxess 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 *industrial*
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)

9.4.1 Sensitive receptors

Discrete receptors were identified as the residential area 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 dominant wind directions.

Table 9-5: Sensitive receptor locations

Receptor	Receptor number	UTM Easting	UTM Northing
Wigwam	1	530517.52 m E	7147455.76 m S
Kroondal	2	530884.55 m E	7154706.63 m S
Marikana	3	547626.86 m E	7157529.37 m S
Marikana Toll Plaza	4	539847.13 m E	7152235.71 m S
Buffelspoort	5	548409.85 m E	7147289.92 m S
Lapologang	6	546987.82 m E	7153315.48 m S
Waterkloof	7	531732.70 m E	7156771.84 m S
Nkaneng	8	538809.40 m E	7158034.5 m S

9.4.2 Source data requirements

The infrastructure layout utilised during the dispersion model was provided by the client as shown in Figure 9-3 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.

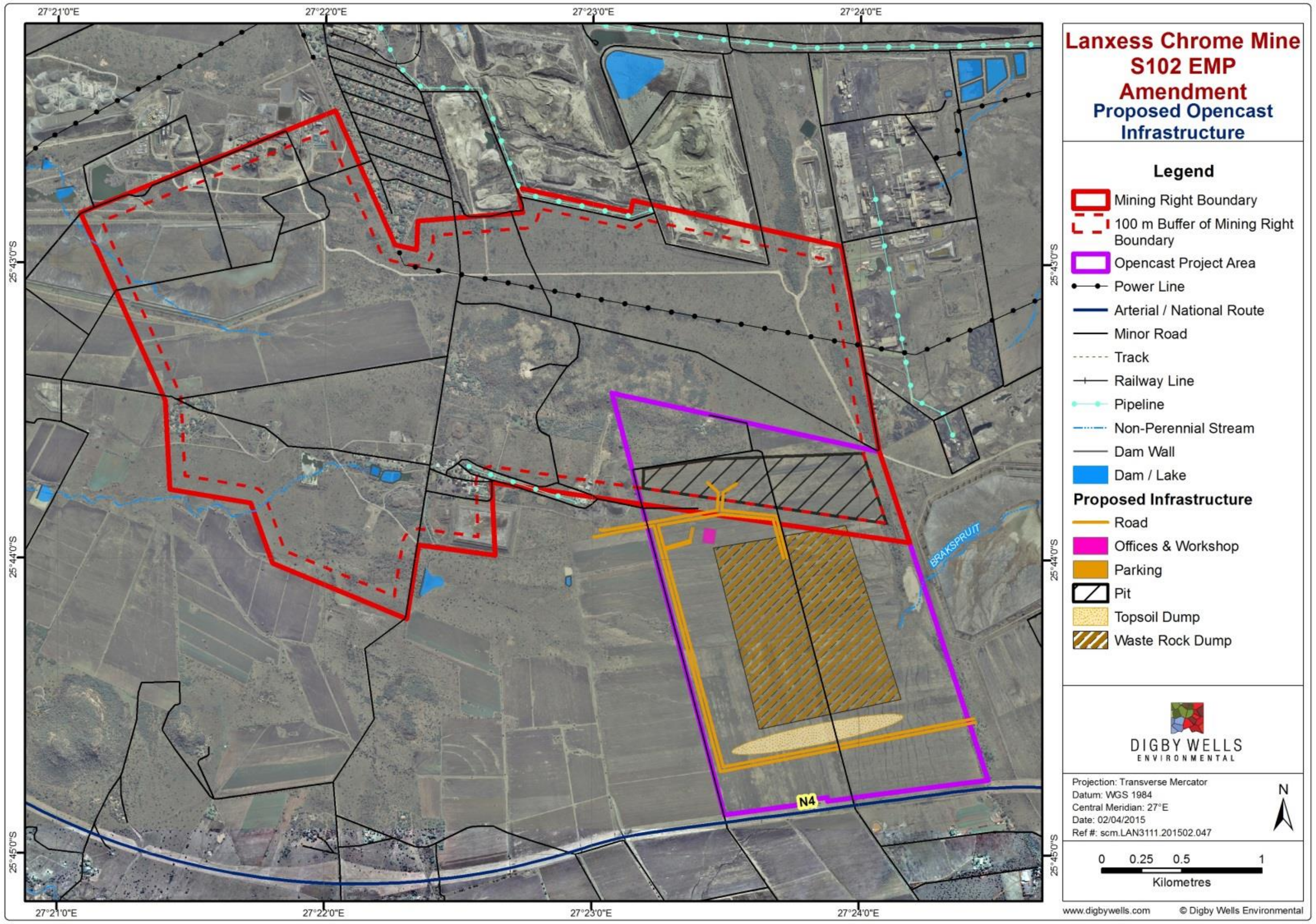

Figure 9-3: Project boundary and infrastructure layout for the proposed open pit operation

9.5 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 on Figure 5-1. Numerical values of maximum depend on the emission rate and the meteorological data used. Simulations were undertaken to determine concentrations of 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 ($PM_{2.5}$), and of deposition of total suspended particulates (TSP) all operations at the Lanxess mine.

9.5.1 Isopleth Plots and Evaluation of Modelling Results

9.5.2 PM_{10} predicted impacts

Isopleth plot of predicted highest daily values for PM_{10} generated by the Lanxess proposed activities is depicted in Figure 9-4, with the highest ground level concentration reaching 191 µg/m^3 (at point 539899.88, 7154370.64) and minimum of 1.9 µg/m^3. The predicted PM_{10} concentrations at the mine boundary do not exceed the current ambient air quality standard of limit 75 µg/m^3. Ambient levels at the various sensitive receptors are shown in Table 9-6.

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 9-6: Predicted 24 hour average PM_{10} concentrations at sensitive receptors

Receptor modelled	PM_{10} concentrations (µg/m^3)
Wigwam	2.0
Kroondal	3.7
Marikana	0.8

Receptor modelled	PM_{10} concentrations (µg/m^3)
Marikana Toll Plaza	5.7
Buffelspoort	1.0
Lapologang	11.3
Waterkloof	10.9
Nkaneng	2.0

The isopleth plot of the predicted highest annual values for PM_{10} generated by the proposed expansion activities is depicted in Figure 9-5 with an annual highest predicted ground level concentration of 43 µg/m^3 (at point 538399.88, 7153625.50) and minimum of 0.4 µg/m^3. This is in exceedance of the current limit 40 µg/m^3, However the levels at the sensitive receptors are below the limit. Concentration at selected sensitive receptors are given in Table 9-7

Table 9-7: Predicted annual average PM_{10} concentrations at sensitive receptors

Annual average PM_{10} concentrations (µg/m^3)	
Receptor modelled	**PM_{10} concentrations (µg/m^3)**
Wigwam	0.16
Kroondal	0.57
Marikana	0.08
Marikana Toll Plaza	0.09
Buffelspoort	0.10
Lapologang	0.67
Waterkloof	0.88
Nkaneng	0.16

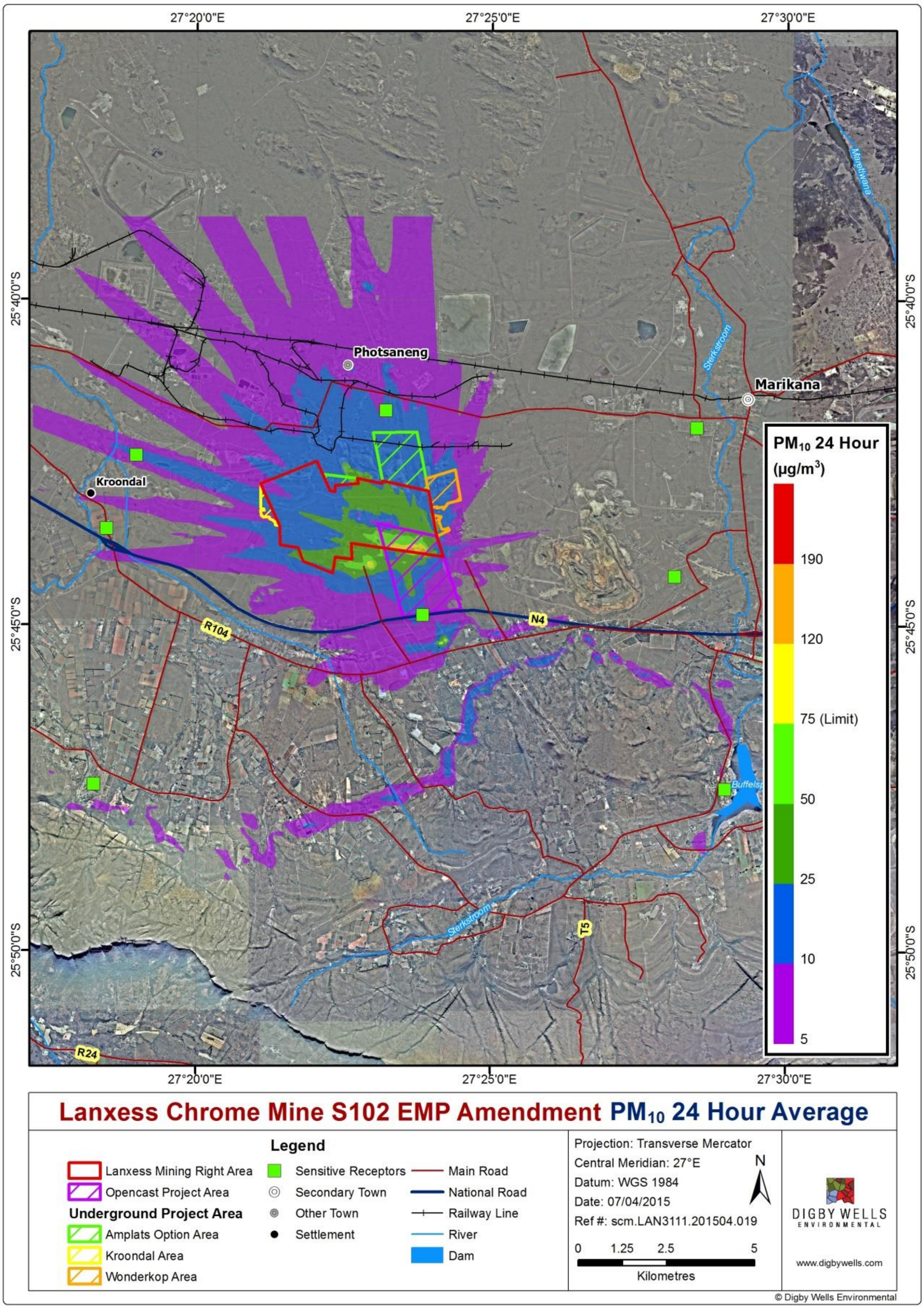

Figure 9-4: Predicted 4th highest (99th percentile) 24 hour average PM_{10} concentrations ($\mu g/m^3$) due to the Lanxess operations activities. (Lanxess boundary highlighted in black and the sensitive receptors in green)

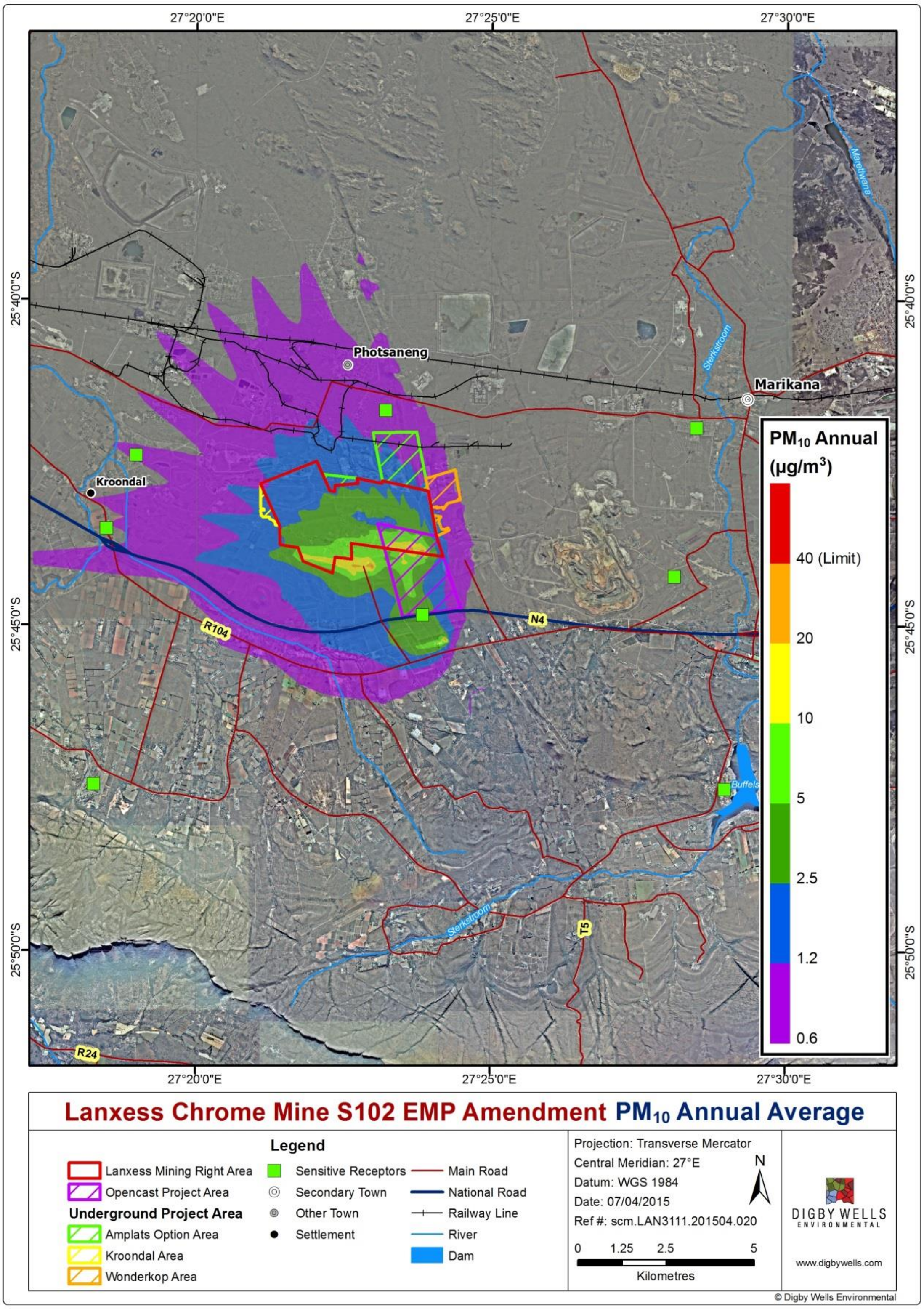

Figure 9-5: Predicted 1st highest (100th percentile) annual average PM_{10} concentrations ($\mu g/m^3$) due to the Lanxess operations activities. (Lanxess boundary highlighted in black and the sensitive receptors in green)

9.5.3 $PM_{2.5}$ Predicted impacts

Isopleth plot of predicted highest daily values for $PM_{2.5}$ likely to be generated from the proposed Lanxess activities is given in Figure 9-6 with highest predicted ground level concentration of 187 µg/m³ (at point 539899.88, 7154025.50). The predicted $PM_{2.5}$ impacts at the mine boundary do not exceed the current 24-hours standard of 65 µg/m³ and future limit 40 µg/m³ (comes into effect 1st January 2016 to 31 December 2029). Predicted concentrations at the sensitive receptors are presented (Table 9-8).

Table 9-8: Predicted 24 hour average $PM_{2.5}$ concentrations at sensitive receptors

Receptor modelled	$PM_{2.5}$ concentrations (µg/m^3)
Wigwam	0.31
Kroondal	0.58
Marikana	0.15
Marikana Toll Plaza	0.86
Buffelspoort	0.22
Lapologang	2.09
Waterkloof	3.40
Nkaneng	0.31

The predicted highest annual concentration of $PM_{2.5}$ likely to be generated from the proposed Lanxess activities is shown in Figure 9-7, with ground level concentration of 28 µg/m³ (at point 539899.88, 7154025.50). The predicted concentrations at the mine boundary do not exceed the current annual standard of 25 µg/m³ and the future limit of 20 µg/m³ (which comes into effect from the 1st of January 2016 to 31 December 2029). The predicted concentrations at the sensitive receptors are presented in Table 9-9.

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

Annual average $PM_{2.5}$ concentrations (µg/m^3)	
Receptor modelled	**$PM_{2.5}$ concentrations (µg/m^3)**
Wigwam	0.03
Kroondal	0.09
Marikana	0.02
Marikana Toll Plaza	0.01
Buffelspoort	0.03

Annual average $PM_{2.5}$ concentrations (µg/m^3)	
Receptor modelled	**$PM_{2.5}$ concentrations (µg/m^3)**
Lapologang	0.16
Waterkloof	0.25
Nkaneng	0.03

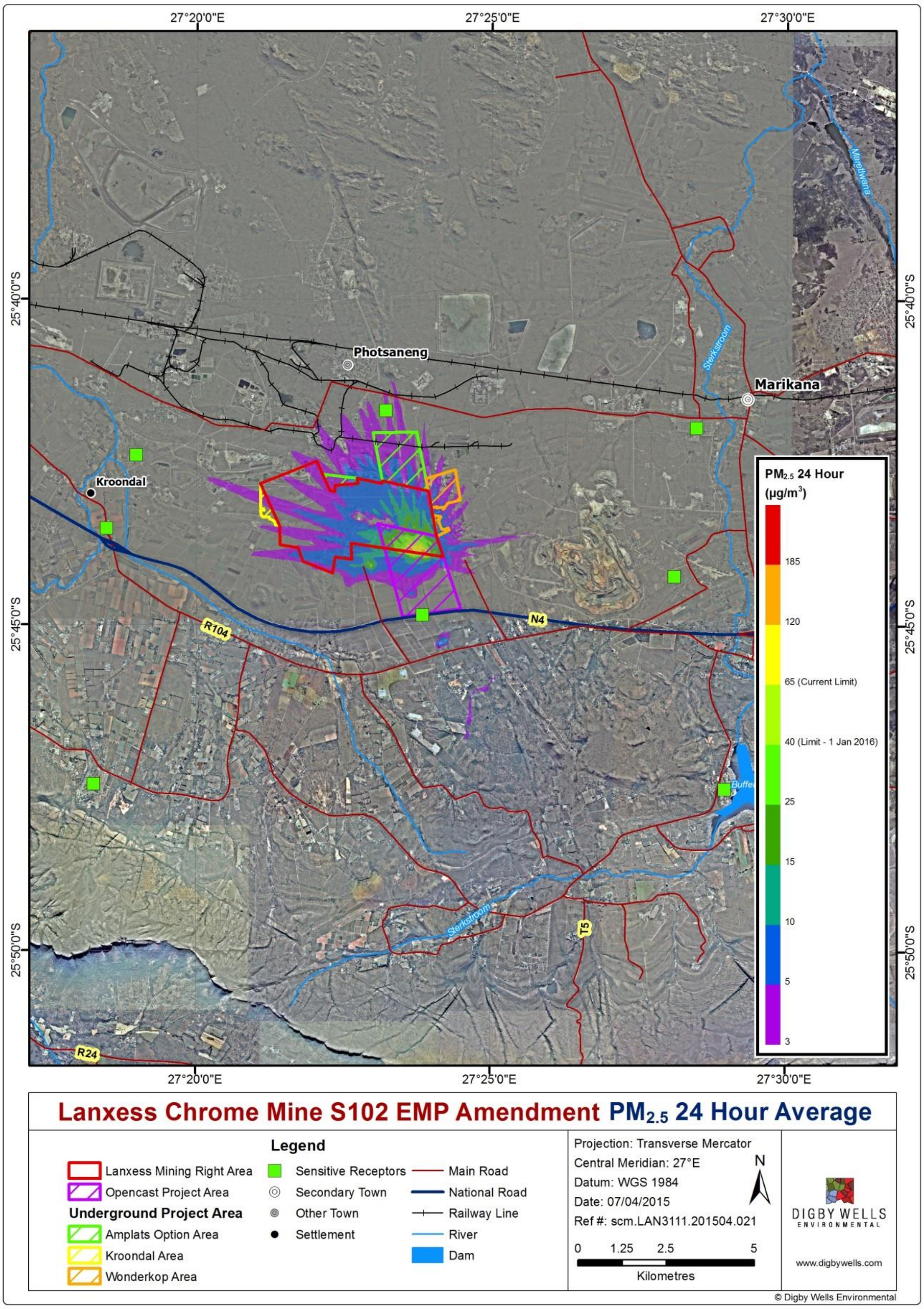

Figure 9-6: Predicted 4th highest (99th percentile) 24 hour average $PM_{2.5}$ concentrations ($\mu g/m^3$) due to the Lanxess operations activities. Lanxess boundary highlighted in red and the sensitive receptors in green)

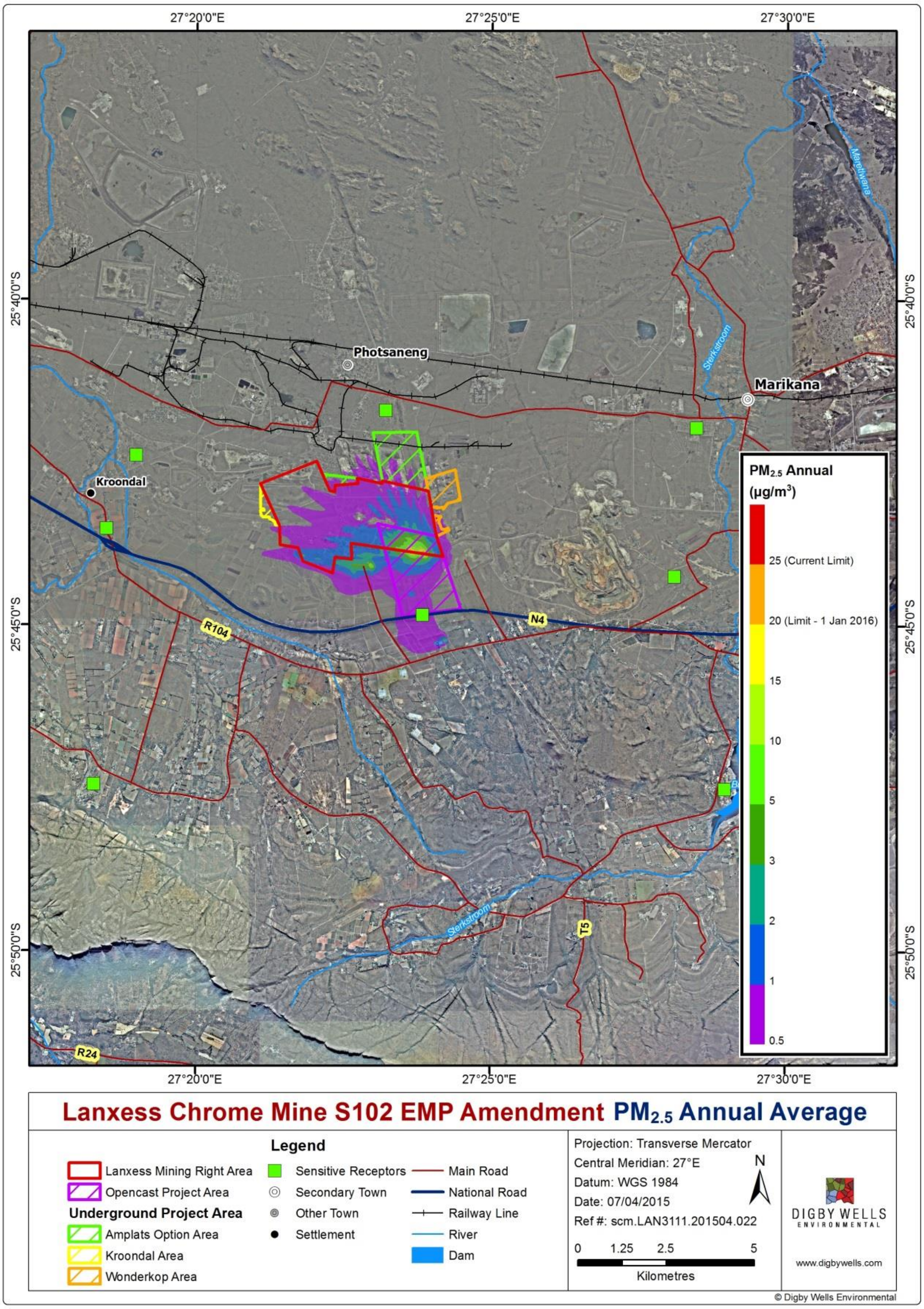

Figure 9-7: Predicted 1st highest (100th percentile) annual average $PM_{2.5}$ concentrations ($\mu g/m^3$) due to the Lanxess operations activities. Lanxess boundary highlighted in red and the sensitive receptors in green)

9.5.4 Dust deposition predicted impacts

The maximum daily dust deposition modelled was 2 292 mg/m²/day (Figure 9-8) located at point 537850.03, 715307853 within the mine boundary. The predicted dust deposition rates outside the mine boundary were not in exceedance of the current standard for residential and non-residential areas i.e. 600 mg/m²/day and 1 200 mg/m²/day (NDCR, 2013). Dust deposition rates at the sensitive receptors are presented in Table 9-10.

Table 9-10: Predicted 30 day average dust deposition (mg/m^2/day) no mitigation for sensitive receptors

Receptor modelled	(mg/m^2/day)
Wigwam	4.9
Kroondal	3.9
Marikana	3.2
Marikana Toll Plaza	4.5
Buffelspoort	5.5
Lapologang	3.3
Waterkloof	15.5
Nkaneng	4.9

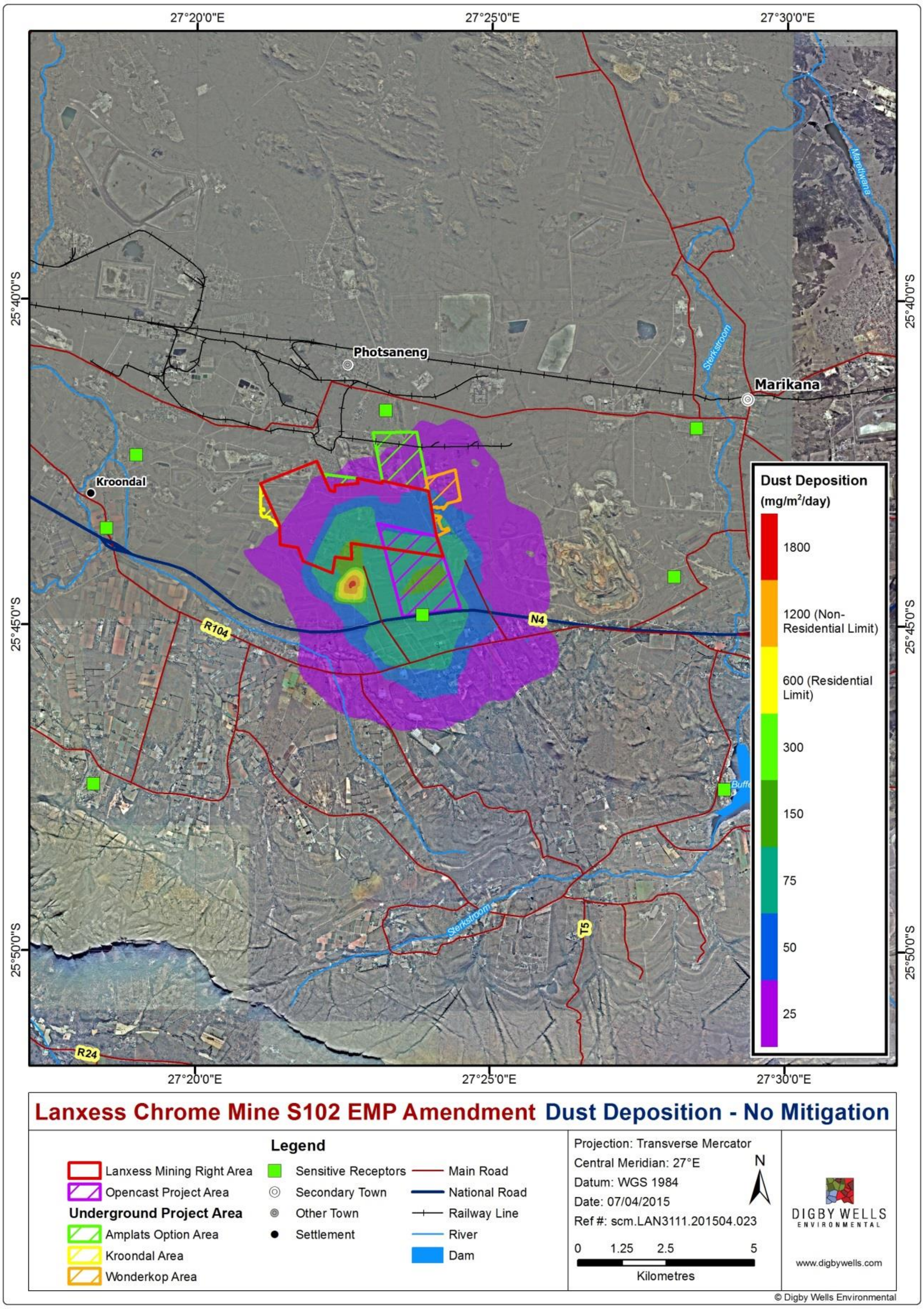

Figure 9-8: Predicted 30-days average (100th percentile) dust deposition (mg/m²/day) due to the Lanxess operations ctivities without mitigation. Lanxess boundary highlighted in red and the sensitive receptors in green

9.5.5 Mitigated dust deposition predicted impacts

To reduce the predicted dust deposition impacts, mitigation measures are implemented on various processes within the operations. The following were the mitigation measures with control factors implemented to ameliorate emission from sources.

Table 9-11: Estimated control factors for the Lanxess activities

Operation / Activity	Control method and emission reduction
Haul roads	75% for level 2 watering (>2 litres/m^2/h)
Tipping to stockpiles	70% for water sprays
Crushers	90% total enclosure
Wind erosion	30% for wind breaks
Drilling	70% water sprays

*Source Australian NPI (2012) Version 3.1

After the above mitigation measures were implemented, the model predicted a reduction in the dust deposition rates, with the predicted maximum decreasing to 1 604 mg/m²/day (Figure 9-9 located at point 537850.03, 715307853). The predicted dust fallout impacts at the mine boundary do not exceed the current NDCR 2013 standard for residential and non-residential areas (i.e. 600 mg/m²/day and 1 200 mg/m²/day). The dust deposition rates measured at the different sensitive receptors were observed to have decreased after mitigation measures were implemented (Table 9-12).

It should be noted that isopleth plots reflecting daily averaging periods contain only the highest predicted ground level dust deposition rates for that averaging period, over the entire period for which simulations were undertaken. These isopleths are likely concentrations that the proposed Lanxess activities would have on ambient air quality and not cumulative impact from all the sources. *It is therefore possible that even though a high daily deposition rate is predicted to occur at certain locations, that this may only be true for one day during the entire period.*

Table 9-12: Predicted 30 day average dust deposition (mg/m^2/day) with mitigation for sensitive receptors

Receptor modelled	(mg/m^2/day)
Wigwam	3.3
Kroondal	2.3
Marikana	2.2
Marikana Toll Plaza	3.1
Buffelspoort	3.7

Receptor modelled	(mg/m^2/day)
Lapologang	2.0
Waterkloof	10.1
Nkaneng	3.3

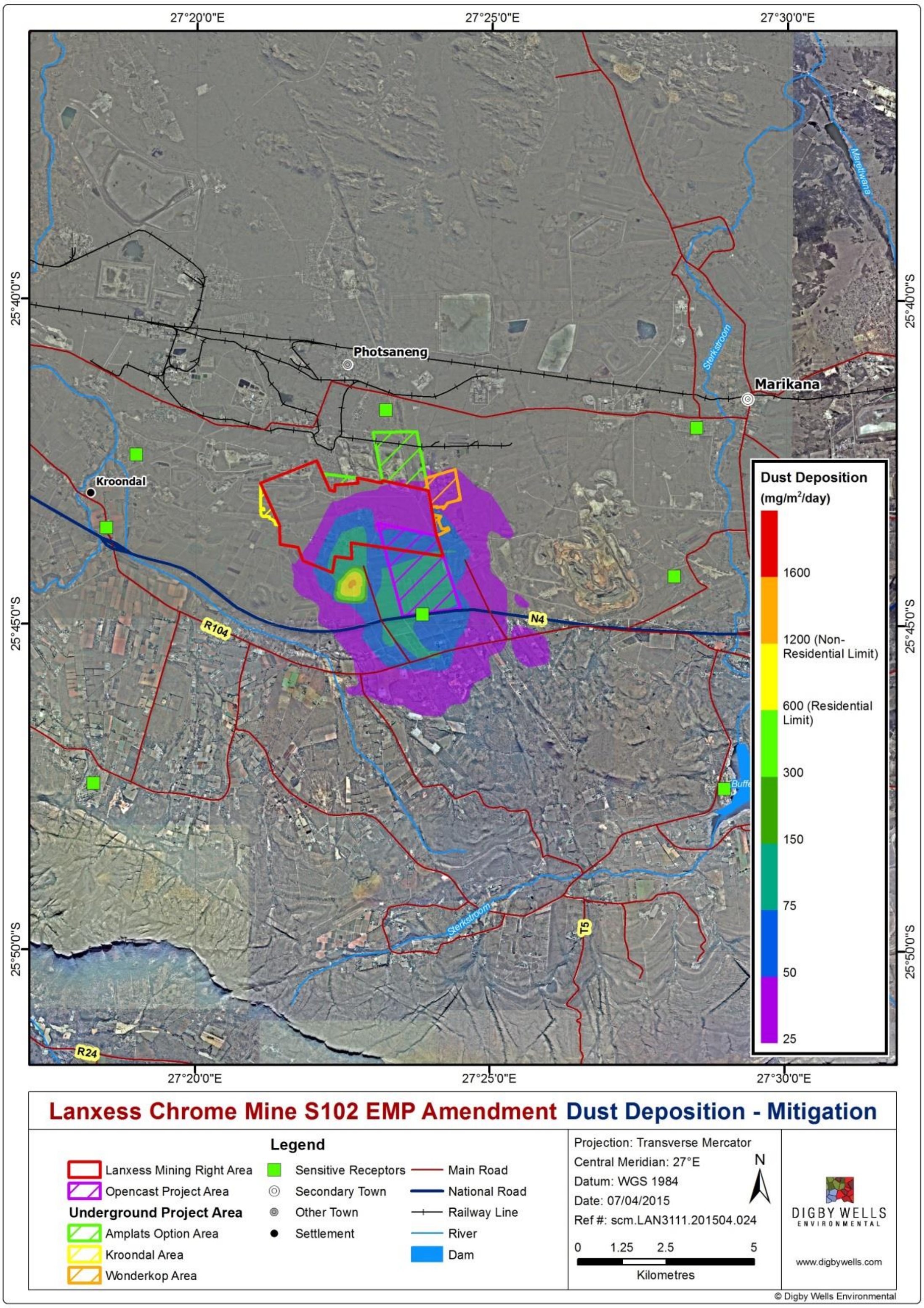

Figure 9-9: Predicted 30-days average (100th percentile) dust deposition (mg/m^2/day) due to the Lanxess operations activities with mitigation. Lanxess boundary highlighted in red and the sensitive receptors in green)

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 within the mine boundary and for downwind communities/other sensitive receptors if management practices are not implemented. Typically, as with Lanxess, the following are air pollution sources: wind erosion of exposed stockpiles, wind erosion of exposed surface areas, unpaved roads, crushing and screening and materials handling processes.

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 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, (eg 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)								
		1	3	5	7	9	11	15	18	21
Probability / Likelihood	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	108	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**	

10.3 Operational Phase

Crushing and screening.	
Criteria	**Details / Discussion**
Description of impact	During this stage, the ore from the underground operations and the open pit will be crushed to reduce the size. The dust generated encompasses TSP, PM_{10} and $PM_{2.5}$ (this fraction is causing health problem in the human respiratory system due to the depth of penetration and the resultant interaction with human tissues).

Mitigation required	To mitigate the impacts, the crusher should be enclosed to control the dust that is generated in the process. The application of water sprays also helps to suppress generated dust thus reducing the impact offsite.				
Parameters	*Spatial*	*Duration*	*Intensity*	*Probability*	*Significant rating*
Pre-Mitigation	3	5	4	4	72
Post-Mitigation	2	5	3	5	50

Dumping of waste rock					
Criteria	**Details / Discussion**				
Description of impact	During this stage, waste rock brought to the surface and those from the open cast process is loaded onto 30 tonne tipper trucks and offloaded at the waste rock dumps. The loading and offloading process results in dust generated comprises TSP, PM_{10} and $PM_{2.5}$ (this fraction is causing health problem in the human respiratory system due to the depth of penetration and the resultant interaction with human tissues).				
Mitigation required	To mitigate the impacts of the loading and dumping process, the drop height when loading and offloading must be lowered.				
Parameters	*Spatial*	*Duration*	*Intensity*	*Probability*	*Significant rating*
Pre-Mitigation	3	5	4	4	72
Post-Mitigation	2	5	3	5	50

Stockpiling material	
Criteria	**Details / Discussion**
Description of impact	Materials i.e. ROM, lumpy ore, crusher fines, HMS fines and stockpiles CO1, CO4 and CO6 are stored at their respective stockpiles. The various

	stockpiles thus represent sources of dust, with the subsequent erosion of dust that comprises TSP, PM_{10} and $PM_{2.5}$.				
Mitigation required	To mitigate the impacts of the stockpiling, water sprays on the stockpiles need to be utilised, use of wind breaks can be implemented near the respective stockpiles as these reduce anticipated dust impacts by 30%.				
Parameters	*Spatial*	*Duration*	*Intensity*	*Probability*	*Significant rating*
Pre-Mitigation	3	5	3	3	66
Post-Mitigation	2	5	3	5	50

Transporting material					
Criteria	**Details / Discussion**				
Description of impact	This focuses on the use haul roads and then the conveyance of chrome using conveyor belts. During this stage, materials are transported to the various stockpile using 3 tonne tipper trucks, which leads to the generation of fugitive dust comprising TSP, PM_{10} and $PM_{2.5}$.				
Mitigation required	To mitigate the impacts, reduce vehicle speed will reduce emission to the atmospheric environment. Water sprays on the road should be used frequently, keeping the road moist. Dust suppressants such as Dust-a-side can be applied on the well-defined truck routes. Making speed humps and ensuring that the speed limits are adhered to or enforced to reduce potential generation of dust particles.				
Parameters	*Spatial*	*Duration*	*Intensity*	*Probability*	*Significant rating*
Pre-Mitigation	3	5	5	6	78
Post-Mitigation	2	5	3	6	60

Activity/Impact	Activity/Impact (4) – Decommissioning				
Criteria	**Details / Discussion**				
Description of impact	This activity entails the removal of buildings and foundations and rehabilitation of the voids and spreading of sub soil and topsoil. The reshaping and restructuring of the landscape though spreading of subsoil and topsoil will generate dust as soil is being transferred from one location to another. There is movement and transfer of soil to rehabilitate the void.				
Mitigation required	Spreading of soil must be performed on less windy days. The bare soil will be prone to erosion there is need to introduce surface vegetation cover to check erosion. Leaving the surface of the soil in a coarse condition reduces wind erosion and ultimately reduces the dust levels. Additional mitigation measures include keeping the soil moist using sprays or water tanks, using wind breaks. The best time to re-vegetate the area must be linked to the distribution and reliability of the rainfall.				
Parameters	*Spatial*	*Duration*	*Intensity*	*Probability*	*Significance rating*
Pre-Mitigation	3	2	4	6	54
Post-Mitigation	3	2	3	5	40

11 MITIGATION MEASURES AND MANAGEMENT PLAN

Mitigation and management measures detailed below will reduce emission of particulate matter from sources into the surrounding environment.

11.1 Material handling operations

Elimination of dust generation at transfer points is not feasible; however, this can be controlled to fall within compliance. An enclosure at the transfer points is necessary to control emissions. Fall heights of the transfer points should be reduced though the use of spiral chutes. Load profiling creates a consistent surface of ore in each truck, which would be implemented at the mine. The magnitude of ore dust emissions from transport of ore in trucks will depend on a number of factors, such as the level of exposure of the open surface to air moving at high speeds and the inherent dustiness of the material. Measures that can be applied include: potential modifications to trucks to reduce wind contact with ore during transport, employ water or air blow-down to reduce parasitic loads on trucks exiting load-out bay. Dust can be mitigated using water and having an enclosure on the crushers. To manage the fugitive dust, the feed side of the crusher must be enclosed (USBM, 1974).

11.2 Haul roads

As ore will be transported for a longer distance from the western shaft to the plant, dust will be generated. The fugitive dust from haul roads increases the particulate loading of the atmosphere and at the same time reduces visibility. Effective dust management measures reduce fugitive dust from haul roads. The effectiveness of dust suppressant is proven on haul roads. Dust suppressants work by forming a layer over the top of the roads i.e. dust-a-aside. Midwest Research Institute (1981) advises that road construction should have the following properties: resistance to wear, soundness, maximum size, particle shape and gradation.

11.2.1 Speed control

Reducing speed on haul roads is an effective way to manage fugitive dust. However, reducing speed may lower the production of mines. Studies by Watson et al., 1996 showed that reducing speed reduces the generation of particles less than 10 micro meters by about 58% when speed controls are reduced from 25 mph (40 km/h) to 15 mph (24 km/h). Reducing the volume of traffic on the haul roads reduces the impacts of dust entrainment.

11.2.2 Load covers

When loads are covered by tarps, the loaded material is prevented from being airborne. Chepil (1958) shows that entrainment may occur when air flow comes into contact with materials exceed 21 km/h for small material (0.1 mm) large materials require high velocities. Wetting of the loaded materials can be done to keep the material moist and further reduce the dust generated.

12 MONITORING PROGRAMME

12.1 Dust Monitoring Programme

It recommended that the management of Lanxess continue the current dust monitoring programme throughout the project life of the mine. This will ensure that historical dust deposition data is available to 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. As trucks are a major source of dust, reducing speed of trucks in haul roads will reduce dust immensely.

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 (this is the threshold for transporting particles) extra dust control measures need to be carried out. During dust generating periods, sprinkling until it is moist is ideal for haul roads and traffic routes (Smolen *et al*., 1988). It must be noted however that excessive sprinkling to manage dust may result in runoff from the site.

12.2 Particulate Monitoring Programme

Lanxess should establish a fine particulate monitoring programme which should include at least one particulate instrument to monitor either PM_{10} or $PM_{2.5}$. Ideally, both set of pollutants should be monitored as required by regulatory authorities. In addition to pollutants, the ambient monitoring unit should include measurement of meteorological parameters representative of the mining area. Air dispersion modelling should always use site specific data if available. It is advised to install the unit at least one year prior to the construction phase to allow for the collection of ambient air quality baseline data set.

13 RECOMMENDATIONS

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

- Ensure that air quality levels during the construction and operational phase comply with all relevant statutory standards, and that air quality impacts on surrounding sensitive receptors are minimised.
- Adherence to the suggested mitigation measures outlined in this report is recommended in order to reduce anticipated impacts.
- Start ambient air monitoring programmes i.e. PM_{10}.

- The air quality impacts on the mine boundary are to be minimised to ensure compliance
- Any changes to the mine infrastructure will require the dispersion model to be updated accordingly and the management and mitigation to be updated.

14 CONCLUSION

The following pollutants were assessed TSP, PM_{10}, and $PM_{2.5}$ within the project boundary and on the 8 sensitive receptors. The 4th highest PM_{10}, 24 hour level of 191 µg/m³ was predicted within the project boundary. Although this is within the mine boundary, it is in exceedance of the current ambient PM_{10} standard of 75 µg/m³. This can have an impact on the health of workers who are exposed to ambient concentration of that level. However, all the sensitive receptor sites were below the 75 µg/m³ limit. The PM_{10} annual level of 43 µg/m³ predicted within the mine boundary is also in exceedance of the current standard. This can have adverse implication on the health of exposed mine workers if mitigation measure are not applied to bring this within compliance. The concentration predicted at all the selected sensitive receptors were all below the limit.

For $PM_{2.5}$, the 4th highest $PM_{2.5}$, 24 hour level of 187 µg/m³ was predicted within the project boundary; however all the sensitive receptors were below the 65 µg/m³ limit. The $PM_{2.5}$ annual level of 28 µg/m³ was experienced in the project boundary but the sensitive receptors were all below the limit. The levels $PM_{2.5}$ daily and annual are in exceedance within the mine boundary. Thus, the exposed workers are at risk due to daily exposure of this pollutant higher than the recommended limit.

In terms of dust deposition, the predicted deposition rates are in agreement with the measured data. The highest dust fallout level was predicted to occur within the project boundary (2 292 mg/m²/day). The deposition rates predicted for the different sensitive receptors were all below the 600 mg/m²/day. When the mitigation measures were implemented, the dust fallout level in the project boundary reduced to 1 604 mg/m²/day and the anticipated fallout dust at the sensitive receptors reduced further.

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