Project done on behalf of
Exxaro Resources Limited

AIR QUALITY IMPACT ASSESSMENT FOR THE PROPOSED BELFAST PROJECT, MPUMALANGA

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Notice	Airshed Planning Professionals (Pty) Ltd is a consulting company located in Midrand, South Africa, specialising in all aspects of air quality, ranging from nearby neighborhood concerns to regional air pollution impacts. The company originated in 1990 as Environmental Management Services, which amalgamated with its sister company, Matrix Environmental Consultants, in 2003.
Declaration	Airshed is an independent consulting firm with no interest in the project other than to fulfil the contract between the client and the consultant for delivery of specialised services as stipulated in the terms of reference.
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Acknowledgements	The authors would like to express their sincere appreciation for the invaluable discussions and technical input from Charles Linstrom of Exxaro Resources Limited.

EXECUTIVE SUMMARY

Airshed Planning Professionals (Pty) Limited was appointed by Exxaro Resources Limited (Pty) Ltd (hereafter referred to as Exxaro) to undertake an air quality impact assessment for the proposed Belfast Coal Mine. Exxaro is evaluating a potential coal reserve on the farms Leeuwbank, Zoekop and Blyvooruitzight. The Belfast site is an undeveloped coal resource situated approximately 10 km southwest of Belfast in Mpumalanga.

The main objective of the study is to determine the significance of air pollution impacts from the proposed mining activities on the surrounding environment and on human health.

TERMS OF REFERENCE

The proposed terms of reference for the *baseline air quality characterisation* component of the assessment are as follows:

- The regional climate and site-specific atmospheric dispersion potential;
- Identification of the potential sensitive receptors within the vicinity of the proposed site;
- Preparation of hourly average meteorological data for the model input;
- Identification of existing sources of emission in the area;
- Characterisation of ambient air quality and dustfall levels in the region based on observational data recorded to date (if available);
- Preparation of background maps;
- The legislative and regulatory context, including emission limits and guidelines, ambient air quality guidelines and dustfall classifications.

The proposed terms of reference for *assessing the air quality impacts* associated with the mining activities:

- Compilation of an emissions inventory, comprising the identification and quantification of all potential *routine* sources of emission from the proposed operations at the mine;
- Dispersion simulations of ambient respirable particulate concentrations and dust fallout from the proposed mining activities;
- Analysis of dispersion modelling results from the proposed mining operations;
- Evaluation of potential for human health and environmental impacts;
- Develop a dust management plan

ASSUMPTIONS AND LIMITATIONS

- The impact assessment was limited to airborne particulates (including Total Suspended Particulates (TSP)) and inhalable particulate matter (PM10). Although the proposed activities would also emit other gaseous pollutants, primarily by vehicle activity, the impact of those was regarded to be low and was omitted from the study.

- As the potential wind erosion from the overburden material will be minimal or negligible due to the large particle sizes associated with this type of material, the impacts from this were not quantified during the study.

- A baseline air quality assessment is established through monitoring and/or simulating the dispersion of air pollutants from all significant sources in the area of interest. Both of these methods require significant time and resources. As this did not form part of the scope of this investigation and as no baseline air pollution monitoring data could be sourced for the study, the predicted concentrations were limited to incremental impacts from the Belfast mining activities.

- Particle size distributions for stockpiles (i.e topsoil, overburden, run of mine (ROM) and road surfaces were not available for the current study. Use was therefore made of particle sizes obtained from similar operations.

- The dispersion model (AERMOD) cannot compute real time mining processes. Average mining process throughputs were therefore utilised.

EVALUATION CRITERIA

Air quality guidelines and standards are fundamental to effective air quality management, providing the link between the source of atmospheric emissions and the user of that air at the downstream receptor site. Ambient air quality guidelines and standards aim to protect public health therefore these are applied to off-site areas rather than on-site occupational impacts. Thus, the predicted impacts at the sensitive receptors identified were the main focus of the assessment. Reference was therefore made to the South African legislation with emphasis on the proposed Ambient Air Quality Standards. In addition, South Africa proposes only 4 allowable exceedances of the proposed 75 µg/m³ daily PM10 standard (Government Notice 263 in Government Gazette 31987).

In the significance evaluation of the unmitigated and mitigated 2016 operations for the proposed Belfast Project, the predicted impacts were assessed against this criteria. Frequency of exceedances for the proposed operational phase were evaluated at the receptor sites.

BASELINE ASSESSMENT

Anthropogenic sources of emissions in the vicinity of the proposed Belfast Project site include power generation from power stations such as Arnot (~24km south west) and Hendrina Power Station (~43km south west). There are numerous coal mines located relatively close to the proposed mine site and these include Kopermyne Colliery (~29 km west), (~20km south east), Arnot Colliery (~24km km south east) and Glisa Colliery (~10 km north east) among others.

The sensitive receptor areas located in close proximity to the proposed mine site include various farmsteads (Jan Burger Farmstead, farmstead located close to the N4 and one located to the south east of the proposed mine site).

Dispersion Potential of the Site

Meteorological data were obtained for the years 2007 to 2009 and included hourly average wind speed, wind direction and temperature. Parameters not measured were estimated based on prognostic equations. The analysis of the meteorological data included a diurnal temperature profile and wind roses.

Over the period (from January 2007 to August 2009), the prevailing winds were recorded from the east, east-southeast and west-northwest with frequencies of occurrence of more than 10%. Day-time wind speeds indicated the dominancy of winds from the north- western sector while night conditions indicated an increase of winds from the east and east-southeast. During the summer months, winds from the east and east south west were dominant, while the prevailing winds during spring were mainly from the north east, east and north-west sectors. The winter months were characterised by west-northwesterly winds, with frequencies of occurrence of more than 10%. Winds from the east and east-south-east were predominant during the autumn months.

Existing Air Quality in the Region

Due to the lack of monitored data in the area around the proposed mine site, the predicted concentrations were limited to incremental impacts from the proposed Belfast mining activities only.

EMISSIONS INVENTORY

Emissions inventories provide the source input required for the simulation of ambient air concentrations. Emission rates were quantified for each hour of the year as a result of wind erosion and materials handling for the proposed construction and operational phases. In addition, fugitive emissions from vehicle entrainment, crushing and screening, drilling, blasting, excavation and scraping were also quantified.

The following scenarios were included in the dispersion modelling:

- *Scenario 1a-* Phase 1: Construction Phase (2011) assuming unmitigated emissions

- *Scenario 1b-* Phase 1: Construction Phase (2011) assuming mitigated emissions for the unpaved roads (75% control efficiency), drilling (99% control efficiency) and crushing and screening (use of high moisture ore emission factors).

- *Scenario 2a-* Phase 2: Operational Phase (2016) assuming unmitigated emissions

- *Scenario 2b-* Phase 2: Operational Phase (2016) assuming mitigated emissions for the unpaved roads (75% control efficiency), drilling (99% control efficiency) and crushing and screening (use of high moisture ore emission factors).

The main sources of *emissions* were as follows:

Scenario 1a

- Unpaved roads were predicted to be the main contributing source to PM10 and second most significant source of TSP emissions (45.2% and 29.1% respectively).
- The second most significant source of PM10 and the most significant source of TSP emissions was crushing and screening (31.1% and 62.4% respectively).

Scenario 1b

- With mitigation measures in place, unpaved roads were still predicted to be the main contributing sources to PM10 and TSP emissions (31.1% and 42.6% respectively).
- The second most significant source of PM10 and TSP emissions was blasting (29% and 21.2% respectively).

Scenario 2a

- Without the application of mitigation measures, unpaved roads were predicted to be the main contributing source to PM10 and TSP emissions (70% and 51.9% respectively).
- The second most significant source of PM10 and TSP emissions was crushing and screening (18.6% and 43.4% respectively).

Scenario 2b

- Unpaved roads were predicted to be the main contributing source to PM10 and TSP emissions (57.5% and 68.9% respectively).
- Crushing and screening was predicted to be the third most significant source of PM10 and second most significant source of TSP (14.4 % and 11.5% respectively).

IMPACT ASSESSMENT

In addition to being the most significant sources of emissions (PM10 and TSP), the unpaved roads and crushing and screening were also predicted to be the most impacting sources at the receptor sites for most of the modelled scenarios.

Scenario 1: Proposed 2011 Construction Phase (Phase 1)

- The predicted unmitigated daily average PM10 ground level concentrations exceeded the proposed SA Standard of 75 µg/m³ at the farmstead located to the south east of the proposed mine site and at the Jan Burger farmstead. However, with mitigation measures in place for the most significant contributing sources to PM10 emissions (unpaved roads and crushing and screening), the predicted impacts at all the sensitive receptor areas were within the proposed SA Standards. Over an annual average, the predicted unmitigated impacts indicated exceedances of the proposed standard at Jan Burger farmstead and at the farmstead located to the south east of the proposed mine site. The application of mitigation measures to unpaved roads, drilling and crushing and screening, resulted in the predicted impacts complying with the proposed SA standard (40µg/m³) at all the sensitive receptor areas.

- The predicted maximum daily dust fallout levels were well within the SANS residential target of 600 mg/m²/day at all the sensitive receptor areas for all the modelled scenarios.

Scenario 2: Proposed 2016 Operational Phase (Phase 2)

- The predicted unmitigated daily and annual ground level concentrations were predicted to exceed the proposed SA Standard of 75 µg/m³ and 40 µg/m³ respectively at all the sensitive receptor areas. The application of mitigation measures to the unpaved roads and crushing and screening, however, resulted in the predicted impacts complying with the proposed SA Standards at the receptor sites.

- When the unmitigated predicted concentrations for the operational phase were evaluated against the proposed allowable exceedance of 4 times a year for the proposed South African Standard of 75µg/m³, predictions at all the receptor sites were in excess of 4 days over the 1 year period (2008). However, the predicted concentrations at the receptor sites indicated frequencies of exceedances of less than 4 days for the mitigated proposed 2016 operations.

- The predicted unmitigated and mitigated maximum daily dust fallout levels did not exceed the SANS residential target of 600 mg/m²/day at the receptor sites.

CONCLUSIONS

The main conclusion is that without the application of suitable mitigation measures to the main contributing sources to PM10 and TSP emissions, i.e the unpaved roads and crushing and screening, the proposed construction and operational mining activities will result in exceedances of the proposed SA Standards at the various sensitive receptors in the vicinity of the mine. Application of mitigation measures will lead to a significant reduction in predicted impacts at the sensitive receptor areas and compliance with the proposed ambient SA PM10 Standards.

RECOMMENDATIONS

Target controls for the Main Sources

Proposed construction and operational phases

- Vehicle entrainment on unpaved haul roads – 75% control efficiency through water suppression, with ~90% control efficiency through the application of chemical surfactants or surface paving.
- Vehicle entrainment on in-pit haul roads – these roads change depending on the area to be mined and hence it is not practical to apply chemicals. It is recommended that a minimum of 75% control efficiency is achieved through affective water sprays.
- Crushing and screening operations - enclosure of crushing operations is very effective in reducing dust. The Australian NPi indicates that a telescopic chute with water sprays would ensure 75% control efficiency and enclosure of storage piles where tipping occur would reduce the emissions by 99%. In addition, chemical suppressants or water sprays on the primary crusher and dry dust extraction units with wet scrubbers on the secondary and tertiary crushers and screens will assist in the reduction of the cumulative dust impacts.

Closure Phase

It is assumed that all mining activities and processing operations will have ceased by the closure phase of the project. The potentials for impacts during this phase will depend on the extent of demolition and rehabilitation efforts during closure.

Suitable Mitigation Measures

Unpaved haul roads

- Chemical suppression (for the main access road) and water suppression (main haul roads and in-pit roads) can be utilised to control unpaved road emissions. It is therefore recommended that mitigation measures be applied to the proposed unpaved haul roads when these operations commence. Wet suppression and chemical suppression can also be used in conjunction to control unpaved road emissions. One of the main benefits of chemical stabilisation in conjunction with wet suppression is the management of water resources. A cost-effective chemical control programme should be developed evaluating the costs and benefits arising from various chemical stabilization practices on site specific roads.

Crushing and Screening

- The control efficiency of pure water suppression provides an effective control mechanism achieving on average 62% efficiency by doubling the moisture content.

Monitoring Requirements

Key performance indicators against which progress may be assessed form the basis for all effective environmental management practices.

Source based performance indicators include the following:

- No visible dust on unpaved roads when trucks/vehicles drive on the roads. It is recommended that dust fallout in the immediate vicinity of the road perimeter be less than 1,200 mg/m^2/day and less than 600 mg/m^2/day at the sensitive receptors.
- The absence of visible dust plume at all tipping points and outside the primary crusher would be the best indicator of effective control equipment in place. In addition the dust fallout in the immediate vicinity of the tipping and crushing sources should be less than 1,200 mg/m^2/day.
- From all activities associated with the proposed construction and operational phases, dust fallout levels should not exceed 600 mg/m^2/day at the sensitive receptor areas.

Record-keeping and Environmental Reporting

It is recommended that site inspections and progress reporting be undertaken at regular intervals (at least quarterly) when mining operations commence, with annual environmental audits being conducted. Annual environmental audits should form part of the overall Environmental Management System (EMS) at the proposed Belfast project mine site. A budget should be drawn to provide a clear indication of the capital and annual maintenance costs associated with dust control measures and dust monitoring plans.

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Airshed	Airshed Planning Professionals (Pty) Ltd
APCS	Air Pollution Control System
APIA	Air Pollution Impact Assessment
APPA	The Atmospheric Pollution Prevention Act (No.45 of 1965)
C	Carbon
CH_4	Methane
CO	Carbon Monoxide
DEA	Department of Environmental Affairs (previously known as the Department of Environmental Affairs and Tourism-DEAT)
DME	The Department of Minerals and Energy
EMP	Environmental Management Programme
EU	The European Union
EMS	Environmental Management System
GDP	Gross Domestic Product
ISCST3	Industrial Source Complex Short Term model (ISCST3)
m^3	Cubic metre
NEMAQA	National Environment Management Air Quality Act No. 39 of 2004)
PM10	Particulate Matter with an aerodynamic diameter of less than 10µ
PM2.5	Particulate Matter with an aerodynamic diameter of less than 2.5µ
PPM	Parts per Million
ROM	Run Off Mine
SANS	South African National Standards
SO_2	Sulphur Dioxide
tpd	Tons Per Day
TSP	Total Suspended Particles
µ	Microns
µg	Micrograms
US-EPA	United States Environmental Protection Agency
WB	The World Bank Group
WHO	The World Health Organisation

AIR QUALITY IMPACT ASSESSMENT FOR THE PROPOSED BELFAST PROJECT, MPUMALANGA

1 INTRODUCTION

Airshed Planning Professionals (Pty) Limited was appointed by Exxaro Resources Limited (Pty) Ltd (hereafter referred to as Exxaro) to undertake an air quality impact assessment for the proposed Belfast Coal Mine. Exxaro is evaluating a potential coal reserve on the farms Leeuwbank, Zoekop and Blyvooruitzight. The Belfast site is an undeveloped coal resource situated approximately 10 km southwest of Belfast in Mpumalanga (Figure 1-1).

The main objective of the study is to determine the significance of air pollution impacts from the proposed mining activities on the surrounding environment and on human health.

Figure 1-1: Location of the town of Belfast, Mpumalanga.

1.1 Description of Proposed Mining Activities

The proposed project will involve the mining of two areas (east and west), separated by a small stream (Figure 1-2). The western area has better quality raw coal than the eastern area. Mining will occur in two phases and these include Phase 1 and Phase 2. When Phase 1 operations cease, mining operations will then be expanded to Phase 2 to supply Eskom and the export markets. Mining will commence in the south to north direction for both Phase 1 and Phase 2. The general mining sequence is shown in Figure 1-3.

Mining will take place using conventional truck and shovel mining method. This method includes pre-stripping of topsoil, blasting and excavation of the overburden to expose the coal. The proposed mining method for the Belfast project is shown in Figure 1-4. The overburden will be transported to the overburden stockpiles (Figure 1-5) while the topsoil will be used in the construction of berms. The coal will be transported to the crushing and screening plant during Phase 1 and to the crushing and screening and washing plants during Phase 2. The infrastructure layout is shown in Figure 1-5.

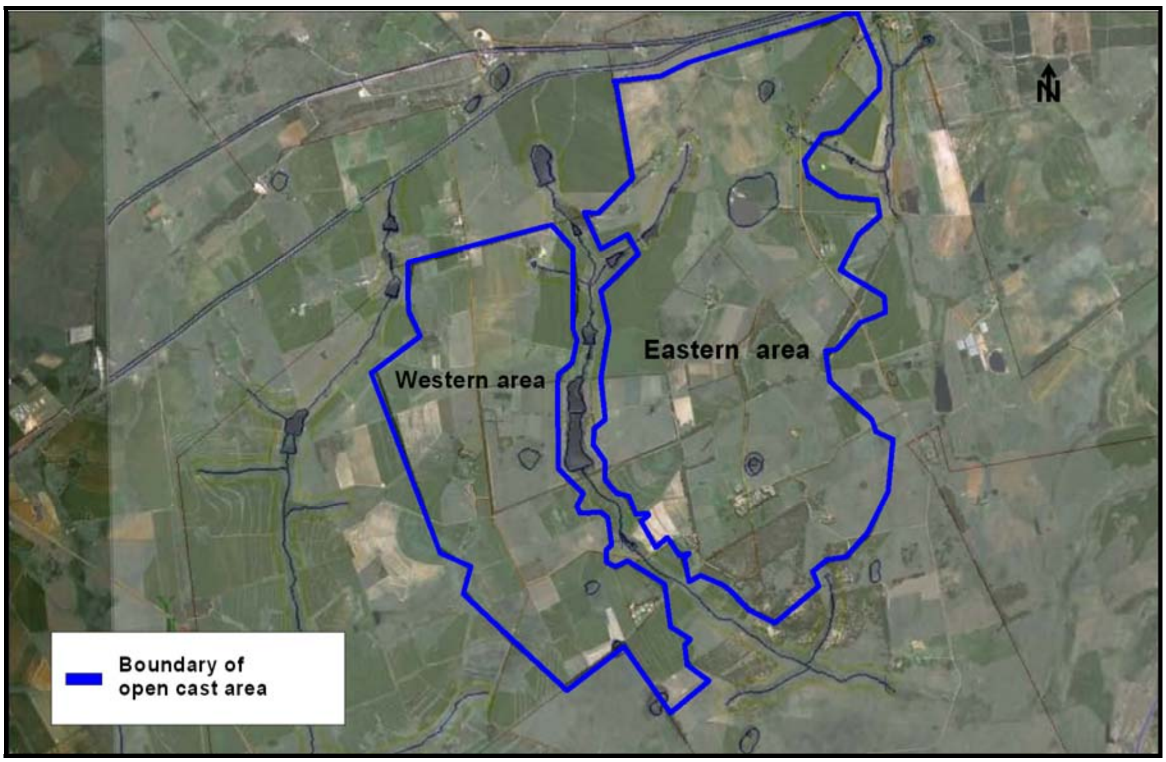

Figure 1-2: Opencast mining area outline.

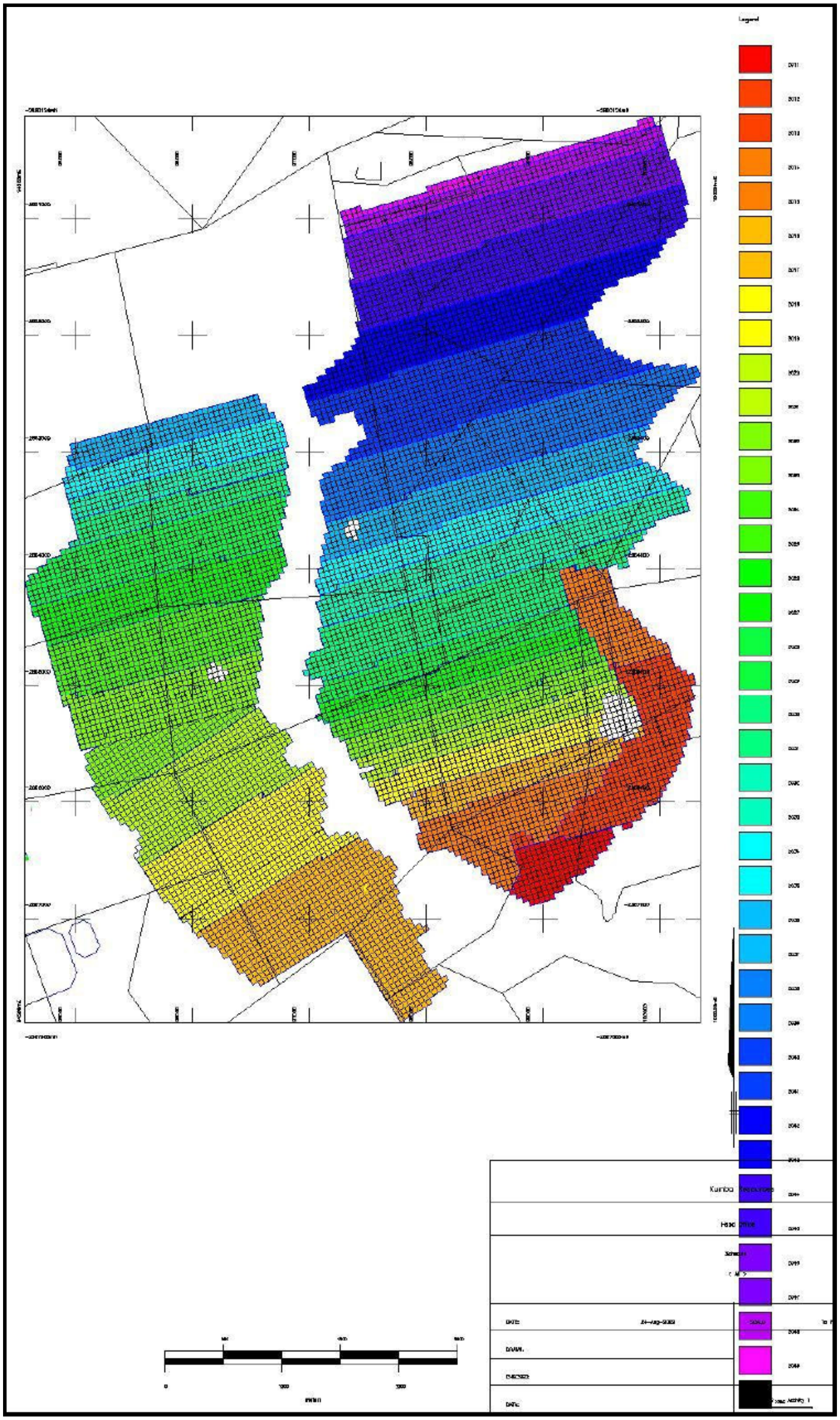

Figure 1-3: Mining schedule for the proposed Belfast Mine.

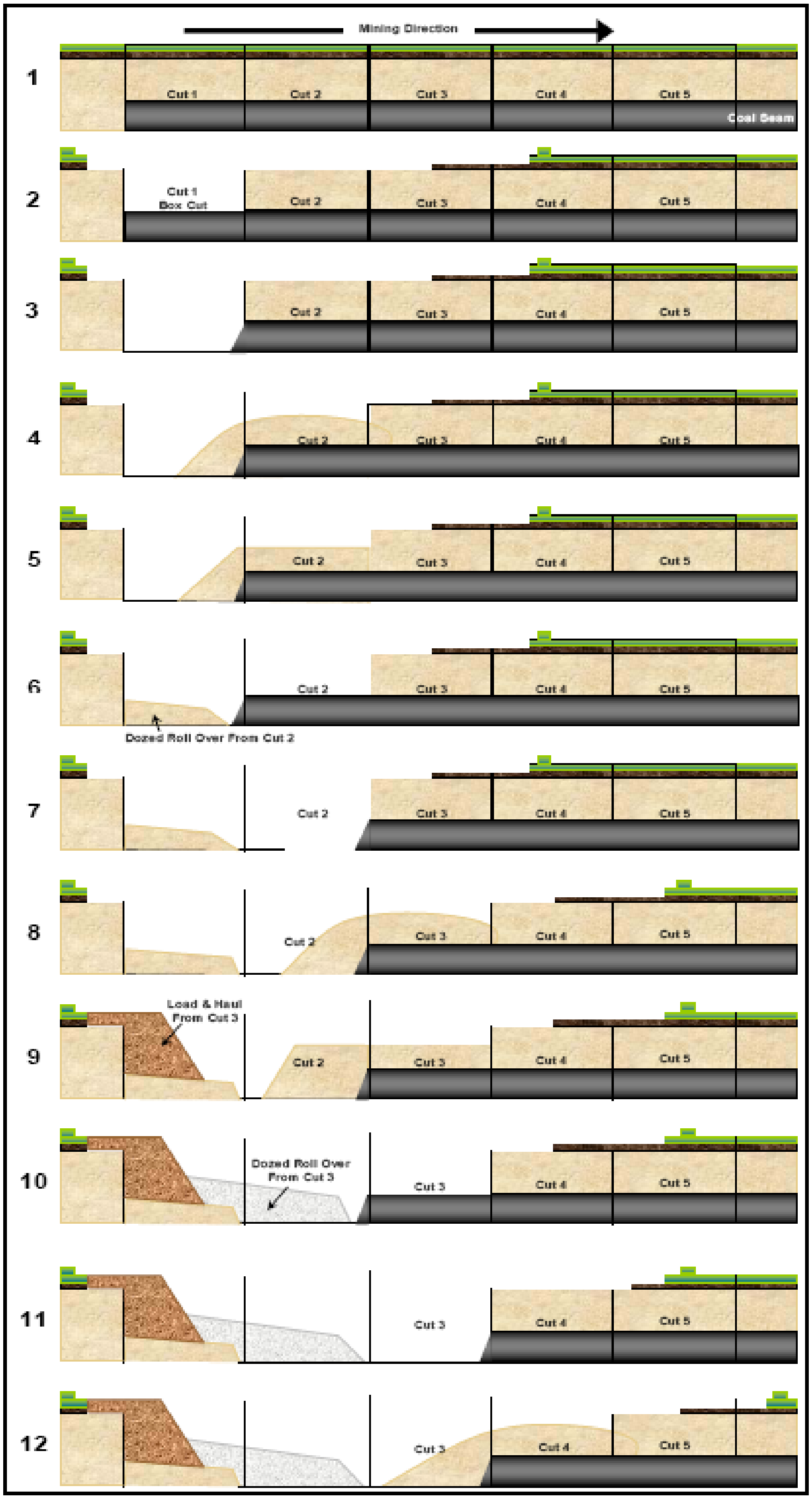

Figure 1-4: Proposed mining method for the Belfast Project.

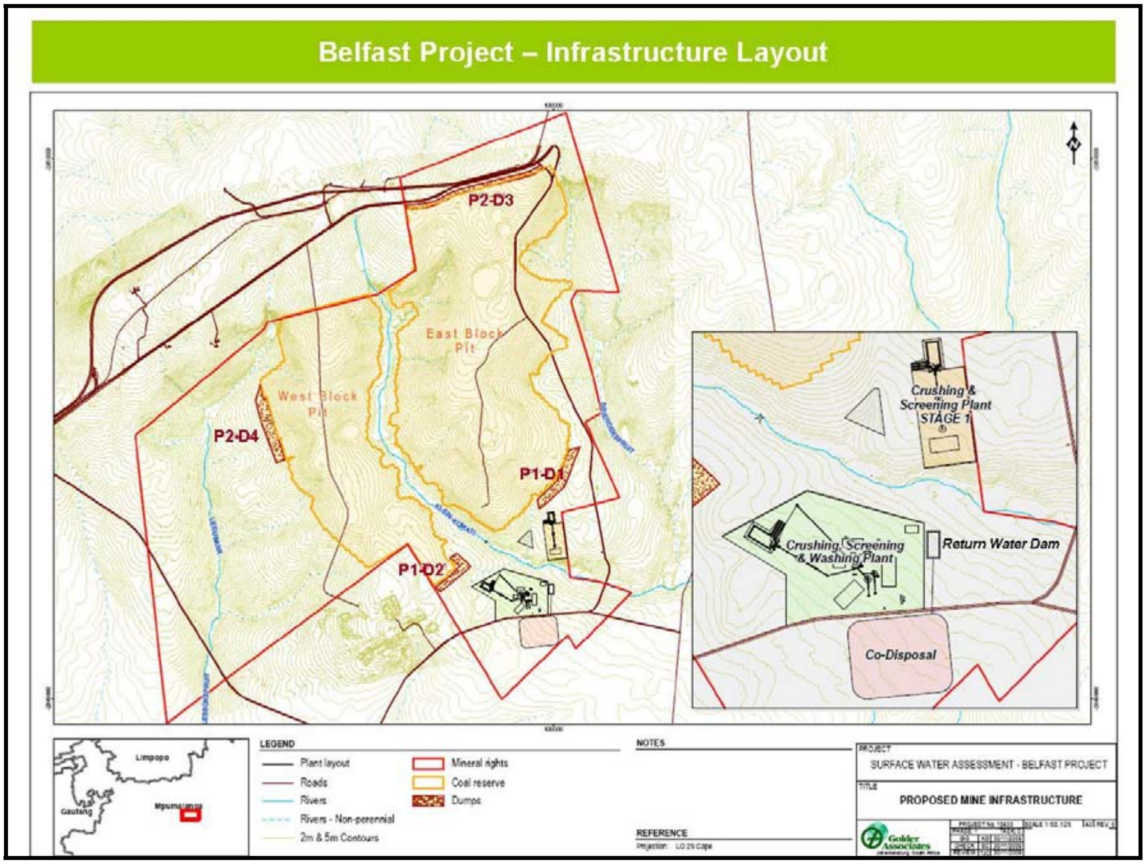

Figure 1-5: Infrastructure layout for the proposed Belfast Project.

1.2 Site Description and Sensitive Receptors

Sensitive receptors close to the proposed mine site include various scattered farmsteads and the larger residential area of Belfast (located ~10km to the north east). The locations of the three farmsteads used in the study are depicted in Figure 1-6. These farmsteads are considered as the most significant individual heritage sources that should be preserved at all costs.

The current land uses in the area include agricultural activities, predominantly cultivated lands used for maize production. Grazing in the form of pastures and natural grassland along wetlands and rocky outcrops also takes place. Regionally, there are several mining and mining related activities (mostly coal mining).

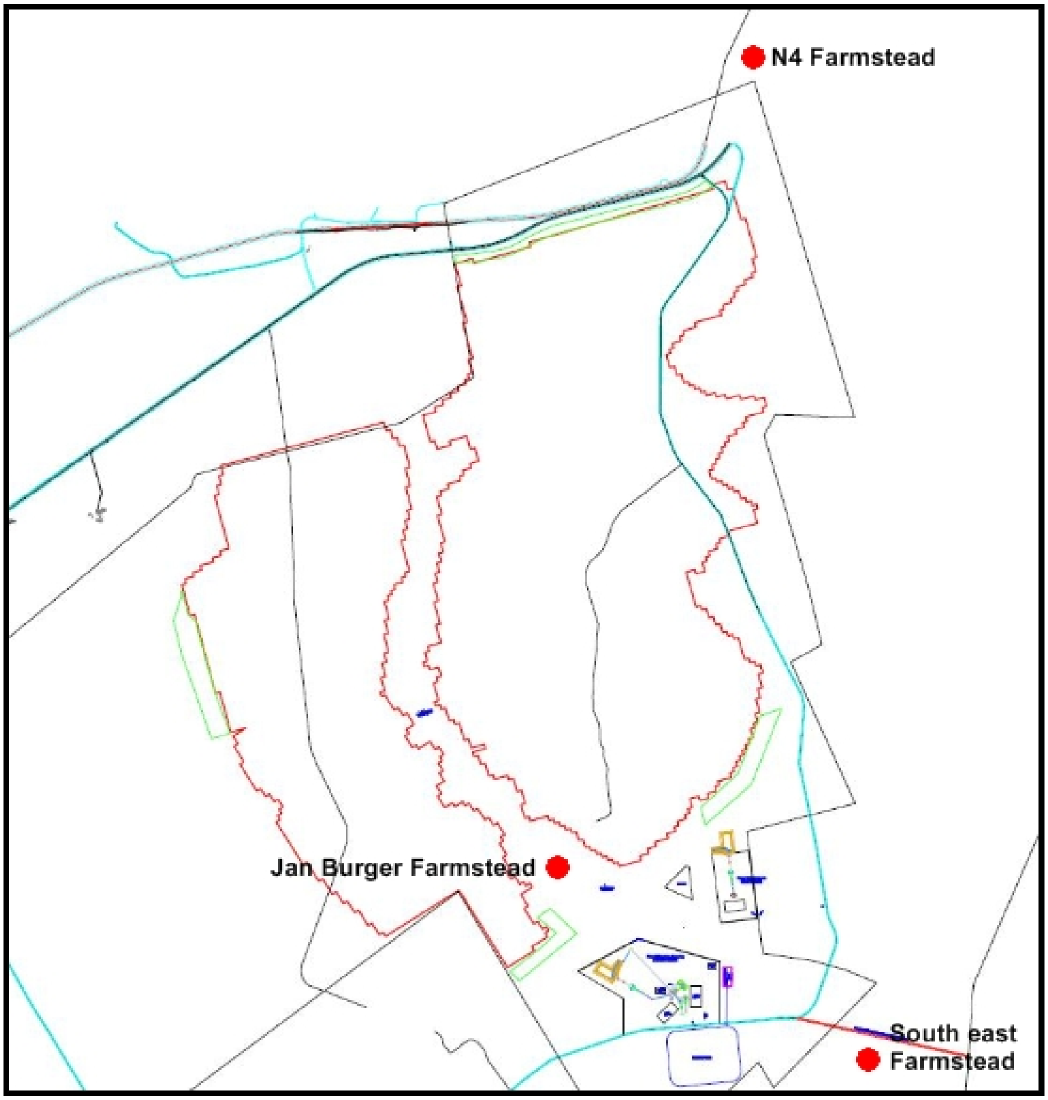

Figure 1-6: Location of the sensitive receptor areas in relation to the proposed Belfast Project mine site.

1.3 Terms of Reference

The terms of reference for the study comprise of two main components, viz, (i) a baseline assessment, and (ii) and air quality impact assessment.

The proposed terms of reference for the *baseline air quality characterisation* component of the assessment are as follows:

- The regional climate and site-specific atmospheric dispersion potential;
- Identification of the potential sensitive receptors within the vicinity of the proposed site;

- Preparation of hourly average meteorological data for the model input;
- Identification of existing sources of emission in the area;
- Characterisation of ambient air quality and dustfall levels in the region based on observational data recorded to date (if available);
- Preparation of background maps;
- The legislative and regulatory context, including emission limits and guidelines, ambient air quality guidelines and dustfall classifications.

The proposed terms of reference for *assessing the air quality impacts* associated with the mining activities:

- Compilation of an emissions inventory, comprising the identification and quantification of all potential *routine* sources of emission from the proposed operations at the mine;
- Dispersion simulations of ambient respirable particulate concentrations and dust fallout from the proposed mining activities;
- Analysis of dispersion modelling results from the proposed mining operations;
- Evaluation of potential for human health and environmental impacts;
- Develop a dust management plan

1.4 Assumptions and Limitations

- The impact assessment was limited to airborne particulates (including Total Suspended Particulates (TSP)) and inhalable particulate matter (PM10). Although the proposed activities would also emit other gaseous pollutants, primarily by vehicle activity, the impact of those was regarded to be low and was omitted from the study.

- As the potential wind erosion from the overburden material will be minimal or negligible due to the large particle sizes associated with this type of material, the impacts from this were not quantified during the study.

- A baseline air quality assessment is established through monitoring and/or simulating the dispersion of air pollutants from all significant sources in the area of interest. Both of these methods require significant time and resources. As this did not form part of the scope of this investigation and as no baseline air pollution monitoring data could be sourced for the study, the predicted concentrations were limited to incremental impacts from the Belfast mining activities.

- Particle size distributions for stockpiles (i.e topsoil, overburden, run of mine (ROM) and road surfaces were not available for the current study. Use was therefore made of particle sizes obtained from similar operations.

- The dispersion model (AERMOD) cannot compute real time mining processes. Average mining process throughputs were therefore utilised.

Based on the detail of the process description, the following dust generating sources were included:

- Material transfer of mined material (ROM and overburden) at stockpiles
- Vehicle dust entrainment (removal of topsoil at the proposed mine sites)
- Wind erosion of exposed areas (proposed stockpiles)
- Drilling and blasting
- Crushing and screening
- Scraping and excavation

- Meteorological data observed in Rietvallei, (located ~9km north west of the proposed mine site) was used as input into the dispersion and wind erosion model (AERMOD and ADDAS respectively).

1.5 Report Structure

Section 2 comprises a description of the legislative overview and the guidelines and standards to which the results are referenced. Section 3 addresses the atmospheric dispersion potential of the region, with a more detailed discussion on the macro dispersion potential attached for further perusal in Appendix B. A baseline assessment incorporating identified sources of emissions in the project area as well as the presentation of available air quality data is discussed in Section 4. The methodology and approach utilised in this study is outlined in Section 5, while the emissions inventory pertaining to the quantification of atmospheric sources and impact assessment are presented in Section 6 (proposed 2011 construction phase) and Section 7 (proposed 2016 operational phase). A qualitative assessment related to the closure phase of the proposed project is presented in Section 8. Section 9 provides a dust management plan for the proposed Belfast Project, conclusions and recommendations.

2 LEGAL REQUIREMENTS AND HUMAN HEALTH CRITERIA

Prior to assessing the impact of the proposed mining operations for the Belfast Project, reference needs to be made to the environmental regulations and guidelines governing the emissions and impact of such operations.

2.1 Review of the Current Air Pollution Legislative Context

Under the Air Pollution Prevention Act (Act No 45 of 1965) (APPA) the focus is mainly on sourced based control with permits issued for Scheduled Processes. Scheduled processes, referred to in the Act, are processes which emit more than a defined quantity of pollutants per year, including combustion sources, smelting and inherently dusty industries. Best Practical Means (BPM), on which the permits are based, represents an attempt to restrict emissions while having regard to local conditions, the prevailing extent of technical knowledge, the available control options, and the cost of abatement. The Department of Environmental Affairs (DEA) is responsible for the administration of this Act with the implementation thereof charged to the Chief Air Pollution Control Officer (CAPCO).

The APPA is outdated and not in line with international best practice. It also proves inadequate to facilitate the implementation of the principles underpinning the National Environmental Management Act (NEMA) and the Integrated Pollution and Waste Management (IP&WM) white paper. In this light, the National Environmental Management: Air Quality Act (Act no. 39 of 2004) was drafted, shifting the approach from source based control to decentralised air quality management through an effects-based approach.

Although emission limits and ambient concentration guidelines are published by the Department of Environmental Affairs no provision was made under the APPA for ambient air quality standards or emission standards. The decision as to what constitutes the best practicable means for each individual case was reached following discussions with the industry. A registration certificate, containing maximum emission limits specific to the industry, was then issued.

The new National Environmental Management Air Quality Act has shifted the approach of air quality management from source-based control only to the control of the receiving environment. The act has also placed the responsibility of air quality management on the shoulders of local authorities that will be tasked with baseline characterisation, management and operation of ambient monitoring networks, licensing of listed activities, and emissions reduction strategies. The main objective of the act is to ensure the protection of the environment and human health through reasonable measures of air pollution control within the sustainable (economic, social and ecological) development framework.

The Air Quality Act (AQA) makes provision for the setting of ambient air quality standards and emission limits on National level, which provides the objective for air quality management. More stringent ambient standards may be implemented by provincial and metropolitan authorities. Listed activities will be identified by the Minister and will include all activities regarded to have a significant detrimental effect on the environment, including health. Emission limits will be established on National level for each of these activities and an atmospheric emission licence will be required in order to operate. With the decentralisation of power down to provincial and local authority level, district and metropolitan municipalities will be responsible for the issuing of licences for listed activities. In addition, the Minister may declare priority pollutants for which an industry emitting this substance will be required to implement air pollution prevention plans. An air quality officer appointed by local authorities and responsible for the issuing of atmospheric emission licences, may also require from a company (or person) to submit atmospheric impact reports in order to demonstrate compliance.

The AQA commenced on the 11th of September 2005[1] with the exclusion of certain sections. These sections pertain to the listing of activities and the issuing of atmospheric emissions licences. Thus, for all Scheduled Processes the conditions as stipulated under the APPA prevails until these sections are appealed by the AQA. It is expected that the Listed Activities under the AQA will as a minimum include the current Scheduled Processes. Further description of AQA and APPA can be found in Appendix A.

2.1.1 Status of Current Legislation

The National Environmental Management: Air Quality Act (Act no.39 of 2004) (AQA) commenced with on the 11th of September 2005 as published in the Government Gazette on the 9th of September 2005. Sections omitted from the implementation are Sections 21, 22, 36 to 49, 51(1)(e),51(1)(f), 51(3),60 and 61. The Air Pollution Prevention Act (Act No 45 of 1965) (APPA) will be repealed on 11 September 2009.

The AQA was developed to reform and update air quality legislation in South Africa with the intention to reflect the overarching principles within the National Environmental Management Act. It also aims to comply with general environmental policies and to bring legislation in line with local and international good air quality management practices.

The most significant change under AQA to the previous approach in air quality management (as under the Atmospheric Pollution Prevention Act (APPA) of 1965) is the control of impacts on the receiving environment. Previously APPA focussed on managing air quality from a national government level by controlling specific sources. Under AQA this responsibility has been delegated down to district and metropolitan municipality level with the Air Quality Officer responsible for issuing Atmospheric Emissions Licenses. Thus, the implication for industry is that all Listed Activities (previously known as scheduled processes) will require Atmospheric Emissions Licences.

The National Framework states that aside from the various spheres of government responsibility towards good air quality, industry too has a responsibility not to impinge on everyone’s right to air that is not harmful to health and well-being. Industries therefore should take reasonable measures to prevent such pollution order degradation from occurring, continuing or recurring.

[1] The National Environmental Management: Air Quality Act (Act no.39 of 2004) commenced with on the 11th of September 2005 as published in the Government Gazette on the 9th of September 2005. Sections omitted from the implementation are Sections 21, 22, 36 to 49, 51(1)(e),51(1)(f), 51(3),60 and 61.

In terms of AQA, certain industries have further responsibilities, including:

- Compliance with any relevant national standards for emissions from point, non-point or mobile sources in respect of substances or mixtures of substances identified by the Minister, MEC or municipality.
- Compliance with the measurements requirements of identified emissions from point, non-point or mobile sources and the form in which such measurements must be reported and the organs of state to whom such measurements must be reported.
- Compliance with relevant emission standards in respect of controlled emitters if an activity undertaken by the industry and/or an appliance used by the industry is identified as a controlled emitter.
- Compliance with any usage, manufacture or sale and/or emissions standards or prohibitions in respect of controlled fuels if such fuels are manufactured, sold or used by the industry.
- Comply with the Minister's requirement for the implementation of a pollution prevention plan in respect of a substance declared as a priority air pollutant.
- Comply with an Air Quality Officer's legal request to submit an atmospheric impact report in a prescribed form.
- Taking reasonable steps to prevent the emission of any offensive odour caused by any activity on their premises.
- Furthermore, industries identified as Listed Activities (see Section 2.2.3) have further responsibilities, including:
    - Making application for an Atmospheric Emission License (AEL) and complying with its provisions.
    - Compliance with any minimum emission standards in respect of a substance or mixture of substances identified as resulting from a listed activity.
    - Designate an Emission Control Officer if required to do so.

2.1.2 Roll Out of the Air Quality Act

Given the specific requirements of the Air Quality Act various projects had to be initiated to ensure these requirements are met. The following provides a brief description of the projects that would have an influence on the proposed town planning.

- *National Framework for Air Quality Management* – according to the Air Quality Act, the Minister must within two years of the date on which this section took effect, establish a national framework for achieving the object of the Act. The project provides the norms and standards to guide air quality management initiatives at national, provincial and local government levels throughout the country. The National Framework is a medium- to long term plan on how to implement the Air Quality Act to ensure the objectives of the act are met. The plan was published in the Government Gazette on the 11th of September 2007.

- *Listed Activities and Minimum Emissions Standard Setting Project* – the minister must in accordance to the act publish a list of activities which result in atmospheric emissions and which is believed to have significant detrimental effects on the environment and human health and social welfare. The project aims to establish minimum emission limits for all the listed activities identified through a consultative process at several forums. All current scheduled processes as stipulated under the APPA would automatically become listed activities with additional activities being added to the list. An initial list of activities forms part of the National Framework. The draft List of Activities with associated minimum emission standards linked to is undergoing the STANSA process for finalisation. The final lists and limits should be published in the first half of 2009 for comment.

The initial list of activities, as published in the National Framework for Air Quality Management 2007 (Table 26), Waste rock Dumps and Slimes Dams are included as proposed listed activities under Category 5: Mineral Processing Industry. Non-metallic mineral processing plants (crushing, screening and handling) are also included as listed activities. This implies that minimum national emission limits will be stipulated for these sources and an Atmospheric Emissions License will be a legal requirement. It is likely that fugitive dust sources dust fallout monitoring and mitigation measures will be a requirement.

Highveld Airshed Priority Area Air Quality Management Plan– the Highveld Airshed was declared the second priority area by the minister in 2007. This requires that an Air Quality Management Plan for the area be developed. The plan includes the establishment of an emissions reduction strategies and intervention programmes based on the findings of a baseline characterisation of the area. The implication of this is that all contributing sources in the area will be assessed to determine the emission reduction targets to be achieved over the following few years.

Although the proposed Belfast Mine falls outside the footprint demarcated as the Highveld Priority Area, due to its close proximity it may contribute to the pollution within the Highveld airshed.

2.2 Ambient Air Quality Criteria

2.2.1 South African Standards

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

The South African Bureau of Standards (SABS) was engaged to assist DEA in the facilitation of the development of ambient air quality standards. This included the establishment of a technical committee to oversee the development of standards. Standards were determined based on international best practice for particulate matter less than 10 µm in aerodynamic diameter (PM10), dustfall, sulphur dioxide, nitrogen dioxide, ozone, carbon monoxide, lead and benzene[2]. These standards were published for comment in the Government Gazette on 9 June 2007 and have gone through the STANSA Technical Committee for Air Quality for finalisation. The revised standards include frequency of exceedance and have been published for public comment on 13 March 2009 (Government Notice 263 in Government Gazette 31987).

2.2.1.1 Inhalable Particulate Matter

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

The nasal openings permit very large dust particles to enter the nasal region, along with much finer airborne particulates. Larger particles are deposited in the nasal region by impaction on the hairs of the nose or at the bends of the nasal passages. Smaller particles (PM10) pass through the nasal region and are deposited in the tracheobronchial and pulmonary regions. Particles are removed by impacting with the wall of the bronchi when they are unable to follow the gaseous streamline flow through subsequent bifurcations of the bronchial tree. As the airflow decreases near the terminal bronchi, the smallest particles are removed by Brownian motion, which pushes them to the alveolar membrane (CEPA/FPAC Working Group, 1998).

Air quality standards for particulates are given for various particle size fractions, including total suspended particulates (TSP), inhalable particulates or PM10 (i.e. particulates with an aerodynamic diameter of less than 10 µm), and respirable particulates of PM2.5 (i.e. particulates with an aerodynamic diameter of less than 2.5 µm). Although TSP is defined as all particulates with an aerodynamic diameter of less than 100 µm, and effective upper limit of 30 µm aerodynamic diameter is frequently assigned. PM10 and PM2.5 are of concern due to their health impact potentials. As indicated previously, such fine particles are able to be deposited in, and damaging to, the lower airways and gas-exchanging portions of the lung.
Table 2-1 provides the list of the current and revised SA Standards.

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[2] *SANS 69 - South African National Standard* - Framework for setting & implementing national ambient air quality standards, and *SANS 1929 - South African National Standard* - Ambient Air Quality - Limits for common pollutants.

Table 2-1: SA Air Quality Standards for inhalable particulates (PM10)

Averaging Period	Status	Standards (µg/m³)	Frequency of permitted Exceedance (FOE)	Compliance Date
24 hour	Current SA standard[(a)]	180	3	Current[(a)]
	Proposed SA standard [(b)]	75	4	Immediate[(c)]
Annual	Current SA standard[(a)]	60	0	Current[(a)]
	Proposed SA standard[(b)]	40	0	Immediate[(c)]

Notes: [(a)] As per Schedule 2 of the NEM Air Quality Act (Act no. 39) of 2004
[(b)] As per Government Notice 263 in Government Gazette 31987 published 13 March 2009 for public comment
[(c)] Once the revised standards have been published as the new SA National Standards

2.2.2 International guidelines and limits

As of April 30, 2007 new versions of the World Bank Group Environmental, Health and Safety Guidelines (known as the 'EHS Guidelines') are now in use.

2.2.2.1 Inhalable Particulate Matter

The World Bank (WB) references the World Health Organisation (WHO) newly published (October 2005) ambient air quality guidelines to be used in air quality assessments. The WB recommends that impacts should be estimated through qualitative or quantitative assessments using baseline air quality and atmospheric dispersion models to assess the potential ground level concentrations. Local meteorological data is required for dispersion modelling and the models used should be internationally recognised (IFC, 2007). Ambient monitoring is recommended to assess the effectiveness of emissions management strategies. Table 2-2 and Table 2-3 provide the WHO ambient air quality guidelines for particulates.

Table 2-2: WHO air quality guideline and interim targets for particulate matter (annual mean) (WHO, 2005).

Annual Mean Level	PM10 (µg/m³)	PM2.5 (µg/m³)	Basis for the selected level
WHO interim target-1 (IT-1)	70	35	These levels were estimated to be associated with about 15% higher long-term mortality than at AQG
WHO interim target-2 (IT-2)	50	25	In addition to other health benefits, these levels lower risk of premature mortality by approximately 6% (2-11%) compared to WHO-IT1
WHO interim target-3 (IT-3)	30	15	In addition to other health benefits, these levels reduce mortality risks by another approximately 6% (2-11%) compared to WHO-IT2 levels.
WHO Air Quality Guideline (AQG)	20	10	These are the lowest levels at which total, cardiopulmonary and lung cancer mortality have been shown to increase with more than 95% confidence in response to PM2.5 in the American Cancer Society (ACS) study (Pope *et al.*, 2002 as cited in WHO 2005). The use of the PM2.5 guideline is preferred.

Table 2-3: WHO air quality guideline and interim targets for particulate matter (daily mean) (WHO, 2005).

Daily Mean Level	PM10 (µg/m³)	PM2.5 (µg/m³)	Basis for the selected level
WHO interim target-1 (IT-1)	150	75	Based on published risk coefficients from multi-centre studies and meta-analyses (about 5% increase of short-term mortality over AQG)
WHO interim target-2 (IT-2)*	100	50	Based on published risk coefficients from multi-centre studies and meta-analyses (about 2.5% increase of short-term mortality over AQG)
WHO interim target-3 (IT-3)**	75	37.5	Based on published risk coefficients from multi-centre studies and meta-analyses (about 1.2% increase of short-term mortality over AQG)
WHO Air Quality Guideline (AQG)	50	25	Based on relation between 24-hour and annual levels

* 99th percentile (3 days/year)

** for management purposes, based on annual average guideline values; precise number to be determined on basis of local frequency distribution of daily means

The United Kingdom Department of Environment classifies air quality on the basis of concentrations of fine particulates as follows (based on 24-hour average concentrations):

< 50 µg/m³	=	Low
50 - 74 µg/m³	=	Moderate
75 - 99 µg/m³	=	High
> 100 µg/m³	=	Very high

The European Community (EC) in their First Daughter Directive, 1999/30/EC (http://europa.eu.int/comm/environment/air/ambient.htm) provides the limits for highest daily and annual average as follows:

- Highest daily PM10 Limit – 50 µg/m³ not to be exceeded more than 35 times per calendar year (by 1 January 2010, no violations of more than 7 times per year will be permitted.)
- Annual average PM10 Limit – 30 µg/m³ (Compliance by 1 January 2005) and 20 µg/m³ (Compliance by 1 January 2010)

The World Bank Guidelines state that pollutant concentrations should not reach or exceed relevant ambient quality guidelines and standards by applying national legislated standards, or in their absence, the current WHO Air Quality Guidelines, or other internationally recognized sources (World Bank Group, 2007. EHS Guidelines (http://www.ifc.org/ifcext/enviro.nsf/Content/EnvironmentalGuidelines).

2.2.3 Dust Deposition Limits

Nuisance impacts due to dust are associated with dustfall and soiling impacts and with reductions in visibility. Atmospheric particulates change the spectral transmission, thus diminishing visibility by scattering light. The scattering efficiency of such particulates is dependent upon the mass concentration and size distribution of the particulates. Various costs are associated with the loss of visibility, including: the need for artificial illumination and heating; delays, disruption and accidents involving traffic; vegetation growth reduction associated with reduced photosynthesis; and commercial losses associated with aesthetics. The soiling of building and materials due to dust frequently gives rise to damages and costs related to the increased need for washing, cleaning and repainting. Dustfall may also impact negatively on sensitive industries, e.g. bakeries, textile industries or paint manufacture.

Locally dust deposition is evaluated according to the criteria published by the South African Department of Environmental Affairs and Tourism (DEAT). In terms of these criteria dust deposition is classified as follows:

SLIGHT	-	less than 250 mg/m^2/day
MODERATE	-	250 to 500 mg/m^2/day
HEAVY	-	500 to 1200 mg/m^2/day
VERY HEAVY	-	more than 1200 mg/m^2/day

The Department of Minerals and Energy (DME) uses the uses the 1 200 mg/m^2/day threshold level as an action level. In the event that on-site dustfall exceeds this threshold, the specific causes of high dustfall should be investigated and remedial steps taken.

"Slight" dustfall is barely visible to the naked eye. "Heavy" dustfall indicates a fine layer of dust on a surface, with "very heavy" dustfall being easily visible should a surface not be cleaned for a few days. Dustfall levels of > 2000 $mg/m^2/day$ constitute a layer of dust thick enough to allow a person to "write" words in the dust with their fingers.

A perceived weakness of the current dustfall guidelines is that they are purely descriptive, without giving any guidance for action or remediation (SLIGHT, MEDIUM, HEAVY, VERY HEAVY). It has recently been proposed (as part of the SANS air quality standard setting processes) that dustfall rates be evaluated against a four-band scale, as presented in Table 2-4. Proposed target, action and alert thresholds for ambient dust deposition are given in Table 2-5.

According to the proposed dustfall limits an enterprise may submit a request to the authorities to operate within the Band 3 ACTION band for a limited period, providing that this is essential in terms of the practical operation of the enterprise (for example the final removal of a tailings deposit) and provided that the best available control technology is applied for the duration. No margin of tolerance will be granted for operations that result in dustfall rates in the Band 4 ALERT.

Table 2-4: Bands of dustfall rates proposed for adoption.

BAND NUMBER	BAND DESCRIPTION LABEL	DUST-FALL RATE (D) ($mg\ m^{-2}\ day^{-1}$, 30-day average)	COMMENT
1	RESIDENTIAL	D < 600	Permissible for residential and light commercial
2	INDUSTRIAL	600 < D < 1 200	Permissible for heavy commercial and industrial
3	ACTION	1 200 < D < 2 400	Requires investigation and remediation if two sequential months lie in this band, or more than three occur in a year.
4	ALERT	2 400 < D	Immediate action and remediation required following the first exceedance. Incident report to be submitted to relevant authority.

Table 2-5: Target, action and alert thresholds for ambient dustfall.

LEVEL	DUST-FALL RATE (D) (mg m^{-2} day^{-1}, 30-day average)	AVERAGING PERIOD	PERMITTED FREQUENCY OF EXCEEDANCES
TARGET	300	Annual	
ACTION RESIDENTIAL	600	30 days	Three within any year, no two sequential months.
ACTION INDUSTRIAL	1 200	30 days	Three within any year, not sequential months.
ALERT THRESHOLD	2 400	30 days	None. First exceedance requires remediation and compulsory report to authorities.

3 REGIONAL CLIMATE AND ATMOSPHERIC DISPERSION POTENTIAL

Meteorological mechanisms govern the dispersion, transformation and eventual removal of pollutants from the atmosphere. The extent to which pollution will accumulate or disperse in the atmosphere is dependent on the degree of thermal and mechanical turbulence within the earth's boundary layer. Dispersion comprises vertical and horizontal components of motion. The stability of the atmosphere and the depth of the surface-mixing layer define the vertical component. The horizontal dispersion of pollution in the boundary layer is primarily a function of the wind field. The wind speed determines both the distance of downwind transport and the rate of dilution as a result of plume 'stretching'. The generation of mechanical turbulence is similarly a function of the wind speed, in combination with the surface roughness. The wind direction, and the variability in wind direction, determines the general path pollutants will follow, and the extent of crosswind spreading. Pollution concentration levels therefore fluctuate in response to changes in atmospheric stability, to concurrent variations in the mixing depth, and to shifts in the wind field (Oke, 1990; Godish, 1990). A further description of the dispersion potential of the region can be found in Appendix B.

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

3.1 Synoptic-scale Circulations and Regional Atmospheric Dispersion Potential

Situated in the subtropical high-pressure belt, southern Africa is influenced by several high-pressure cells, in addition to various circulation systems prevailing in the adjacent tropical and temperate latitudes. The mean circulation of the atmosphere over the subcontinent is anticyclonic throughout the year (except near the surface) due to the dominance of three high pressure cells, viz. the South Atlantic High Pressure (HP), the South Indian HP off the east coast, and the continental HP over the interior.

Seasonal variations in the positioning and intensity of the HP cells determine the extent to which the circumpolar westerlies impact on the atmosphere over the region. In winter, the high-pressure belt intensifies and moves northward and the upper level circumpolar westerlies are able to impact significantly on the region. The winter weather of the region is, therefore, largely dominated by perturbations in the westerly circulation. Such perturbations take the form of a succession of cyclones or ridging anticyclones moving eastwards around the South African coast or across the country. During summer months, the anticyclonic belt weakens and shifts southwards and the influence of the circumpolar westerlies diminishes. A weak heat low characterises the near surface summer circulation over the interior, replacing the strongly anticyclonic wintertime circulation (Preston-Whyte and Tyson, 1988; Schulze, 1980).

The general circulation of the atmosphere over southern Africa as a whole is anticyclonic throughout the year above the 700 hPa level (i.e. altitude of ~3 000m). Anticyclones are associated with convergence in the upper levels of the troposphere, strong subsidence throughout the troposphere, and divergence in the near-surface wind field. Subsidence inversions, fine conditions and little to no rainfall occur as a result of such airflow. The climatology of the highveld region has been studied extensively in the past, where the frequency of anticyclonic conditions reaches a maximum in winter. The dominant effect of the winter subsidence is that, averaged over the year, the mean vertical motion is downward. The clear, dry air and light winds, often associated with anticyclonic circulation are ideal for surface radiation inversions of temperature, responsible for limited dispersion of especially low level pollution emissions (e.g. domestic coal fires). Surface inversions increase in frequency during night time and vary in depth between ~300 m to more than 500 m. The mean inversion strength during the winter is about 5°C – 6°C, whereas, in summer the strength is less than 2°C.

Circumpolar westerly waves are characterised by concomitant surface convergence and upper-level divergence that produce sustained uplift, cloud and the potential for precipitation. Cold fronts, which are associated with westerly waves, occur predominantly during winter when the amplitude of such disturbances is greatest. The passage of a cold front is characterised by distinctive cloud bands and pronounced variations in wind direction, wind speed, temperature, humidity, and surface pressure. Airflow ahead of a front passing over has a distinct north-north -easterly component and stable and generally cloud-free conditions prevail as a result of subsidence and low-level divergence. Following the passage of the cold front the north-easterly wind is replaced by winds with a distinct southerly component. The low-level convergence in the south-westerly airflow to the rear of the front produce favourable conditions for convection. Temperature decreases immediately after the passage of the front, with minimum temperatures being experienced on the first morning after the cloud associated with the front clears. Strong radiation cooling due to the absence of cloud cover, and the advection of cold southerly air combine to produce the lowest temperatures

The tropical easterlies, and the occurrence of easterly waves and lows affect most of southern Africa throughout the year, but occur almost exclusively during summer months. The easterly waves and lows are largely responsible for the summer rainfall pattern and the northeasterly wind component that occurs over the region (Schulze, 1986; Preston-Whyte and Tyson, 1988).

In contrast to anticyclonic circulation, convective activity associated with westerly and easterly wave disturbances hinders the persistence of inversions. Cyclonic disturbances, which are associated with strong winds and upward vertical air motion destroy, weaken, or increase the altitude of elevated inversions. Easterly and westerly wave disturbances therefore facilitate the dispersion and dilution of accumulated atmospheric pollution.

3.2 Meso-scale ventilation and site-specific dispersion potential

The meteorological characteristic of a site govern the dispersion, transformation and eventual removal of pollutants from the atmosphere (Pasquill and Smith, 1983; Godish, 1990). The extent to which pollution will accumulate or disperse in the atmosphere is dependent on the degree of thermal and mechanical turbulence within the earth's boundary layer. Dispersion comprises vertical and horizontal components of motion. The vertical component is defined by the stability of the atmosphere and the depth of the surface mixing layer. The horizontal dispersion of pollution in the boundary layer is primarily a function of the wind field. The wind speed determines both the distance of downwind transport and the rate of dilution as a result of plume 'stretching' (Shaw and Munn, 1971; Pasquill and Smith, 1983; Oke, 1990).

3.2.1 Local Wind Field

The vertical dispersion of pollution is largely a function of the wind field. The wind speed determines both the distance of downward transport and the rate of dilution of pollutants. The generation of mechanical turbulence is similarly a function of the wind speed, in combination with the surface roughness. In order to understand the potential for dispersion at a given site, it is preferred to have an on-site meteorological station. No meteorological station is in place at the proposed Belfast Project mine site and to overcome this problem, it was decided to make use of meteorological data from the Rietvallei South African Weather Services surface station and upper air station were obtained for inclusion in the simulations.

Figure 3-1 shows the local wind field for the Rietvallei based on the meteorological data from the weather station.

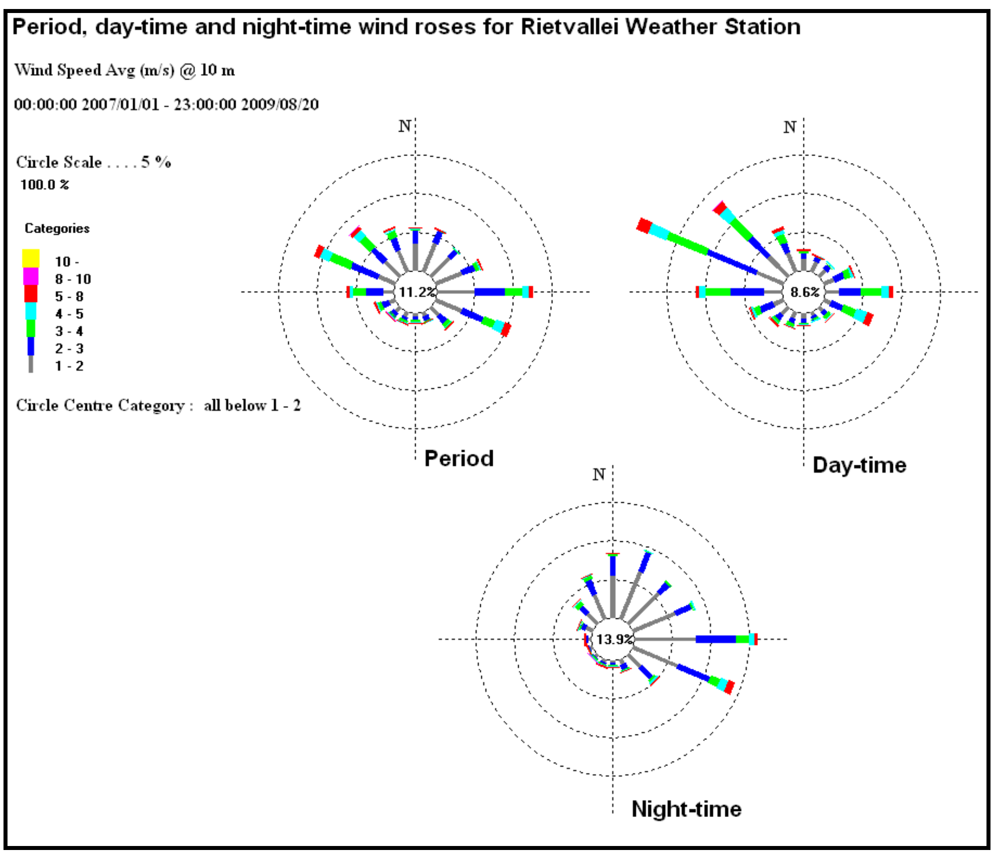

Figure 3-1: Wind roses for Rietvallei site for the period 2007-2009

Over the period (from January 2007 to August 2009), the prevailing winds are recorded from the east, east-southeast and west-northwest with frequencies of occurrence of more than 10%. Day-time wind speeds indicate the dominancy of winds from the north- western sector while night conditions indicate an increase of winds from the east and east-southeast.

The seasonal variation in wind-flow is shown in Figure 3-2. During the summer months, winds from the east and east southeast are dominant, while the prevailing winds during spring are mainly from the north east, east and north-west sectors. The winter months are characterised by west-northwesterly winds, with frequencies of occurrence of more than 10%. Winds from the east and east-southeast are predominant during the autumn months.

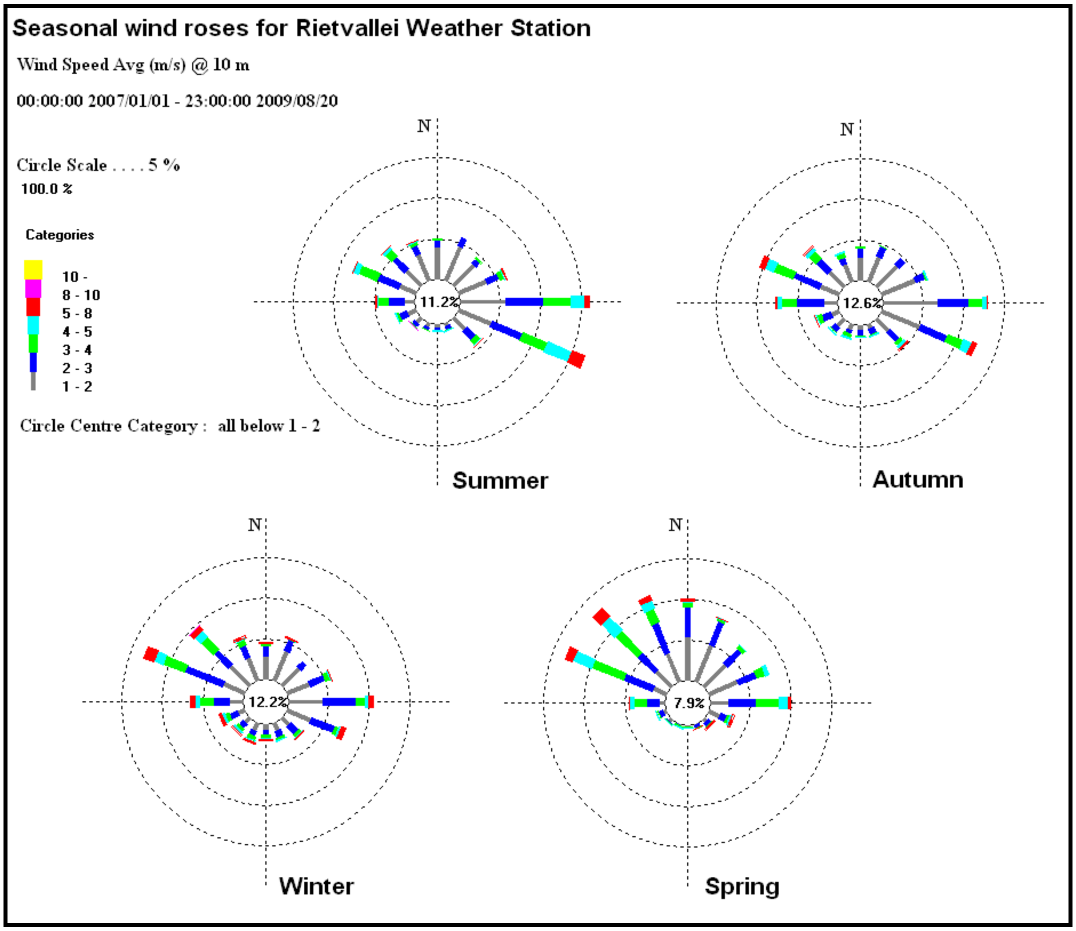

Figure 3-2: Seasonal wind roses for Rietvallei for the period 2007- August 2009.

3.2.2 Air 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. The temperature trends for Rietvallei for the year 2008 are presented in Figure 3-3.

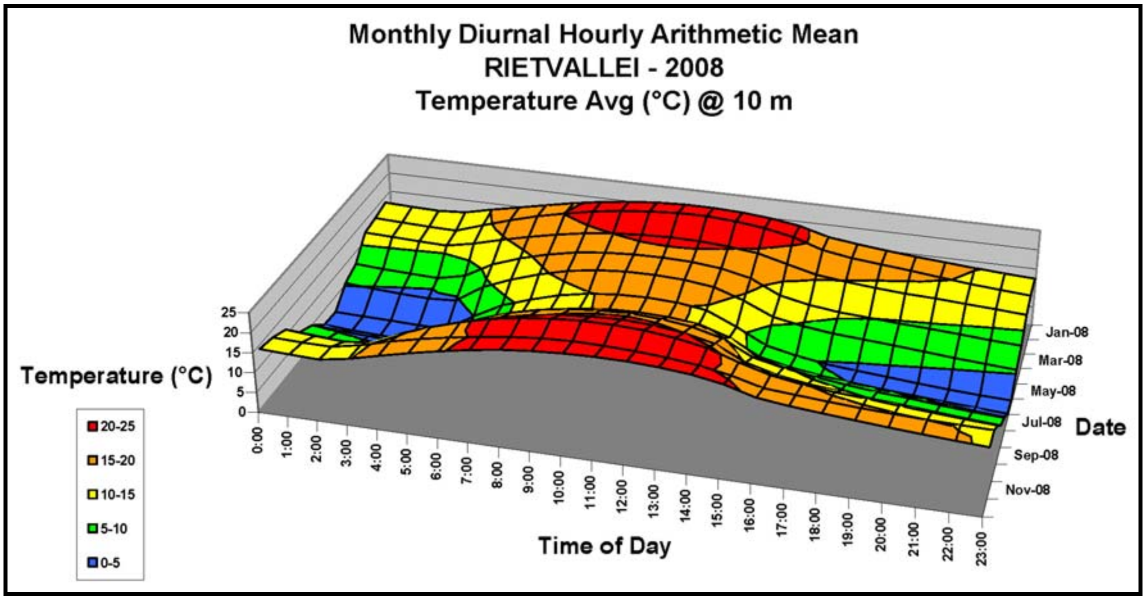

Figure 3-3: Air temperature trends for Rietvallei for the period 2008.

Since no long term data was available for the proposed mine site area, reference was made to long term climate data for Belfast. The long term temperature trends recorded for Belfast from 1920-1959 are presented in Table 3-1. Minimum long-term temperatures have been recorded as ranging from -1.6°C to 16.6°C with maximum temperatures ranging between 15.2°C and 22.8°C, as presented in Table 3-1. Mean temperatures, recorded over the long-term, ranged between 6.6°C and 16.6°C.

Table 3-1: Long-term minimum, maximum and mean temperature for Belfast-1920-1959 (Schulze, 1986)

Station		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Belfast	Maximum	22.3	22.2	21.3	20.1	17.6	15.2	15.3	17.8	20.4	22.2	22	22.8
	Mean	16.6	16.4	15.2	12.9	9.5	6.6	6.8	9	12	14.7	15.5	16.5
	Minimum	10.9	10.7	9.1	5.8	1.4	-1.8	-1.6	0.2	3.6	7.4	9	10.2

3.2.3 Precipitation

Precipitation is important to air pollution studies since it represents an effective removal mechanism for atmospheric pollutants and inhibits dust generation potentials. Particulates can be removed from the atmosphere through by dry and wet removal processes. Gravitational settling of large particles (>10µm) occurs near the source within the first day of transport. Wet removal occurs sporadically throughout the 5-10 days lifetime of the remaining smaller dust particles. The major mechanism of the incorporation of particulate matter into rain drops is the collision among the particles below the cloud base. The efficiency of the collision depends on the size distributions of particles and raindrops. Large particles are scavenged from the atmosphere more rapidly than small ones (Figure 3-4) (Ma *et al*, 2004).

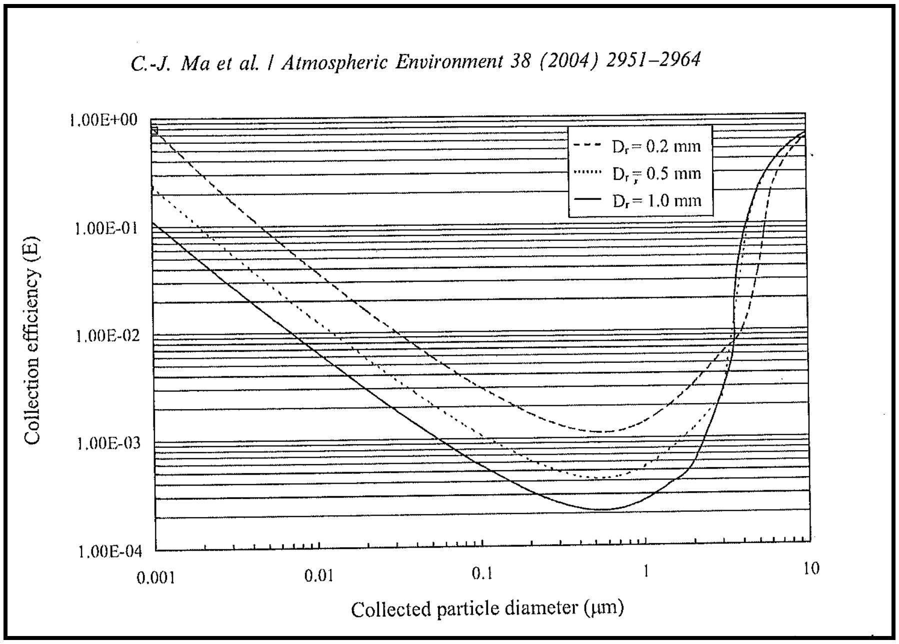

Figure 3-4: Particle scavenging co-efficient as a function of raindrop size combined with Brownian diffusion, interception and inertial impaction. *Dr* is raindrop diameter (Ma *et al*, 2004).

Long-term monthly average rainfall data for Belfast is shown in Table 3-2. The average total annual rainfall is ~842 mm. Rain falls mainly in summer from October to April, with the peak being in January for the region (Weather Bureau, 1986).

Monthly rainfall maximums and average thunderstorm, hail, snow and fog days observed to occur at Belfast during the period 1905 to 1959 are shown in Table 3-3. Monthly average rainfall data for Rietvallei for the period 2007- August 2009 is shown in Figure 3-5.

Table 3-2: Long-term *average* monthly rainfall figures (mm) for Belfast (1905-1959) (Schulze, 1986).

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Belfast (1905-1959)	145	116	101	50	25	8	9	11	33	81	131	132	842

Table 3-3: Monthly rainfall *maximums* and average thunderstorm, hail, snow and fog days observed to occur at Belfast during the period 1905 to 1959 (Schulze, 1986).

Month	Maximum Monthly Rainfall (mm)	Maximum No. of Rain-days	Average No. Days Experiencing:			
			Thunder-storms	Hail	Snow	Fog
Jan	122	20	5.4	0.2	0.0	4
Feb	72	15	4.7	0	0.0	3.8
Mar	56	12	4.8	0	0.0	3
Apr	112	11	2.8	0	0.0	4.8
May	76	11	1.6	0	0.0	2.3
June	36	3	0.4	0	0.3	2.2
July	30	6	0.6	0	0.00	1.6
Aug	56	6	0.5	0	0.00	4.6
Sep	53	9	2.3	0.1	0.1	3.3
Oct	60	16	5.4	0.5	0.0	6.3
Nov	76	16	6.8	0.4	0.0	5.2
Dec	103	17	6.3	0.1	0.0	2
Annual	964		41.6	1.3	0.4	43.1

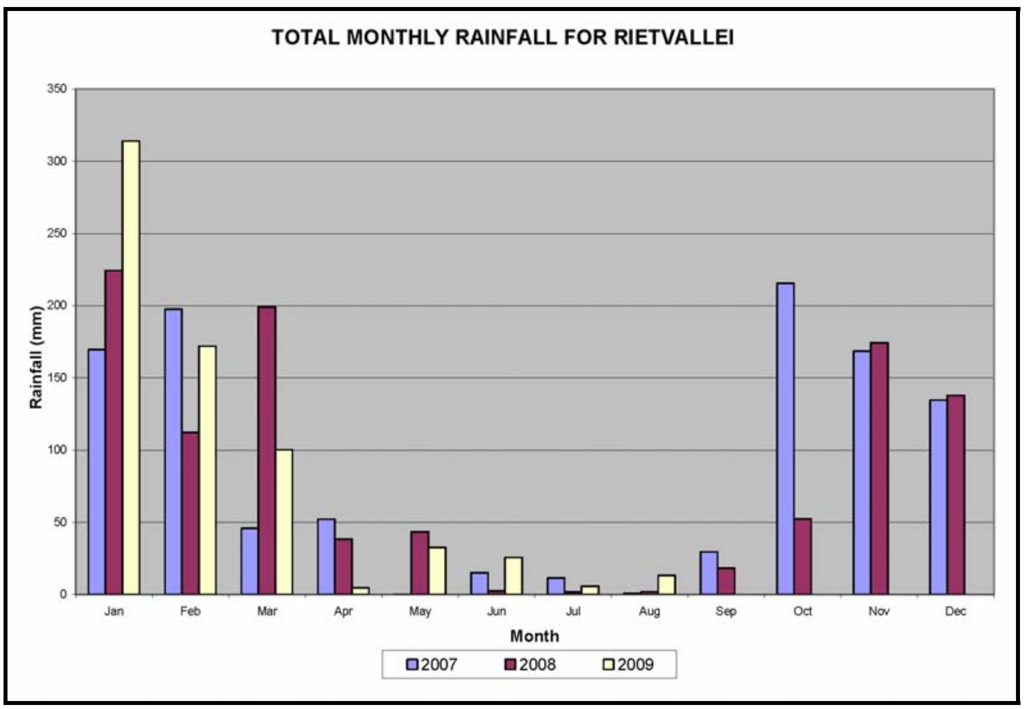

Figure 3-5: Average monthly rainfall for Rietvallei for the period 2007-August 2009.

3.2.4 Fog formation

Fog is a cloud that is in contact with the ground and forms when the difference between temperature and dew point is generally less than 2.5°C. Fog begins to form when water vapour condenses into tiny liquid water droplets in the air. Since water vapor is colorless, it is actually the small liquid water droplets that are condensed from it that make water suspended in the atmosphere visible in the form of fog or any other type of cloud. Fog normally occurs at a relative humidity near 100%. This can be achieved by either adding moisture to the air or dropping the ambient air temperature.

Fog formation requires all of the elements that normal cloud formation requires, the most important being condensation nuclei, in the form of dust, aerosols, pollutants, etc., for the water to condense upon. When there are exceptional amounts of condensation nuclei present, especially hygroscopic (water seeking) particles such as salt, then the water vapour may condense below 100% relative humidity. Fog can form suddenly, and can dissipate just as rapidly, depending what side of the dew point the temperature is on. This phenomenon is known as flash fog.

There are different types of fog and these include advection fog (which occurs when moist air passes over a cool surface by advection (wind) and is cooled) and radiation fog (which forms when the atmosphere is very stable and the skies are clear leading to heat radiation from the ground). Radiation fog (as is characteristic at Belfast) mostly occurs in the morning and has been largely linked to the ‘cleaning up of air pollution’. When the sun comes up, it evaporates the water droplets (dissipating the fog), cleaning the particles out of the air and leaving dirt and dust on the ground.

Although fog will contribute to collection of particles, this is dependent on the particle size distribution. The particle collection efficiency is however, known to decrease as the particle sizes get smaller than 10µm (Figure 3-4) (Ma *et al*, 2004).

Fog is a common phenomenon in the Belfast and may contribute to the collection of particles. However, site specific information on fog scavenging in the Belfast area is not available to verify the extent of this removal process.

3.2.5 Atmospheric Stability and Mixing Depth

The atmospheric boundary layer constitutes the first few hundred metres of the atmosphere. This layer is directly affected by the earth’s surface, either through the retardation of flow due to the frictional drag of the earth’s surface, or as result of the heat and moisture exchanges that take place at the surface. During the daytime, the atmospheric boundary layer is characterised by thermal turbulence due to the heating of the earth’s surface and the extension of the mixing layer to the lowest elevated inversion. Radiative flux divergence during the night usually results in the establishment of ground-based inversions and the erosion of the mixing layer. Night times are characterised by weak vertical mixing and the predominance of a stable layer. These conditions are normally associated with low wind speeds, hence less dilution potential.

The mixed layer (i.e. layer within which air pollutants are able to mix) therefore ranges in depth from a few metres during the evening and early morning to the base of the lowest-level elevated inversion during unstable, daytime conditions. Elevated inversions may occur for a variety of reasons, and on some occasions as many as five may occur in the first 1000 m above the surface. The lowest-level elevated inversion is located at a mean height above ground of 1 550 m during winter months with a 78 % frequency of occurrence. By contrast, the mean summer subsidence inversion occurs at 2 600 m with a 40% frequency.

For elevated releases such as stack emissions, the highest ground level concentrations would occur during unstable, daytime conditions. The wind speed resulting in the highest ground level concentration depends on the plume buoyancy. If the plume is considerably buoyant (high exit gas velocity and temperature) together with a low wind, the plume will reach the ground relatively far downwind. With stronger wind speeds, on the other hand, the plume may reach the ground closer, but due to the increased ventilation, it would be more diluted. A wind speed between these extremes would therefore be responsible for the highest ground level concentrations. In contrast, the highest concentrations for ground level, or near-ground level releases from non-wind dependent sources would occur during weak wind speeds and stable (night-time) atmospheric conditions.

4 BASELINE CHARACTERISATION

Various components of the bio-physical and socio-economic environment may be impacted by atmospheric emissions associated with the various phases of the project. These components include the possible impact on:

- ambient air quality;
- the aesthetic environment;
- local residents and neighbouring communities; and
- employees

It is important to identify significant sources of air pollutants in a region, as these are important to consider in terms of assessing the cumulative impact potential on air quality. Sources identified as possibly impacting the air quality in the region include, but are not limited to:

- Industrial sources
- Fugitive dust sources
- Mining emission sources
- Domestic fuel combustion
- Biomass burning
- Vehicle tailpipe emissions

4.1 Existing Air Quality within the Region

The Mpumalanga Highveld (formerly known as the Eastern Transvaal Highveld) has frequently been the focus of air pollution studies for two reasons. Firstly, elevated air pollution concentrations have been noted to occur in the region itself. Secondly, various elevated sources of emission located in this region have been associated with the long-range transportation of pollutants and with the potential for impacting on the air quality of the adjacent and more distant regions (Piketh, 1994). Criteria pollutants identified as of major concern in the region include particulates, sulphur dioxide and nitrogen oxides. Sources of SO_2 and NO_x that occur in the region include industrial emissions, blasting operations at mines and spontaneous combustion of discard coal dumps, veldt burning, vehicle exhaust emissions and household fuel burning (Scorgie *et al*, 2004).

The predicted highest and annual average concentrations of particulates in the study region for all the sources according to a cumulative study conducted to the NEDLAC study as shown in Figure 4-1 and Figure 4-2. The study led to the conclusion that elevated PM10 concentrations were predicted to occur in the study region.

Background maximum daily concentrations are therefore estimated to be between 25 µg/m³ and 75µg/m³ in the region. Annual average concentrations are estimated to be about 10 µg/m³.

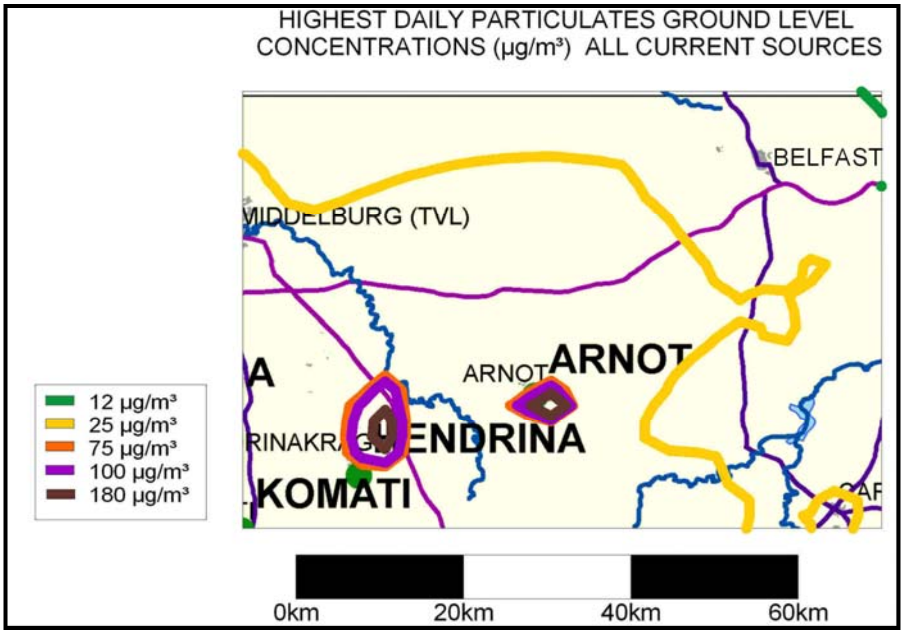

Figure 4-1: Highest daily average predicted PM10 ground level concentrations (µg/m³) for all sources in the study region due for the current operations (Scorgie *et al*, 2004).

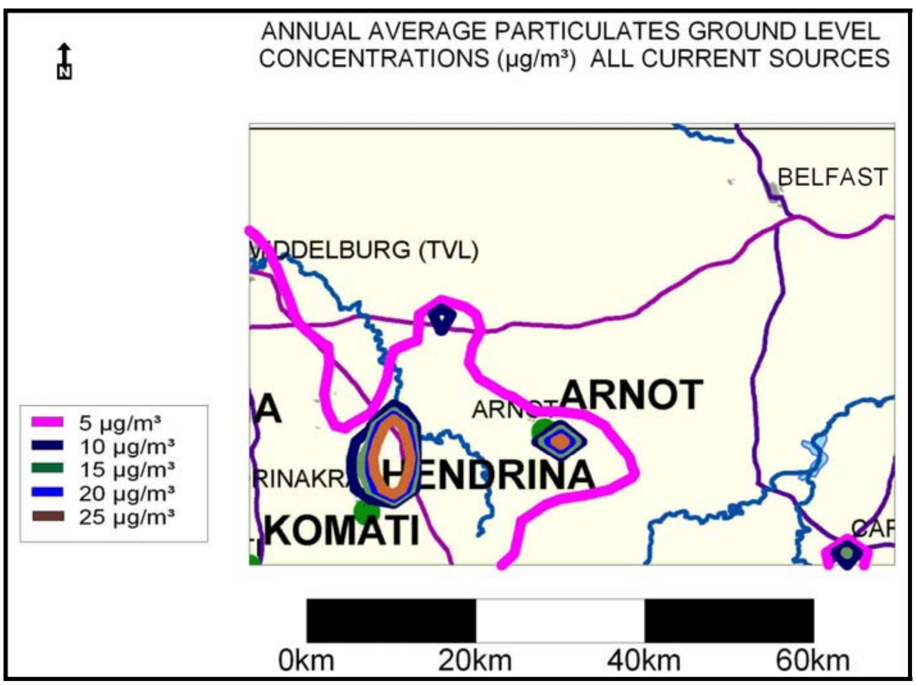

Figure 4-2: Annual average predicted PM10 ground level concentrations (µg/m³) for all sources in the study region due to current operations (Scorgie *et al*, 2004).

Neighbouring landuse in the region comprises of power generation, mining activities, farming and residential, contributing vehicle tailpipe emissions, household fuel combustion, biomass burning and various fugitive dust sources.

4.1.1 Power Generation

Eight operational power stations (Eskom operated) fall within the Mpumalanga Highveld region. The power stations are large sources of sulphur dioxide. Sulphur dioxide oxidises in the atmosphere to particulate sulphate at a rate of between 1 and 4% per hour. Fine particulate sulphate has been used to trace the transportation of power station plumes across the Southern African sub-continent. The power stations in proximity to the proposed Belfast Mine site include Arnot Power Station, located ~24 km to the south west, Hendrina Power Station (~43 km south west), Duvha Power Station (~50 km south west), Kriel Power Station (~93 km south west) and Matla Power Station located approximately ~98 km south west. Kendal Power Station is located ~104km south west of the proposed mine site. Due to the elevated height at which these power stations emit, the potential exists for their emissions to impact on the air quality of the Witbank and Middelburg areas.

The main emissions from such electricity generation are carbon dioxide, sulphur dioxide, nitrogen dioxides and ash (particulates). Fly-ash particle emitted comprise various trace elements such as arsenic, chromium, cadmium, lead, manganese, nickel, vanadium and zinc. Small quantities of volatile organic compounds are also released from such operations.

4.1.2 Mining Operations

There are numerous coal mines located around the proposed mine site. Some of the mines include Kopermyne Colliery (~29 km west), (~20km south east), Arnot Colliery (~24km km south east), Glisa Colliery (~10 km north east), Optimum Colliery (~44 km south west), Blackwattle Colliery (~50 km west), Middelburg Mine (~33 km south west) and Bank Colliery (~55 km south west) (Figure 4-3). Fugitive emissions from open cast and underground mining operations mainly comprise of land clearing operations (i.e. scraping, dozing and excavating), materials handling operations (i.e. tipping, off-loading and loading, conveyor transfer points), vehicle entrainment from haul roads, wind erosion from open areas and drilling and blasting. These activities mainly result in fugitive dust releases with small amounts of $NO_{x,}$ CO, SO_2, methane and CO_2 being released during blasting operations.

4.1.3 Fugitive Dust Sources

These sources are termed fugitive because they are not discharged to the atmosphere in a confined flow stream. Sources of fugitive dust identified to potentially occur in the study area include paved and unpaved roads; agricultural tilling operations; and wind erosion of sparsely vegetated surfaces.

Unpaved and paved roads

Emissions from unpaved roads constitute a major source of emissions to the atmosphere in the South African context. When a vehicle travels on an unpaved road, the force of the wheels on the road surface causes pulverization of surface material. Particles are lifted and dropped from the rolling wheels, and the road surface is exposed to strong turbulent air shear with the surface. The turbulent wake behind the vehicle continues to act on the road surface after the vehicle has passed. Dust emissions from unpaved roads vary in relation to the vehicle traffic and the silt loading on the roads.

Emission from paved roads are significantly less than those originating from unpaved roads, however they do contribute to the particulate load of the atmosphere. Particulate emissions occur whenever vehicles travel over a paved surface. The fugitive dust emissions are due to the re-suspension of loose material on the road surface.

Wind erosion of open areas

Emissions generated by wind erosion are dependant on the frequency of disturbance of the erodible surface. Every time that a surface is disturbed, its erosion potential is restored (EPA, 2004). Further erodible surfaces may occur as a result of agriculture and/or grazing activities.

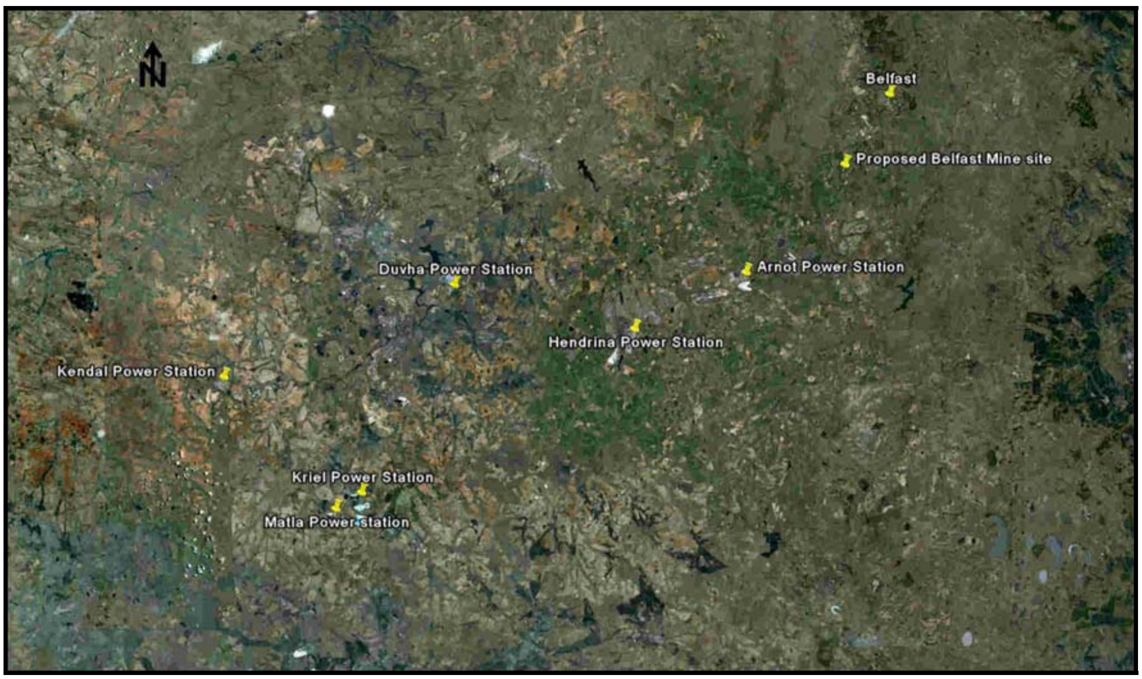

Figure 4-3: Power Stations in the Highveld located close to the proposed Belfast Mine site.

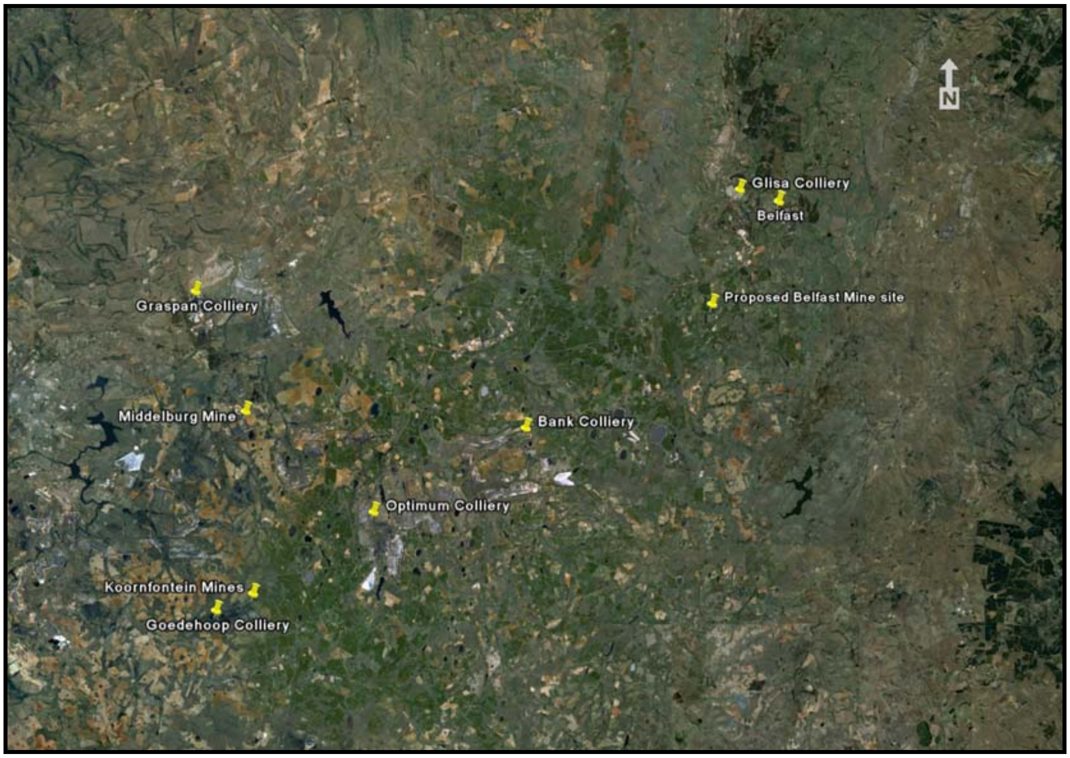

Figure 4-4: Mining operations located close to the proposed Belfast Mine site.

4.1.4 Domestic Fuel Combustion

Domestic households are known to have the potential to be one the most important sources contributing to poor air quality within residential areas. Individual households are low volume emitters, but their cumulative impact is significant. It is likely that households within the local communities/settlements utilise coal, paraffin and /or wood for cooking and / or space heating (mainly during winter) purposes. Pollutants arising from the combustion of wood include respirable particulates, carbon monoxide (CO) and sulphur dioxide (SO_2) with trace amounts of polycyclic aromatic hydrocarbons (PAHs), in particular benzo(a)pyrene and formaldehyde. Particulate emissions from wood burning have been found to contain about 50% elemental carbon and about 50% condensed hydrocarbons.

Coal is relatively inexpensive in the Mpumalanga region and is easily accessible due to the proximity of the region to coal mines and the well-developed coal merchant industry. Coal burning emits a large amount of gaseous and particulate pollutants including SO_2, heavy metals, total and respirable particulates including heavy metals and inorganic ash, CO, polycyclic aromatic hydrocarbons (PAHs) such as benzo(a)pyrene, NO_2 and various toxins. Polyaromatic hydrocarbons are recognised as carcinogens. The main pollutants emitted from the combustion of paraffin are NO_2, particulates carbon monoxide and polycyclic aromatic hydrocarbons.

4.1.5 Biomass Burning

Biomass burning includes the burning of evergreen and deciduous forests, woodlands, grasslands, and agricultural lands (Jacobson, 2002). Within the project vicinity, crop-residue burning and wild fires (locally known as veldt fires) may represent significant sources of combustion-related emissions.

Biomass burning is an incomplete combustion process (Cachier, 1992), with carbon monoxide, methane and nitrogen dioxide gases being emitted. Approximately 40% of the nitrogen in biomass is emitted as nitrogen, 10% is left is the ashes, and it may be assumed that 20% of the nitrogen is emitted as higher molecular weight nitrogen compounds (Held *et al*, 1996). The visibility of the smoke plumes is attributed to the aerosol (particulate matter) content. In addition to the impact of biomass burning within the vicinity of the proposed mining activity, long-range transported emissions from this source can be expected to impact on the air quality between the months August to October. It is impossible to control this source of atmospheric pollution loading, however, it should be noted as part of the background or baseline condition before considering the impacts of other local sources.

4.1.6 Vehicle Tailpipe Emissions

Emissions resulting from motor vehicles can be grouped into primary and secondary pollutants. While primary pollutants are emitted directly into the atmosphere, secondary pollutants form in the atmosphere as a result of chemical reactions. Significant primary pollutants emitted by internal combustion engines include carbon dioxide (CO_2), carbon monoxide (CO), carbon (C), sulphur dioxide (SO_2), oxides of nitrogen (mainly NO), particulates and lead. Secondary pollutants include NO_2, photochemical oxidants such as ozone, sulphur acid, sulphates, nitric acid, and nitrate aerosols (particulate matter). Vehicle (i.e. model-year, fuel delivery system), fuel (i.e. type, oxygen content), operating (i.e. vehicle speed, load), and environmental parameters (i.e. altitude, humidity) influence vehicle emission rates (Onursal, 1997). Due to the close proximity of the proposed mine site to the N4 highway, it is highly likely that this highway will be a source of vehicle emissions.

4.1.7 Informal refuse burning

Additional sources of emissions come from the waste sector and typically includes informal refuse and tyre burning. The informal burning of refuse tips within former township areas and burning of waste at local municipal landfill sites represents a source of concern in all provinces. For example, refuse tip combustion has been found to contribute significantly to the total airborne particulate concentrations within Soweto in the Gauteng Province. This source was estimated during a source apportionment study conducted in Soweto during 1996-1997 to be responsible for between 10% and 25% of the PM2.5 concentrations recorded (Annegarn and Grant, 1999).

5 METHODOLOGY

In assessing atmospheric impacts from the proposed mining activities, an emissions inventory was undertaken, atmospheric dispersion modelling conducted and predicted air pollutant concentrations evaluated.

The phases undertaken in the impact assessment are described in the following subsections.

5.1 Emissions Inventory

An emissions inventory was established and comprised emissions for the proposed 2011 construction and 2016 operational phases' emissions without mitigation and with mitigation measures for unpaved roads, drilling, crushing and screening. The establishment of an emissions inventory for the proposed operations is necessary to provide the source and emissions data required as input to the dispersion simulations. The release of particulates represents the most significant emission and is the focus of this study.

In the quantification of emissions from the proposed construction and operational phases (Section 6 and Section 7 respectively), use was made of predictive emissions factor equations published by the US-EPA (EPA, 1996). An emission factor is a representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant. Detailed information pertaining to these quantifications is provided in Appendix C.

5.2 Selection of dispersion model

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.

Gaussian-plume models are best used for near-field applications where the steady-state meteorology assumption is most likely to apply. The most widely used Gaussian plume model is the US-EPA Industrial Source Complex Short Term model (ISCST3).

The AERMET/AERMOD dispersion model suite was chosen for the study as it is the new regulatory model that has replaced the US-EPA Industrial Source Complex Model (ISC Version 3) Gaussian plume model. AERMET uses more comprehensive meteorological data sets including upper air data. The model also has a terrain pre-processor (AERMAP) for including a large topography into the model. The AERMET/AERMOD suite was developed with the support of the AMS/EPA Regulatory Model Improvement Committee (AERMIC), whose objective has been to include state-of the-art science in regulatory models.

- AERMOD is an advanced new-generation model. It is designed to predict pollution concentrations from continuous point, flare, area, line, and volume sources (Trinity Consultants, 2004). AERMOD offers new and potentially improved algorithms for plume rise and buoyancy, and the computation of vertical profiles of wind, turbulence and temperature, but retains the single straight line trajectory limitation of ISCST3 (Hanna *et al*).
- AERMET is a meteorological preprocessor for AERMOD. Input data can come from hourly cloud cover observations, surface meteorological observations and twice-a-day upper air soundings. Output includes surface meteorological observations and parameters and vertical profiles of several atmospheric parameters.
- AERMAP is a terrain preprocessor designed to simplify and standardize the input of terrain data for AERMOD. Input data includes receptor terrain elevation data. The terrain data may be in the form of digital terrain data. Output includes, for each receptor, location and height scale, which are elevations used for the computation of air flow around hills.

Similar to the ISCST3 a disadvantage of the model is that spatial varying wind fields, due to topography or other factors cannot be included. Also, the range of uncertainty of the model predictions could to be -50% to 200%. The accuracy improves with fairly strong wind speeds and during neutral atmospheric conditions.

There will always be some error in any geophysical model, but it is desirable to structure the model in such a way to minimise the total error. A model represents the most likely outcome of an ensemble of experimental results. The total uncertainty can be thought of as the sum of three components: the uncertainty due to errors in the model physics; the uncertainty due to data errors; and the uncertainty due to stochastic processes (turbulence) in the atmosphere.

The stochastic uncertainty includes all errors or uncertainties in data such as source variability, observed concentrations, and meteorological data. Even if the field instrument accuracy is excellent, there can still be large uncertainties due to unrepresentative placement of the instrument (or taking of a sample for analysis). Model evaluation studies suggest that the data input error term is often a major contributor to total uncertainty. Even in the best tracer studies, the source emissions are known only with an accuracy of ±5%, which translates directly into a minimum error of that magnitude in the model predictions. It is also well known that wind direction errors are the major cause of poor agreement, especially for relatively short-term predictions (minutes to hourly) and long downwind distances. All of the above factors contribute to the inaccuracies not associated with the mathematical models themselves.

Input data types required for the AERMOD model include: source data, meteorological data (pre-processed by the AERMET model), terrain data and information on the nature of the receptor grid.

5.3 Meteorological data requirements

AERMOD requires two specific input files generated by the AERMET pre-processor. AERMET is designed to be run as a three-stage processor and operates on three types of data (upper air data, on-site measurements, and the national meteorological database). Since the model was designed for the USA environment, various difficulties are found compiling the required dataset for the South African environment. The main data shortfalls include the following:

- The national meteorological database does not accommodate all the parameters required by AERMET.
- Upper air measurements are taken at only 5 locations in South Africa. The South African Weather Services has modelled upper air data for the entire country on a half degree interval.
- Surface meteorological stations seldom measure all the required parameters (such as solar radiation, cloud cover, humidity).

For the current study, use was made of the South African Weather Service Station (SAWS) at Rietvallei for the period January 2007 to August 2009. Calculated Unified Model data for the position closest to the proposed mine site was obtained from the SAWS for the upper air data.

The Unified Model is the collection of Numerical Weather Prediction computer models used by the United Kingdom Meteorological Office. It includes the main suite of a Global Model, a UK and North Atlantic model and a high resolution UK model, in addition to a variety of Crisis Area Models and other models that can be run on demand. The models are grid based, rather than wave-based and are run on a variety of supercomputers. Data are provided by observations (human and automatic), satellites, radar, radiosonde weather balloons, wind profilers and a background field from previous model runs. The produced data are verified against actual data for initial conditions and the first two hours and problems are worked towards in subsequent model runs, rather than force the model to accept a real value that may make the system unstable. The models are written in Fortran and use height as the vertical variable. Because most developments of interest are at near to the ground, the vertical layers are closer together near the surface.

Although Unified Model data was used for upper air in the study, MM5 data could also have been used as an alternative. MM5 is a widely-used three-dimensional numerical meteorological model which contains non-hydrostatic dynamics, a variety of physics options for parameterising cumulus clouds, microphysics, the planetary boundary layer and atmospheric radiation. MM5 has the capability to perform Four Dimensional Data

Assimilation (FDDA). MM5 is capable of simulating a variety of meteorological phenomena such as tropical cyclones, severe convective storms, sea-land breezes, and terrain forced flows such as mountain valley wind systems.

A comparison between the Unified Model and MM5 is shown in Table 5-1 below.

Table 5-1: A comparison between the Unified Model and MM5.

Model	Resolution	Number of Vertical Layers	Availability	Model Input
Unified Model	12km x 12km	40	Run locally by the SAWS	Makes use of measured meteorological data. The model utilises parameterisation for unmeasured weather parameters
MM5	12km x 12km	40	Run by TRC Solutions in the United States of America	Makes use of measured meteorological data. The model utilises parameterisation for unmeasured weather parameters

It can be concluded that the two models are similar in terms of resolution, number of vertical layers, model input and the fact that both utilise parameterisation to output other unmeasured weather parameters.

5.4 Preparation of source data

AERMOD is able to model point, area, volume and line sources. Wind erosion sources, unpaved roads, excavation, drilling, blasting and scraping were modelled as area sources while materials handling and crushing and screening activities were modelled as volume sources. Hourly files incorporating meteorological data were prepared for the various wind erosion and materials handling sources.

5.5 Preparation of receptor grid

Due to the location of the proposed mining area, the dispersion of pollutants was modelled for an area covering 12 km (north-south) by 12 km (east-west). The area was divided into a grid with a resolution 200m (north south) by 200m (east-west). AERMOD simulates ground-level concentrations for each of the receptor grid points. The nearby farmsteads were included as discrete receptors.

5.6 Model input and execution

Input into the dispersion model includes prepared upper air and surface meteorological data, source data, information on the nature of the receptor grid and emissions input data. The model inputs were verified before the model was executed. Dispersion modelling was undertaken for four scenarios:

- *Scenario 1a-* Phase 1: Construction Phase (2011) assuming unmitigated emissions
- *Scenario 1b-* Phase 1: Construction Phase (2011) assuming mitigated emissions for the unpaved roads (75% control efficiency), drilling (99% control efficiency) and crushing and screening (use of high moisture ore emission factors).
- *Scenario 2a-* Phase 2: Operational Phase (2016) assuming unmitigated emissions
- *Scenario 2b-* Phase 2: Operational Phase (2016) assuming mitigated emissions for the unpaved roads (75% control efficiency), drilling (99% control efficiency) and crushing and screening (use of high moisture ore emission factors).

5.7 Plotting of model outputs

Simulated outputs for PM10 concentrations and dust fallout rates were plotted for the unmitigated and mitigated scenarios.

5.8 Compliance analysis and impact assessment

The predicted air pollution concentrations and dust-fallout rates were compared to proposed SA standards to facilitate compliance and impact assessments. These concentrations were summarised and form the basis of the compliance assessment and evaluation.

6 CONSTRUCTION PHASE

The release of emissions represents the environmental impact of concern during the proposed Belfast Project operations. In the development of an emissions inventory the first approach is to establish a comprehensive list of all sources that would generate the pollutants of concern. Such sources were identified by firstly utilising the inputs and outputs to the operational processes and secondly considering the disturbance to the environment. Emission inventories were established for the proposed construction phase (2011) as part of Phase 1 operations and operational phase (2016) as part of the Phase 2 operations. Dispersion modelled was undertaken for the unmitigated and mitigated scenarios for the construction phase during 2011 and operational phase during 2016. Mitigation measures are applied to the unpaved roads, crushing and screening and drilling. For most mining operations, unpaved roads and crushing and screening are the most significant contributing sources to PM10 and TSP emissions and hence mitigation measures were applied to these sources in the study.

The current section discusses the impacts due to the construction phase (2011). The impact assessment due to the operational phase (2016) is discussed in Section 7.

6.1 Emissions Inventory: Construction Phase (2011)

The construction phase will initially comprise land clearing and site development operations at the proposed mine site and the associated infrastructure.

Activities associated with this phase will comprise a series of different operations including land clearing, topsoil removal, material loading and hauling, stockpiling, grading, bulldozing, compaction, (etc.). Each of these operations has its own duration and potential for dust generation. It is anticipated therefore that the extent of dust emissions would vary substantially from day to day depending on the level of activity, the specific operations, and the prevailing meteorological conditions. This is in contrast to most other fugitive dust sources where emissions are either relatively steady or follow a discernible annual cycle. Aspects associated with the construction phase in terms of air quality are outlined in Table 6-1.

A detailed construction plan is required to quantitatively assess air pollution. Due to the relatively short duration of most of the preparatory activities (eg land clearing, topsoil removal and plant construction) associated with the construction phase, dispersion simulations were undertaken for when mining commences and not the preparatory phase.

The main pollutant of concern from construction operations is particulate matter, including PM10, PM2.5 and TSP. PM10 and PM2.5 concentrations are associated with potential health impacts due to the size of the particulates being small enough to be inhaled. Nuisance effects are caused by the TSP fraction (20 µm to 75 µm in diameter) resulting in soiling of materials and visibility reductions. This could in effect also have financial implications due to the requirement for more cleaning materials.

From the proposed operations, the main construction activities likely to result in noticeable impacts of PM10 and TSP include vehicle entrainment from unpaved roads, drilling and blasting and wind erosion from the coal stockpiles. During the proposed 2011 construction phase, mining is scheduled to only occur on the eastern area. After mining, the run of mine will be crushed and screened, stockpiled and then transported as Eskom coal supply.

Table 6-1: Activities and aspects identified for the construction phase of the proposed Belfast Project during 2011.

Impact	Source	Activity	Relevant section
Particulates	Materials handling operations	Tipping of run of mine onto haul trucks to the crushing and screening plant.	6.1.1
		Tipping of topsoil to areas earmarked for topsoil berm construction and overburden to respective stockpiles	
		Tipping of ROM at the crushing and screening plant	
		Tipping of crushed ore to haul trucks	
		Backfilling of topsoil and overburden into pits	
	Vehicle activity on unpaved roads	Vehicles travelling on the unpaved roads to the various open pit areas and stockpiles.	6.1.2
	Wind erosion	ROM storage piles at the crushing and screening plant.	6.1.3
	Crushing and screening	Crushing activities at the crushing and screening plant	6.1.4
	Drilling and blasting	Drilling and blasting at the open pit	6.1.5 6.1.6
	Excavation and scraping	At the mine site	6.1.7 6.1.8
Gases and Particulates[1]	Vehicle tailpipe[1]	Tailpipe emissions from haul vehicles	
		Tailpipe emissions from further transport mediums (private motor vehicles, mine personnel movement etc)	
Notes: 1. Gases and particulates resultant from the vehicle activity were not simulated			

In assessing atmospheric impacts from the afore-mentioned activities, an emissions inventory is compiled for the proposed unmitigated and mitigated construction activities during 2011. The main pollutant of concern generated as a result of the operations is fugitive dust emissions. In the quantification of these emissions, use is made of the predictive emission factors published by the US-EPA (EPA, 1996), since no local emission factors are available.

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

6.1.1 Materials Handling Operations

Materials handling operations associated with mining and predicted to result in significant fugitive dust emissions include the transfer of material by means of tipping, loading and offloading trucks. The quantity of dust which will be generated from such loading and off-loading operations will depend on various climatic parameters, such as wind speed and precipitation, in addition to non-climatic parameters such as the nature (moisture content) and volume of the material handled. Fine particulates are more readily disaggregated and released to the atmosphere during the material transfer process, as a result of exposure to strong winds. Increase in the moisture content of the material being transferred would decrease the potential for dust emission, since moisture promotes the aggregation and cementation of fines to the surfaces of larger particles.

Equation 1, as depicted and discussed in Appendix C is used to calculate the emissions from tipping. The PM10 fraction of the TSP is taken to be 35% as is indicated in the US-EPA AP42 documentation. The parameters used in the calculation of emissions as a result of materials handling activities are depicted in Table 6-2.

Table 6-2: Material handling operations for the construction phase (2011) of the proposed Belfast Project during Phase 1.

Operation	Location	Throughput (t/hr)
Tipping coal to haul trucks	Open pit	171
Tipping overburden to haul trucks	Open pit	377
Tipping of overburden to overburden dump	Waste rock dump P1-D1	377
Tipping of ore at crushing and screening plant	Crushing and screening plant	171
Tipping crushed ore to trucks	Crushing and screening plant	320

6.1.2 Vehicle Activity on Unpaved Roads

Vehicle-entrained dust emissions from the unpaved haul roads within the open pit, to and from the waste rock dumps and crushing and screening plant during the proposed construction phase potentially represent a significant source of fugitive dust. Such sources have been found to account for the greatest portion of fugitive emissions from many mining operations. The quantification of the release of fugitive dust from the unpaved roads was calculated separately for roads that were unmitigated, as well as assuming 75% control efficiency for the mitigated unpaved roads. Table 6-3 depicts the parameters used in the calculation of emission rates from the proposed unpaved roads. The assumed locations of the unpaved roads for the proposed 2011 eastern area operations are shown in Figure 6-1.

Table 6-3: Parameters of the unpaved haul roads simulated for the proposed construction phase during 2011.

Unpaved road description	Length	Width
Road 1 to overburden pile	920	10
Road 2 to crushing plant	1400	10
Road 3 to R33	2330	10

The unpaved road size-specific emission factor equation of the US.EPA, used in the quantification of emissions is given in Appendix C, Equation 2. In addition to traffic volumes, emissions also depend on a number of parameters which characterise the condition of a particular road and the associated vehicle traffic. Such parameters include average vehicle speed, mean vehicle weight, average number of wheels per vehicle, road surface texture, and road surface moisture (EPA, 1996). The silt percentage utilised for the unpaved roads within the proposed open pit area and to the overburden stockpiles is 8.4% and 5.1% for unpaved roads to the crushing and screening plant as given in the US-EPA AP-42 document for coal mining operations in cases where the silt content of the area is unknown.

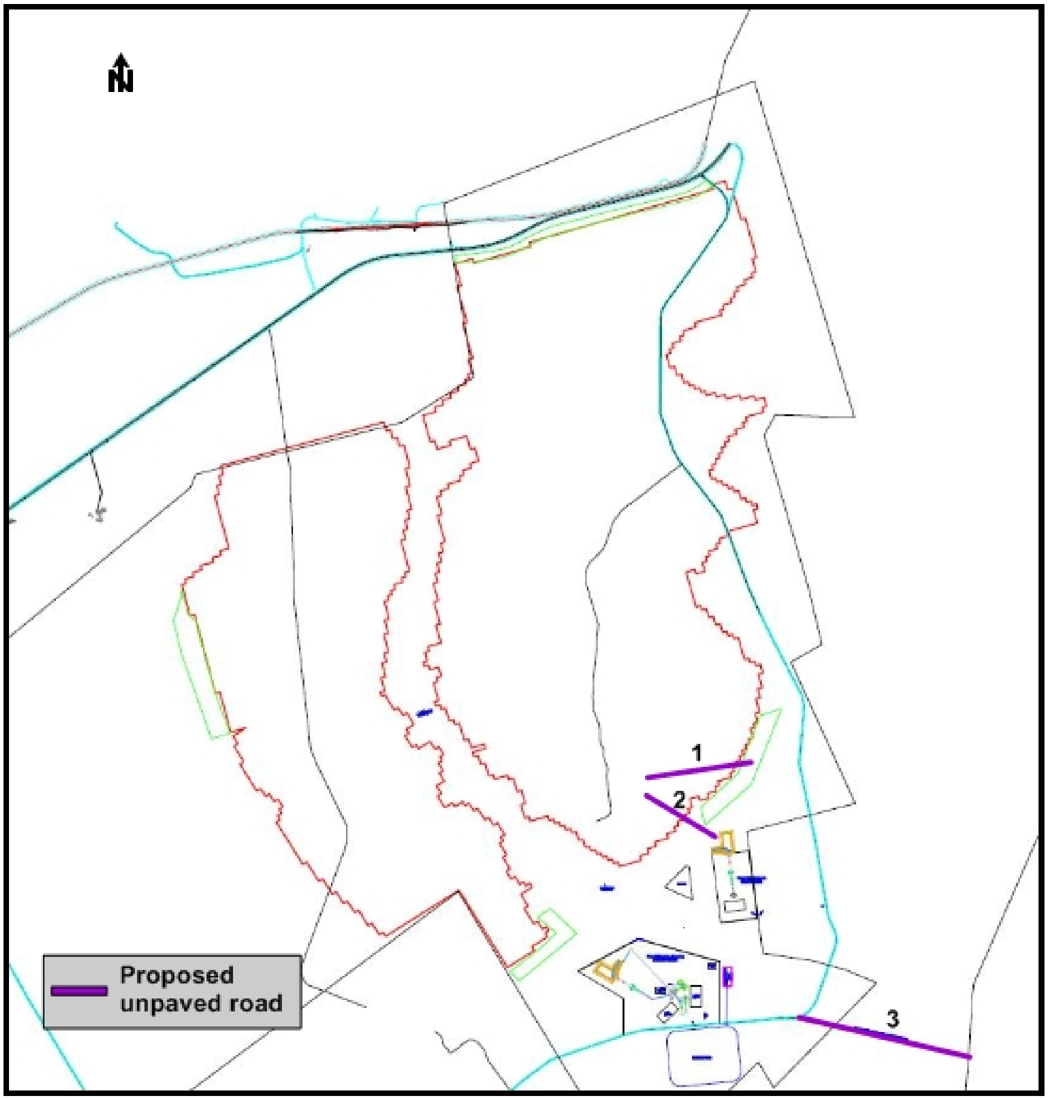

Figure 6-1: Locations of the unpaved roads for the construction phase (2011) of the proposed Belfast project.

6.1.3 Wind erosion from Exposed Areas

Significant emissions 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, promote 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 or disposal dump 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 (Burger, 1994; Burger et al., 1995).

The run of mine stockpile for crushed ore is identified to be a source that is prone to wind erosion. Topsoil and overburden stockpiles are not included in the dispersion modelling as part of the wind erosion sources. This is because topsoil will be used in berm construction and overburden generally consists of very coarse material that is not prone to wind erosion.

The calculation of an emission rate for every hour of the simulation period was carried out using the ADDAS model. This model is based on the dust emission model proposed by Marticorena and Bergametti (1995). The model attempts to account for the variability in source erodibility through the parameterisation of the erosion threshold (based on the particle size distribution of the source) and the roughness length of the surface. Equations used for calculating emission rates from wind erosion sources are shown in Appendix C (Equations 3-6).

In the quantification of wind erosion emissions, the model incorporates the calculation of two important parameters, viz. the threshold friction velocity of each particle size, and the vertically integrated horizontal dust flux, in the quantification of the vertical dust flux (i.e. the emission rate).

Information pertaining to the ROM stockpile utilised for the proposed construction phase is shown in Table 6-4.

Table 6-4: Information Input into the ADDAS Emission Model for the run of mine stockpile for the construction phase of the proposed Belfast Project

Source	Height (m)	Area (m^2)	x-length (m)	y-length (m)	Bulk density (kg/m^3)	Moisture (%)
Crushed coal stockpile	5	10000	100	100	1000	3.65

6.1.4 Crushing and Screening Activities

Primary crushing operations represent significant dust-generating sources if uncontrolled. Dust fallout in the vicinity of crushers also gives rise to the potential for the re-entrainment of emitted dust by vehicles or by the wind at a later date. The large percentage of fines in this dustfall material enhances the potential for it to become airborne. Equations 7 -8 in Appendix C (for low moisture content ore) are used in the calculation of emissions from primary and secondary crushing and screening activities. For the mitigated crushing and screening activities, the US-EPA high moisture emission factors are utilised (Equations 9-10 in Appendix C).

The parameters used for the calculation of emissions for crushing and screening activities for the proposed construction phase are shown in Table 6-5. It was assumed that the same tonnes of ore crushed and screened at the primary crusher will be transferred to the secondary crusher.

Table 6-5: Parameters used in the calculation of emissions from crushing and screening operations for the proposed construction phase during 2011.

Crushing and screening	Tonnes per day	Moisture (%)
Primary crushing and screening	7680	3.65
Secondary crushing and screening	7680	3.65

6.1.5 Drilling

Fugitive dust emissions due to drilling operations during the construction phase of the proposed project are quantified using the Australian NPI single value emission factors for mining (Equations 11 and 12 in Appendix C). The drilling parameters that are utilised for coal and overburden are presented in Table 6-6. A control efficiency of 99% is applied for the mitigated drilling operations as given in the Australian NPi document for mining operations where drilling activities include the use of filters and extractor fans as mitigation measures.

Table 6-6: Drilling source specific information: construction phase operations (2011) for the proposed Belfast Project.

Drilling parameter	Coal	Overburden
Drilling area	13500m² (116mx 116m)	13500m² (116mx 116m)
No of drill holes	36 drill holes/ 45m block	30 drill holes/ 45m block
Depth of each drill hole	12.2m	12.2
No of drill holes/day	364	280

6.1.6 Blasting

Source specific information used in the calculation of emissions due to blasting activities is presented in Table 6-7. No control efficiency is assumed for blasting. Equation 13 in Appendix C is used in the calculation of emissions from blasting.

Table 6-7: Blasting source specific information for the proposed construction phase during 2011.

Blasting parameter	Parameter units/ value
Blasting area	13500m²
Blasts per week (coal)	1
Blasts per week (overburden)	1
Days per year	365

6.1.7 Excavation

The US–EPA equation (Equation 14 in Appendix C) is used to calculate emissions due to proposed excavation activities. Table 6-8 depicts the parameters used in calculating emissions due to excavating activities. No control efficiency is assumed for excavation.

Table 6-8: Parameters used in the calculation of emissions from excavating activities during the construction phase (2011).

Scenario	Parameters of excavated area		
	Length (m)	Width (m)	Total area
Construction phase	116	116	13500

6.1.8 Scraping

The US–EPA Equations 15 and 16 in Appendix C are used to calculate emissions due to proposed scraping activities. The parameters used in calculating emissions due to the scraping activities are shown in Table 6-9. No control efficiency is assumed for scraping.

Table 6-9: Parameters used in the calculation of emissions from scraping activities during the construction phase (2011).

Scenario	Parameters of scraped area		
	Length (m)	Width (m)	Total area
Construction phase	116	116	13500

6.2 Synopsis of Estimated Emissions for the Construction Phase of the proposed Belfast Project

6.2.1 Scenario 1a: Unmitigated proposed 2011 construction activities

A synopsis of the estimated particulate emissions as a result of the unmitigated 2011 construction mining activities is presented in Table 6-10 and depicted in Figure 6-2 (PM10 source contributions) and Figure 6-3 (TSP source contributions). Unpaved roads are the most contributing source to PM10 and the second most contributing source to TSP emissions (45.2% and 29.1% respectively). The second most significant source of PM10 and the most significant source of TSP is predicted to be crushing and screening, with a contribution of 31.1% to PM10 and 62.4% to TSP. Blasting is predicted to be the third most significant source of both PM10 and TSP emissions, with a contribution of 10.5% and 3.6% respectively. The fourth most significant source of PM10 and TSP is predicted to be drilling, with a contribution of 6.2% to PM10 emissions and 1.9% to TSP emissions. Wind erosion is the sixth most significant source of PM10 and the seventh contributing source to TSP (1.5% and 0.8% respectively). The least contributing source to PM10 and TSP emissions is predicted to be materials handling.

Table 6-10: Source group contribution to unmitigated PM10 and TSP emissions (tpa) during the construction phase (2011) of the proposed Belfast Project.

Source	PM10	TSP	PM10 %	TSP %	Rank PM10	Rank TSP
Crushing and screening	191	2243	31.1	62.4	2	1
Materials handling	1	3	0.2	0.1	8	8
Wind erosion	9.1	27	1.5	0.8	6	7
Unpaved roads	277	1045	45.2	29.1	1	2
Blasting	64	130	10.5	3.6	3	3
Excavation	24	50	3.9	1.4	5	5
Drilling	38	69	6.2	1.9	4	4
Scraping	8.8	29	1.4	0.8	7	6
Total	613.5	3596.4	100.0	100.0		

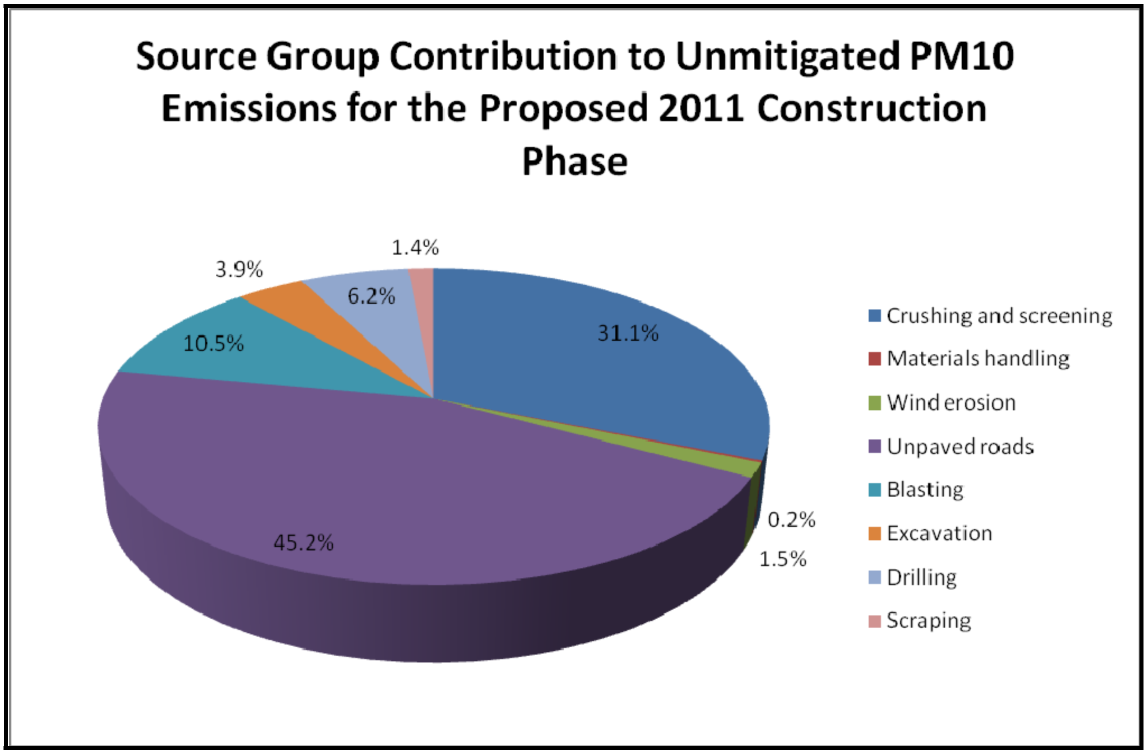

Figure 6-2: Source group contribution to estimated unmitigated 2011 construction phase PM10 emissions.

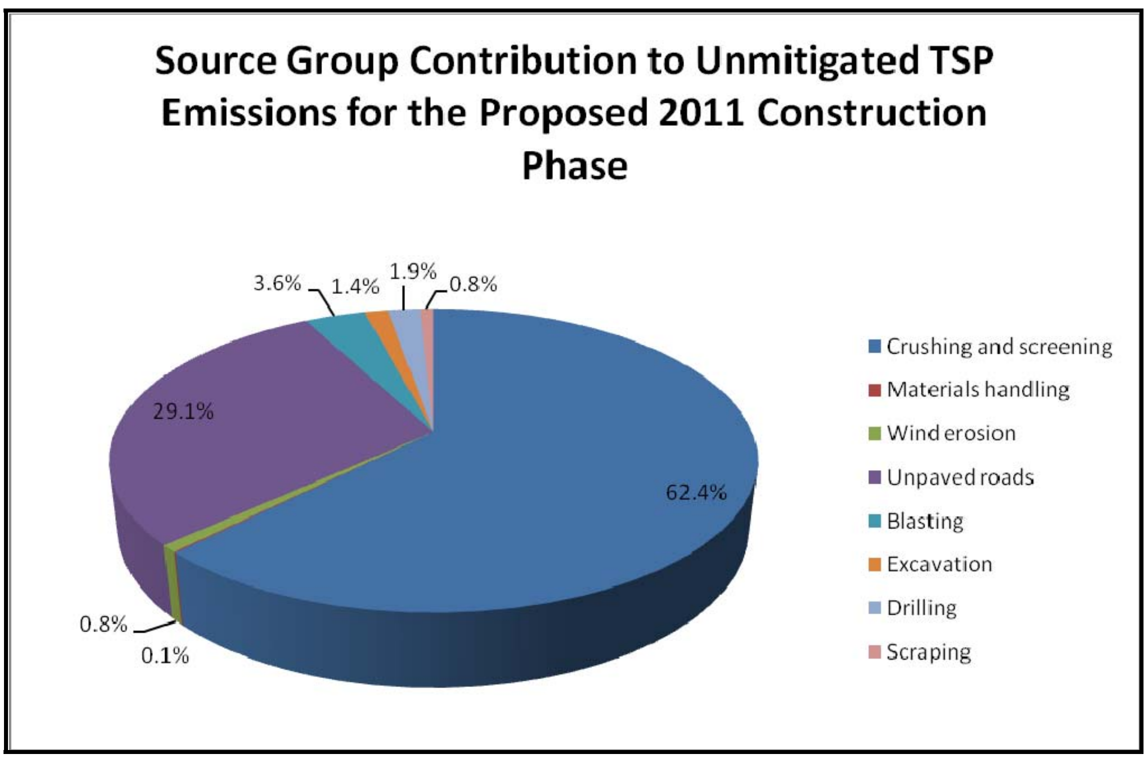

Figure 6-3: Source group contribution to estimated unmitigated 2011 construction phase TSP emissions.

6.2.2 *Scenario 1b: Mitigated proposed 2011 construction activities*

For this scenario, mitigation measures are applied to unpaved roads, crushing and screening and drilling. Mitigation measures are applied to these sources as the project proponent has indicated that control measures will be in place for each of them (water suppression for the unpaved roads, with a possibility of chemical suppression, water sprays at the primary crusher and extractor fans and filters on all drills). A synopsis of the estimated particulate emissions as a result of the application of mitigation measures for the above-mentioned sources during the 2011 construction phase is presented in Table 6-11 and depicted in Figure 6-4 (PM10 source contributions) and Figure 6-5 (TSP source contributions). Even with controls in place, unpaved roads are still predicted to be the most contributing source to PM10 and TSP emissions (31.1% and 42.6% respectively). The second most significant source of PM10 and TSP is predicted to be blasting, with a contribution of 29% to PM10 and 21.2% to TSP. Crushing and screening is predicted to be the third most significant source of PM10 and TSP emissions, with a contribution of 20.3% and 18.3% respectively. The fourth most significant source of PM10 and TSP is predicted to be excavation, with a contribution of 10.8% to PM10 emissions and 8.2% to TSP emissions. Wind erosion is the fifth most significant source of PM10 and the sixth contributing source to TSP (4.1% and 4.4% respectively). Drilling is predicted to be the least contributing source to PM10 and TSP emissions and this can be attributed to the application of control measures with high control efficiencies (99% control efficiency with the proposed drilling control measures).

Table 6-11: Source group contribution to partially mitigated PM10 and TSP emissions (tpa) during the construction phase (2011) of the proposed Belfast Project.

Source	PM10	TSP	PM10 %	TSP %	Rank PM10	Rank TSP
Crushing and screening	45	112	20.3	18.3	3	3
Materials handling	1	3	0.5	0.6	7	7
Wind erosion	9.1	27	4.1	4.4	5	6
Unpaved roads	69	261	31.1	42.6	1	1
Blasting	64	130	29.0	21.2	2	2
Excavation	24	50	10.8	8.2	4	4
Drilling	0.4	0.6	0.2	0.1	8	8
Scraping	8.8	29	4.0	4.7	6	5
Total	221.9	613.0	100.00	100.00		

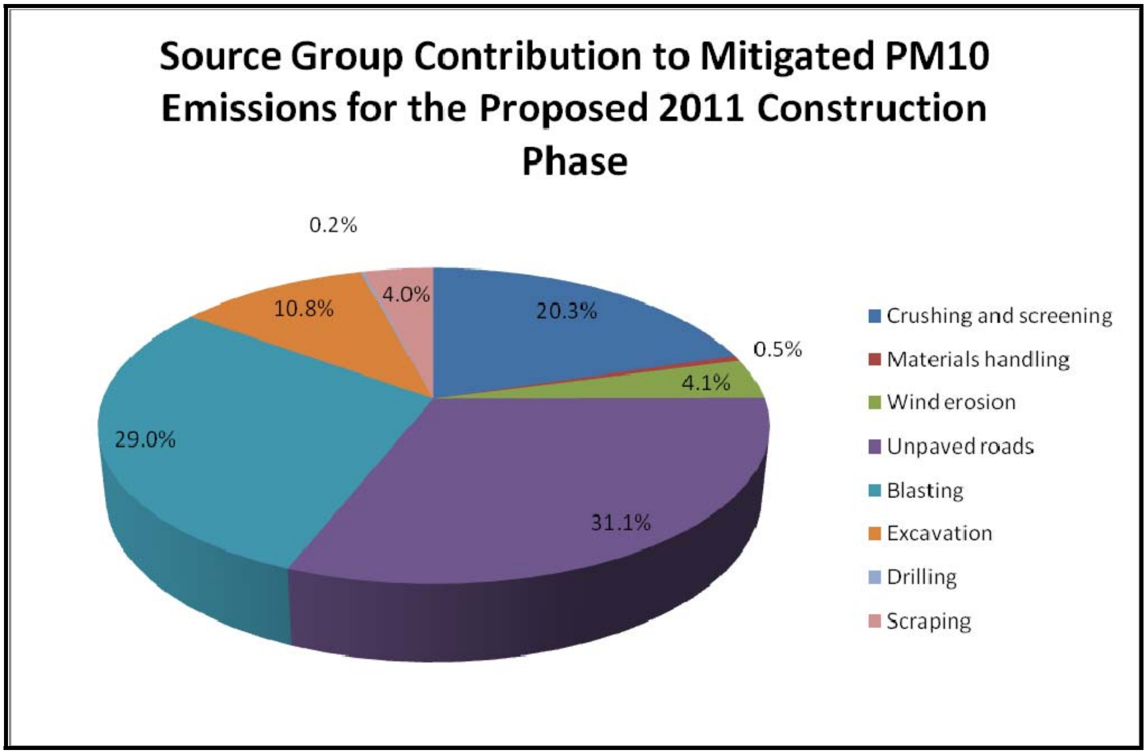

Figure 6-4: Source group contribution to estimated mitigated 2011 construction phase PM10 emissions.

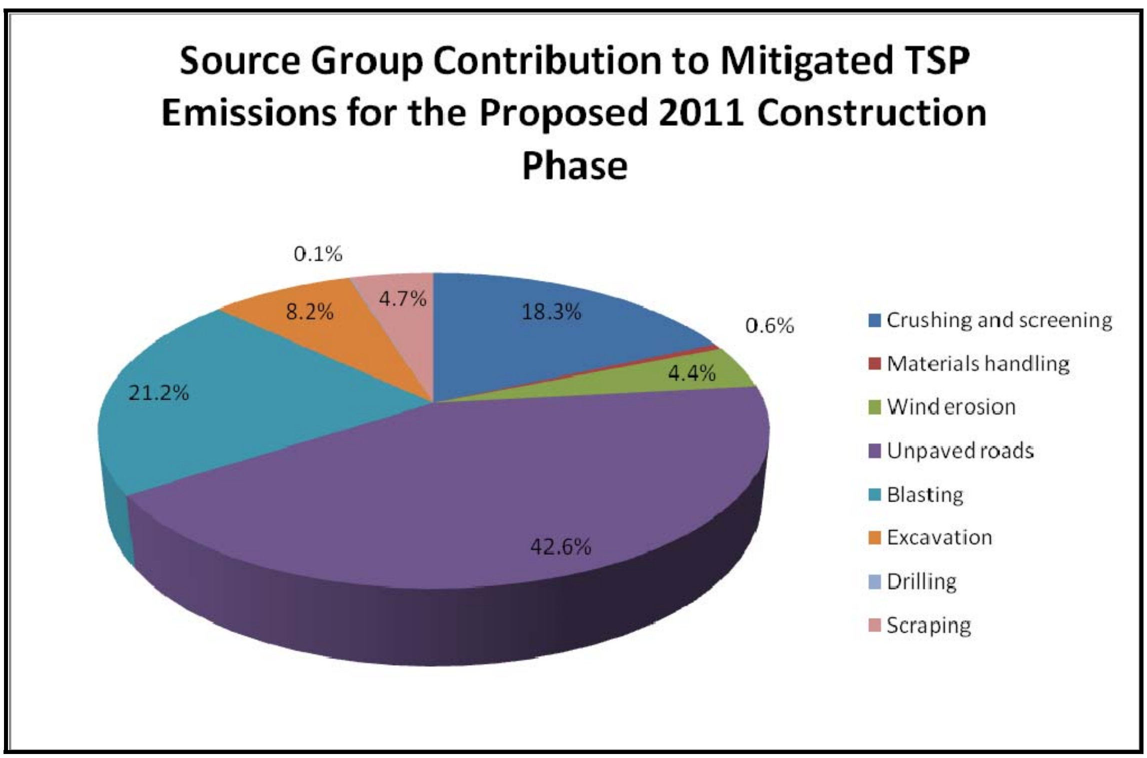

Figure 6-5: Source group contribution to estimated mitigated 2011 construction phase TSP emissions.

6.3 Dispersion Model Results for 2011 Construction Phase

This section focuses on potential impacts (due to the proposed 2011 construction activities) at the sensitive receptor sites located close to the proposed mine. The identified sensitive receptors include the Jan Burger Farmstead, farmstead located to the north west of the N4 and the one located to the south east of the proposed mine boundary.

6.3.1 Predicted PM10 Concentrations due to the 2011 Construction Phase of the Belfast Project (Scenario 1)

- The predicted unmitigated daily average ground level concentrations for the proposed 2011 construction activities exceed the proposed SA Standard and the EC PM10 limit of 50 µg/m³ at the Jan Burger Farmstead and the farmstead located to the south east of the proposed mine site (Table 6-12 and Figure 6-6). The application of mitigation measures to the most significant contributing sources (unpaved roads, drilling, crushing and screening) results in the predicted impacts complying with the proposed SA Standard at all the sensitive receptor sites (Table 6-12 and Figure 6-7).

- Unpaved roads and crushing and screening were predicted to be the most significant sources of PM10 emissions during the proposed construction phase. Predicted impacts due to the absence of mitigation measures and the application of mitigation measures to these sources are shown in Figure 6-8 and Figure 6-9 (unpaved roads), Figure 6-10 and Figure 6-11 (crushing and screening). It is evident that the application of mitigation measures to these sources results in a significant reduction of impacts.

- The predicted unmitigated annual average ground level concentrations for the proposed construction phase exceed the proposed SA Standard of 40 µg/m³ and the EC air quality standard of 40 µg/m³ at Jan Burger Farmstead and the farmstead located to the south east of the proposed mine site (Table 6-12 and Figure 6-12). The predicted impacts, however, do not exceed the proposed SA Standard at all the sensitive receptor areas if mitigation measures are applied to the main contributing sources (Table 6-12 and Figure 6-13).

- The plots indicating the predicted annual average ground level concentrations due to unpaved roads and crushing and screening are shown in Figure 6-14 and Figure 6-15 (unpaved roads) and Figure 6-16 and Figure 6-17 (crushing and screening).

Table 6-12: Predicted highest daily average and annual PM10 concentrations (µg/m³) at the sensitive receptor sites due to the proposed 2011 construction activities.

Sensitive Receptor Area	*Scenario*	PM10 Concentration (µg/m³)	
		Daily concentration	Annual concentration
Jan Burger Farmstead	Unmitigated construction phase *(Scenario 1a)*	195	58
	Mitigated construction phase (*Scenario 1b)*	49	14
Farmstead next to N4	Unmitigated construction phase *(Scenario 1a)*	5	0.6
	Mitigated construction phase (*Scenario 1b)*	1.2	0.2
Farmstead to the south east	Unmitigated construction phase *(Scenario 1a)*	180	95
	Mitigated construction phase (*Scenario 1b)*	44	23

It is possible that the predicted concentrations at the sensitive receptors as a result of the proposed construction activities would be much higher when background concentrations in the region are taken into consideration and if reasonable mitigation measures are not applied.

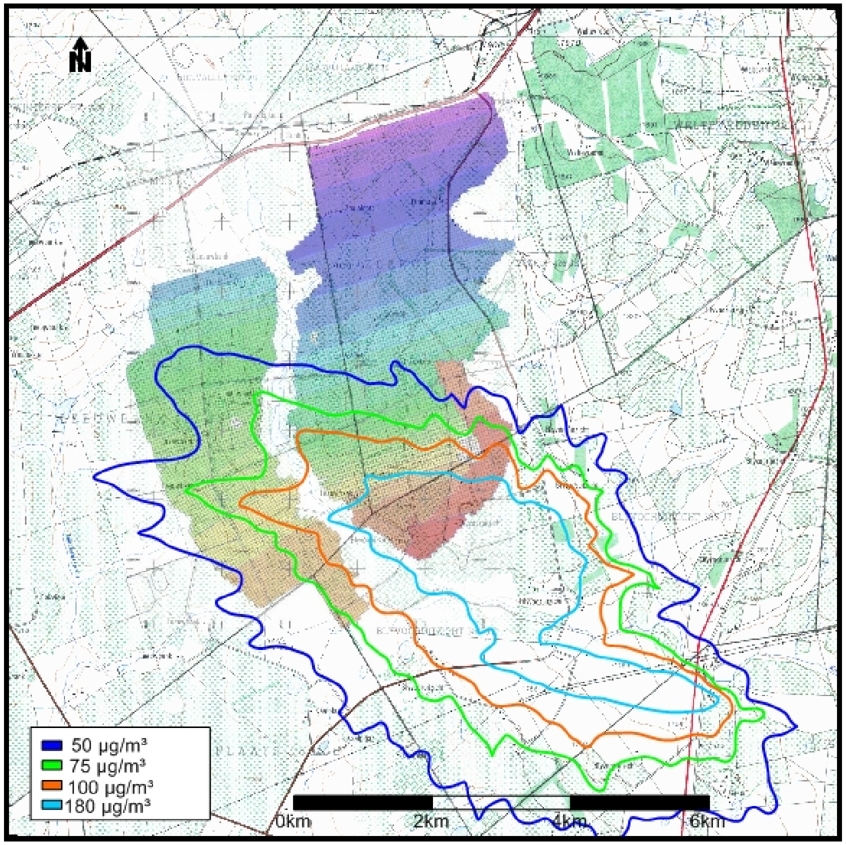

Figure 6-6: Highest daily average predicted PM10 ground level concentrations (µg/m³) for all sources due to unmitigated emissions- 2011 construction phase of the proposed Belfast Project.

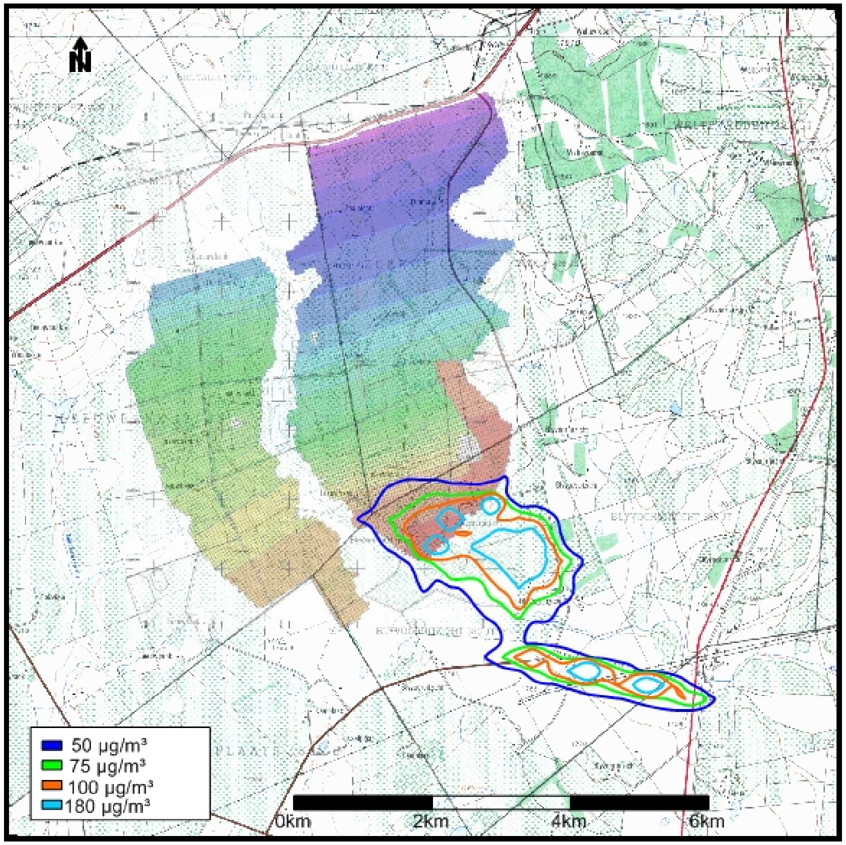

Figure 6-7: Highest daily average predicted PM10 ground level concentrations (µg/m³) for all sources due to partially mitigated unpaved roads, drilling, crushing and screening emissions- 2011 construction phase of the proposed Belfast Project.

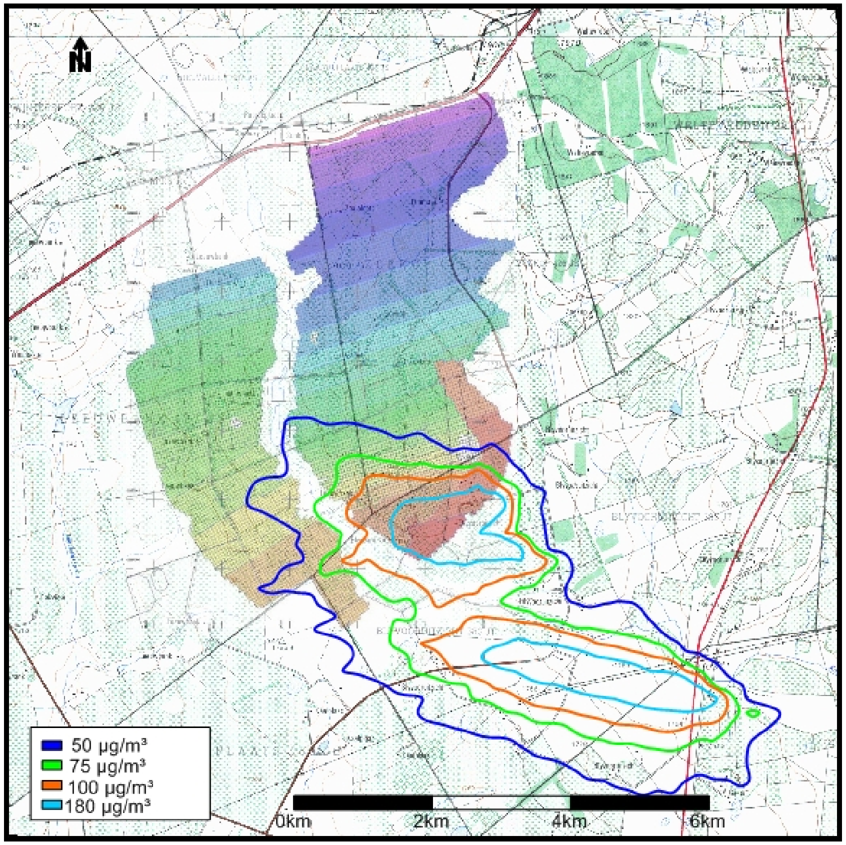

Figure 6-8: Highest daily average predicted PM10 ground level concentrations (µg/m³) due to unmitigated unpaved roads emissions- 2011 construction phase of the proposed Belfast Project.

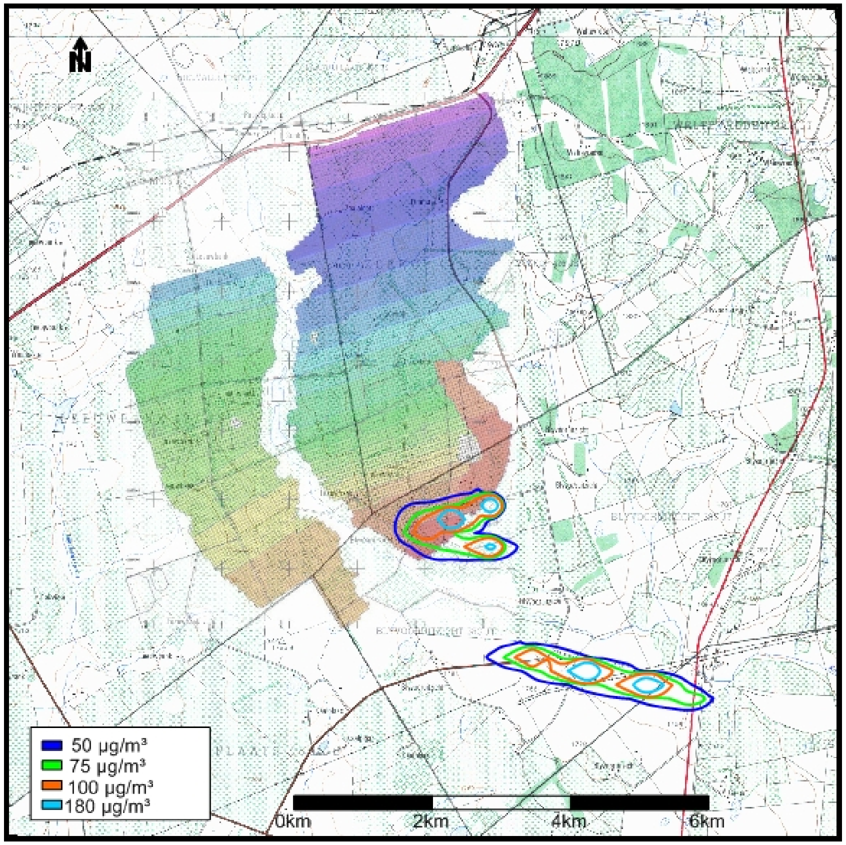

Figure 6-9: Highest daily average predicted PM10 ground level concentrations (µg/m³) due to mitigated unpaved roads emissions- 2011 construction phase of the proposed Belfast Project.

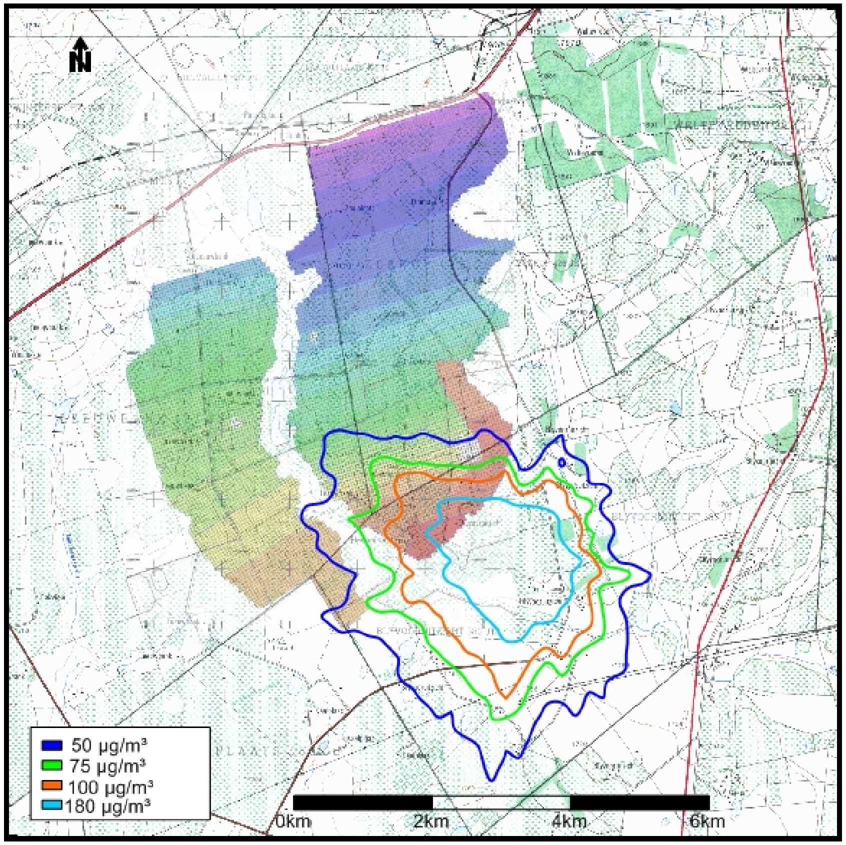

Figure 6-10: Highest daily average predicted PM10 ground level concentrations (µg/m³) due to unmitigated crushing and screening emissions- 2011 construction phase of the proposed Belfast Project.

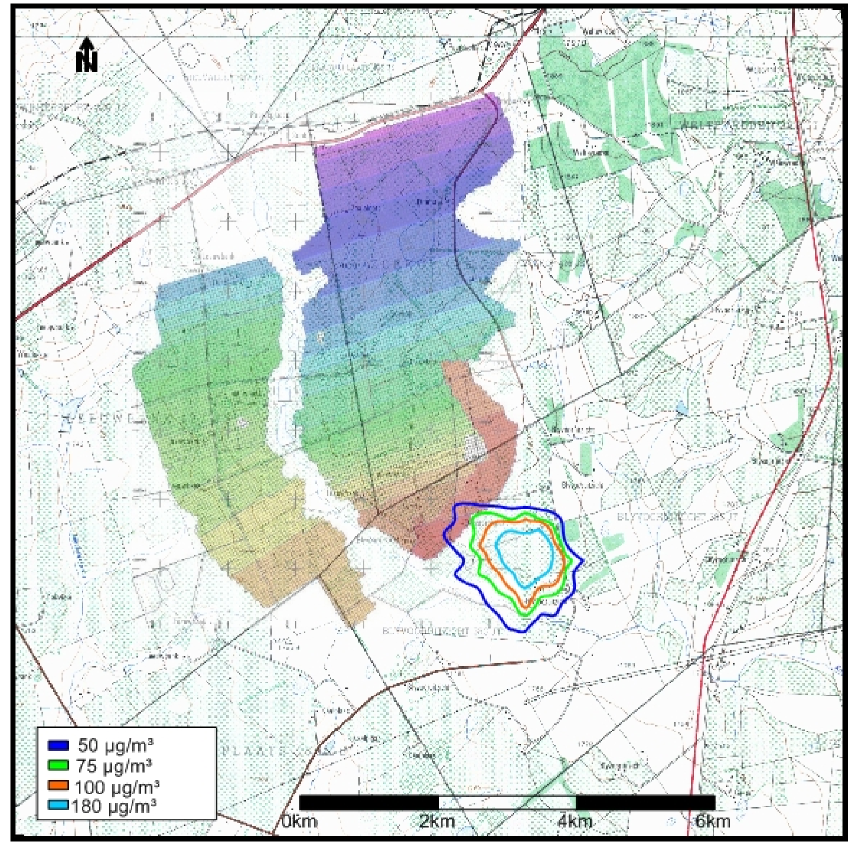

Figure 6-11: Highest daily average predicted PM10 ground level concentrations (µg/m³) due to mitigated crushing and screening emissions- 2011 construction phase of the proposed Belfast Project.

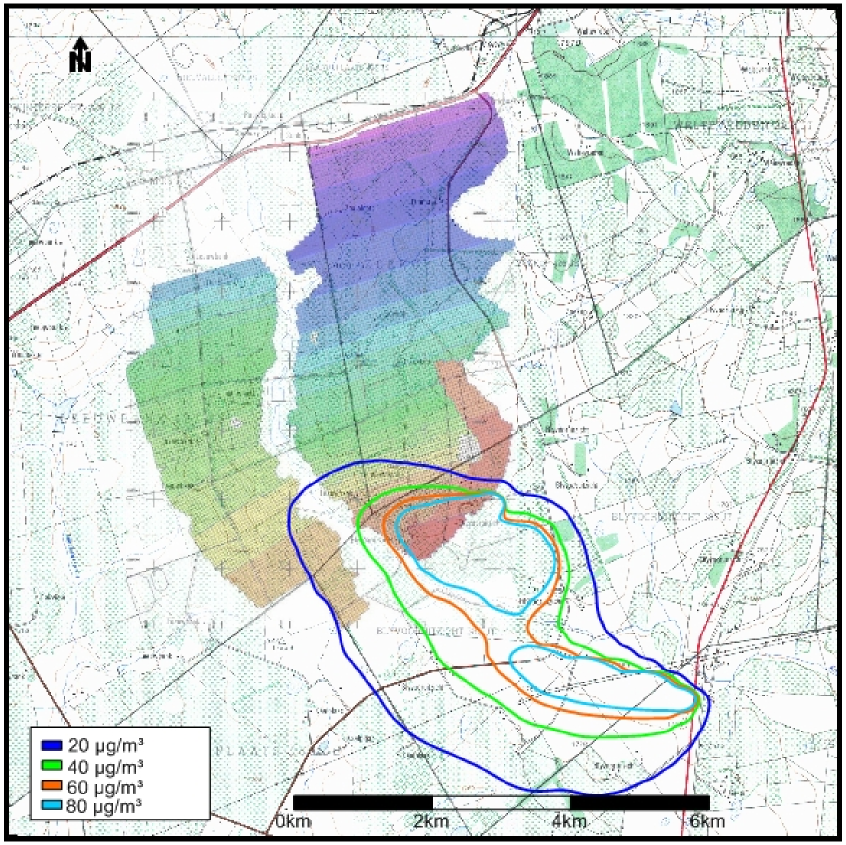

Figure 6-12: Annual average predicted PM10 ground level concentrations (µg/m³) for all sources due to unmitigated emissions-2011 construction phase of the proposed Belfast Project.

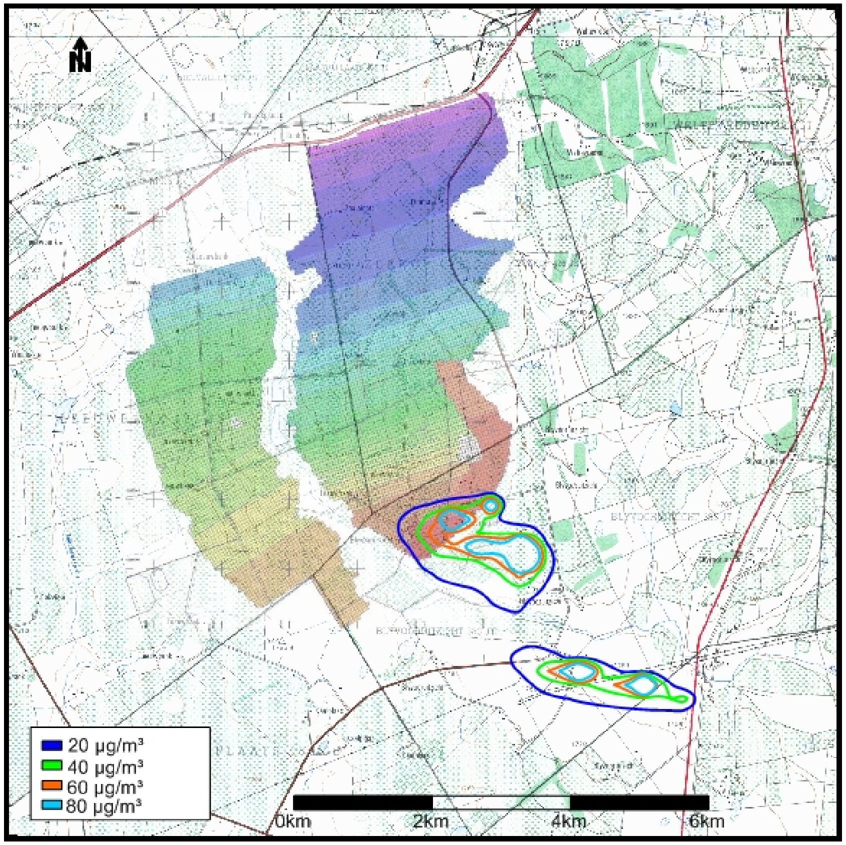

Figure 6-13: Annual average predicted PM10 ground level concentrations (µg/m³) for all sources due to partially mitigated unpaved roads, drilling, crushing and screening emissions - 2011 construction phase of the proposed Belfast Project.

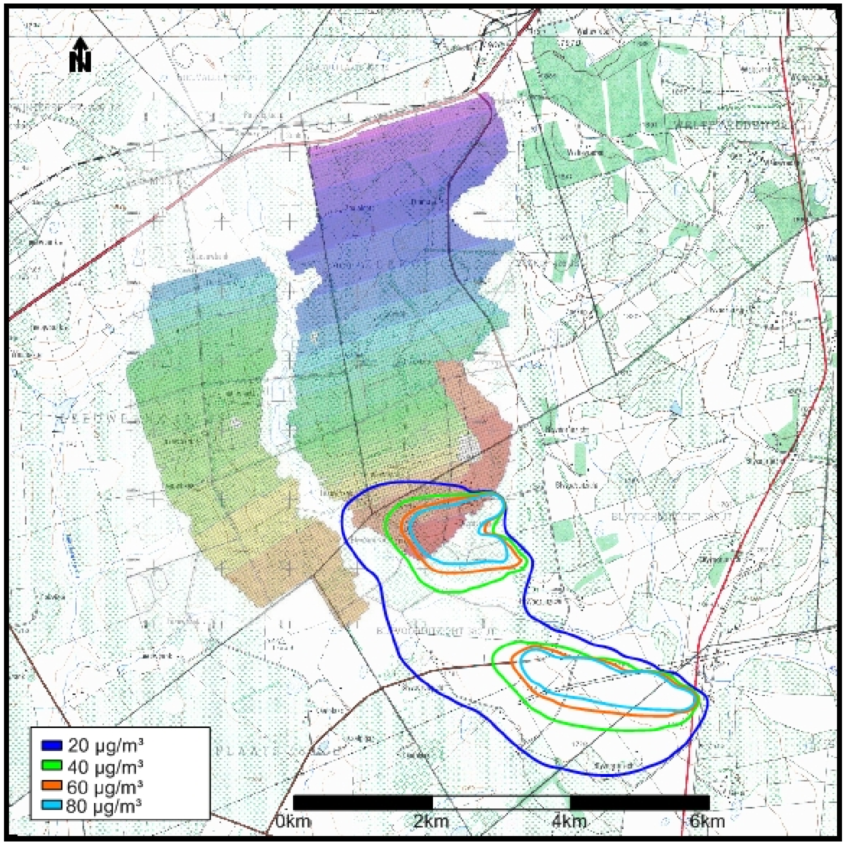

Figure 6-14: Annual average predicted PM10 ground level concentrations (µg/m³) due to unmitigated unpaved road emissions- 2011 construction phase of the proposed Belfast Project.

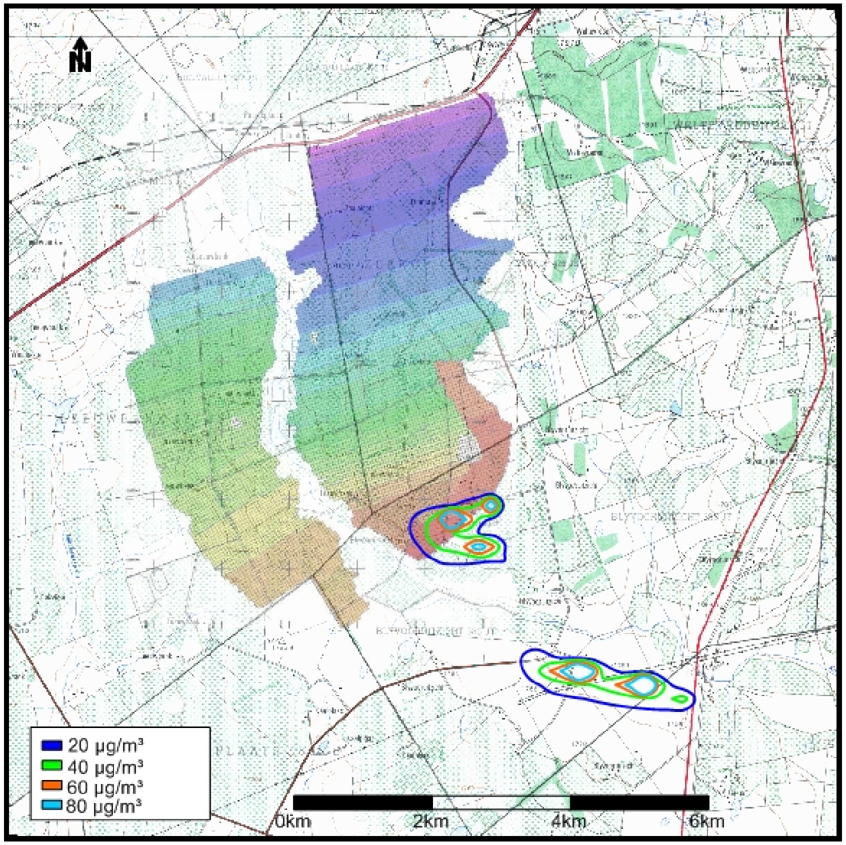

Figure 6-15: Annual average predicted PM10 ground level concentrations (µg/m³) due to mitigated unpaved road emissions- 2011 construction phase of the proposed Belfast Project.

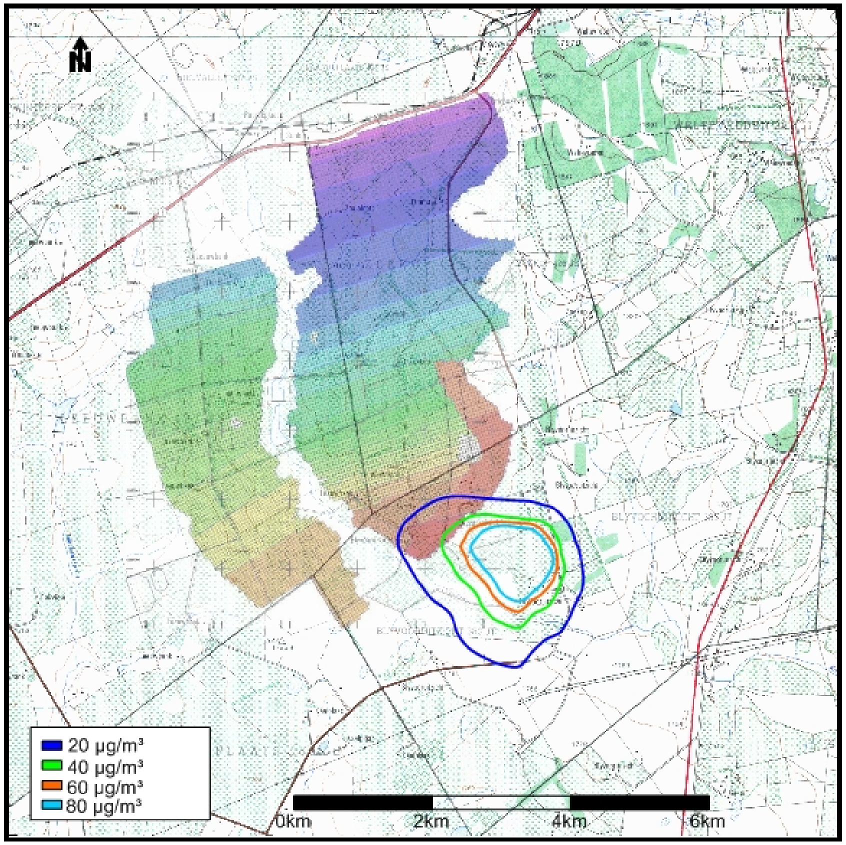

Figure 6-16: Annual average predicted PM10 ground level concentrations (µg/m³) due to unmitigated crushing and screening emissions- 2011 construction phase of the proposed Belfast Project.

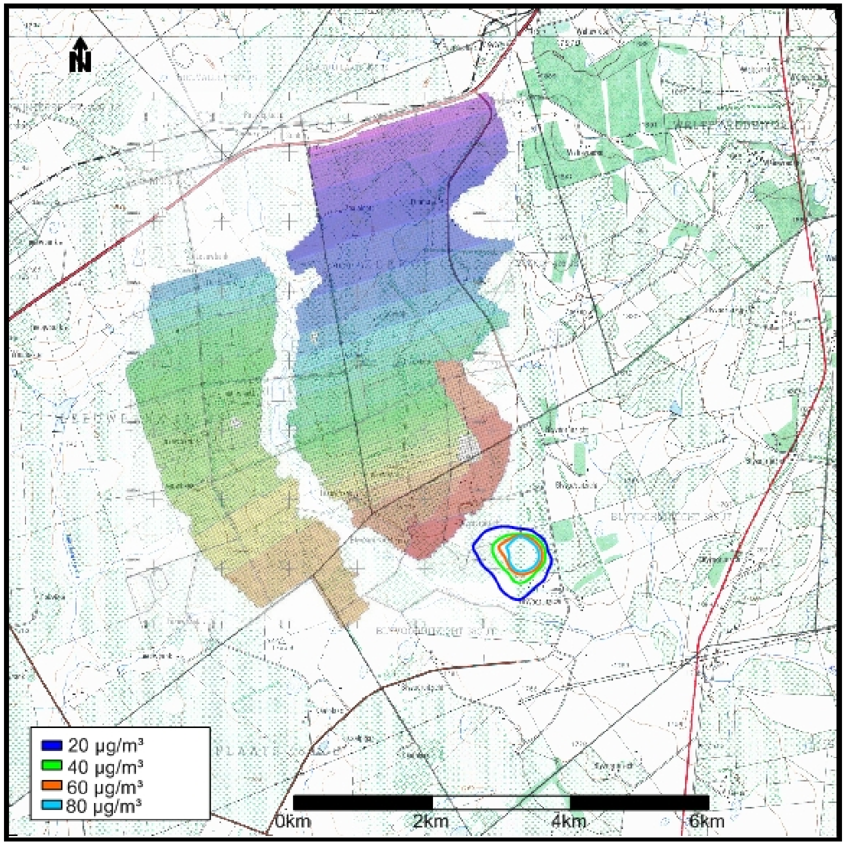

Figure 6-17: Annual average predicted PM10 ground level concentrations (µg/m³) due to mitigated crushing and screening emissions- 2011 construction phase of the proposed Belfast Project

6.3.2 Predicted Dust Fallout Levels due to the 2011 Construction Phase of the Belfast Project

- The predicted maximum daily dust fallout levels due to unmitigated and mitigated proposed 2011 construction phase fall within the SANS residential target of 600 mg/m²/day at all the sensitive receptor areas (Table 6-13, Figure 6-18 and Figure 6-19).

- The predicted maximum dust fallout levels due to the unmitigated and mitigated unpaved roads are shown in Figure 6-20 and Figure 6-21, while those for crushing and screening are shown in Figure 6-22 and Figure 6-23. The application of mitigation measures to these significant sources of particulates results in significant reductions of predicted impacts.

Table 6-13: Predicted maximum dust fallout levels (mg/m²/day) at the sensitive receptor sites due to the proposed 2011 construction activities.

Sensitive Receptor Area	***Scenario***	**Maximum daily dust fallout (mg/m²/day)**
Jan Burger Farmstead	Unmitigated 201 operational phase *(Scenario 1a)*	89
	Mitigated 2016 operational phase (*Scenario 1b)*	10
Farmstead next to N4	Unmitigated 2016 operational phase *(Scenario 1a)*	8
	Mitigated 2016 operational phase: (*Scenario 1b)*	2
Farmstead to the south east	Unmitigated 2016 operational phase *(Scenario 1a)*	81
	Mitigated 2016 operational phase: (*Scenario 1b)*	18

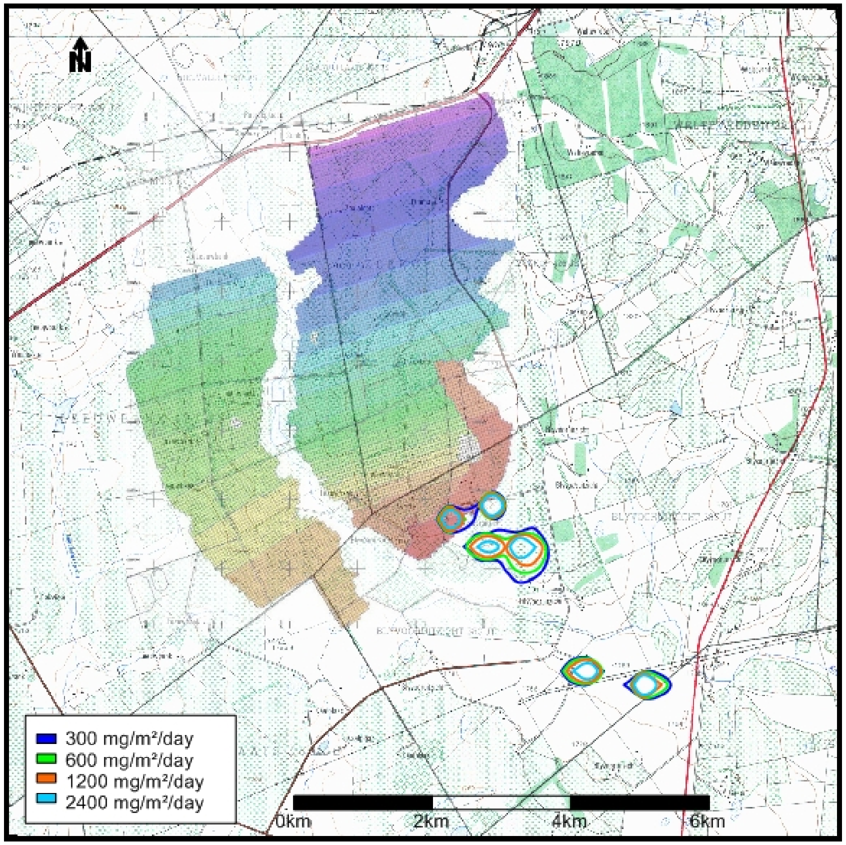

Figure 6-18: Predicted maximum daily dust deposition rates (mg/m²/day) for all sources due to unmitigated emissions- 2011 construction phase of the proposed Belfast Project.

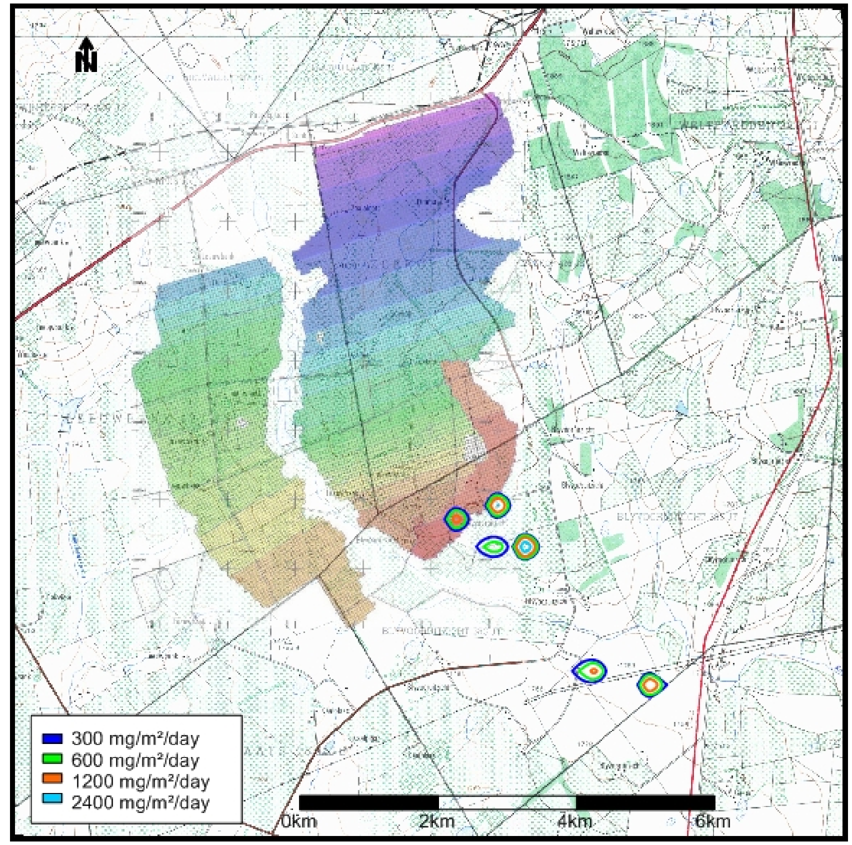

Figure 6-19: Predicted maximum daily dust deposition rates (mg/m²/day) for all sources due to partially mitigated unpaved roads, drilling, crushing and screening emissions- 2011 construction phase of the proposed Belfast Project.

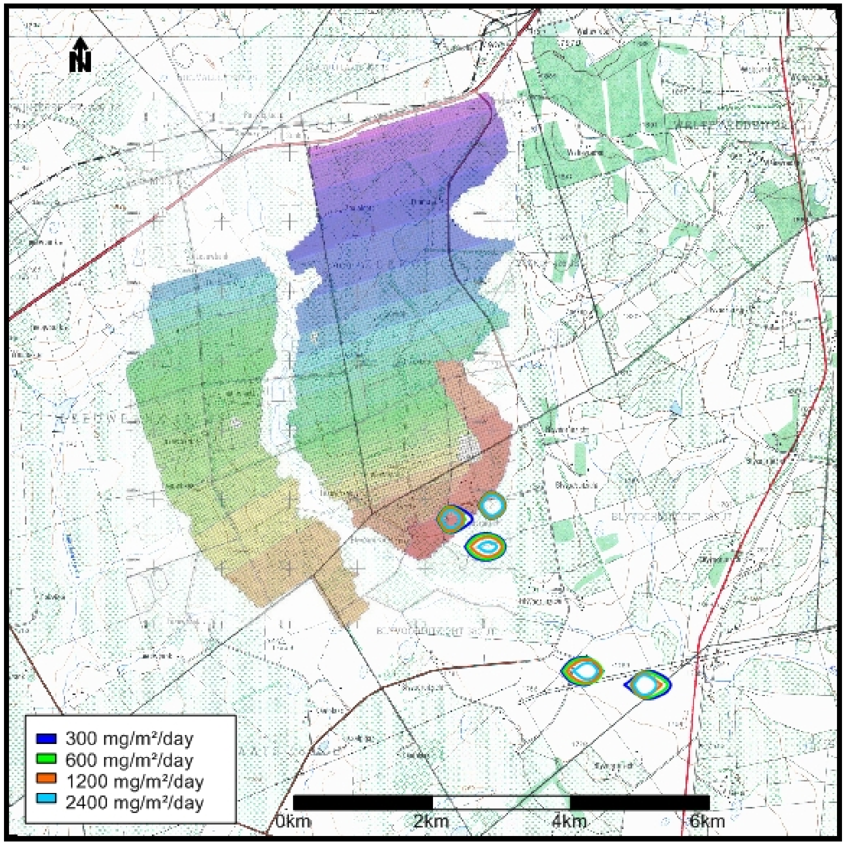

Figure 6-20: Predicted maximum daily dust deposition rates (mg/m²/day) due to unmitigated unpaved roads emissions- 2011 construction phase of the proposed Belfast Project.

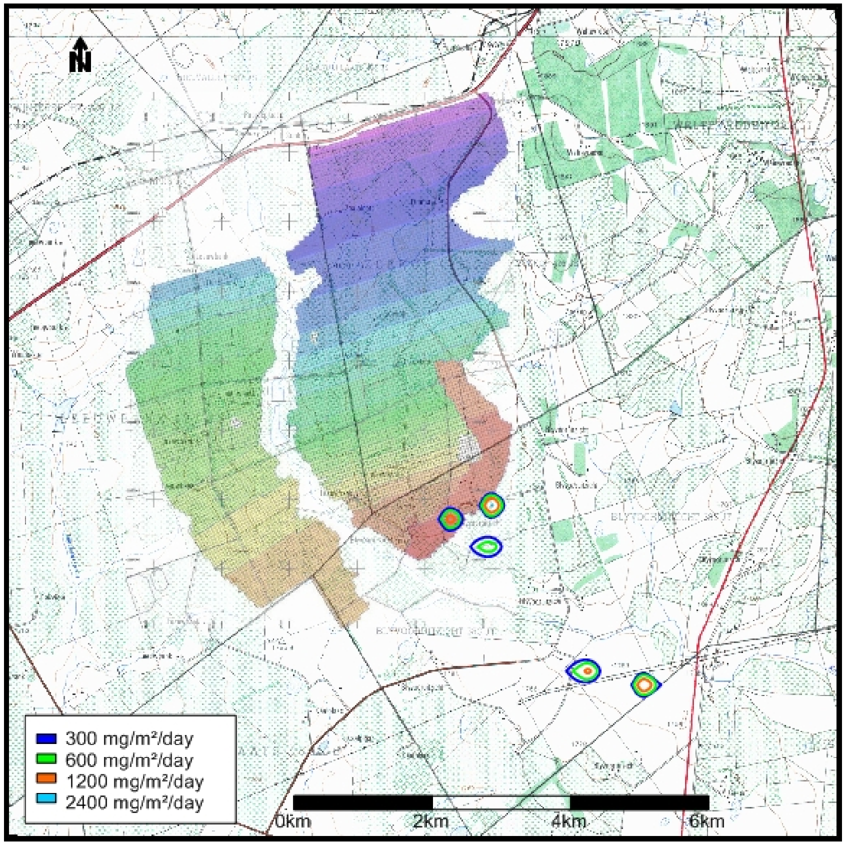

Figure 6-21: Predicted maximum daily dust deposition rates (mg/m²/day) due to mitigated unpaved roads emissions- 2011 construction phase of the proposed Belfast Project.

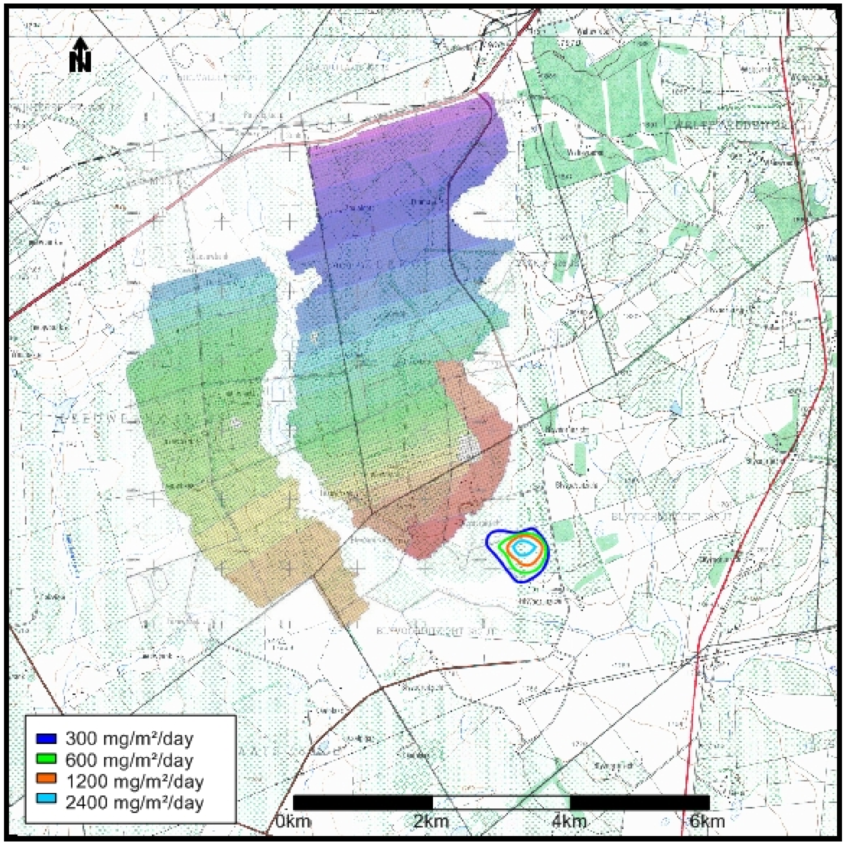

Figure 6-22: Predicted maximum daily dust deposition rates (mg/m²/day) due to unmitigated crushing and screening emissions-2011 construction phase of the proposed Belfast Project.

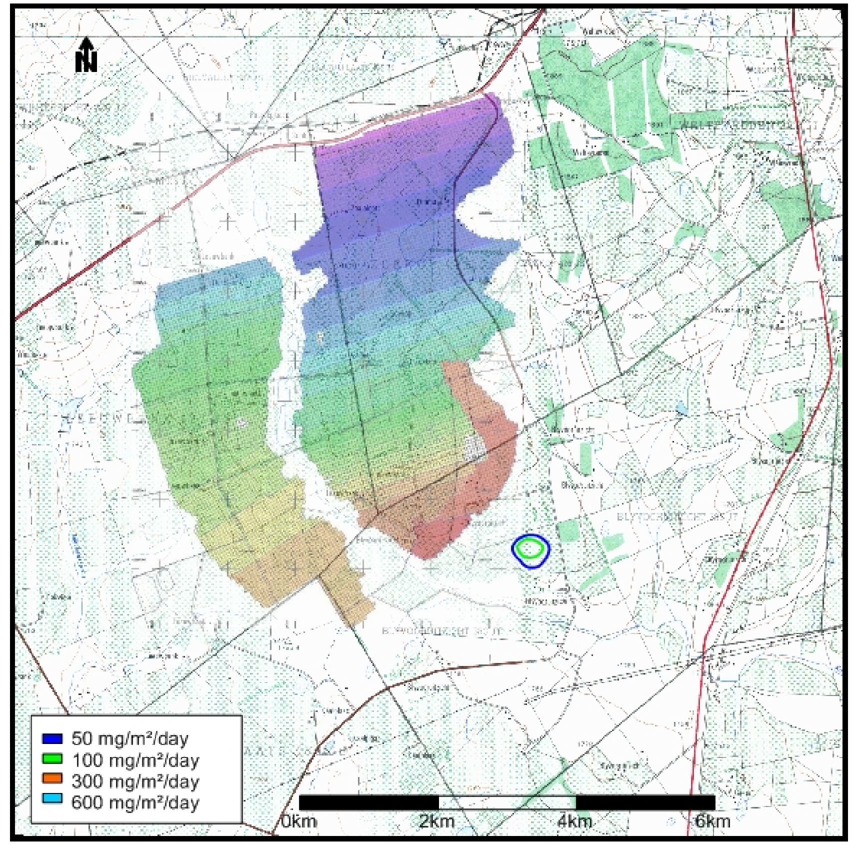

Figure 6-23: Predicted maximum daily dust deposition rates (mg/m²/day) due to mitigated crushing and screening emissions-2011 construction phase of the proposed Belfast.

6.4 Proposed mitigation measures

Although mitigation measures were assumed for the unpaved roads, drilling, crushing and screening in this study, other effective dust control mitigation measures can be applied (based on good practice) during the proposed construction phase. The implementation of effective controls during this phase would also serve to set the precedent for mitigation during the operational phase.

Control techniques for fugitive dust sources generally involve watering, chemical stabilization, and the reduction of surface wind speed though the use of windbreaks and source enclosures. Proposed dust control measures which may be implemented during the construction phase are as follows:

- Debris handling - wind speed reduction through sheltering and wet suppression.
- Truck transport - wet suppression or chemical stabilization of unpaved roads;
- Dust entrainment – reduction of unnecessary traffic and strict speed control, require haul trucks to be covered, and ensure material being hauled is wet or covered.
- Materials storage, handling and transfer operations - wet suppression.
- Earthmoving and dozing operations - wet suppression.
- General construction - wind speed reduction, wet suppression and early paving of permanent roads. Phasing of earthmoving activities to reduce source size.
- Open areas (wind-blown emissions) - early vegetation and stabilization of disturbed soil and reduction of the frequency of disturbance.

7 OPERATIONAL PHASE (2016)

An emissions inventory was also established for the 2016 operational phase mining activities where mining is proposed to take place at both the western and eastern sides of the areas scheduled for open cast mining. Emission rates are calculated for unmitigated and mitigated sources (unpaved roads, crushing and screening and drilling). The same emission factors and equations used in the calculation of emissions from the various sources during the proposed construction phase are applied in the calculation of emissions for the proposed 2016 operational phase sources.

7.1.1 Materials Handling Operations

The parameters used in the calculation of emissions as a result of materials handling activities handling operations for the eastern and western area during the proposed 2016 operations are depicted in Table 7-1.

Table 7-1: Material handling operations for the operational phase of the proposed Belfast Project during Phase 2 (2016).

Operation	Location	Throughput (t/hr)
Tipping coal to haul trucks	Eastern area open pit	113
	Western area open pit	263
Tipping overburden to haul trucks	Eastern area open pit	628
	Western area open pit	1268
Tipping overburden to pile	P2-D3 waste dump	628
	P2-D4 waste dump	1268
Tipping of crushed and washed ore to haul trucks	Washing plant	571
Tipping of surplus coal	Surplus coal stockpile 1	6
Tipping of surplus coal	Surplus coal stockpile 2	6

7.1.2 Vehicle Activity on Unpaved Roads

Table 7-2 depicts the parameters used in the calculation of emission rates from the proposed unpaved roads located in the western and eastern open pit areas. The silt percentage for the unpaved roads (as obtained from recommended US-EPA values in the absence of site-specific data) within the proposed open pit area and to the overburden stockpiles is 8.4% and 5.1% for unpaved roads to the crushing and screening plant.

Table 7-2: Parameters of the unpaved haul roads simulated for the operational phase (2016) for the proposed Belfast Project.

Unpaved road description	Length	Width
Road 1 to overburden pile (P2-D3)	450	10
Road 2 to overburden pile (P2-D3)	700	10
Road 3 to overburden pile (P2-D3)	750	10
Road 4 to overburden pile (P2-D3)	450	10
Road 5 to overburden pile (P2-D3)	1140	10
Road 6 to overburden pile (P2-D3)	1100	10
Road 7 to overburden pile (P2-D3)	450	10
Road 8- eastern area coal to plant	1950	10
Road 9- eastern area overburden and ore to plant	1400	10
Road 10- western area coal to plant	700	10
Road 11- western area coal to plant	500	10
Road 12- eastern and western areas coal to plant	1600	10
Road 13- eastern and western areas coal to plant	1500	10
Road 14 -Western area overburden to pile	1500	10
Road 15 to R33 public road	2330	10

The assumed locations of the unpaved roads (eastern and western area) for the proposed 2016 operational phase are shown in Figure 7-1.

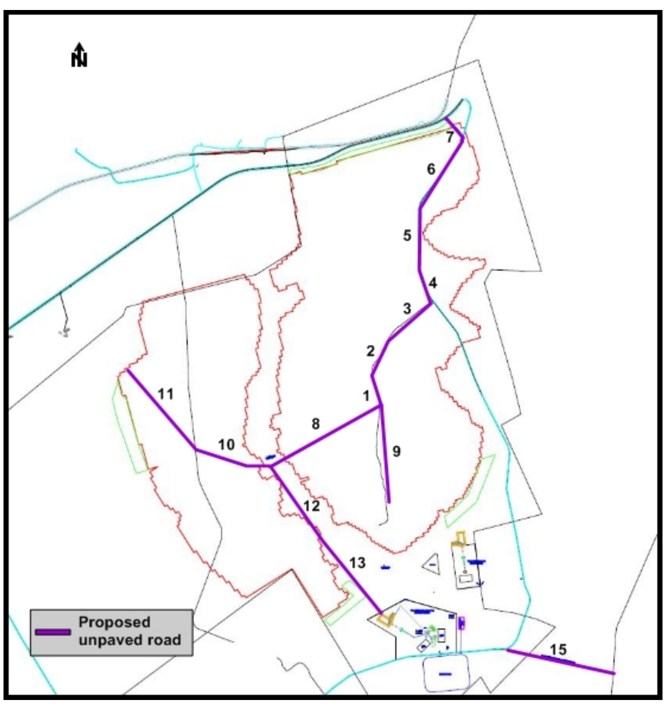

Figure 7-1: Locations of the unpaved roads for the operational phase (2016) of the proposed Belfast project.

7.1.2.1 Vehicle exhaust emissions for the proposed 2016 operational phase

In the development of an emissions inventory for vehicle emissions, the first approach is to establish a comprehensive list of all vehicles that would generate the pollutants of concern. This information should include;

- Type of vehicles (I.e. light duty vehicle, earthmoving vehicles, busses, cranes, heavy duty vehicles, etc.);
- Number of vehicles (per type);
- Type of fuel used (i.e. diesel or petrol) per type of vehicle;
- Fuel consumption; and,
- Total vehicle kilometres travelled.

The vehicle information obtained from the client was utilised to quantify the vehicle emissions from the 2016 operational phase of the proposed Belfast Project. To quantify the exhaust emissions from the vehicles, use was made of the Australia National Pollutant Inventory (NPi) emission factors for combustion engines (Table 7-3).

Table 7-3: Emission factors (kg/kWh) for diesel industrial vehicle (off-highway truck) exhaust emissions.

Substance	Emission factor[1,3] (kg/kWh)	Emission factor scientific notation (kg/kWh)	Rating
Carbon monoxide	0.0047	$4.70x10^{-03}$	U
Fluoride compounds[6]	0	$0.00x10^{+00}$	U
Formaldehyde (methyl aldehyde)	0.0003	$2.95x10^{-04}$	U
Oxides of nitrogen	0.011	$1.09x10^{-02}$	U
Particulate matter 2.5 µm[2]	0.00062	$6.19x10^{-04}$	U
Particulate matter 10.0 µm	0.00067	$6.73x10^{-04}$	U
Polycyclic aromatic hydrocarbons[5]	0.00000019	$1.90x10^{-07}$	U
Sulphur dioxide [4]	0.0000077	$7.73x10^{-06}$	U
Total volatile organic compounds	0.0005	$5.00x10^{-04}$	U

Notes:

1. Source: Reference 5. Table II-7.1, Reference 14.
2. Emission factor for PM2.5 is calculated using PM profile ID 425 from the California Emission Inventory and Reporting System, (Reference 14).
3. The emission factors can be converted from kg/kWh to kg/litre by multiplying the emission factors by 3.1 for off-highway truck.
4. Sulphur dioxide emission factor was estimated based on a 10 ppm maximum sulphur content in diesel fuel as per the Australian Diesel Fuel Standard.
5. Emission factor presented in units of kg TEQ/kWh. Emission factor was derived from total VOC emission factor and organic speciation profile for diesel exhaust sourced from Reference 22.
6. It is expected that all fluoride present in diesel will be emitted as hydrogen fluoride. However, the fluoride content of diesel is unknown. If the fluoride content of diesel is known the emission factor can be calculated using the following equation: EFfluoride = 0.00000028 x Cfluoride, where Cfluoride is the concentration of fluoride in diesel fuel (ppm mass basis).

The parameters used in the calculation of vehicle emissions due to the proposed 2016 operational phase are shown in Table 7-4 below. Emissions are calculated for the 180 tonne and 90 tonne capacity trucks. It was assumed that the vehicles will travel at an average speed of 25km/hour (including idling). The fuel consumption of the vehicles (litres/hour) was obtained from the NPi document and it was assumed that the haul conditions will be medium (between low and steep gradients and medium idling times). The NPi document gives the following criteria for the haul conditions:

- Low: Low gradients, long idling times
- High: Steep gradients, short idling times.

Table 7-4: Parameters used in the calculation of vehicle exhaust emissions due to the 2016 operational phase of the proposed Belfast Project.

Vehicle type	Vehicle km/day	Average speed	Operation hours	Vehicles/year	Fuel consumption/year
180 tonne	981	25	24	14335	1734578
90 tonne	2059	25	24	30068	2059645

Vehicle exhaust emissions were calculated for the following pollutants: PM2.5 and PM10 (particulate matter), carbon monoxide (CO), nitrogen oxides (NO_x), volatile organic compounds (VOC), sulphur dioxide (SO_2), formaldehyde and polynuclear aromatic hydrocarbon (PAH). Table 7-5 depicts the calculated vehicle exhaust emissions (tonnes per annum) for each pollutant as a result of the proposed 2016 Belfast Project operations.

Table 7-5: Parameters used in the calculation of vehicle exhaust emissions due to the 2016 operational phase of the proposed Belfast Project.

Pollutant	Emission (NPi)	*180t capacity*	*90t capacity*
	kg/liter	tpa	tpa
PM2.5	1.92E-03	3.33	3.95
PM10	2.09E-03	3.62	4.30
CO	1.46E-02	25.27	30.01
NO_x	3.38E-02	58.61	69.60
VOC	1.55E-03	2.69	3.19
SO_2	2.40E-05	0.04	0.05
Formaldehyde	9.15E-04	1.59	1.88
PAH	5.89E-07	0.0010	0.0012

7.1.3 Wind erosion from Exposed Areas

The proposed two surplus coal stockpiles during the operational phase are considered to be wind erosion sources. Information pertaining to these ROM stockpiles utilised for the in the ADDAS emission model is shown in Table 7-6.

Table 7-6: Information Input into the ADDAS emission model for the run of surplus coal stockpiles for the operational phase of the proposed Belfast Project.

Source	Height (m)	Area (m^2)	x-length (m)	y-length (m)	Bulk density (kg/m^3)	Moisture (%)
Surplus coal stockpile 1	5	10000	100	100	1000	3.65
Surplus coal stockpile 1	5	10000	100	100	1000	3.65

7.1.4 Crushing and Screening Activities

Crushing and screening activities will be part of the 2016 Phase 2 proposed operations, with a proposed new crushing and screening plant. However, in the calculation of emissions from crushing and screening for the proposed Phase 2 operational phase during 2016, it is assumed that the Phase 1 crushing and screening plant will still be operational. The parameters used in the calculation of emissions for crushing and screening activities for both the Phase 1 and Phase 2 primary and secondary crushers are depicted in Table 7-7. It is assumed that the same tonnes of ore crushed and screened at the primary crushers will be transferred to the secondary crushers. For the mitigated crushing and screening activities, the US-EPA high moisture emission factors are utilised.

Table 7-7: Parameters used in the calculation of emissions from crushing and screening operations for the proposed operational phase during 2016.

Crushing and screening	Tonnes per day	Moisture (%)
Primary crushing and screening- Phase 1	7680	3.65
Secondary crushing and screening- Phase 1	7680	3.65
Primary crushing and screening- Phase 2	12000	3.65
Secondary crushing and screening- Phase 2	12000	3.65

7.1.5 Drilling

The drilling parameters that are utilised for coal and overburden for the proposed Phase 2 2016 operational phase for the western and eastern open pit areas are presented in Table 7-8. A control efficiency of 99% is applied for the mitigated drilling operations as given in the Australian NPi document for mining operations.

Table 7-8: Drilling source specific information: operational phase operations (2016) for the proposed Belfast Project.

Drilling parameter	Coal	Overburden
Drilling area	13500m² (116mx 116m)	13500m² (116mx 116m)
No of drill holes	36 drill holes/ 45m block	30 drill holes/ 45m block
Depth of each drill hole	12.2m	12.2
No of drill holes/day	364	280

7.1.6 Blasting

Source specific information used in the calculation of emissions due to blasting activities in the eastern and western open pit areas during the proposed operational phase are presented in Table 7-9. No control efficiencies are assumed for blasting.

Table 7-9: Blasting source specific information for the operational phase during 2016 for the proposed Belfast Project.

Blasting parameter	Parameter units/ value
Blasting area	13500m²
Blasts per week (coal)	2
Blasts per week (overburden)	2
Days per year	365

7.1.7 Excavation

Emissions from excavating activities at the eastern and western open pit areas were calculated for the proposed operational phase. No control efficiency is assumed for excavation. Table 7-10 depicts the parameters used in the calculation of excavation emissions.

Table 7-10: Parameters used in the calculation of emissions from excavating activities during the operational phase (2016) the proposed Belfast Project.

Scenario	Parameters of excavated area		
	Length (m)	Width (m)	Total area
Operational phase: Eastern open pit area	116	116	13500
Operational phase: Western open pit area	116	116	13500

7.1.8 Scraping

The calculation of emissions due to scraping activities at the eastern and western open pit areas during the proposed operational phase was undertaken and the parameters used in the calculation of these emissions are shown in Table 7-11. No control efficiency is assumed for scraping.

Table 7-11: Parameters used in the calculation of emissions from scraping activities during the operational phase (2016) the proposed Belfast Project.

Scenario	Parameters of scraped area		
	Length (m)	Width (m)	Total area
Operational phase: Eastern open pit area	116	116	13500
Operational phase: Western open pit area	116	116	13500

7.2 Synopsis of Estimated Emissions for the Current Operational Phase

7.2.1 Scenario 2a: Unmitigated Proposed 2016 Operations

A synopsis of the estimated particulate emissions as a result of the unmitigated 2016 operational phase is presented in Table 7-12 and depicted in Figure 7-2 (PM10 source contributions) and Figure 7-3 (TSP source contributions). Unpaved roads are the highest contributing source to PM10 and TSP emissions (70 % and 51.9% respectively). The second most significant source of PM10 and TSP emission is predicted to be crushing and screening, with a contribution of 18.6 % and 43.4% PM10 and 62.4% respectively. Blasting is predicted to be the third most significant source of both PM10 and TSP emissions, with a contribution of 5.1% and 2% respectively. The fourth most significant source of PM10 and TSP is predicted to be drilling, with a contribution of 2.9% to PM10 emissions and 1% to TSP emissions. Wind erosion is the sixth most significant source of PM10 and the seventh contributing source to TSP (0.7% and 0.4% respectively). The least contributing source to PM10 and TSP emissions is predicted to be materials handling.

Table 7-12: Source group contribution to unmitigated current PM10 and TSP emissions (tpa) due to the 2016 operational phase of the proposed Belfast Project.

Source	PM10	TSP	PM10 %	TSP %	Rank PM10	Rank TSP
Crushing and screening	486	5710	18.6	43.4	2	2
Materials handling	4	12	0.2	0.1	8	8
Wind erosion	18	54	0.7	0.4	6	7
Unpaved roads	1824	6816	70.0	51.9	1	1
Blasting	134	259	5.1	2.0	3	3
Excavation	48	99	1.8	0.8	5	5
Drilling	75	138	2.9	1.0	4	4
Scraping	18	57	0.68	0.4	7	6
Total	2606.4	13145.2	100.0	100.0		

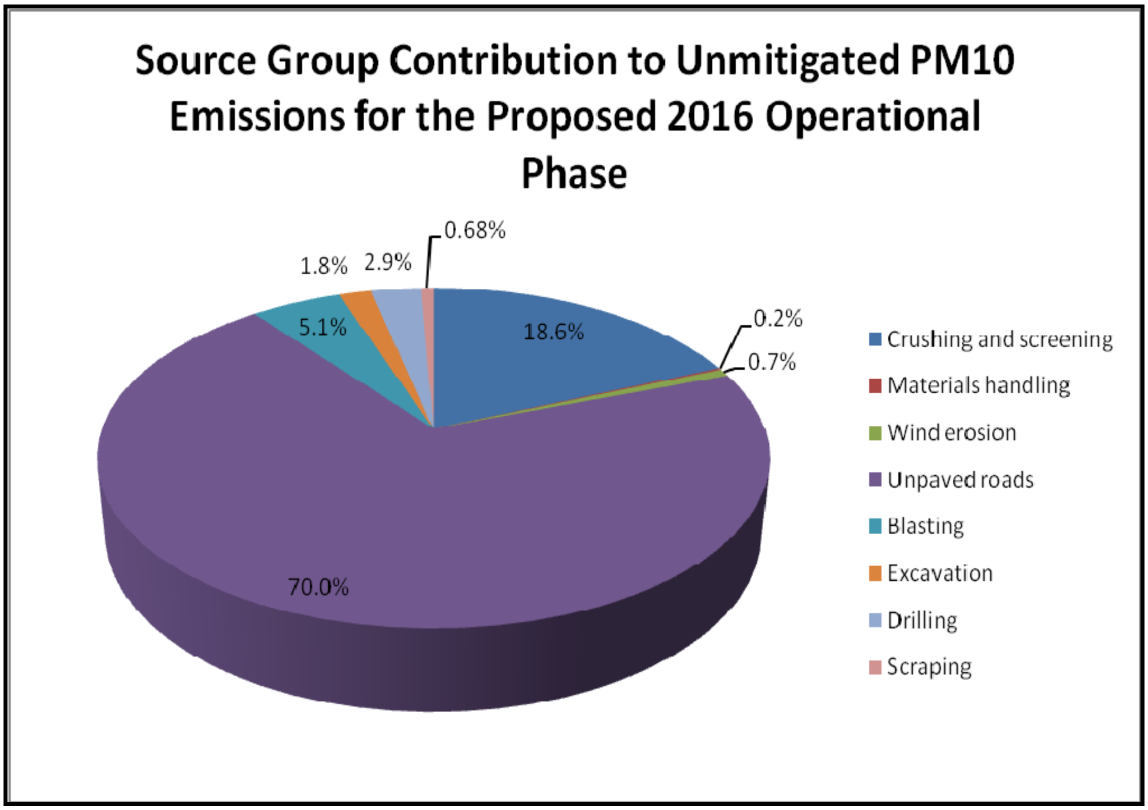

Figure 7-2: Source group contribution to estimated unmitigated 2016 proposed operational phase PM10 emissions.

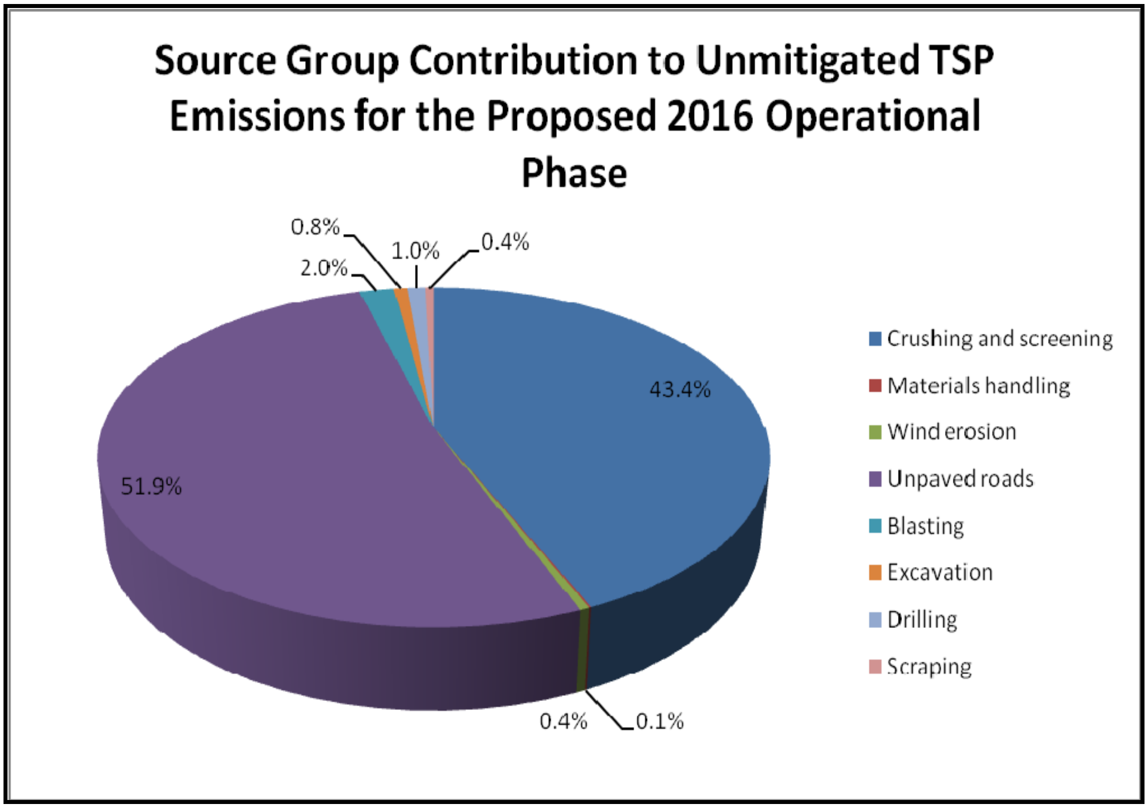

Figure 7-3: Source group contribution to estimated unmitigated 2016 proposed operational phase TSP emissions.

7.2.2 Scenario 2b: Mitigated Proposed 2016 Operations

Similar to the proposed 2011 construction phase mitigation measures are applied to unpaved roads, crushing and screening and drilling in this scenario. Even with mitigation measures in place, unpaved roads are still predicted to be the most contributing source to PM10 and TSP emissions (57.5 % and 68.9% respectively) (Table 7-13, Figure 7-4 (PM10) and Figure 7-5 (TSP)). The second most significant source of PM10 emissions and third most significant source of TSP emissions is predicted to be blasting, with a contribution of 16.9% and 10.5% respectively. Crushing and screening is predicted to be the third most significant source of PM10 and the second most significant source of TSP emissions, with a contribution of 14.4% and 11.5% respectively. The fourth most significant source of PM10 and TSP is predicted to be excavating, with a contribution of 6% to PM10 emissions and 4% to TSP emissions. Wind erosion is the fifth most significant source of PM10 and the sixth contributing source to TSP (2.3% and 2.2% respectively). With mitigation measures in place, drilling is predicted to be the least contributing source to PM10 and TSP emissions.

Table 7-13: Source group contribution to unmitigated current PM10 and TSP emissions (tpa) due to the 2016 operational phase of the proposed Belfast Project.

Source	PM10	TSP	PM10 %	TSP %	Rank PM10	Rank TSP
Crushing and screening	114	285	14.4	11.5	3	2
Materials handling	4	12	0.5	0.5	7	7
Wind erosion	18	54	2.3	2.2	5	6
Unpaved roads	456	1704	57.5	68.9	1	1
Blasting	134	259	16.9	10.5	2	3
Excavation	48	99	6.0	4.0	4	4
Drilling	1	1	0.1	0.1	8	8
Scraping	18	57	2.2	2.3	6	5
Total	792.6	2471.6	100.0	100.0		

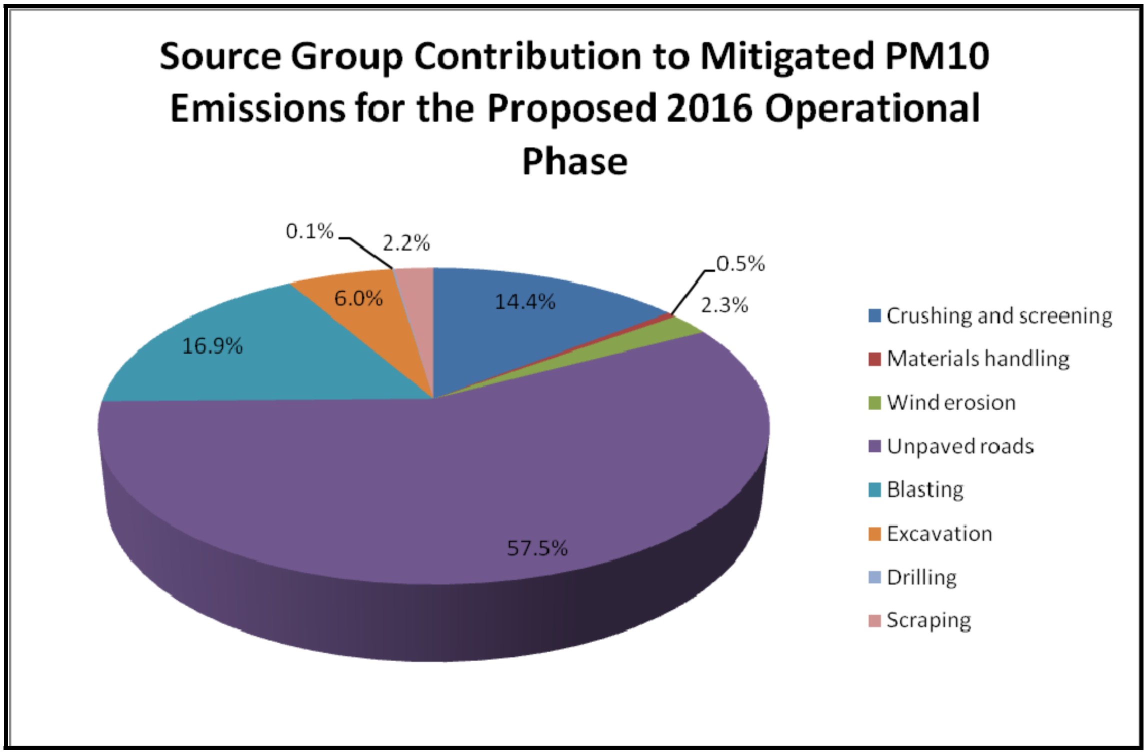

Figure 7-4: Source group contribution to estimated mitigated 2016 proposed operational phase PM10 emissions.

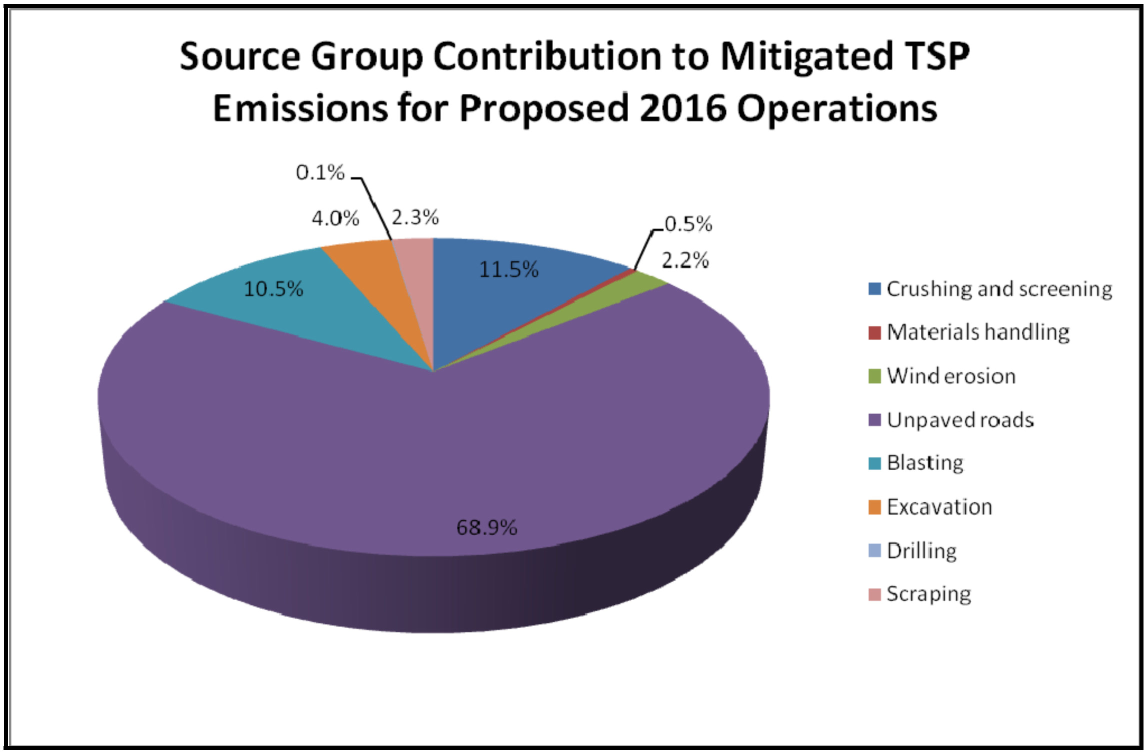

Figure 7-5: Source group contribution to estimated mitigated 2016 proposed operational phase TSP emissions.

7.3 Dispersion Model Results

This section focuses on potential impacts due to the proposed 2016 operational phase activities at the human sensitive receptor sites closest and within the mine boundary. The identified sensitive receptors include the Jan Burger Farmstead, farmstead located to the north west of the N4 and the one located to the south east of the proposed mine boundary.

7.3.1 Predicted PM10 Concentrations due to the 2016 Operational Phase of the Belfast Project

- The predicted unmitigated daily average ground level concentrations for the proposed 2016 operational phase exceed the proposed SA Standard of 75 µg/m³ and the EC limit of 50 µg/m³ at all the sensitive receptors (Table 7-14 and Figure 7-6). This could mainly be attributed to the proximity of the unpaved roads (which are the most significant sources of PM10 emissions) to the sensitive receptor areas. However, with mitigation measures in place for the unpaved roads, drilling and crushing and screening, the predicted impacts at the sensitive receptor areas are within the proposed SA Standard (Table 7-14 and Figure 7-7). The EC limit is, however, still predicted to be exceeded at the receptor sites even with the application of mitigation measures.

- o Unpaved roads and crushing and screening were predicted to be the most significant sources of PM10 (see section 7.2). Predicted impacts due to the absence of mitigation measures and the application of mitigation measures to these sources are shown in Figure 7-8 and Figure 7-9 (unpaved roads) and Figure 7-10 and Figure 7-11 (crushing and screening).

- o The predicted unmitigated annual average PM10 ground level concentrations for the proposed 2016 operational phase exceed the proposed SA Standard of 40 µg/m³ and the EC limit of 40 µg/m³ at the Jan Burger farmstead and at the farmstead located to the south east of the proposed mine site as shown in Table 7-14 and Figure 7-12. The application of mitigation measures to the unpaved roads, drilling operations and crushing and screening results in the predicted impacts not exceeding the proposed SA annual standard at Jan Burger Farmstead and a further reduction in the impacts at the farmstead located close to the N4 (Table 7-12 and Figure 7-13). The proposed SA annual Standard is exceeded by 5% at the farmstead located to the south west of the proposed mine site.

- o The predicted unmitigated and mitigated impacts due to the main contributing sources are shown in Figure 7-14 and Figure 7-15 (unpaved roads) and Figure 7-16 and Figure 7-17 for crushing and screening.

Table 7-14: Predicted highest daily average and annual PM10 concentrations (µg/m³) at the sensitive receptor sites due to the proposed 2016 operational phase activities.

Sensitive Receptor Area	*Scenario*	PM10 Concentration (µg/m³)	
		Daily concentration	Annual concentration
Jan Burger Farmstead	Unmitigated 2016 operational phase *(Scenario 2a)*	252	98
	Mitigated 2016 operational phase (*Scenario 2b)*	61	23
Farmstead next to N4	Unmitigated 2016 operational phase *(Scenario 2a)*	130	4
	Mitigated 2016 operational phase (*Scenario 2b)*	33	1
Farmstead to the south east	Unmitigated 2016 operational phase *(Scenario 2a)*	300	171
	Mitigated 2016 operational phase (*Scenario 2b)*	74	42

Similar to the proposed 2011 construction phase, it is possible that the predicted concentrations at the sensitive receptors as a result of the proposed 2016 operational activities would be much higher when background concentrations in the region are taken into consideration and if reasonable mitigation measures are not applied. Reasonable mitigation measures would lead to further reduction of emissions at the sensitive receptor areas.

7.3.2 Predicted Dust Fallout Levels due to the 2016 Operational Phase of the Belfast Project

- The predicted maximum daily dust fallout levels due to unmitigated and mitigated proposed 2016 mining operations fall within the SANS residential target of 600 mg/m²/day at all the sensitive receptor areas (Table 7-15, Figure 7-18 and Figure 7-19).

- The predicted maximum daily dust fallout levels due to the unmitigated and mitigated unpaved roads are shown in Figure 7-20 and Figure 7-21, while those for crushing and screening are shown in Figure 7-22 and Figure 7-23.

Table 7-15: Predicted maximum daily dust fallout levels (mg/m²/day) at the sensitive receptor sites due to the proposed 2016 operational phase activities.

Sensitive Receptor Area	*Scenario*	Maximum daily dust fallout (mg/m²/day)
Jan Burger Farmstead	Unmitigated 2016 operational phase *(Scenario 2a)*	89
	Mitigated 2016 operational phase (*Scenario 2b)*	10
Farmstead next to N4	Unmitigated 2016 operational phase *(Scenario 2a)*	8
	Mitigated 2016 operational phase (*Scenario 2b)*	2
Farmstead to the south west	Unmitigated 2016 operational phase *(Scenario 2a)*	81
	Mitigated 2016 operational phase (*Scenario 2b)*	18

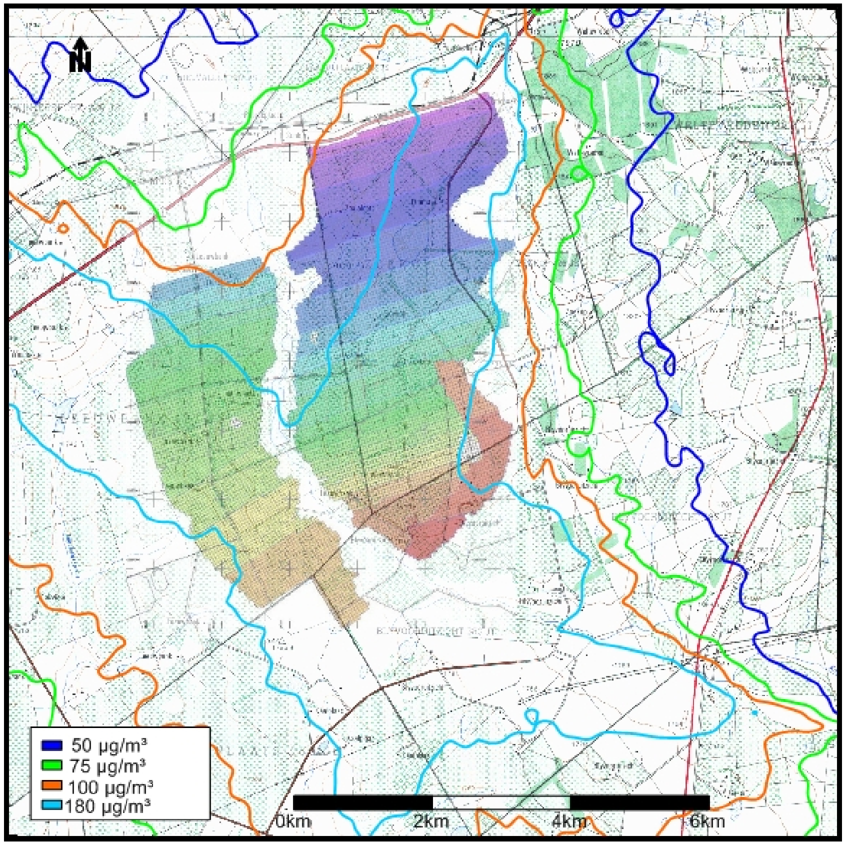

Figure 7-6: Highest daily average predicted PM10 ground level concentrations (µg/m³) for all sources due to unmitigated emissions- 2016 operational phase of the proposed Belfast Project.

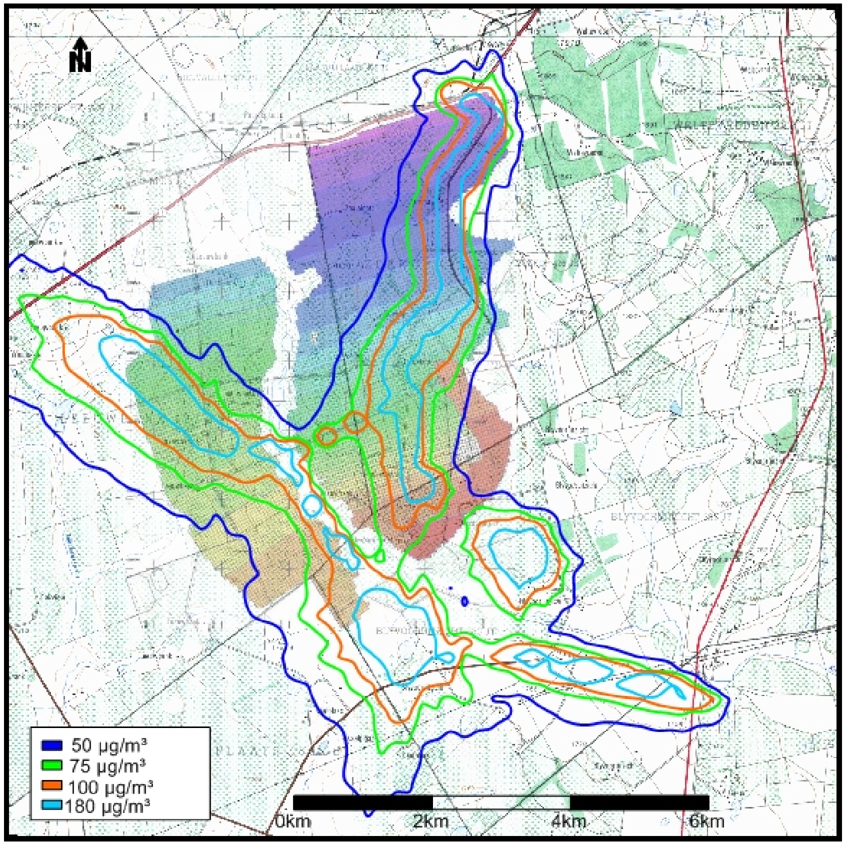

Figure 7-7: Highest daily average predicted PM10 ground level concentrations (µg/m³) for all sources due to partially mitigated unpaved roads, drilling, crushing and screening emissions- 2016 operational phase of the proposed Belfast Project.

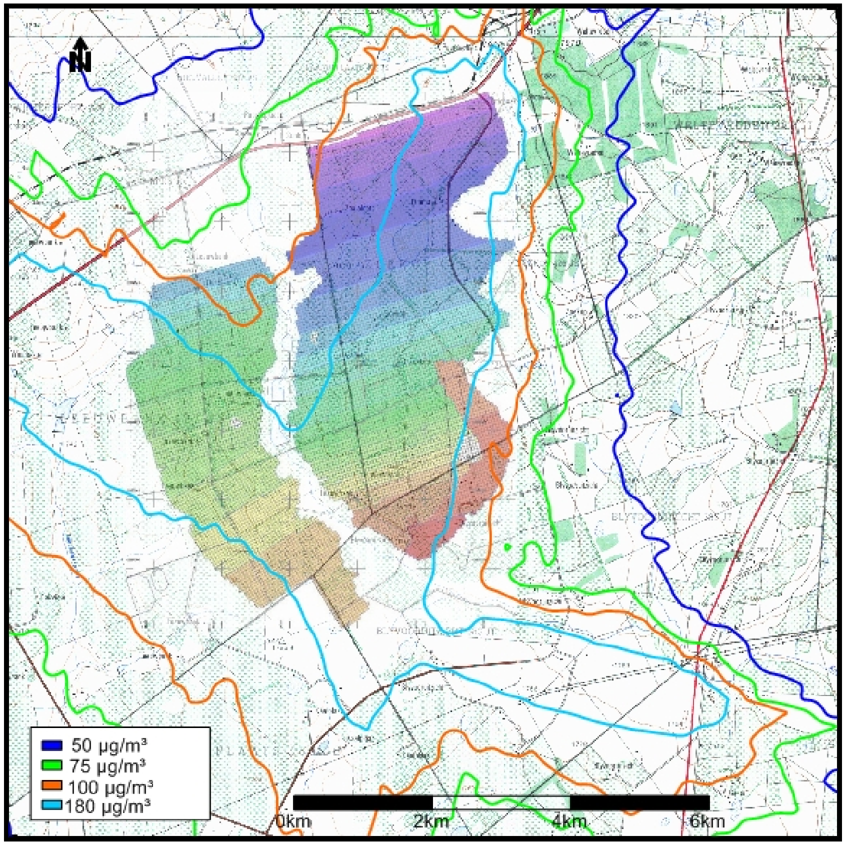

Figure 7-8: Highest daily average predicted PM10 ground level concentrations (µg/m³) due to unmitigated unpaved roads emissions-2016 operational phase of the proposed Belfast Project.

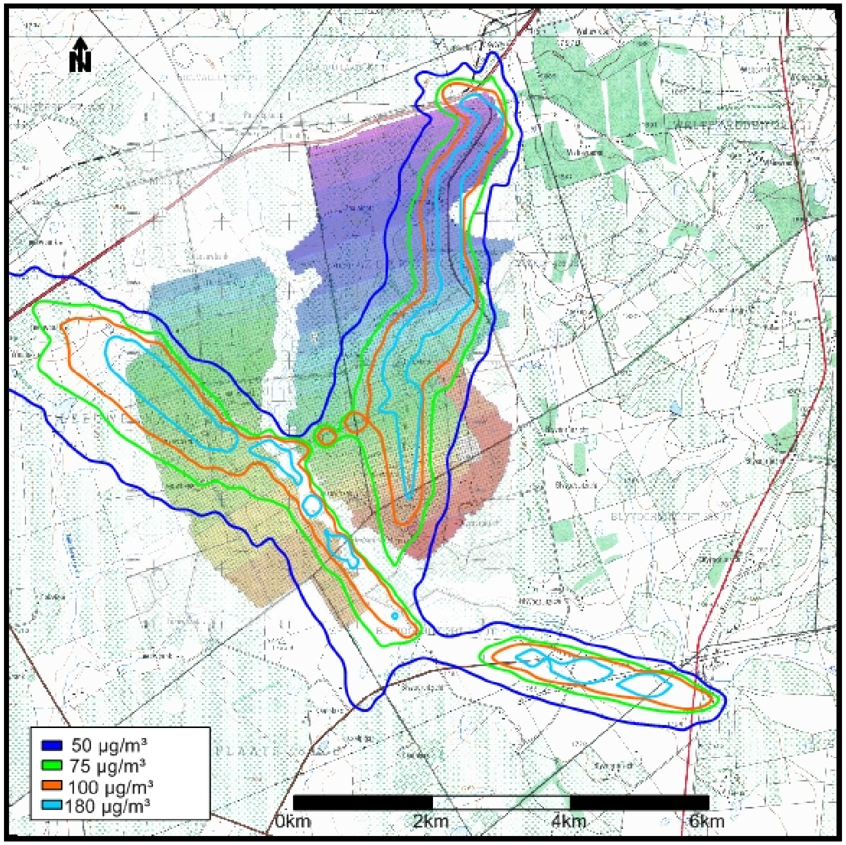

Figure 7-9: Highest daily average predicted PM10 ground level concentrations (µg/m³) due to mitigated unpaved roads emissions-2016 operational phase of the proposed Belfast Project.

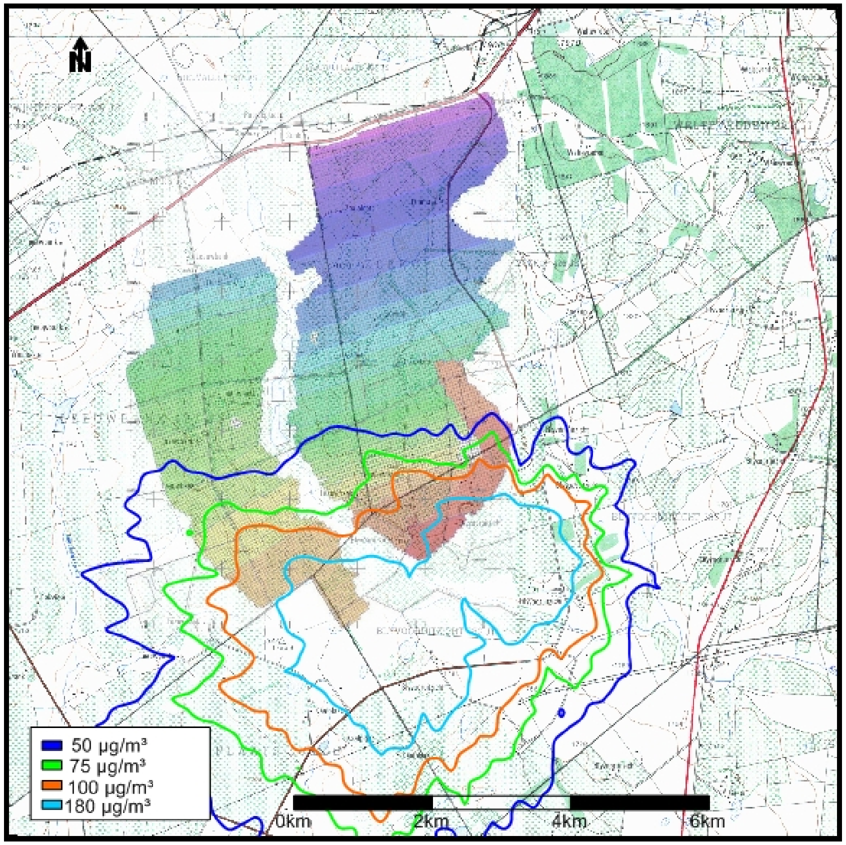

Figure 7-10: Highest daily average predicted PM10 ground level concentrations (µg/m³) due to unmitigated crushing and screening emissions- 2016 operational phase of the proposed Belfast Project.

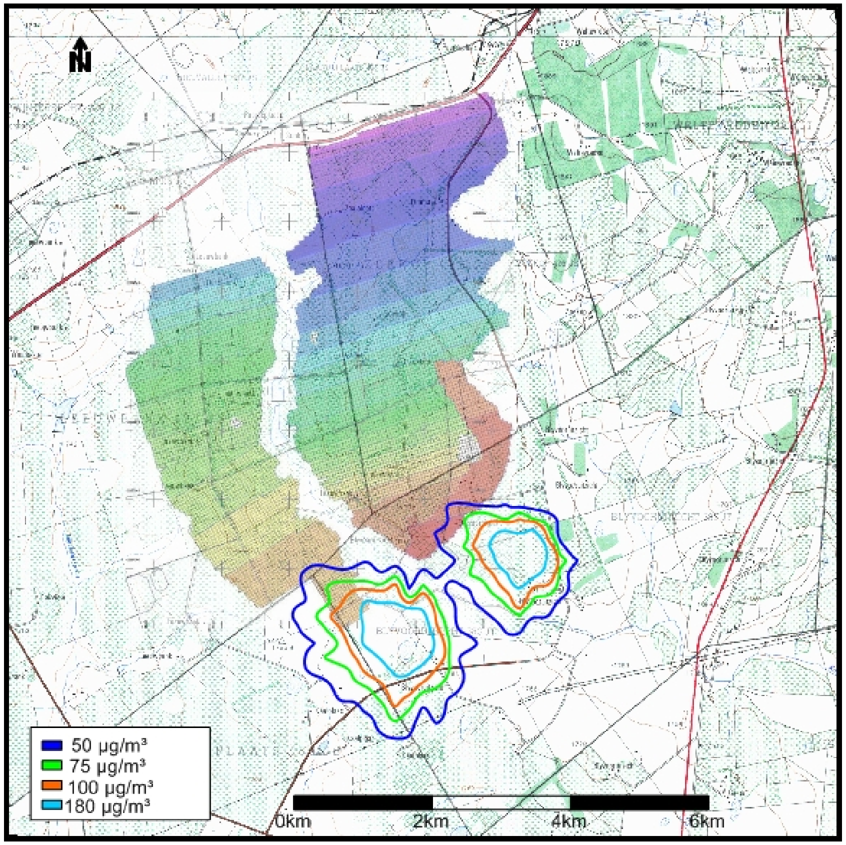

Figure 7-11: Highest daily average predicted PM10 ground level concentrations (µg/m³) due to mitigated crushing and screening emissions- 2016 operational phase of the proposed Belfast Project.

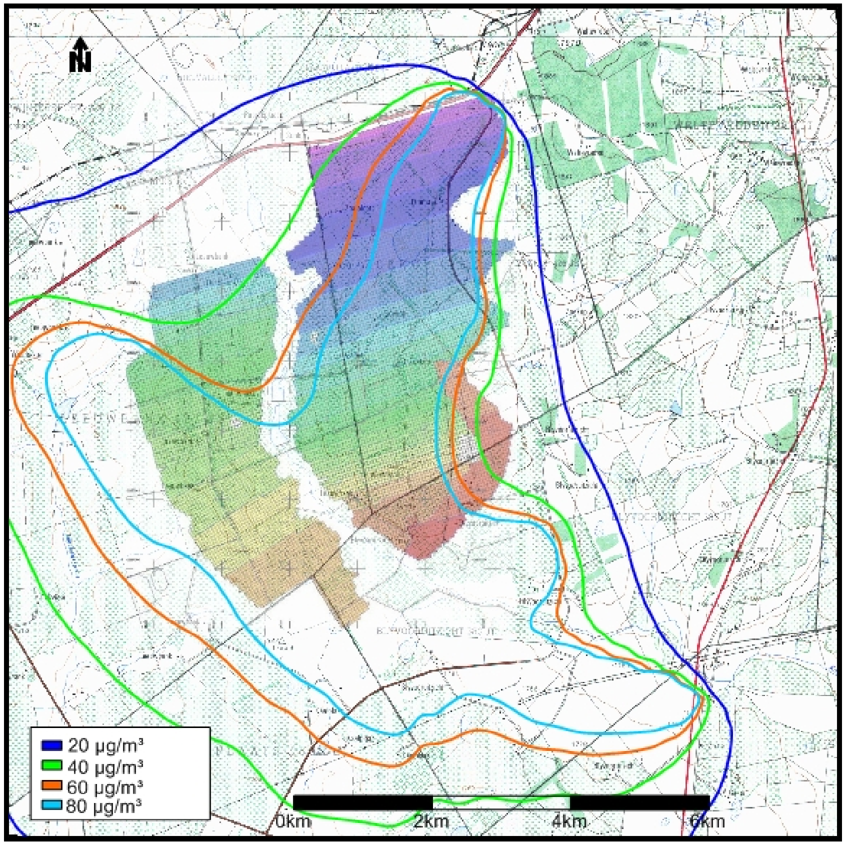

Figure 7-12: Annual average predicted PM10 ground level concentrations (µg/m³) for all sources due to unmitigated emissions- 2016 operational phase of the proposed Belfast Project.

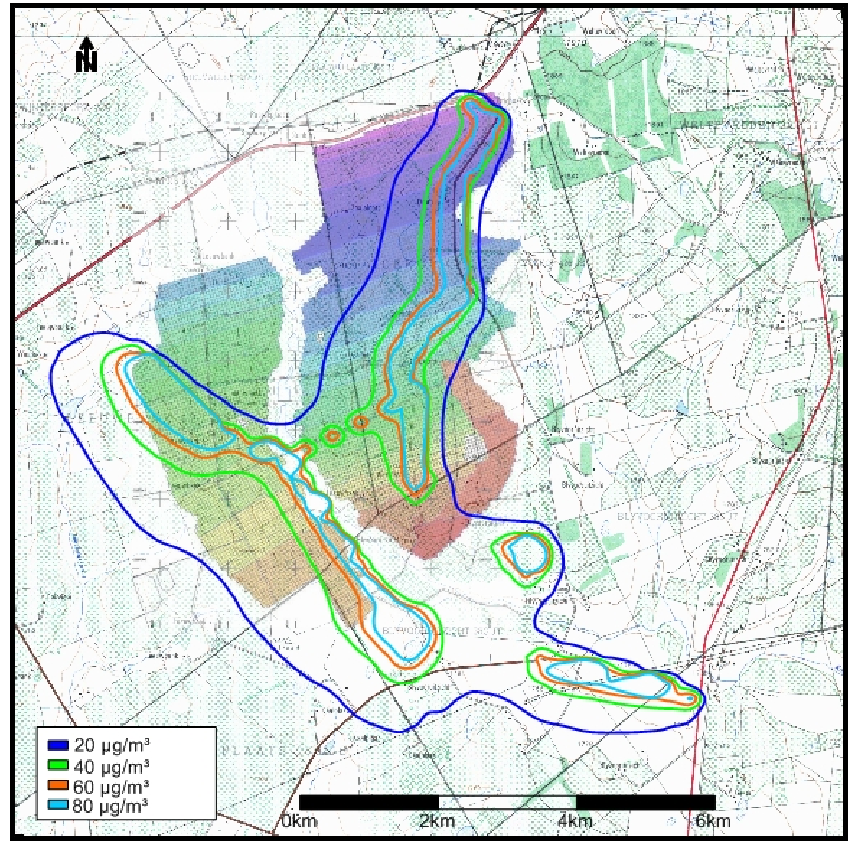

Figure 7-13: Annual average predicted PM10 ground level concentrations (µg/m³) for all sources due to partially mitigated unpaved roads, drilling, crushing and screening emissions- 2016 operational phase of the proposed Belfast Project.

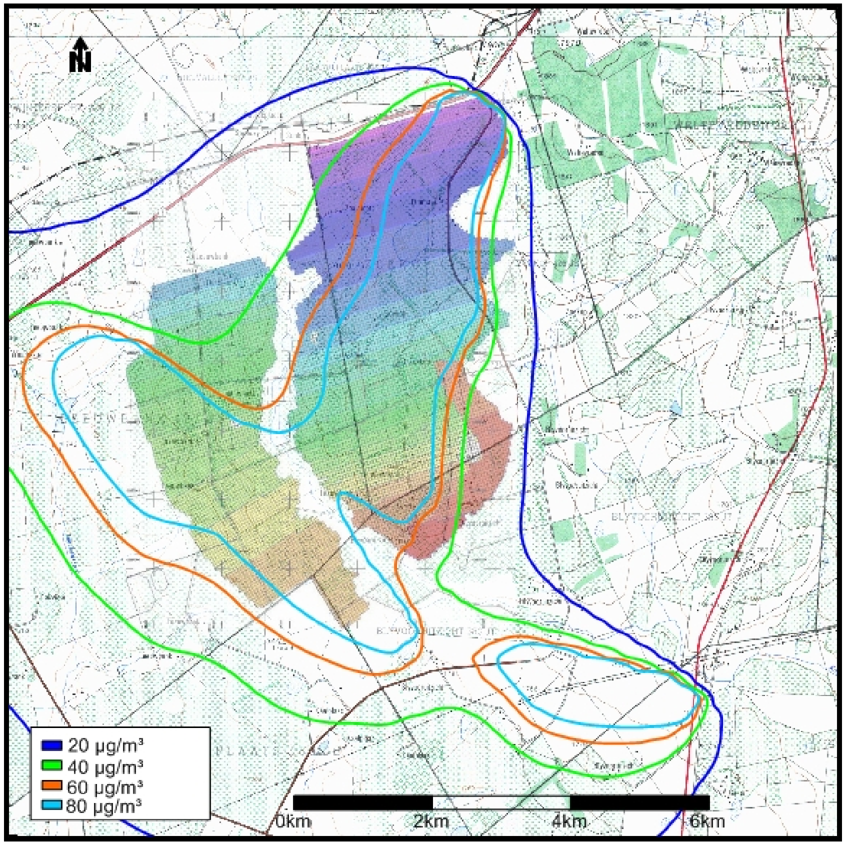

Figure 7-14: Annual average predicted PM10 ground level concentrations (µg/m³) due to unmitigated unpaved road emissions-2016 operational phase of the proposed Belfast Project.

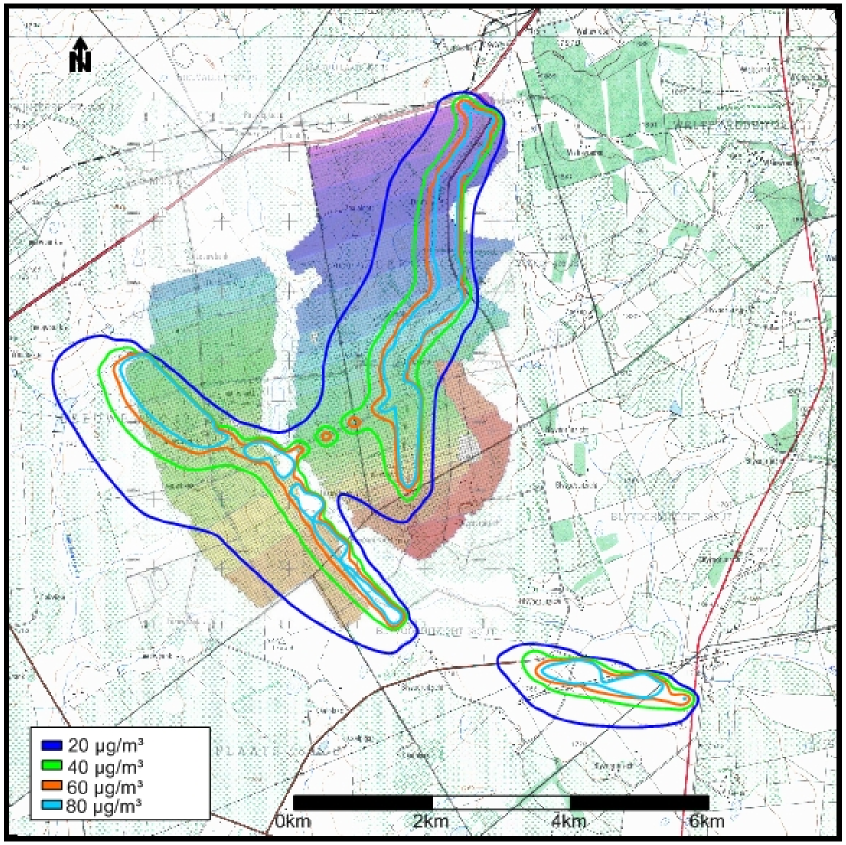

Figure 7-15: Annual average predicted PM10 ground level concentrations (µg/m³) due to mitigated unpaved road emissions-2016 operational phase of the proposed Belfast Project.

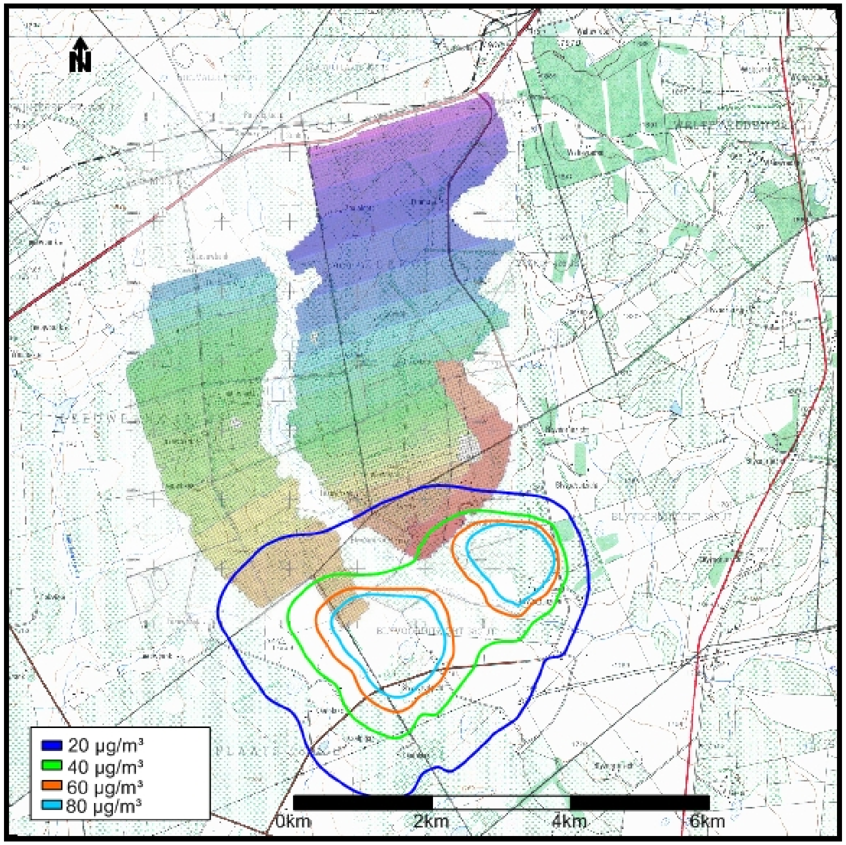

Figure 7-16: Annual average predicted PM10 ground level concentrations (µg/m³) due to unmitigated crushing and screening emissions- 2016 operational phase of the proposed Belfast Project.

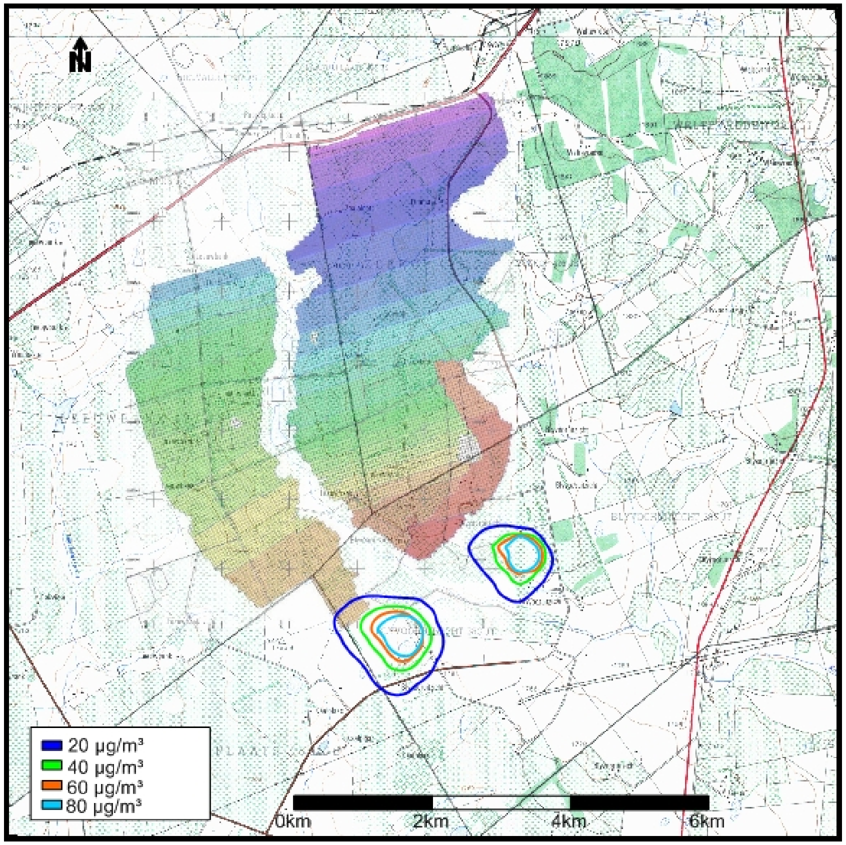

Figure 7-17: Annual average predicted PM10 ground level concentrations (µg/m³) due to mitigated crushing and screening emissions- 2016 operational phase of the proposed Belfast Project.

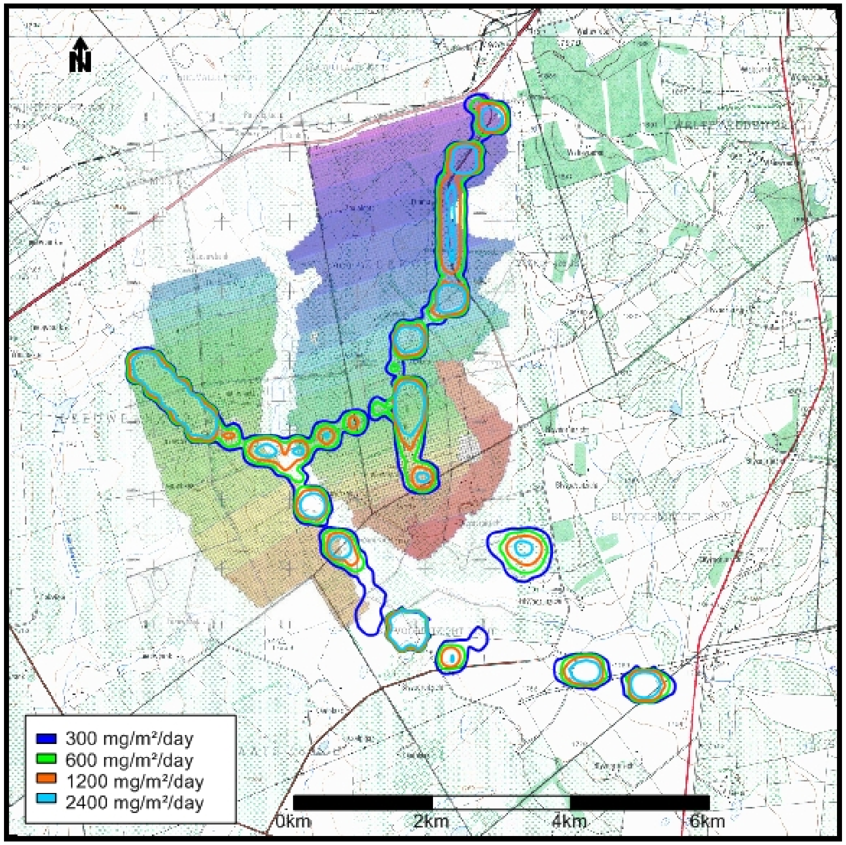

Figure 7-18: Predicted maximum daily dust deposition rates (mg/m²/day) for all sources due to unmitigated emissions- 2016 operational phase of the proposed Belfast Project.

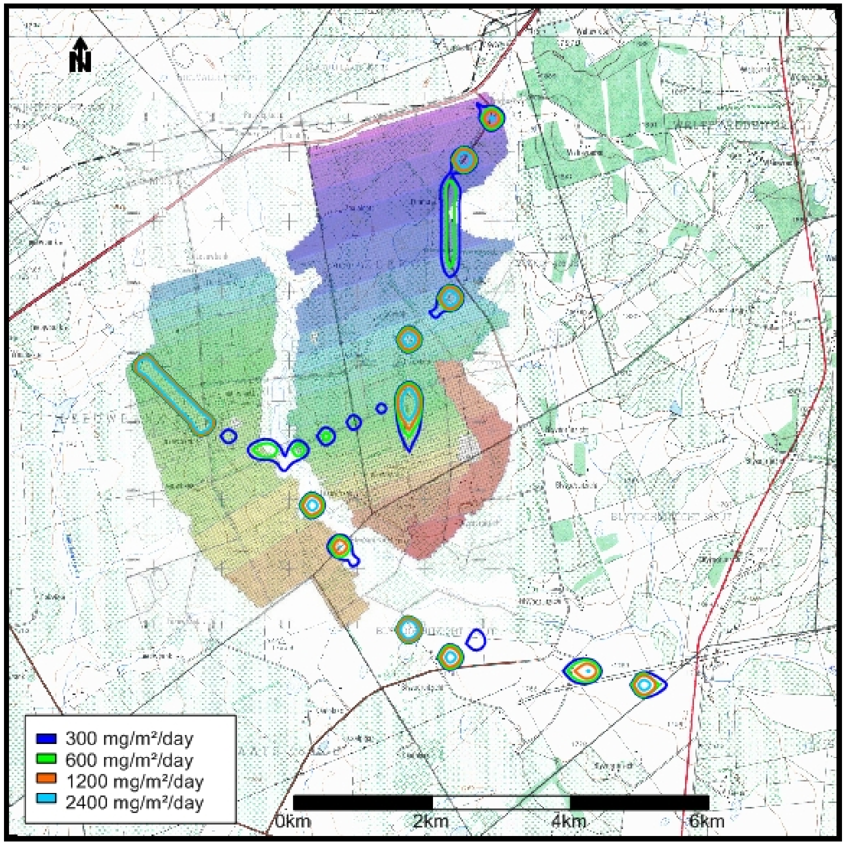

Figure 7-19: Predicted maximum daily dust deposition rates (mg/m²/day) for all sources due to partially mitigated unpaved roads, drilling, crushing and screening emissions- 2016 operational phase of the proposed Belfast Project.

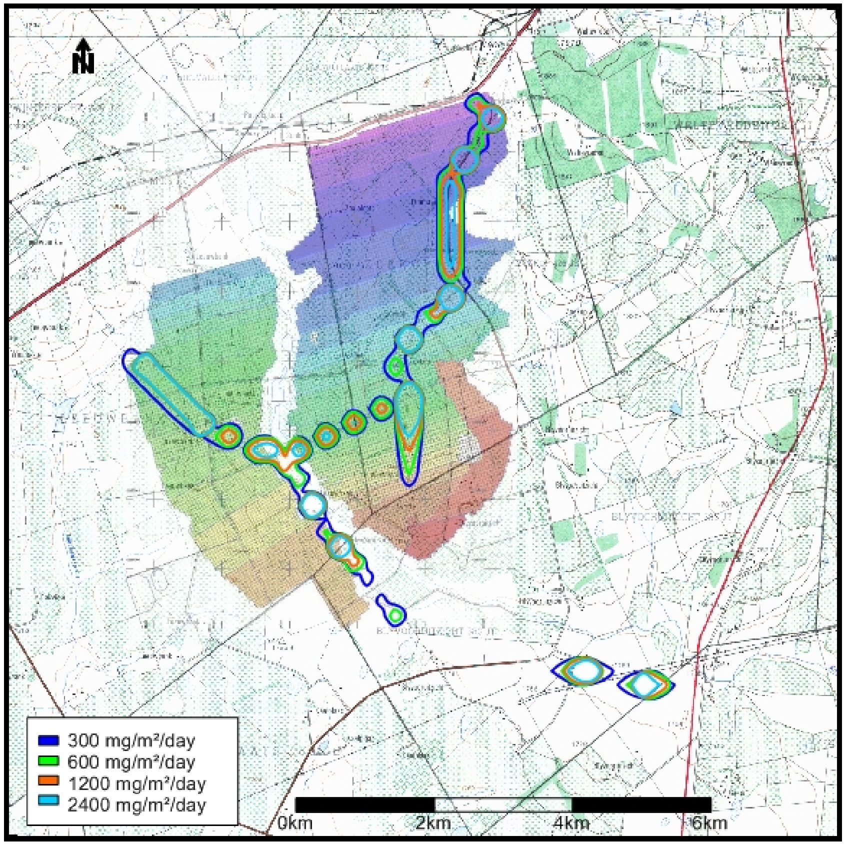

Figure 7-20: Predicted maximum daily dust deposition rates (mg/m²/day) due to unmitigated unpaved roads emissions- 2016 operational phase of the proposed Belfast Project.

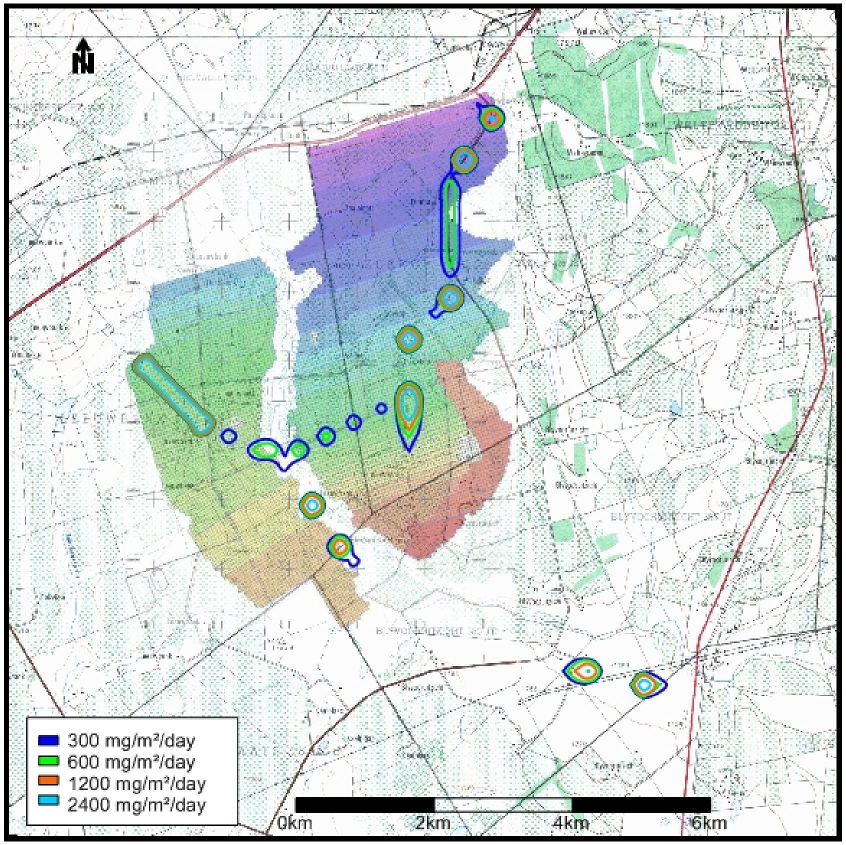

Figure 7-21: Predicted maximum daily dust deposition rates (mg/m²/day) due to mitigated unpaved roads emissions- 2016 operational phase of the proposed Belfast Project.

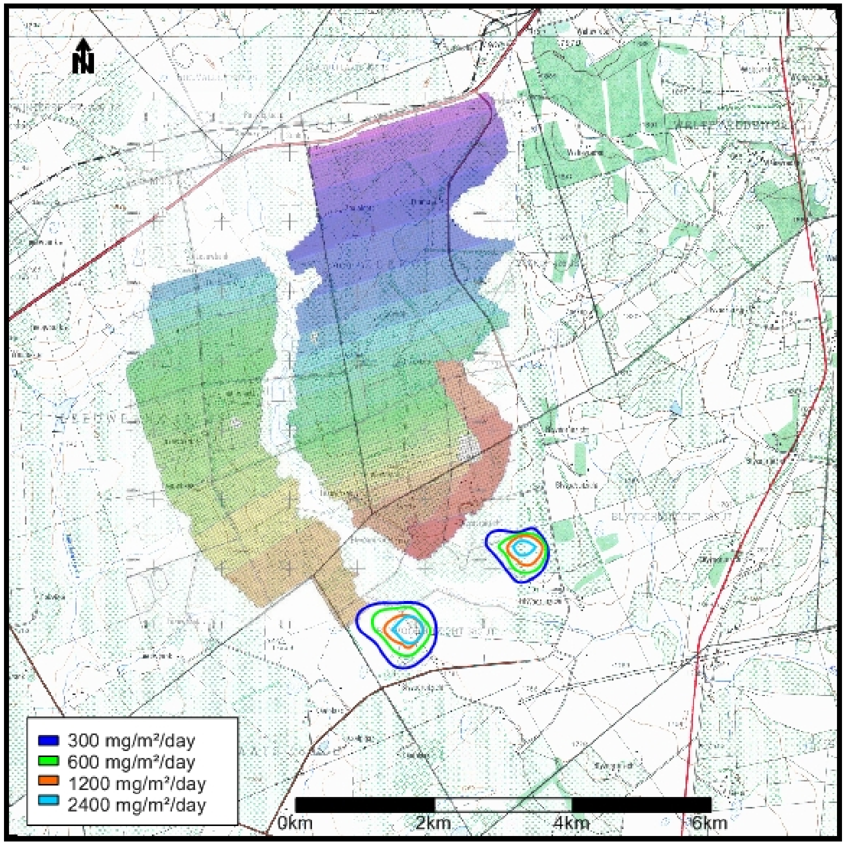

Figure 7-22: Predicted maximum daily dust deposition rates (mg/m²/day) due to unmitigated crushing and screening emissions- 2016 operational phase of the proposed Belfast Project.

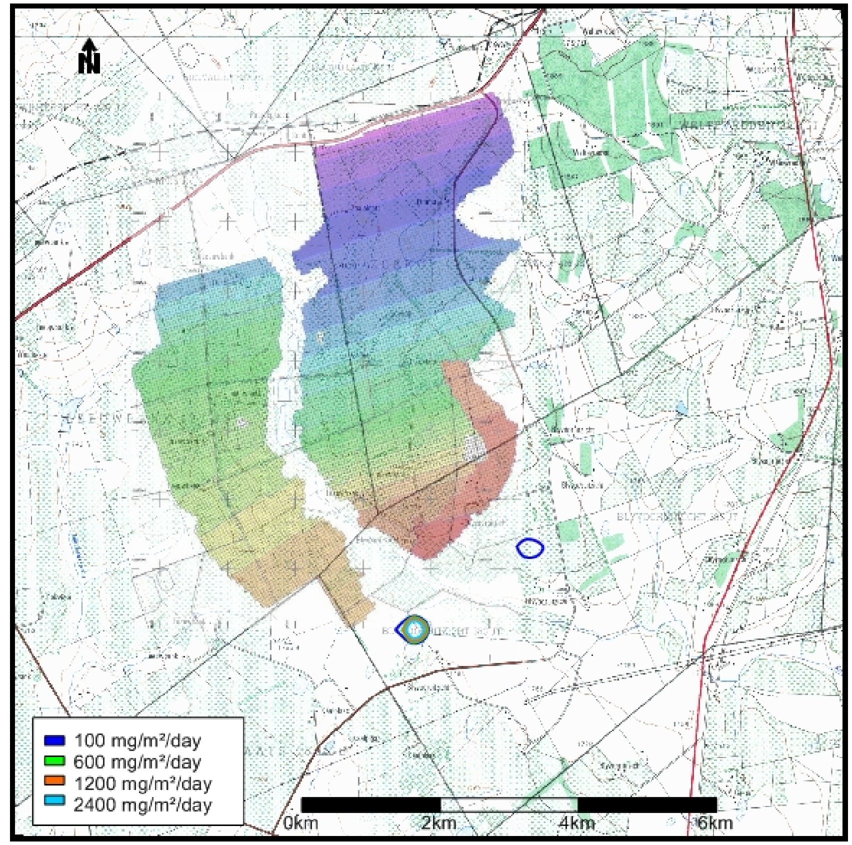

Figure 7-23: Predicted maximum daily dust deposition rates (mg/m²/day) due to mitigated crushing and screening emissions- 2016 operational phase of the proposed Belfast Project.

7.4 Significance Evaluation of Predicted Impacts

Isopleth plots reflecting daily averaging periods contain only the highest predicted PM10 ground level concentrations for that averaging period, over the entire period for which simulations were undertaken. It is therefore possible that even though a high daily concentration is predicted to occur at certain locations, this may only be true for one day during the entire period of operation. It is therefore necessary to evaluate the number of days (frequency of exceedance) the relevant standard was exceeded at a specific location to determine the significance of the predicted impact.

South Africa proposes only 4 allowable exceedances of the 75 µg/m³ daily Standard. In the significance evaluation of the unmitigated and mitigated 2016 operations for the proposed Belfast Project, the predicted impacts were assessed against this criteria.

Frequency of exceedances for the proposed operational phase were evaluated at the sensitive receptor sites. It should be noted that the frequency of exceedance plot reflects the total number of days when the standards were exceeded over a one year modelling period. For this study, the year 2008 is used for the frequency of exceedance evaluation at the sensitive receptors. When the unmitigated predicted concentrations for the operational phase were evaluated, predictions at the receptor sites exceed 4 days over the 1 year period as depicted in Figure 7-30. However, with mitigation measures in place for the unpaved roads, drilling and crushing and screening, the predicted concentrations at the receptor sites indicate frequencies of exceedances of less than 4 days (Figure 7-31).

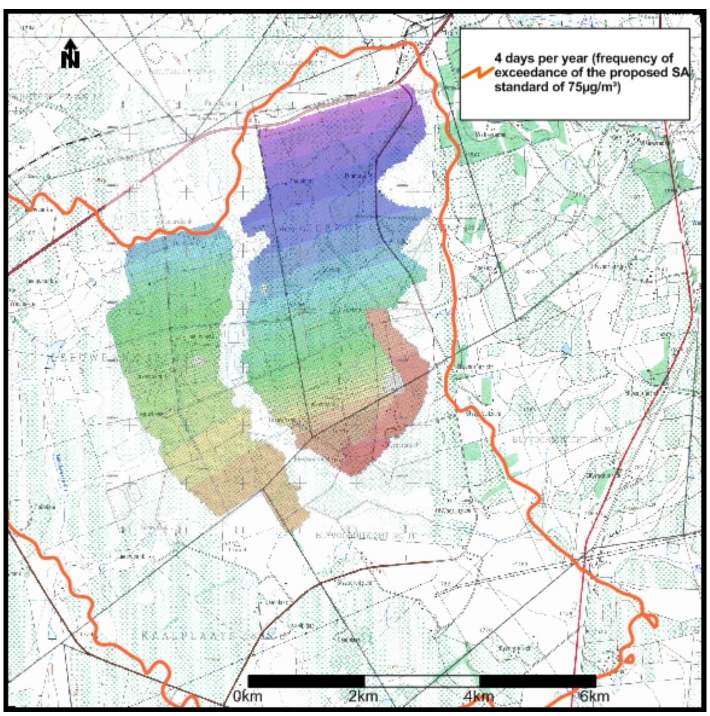

Figure 7-24: Frequency of exceedance for predicted PM10 concentrations when compared to the SA standards (unmitigated 2016 proposed mining operations - *Scenario 2a*).

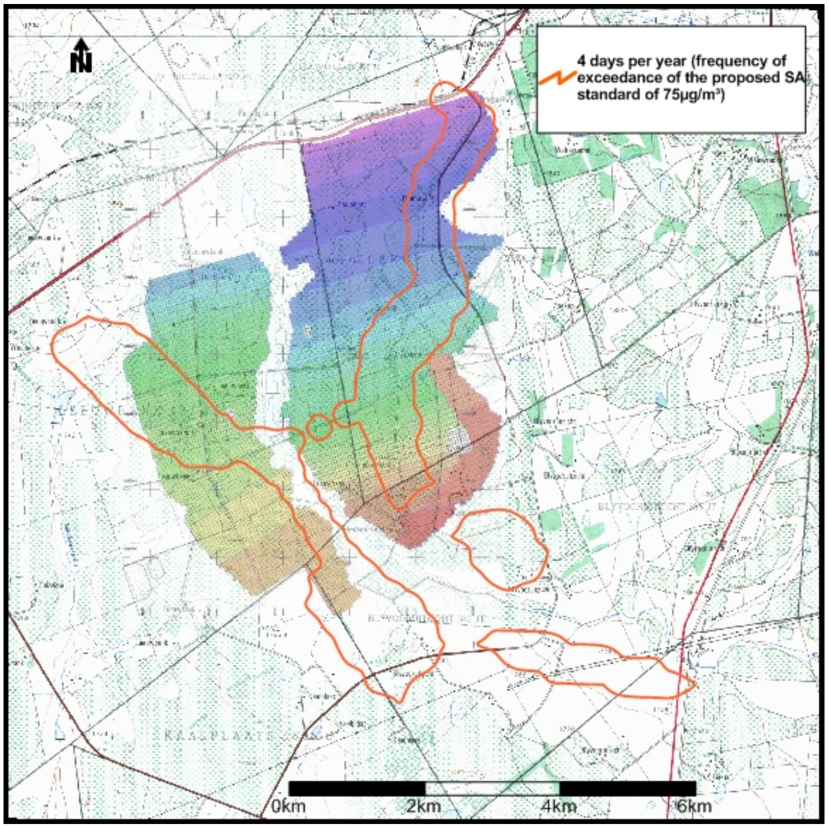

Figure 7-25: Frequency of exceedance for predicted PM10 concentrations when compared to the SA standards (mitigated 2016 proposed mining operations - *Scenario 2b*).

7.5 Impacts of Particulates on Plants and Animals

Limited reference data exists on the impacts of particulates on plants and animals. Most of the studies done on the effects of particulate matter on animals, particularly cattle, have concurred that the main impact of dusty environments is causing animal stress which is detrimental to their health. However, no threshold levels exist to indicate at what levels the negative effects begin to occur.

The Canadian Environmental Protection Act (CEPA) has published a document on the effects of particulates on vegetation. The conclusion was however that the information about the effects of particulates on vegetation is quite limited and that dose-response information is lacking. Research found that the primary mechanisms by which particles affect vegetation are by physical smothering of the leaf surface. The main impacts are on the physical blocking of stomata through particle lodging or penetration of stomata apertures. The chemical composition of the dust particles can also affect the plant and have indirect effects on the soil pH and ionic composition.

8 IMPACT ASSESSMENT: CLOSURE PHASE

It is assumed that all mining activities and processing operations will have ceased by the closure phase of the project. The potentials for impacts during this phase will depend on the extent of demolition and rehabilitation efforts during closure.

Aspects and activities associated with the closure phase of the proposed mining operations are listed in Table 8-1.

Table 8-1: Activities and aspects identified for the closure phase of the proposed Belfast Project mining operations.

Impact	Source	Activity
Generation of TSP and PM10	Unpaved roads	Vehicle entrainment on unpaved road surfaces
	Topsoil stockpiles	Topsoil recovered from stockpiles for rehabilitation and re-vegetation of surroundings
	Overburden stockpiles	Overburden removed from stockpiles for rehabilitation purposes
Gas emissions [(1)]	Blasting	Demolition of infrastructure may necessitate the use of blasting.
	Vehicles	Tailpipe emissions from vehicles utilised during the closure phase.
Notes: [(1)] Gaseous emissions from tailpipes typically include: sulphur dioxide, oxides of nitrogen, carbon monoxide, hydrocarbons, lead (petrol powered vehicles only), potentially carbon dioxide.		

9 AIR QUALITY MANAGEMENT PLAN FOR THE PROPOSED BELFAST PROJECT

An air quality impact assessment was conducted for the 2011 construction and 2016 operational phases of the proposed Belfast Project as part of an Environmental Impact Assessment. The main objective of this study was to determine the significance of the predicted impacts from the proposed mining operations on the surrounding environment and on human health.

To achieve this objective, the local climate was characterised and existing ambient air quality data and dust fallout information evaluated, albeit only qualitatively. Particulates were identified to be the main pollutant of concern resulting from the proposed mining operations and all potential sources of fugitive dust have been identified and quantified. Dispersion simulations were undertaken to reflect both incremental (separate sources) and cumulative (all sources combined) impacts for the construction and operational phases.

The comparison of predicted pollutant concentrations to ambient air quality standards facilitated a preliminary screening of the potential human health impacts. The sensitive receptors identified to be included in the assessment were the most significant scattered farmsteads located around the proposed mining site.

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9.1 Main Impact Assessment Findings

The comparison of predicted pollutant concentrations to ambient air quality standards facilitated a preliminary screening of the potential, which exists for human health impacts. The sensitive receptors identified to be included in the assessment are the various farmsteads located close to the proposed mine site (Jan Burger Farmstead, farmstead located close to the N4 and one located to the south west). It was assumed that people reside at these farmsteads for a minimum of 24-hours, with the frequency of exceedances evaluated as if people are there every day. In reality, this might not be the case with people staying for less than 24 hours.

When interpreting the modelling results, it is therefore important to take cognisance of the temporary occupancy of the sensitive receptor sites, the assumptions and limitations (Section 1.4) and the inherent range of uncertainty of the dispersion model (between -50% to 200%). The predicted results are a function of the meteorological data and the source strengths (emissions data). For the purpose of this project, meteorological data and maximum emissions rates (based on the production rate for each year) were used thus providing a conservative approach (worst-case scenario) in predicted results.

9.2 Baseline Assessment

Meteorological data were obtained for the years 2007 to 2009 from the Rietvallei weather station and included hourly average wind speed, wind direction and temperature.

Over the period (from January 2007 to August 2009), the prevailing winds were recorded from the east, east-southeast and west-northwest with frequencies of occurrence of more than 10%. Day-time wind speeds indicated the dominancy of winds from the north- western sector while night conditions indicated an increase of winds from the east and east-southeast. During the summer months, winds from the east and east southeast were dominant, while the prevailing winds during spring were mainly from the north east, east and north-west sectors. The winter months were characterised by west-northwesterly winds, with frequencies of occurrence of more than 10%. Winds from the east and east-southeast were predominant during the autumn months.

No ambient monitored data was available for the area. However, the predicted highest and annual average concentrations of particulates in the Highveld region for all the sources according to a NEDLAC study, led to the conclusion that elevated PM10 concentrations were predicted to occur in the study region. Background maximum daily concentrations are therefore estimated to be between 25 µg/m³ and 75µg/m³ in the region. Annual average concentrations are estimated to be about 10 µg/m³.

9.2.1 Impact Assessment: Proposed 2011 Construction Phase

The predicted unmitigated daily average PM10 ground level concentrations exceeded the proposed SA standard of 75 µg/m³ at the farmstead located to the south east of the proposed mine site and at the Jan Burger farmstead. However, with mitigation measures in place for the most significant contributing sources to PM10 emissions (unpaved roads and crushing and screening), the predicted impacts at all the sensitive receptor areas were within the proposed SA Standards. Over an annual average, the predicted unmitigated impacts indicated exceedances of the proposed standard at Jan Burger farmstead and at the farmstead located to the south east of the proposed mine site. The application of mitigation measures to unpaved roads, drilling and crushing and screening, resulted in the predicted impacts complying with the proposed SA standard (40µg/m³) at all the sensitive receptor areas.

The predicted maximum daily dust fallout levels were well within the SANS residential target of 600 mg/m²/day at all the sensitive receptor areas for all the modelled scenarios.

9.2.2 Impact Assessment: Proposed 2016 Operational Phase (Phase 2)

The predicted unmitigated daily and annual ground level concentrations were predicted to exceed the proposed SA standard of 75 µg/m³ and 40 µg/m³ respectively at all the sensitive receptor areas. The application of mitigation measures to the unpaved roads and crushing and screening, however, resulted in the predicted impacts complying with the proposed SA standards at the receptor sites. When the unmitigated predicted concentrations for the operational phase were evaluated against the proposed allowable exceedance of 4 times a year for the proposed South African Standard of 75µg/m³, predictions at all the receptor sites were in excess of 4 days over the 1 year period (2008). However, the predicted concentrations at the receptor sites indicated frequencies of exceedances of less than 4 days for the mitigated proposed 2016 operations.

The predicted unmitigated and mitigated maximum daily dust fallout levels did not exceed the SANS residential target of 600 mg/m²/day at the receptor sites.

9.3 Conclusions

The main conclusion is that without the application of suitable mitigation measures to the main contributing sources to PM10 and TSP emissions, i.e the unpaved roads and crushing and screening, the proposed construction and operational mining activities will result in exceedances of the proposed SA Standards at the various sensitive receptors in the vicinity of the mine. Application of mitigation measures will lead to a significant reduction in predicted impacts at the sensitive receptor areas and compliance with the proposed ambient SA PM10 Standards.

9.4 Recommendations

9.4.1 Mitigation Recommendations

Due to the generally high existing background levels of particulate air concentrations in the region, it is highly recommended to control major contributing sources such as unpaved roads and crushing and screening.

9.4.2 Monitoring Recommendations

Dust fallout monitoring should be carried out close to the sensitive receptors around the mine area and proposed sites such as the plant areas. It is recommended that dust deposition monitoring be confined to sites within and in close proximity (< 2 km) to the proposed mine operations.

9.5 Project-specific Management Measures

Air Quality Management measures will ensure that the proposed construction and operational phases of the Belfast Project will have the lowest possible impacts on the surrounding environment. This can be achieved through a combination of mitigation measures and ambient monitoring. Mitigation measures are usually implemented at the main sources of pollution with the monitoring network designed as such to track the effectiveness of the mitigation measures. To identify the most significant sources, these need to be ranked according to sources strengths (emissions) and impacts. Once the main sources have been identified, target control efficiencies for each source can be defined to ensure acceptable cumulative ground level concentrations.

9.5.1 Source Ranking by Emissions

The main pollutant of concern for the proposed construction and operational phase mining operations is particulates (PM10/PM2.5 and TSP). The main sources of *emissions* were similar for the proposed 2011 construction and 2016 operational phases and can be identified as follows:

- Vehicle entrainment on the unpaved haul roads*;*
- Crushing and screening operations

9.5.2 Source Ranking by Impacts

9.5.2.1 Proposed 2011 Construction Phase

For the proposed 2011 construction phase, the main impacting sources at the sensitive receptor areas as shown in Figure 9-1 (unmitigated PM10 annual average), Figure 9-2 (mitigated PM10 annual average), Figure 9-3 (unmitigated maximum daily dust deposition) and Figure 9-4 (mitigated maximum daily dust deposition) were in order of importance:

- Vehicle entrainment from the unpaved roads; and,
- Crushing and screening

9.5.2.2 Proposed 2016 Operational Phase

The main impacting sources at the sensitive receptor areas due to the proposed 2016 mining operations are shown in Figure 9-5 (unmitigated PM10 annual average) and Figure 9-6 (mitigated PM10 annual average), Figure 9-7 (unmitigated maximum daily dust deposition) and Figure 9-8 (mitigated maximum daily dust deposition) were in order of importance:

- Vehicle entrainment from the unpaved roads; and,
- Crushing and screening

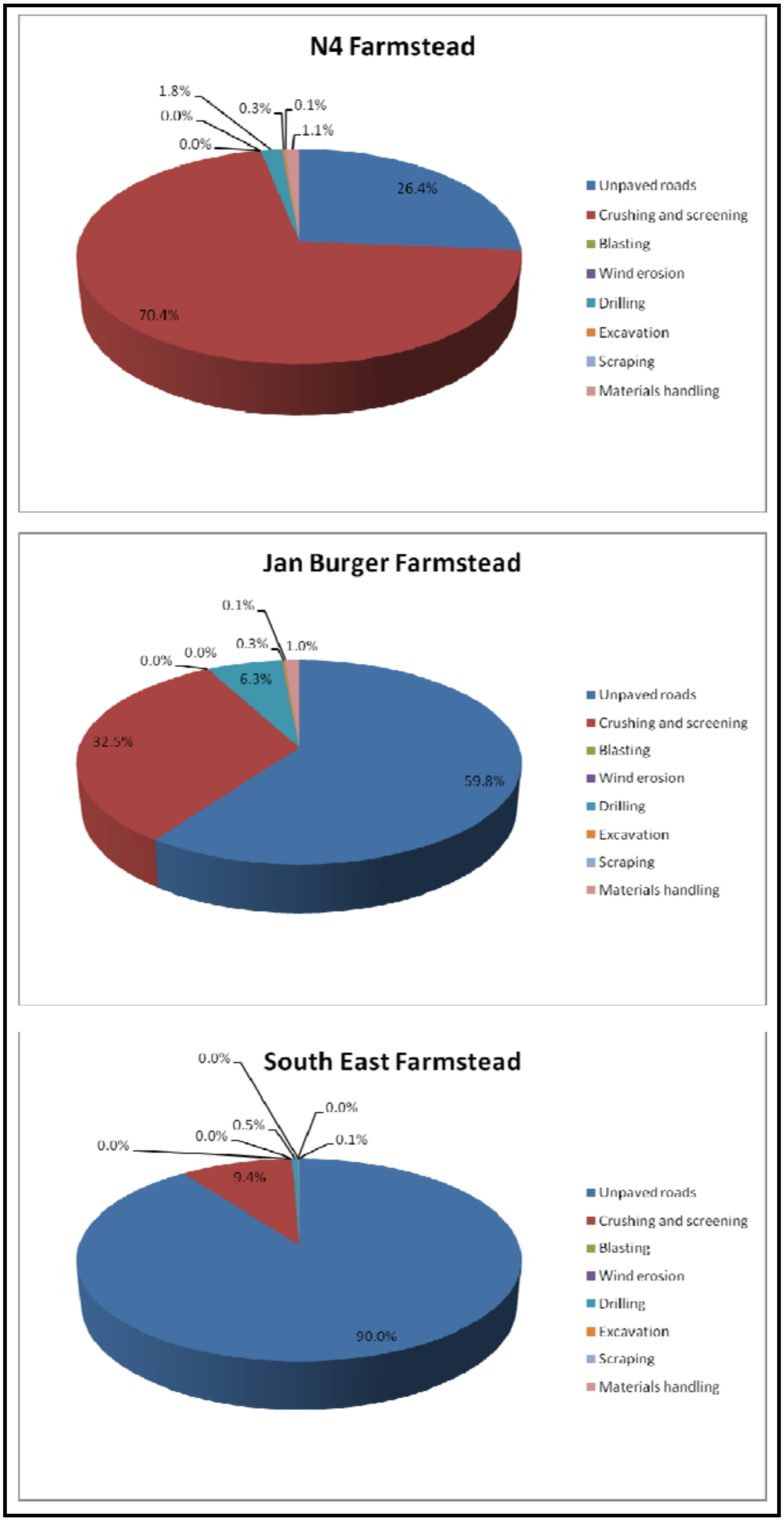

Figure 9-1: Source impacts at the sensitive receptor sites due to the unmitigated proposed 2011 construction phase activities (annual average PM10).

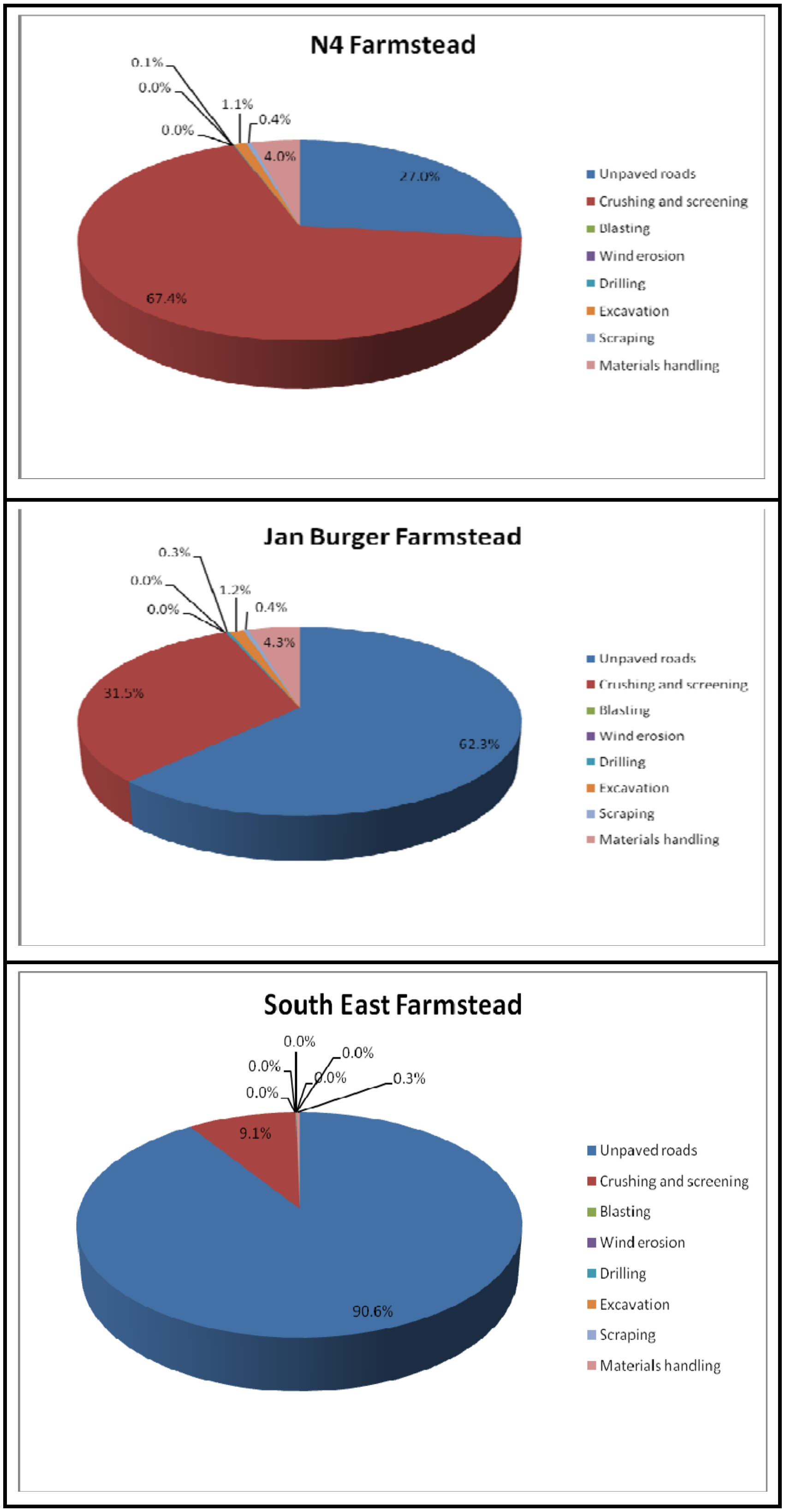

Figure 9-2: Source impacts at the sensitive receptor sites due to the mitigated proposed 2011 construction phase activities (annual average PM10).

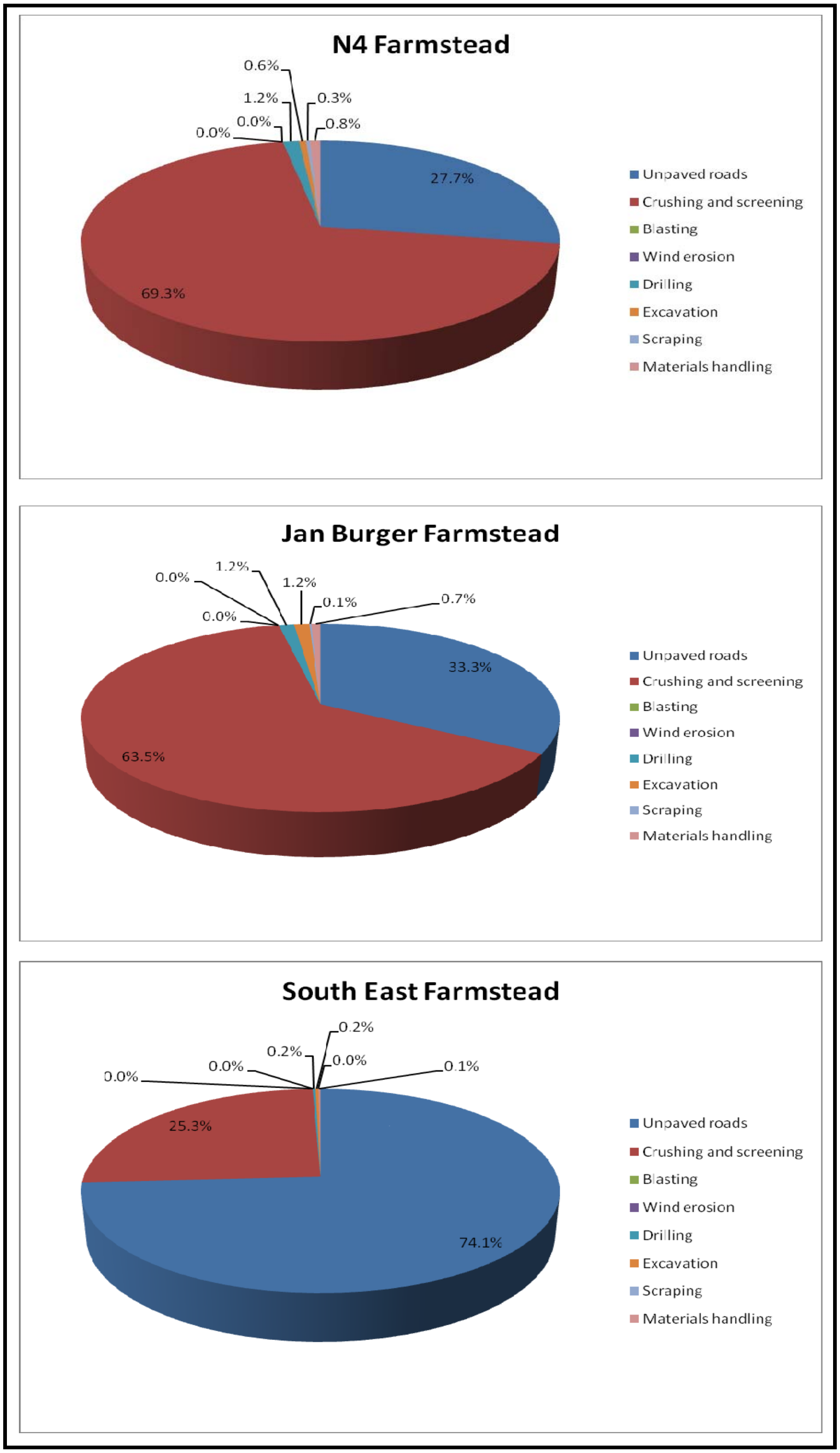

Figure 9-3: Source impacts at the sensitive receptor sites due to unmitigated proposed 2011 construction phase activities (maximum daily average dust fallout).

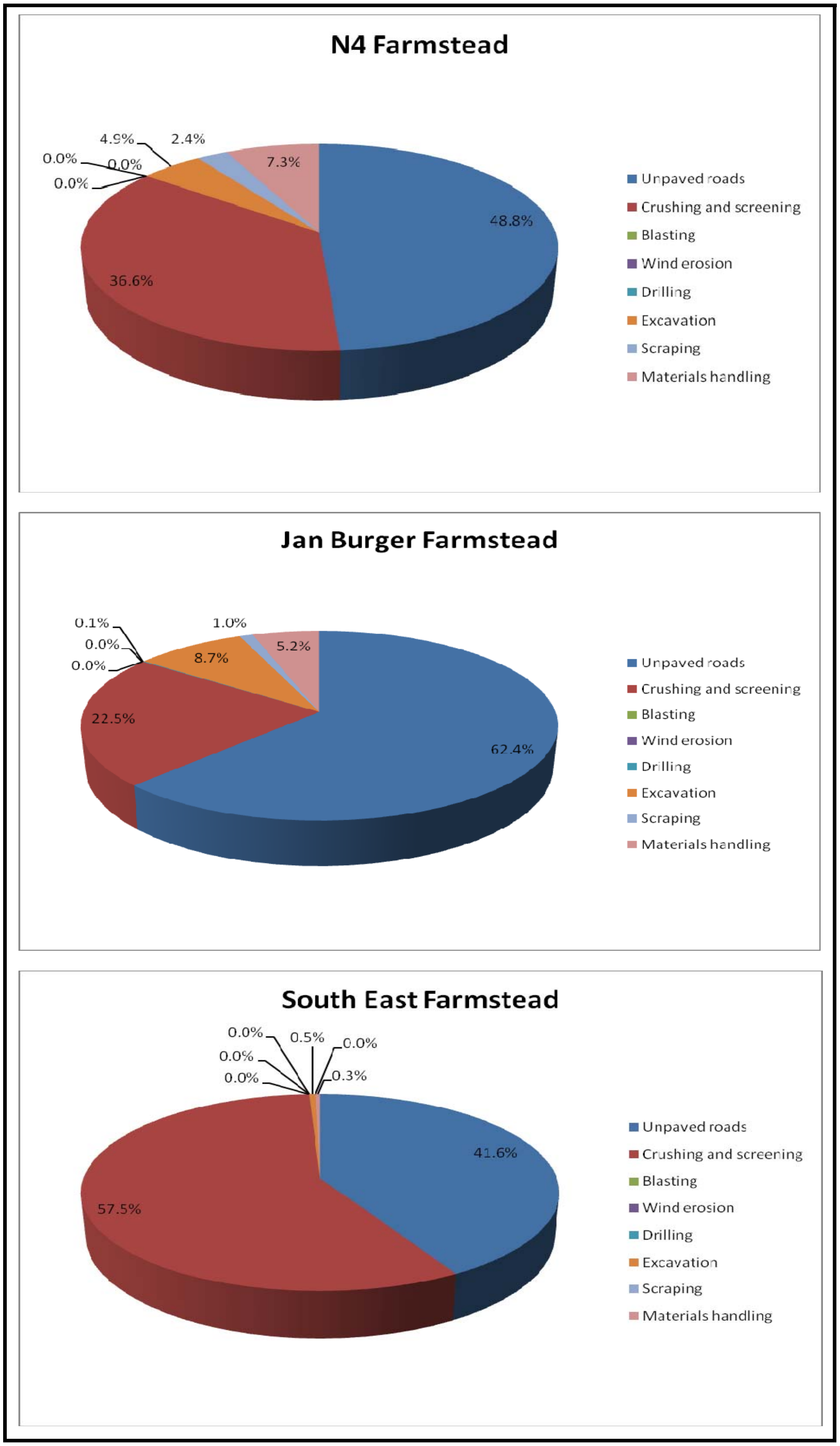

Figure 9-4: Source impacts at the sensitive receptor sites due to mitigated proposed 2011 construction phase activities (maximum daily average dust fallout).

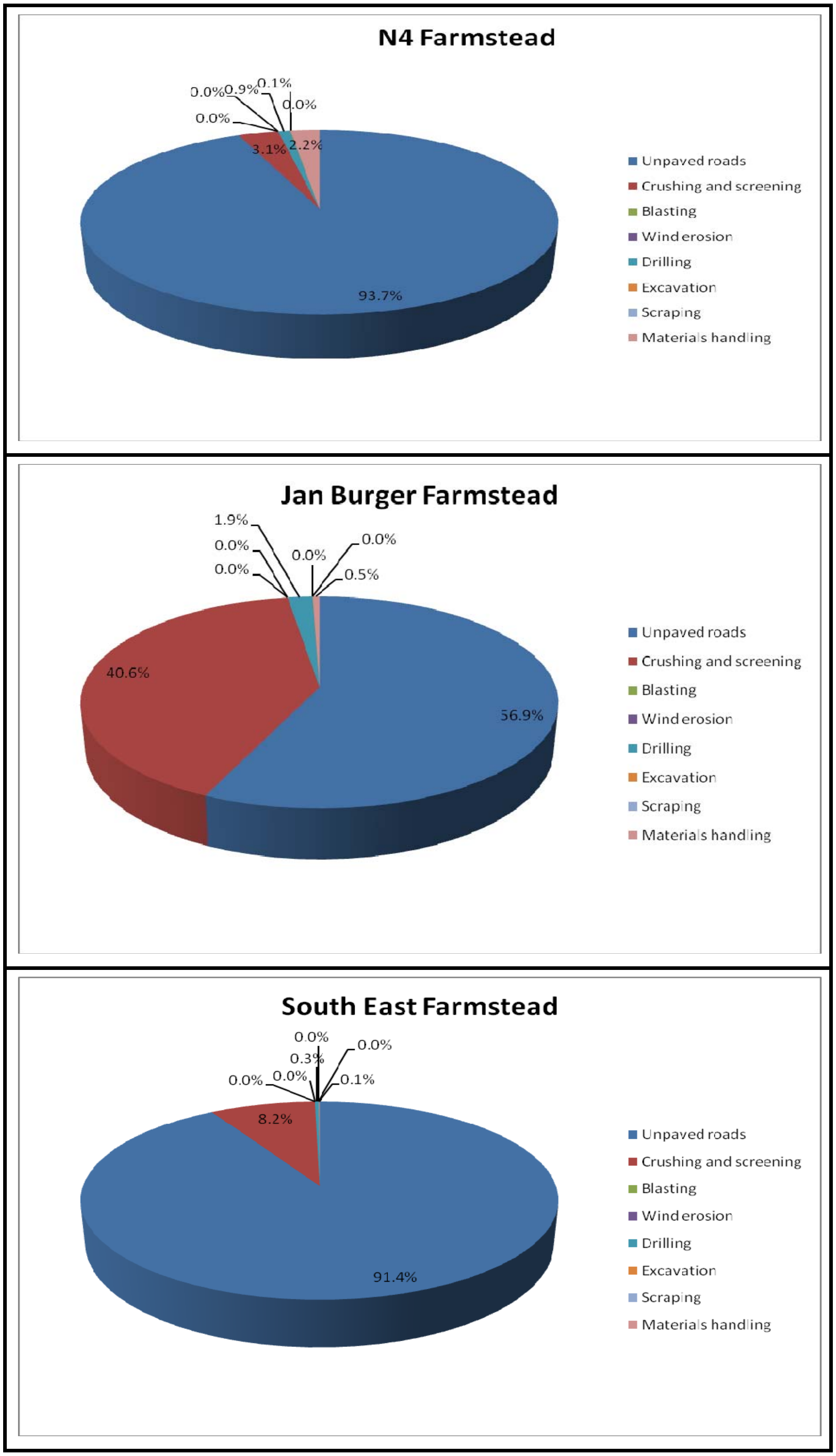

Figure 9-5: Source impacts at the sensitive receptor sites due to unmitigated proposed 2016 operational phase activities (annual average PM10).

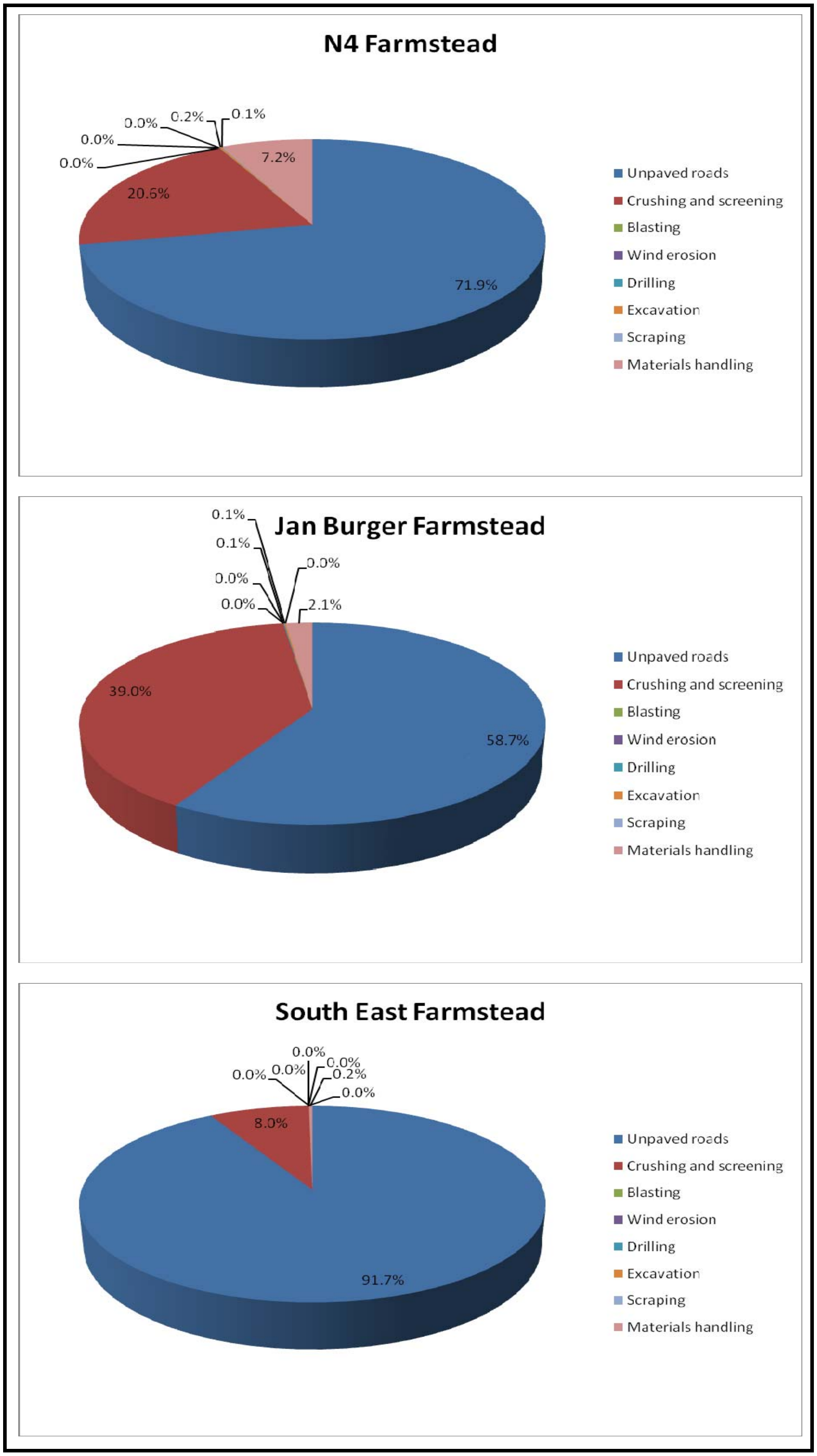

Figure 9-6: Source impacts at the sensitive receptor sites due to mitigated proposed 2016 operational phase activities (annual average PM10).

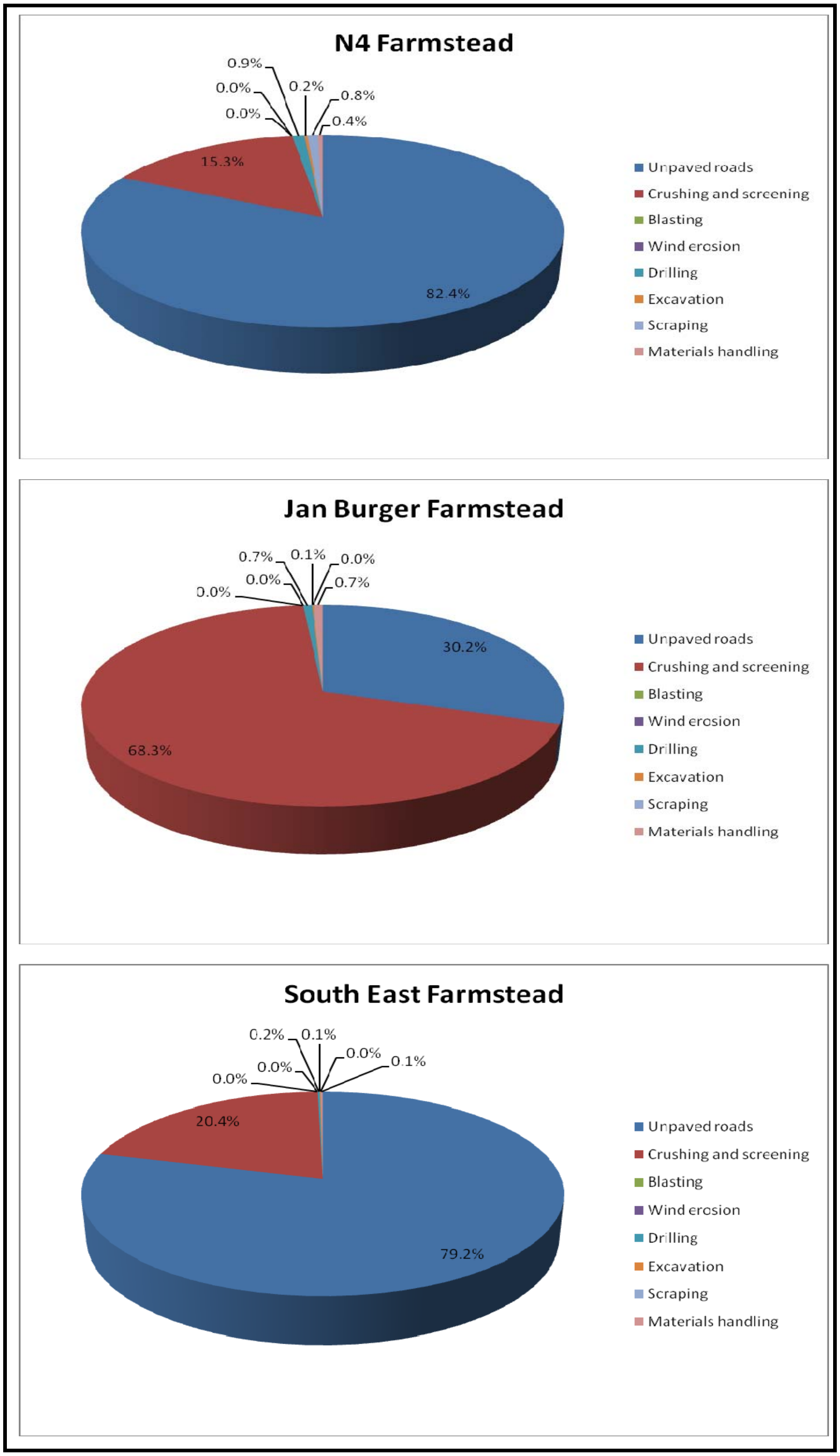

Figure 9-7: Source impacts at the sensitive receptor sites due to unmitigated proposed 2016 operational phase activities (maximum daily average dust fallout).

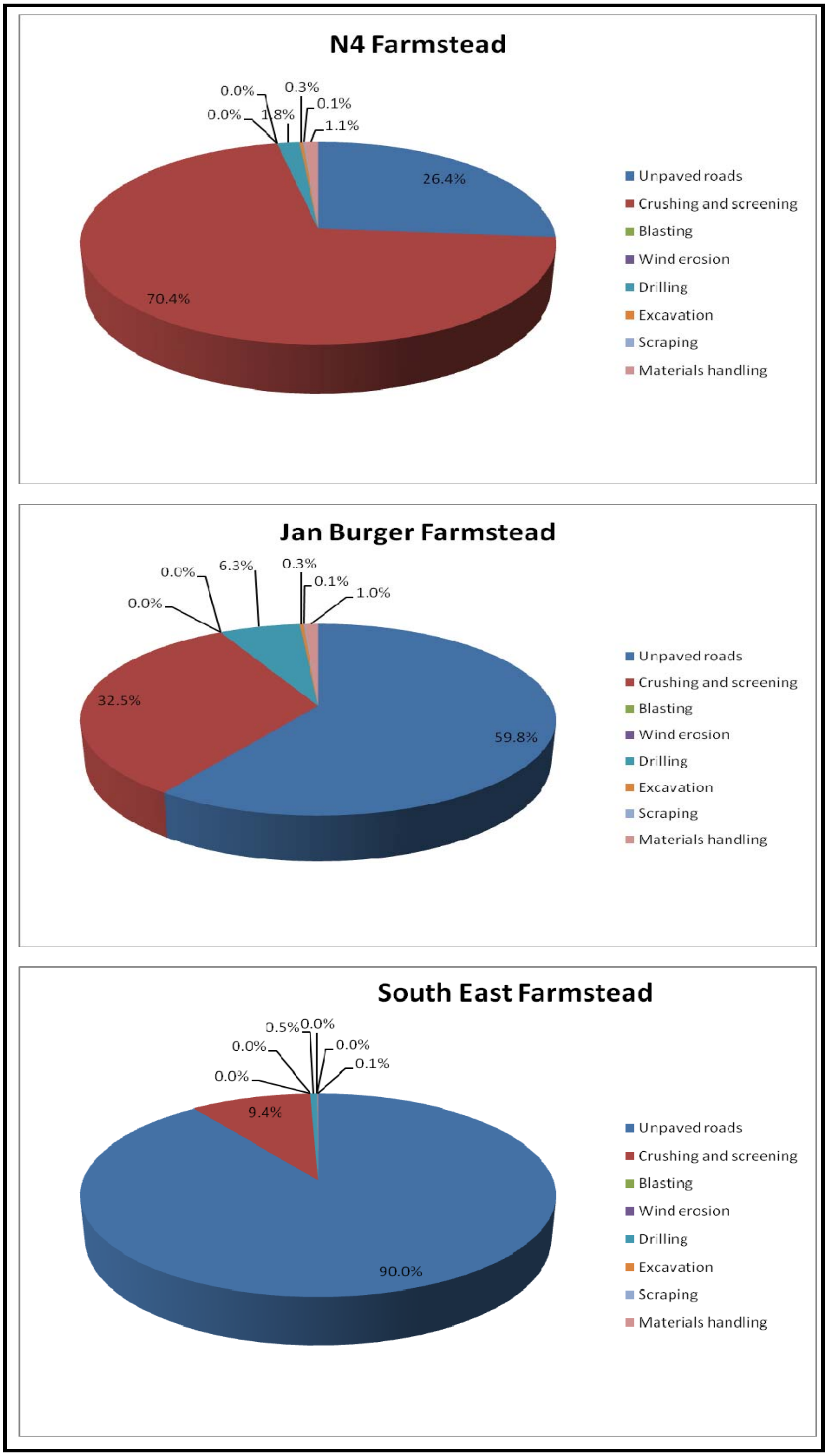

Figure 9-8: Source impacts at the sensitive receptor sites due to mitigated proposed 2016 operational phase activities (maximum daily average dust fallout).

9.5.3 Target Controls for the Main Sources

The main sources of emissions for the modelled scenarios are the unpaved haul roads and crushing and screening operations. The main pollutant of concern is particulates, specifically PM10 and TSP. The proposed target controls on the various sources are provided below.

9.5.3.1 Proposed 2011 Construction Phase

- o Vehicle entrainment on unpaved roads– 75% control efficiency through effective water sprays on in-pit and main haul roads.
- o Crushing and screening- the application of water sprays to ensure high moisture content of the ore. This can lead to control efficiencies of up to 62%. Also, the enclosure of crushing operations is very effective in reducing dust emissions.

9.5.3.2 Proposed 2016 Operational Phase

- o Vehicle entrainment on unpaved haul roads – 75% control efficiency through water suppression, with ~90% control efficiency through the application of chemical surfactants or surface paving.
- o Vehicle entrainment on in-pit haul roads – these roads change depending on the area to be mined and hence it is not practical to apply chemicals. It is recommended that a minimum of 75% control efficiency is achieved through affective water sprays.
- Crushing and screening operations- enclosure of crushing operations is very effective in reducing dust. The Australian NPi indicates that a telescopic chute with water sprays would ensure 75% control efficiency and enclosure of storage piles where tipping occur would reduce the emissions by 99%. In addition, chemical suppressants or water sprays on the primary crusher and dry dust extraction units with wet scrubbers on the secondary and tertiary crushers and screens will assist in the reduction of the cumulative dust impacts.

9.5.3.3 Closure Phase

The potential for impacts during the closure phase are dependent on the extent of demolition and rehabilitation efforts during closure and on features which remain (viz. the tailings dams). It was assumed that the potential for fugitive dust impacts due to these sources could be rendered negligible (and proven to be so) through comprehensive rehabilitation prior to closure.

9.5.4 Identification of Suitable Mitigation Measures

9.5.4.1 Vehicle Entrainment on Unpaved Haul Roads

Three types of measures may be taken to reduce emissions from unpaved roads: (a) measures aimed at reducing the extent of unpaved roads, e.g. paving, (b) traffic control measures aimed at reducing the entrainment of material by restricting traffic volumes and reducing vehicle speeds, and (c) measures aimed at binding the surface material or enhancing moisture retention, such as wet suppression and chemical stabilization (EPA, 1987; Cowhert *et al.*, 1988; APCD, 1995).

The main dust generating factors on unpaved road surfaces include:

- Vehicle speeds
- Number of wheels per vehicle
- Traffic volumes
- Particle size distribution of the aggregate
- Compaction of the surface material
- Surface moisture
- Climate

When quantifying emissions from unpaved road surfaces, most of these factors are accounted for. Vehicle speed is one of the significant factors influencing the amount of fugitive dust generated from unpaved roads surfaces. According to research conducted by the Desert Research Institute at the University of Nevada, an increase in vehicle speed of 10 miles per hour resulted in an increase in PM10 emissions of between 1.5 and 3 times. A similar study conducted by Flocchini et.al. (1994) found a decrease in PM10 emissions of 42±35% with a speed reduction from 40 km/hr to 24 km/hr (Stevenson, 2004). The control efficiency obtained by speed reduction can be calculated by varying the vehicle speed input parameter in the predictive emission factor equation given for unpaved roads. An evaluation of control efficiencies resulting from reductions in traffic volumes can be calculated due to the linear relationship between traffic volume, given in terms of vehicle kilometres travelled, and fugitive dust emitted. Similar affects will be achieved by reducing the truck volumes on the roads. Thus, by increasing the payload of the truck, fewer trips will be required to transport the same amount of material.

Water sprays on unpaved roads is the most common means of suppressing fugitive dust due to vehicle entrainment at mines, but it is not necessarily the most efficient means (Thompson and Visser, 2000). Thompson and Visser (2000) developed a model to determine the cost and management implications of dust suppression on mine haul roads using water or other chemical palliatives. The study was undertaken at 10 mine sites in Southern Africa. The model was first developed looking at the re-application frequency of water required for maintaining a specific degree of dust palliation. From this the cost effectiveness of water spray suppression could be determined and compared to other strategies. Factors accounted for in the model included climate, traffic, vehicle speed and the road aggregate material. A number of chemical palliative products, including hygroscopic salts, lignosulponates, petroleum resins, polymer emulsions and tar and bitumen products were assessed to benchmark their performance and identify appropriate management strategies. Cost elements taken into consideration included amongst others capital equipment, operation and maintenance costs, material costs and activity related costs. The main findings were that water-based spraying is the cheapest dust suppression option over the short term. Over the longer term however, the polymer-emulsion option is marginally cheaper with added benefits such as improved road surfaces during wet weather, reduced erosion and dry skid resistance (Thompson and Visser, 2000).

An empirical model, developed by the US-EPA (EPA, 1996), was used to estimate the average control efficiency of certain quantifies of water applied to a road. The model takes into account rainfall, evaporation rates and traffic. Water and chemical sprays resulting in at least 90% control efficiency would be a requirement to result in a significant reduction in ground level concentrations and dustfall levels. Should only water be applied, the amounts needed to ensure 75% control efficiency on the main and in-pit haul roads (assuming 8 trucks/hour) are 0.069 $l/m^2/hour$ including mitigation due to rainfall. Watering rates for a variety of control efficiencies are presented in Figure 9-9.

Chemical suppressant has been proven to be affective due to the binding of fine particulates in the road surface, hence increasing the density of the surface material. In addition, dust control additives are beneficial in the fact that it also improves the compaction and stability of the road. The effectiveness of a dust palliative include numerous factors such as the application rate, method of application, moisture content of the surface material during application, palliative concentrations, mineralogy of aggregate and environmental conditions. Thus, for different climates and conditions you need different chemicals, one chemical might not be as effective as another under the same conditions and each product comes with various advantages and limitations of each own. In general, chemical suppressants are given to achieve a PM10 control efficiency of 80% when applied regularly on the road surfaces (Stevenson, 2004).

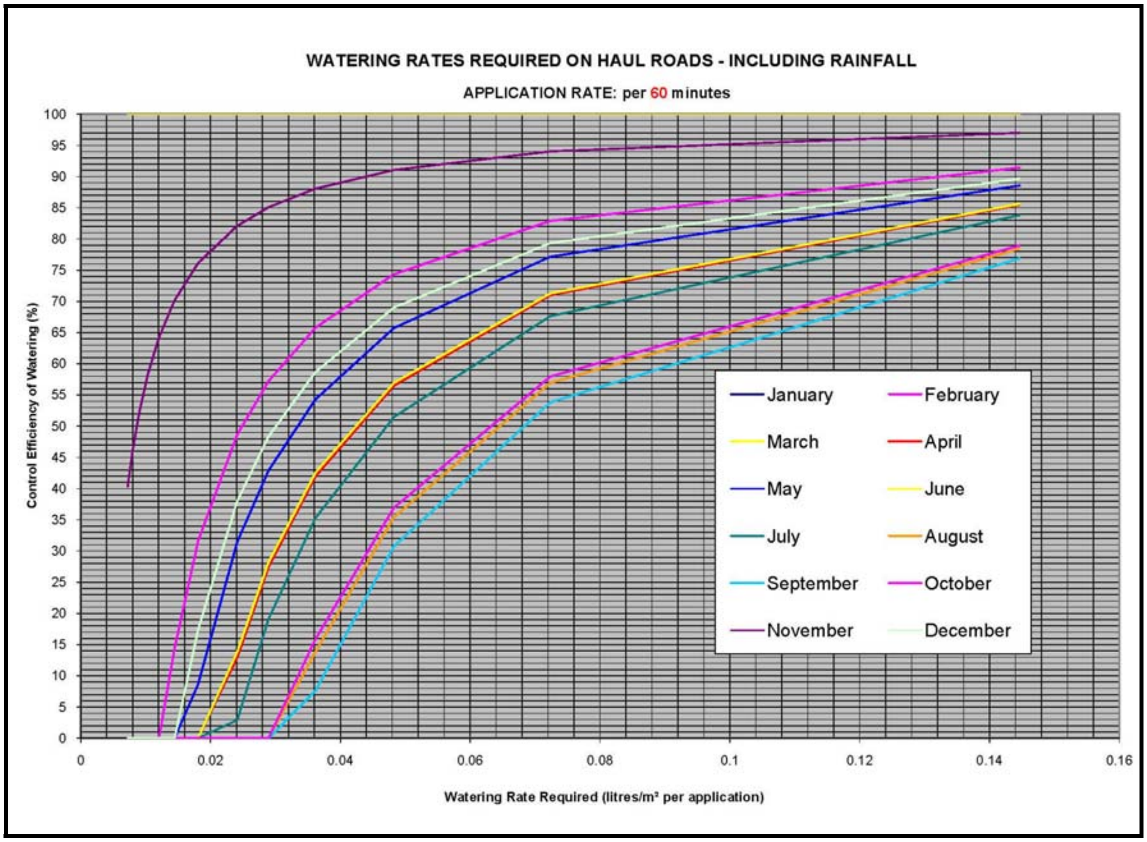

Figure 9-9: Monthly watering rates including rainfall.

There is however no cure-all solution but rather a combination of solutions. A cost-effective chemical control programme may be developed through establishing the minimum control efficiency required on a particular roadway, and evaluating the costs and benefits arising from various chemical stabilization practices. Appropriate chemicals and the most effective relationships between application intensities, reapplication frequencies, and dilution ratios may be taken into account in the evaluation of such practices.

Spillage and track-on from the surrounding unpaved areas may result in the deposition of materials onto the chemically treated or watered road resulting in the need for periodic "housekeeping" activities (Cowherd et al., 1988; EPA, 1996). In addition, the gradual abrasion of the chemically treated surface by traffic will result in loose material on the surface which would have to be controlled. The minimum frequency for the reapplication of watering or chemical stabilizers thus depends not only on the control efficiency of the suppressant but also on the degree of spillage and track-on from adjacent areas, and the rate at which the treated surface is abraded. The best way to avoid dust generating problems from unpaved roads is to properly maintain the surface by grading and shaping for cross sectional crowing to prevent dust generation caused by excessive road surface wear (Stevenson, 2004).

One of the main benefits of chemical stabilisation in conjunction with wet suppression is the management of water resources (MFE, 2001). It is therefore recommended that water be used in combination with chemical surfactants to reduce the amount of water required to achieve control efficiencies in excess of 90% on the main haul roads of the proposed mine site.

9.5.4.2 Materials Handling Operations

Materials handling operations including primary crushing and screening of ore and materials transfer point were identified as significant sources of emissions during the proposed mining operations.

Enclosure of crushing operations is very effective in reducing dust. The Australian NPi indicates that a telescopic chute with water sprays would ensure 75% control efficiency and enclosure of storage piles where tipping occur would reduce the emissions by 99%. In addition, chemical suppressants or water sprays on the primary crusher and dry dust extraction units with wet scrubbers on the secondary and tertiary crushers and screens will assist in the reduction of the cumulative dust impacts. According to the Australian NPi, water sprays can have up to 50% control efficiency, and hoods with scrubbers up to 75%. If in addition, the scrubbers and screens were to be enclosed, up to 100% control efficiency can be achieved. With these control measures in place, the impacts would reduce to negligible levels. It is important that these control equipment be maintained and inspected on a regular basis to ensure that the expected control efficiencies are met.

The control efficiency of pure water suppression can be estimated based on the US-EPA emission factor which relates material moisture content to control efficiency. This relationship is illustrated in Figure 9-10. From the relationship between moisture content and dust control efficiency it is apparent that by doubling the moisture content of the material an emission reduction of 62% could be achieved. Thus chemicals mixed into the water will not just save on water consumption but also improve the control efficiency of the application even further.

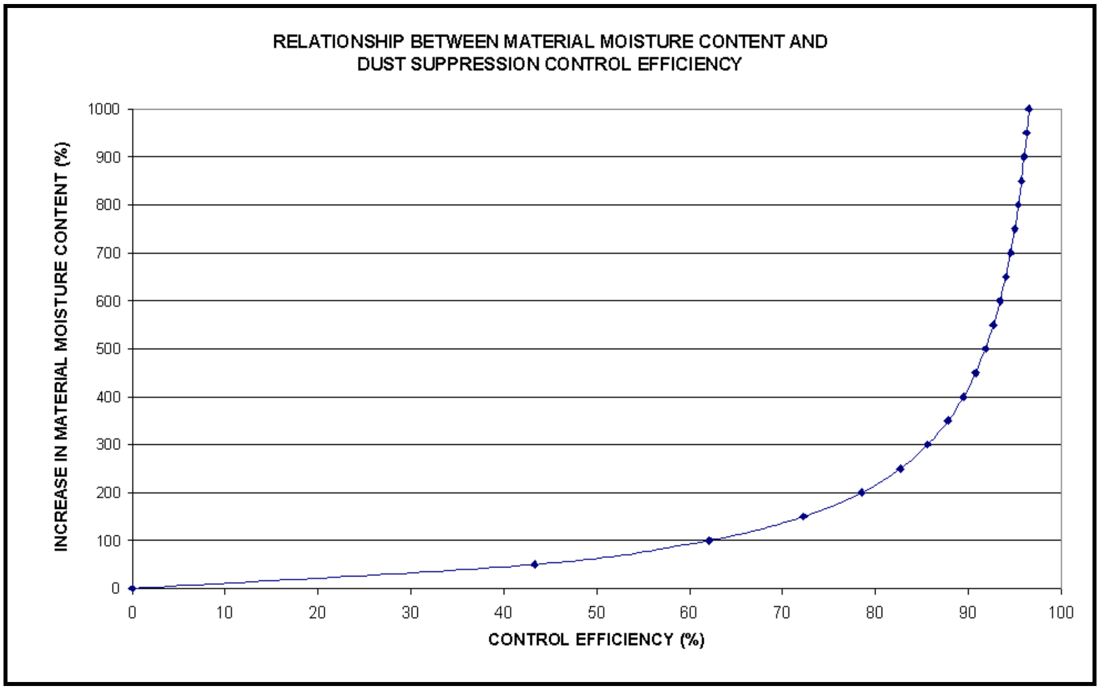

Figure 9-10: Relationship between the moisture content of the material handled and the dust control efficiency (calculated based on the US-EPA predictive emission factor equation for continuous and batch drop operations).

9.5.4.3 Open Pit Operations: Drilling and Blasting

All materials handling operations within the open pit will reduce dust generation by 62% by merely doubling the moisture content of the material handled. A 75% reduction in dust emissions from unpaved in-pit haul roads can be achieved through effective water sprays combined with chemicals. The Australian NPi in their Emission Estimation Technique Manual for Mining states that a 70% and 95% reduction in dust emissions from drilling can be achieved through effective water sprays and fabric filters respectively.

In addition, the Australian NPi stipulates a 50% reduction of TSP emissions due to pit retention, and 5% for PM10 emissions. This is based on the increase in volume (the deeper the pit becomes) and thus resulting in better dispersion potential for specifically PM10 emissions before reaching the surface. Similarly for TSP, the potential for deposition on the surface becomes smaller for more dust would settle within the pit. This as the pit becomes bigger and deeper; the impacts from the in-pit operations should reduce.

9.5.5 Monitoring Requirements

Key performance indicators against which progress may be assessed form the basis for all effective environmental management practices. Performance indicators are usually selected to reflect both the source of the emission directly and the impact on the receiving environment. Ensuring that no visible evidence of windblown dust exists represents an example of a source-based indicator, whereas maintaining off-site dustfall levels to below 250 mg/m^2/day represents an impact- or receptor-based performance indicator. Source-based performance indicators have been included in regulations abroad.

- Source based performance indicators for the unpaved roads would be no visible dust when trucks/vehicles drive on the roads. It is recommended that dust fallout in the immediate vicinity of the road perimeter be less than 1,200 mg/m^2/day and less than 600 mg/m^2/day at the sensitive receptors.
- The absence of visible dust plume at all tipping points and outside the primary crusher would be the best indicator of effective control equipment in place. In addition the dust fallout in the immediate vicinity of the tipping and crushing sources should be less than 1,200 mg/m^2/day.
- From all activities associated with the proposed Belfast Project operations, dust fallout levels should not exceed 600 mg/m^2/day at the sensitive receptor areas.

In addition to the above-mentioned monitoring requirements, a dust control checklist by Environment Australia can also be used in the monitoring and management of dust emissions due to the proposed Belfast Project. Detail on this dust control checklist is provided in Appendix D.

9.5.5.1 Proposed 2016 operational phase dust fallout monitoring network

A dust fallout network provides management with an indication of what the reduction in fugitive dust levels are once mitigation measures are implemented. In addition, a dust fallout network can serve to meet various objectives, such as:

- Compliance monitoring;
- Validate dispersion model results;
- Use as input for health risk assessment;
- Assist in source apportionment;
- Temporal trend analysis;
- Spatial trend analysis;
- Source quantification; and,
- Tracking progress made by control measures.

It is therefore recommended that a dust fallout monitoring network, consisting of 6 single buckets be implemented for the proposed Belfast Project operational phase (Figure 9-11). These proposed dust buckets are strategically placed near the largest contributing sources due to proposed operating activities at the proposed mine site and at receptors. Dust bucket 1 and 2 (placed close to the unpaved roads, which have been predicted as significant sources of particulate emissions) are recommended to assess the impacts and mitigation performance from these sources. Dust bucket 2 is also placed close to a receptor (Jan Burger farmstead). Dust bucket 3 and 4 are placed close to the crushing and screening plants to capture the impacts due to plant operations. Dust bucket 5 is recommended to assess the impact of vehicle entrainment at the receptor (farmstead on the south east) while dust bucket 6 is placed at the sensitive receptor site (farmstead close to the N4).

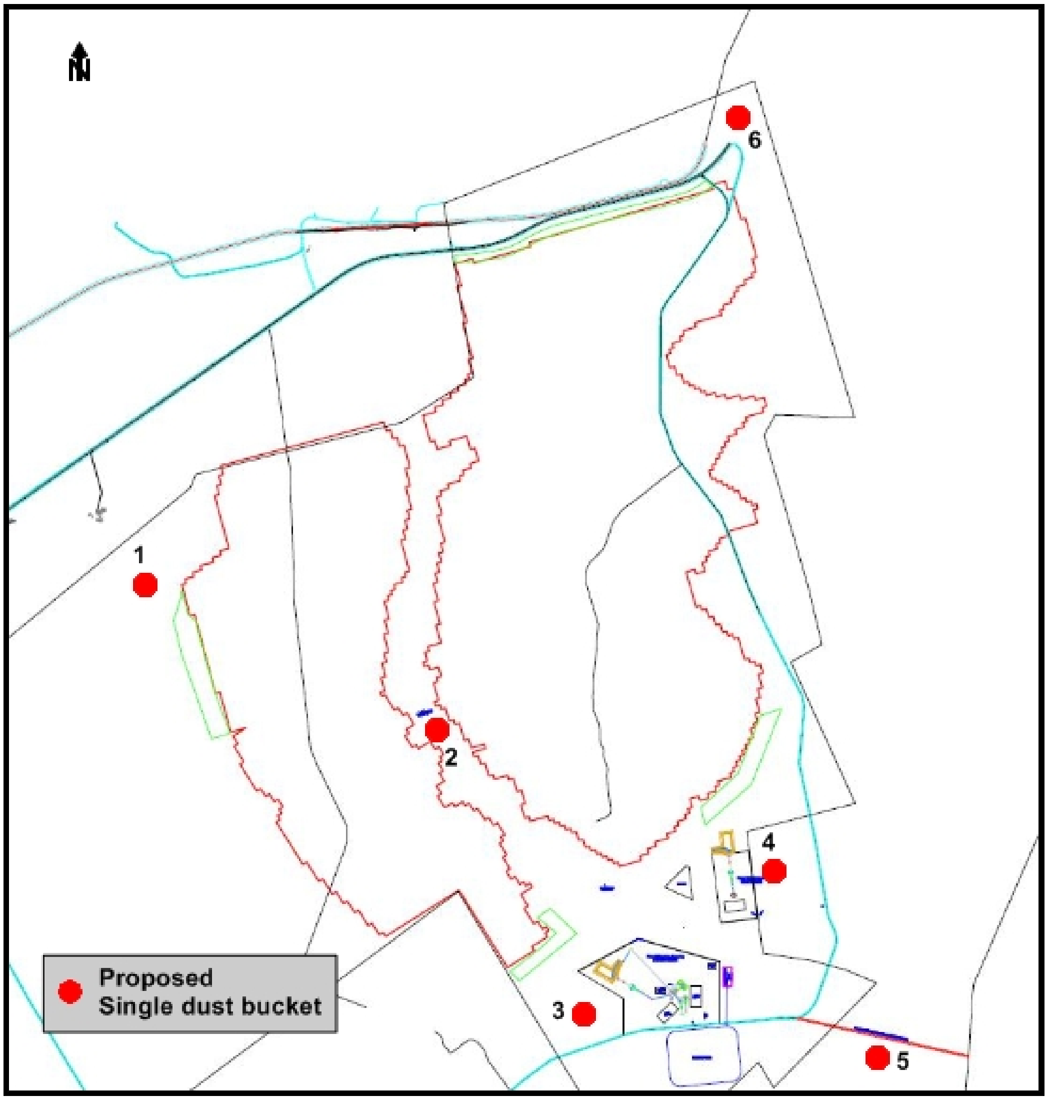

Figure 9-11: Proposed dust fallout monitoring network for the proposed 2016 operational phase.

9.6 Record-keeping, Environmental Reporting and Community Liaison

9.6.1 Periodic Inspections and Audits

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

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

9.6.2 Liaison Strategy for Communication with I&APs

Stakeholder forums provide possibly the most effective mechanisms for information dissemination and consultation. Specific intervals at which forums will be held, and provide information on how people will be notified of such meetings.

9.6.3 Financial Provision (Budget)

The budget should provide a clear indication of the capital and annual maintenance costs associated with dust control measures and dust monitoring plans. It may be necessary to make assumptions about the duration of aftercare prior to obtaining closure. This assumption must be made explicit so that the financial plan can be assessed within this framework. Costs related to inspections, audits, environmental reporting and I&AP liaison should also be indicated where applicable. Provision should also be made for capital and running costs associated with dust control contingency measures and for security measures.

The financial plan should be audited by an independent consultant, with reviews conducted on an annual basis.

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http://www.src.com/MM5

http://en.wikipedia.org/wiki/Fog

http://www.sciencedaily.com/fog cleans air pollution.htm

APPENDIX A:

LEGISLATIVE OVERVIEW

A.1: The Atmospheric Pollution Prevention Act (No.45 of 1965) (APPA)

Under the Air Pollution Prevention Act (Act No 45 of 1965) (APPA) the focus is mainly on sourced based control with permits issued for Scheduled Processes. Scheduled processes, referred to in the Act, are processes which emit more than a defined quantity of pollutants per year, including combustion sources, smelting and inherently dusty industries. Best Practical Means (BPM), on which the permits are based, represents an attempt to restrict emissions while having regard to local conditions, the prevailing extent of technical knowledge, the available control options, and the cost of abatement. The Department of Environmental Affairs is responsible for the administration of this Act with the implementation thereof charged to the Chief Air Pollution Control Officer (CAPCO).

The APPA is outdated and not in line with international best practice. It also proves inadequate to facilitate the implementation of the principles underpinning the National Environmental Management Act (NEMA) and the Integrated Pollution and Waste Management (IP&WM) white paper. In this light, the National Environmental Management: Air Quality Act (Act no. 39 of 2004) was drafted, shifting the approach from source based control to decentralised air quality management through an effects-based approach.

Although emission limits and ambient concentration guidelines are published by the Department of Environmental Affairs, no provision was made under the APPA for ambient air quality standards or emission standards. The decision as to what constitutes the best practicable means for each individual case was reached following discussions with the industry. A registration certificate, containing maximum emission limits specific

A.2: The National Environmental Management: Air Quality Act (No. 39 of 2004) (NEMAQA)

National, Provincial and Local authorities (district and metropolitan municipalities) will be responsible to manage air quality under the new National Environmental Management: Air Quality Act of 2004[3]. With the shift of the new Air Quality Act from source control to the impacts on the receiving environment, the responsibility to achieve and manage sustainable development has reached a new dimension. The Air Quality Act has placed the responsibility of air quality management on the shoulders of provincial and local authorities that will be tasked with baseline characterisation, management and operation of ambient monitoring networks, licensing of listed activities, and emissions reduction strategies. The main objective of the act is to ensure the protection of the environment and human health through reasonable measures of air pollution control within the sustainable (economic, social and ecological) development framework.

The aim of the new National Environmental Management Air Quality Act is to reform the law regulating air quality in order to protect and enhance the quality of air in the Republic, taking

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[3]. The National Environmental Management: Air Quality Act (Act no.39 of 2004) commenced with on the 11th of September 2005 as published in the Government Gazette on the 9th of September 2005. Sections omitted from the implementation are Sections 21, 22, 36 to 49, 51(1)(e),51(1)(f), 51(3),60 and 61

into account the need for sustainable development, to provide for national norms and standards regulating air quality monitoring, management and control by all spheres of government; for specific air quality measures; and for matters incidental thereto.

The approach of the Air Quality Act is to shift the focus to the receiving environment and to decentralise responsibilities to provincial and local government. This would require baseline air quality characterisation studies to be conducted for regions and provinces to identify areas and pollutants of concern. All sources within a region would have to be addressed and if identified as a main contributing source would be expected to develop and implement emission reduction strategies. Standardisation of various aspects of air quality management would be required including methodologies on monitoring, modelling, management and reporting. Public participation is a requirement of the impending act which would require industries to follow a transparent management approach.

The minister must, within two years of the date on which this section took effect, establish a national framework for achieving the object of this Act. This needs to include mechanisms, systems and procedures to attain compliance with ambient air quality standards, to give effect to the Republic's responsibility to international agreements and to control emissions from point and non-point sources. In addition, national norms and standards needs to be set for air quality -monitoring; -management planning, - information management, and any other matter which the Minister considers necessary for achieving the object of this Act.

Chapter 2 states that substances and mixtures of substances that present a threat to health, well-being or the environment must be identified and national standards be established (including the permissible amount or concentration of each such substance or mixture of substances in ambient air). In addition, emission standards need to be established for each of these substances and mixtures of substances from point, non-point or mobile sources.

Chapter 4 of the impending Air Quality Act focus on Air Quality Management Measures. Section 21 of this chapter states that the Minister must, or MEC of a province may publish a list of activities which he/she thinks might have a negative effect on the environment (including health, social conditions, economic conditions, ecological conditions or cultural heritage) and this list can be amended from time to time by adding or removing activities. In addition, if an activity is listed, emission standards need to be set for pollutants emanating from such an activity.

Section 32 of Chapter 4 states that the Minister or MEC may prescribe measures for the control of dust in specified places or areas, steps that must be taken to prevent nuisance by dust; or other measures aimed at the control of dust. In Section 33 reference is made to the ceasing of mining operations where a mine has to notify the Minister 5 years prior to closure, clearly stating plans for rehabilitation and prevention of pollution of the atmosphere by dust after those operations have stopped.

APPENDIX B:
MACRO – SCALE ATMOSPHERIC DISPERSION POTENTIAL

The macro-ventilation characteristics of the region are determined by the nature of the synoptic systems which dominate the circulation of the region, and the nature and frequency of occurrence of alternative systems and weather perturbations over the region.

B.1 Regional Climate

Situated in the subtropical high pressure belt, southern Africa is influenced by several high pressure cells, in addition to various circulation systems prevailing in the adjacent tropical and temperature latitudes. The mean circulation of the atmosphere over southern Africa is anticyclonic throughout the year (except near the surface) due to the dominance of three high pressure cells, viz. the South Atlantic HP off the west coast, the South Indian HP off the east coast, and the continental HP over the interior.

Five major synoptic scale circulation patterns dominate (Figure A-1) (Vowinckel, 1956; Schulze, 1965; Taljaard, 1972; Preston-Whyte and Tyson, 1988). The most important of these is the semi-permanent, subtropical continental anticyclones which are shown by both Vowinckel (1956) and Tyson (1986) to dominate 70 % of the time during winter and 20 % of the time in summer. This leads to the establishment of extremely stable atmospheric conditions which can persist at various levels in the atmosphere for long periods.

Seasonal variations in the position and intensity of the HP cells determine the extent to which the tropical easterlies and the circumpolar westerlies impact on the atmosphere over the subcontinent. The tropical easterlies, and the occurrence of easterly waves and lows, affect most of southern Africa throughout the year. In winter, the high pressure belt intensifies and moves northward, the upper level circumpolar westerlies expand and displace the upper tropical easterlies equatorward. The winter weather of South Africa is, therefore, largely dominated by perturbations in the westerly circulation. Such perturbations take the form of a succession of cyclones or anticyclones moving eastwards around the coast or across the country. During summer months, the anticyclonic belt weakens and shifts southwards, allowing the tropical easterly flow to resume its influence over South Africa. A weak heat low characterises the near surface summer circulation over the interior, replacing the strongly anticyclonic winter-time circulation (Schulze, 1986; Preston-Whyte and Tyson, 1988).

Anticyclones situated over the subcontinent are associated with convergence in the upper levels of the troposphere, strong subsidence throughout the troposphere, and divergence in the near-surface wind field. Subsidence inversions, fine conditions with little or no rainfall, and light variable winds occur as a result of such widespread anticyclonic subsidence. Anticyclones occur most frequently over the interior during winter months, with a maximum frequency of occurrence of 79 percent in June and July. During December such anticyclones only occur 11 percent of the time. Although widespread subsidence dominates the winter months, weather occurs as a result of uplift produced by localized systems.

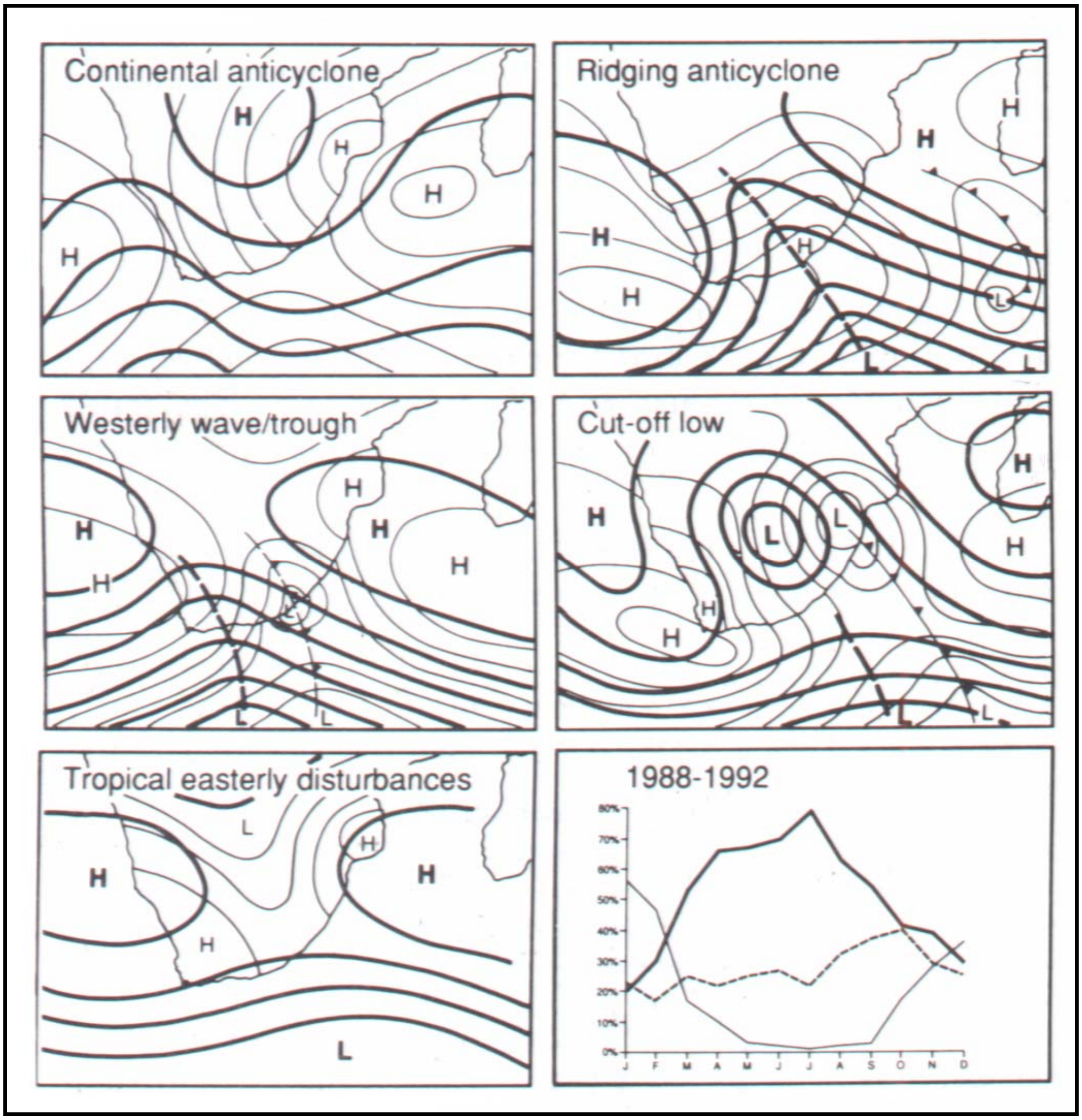

Figure B-1. Major synoptic circulation types affecting southern Africa and their monthly frequencies of occurrence over a five year period (after Preston-Whyte and Tyson, 1988 and Garstang *et al.,* 1996a).

Tropical easterly waves give rise to surface convergence and upper air (500 hPa) divergence to the east of the wave resulting in strong uplift, instability and the potential for precipitation. To the west of the wave, surface divergence and upper-level convergence produces subsidence, and consequently fine clear conditions with no precipitation. Easterly lows are usually deeper systems than are easterly waves, with upper-level divergence to the east of the low occurring at higher levels resulting in strong uplift through the 500 hPa level and the occurrence of copious rains. Easterly waves and lows occur almost exclusively during summer months, and are largely responsible for the summer rainfall pattern and the northerly wind component which occurs over the interior.

Westerly waves are characterised by concomitant surface convergence and upper-level divergence which produce sustained uplift, cloud and the potential for precipitation to the rear of the trough. Cold fronts are associated with westerly waves and occur predominantly during winter when the amplitude of such disturbances is greatest. Low-level convergence in the southerly airflow occurs to the rear of the front producing favourable conditions for convection. Airflow ahead of the front has a distinct northerly component, and stable and generally cloud-free conditions prevail as a result of subsidence and low-level divergence. The passage of a cold front is therefore characterised by distinctive cloud bands and pronounced variations in wind direction, wind speeds, temperature, humidity, and surface pressure. Following the passage of the cold front the northerly wind is replaced by winds with a distinct southerly component. Temperature decrease immediately after the passage of the front, with minimum temperatures being experienced on the first morning after the cloud associated with the front clears. Strong radiational cooling due to the absence of cloud cover, and the advection of cold southerly air combining to produce the lowest temperatures.

B.2 Regional Atmospheric Dispersion Potential

The impact of various synoptic systems and weather disturbances on the dispersion potential of the atmosphere largely depends on the effect of such systems on the height and persistence of elevated inversions. Elevated inversions suppress the diffusion and vertical dispersion of pollutants by reducing the height to which such pollutants are able to mix, and consequently result in the concentration of pollutants below their bases. Such inversions therefore play an important role in controlling the long-range transport, and recirculation of pollution.

Subsidence inversions, which represent the predominant type of elevated inversion occurring over South Africa, result from the large-scale anticyclonic activity which dominates the synoptic circulation of the subcontinent. Subsiding air warms adiabatically to temperatures in excess of those in the mixed boundary layer. The interface between the subsiding air and the mixed boundary layer is thus characterised by a marked elevated inversion. Protracted periods of anticyclonic weather, such as characterize the plateau during winter, result in subsidence inversions which are persistent in time, and continuous over considerable distances. The fairly constant afternoon mixing depths, with little diurnal variation, associated with the persistence of subsidence inversions, are believed to greatly reduce the dispersion potential of the atmosphere over the plateau, resulting in the accumulation of pollutants over the region.

Multiple elevated inversions occur in the middle to upper troposphere as a result of large-scale anticyclonic subsidence. The mean annual height and depth of such absolutely stable layers are illustrated in Figure A-2. Three distinct elevated inversions, situated at altitudes of approximately 700 hPa (~3 km), 500 hPa (~5 km) and 300 hPa (~7 km), were identified over southern Africa. The height and persistence of such elevated inversions vary with latitudinal and longitudinal position. During winter months the first elevated inversion is located at an altitude of around 3 km over the plateau. In summer this inversion is known to increase in to 4 to 5 km over the plateau (Diab, 1975; Cosijn, 1996).

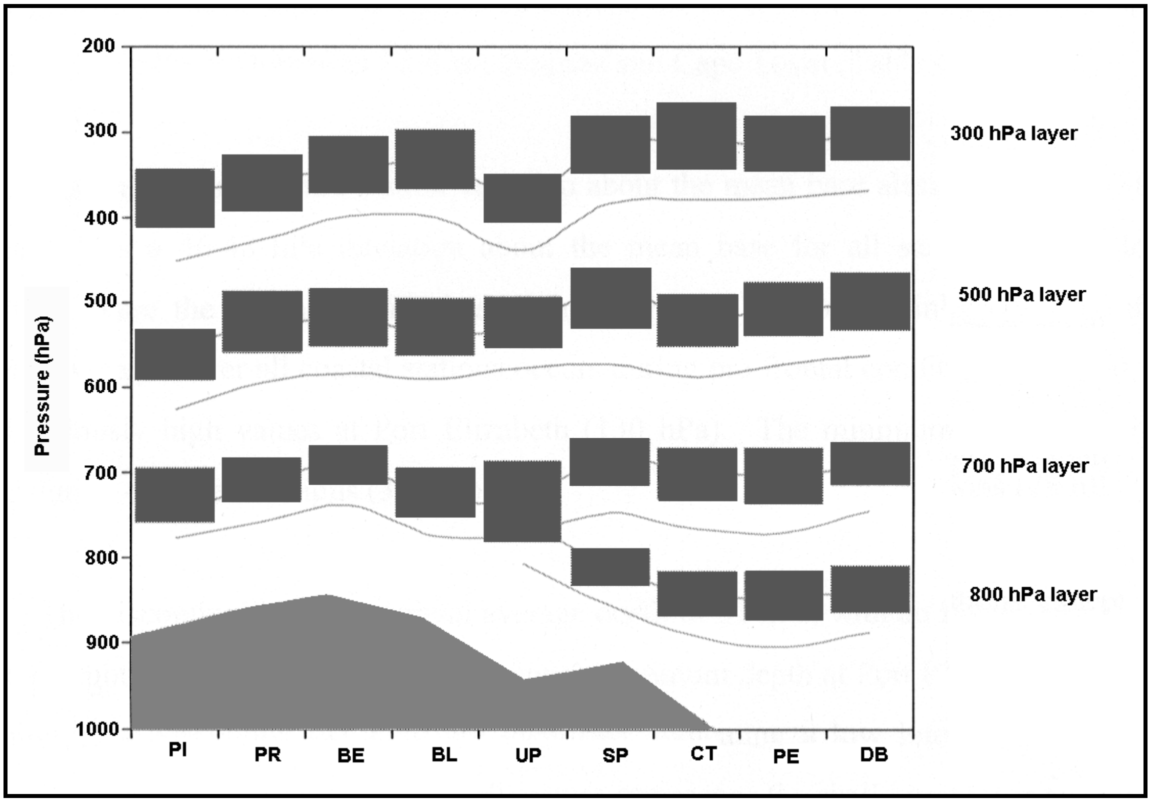

Figure B-2: Mean annual stable layers (shaded) over Pietersburg (PI), Pretoria (PR), Bethlehem (BE), Bloemfontein (BL), Upington (UP), Springbok (SP), Cape Town (CT), Port Elizabeth (PE) and Durban DB). Upper and lower 95% confidence limits for the base heights of the layers are shown in each case (after Cosijn, 1996).

In contrast to anticyclonic circulation, convective activity associated with westerly and easterly wave disturbances hinders the formation of inversions. Cyclonic disturbances, which are associated with strong winds and upward vertical air motion, either destroy, weaken, or increase the altitude of, elevated inversions. Although cyclonic disturbances are generally associated with the dissipation of inversions, pre-frontal conditions tend to lower the base of the elevated inversion, so reducing the mixing depth. Pre-frontal conditions are also characterised by relatively calm winds. Over the interior due to the passage of a cold front, there is a tendency for the lowest mixing depths to coincide with the coldest air temperatures and rising pressure. Following the passage of the front, a gradual rise in the mixing depth occurs over the interior (Cosijn, 1996; Preston-Whyte and Tyson, 1988).

APPENDIX C:
TECHNICAL DESCRIPTION OF EMISSIONS QUANTIFICATION

C.1: Fugitive Dust Emissions from Materials Handling Operations

The following predictive equation was used to estimate emissions from anticipated material tipping operations:

$$E_{TSP} = 0.0016 \frac{(U/2.2)^{1.3}}{(M/2)^{1.4}} \quad (1)$$

where,

E_{TSP}	=	Total Suspended Particulate emission factor (kg dust / t transferred)
U	=	mean wind speed (m/s)
M	=	material moisture content (%)
k	=	particle size multiplier (dimensionless)

The particle size multiplier varies with aerodynamic particle sizes and is given as a fraction of TSP. For PM30 the fraction is 74%, with 35% of TSP given to be equal to PM10, and the PM2.5 fraction is 11% of TSP (EPA, 1998a). Hourly emission factors, varying according to the prevailing wind speed, were used as input in the dispersion simulations. Moisture content for the different types of material were not available and use was made of the typical moisture contents given by US-EPA in the section pertaining aggregate handling and storage piles (EPA, 1998a).

Hourly emission rates, varying according to the prevailing wind speed, were used as input in the dispersion simulations.

C.2: Vehicle –Entrained Emissions from Unpaved Roads

The force of the wheels of vehicles travelling on unpaved roadways causes pulverisation of surface material. Particles are lifted and dropped from the rotating wheels, and the road surface is exposed to strong air currents in turbulent shear with the surface. The turbulent wake behind the vehicle continues to affect the road surface once the vehicle has passed. The quantity of dust emissions from unpaved roads varies linearly with the volume of traffic. In addition to traffic volumes, emissions also depend on a number of parameters which characterise the condition of a particular road and the associated vehicle traffic, including average vehicle speed, mean vehicle weight, average number of wheels per vehicle, road surface texture, and road surface moisture (EPA, 1998b).

The unpaved road size-specific emission factor equation of the US-EPA was revised in their 1998 AP42 document on Unpaved Roads and was used in the quantification of emissions for the current study. It is given as follows:

$$E = k(\frac{s}{12})^a (\frac{W}{3})^b \qquad \textbf{(2)}$$

where,

E = emissions in kg of particulates per vehicle kilometre travelled (lb/VMT)

K,a,b and c = empirical constants (Table C-1)

s = surface material silt content (%)

W = mean vehicle weight (tons)

C.3 Wind Erosion from Exposed Areas

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

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

where,

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

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

and,

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

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

The logarithmic wind speed profile may be used to estimate friction velocities from wind speed data recorded at a reference anemometer height of 10 m (EPA, 1996):

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

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

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

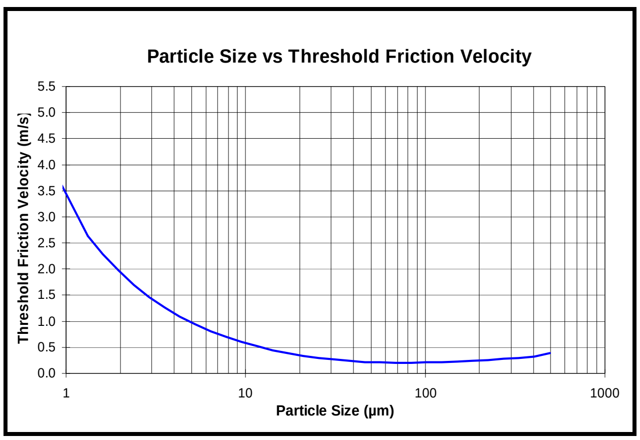

Figure C.1: Relationship between particle sizes and threshold friction velocities using the calculation methods proposed by Marticorena and Bergametti (1995)

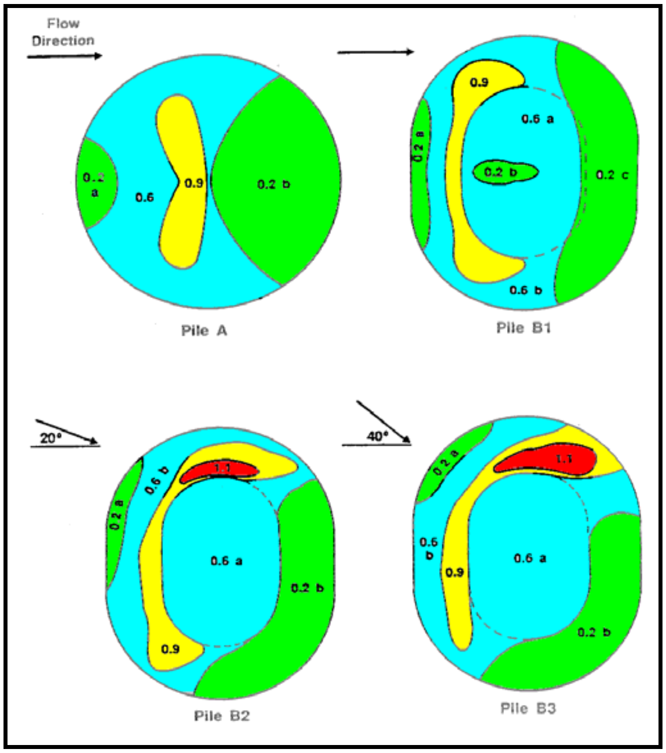

Figure C.2: Contours of normalised surface wind speeds (i.e. surface wind speed / approach wind speed (After EPA, 1996)

C.4 Crushing and Screening

Fugitive dust emissions due to the crushing and screening operations of the proposed 2011 construction and 2016 operational phase of the proposed Belfast project were quantified using US-EPA single valued emission factors for such operations (Table B-1).

Table C-1: US-EPA emission factors for crushing

Source	Emission Factor (kg/ton material processed)			
	Low Moisture Material[(a)]		High Moisture Material [(b)]	
	PM10	TSP	PM10	TSP
Primary crushing	0.02	0.2 **(7)**	0.004	0.01 **(9)**
Secondary crushing	0.04	0.6 **(8)**	0.012	0.03 **(10)**

C.5: Drilling

Australian NPI emission factors for drilling operations

$$E_{TSP} = 0.59 \text{ kg TSP/hole drilled} \quad \textbf{(11)}$$

$$E_{PM10} = 0.31 \text{ kg PM10/hole drilled} \quad \textbf{(12)}$$

C.6: Blasting

Fugitive dust emissions due to blasting were quantified using the NPI predictive emission factor for mining:

$$E_{TSP} = 344\left(\frac{A^{0.8}}{M^{1.9} \times D^{1.8}}\right) \quad \textbf{(13)}$$

This equation takes into account other variables that are likely to be important in the generation of dust. Thus the equation was used to calculate emissions for the study. The PM10 fraction constitutes 52% of the TSP for blasting (US-EPA, 1998).

Where,
M is the moisture content of the material
D is the depth of the hole
A is the blasting area

C.7 Excavating

The excavation equation used in the study is shown below

$$EF = k * 0.0056 * M^{-0.9} \quad \textbf{(14)}$$

Where,

k=1.56 for TSP
k=0.75 for PM10

C.8 Scraping

The US-EPA TSP emission factor for scraping is shown below

$$E = 7.6 * 10^{-6}\ s^{1.3} W^{2.4} \text{ kg/VKT} \quad \textbf{(15)}$$

The US-EPA PM10emission factor for scraping is shown below

$$E = 1.32 * 10^{-6}\ s^{1.4} W^{2.5} \text{ kg/VKT} \quad \textbf{(16)}$$

Where,

s = silt content (%)
W = vehicle gross mass (t)
VKT = Vehicle Kilometres Travelled

APPENDIX D:

CHECKLIST FOR DUST CONTROL (AFTER ENVIRONMENT AUSTRALIA, 1998).

Table D-1: Checklist for Dust Control (After Environment Australia, 1998)

ISSUE	OUTPUTS	PERFORMANCE MEASURES	IMPROVEMENT
Information and Planning			
HAVE YOU, determined the sources of dust in the operations?	Potential sources of dust identified in the EIA	Comprehensive list of individual sources	Sources considered for each stage of the mine (i.e. exploration, construction, operation, decommissioning, rehabilitation and closure)
HAVE YOU attempted to characterise the types of dust and quantities produced (modelling)?	Estimates of dust types and levels to be produced Dust emission inventory and determination of dust emission factors	Estimates based on typical measured levels for a mining plant. Dust inventory is derived by analysing the mine plan to establish potential dust sources and estimate the level of dust-producing activity associated with each source. Emission factors are derived by assessing the quantifiable activities or aspects which generate dust, such as vehicle size, speed and distance travelled on haul roads.	Estimates, inventory and emission factors made for all potential sources for each stage of the mine (emission factors are only applicable when emissions are to be modelled).
DOES YOUR characterisation of the types and quantities of dust include diffuse dust sources?	All types and locations of dust emissions can be ranked and controls planned in a systematic manner	Quantitative estimates of dust emission rates from different classes of mining activity and land surface types	Use of models to produce estimates of dust types and levels across a wide range of operating and climatic conditions
HAVE YOU undertaken an impact assessment?	Identification of sensitive receptor areas Assessment of maximum levels to avoid impacts, significant concerns or discomfort	Assessment identifies dust levels likely to be experienced by workers and at key locations.	The potential health risk from dust is related to the size of dust particles. Mine dust lies in the range of 1-100 µ
HAVE YOU developed a draft management strategy, based on the impact assessment?	Incorporates input from the community and the regulatory authorities Addresses all environmental and social issues likely to arise from dust at the proposed project	Initial planning should include development of a draft management strategy which: • Identifies all the potential sources and risks • Sets out objectives for environmental protection and risk minimisation • Provides a framework for evaluating different options and choosing a design which reflects site conditions and environmental sensitivities	Consultation with key stakeholders during preparations of the draft management strategy
HAVE YOU devised approaches to mitigate impacts to acceptable levels?	Strategy incorporates “built in” design features to minimise the generation of dust at source	Strategy includes addressing the mitigation of dust	The EIA and mine plan for the project set out in a framework based upon: Mine design to avoid the generation of dust Systems design and management to minimise the generation of dust during operations Treatment of dust problems through active monitoring and response, and redesign of strategies if required.
Information and Planning Continued			
HAVE YOU considered the probable regulatory requirements?	Level to which targets in the strategy conform to standards and regulations taking into account estimates of inputs from all probable sources of dust.	Dust strategy describes relevant standards and regulations	
ARE THE target levels developed in consultation with the community?	Documented agreement on maximum permissible levels between company and key community group/s	Maximum dust levels explained and agreed with the community	Establishment of formal and frequent consultation with the local community early in the planning process.
DO THE provisions of the dust	Smooth transition from operational to decommissioning stages,	Decommissioning, rehabilitation and closure plans for all	Plans incorporate provisions which must reflect the

ISSUE	OUTPUTS	PERFORMANCE MEASURES	IMPROVEMENT
management plan also apply to the decommissioning, rehabilitation, and closure stages?	with low risk of exceedance of dust control targets.	include provisions for control of dust.	specific activities involved at the end of mining.
Management and Operation			
HAVE YOU prepared an operational dust management plan?	Dust management plan	The management plan: • sets out targets and management strategies for all issues identified in the impact assessment and in community consultations • must be integrated with other operational plans into an overall environmental management system	ISO 14001 accreditation may help to demonstrate the environmental commitment to regulators and other stakeholders.
IS the management plan known and understood by all staff including plant operators?	Staff awareness of the management plan and its contents	Relevant documentation must be available to staff, regulators and auditors.	Management plan available to staff, staff instructions on the control of dust, regular checks on effectiveness of operational systems, dust included in environmental awareness training seasons.
HAVE YOU selected appropriate options to minimise the generation of dust?	Few significant issues related to dust at site	Evidence of good design to reduce dust generation through mine design, choice of equipment, and work practices Consistent application of good design across all types of dust sources, including road transport outside the mining area.	The use of computer modelling to investigate the control measures needed to achieve targets.
HAVE YOU incorporated design features to mitigate the potential impacts from the dust generated at site?	Few significant issues related to dust at the site	Evidence of installation of engineering works, equipment modification etc to minimise dust Any significant dust sources identified via monitoring have been objectively evaluated and remedial action taken.	All reasonable measures taken to reduce from all fixed and mobile equipment
DO YOU have operational systems to control dust in all areas with dust potential?	Procedures described in the mine plan and EIA implemented correctly, and dust control targets achieved.	The EIA and related manuals will set out procedures for dust management in all relevant areas of the site	Documented procedures need to cover all mining activities.
Management and Operation Continued			
IS THERE documentation to demonstrate that the dust management plan is carried out properly?	Assurance to managers that dust control targets for the operation are being met.	Regular reports (monthly) of dust management activities and assessment against control targets and requirements of the management plan.	Standard operating procedures for staff working in dusty areas, operating dusty equipment, and involved in drilling and blasting activity, setting out responsibilities, and methods for limiting and reporting dust levels and incidents.
DO YOU have a system in place to incorporate improvement?	Continual improvement and reduced probability of recurrence of undesirable dust events	Evidence of review and update of systems and equipment where unsatisfactory dust levels have been recorded.	Assessment of the adequacy of dust control should be incorporated in annual environmental audits of the project.
Monitoring and Assessment			
IS THERE a monitoring regime in place which addresses all of the possible areas for environmental and social impact from dust identified at the planning stage?	The level of performance of dust control and potential impacts on workers, the public and environment is well known to managers	Comprehensive monitoring regime which includes measurement of levels in worker areas and areas of the community sensitivity. Monitoring regime sets out: • Parameters to be monitored • Monitoring locations • Monitoring interval	Reporting and record keeping includes: Recording intervals Location of attended and unattended monitoring instruments Comparison of monitoring results with those from modelling (if applicable)

ISSUE	OUTPUTS	PERFORMANCE MEASURES	IMPROVEMENT
		• Data and data analysis requirements for monitoring reports • Reporting interval	
ARE environmental and community targets set, and are the layout, techniques, frequency, quality and sensitivity of monitoring and sampling appropriate to these targets?	Low probability of community concern provided dust is controlled to within levels agreed by the community.	Control targets agreed with the community are set out in the management plan and monitoring regime and are used as key benchmarks to evaluate adequacy of performance in regular monitoring reports.	Tools for effective dust monitoring include: Baseline sampling Control site sampling Dust deposition gauges (provides long term data) High volume samplers (quantitative data over 24hr periods) Continuous particle monitors (provides data relevant to sort term events) Size-selective samplers (samples dust in size fractions) Personal exposure samplers (worn by workers)
IS monitoring undertaken in accordance with appropriate standards?	High level of assurance or the reliability of dust monitoring results	Evidence that monitoring techniques accord with appropriate standards	Measures outlined in the South African National Standards, SANS 1929:2004 are recommended.
	Monitoring and Assessment Continued		
DOES monitoring include meteorological data?	Proactive management of site activities can be undertaken to avoid significant dust events in periods of bad weather.	Routine collection of data on predicted rainfall, temperature and wind velocity	The erection of a site specific meteorological is highly recommended.
ARE data collected in accordance with the requirements of the monitoring regime?	Low risk of regulatory non-compliance or of community concerns regarding dust.	Monthly and annual reports of dust data, which cross refer to monitoring requirements	
ARE the data analysed and regularly reported to the regulatory authorities?	Assurance that all regulatory requirements for dust are being met continuously	Regular reports (i.e., monthly) provided, where deemed necessary.	Dust control performance is reported against community-agreed targets in public reports.
ARE non-compliance issues or abnormalities in the data routinely recorded?	Management aware of any areas of poor performance Management provides an ongoing measure of effectiveness of the current system and past improvements	Register of non-compliance and unplanned events, indicates time of event, time of action, type of action, result and interaction with authorities.	Regulatory authority advised immediately of all non-compliance and sign cant unplanned events.
IS THERE a system in place for significant dust events or issues to be addressed to reduce prospects of recurrence?	Reduced risk of recurrence of significant dust events	Evidence that entries in the register of non-compliance and unplanned events are investigated properly and appropriate remedial action is identified and implemented promptly.	Standard deadline set for completion of actions to remedy dust events. Number of entries in the register and speed of actioning improvements can be used as reporting criteria to staff, management, regulators, and the community.
IS liaison with the community maintained in relation to dust issues?	Good community relationships maintained	Documentation of regular community liaison that addresses issues of dust.	Community meetings / stakeholder forum held regularly with dust standing as an agenda item. Special meeting held immediately after a significant event raising community concern
IS a complaints register maintained and are complaints investigated?	Areas of poor dust control are addressed quickly so that the risk of recurrence is minimised Good community relationships must be maintained.	Documented complaints register which records details of complaints and any follow-up action.	Register records date, time, and type of event, which is the subject of the complaint; follow-up action, risk of recurrence. Reporting back to the complainant