Project done on behalf of

Metago Engineering Services (Pty) Ltd

AIR QUALITY IMPACT ASSESSMENT FOR THE PROPOSED NTSIMBINTLE MANGANESE MINING OPERATIONS

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REPORT DETAILS

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Client	Metago Engineering Services (Pty) Ltd
Prepared by	Nicolette Krause, BEng (University of Pretoria)
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Acknowledgements	The authors would like to express their appreciation to Jeff Leader from for his invaluable discussions and technical inputs to the project as well as Mamatwan mine for making their baseline impact information available for the assessment of potential cumulative air quality impacts.

GLOSSARY

AEL	Atmospheric Emission License
APPA	Air Pollution Prevention Act
AQA	Air Quality Act
BPM	Best Practicable Means
California OEHHA	California Office of Environmental Health Hazard Assessment
California ARB	California Air Resources Board
CAPCO	Chief Air Pollution Control Officer
CO	Carbon Monoxide
DE	Diesel Engine Emissions
DEAT	Department of Environmental Affairs and Tourism
DPM	Diesel Particulate Matter
EC	European Community
EMPR	Environmental Management Plan Report
ESL	Effects Screening Level
g	gram
h	hour
HMM	Hotazel Manganese Mines
L	liter
m	meter
Mn	Manganese
NEMA	National Environmental Management Act
NO	Nitrogen Oxide
NO_2	Nitrogen Dioxide
NO_x	Oxides of Nitrogen
NPI	National Pollutant Inventory
PM10	Particulate Matter with an aerodynamic diameter of less tan 10 µm
RfC	Inhalation Reference Concentrations
SABS	South African Bureau of Standards
SANS	South African National Standards
SAWS	South African Weather Service

SO_2	Sulphur Dioxide
TARA	Toxicology and Risk Assessment Division of the Texas Natural Resource Conservation Commissions
tpa	tons per annum
TSP	Total Suspended Particulate
US ATSDR	United States Federal Agency for Toxic Substances and Disease Registry
US EPA	United States Environmental Protection Agency
US EPA IRIS	United States Integrated Risk Information System
WHO	World Health Organization

EXECUTIVE SUMMARY

Introduction

Ntsimbintle Mining (Pty) Ltd (Ntsimbintle) proposes the development of a new manganese mining operation in the Kgalagadi District Municipality of the Northern Cape Province. The project will include opencast mining and a processing plant as well as various support infrastructure and services. Underground mining, a sinter plant and a power generation plant are also being considered.

Airshed Planning Professionals (Pty) Ltd was appointed by Metago Engineering Services (Pty) Ltd (Metago) to undertake an air quality impact assessment for the proposed Ntsimbintle manganese mining operations near Hotazel in the Northern Cape Province. The main objective of the study was to do an air dispersion impact assessment using project specific data to determine potential impacts on the surrounding environment and human health.

Methodology

The establishment of a comprehensive emission inventory formed the basis for the assessment of the impacts from of the proposed operation's emissions on the receiving environment. The establishment of an emissions inventory comprises the identification of sources of emission, and the quantification of each source's contribution to ambient air pollution concentrations.

Fugitive dust emissions occur as a result of vehicle-entrained dust from paved and unpaved roads, wind erosion from open areas, material handling operations, drilling and blasting as well as crushing and screening operations. In the quantification of fugitive dust emissions use was made of emission factors which associate the quantity of a pollutant to the activity associated with the release of that pollutant. Due to the absence of locally generated emission factors, reference was made to emission factors such as those published by the US Environmental Protection Agency (US-EPA) in its AP-42 document and the Australian National Pollutant Inventory (NPI). The US-EPA AP-42 emission factors are of the most widely used in the field of air pollution. Point source emissions were estimated based on emission limits and design specifications.

In the estimation of emissions and the simulation of patterns of dispersion, a distinction was made between Total Suspended Particulates (TSP) and inhalable particulates (PM10, particulate matter with an aerodynamic diameter of less than 10 µm). Whereas TSP is of interest due to its implications in terms of nuisance dust impacts, the PM10 fraction is taken into account to determine the potential for human health risks. Inhalable manganese emissions (Mn emissions of the PM10 size fraction), SO_2, NO_2, DPM and CO emissions were taken into account due to it's implications in terms of human health risks.

Emissions were quantified for the following phases:

- Construction phase
- Operational Phase, Scenario 1: Included opencast and underground mining as well as ore processing, beneficiation (sintering) and power generation
- Operational Phase, Scenario 2: Included underground mining and the rehabilitation of the opencast mining area as well as ore processing, beneficiation and power generation

Completely **unmitigated** as well as partially **mitigated** fugitive dust emissions were determined and assessed in terms of predicted impacts. The mitigation measures that were applied in the mitigated case were as follows:

- Water in combination with chemical dust suppressants on unpaved road surfaces - 90% reduction in PM10, TSP and Mn emissions as a result of vehicle entrainment from unpaved roads
- Sweeper on paved road surfaces - 90% reduction in PM10, TSP and Mn emissions as a result of vehicle entrainment from paved roads
- Water sprays – 70% and 50% reduction in PM10, TSP and Mn emissions from truck offloading and conveyor transfer points respectively
- Hooding with fabric filters at crushing and screening plants – 83% reduction in PM10, TSP and Mn emissions
- Drill fitted with cyclone – 25% reduction in PM10, TSP and Mn emissions from in-pit drilling

Incremental and cumulative air quality impacts were determined. **Incremental** concentrations and impacts refer to impacts associated with proposed operations at Ntsimbintle in isolation. **Cumulative** concentrations and impact refer to impacts associated with proposed operations at Ntsimbintle in addition to impacts associated with current operations at Mamatwan manganese mine. Due to uncertainty in the exact timeframes associated with operations at UMK, potential impacts from this mine was not included in the cumulative air quality impact assessment.

In characterising the dispersion potential of the site reference was made to hourly average meteorological data recorded the South African Weather Service (SAWS) station at Kuruman for the period January to December 2004.

PM10, Mn, SO_2, NO_2, CO and DPM concentrations and dustfall rates were simulated for the proposed operations. The simulation of ambient air pollutant concentrations and dust deposition were undertaken through the application of the US-EPA AERMOD (version 5). The USA-EPA (EPA, 1986) considers the range of uncertainty of this model to be -50% to 200%. Ground level concentrations and dustfall levels were calculated at grid intervals of 357 m over a 20 x 20km study area and at the discreet receptors shown in Figure 1.

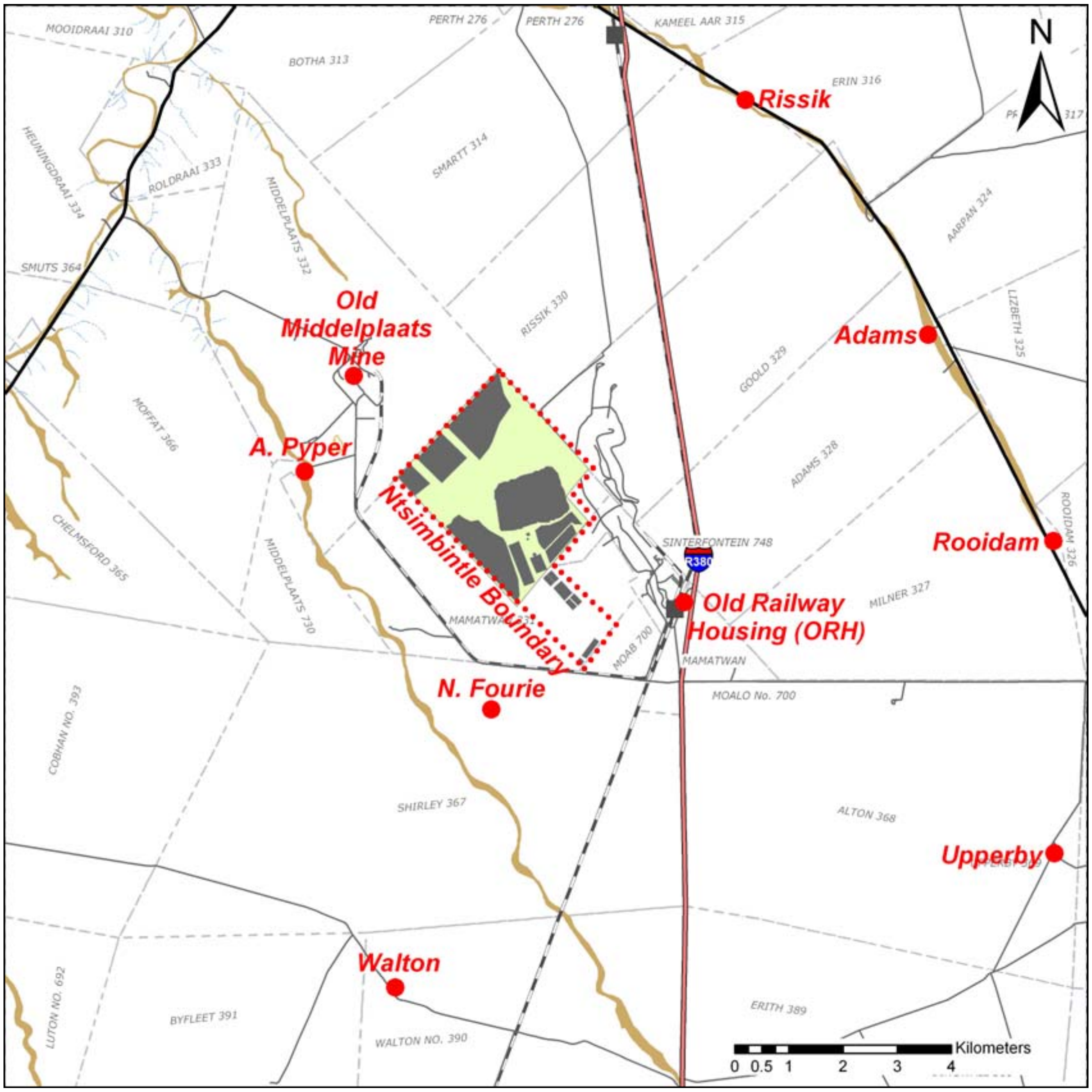

Figure 1: Discreet receptors included in the dispersion modelling

Assumptions and Limitations

Due to data limitations some assumptions had to be made during the assessment. These were:

- No onsite meteorological data was available for use in the current study and use was therefore made of the SAWS Kuruman meteorological station that is situated ~50 km to the east of the site.

- The dispersion model cannot compute real-time mining and production processes; average throughputs were therefore used. Operational locations and periods were selected to reflect the worst case scenarios.

- Diesel engines emit benzene and 1,3-butadiene which have both been classified as carcinogens. Standards for carcinogens are not set using the same methodology as for non-carcinogens, as they have no lower threshold for adverse effects. However, using an appropriate acceptable risk level, annual average concentration standards may be derived. In South Africa, the proposed SANS standard for benzene is 5 µg/m³ (annual average). Using the relative toxicity of 1,3 butadiene to benzene (as indicated by the relative US EPA unit risk factors) the standard for 1,3 butadiene on the same basis would be 1.3 µg/m³. However, the rate of emissions of the benzene and 1,3 butadiene is approximately 1% of the emission rate of particulates (California ARB 2002). Screening for diesel particulate as an indicator of transport-related emissions therefore provides a conservative screening value for the carcinogens mentioned above.

- Nitrogen oxide (NO) is rapidly converted in the atmosphere into the much more toxic nitrogen dioxide (NO_2). The rate of this conversion process is determined by both the rate of the physical processes of dispersion and mixing of the plume and the chemical reaction rates. It appeared from model calculations (Janssen 1988) in comparison to actual measurements that at larger distances from the source, chemical equilibrium is not measured in the plume because the momentary plume is inhomogeneously mixed and consists of parcels of flue gas and parcels of ambient air. The general conclusion may therefore be drawn that the oxidation rate of NO at smaller distances from the source is determined by the chemical reaction rates, whereas the oxidation rate at greater distances from the source (> 5 km) is determined by the mixing rate of the plume with its ambient air. Observed NO_2/NO_x for varying travel times have been reported by Janssen (1988). The daytime range was from about 18% to 80%, with an average of about 50%. The night-time range was about 4% to 40%. Based on these observations NO_2/NO_x ratios had to be assumed for hourly and annual average NO_2 concentrations.

Conclusions

In order to determine worst case conditions with respect to estimated emissions and predicted impacts four phases in the life of the Ntsimbintle project were considered:

- **Construction phase**: Due to uncertainty as to the exact construction schedule and activities as well as the fact that in general the construction phase is often of short duration, emissions were quantified but not applied in the dispersion modelling.
- **Operational phases**:
  - Scenario 1: Included opencast and underground mining, processing, the beneficiation of manganese ore and power generation. The emissions from this scenario were quantified and impacts determined through dispersion modelling.
  - Scenario 2: Included underground mining, the rehabilitation of the open cast mining area, processing, the beneficiation of manganese ore and power generation. The emissions from this scenario were quantified and impacts determined through dispersion modelling.
- **Closure phase:** It was assumed that all processing operations will have ceased by the closure phase of the project. The potential for impacts during this phase will depend on the extent of demolition and rehabilitation efforts during closure and on features which will remain. Information regarding the extent of demolition and/or rehabilitation procedures were limited and therefore not included in the emissions inventory or the dispersion modelling.

From the air quality impact assessment it was evident that Scenario 1 (opencast and underground mining, processing and beneficiation) would constitute the worst case scenario for the Ntsimbintle project. Consequently all conclusions and recommendations were based on this scenario.

The main findings of the study, based on worst case emissions and predicted impacts were as follows:

<u>Estimated emissions:</u>

- **PM10** emissions:
  - Total **unmitigated PM10** emissions were estimated at 4 520 tpa of which 92% were as a result of vehicle entrainment of dust from unpaved haul roads.

  - The total **mitigated PM10** emissions were estimated at 688 tpa. Vehicle entrainment and emissions from the sinter plant contributed 80% and 32% to the total, respectively.

- **TSP** emissions:

  - Total **unmitigated TSP** emissions amounted to 15 100 tpa of which 96% were as a result of vehicle entrainment of dust from unpaved haul roads.

  - **Mitigated TSP** emissions amounted to 1 790 tpa. Vehicle entrained dust from unpaved haul roads were estimated to be the most significant contributor to mitigated TSP emissions, contributing approximately 82%.

- **Manganese** emissions:

  - Total unmitigated Mn emissions amounted to 303 tpa. Vehicle entrainment was estimated to contribute most significantly, 64%, to the total followed by sinter plant emissions at 25%.

  - With **mitigation** measures in place the total **Mn** emissions were estimated to reduce to 104 tpa with the sinter plant emissions contributing 79% to the total.

- **SO_2** emissions: Total SO_2 emissions were estimated to be 1 290 tpa. Sinter plant emissions were estimated to contribute 98% to the total.

- **NO_x** emissions amounted to 2 820 tpa. Sinter plant emissions were estimated to contribute the most significantly (63%) to NO_x emissions followed by emissions from the power generation plant (31%).

- Estimated **DPM** as a result of vehicle tailpipe emissions amounted to 10.8 tpa.

- Estimated **CO** amounted to 173 tpa. The power generation plant and vehicle tailpipe emissions contributed 53% and 47% to estimated CO emissions respectively.

<u>Predicted Impacts:</u>

- **PM10** impacts:

  - The predicted annual average and highest daily average **incremental unmitigated** PM10 concentration at the Ntsimbintle boundary were 3650 and 7060 µg/m³ respectively. The proposed annual PM10 standard of 40µg/m³ was exceeded at the

Ntsimbintle boundary and the old Middelplaats mine. The proposed daily standard of 75µg/m³ was exceeded at the Ntsimbintle boundary, A. Pyper, the old Middelplaats mine and N. Fourie.

- **Cumulatively** the predicted annual average and highest daily average **unmitigated** PM10 concentrations at the Ntsimbintle boundary were 3650 and 7060 µg/m³ respectively. Exceedance of the proposed annual PM10 standard was predicted the Ntsimbintle boundary and the old Middelplaats mine. Exceedance of the proposed daily PM10 standard was predicted at the Ntsimbintle boundary, A. Pyper, the old railway housing, the old Middelplaats mine and N. Fourie.

- The predicted annual average and highest daily average **incremental mitigated** PM10 concentration at the Ntsimbintle boundary were 366 and 709 µg/m³ respectively. The proposed annual and daily PM10 standards were exceeded at the Ntsimbintle boundary.

- The predicted annual average and highest daily average **cumulative mitigated** PM10 concentration at the Ntsimbintle boundary were 370 and 709 µg/m³ respectively. The proposed annual and daily PM10 standards were exceeded at the Ntsimbintle boundary.

- Mitigation of fugitive dust sources resulted in an average reduction of 87% in predicted PM10 concentrations.

- Vehicle entrained dust from unpaved roads were predicted to result in the most significant unmitigated and mitigated PM10 concentrations contributing, on average, 88% and 67% respectively.

- A summary of predicted annual average and daily average concentrations at the off-site discreet receptors are presented in Figure 2 and Figure 3.

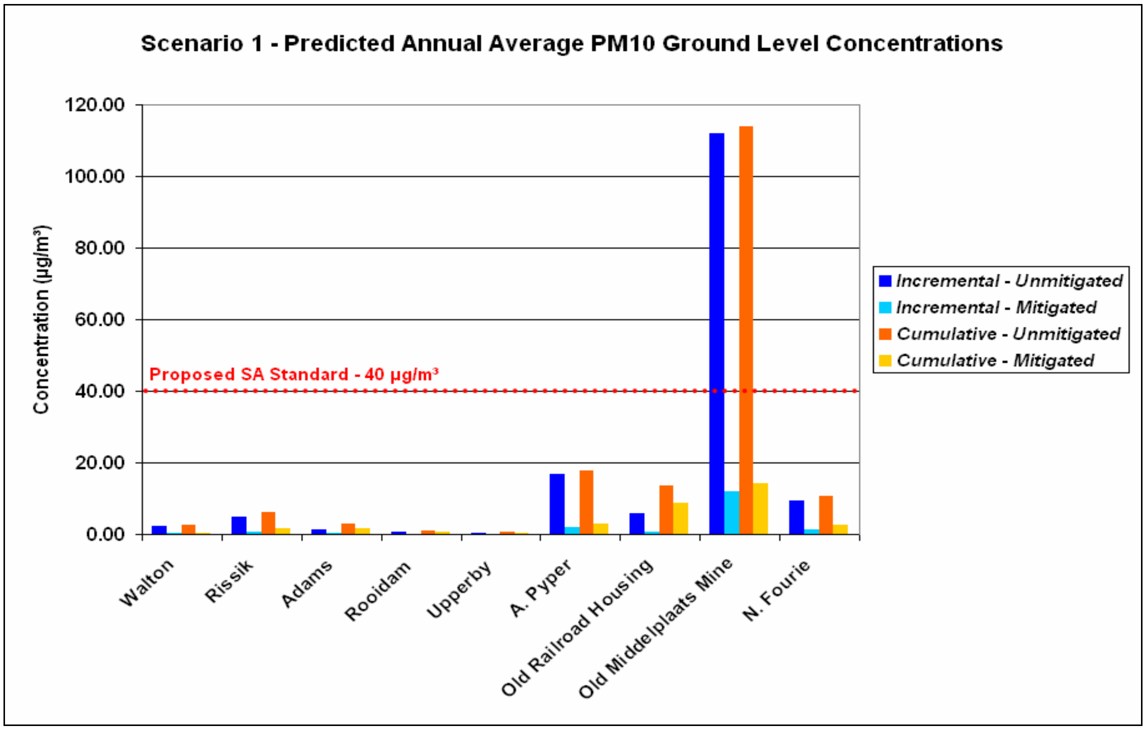

Figure 2: Summary of predicted off-site annual average PM10 concentrations

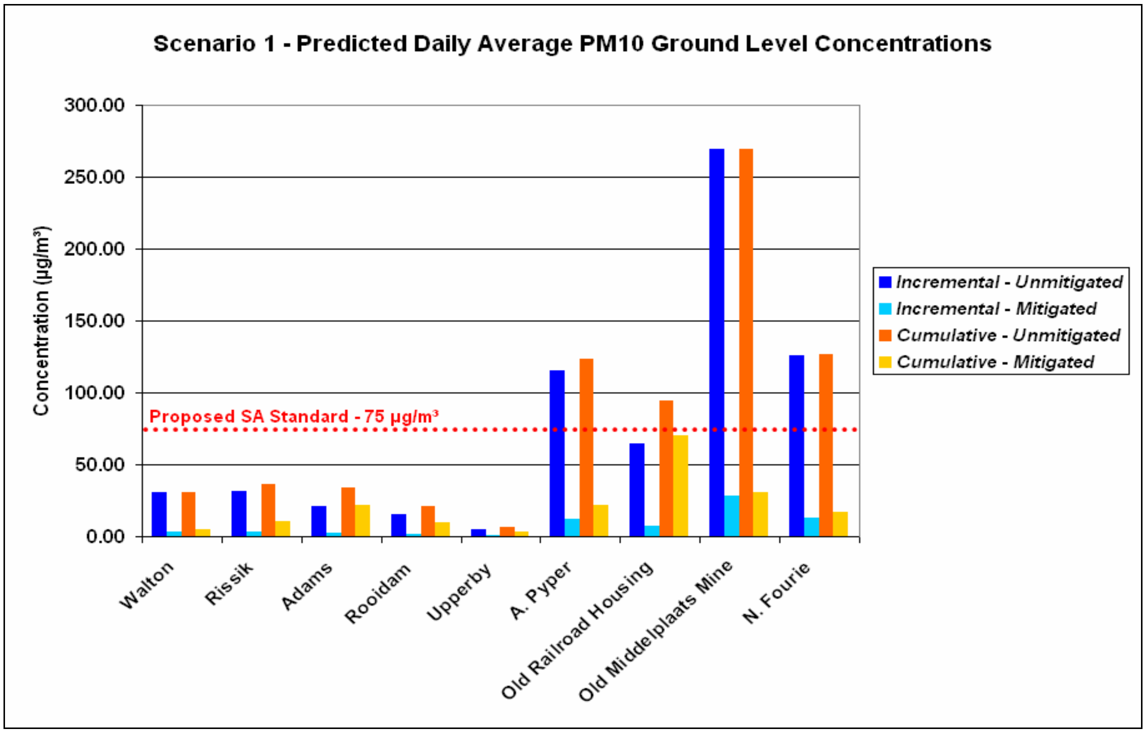

Figure 3: Summary of predicted off-site highest daily average PM10 concentrations

- **Manganese** impacts:
  - The predicted annual average **incremental unmitigated** Mn concentration at the Ntsimbintle boundary was 20.1µg/m³. The annual WHO guideline of 0.15µg/m³ was exceeded at the Ntsimbintle boundary, A. Pyper, the old railway housing, the old Middelplaats mine and N. Fourie.
  - **Cumulatively** the predicted annual average **unmitigated** Mn concentration at the Ntsimbintle boundary was 20.7µg/m³. Exceedance of the annual WHO guideline was predicted the Ntsimbintle boundary, Rissik, Adams, A. Pyper, the old railway housing, the old Middelplaats mine and N. Fourie.
  - The predicted annual average **incremental mitigated** Mn concentration at the Ntsimbintle boundary was 3.64µg/m³. The annual WHO guideline was exceeded at the Ntsimbintle boundary, the old Middelplaats mine and N. Fourie.
  - The predicted annual average **cumulative mitigated** Mn concentration at the Ntsimbintle boundary was 9.71µg/m³. The annual WHO guideline was exceeded at the Ntsimbintle boundary, Rissik, Adams, A. Pyper, the old railway housing, the old Middelplaats mine and N. Fourie.
  - Mitigation of fugitive dust sources resulted in an average reduction of 69% in predicted Mn concentrations.
  - Manganese dust as a result of crushing and screening operations contributed most significantly, 61%, to predicted unmitigated Mn concentrations. With mitigation measures in place emissions from the sinter plant contributed most significantly to predicted manganese concentrations.
  - A summary of predicted annual average Mn concentrations at the off-site discreet receptors are presented in Figure 4

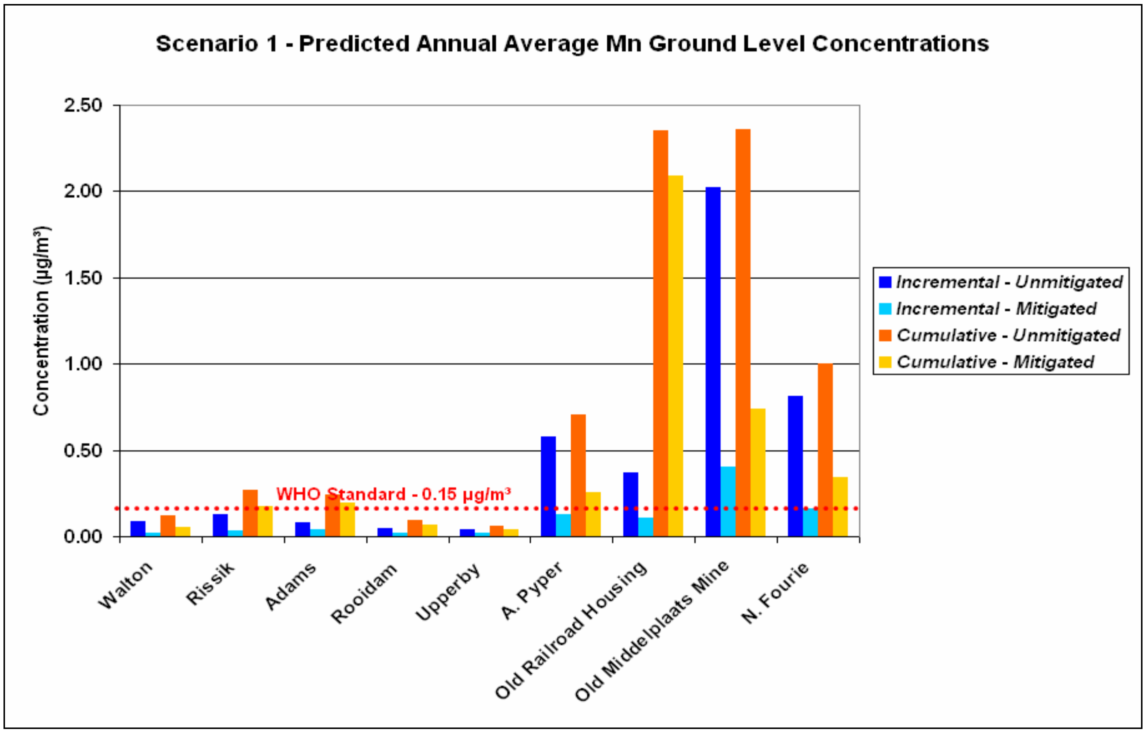

Figure 4: **Summary of predicted off-site annual average Mn concentrations**

- **SO_2** impacts:
  - The predicted annual, highest daily and highest hourly average **incremental** SO_2 concentration at the Ntsimbintle boundary was 8.44, 50 and 534 µg/m³ respectively. The proposed hourly SA SO_2 standard of 350µg/m³ was exceeded at the Ntsimbintle boundary.
  - The predicted annual, highest daily and highest hourly average **cumulative** SO_2 concentration at the Ntsimbintle boundary was 8.69, 50 and 534 µg/m³ respectively. Only the proposed SA hourly standard of 350µg/m³ for SO_2 was exceeded at the Ntsimbintle boundary.
  - Sinter plant emissions were estimated to be the most significant contributor, contributing on average 89%, to predicted incremental SO_2 concentrations.
  - A summary of predicted annual, highest daily and highest hourly average SO_2 concentrations at the off-site discreet receptors are presented in Figure 5, Figure 6 and Figure 7 respectively.

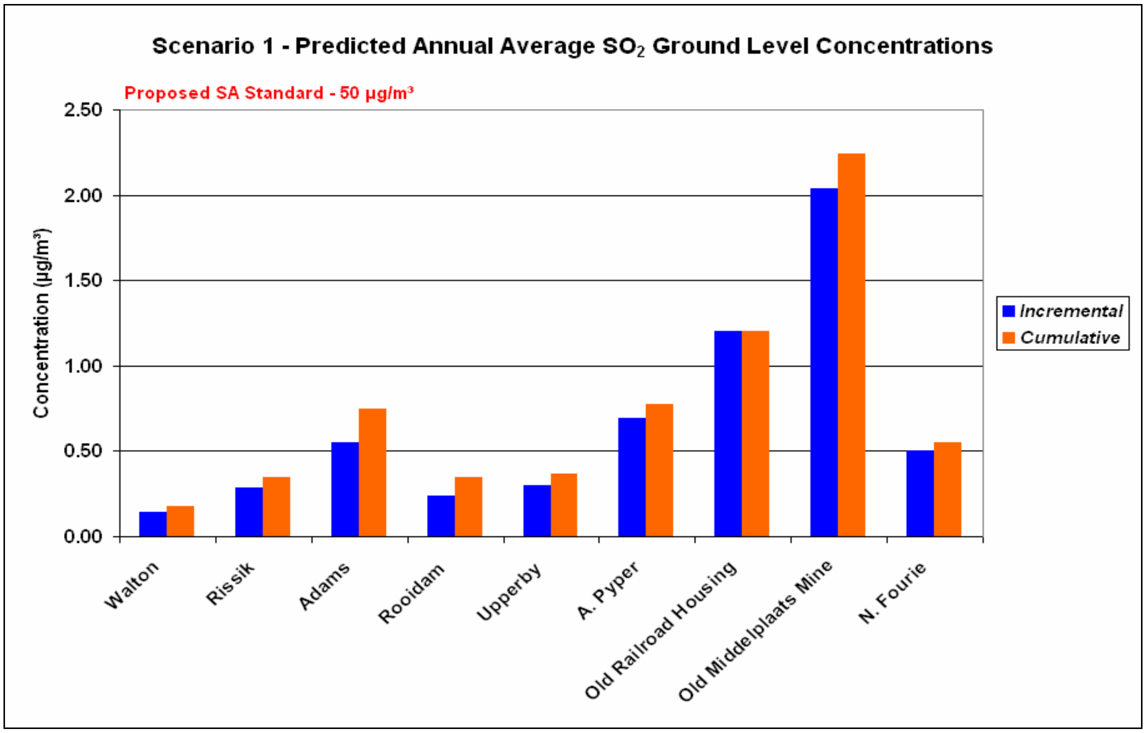

Figure 5: Summary of predicted off-site annual average SO2 concentrations

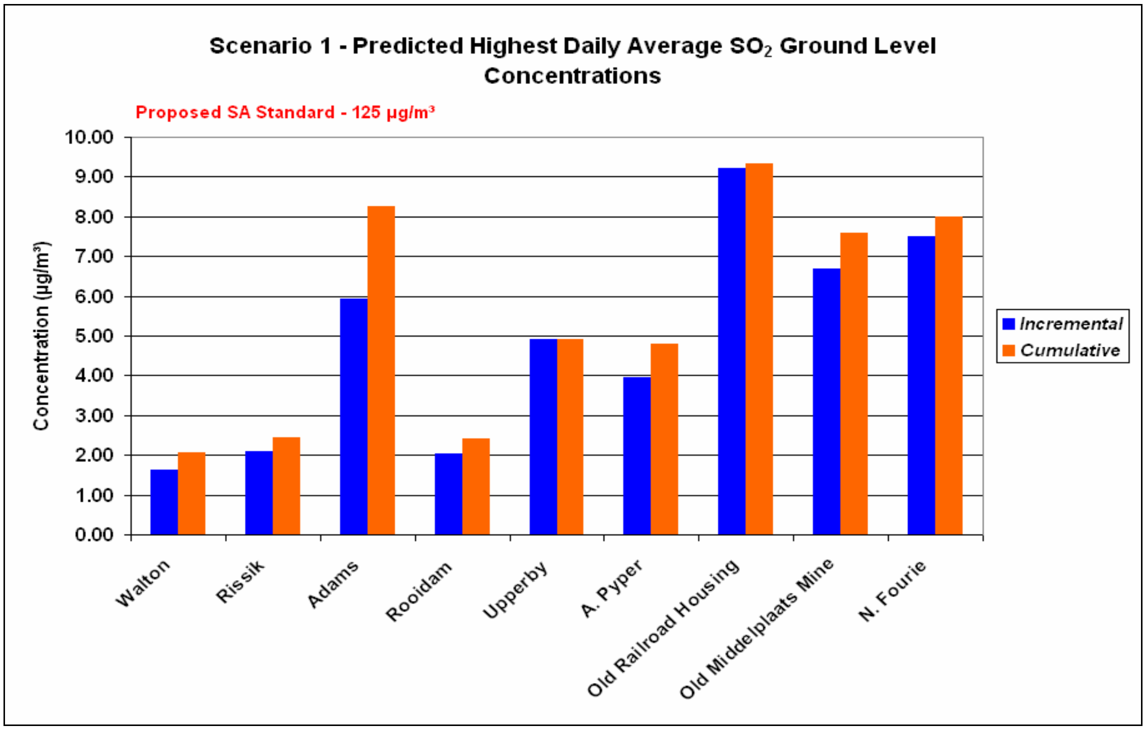

Figure 6: Summary of predicted off-site highest daily average SO2 concentrations

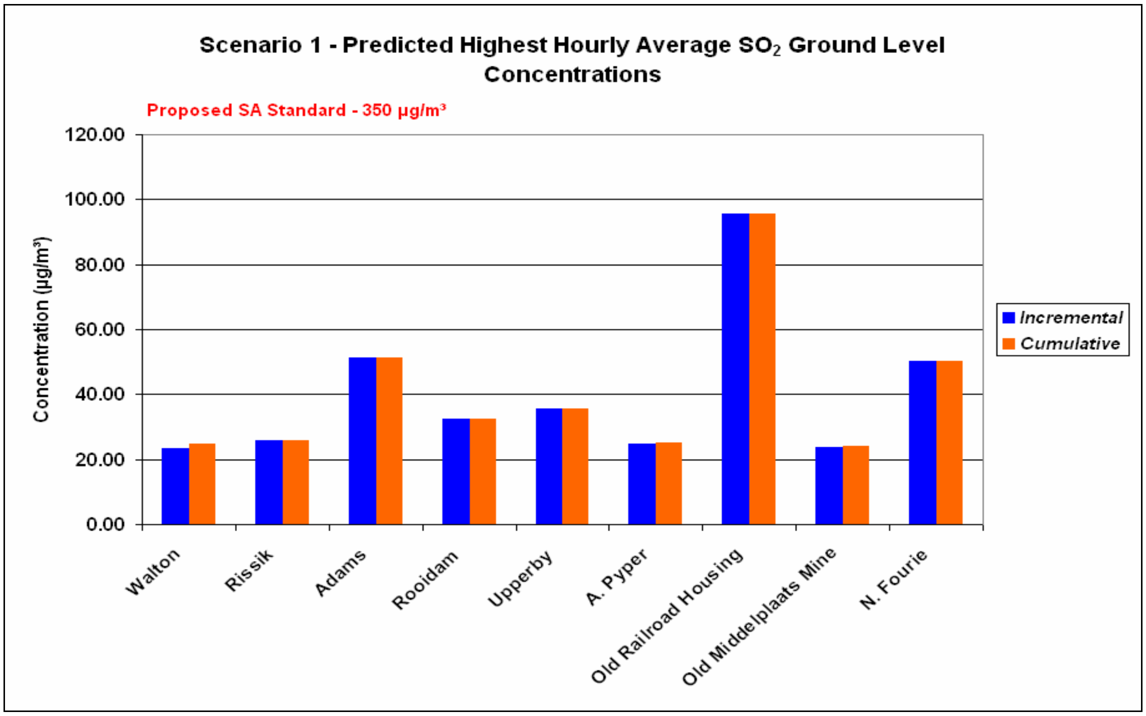

Figure 7: **Summary of predicted off-site highest hourly average SO2 concentrations**

- **NO_2** impacts:
  - The predicted annual and highest hourly average **incremental** NO_2 concentration at the Ntsimbintle boundary was 35.1 and 219 µg/m³ respectively. The proposed hourly SA NO_2 standard of 200µg/m³ was exceeded at the Ntsimbintle boundary.
  - The predicted annual and highest hourly average **cumulative** NO_2 concentration at the Ntsimbintle boundary was 35.2 and 219 µg/m³ respectively. Only the proposed SA hourly standard of 200µg/m³ for NO_2 was exceeded at the Ntsimbintle boundary.
  - Sinter plant emissions were estimated to be the most significant contributor, contributing on average 39%, to predicted incremental NO_2 concentrations.
  - A summary of predicted annual and highest hourly average NO_2 concentrations at the off-site discreet receptors are presented in Figure 8 and Figure 9 respectively.

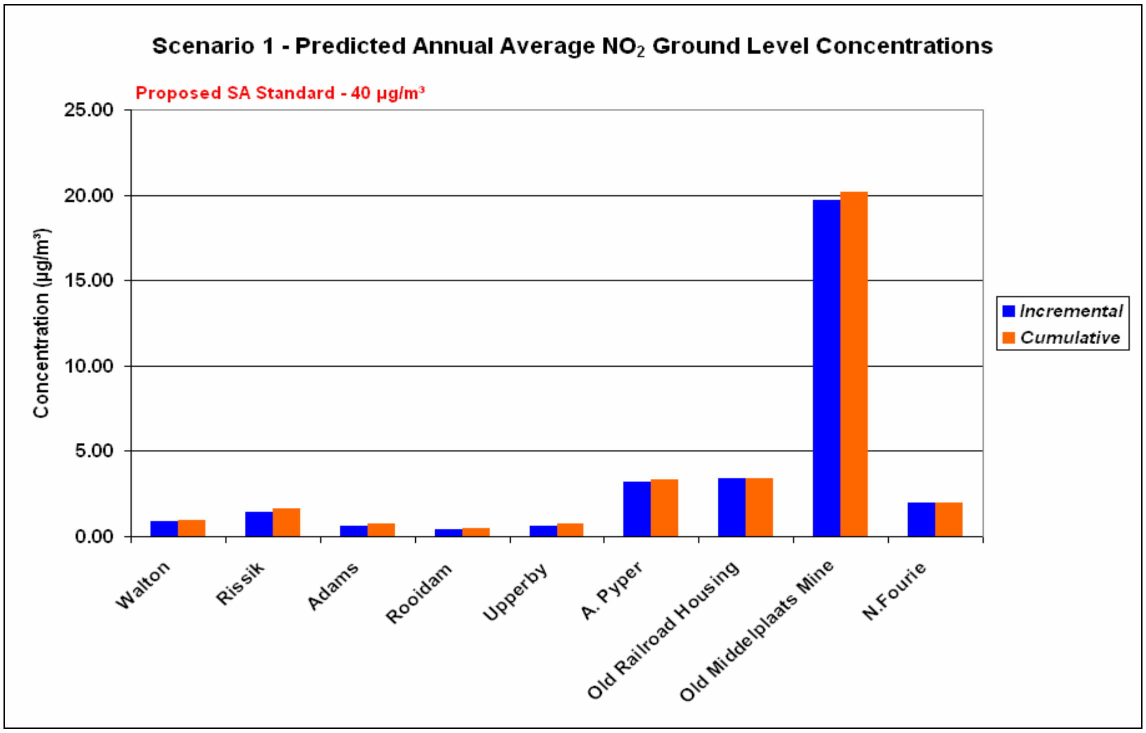

Figure 8: **Summary of predicted off-site annual average NO2 concentrations**

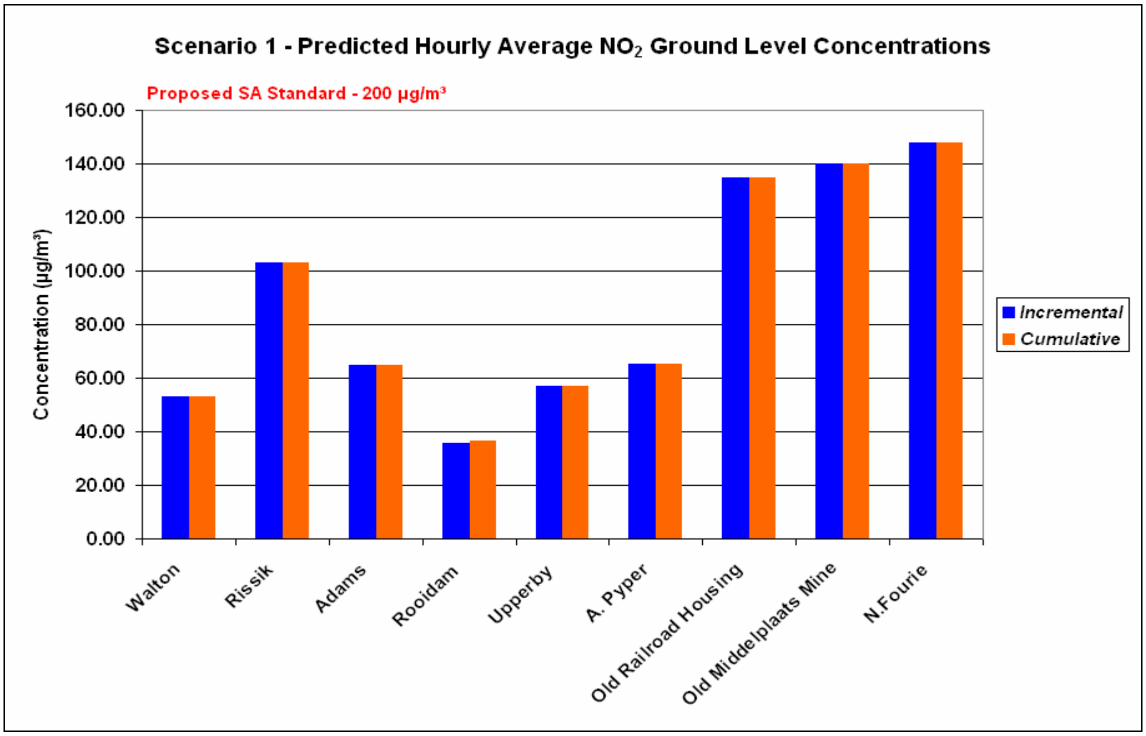

Figure 9: **Summary of predicted off-site highest hourly average NO2 concentrations**

- **DPM** impacts:
    - The predicted annual average **incremental** DPM concentration at the Ntsimbintle boundary was 9.45µg/m³. The proposed annual SA standard of 5µg/m³ as used in the assessment of DPM impacts was exceeded at the Ntsimbintle boundary.
    - A summary of predicted annual average DPM concentrations at the off-site discreet receptors are presented in Figure 10.

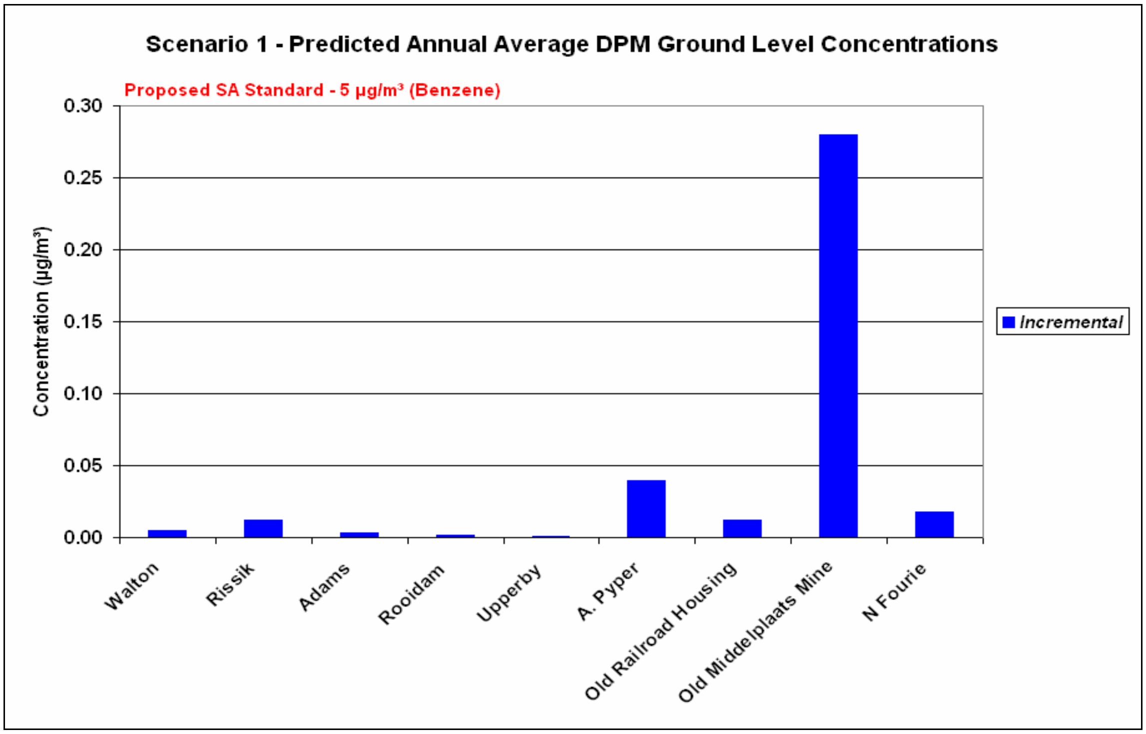

Figure 10: Summary of predicted off-site annual average DPM concentrations

- **CO** impacts:
    - The predicted highest hourly average **incremental** CO concentration at the Ntsimbintle boundary was 467µg/m³. The proposed hourly SA standard of 30000µg/m³ not exceeded at any of the discreet receptors included in the study.

- Vehicle tailpipe emissions were estimated to be the most significant contributor, contributing on average 68%, to predicted incremental CO concentrations.

- A summary of predicted highest hourly average CO concentrations at the off-site discreet receptors are presented in Figure 11.

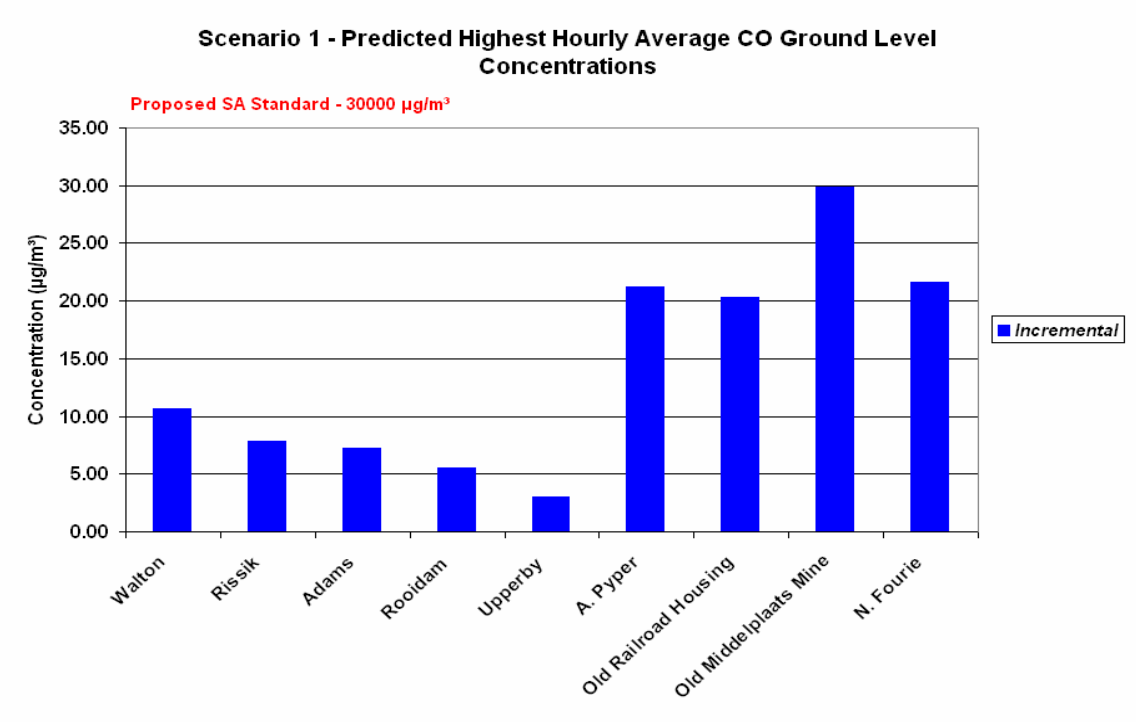

Figure 11: Summary of predicted off-site highest hourly average CO concentrations

- **Dustfall** impacts:

  - The predicted maximum daily **incremental unmitigated** dustfall level at the Ntsimbintle boundary was 756mg/m²/day. The SANS residential dustfall band, permissible for residential and light commercial areas, of 600 mg/m²/day was exceeded at the Ntsimbintle boundary.

  - **Cumulatively** the predicted maximum daily **unmitigated** dustfall level at the Ntsimbintle boundary was 756mg/m²/day. The SANS residential dustfall band of 600 mg/m²/day was exceeded at the Ntsimbintle boundary.

- The predicted maximum daily **incremental mitigated** dustfall level at the Ntsimbintle boundary was 77.4mg/m²/day. The SANS residential dustfall band of 600 mg/m²/day was exceeded at the Ntsimbintle boundary.

- The predicted maximum daily **cumulative mitigated** dustfall level at the Ntsimbintle boundary was 664mg/m²/day. The SANS residential dustfall band of 600 mg/m²/day was exceeded at the Ntsimbintle boundary.

- Mitigation of fugitive dust sources resulted in an average reduction of 66% in predicted incremental dustfall levels.

- A summary of predicted maximum daily dustfall levels at the off-site discreet receptors are presented in Figure 12.

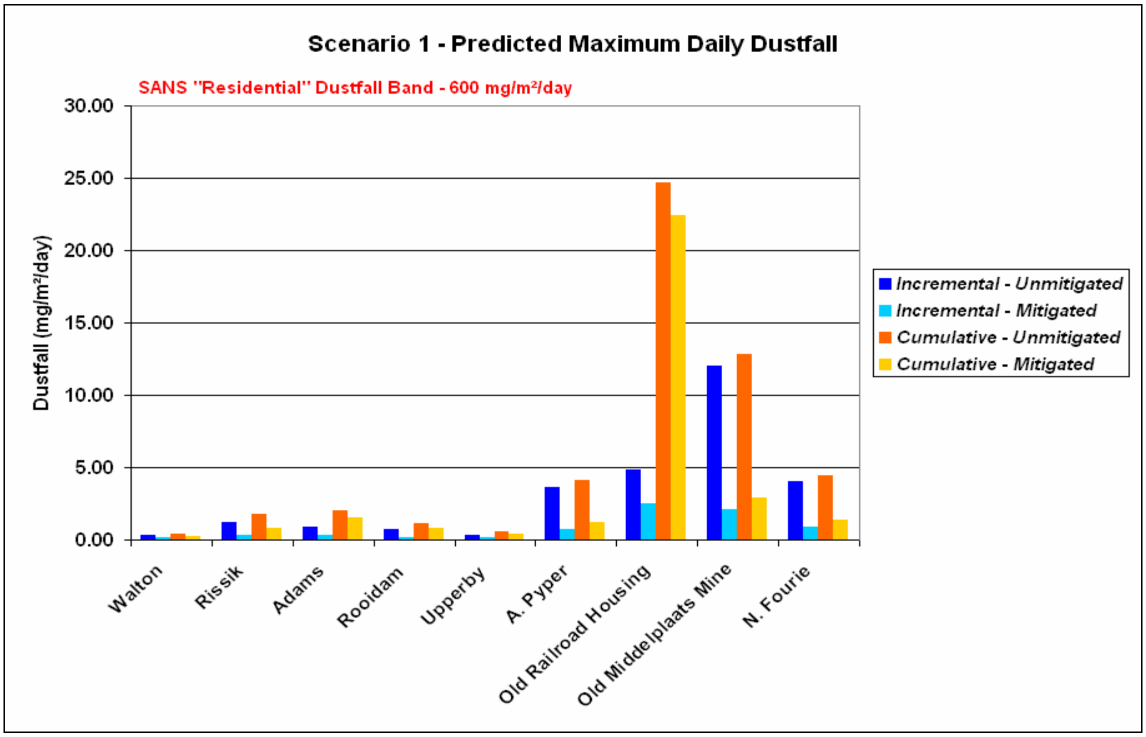

Figure 12: **Summary of predicted off-site maximum daily dustfall levels**

Recommendations

Based on the conclusions discussed above, the main objective of the recommendations discussed in this section is to try and ensure that the proposed operations at Ntsimbintle comply with the relevant air quality requirements.

Recommendations regarding proposed operations at Ntsimbintle were based on worst case emissions and predicted impacts are:

- **Health Risk Assessment:**

  A specialist health risk assessment is required for manganese exposures. Predicted Mn concentrations were compared to international community exposure limits, but most of the Mn exposure in this instance is occupational-related.

  The purpose of a human health risk assessment is to consider modelled air concentrations of substances that can cause harm to human health in a site-specific exposure scenario, to quantify human exposure and to predict the potential for adverse health effects in the exposed individuals. Modelled air concentrations of environmental pollutants are required to assess regulatory compliance to air quality regulations and may be used for screening purposes, but that does not constitute a quantitative human health risk assessment. In a health risk assessment the knowledge of toxicology and epidemiology is applied within an internationally accepted health risk assessment paradigm to quantify potential human health risks. In this assessment the risks are contextualised and regulatory authorities are provided with a firm scientific basis to reach conclusions on potential impacts that a source of air contamination may have on the health of neighbouring communities. The assessment not only is in the interest of receptor communities, but it also supports the interest of regulatory authorities and the industry that has to manage its operations and apply mitigation measures, where required.

- **Mitigation and Management Measures:**

  From the air quality impact assessment it was concluded that potential for health risk primarily exists with regards to predicted PM10 and manganese concentrations. The most significant sources of fugitive dust emission at the proposed Ntsimbintle operation, based on predicted ground level concentrations were vehicle entrained dust from unpaved roads and dust as a result from crushing and screening operations

  It was shown that 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 will ensure no exceedances at the residential receptors in the area. Should only water be applied, the maximum watering rate (excluding rainfall) to ensure 90% control efficiency would be 3.112litres/m²/hour.

As a minimum, to reduce predicted unmitigated maximum impacts at the Ntsimbintle boundary as a result of crushing and screening operations only, the predicted annual average PM10 concentration of 57.2µg/m³ needs to reduce to 40µg/m³ (the proposed SA standard) i.e. by 30%. This can be achieved by increasing the moisture content of the material 1.3 fold (i.e. we assumed the ore would have a moisture content of 5%, increasing it 1.3 fold would result in a moisture content of 6.5%). To achieve a 30% reduction in crushing and screening emissions, based on 5% ore moisture content, 15 liters of water is required for every ton of ore that is processed.

- **Monitoring Requirements:**

  Based on the impacts predicted as a result of proposed operations at Ntsimbintle on the surrounding environment it was recommended that ambient PM10, SO_2 and NO_2 monitoring be done and a dust fallout monitoring network established as soon as possible for the purpose of defining baseline air quality prior to the start of operations associated with Ntsimbintle. The proposed locations of the monitoring are presented in Figure 13.

  In addition to air quality monitoring, the absence of local meteorological data necessitates the installation of a meteorological station measuring, as a minimum, hourly average wind speed, wind direction, temperature, pressure, rainfall, relative humidity and solar radiation.

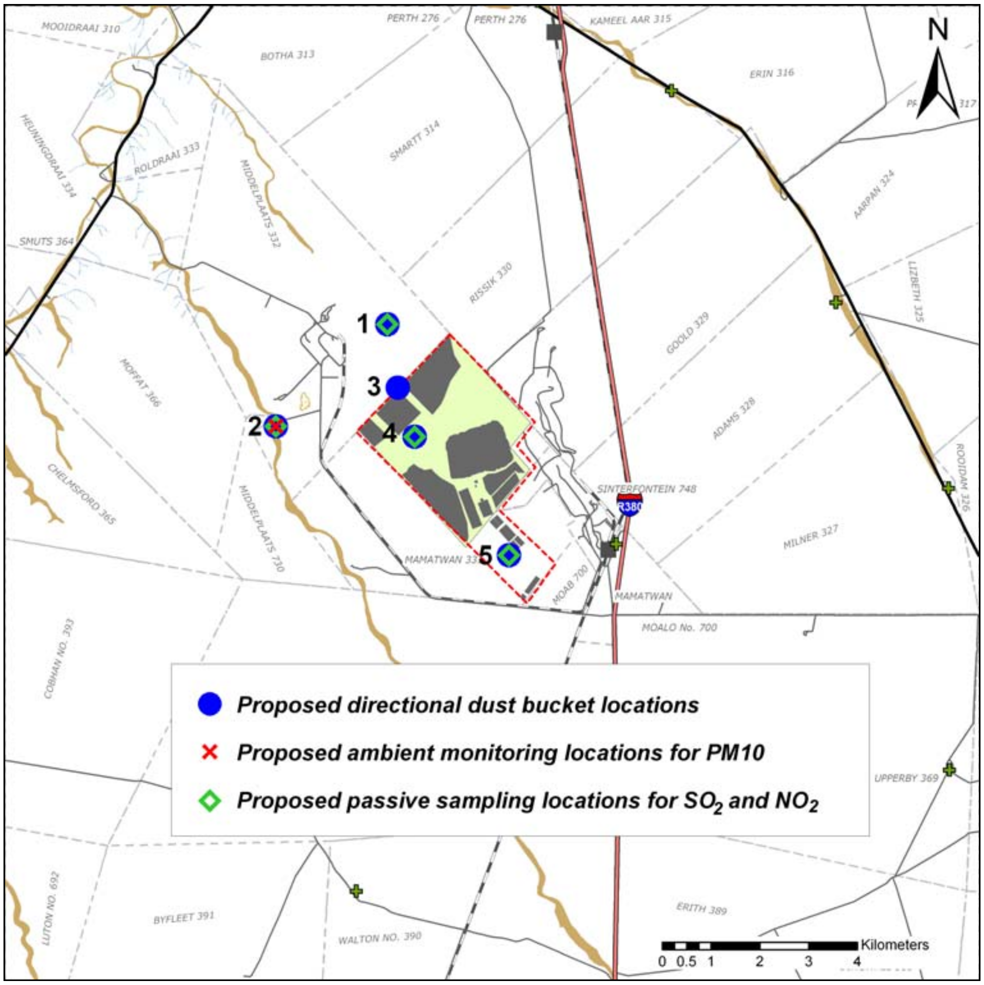

Figure 13: **Proposed air quality monitoring locations**

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1 INTRODUCTION

Airshed Planning Professionals (Pty) Ltd was appointed by Metago Engineering Services (Pty) Ltd (Metago) to undertake an air quality impact assessment for the proposed Ntsimbintle manganese mining operations near Hotazel in the Northern Cape Province. The main objective of the study was to do an air dispersion impact assessment using project specific data to determine potential impacts on the surrounding environment and human health.

1.1 Project Overview

Ntsimbintle Mining (Pty) Ltd (Ntsimbintle) proposes the development of a new manganese mining operation in the Kgalagadi District Municipality of the Northern Cape Province.

The proposed Ntsimbintle project will be situated adjacent to Hotazel Manganese Mine's (HMM's) Mamatwan Mine. Ntsimbintle will be ~25 km south of Hotazel, ~40 km north of Khatu and ~50 km west of Kuruman (Figure 1-1). The site is surrounded by farmland used for grazing. The area surrounding the site is mostly flat (Figure 1-2).

The project will include opencast mining and, a processing plant, a power generation plant, as well as various support infrastructure and services. Underground mining and a sinter plant are also being considered.

1.2 Scope of Study

The air quality impact assessment for the proposed project will form part of the Environmental Impact Assessment (EIA) undertaken by Metago. In order to determine the possible impacts from the proposed operations on the surrounding environment and human health, a baseline study, an impact assessment and mitigation recommendation study was undertaken.

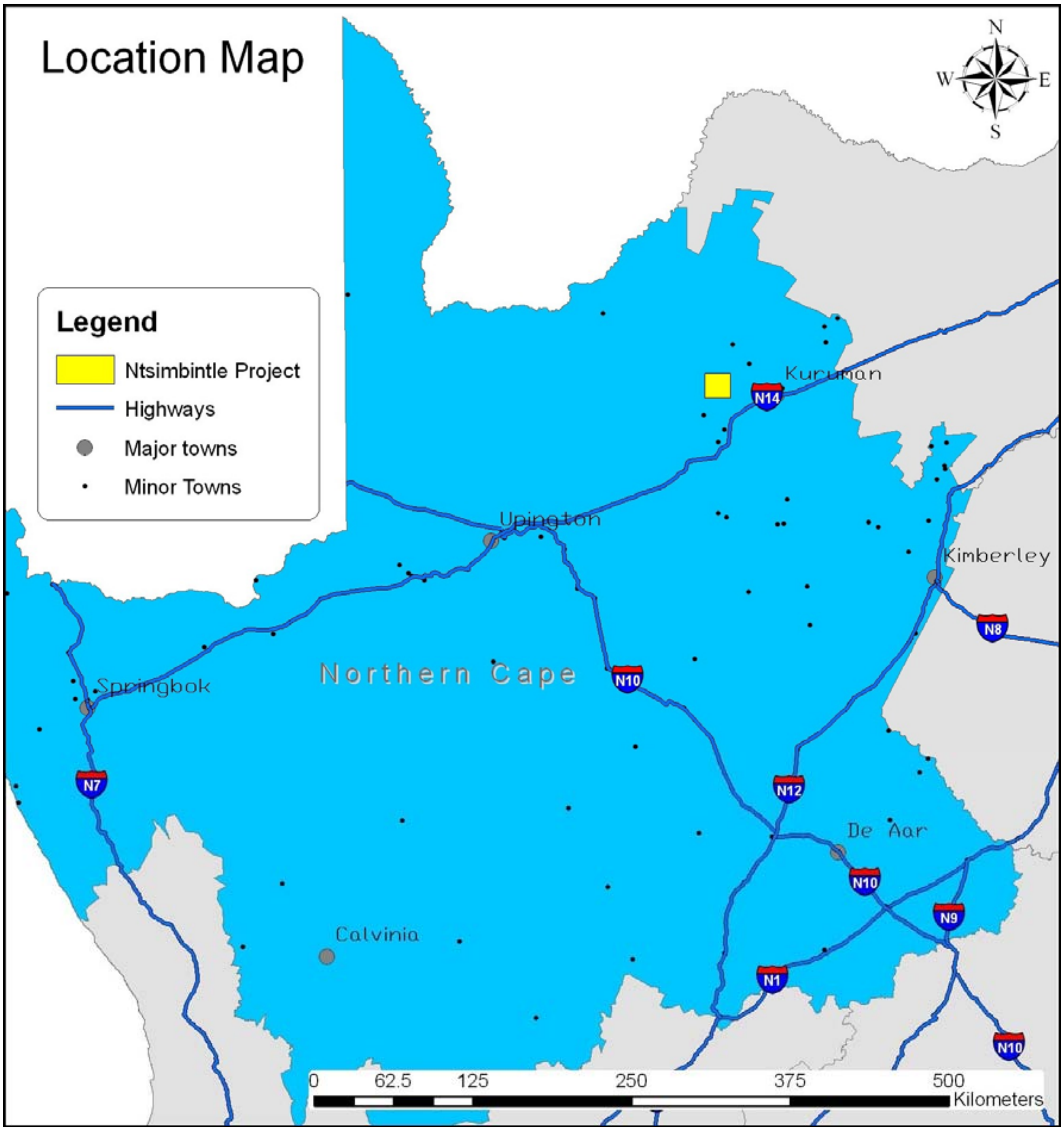

Figure 1-1: Location of the proposed Ntsimbintle Project in the Northern Cape

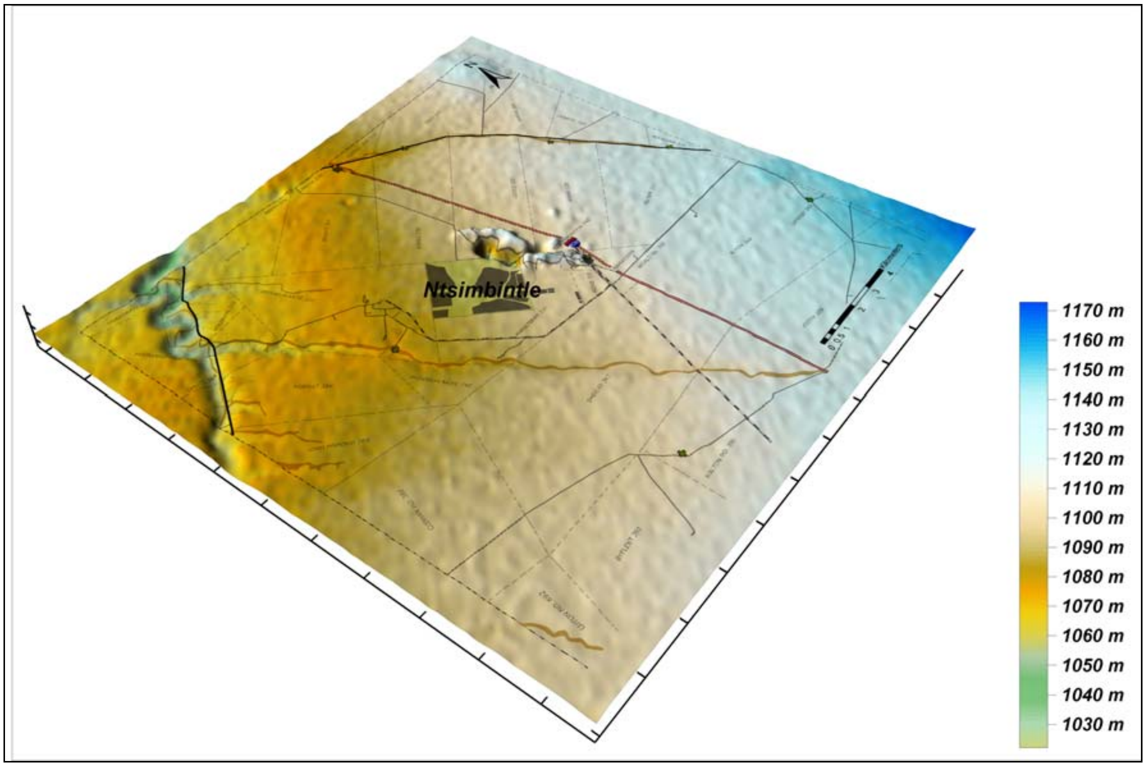

Figure 1-2: Topography of the study area

The **baseline air quality characterisation** included:

- The assessment of regional climate and site-specific atmospheric dispersion potential;
- The identification of potential sensitive receptors in the vicinity of the proposed site;
- The preparation of hourly average meteorological data for dispersion modelling purposes;
- The identification existing sources of emissions in the area;
- A description of the legislative and regulatory context, including emission limits and guidelines, ambient air quality guidelines and dustfall classifications with specific reference to the new legislation.

The **air quality impact study** included:

- The compilation of an emissions inventory comprising the identification and quantification of all potential routine sources of emission from the proposed project;
- Dispersion simulations of the following pollutants relevant to the study:

  - Respirable particulate (PM10) concentrations;
  - Total suspended particulate (TSP) dust-fall levels;
  - Manganese (Mn) concentrations;
  - Sulphur dioxide (SO_2) concentrations;
  - Nitrogen dioxide (NO_2) concentrations;
  - Carbon monoxide (CO) concentrations; and
  - Diesel particulate matter (DPM) concentrations.
- An analysis of the dispersion modelling results;
- The evaluation of potential for human health and environmental impacts based on ambient air quality guidelines and standards; and
- Recommendations of mitigation and management measures.

1.3 Air Quality Impact Assessment Methodology

The establishment of a comprehensive emission inventory formed the basis for the assessment of the impacts from of the proposed operation's emissions on the receiving environment. The establishment of an emissions inventory comprises the identification of sources of emission, and the quantification of each source's contribution to ambient air pollution concentrations.

Fugitive dust emissions occur as a result of vehicle-entrained dust from paved and unpaved roads, wind erosion from open areas, material handling operations, drilling and blasting as well as crushing and screening operations. In the quantification of fugitive dust emissions use was made of emission factors which associate the quantity of a pollutant to the activity associated with the release of that pollutant. Due to the absence of locally generated emission factors, reference was made to emission factors such as those published by the US Environmental Protection Agency (US-EPA) in its AP-42 document and the Australian National Pollutant Inventory (NPI). The US-EPA AP-42 emission factors are of the most widely used in the field of air pollution. Point source emissions were estimated based on emission limits.

In the estimation of emissions and the simulation of patterns of dispersion, a distinction was made between Total Suspended Particulates (TSP) and inhalable particulates (PM10, particulate matter with an aerodynamic diameter of less than 10 µm). Whereas TSP is of interest due to its implications in terms of nuisance dust impacts, the PM10 fraction is taken into account to determine the potential for human health risks. Inhalable manganese emissions (Mn emissions of the PM10 size fraction), SO_2, NO_2, DPM and CO emissions are taken into account due to it's implications in terms of human health risks.

In characterising the dispersion potential of the site reference was made to hourly average meteorological data recorded the South African Weather Service (SAWS) station at Kuruman for the period January 2001 to December 2005.

PM10, Mn, SO_2, NO_2, CO and DPM concentrations and dustfall rates were simulated for the proposed operations. The simulation of ambient air pollutant concentrations and dust deposition were undertaken through the application of the US-EPA AERMOD (version 5). The USA-EPA (EPA, 1986) considers the range of uncertainty of this model to be -50% to 200%.

1.4 Assumptions and Limitations

Due to data limitations some assumptions had to be made during the assessment. These were:

- No onsite meteorological data was available for use in the current study and use was therefore made of the SAWS Kuruman meteorological station that is situated ~50 km to the east of the site.

- The dispersion model cannot compute real-time mining and production processes; average throughputs were therefore used. Operational locations and periods were selected to reflect the worst case scenarios.

- Diesel engines emit benzene and 1,3-butadiene which have both been classified as carcinogens. Standards for carcinogens are not set using the same methodology as for non-carcinogens, as they have no lower threshold for adverse effects. However, using an appropriate acceptable risk level, annual average concentration standards may be derived. In South Africa, the proposed SANS standard for benzene is 5 µg/m³ (annual average). Using the relative toxicity of 1,3 butadiene to benzene (as indicated by the relative US EPA unit risk factors) the standard for 1,3 butadiene on the same basis would be 1.3 µg/m³. However, the rate of emissions of the benzene and 1,3 butadiene is approximately 1% of the emission rate of particulates (California ARB 2002). Screening for diesel particulate as an indicator of transport-related emissions therefore provides a conservative screening value for the carcinogens mentioned above.

- Nitrogen oxide (NO) is rapidly converted in the atmosphere into the much more toxic nitrogen dioxide (NO_2). The rate of this conversion process is determined by both the rate of the physical processes of dispersion and mixing of the plume and the chemical reaction rates. It appeared from model calculations (Janssen 1988) in comparison to actual measurements that at larger distances from the source, chemical equilibrium is not measured in the plume because the momentary plume is heterogeneously mixed and consists of parcels of flue gas and parcels of ambient air. The general conclusion may therefore be drawn that the oxidation rate of NO at smaller distances from the source is determined by the chemical reaction rates, whereas the oxidation rate at greater distances from the source (> 5 km) is determined by the mixing rate of the plume with its ambient air. Observed NO_2/NO_x for varying travel times have been reported by Janssen (1988). The daytime range was from about 18% to 80%, with an average of about 50%. The night-time range was about 4% to 40%. Based on these observations NO_2/NO_x ratios had to be assumed for hourly and annual average NO_2 concentrations.

1.5 Report Outline

The report is structured as follows:

Section 2	Overview of the relevant ambient air quality guidelines and dustfall limits.
Section 3	Characterisation of the regional climate and the atmospheric dispersion potential.
Section 4	Characterisation of baseline air quality
Section 5	Air quality impact assessment
Section 6	Conclusions
Section 7	Air quality management measures and recommendations
Section 8	References
Appendix A	Regional climate and atmospheric dispersion potential
Appendix B	Fugitive dust emission factors and equations
Appendix C	Manganese exposures
Appendix D	Air quality issues raised by interested and affected parties
Appendix E	Power generation plant stack height calculations

2 REGULATORY CONTEXT

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

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.

2.1 Review of the Current Air Pollution Legislative Context

Under the Atmospheric 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 Practicable 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 and Tourism (DEAT) 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 and Tourism (DEAT), no provision was made under the APPA to publish formal 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 a company or person to submit atmospheric impact reports in order to demonstrate compliance.

The AQA commenced on the 11th of September 2005 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.

2.2 Legal Requirements According to the New Air Quality Act No.39 of 2004

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.

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.

2.3 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 might have an influence on the proposed operations.

- *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 first generation plan was published in the Government Gazette on the 11th of September 2007 and will be revised and updated by 11 September 2009.

- *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 are included as listed activities with additional activities being added to the list. An initial list of activities forms part of the National Framework. The draft Listed Activities and Minimum National Emission Standards was published in February 2008 and is currently with the STANSA Technical Committee for Air Quality for finalization.The final list and limits will be published by September 2009.

The draft Listed Activities and Minimum Emission Standards was published in February 2008 and is currently under review to be adopted as standards. The initial list of activities, as published in the National Framework for Air Quality Management 2007 (Table 26), included sinter plant activities (for agglomeration of fine ores using a heating process) as proposed listed activities under Category 4.5. For these activities draft minimum national emission limits have been stipulated and an Atmospheric Emissions License will be a legal requirement.

- *The APPA permit review proj*ect – the project commenced in January 2006 and will be completed by September 2009. The project aims to develop a Registration Certificate template that is in line with the requirements of the Air Quality Act and to issue revised Registration Certificates that will ensure ambient air quality improvement. This project also aims to capacitate the provincial and local authorities to apply procedures, protocols; standard formats etc. for developing an atmospheric emissions licence (AEL). The project included the capturing of all current APPA Registration Certificates into a central database at DEAT. The database was used to sort and assess the various industries and develop a prioritisation matrix from where 9 industry sectors were identified for review resulting in a total of 69 individual industries, excluding the almost 200 brickworks. The Registration Certificate was used to test the template and to review the current industries within the various sectors.

The ferromanganese industry is one of the industry sectors forming part of this process; all listed activities (currently scheduled processes) will be required to conform to the new Atmospheric emissions Licences (AEL) which will include all point and non-point sources on-site.

2.4 Listed Activities and Minimum Emission Standards

The ferromanganese industry is a Scheduled Process under the Atmospheric Pollution Prevention Act of 1965 (Process 14) and a Listed Activity under the NEM Air Quality Act of 2004 (AQA). Minimum national emission limits are in the process of being developed for the ferromanganese industry. These include emission limits for sinter plants (the agglomeration of fine ores using a heating process, including sinter cooling where applicable). All new applications will be subject to the new revised

Registration Certificate as developed under the APPA Registration Certificate Review project. This certificate requires provision of all point and non-point emissions deriving from the project.

In addition, the current South African Ambient Air Quality Standards are also under review and the newly proposed standards are currently undergoing the standard setting process. Any facility will have to comply with both the emission limits for that process and the ambient air quality standards.

Table 2-1 lists the proposed emission limits for sintering operations as set out in the Draft Schedule for Section 21 Air Quality Act, February 2008. Note that “New plan” relates per definition to all installations staring operations three years after the final publication of these regulations, thus for the proposed sinter plant emission limits for Existing Plants have relevance.

Table 2-1: Proposed emission limits for sintering operations

1. Category of Listed Activity			
Number:	4	**Category Title:**	Metallurgical Industry
2. Listed Activity Being an activity which result in atmospheric emissions and which the Minister reasonably believes have or may have significant detrimental effect on the environment, including health, social conditions, economic conditions, ecological conditions or cultural heritage as contemplated in Section 21(1)(a) of the Act.			
Number:	4.5	**Name:**	Sinter Plant
Description:	Sinter plants for agglomeration of fine ores using a heating process, including cooling where applicable.		
Size:	All Installations		
3. Minimum Emission Standards for Point Source Emissions Being the minimum emission standards for emissions from a single identifiable source and fixed location of atmospheric emission in respect of substances or mixture of substances resulting from a listed activity including the permissible amount, volume, emission rate or concentration of that substance or mixture of substances that may be emitted and the manner in which measurements of such emissions must be carried out as contemplated in Section 21(3)(a) of the Act.			

Substance or Mixture of Substances		**mg/Nm^3 under standard conditions of 6% O_2, 273 Kelvin and 101 kPa**		**Manner in which measurements of emissions must be carried out**
Common Name	**Chemical Symbol**	**New Plant**	**Existing Plant**	
Particulate matter (PM) (6% O_2 standard conditions does not apply to sinter coolers)	Not Applicable	50	100	Appropriate method selected from Table 1
Sulphur dioxide	SO_2	500	500	
Oxides of nitrogen	NO_x	700	2000	

2.5 Ambient Air Quality Criteria

2.5.1 South African Ambient Air Quality 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 DEAT 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[1]. These standards were published for comment in the Government Gazette on 9 June 2007 and are currently with the STANSA Technical Committee for Air Quality for finalisation. The final standards will be published in the first half of 2009 and will have margins of tolerance (i.e. frequency of exceedances) and implementation timelines linked to it. Table 2-2 provides the list of the proposed standards as published in the Government Gazette on 9 June 2007.

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[1] *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 2-2: Proposed new National Ambient Air Quality Standards

Substance	10-minute maximum	1-hour maximum	8-hour maximum	24-hour maximum	Annual average
	(µg/m³)	(µg/m³)	(µg/m³)	(µg/m³)	(µg/m³)
Sulphur dioxide (SO_2)	500	350		125	50
Nitrogen dioxide (NO_2)		200			40
Carbon Monoxide (CO)		30 000	10 000		
Particulate Matter (PM10)				75	40
Ozone (O_3)		200	120		
Lead (Pb)					0.5
Benzene (C_6H_6)					5

2.5.2 International Ambient Air Quality Criteria for Manganese

Manganese is an essential trace element and is necessary for good health. The human body typically contains small quantities of manganese, and under normal circumstances, the body controls these amounts so that neither too little nor too much is present. In addition to occurring naturally in the environment, manganese can be introduced by human activity. Manganese can be released into the air by industry and by the burning of fossil fuels. More specifically, sources of airborne manganese include iron- and steel-producing plants, power plants, coke ovens, and dust from uncontrolled mining operations (ASTD, 2003). A description of the exposure pathways and health risks associated with manganese are provided in Appendix C.

Inhalation-related health thresholds published for public exposures to manganese are summarised in Table 2-2. It is important to note that less stringent thresholds are recommended for occupational exposures for various reasons (e.g. differences in the sensitivities of individuals and exposure periods; focus of different particulate fractions; voluntary versus involuntary risks; use of personal protective equipment in the workplace). According to Levy *et al*. (2004), for inorganic forms of manganese, limiting exposure to 100µg/m³ respirable manganese will prevent most workers from developing the subtlest detectable effect (i.e. small non-clinical decrement in motor neurobehavioural function). A supplementary limit of 500 µg/m³ inhalable manganese is recommended as a safeguard in case the gastrointestinal route, subsequent to inhalation is not insignificant. Health thresholds for inhalation exposures to inhalable (i.e. <10 µm) manganese (applicable to non-occupational, i.e. public, exposures) are presented in Table 2-3.

Table 2-3: Health thresholds for inhalation exposures to inhalable (i.e. <10 µm) manganese

Agency	Description	Threshold (µg/m^3)	Reference
International Regulations			
US-EPA (1)	Chronic Inhalation Reference Concentration	0.05	IRIS 2006
WHO (2)	Chronic Guideline Value	0.15	WHO 2000
California OEHHA (4)	Chronic Reference Exposure Level	0.2	OEHHA 2006
TARA (5)	Long-Term (Chronic) Effect Screening Level	0.2	TARA 2003
TARA (5)	Short-Term (Acute) Effect Screening Level	2	TARA 2003
US ATSDR(6)	Chronic Minimal Risk Level	0.04	ATSDR 2004
U.S. States - Regulations and Guidelines			
Arizona	24-hours (Manganese)	8	NATICH 1992 (unless otherwise specified)
Connecticut	8-hours (Manganese)	20	
	30 min (Manganese)	100	
	8-hours (Manganese fume, as manganese)	20	CT DEP 1999
	30 min (Manganese fume, as manganese)	100	
Florida – Pinella	24-hours (Manganese)	12	
Louisiana	8-hours (Manganese)	27.6	
Nevada	8-hours (Manganese)	119	
South Carolina	Maximum allowable concentration	25	SC DHEC 1999
North Carolina	24-hours (Manganese)	31	
North Carolina – Forco	24-hours (Manganese)	31	
North Dakota	1-hour (Manganese)	30	
Oklahoma	24-hours (Manganese)	100	
Pennsylvania	Annual (Manganese)	$2.4x10^{-1}$	
Rhode Island	1-hour (Manganese)	2	
South Dekota	8-hours (Manganese)	20	

Agency	Description	Threshold ($\mu g/m^3$)	Reference
Texas	Annual (Manganese)	30	
Vermont	Annual (Manganese)	119	VT DEC 1999
Virginia	24-hours (Manganese)	17	
Washington - Southwest	24-hours (Manganese)	16.7	
Idaho	24-hours (Manganese fume, as manganese)	50	ID DHW 1999

Note:

(a) EPA = Environmental Protection Agency

(b) WHO = World Health Organisation

(c) RfC = Inhalation Reference Concentrations

(d) OEHHA REL = Office of Environmental Health Reference Exposure Level

(e) TARA =Toxicology and Risk Assessment Division of the Texas Natural Resource Conservation Commissions; ESL = Effects Screening Level)

(f) ATSDR- US Federal Agency for Toxic Substances and Disease Registry

2.5.3 Ambient Air Quality Criteria for Diesel Particulate Matter

Diesel particulate has been classified by the US EPA as a compound with non-cancer chronic inhalation risk for which a reference concentration (RfC) is given (as derived from clinical studies). Concentration values below the RfC imply that no risk has been identified; above the RfC does not necessarily imply risk, but further investigation might be warranted. The USA EPA IRIS database gives an RfC value of 5μg/m^3 for annual exposure, and this value will be used for the preliminary health screening.

In addition, diesel engines emit benzene and 1,3-butadiene which have both been classified as carcinogens. In South Africa, the proposed SANS standard for benzene is 5 μg/m^3 (annual average). Using the relative toxicity of 1,3 butadiene to benzene (as indicated by the relative US EPA unit risk factors) the standard for 1,3 butadiene on the same basis would be 1.3 μg/m^3. However, the rate of emissions of the benzene and 1,3 butadiene is approximately 1% of the emission rate of particulates (California ARB 2002). Screening for diesel particulate as an indicator of transport-related emissions therefore provides a conservative screening value for the carcinogens mentioned above.

Diesel engine exhaust (DE) is an intricate mixture of airborne particles and gases. Diesel particulate matter (DPM) is composed of elemental carbon particles and adsorbed organic compounds and is the most frequently determined measure of DE and the measure reported in toxicological studies of diesel engine exhaust (US EPA IRIS,2003). Chronic respiratory effects are the main non-cancer hazard to humans from long-term environmental exposure to diesel engine exhaust, or emissions (DE).

2.5.4 Dust Deposition Standards

Dust deposition in South Africa 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, and 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	Dustfall 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	Dustfall Rate (D) ($mg\ m^{-2}\ day^{-1}$, 30-day average)	Averaging Period	Permitted Frequencies of Exceedance
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 ATMOSPHERIC DISPERSION POTENTIAL

In the assessment of the possible impacts from air pollutants on the surrounding environment and human health, a good understanding of the regional climate (as described in Appendix A) and local air dispersion potential of a site is essential. Meteorological characteristics 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.

Pollution concentration levels fluctuate in response to changes in atmospheric stability, to concurrent variations in the mixing depth, and to shifts in the wind field. 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.

Parameters that need to be taken into account in the characterisation of meso-scale ventilation potentials include wind speed, wind direction, extent of atmospheric turbulence, ambient air temperature and mixing depth.

3.1 Local Wind Field

Dispersion comprises vertical and horizontal components of motion. The wind field largely determines the horizontal dispersion of pollution in the atmospheric boundary layer. 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, determine the general path pollutants will follow, and the extent of cross-wind spreading (Shaw and Munn, 1971; Pasquill and Smith, 1983; Oke, 1990).

In characterising the dispersion potential of the site reference was made to hourly average meteorological data recorded the SAWS Kuruman station for the period January 2001 to December 2005.

Wind roses comprise 16 spokes, which represent the directions from which winds blew during the period. The colours used in the wind roses below, reflect the different categories of wind speeds; the grey area, for example, representing winds of 1 m/s to 1.5 m/s. The dotted circles provide information regarding the frequency of occurrence of wind speed and direction categories. For the current wind roses, each dotted circle represents a 5% frequency of occurrence. The value given in the centre of the circle described the frequency with which calms occurred, i.e. periods during which the wind speed was below 1 m/s.

The predominant wind direction is from the southeast with a high frequency of strong wind also occurring from the northwest. Over the five-year period, the frequency of occurrence of south-easterly wind was between 12% and 17%, with winds with a northerly component occurring approximately 8% of the time. Winds occur less frequently (~6% of the time) from the north-easterly and south-westerly sectors. Calm conditions (wind speeds < 1 m/s) occurred for 11.6% of the time.

A distinct diurnal variation was evident in the airflow recorded at Kuruman. During daytime there is an increase in winds from the north and northwest, with frequencies of 13% and 12% respectively. During the night-time there is an increase in south-easterly flow with a decrease in northerly air flow. Night-time conditions also reflect a decrease in wind speeds, with speeds ranging mainly from 1-4 m/s in comparison to daily wind speeds of between 2 m/s and 12 m/s. Calm conditions (wind speeds < 1 m/s) occurred for 16.6% of the time during night-times.

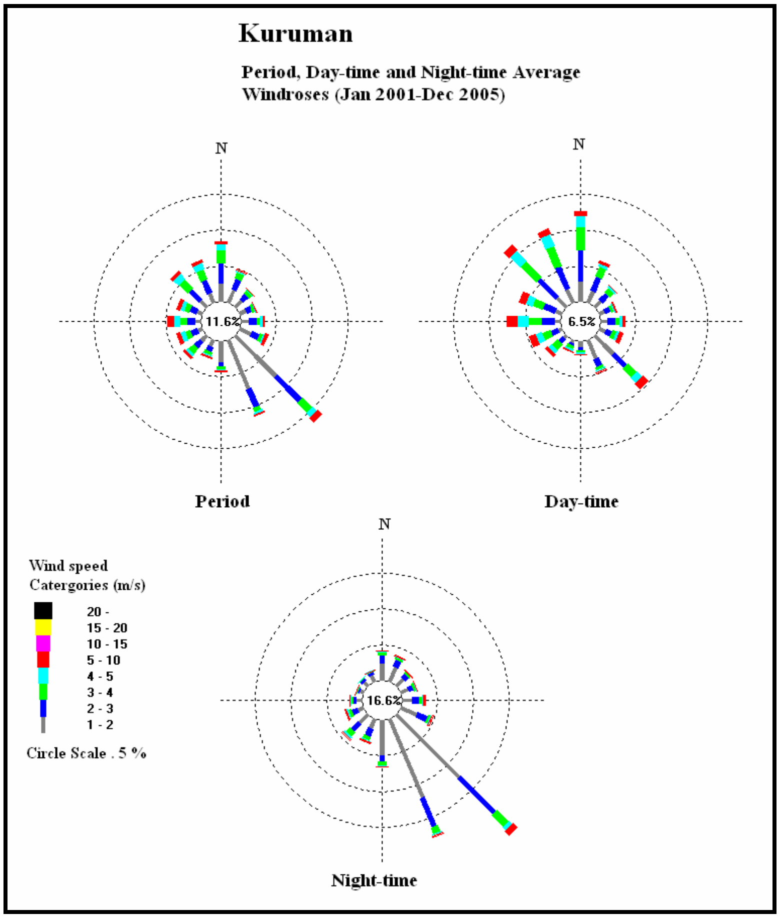

Figure 3-1: **Wind roses for the period 2001 - 2005 based on weather data recorded at Kuruman**

The seasonal variability in the wind field recorded at Kuruman is shown in Figure 3-2. During the summer months, wind from the north and southeast sectors dominate, with stronger winds of up to 10 m/s occurring. Infrequent but strong winds occur from the north-westerly sector. During autumn, the winds blow more frequently from the south-easterly sector, with a notable decrease in wind velocity. Winter months reflect a more frequent flow from the southeast with stronger but less frequent winds from the northwest. During spring, wind flow is still predominant from the south-easterly and north-westerly sectors, with an increase in wind speed being evident.

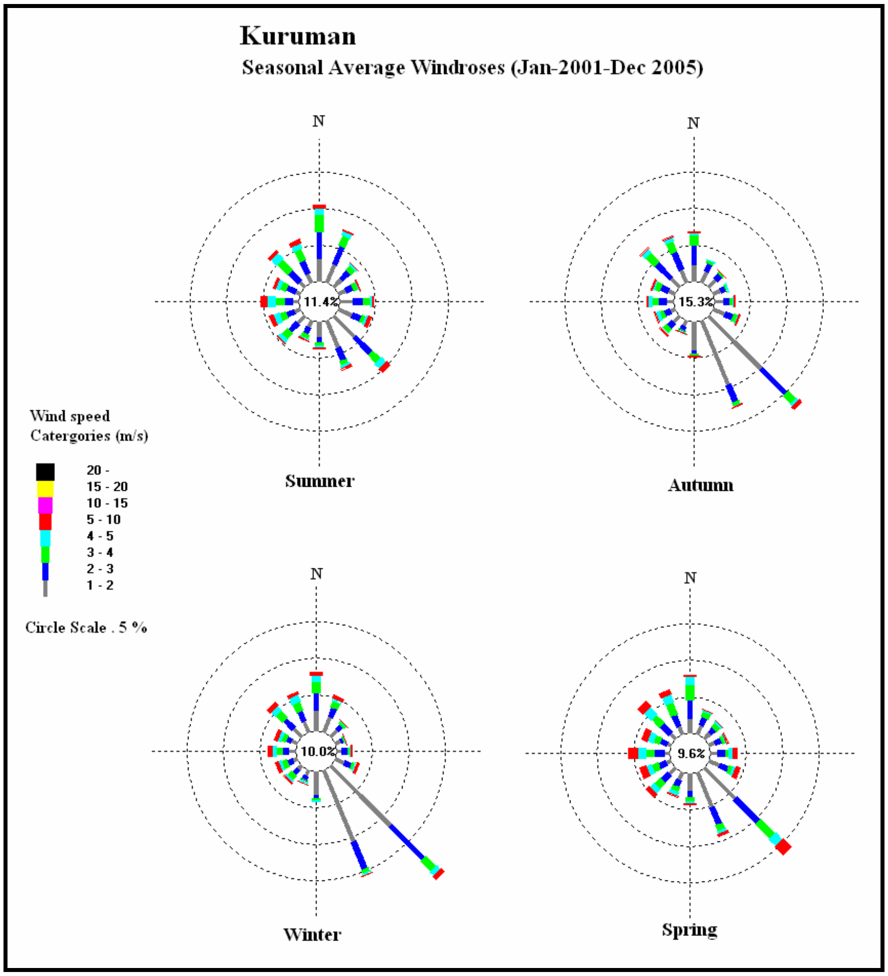

Figure 3-2: **Seasonal wind roses (2001 – 2005) based on weather data recorded at Kuruman**

3.2 Temperature

Air temperature is important, both for determining the effect of plume buoyancy (the larger the temperature difference between the plume and the ambient air, the higher the plume is able to rise), and determining the development of the mixing and inversion layers. The temperature trends recorded at Kuruman for the year 2004 are presented in Figure 3-3.

Temperatures provide an indication of the extent of insulation, and therefore of the rate of development and dissipation of the mixing layer. Long-term average maximum, mean and minimum temperatures for Sishen (1958 -1984) and Kuruman (1945 -1984) are given in Table 3-1 (Schulze, 1986). Minimum long-term temperatures have been recorded as ranging from 1.1 °C -16.4 °C for

Kuruman with maximum temperatures ranging between 19.0 °C and 31.5 °C, as presented in Table 3-1. Mean temperatures, recorded over the long-term, ranged between 10°C and 24°C. Based on data received from the South African Weather Services' Kuruman station for the period 2001-2005, a minimum temperature of 0°C, a maximum temperature of 38.1°C, and average temperatures of 17.6°C were observed.

Table 3-1: Long-term minimum, maximum and mean temperature for Sishen and Kuruman

Station		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Sishen	Maximum	32.6	31.6	29.2	25.6	21.9	19.1	19.6	21.7	26.2	28.6	30.8	32.4
	Mean	25.8	25.1	22.9	18.6	14.5	11.1	11.2	13.6	17.8	20.6	23.4	25.2
	Minimum	18.6	18.1	16.0	11.4	6.8	3.2	2.9	5.1	9.4	12.7	15.8	17.8
Kuruman	Maximum	31.5	30.2	28.1	24.9	21.5	18.7	19.0	21.5	25.7	28.0	29.9	31.0
	Mean	24.0	23.2	21.1	17.3	13.2	10.2	10.1	12.2	16.4	19.4	21.6	23.0
	Minimum	16.4	16.0	14.1	9.6	4.9	1.6	1.1	2.8	7.3	10.8	13.4	15.2

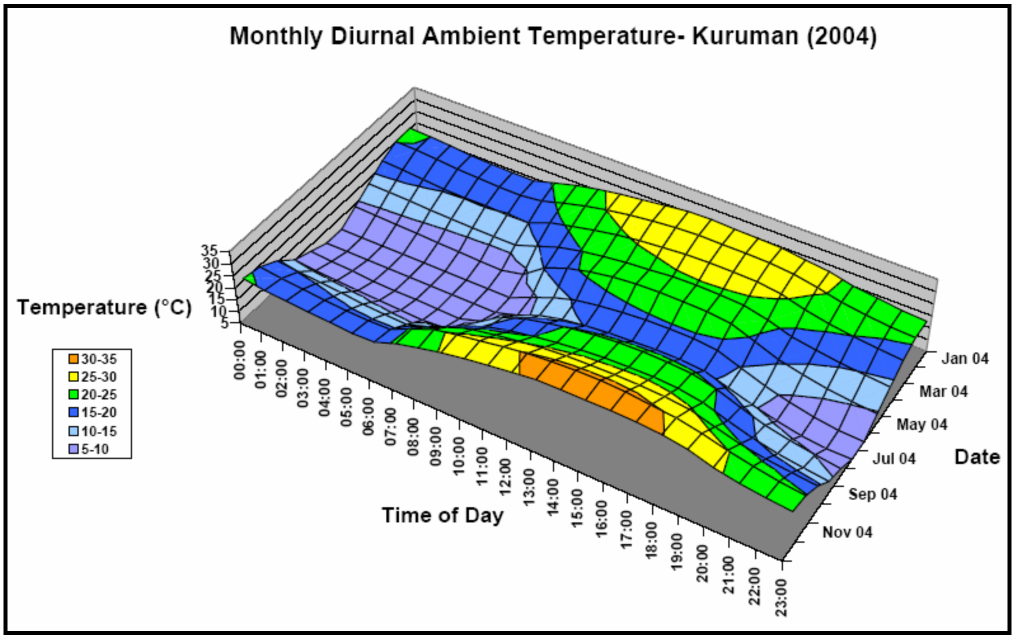

Figure 3-3: Air temperature trends for Kuruman for the year 2004

3.3 Rainfall and Precipitation

Precipitation is important to air pollution studies since it represents an effective removal mechanism for atmospheric pollutants and inhibits dust generation potentials. Long-term monthly average rainfall figures for two stations, Kuruman and Sishen are given in Table 3-2 and depicted in Figure 3-4. Long-term average total annual rainfall is in the range of 386 mm to 455 mm. Rain falls mainly in summer from October to April, with the peak occurring in the month of January for the region (Schulze, 1984).

Table 3-2: Long-term monthly rainfall figures (mm)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Sishen (1958 – 1984)	73	60	71	41	15	6	3	7	5	22	29	54	386
Kuruman (1932 – 1984)	81	83	80	48	21	10	4	8	7	27	36	50	455

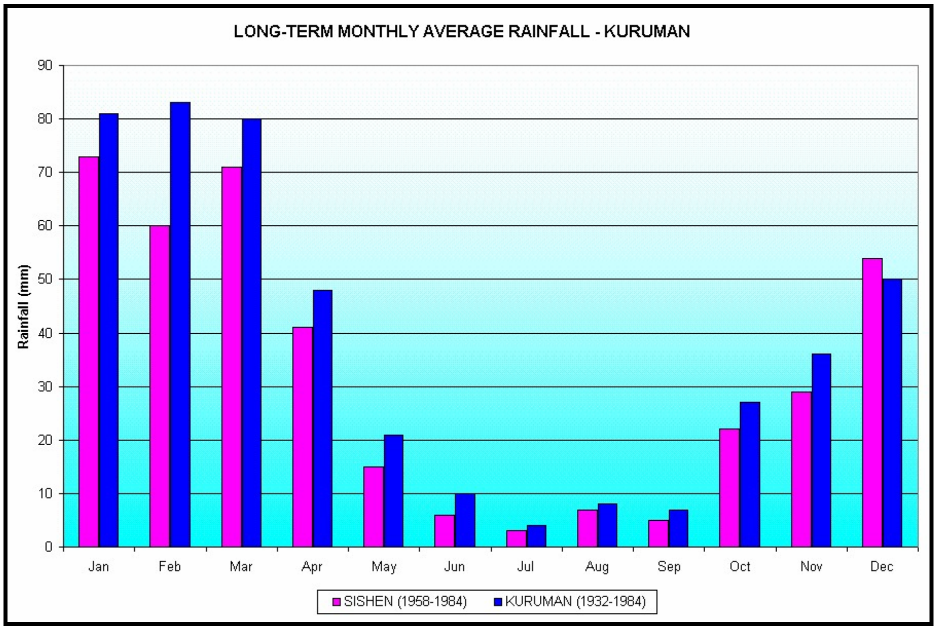

Figure 3-4: Long-term average monthly rainfall for Sishen and Kuruman

3.4 Mixing Height and Atmospheric Stability

The vertical component of dispersion is a function of the extent of thermal turbulence and the depth of the surface mixing layer. Unfortunately, the mixing layer is not easily measured, and must therefore often be estimated using prognostic models that derive the depth from some of the other parameters that are routinely measured, e.g. solar radiation and temperature. 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. Day-time mixing heights were calculated with the prognostic equations of Batchvarova and Gryning (1990), while night-time boundary layer heights were calculated from various diagnostic approaches for stable and neutral conditions. The mixing layer at the proposed sites ranges in depth from 0 metres (i.e. only a stable or neutral layer exists) during night-times to the base of the lowest-level elevated inversion during unstable, day-time conditions.

Atmospheric stability is frequently categorised into one of six stability classes. These are briefly described in Table 3-3. The hourly standard deviation of wind direction, wind speed and solar radiation were used to determine hourly-average stability classes (STAR method).

Table 3-3: Atmospheric Stability Classes

A	very unstable	calm wind, clear skies, hot daytime conditions
B	moderately unstable	clear skies, daytime conditions
C	unstable	moderate wind, slightly overcast daytime conditions
D	neutral	high winds or cloudy days and nights
E	stable	moderate wind, slightly overcast night-time conditions
F	very stable	low winds, clear skies, cold night-time conditions

The atmospheric boundary layer is normally unstable during the day as a result of the turbulence due to the sun's heating effect on the earth's surface. The thickness of this mixing layer depends predominantly on the extent of solar radiation, growing gradually from sunrise to reach a maximum at about 5-6 hours after sunrise. This situation is more pronounced during the winter months due to strong night-time inversions and a slower developing mixing layer. During the night a stable layer, with limited vertical mixing, exists. During windy and/or cloudy conditions, the atmosphere is normally neutral.

For elevated releases, 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. The highest concentrations for low level releases would occur during weak wind speeds and stable (night-time) atmospheric conditions. Air pollution episodes frequently occur just prior to the passage of a frontal system that is characterised by calm winds and stable conditions.

4 BASELINE AIR QUALITY CHARACTERISATION

The consideration of the existing air quality is important so as to facilitate the assessment of the potential for cumulative air pollutant concentrations arising due to the proposed development. In characterising the baseline air quality, reference is made to other potential sources of atmospheric emissions in the area.

4.1 Existing Sources of Atmospheric Emissions

The Ntsimbintle project is proposed for development on portions 1, 2, 3, 8 and the remaining extent of the farm Mamatwan 331 and the farm Moab 700. Neighbouring land-use in the region mainly comprises agricultural (livestock farming) and mining activities. The mines located in the vicinity of the proposed development site include various manganese mines like the adjacent Mamatwan Mine (~20km to the south of Hotazel), Wessels Mine (situated 20km to the north west of Hotazel) as well as the Gloria and Nchwaning mines which are situated to the north-west and north of the proposed development site respectively. The location of these manganese mines in relation to the proposed development site is shown in Figure 4-1.

4.1.1 Current Mining Operations

Operating mines located in relatively close proximity to the proposed development site include AssMang's N'Chwaning and Gloria mines and Samancor's Wessels and Mamatwan mines. (N'Chwaning I, Black Rock, Hotazel, Langdon-Annex, Devon, York, Perth, Smart, Adams and A. Pyper mines are no longer in operation). The N'Chwaning (shafts 2 and 3), Gloria and Wessels mines are exclusively underground operations, whereas opencast mining is practiced at Mamatwan. Mamatwan is also the only mine in the area that currently has on-site sintering.

The Nchawaning mine was originally established in 1972 with the No.2 shaft coming into production in 1981. The still active shaft, with a capacity of approximately 120 000 tons per month, produces ore that is crushed underground before it is brought to the surface. The No.3 shaft complex became fully operational in 2006 and has a capacity of approximately 200 000 tons per month. The ore from No.2 and No.3 shafts is crushed, washed and stacked according to size and grade (Assmang, 2008).

Gloria mine started production in 1978 and consists of a vertical and an inclines shaft. The ore, approximately 1 million tons per annum, is crushed underground and conveyed to the ore processing plant where it is crushed, washed and screened (Assmang, 2008).

BHP Billiton's Hotazel Manganese Mines (HMM), produces manganese ores and integrated ferroalloys. HMM operates two manganese mines – Wessels (underground) and Mamatwan (open-cut). Wessels mine is situated 300m below the surface and access is gained through a vertical shaft and two incline shafts. The manganese ore is crushed underground and temporarily stored underground before it is conveyed to the surface for washing and screening (BHP Billiton, 2009).

The opencast Mamatwan mine was initially developed to provide ore for the local ferroalloy industry. Ore is hauled to an in-pit primary crusher and thereafter conveyed to a beneficiation plant. At the beneficiation plant ore is conveyed to two parallel circuits that comprises secondary crushing and screening. A dense medium separation (DMS) plant is used to beneficiate the ore before sintering. At the sinter plant the ore is calcined and partially reduced. The final sinter product is transported to the rail loading facility (BHP Billiton, 2009).

United Manganese of the Kalahari Mine (UMK) is a new manganese mine that is currently in the construction phase (personal communication, B. Diko, Metago). UMK is situated approximately 5 km to the north-north-east of the proposed Ntsimbintle mine. UMK will be an opencast operation and will include a crushing and screening plant, a dense media separation (DMS) plant and a sinter plant. Approximately 900 000 tons of sinter will be produced at the sinter plant per year.

Fugitive dust sources from the abovementioned mining operations may include wind blown dust from open areas, vehicle entrained dust from paved and unpaved roads, dust from materials handling operations and crushing and screening operations. Mamatwan opencast and sintering operations may also include fugitive dust emissions from drilling and blasting as well as point source emissions from the sinter plant.

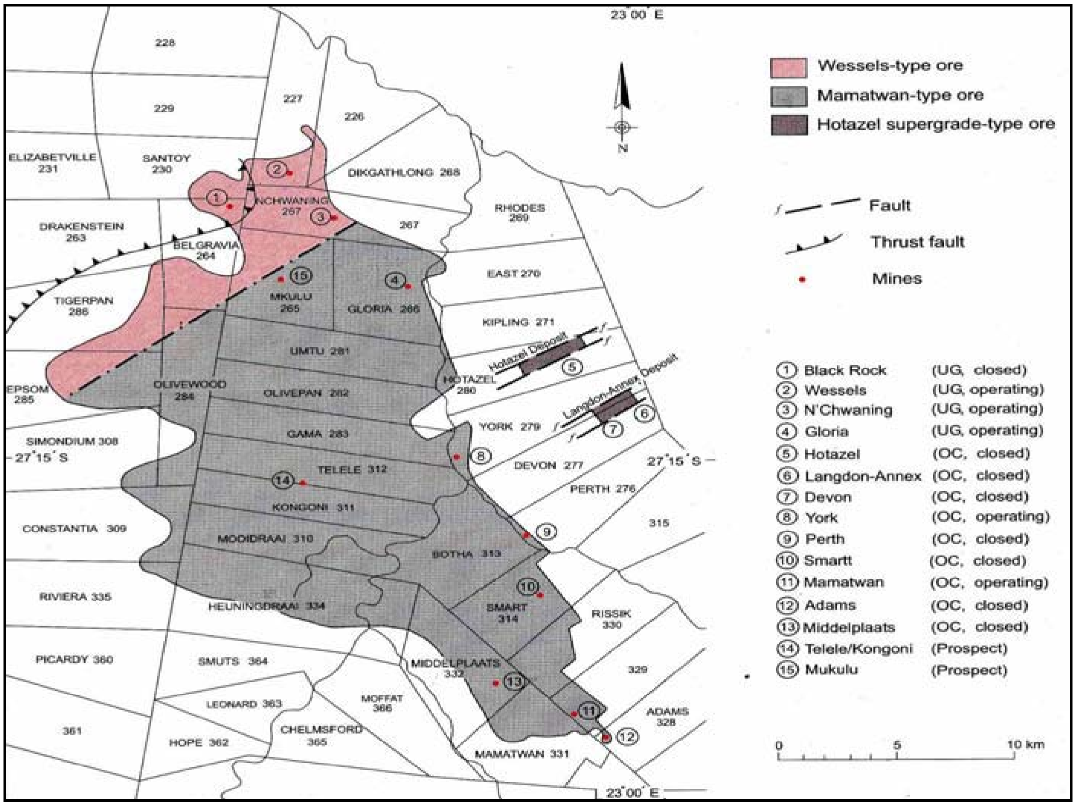

Figure 4-1: **Kalahari Manganese Field (Astrup and Tsikos, 1998)**

Delta Electrolytic Manganese Dioxide (EMD), owned by Delta Electrical industries Limited, is an ore reduction facility next to the N'Chwaning mine (Figure 4-12). Delta recently installed its kiln in the Northern Cape for the purpose of producing its own reduced ore feed for its EMD plant at Nelspruit, Mpumalanga Province. Atmospheric emissions from this facility may occur as a result of fugitive dust sources (materials handling, vehicle entrainment, wind erosion, etc.) in addition to process emissions from their kiln operations.

4.1.2 Fugitive Dust Releases unrelated to Mining

Fugitive dust emissions may occur as a result of vehicle entrainment of dust from local paved and unpaved roads, wind erosion from open areas and dust generated by agricultural activities. Given that the agriculture in the area is primarily restricted to livestock and game farming, agriculture is not anticipated to contribute significantly to ambient dust rates. Vehicle entrainment from the various unpaved farm and public roads is anticipated to be a significant but localised source of dust. Several of the unpaved roads in the area are planned to be paved in the near future.

4.1.3 Vehicle Exhaust Emissions

Air pollution from vehicle exhausts may be grouped into *primary* and *secondary* pollutants. Primary pollutants are those emitted directly into the atmosphere, and secondary, those formed in the atmosphere as a result of chemical reactions, such as hydrolysis, oxidation, or photochemical reactions. The significant primary pollutants emitted by motor vehicles include carbon dioxide (CO_2), carbon monoxide (CO), hydrocarbons (HCs), sulphur dioxide, oxides of nitrogen (NOx) and particulates. Secondary pollutants include nitrogen dioxide (NO_2) and photochemical oxidants (e.g. ozone), sulphuric acid and nitric acid. Given the relatively low traffic volumes in the region, atmospheric emissions from vehicle activity are anticipated to be a relatively minor source of air pollution.

4.1.4 Household Fuel Combustion

The proposed development is located within the Kgalagadi District Municipality. According to the 2001 census information, Kgalagadi District Municipality comprises ~44 700 households, of which approximately 30% are classified as either “traditional” or “informal”. About 60% of households were given as using electricity for lighting purposes, implying that the remaining households are likely to have been unelectrified and therefore reliant on the combustion of fuels to meet their energy requirements. A number of electrified households are also likely to burn fuels for their cooking and heating requirements due to the relatively higher cost of using electricity for these purposes. From the 2001 census information it is evident that numerous households burn fuels, primarily wood and paraffin, to meet their energy requirements. Wood was burned by 38% of households for cooking purposes (paraffin by 17% of households) and by 51% of households for heating purposes (paraffin by 10% of households) (Table 4-1).

Table 4-1: Household energy use within Kgalagadi District Municipality (2001 census data)

Energy Use	Energy Carrier Used	% of Households
Cooking	Electricity	34.20
	Gas	6.88
	Paraffin	16.97
	Wood	38.27
	Coal	0.20

Energy Use	Energy Carrier Used	% of Households
	Animal dung	3.26
	Solar	0.11
	Other	0.12
	Not Applicable	0.00
Heating	Electricity	31.07
	Gas	1.36
	Paraffin	9.99
	Wood	51.20
	Coal	0.63
	Animal dung	3.28
	Solar	0.08
	Other	2.39
	Not Applicable	0.00
Lighting	Electricity	59.40
	Gas	0.10
	Paraffin	4.59
	Candles	35.43
	Solar	0.10
	Other	0.37
	Not Applicable	0.00

Pollutants arising due to the combustion of wood include respirable particulates, nitrogen dioxide, carbon monoxide, polycyclic aromatic hydrocarbons, particulate benzo(a)pyrene and formaldehyde. Particulate emissions from wood burning within South Africa have been found to contain about 50% elemental carbon and about 50% condensed hydrocarbons.

The main pollutants emitted from the combustion of paraffin are NO_2, particulates, carbon monoxide and polycyclic aromatic hydrocarbons.

4.1.5 Rail Related Emissions

Rail-related emissions are another source of emissions in the region with diesel locomotives being used to transport ore from mines in the area. Pollutants associated with diesel-powered locomotives include particulates, nitrogen oxides, particulates, sulphur dioxide, carbon monoxide and various volatile organic compounds including polycyclic aromatic hydrocarbons.

4.1.6 Veld Burning

General wild fires (veld fires) represent significant sources of combustion-related emissions in many areas of the country. The extent of emissions from veld burning is dependent on the frequency and quantity of material (biomass) available for combustion. The quantity of dry, combustible matter per unit area is on average 4.5 ton per hectare for savannah areas.

Biomass burning is an incomplete combustion process with carbon monoxide, methane and nitrogen dioxide being emitted during the process. About 40% of the nitrogen in biomass is emitted as nitrogen, 10% remains in the ashes and it is assumed that 20% of the nitrogen is emitted as higher molecular weight nitrogen compounds. Unlike nitrogen species, only small amount of sulphur dioxide and sulphate aerosols are emitted. The visibility of smoke plumes from vegetation fires is due to their aerosol content (Helas and Pienaar, 1996).

According to local residents and evidence from satellite images showing burn scars veld fires occur relatively infrequently in the region. Local veld burning is therefore classified as being of low significance to air pollutant concentrations, with resultant air pollutant episodes being intermittent and of relatively short duration.

4.1.7 Long-Range Transport of Aerosols

Regionally-transported, aged aerosols (particulates) have been shown to contribute significantly to background particulate concentrations over much of the country including remote sites. Source apportionment studies have identified four major contributing source types of regional significance to the atmospheric aerosol loading. The four source types include aeolian crustal material consisting of mineral soil dust, marine aerosols from the two adjacent oceans, biomass burning particles occurring mainly north of 20°S and finally, aerosols from industrial emissions. Emissions from these four sources have been observed in the past at remote sites in South Africa (Piketh *et al.,* 1996; Salma *et al.*, 1992). The exact contribution of aged aerosols to fine particulate loadings at the study site is not known.

4.2 Measured Air Pollutant Concentrations

No baseline ambient air quality monitoring was conducted during the current study with the scope of study being restricted to the collation of existing monitoring data sets. Suspended total particulate concentrations and ambient manganese concentrations have been recorded in the study region by the CSIR. Access to this information was facilitated through the measurements having been documented within EMPRs for local mining operations. Monitoring of total suspended particulates in close proximity to sources at the Wessels and Mamatwan mines were similarly obtained from the EMPRs undertaken for these mining operations.

Although dust deposition monitoring, aimed at determining nuisance fallout dust, has been undertaken by certain mines within the study region, results from this monitoring are not in the public domain nor could permission be obtained to access such results for the purpose of this study.

4.2.1 Suspended Particulate Concentrations

Peak total suspended particulate (TSP) concentrations were measured ~20 metres downwind from various sources at the Wessels Mine. TSP concentrations were recorded as typically being in the order of 300µg/m³ in close proximity to Wessels mining operations (Jones & Wagener, 2005a). Higher TSP concentrations were noted to occur within the vicinity of Mamatwan mining operations (~ 3000 µg/m³) (Jones & Wagener, 2005b).

In contrast to the high suspended particulate concentrations occurring on-site at mining operations in close proximity to significant sources, ambient airborne particulate concentrations are notably lower. In 1999 CSIR, on behalf of Assmang, conducted ambient monitoring of TSP and manganese levels within residential areas close to local mining operations near Black Rock and at two baseline sites in Kuruman and van Zylsrus (as documented in Wates, Meiring and Barnard, 2002, 2003) (Table 4-2). Average ambient TSP concentrations were recorded to be relatively low, in the order of 20 µg/m³ to 30 µg/m³, even at hostels and residential areas located in relative proximity to mining operations (during 1999).

Table 4-2: Average recorded TSP and manganese concentrations

Site	TSP (mg/m³)	Manganese in TSP Fraction (µg/m³)	Manganese Portion as % of Total TSP
Kuruman	22.3	0.095	0.43
Van Zylsrus	4.3	0.005	0.12
Black Rock Hostel	33.0	2.25	6.82
Black Rock Village	27.0	0.87	3.22
Schoonspruit Village	21.0	0.89	4.24

4.2.2 Ambient Manganese Concentrations

Crustal manganese enters the atmosphere by a number of natural and anthropogenic processes, which include the suspension of road dusts by vehicles and wind erosion and the suspension of soils, particularly in agricultural, construction and quarrying activities. The resulting mechanically generated aerosols consist primarily of coarse particles ≥ 2.5 µm mass median aerodynamic diameter (MMAD). The smelting of natural ores and the combustion of fossil fuels also result in the ejection of crustal manganese to the atmosphere in the form of fume or ash in the fine-particle range (< 2.5 µm MMAD). The manufacture of ferroalloys and other industrial processes are major sources of manganese in the fine fraction released to the atmosphere (WHO, 2000).

Coarse particles of manganese tend to settle out near sources of pollution, but fine particulate manganese can be distributed very widely. The most common forms of manganese compounds in coarse particles of crustal origin are oxides or hydroxides of oxidation state +2, +3 or +4, and manganese carbonate. The manganese emitted by metallurgical processes consists primarily of oxides.

4.2.2.1 Typical Ranges of Ambient Manganese Concentrations from the Literature

To determine likely levels of manganese in the inhalable fraction reference is made to the literature. Background manganese concentrations of 0.05 – 5.4 ng/m^3 over the Atlantic Ocean and 0.01ng/m^3 at the South Pole have been reported. For the period 1979 – 1983, the median ambient concentration of particulate manganese with an MMAD =10 µm (PM10) for sites in the US Environmental Protection Agency's Inhalable Particulate Network was approximately 0.02 µg/m^3, with a 10th percentile level of 0.01 µg/m^3 and a 99th percentile value of over 0.2 µg/m^3. In the Federal Republic of Germany, annual mean concentrations of manganese ranged between 0.003 µg/m^3 and 0.016 µg/m^3 in Frankfurt, Main and Munich; in Belgium over the period 1972 – 1977, annual mean manganese concentrations of between 0.042 µg/m^3 and 0.456 µg/m^3 were reported. The Environmental Agency of Japan reported an annual mean manganese concentration of about 0.02–0.8 µg/m^3 in Japanese cities, with maximum 24-hour concentrations of 2 – 3 µg/m^3. Typical ambient levels of manganese, observed in the Johannesburg and Pretoria regions of South Africa, range from 0.004 to 0.16 µg/m^3 with a mean value reported of 0.047 µg/m^3 (Burger, 2002).

The highest concentrations of manganese in the working environment have been reported from manganese mines, ore-processing plants, dry-cell battery plants and ferromanganese plants. In mining operations, manganese concentrations of up to 250 mg/m^3 or even higher have sometimes were found. In dry-cell battery and ferromanganese plants, the concentrations of manganese in air are lower. Values of 5 – 8 mg/m^3, and occasionally up to 20 mg/m^3 or more, have been reported.

From the studies documented above it can be concluded that *ambient* annual average levels of manganese in urban and rural areas without major point sources of manganese pollution are typically in the range of 0.01 - 0.07 µg/m^3 (WHO, 2000). In the proximity of foundries, manganese concentrations may rise to an annual average of 0.2 - 0.3 µg/m^3 and, in the presence of ferromanganese and silicomanganese industries, to over 0.5 µg/m^3. In such places, the average 24-hour concentrations may exceed 10µg/m^3. *On-site*, within the work environment, manganese concentrations in the 5 to 20 mg/m^3 range are typical.

4.2.2.2 Measured Ambient Manganese Concentrations within the Study Region

Measured ambient manganese concentrations within the study region, as obtained from EMPRs, are presented in Table 4-2. It should be noted that the manganese concentrations documented are given as total manganese (all fractions) and that the health thresholds given in Table 2-3 for *inhalable* (>10 µm) manganese exposures are therefore not directly comparable.

Whereas the manganese fraction of the recorded TSP was measured to be below 0.5% for the baseline sites at Kuruman and Van Zylsrus, the manganese fraction was observed to be higher (3.2% to 3.8%) at the residential locations situated closer to the manganese mining operations. Based on the assumption that the PM10 fraction comprises at least 20% of the TSP recorded, and assuming that the manganese content of PM10 is similar to that of the TSP, it may be concluded that suspended Mn concentrations at the remote Kuruman and van Zylsrus sites are within the annual WHO limit, whereas concentrations recorded at Black Rock Hostel, Black Rock Village and Schoonspruit Village may potentially exceed this limit.

4.3 Synopsis of Baseline Air Quality Findings

The existing air quality at the proposed development site is anticipated to be significantly affected, given the nature, extent and relative location of existing atmospheric sources in the area. The potential for cumulative air pollution concentrations, and hence impacts, does therefore exist. Elevated manganese concentrations are however noted to occur within the vicinity of other manganese mining operations indicating the importance of minimising manganese emissions from the proposed mine as far as possible.

5 AIR QUALITY IMPACT ASSESSMENT

5.1 Process Description

The Ntsimbintle manganese mining operation will include opencast as well as underground mining. The proposed opencast mining will extend over 6 to 10 square kilometres with an expected life of between 30 and 50 years. The underground mining operations could continue between 10 to 30 years depending on market conditions.

The planned production rate at the mine is between 1.5 and 4 million tons of manganese ore per year. Waste rock from the mining operations will be stockpiled and/or used for rehabilitation and construction. Ore will be conveyed from the pit area to the processing plant area.

The processing plant will produce manganese product of different grades and sizes as per customer requirements. The planned production rate of the processing plant is approximately 125 000 to 335 000 tons per month. Ore will be transported to markets by rail.

Ntsimbintle also proposes the operation of a sinter plant for the beneficiation of ore and a power generation plant (Metago, 2008).

The planned timing of the proposed operations is as follows:

1. Opencast Mining: start - 2011, duration - 30 to 50 years
2. Processing Plant: construction - 2012
3. Underground Mining: start - 5 years before opencast mining ends, duration - 30 years
4. Sinter Plant: start - 2020

The proposed activities at Ntsimbintle which may become sources of atmospheric emission are:

- Drilling of waste rock and ore;
- Blasting of waste rock and ore;
- Truck and shovel operations in the pit;
- Primary, secondary and tertiary crushing and screening at the processing plant;
- Stockpiling and storage of products and waste;

- On-site vehicle movement;
- Electricity generation; and
- Sintering operations

The process flow diagram of the proposed processing and beneficiation operations are provided in Figure 5-1. The proposed site layout of the Ntsimbintle mine is shown in Figure 5-2.

5.2 Emissions Inventory

The establishment of a comprehensive emission inventory formed the basis for the assessment of the impacts from of the proposed operation's emissions on the receiving environment. The establishment of an emissions inventory comprised the identification of sources of emission, and the quantification of each source's contribution to ambient air pollution concentrations.

Potential sources of atmospheric emission as well as the possible pollutants were identified based on the process description and flow diagram as provided by the client (Section 5.1).

Fugitive dust emissions occur as a result of vehicle-entrained dust from paved and unpaved roads, wind erosion from open areas, material handling operations, drilling and blasting as well as crushing and screening operations. In the quantification of fugitive dust emissions use was made of emission factors which associate the quantity of a pollutant to the activity associated with the release of that pollutant. Due to the absence of locally generated emission factors, reference was made to emission factors such as those published by the US Environmental Protection Agency (US-EPA) in its AP-42 document and the Australian National Pollutant Inventory (NPI). The US-EPA AP-42 emission factors are of the most widely used in the field of air pollution.

Sinter plant point source emissions (PM10, SO_2 and NO_2) were estimated based on emission limits (Section 2.4). Inhalable size fraction (<10 μm) manganese emissions were calculated based estimated PM10 emissions and the expected manganese content of the various materials that will be handled at Ntsimbintle.

Emissions from the four 2000 kVA Cat diesel generators proposed for electricity generation purposes were determined based on information provided by Metago.

In the estimation of haul truck exhaust emissions reference was made to the NPI emission factors for combustion engines.

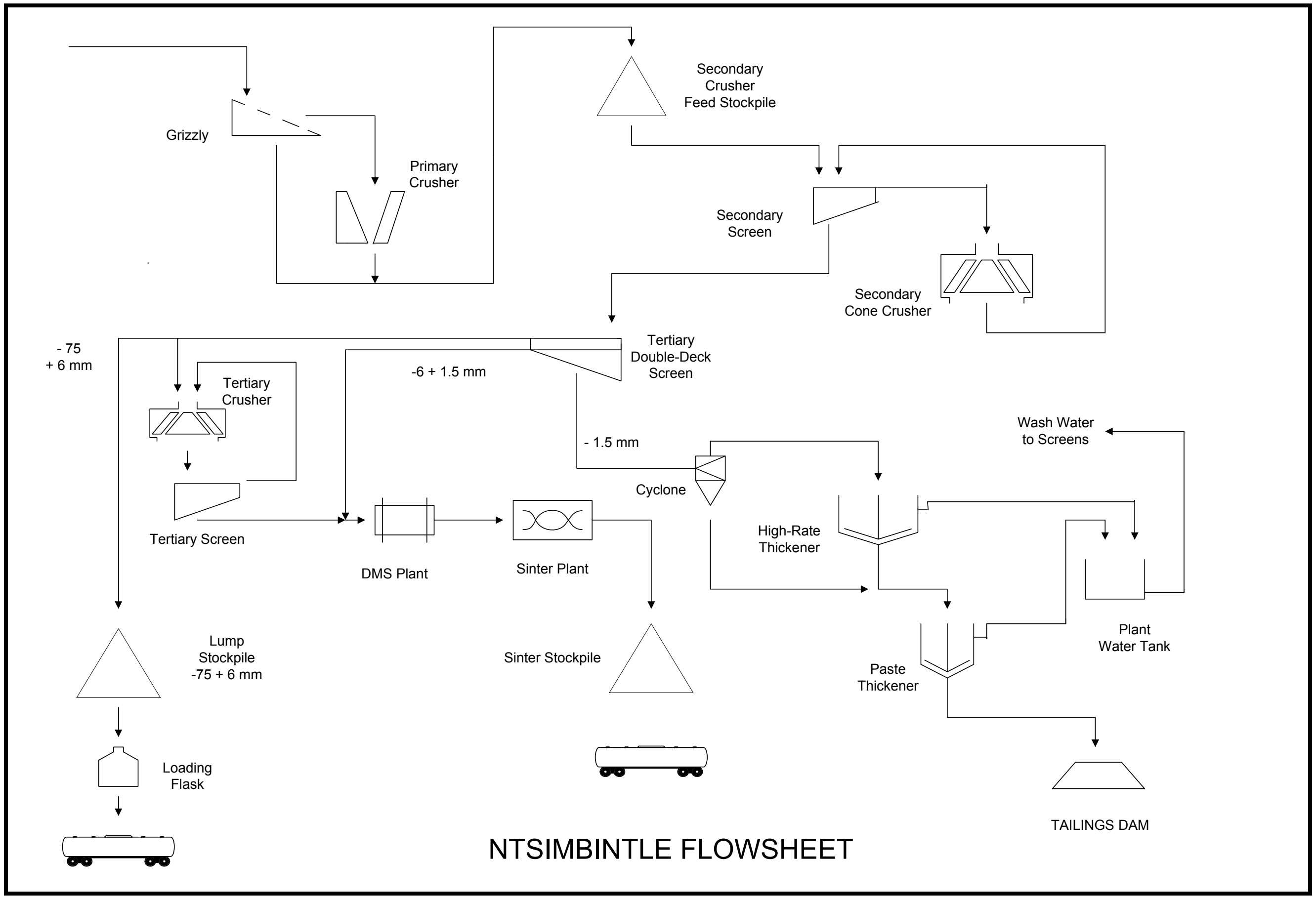

Figure 5-1: Flow diagram of current operations at Ntsimbintle

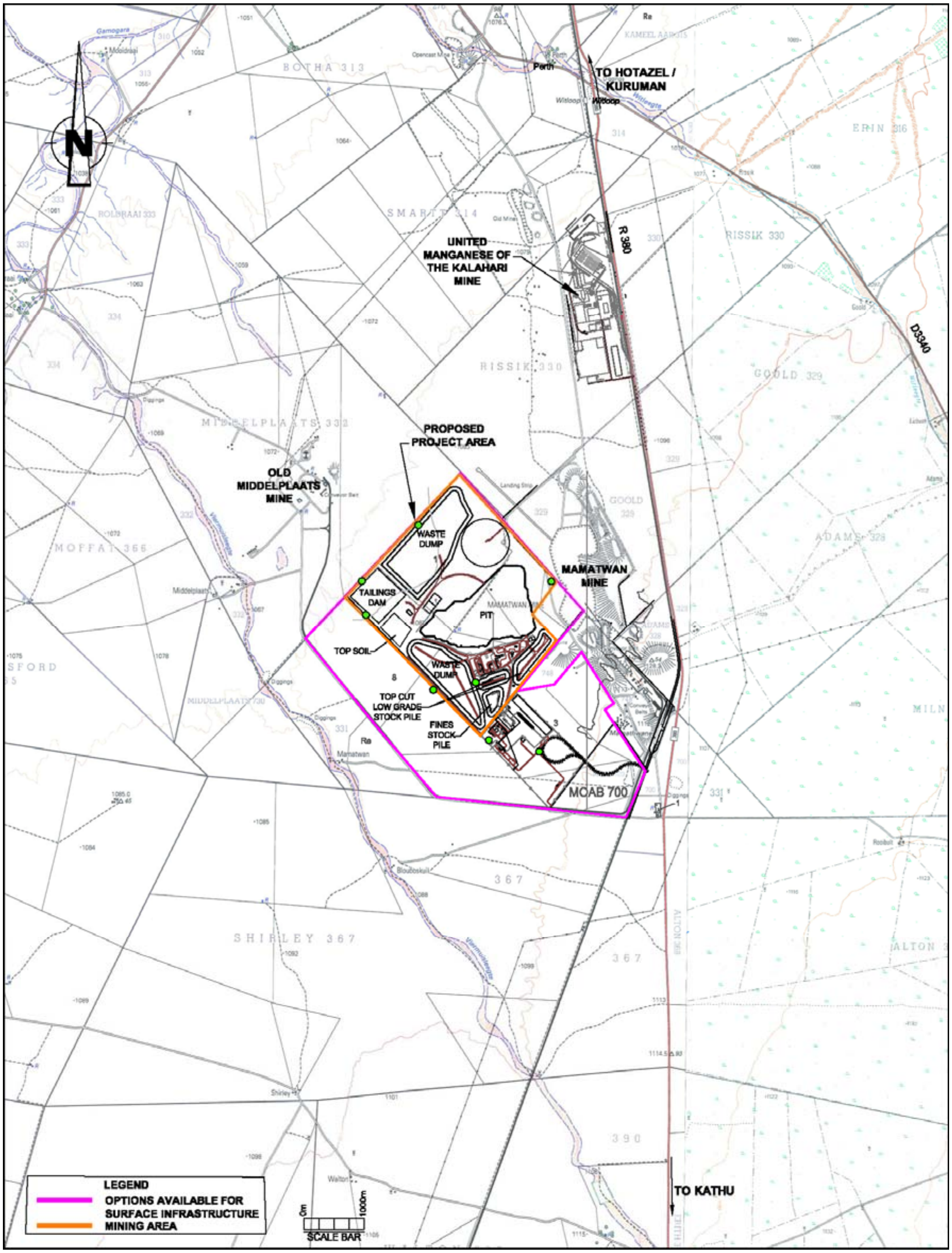

Figure 5-2: Proposed Ntsimbintle site layout

Emissions from Ntsimbintle were quantified for three phases namely:

1. a construction phase
2. an operational phase (Scenario 1) that includes the power generation plant, opencast and underground mining, processing and the beneficiation of manganese ore; and
3. an operational phase (Scenario 2) that only includes s the power generation plant, underground mining, the rehabilitation of the opencast mine and the processing and beneficiation of the manganese ore

It is assumed that all processing operations will have ceased by the closure phase of the project. The potential for impacts during this phase will depend on the extent of demolition and rehabilitation efforts during closure and on features which will remain. Information regarding the extent of demolition and/or rehabilitation procedures were limited and therefore not included in the emissions inventory.

Material production and throughput rates as well as manganese contents relevant to the estimation of emissions from the proposed development are given in Table 5-1. The mine will operate 24 hours per day, 365 days per year and the processing plant 24 hours per day, 260 days per year.

A summary of the sources of emission associated with the various phases of the mine considered in the study as well as the pollutants of concern are provided in Table 5-2.

Table 5-1: Planned material consumption and production rates

Operational Area	Material	Tons per Annum	
		Scenario 1	Scenario 2
Opencast Mining	Waste Rock	12,760,000.00	0.00
	Topsoil	2,000,000.00	0.00
	ROM	4,460,000.00	0.00
	Lumpy Product	3,000,000.00	0.00
Underground Mining	ROM	2,000,000.00	2,000,000.00
Crusher Plant	Primary	6,460,000.00	2,000,000.00
	Secondary	6,460,000.00	2,000,000.00
	Tertiary	1,500,000.00	1,500,000.00
	Tailings	180,000.00	180,000.00
DMS Plant	Ore Input	1,500,000.00	1,500,000.00
	Tailings	250,000.00	250,000.00
Sinter Plant	Ore Input	1,500,000.00	1,500,000.00
	Anthracite	80,000.00	80,000.00
	HFO	2,790.00	2,790.00
	Sinter	1,000,000.00	1,000,000.00
Power Generation Plant	Diesel	19,550.00	19,550.00

Table 5-2: Sources of atmospheric emission associated with the proposed Ntsimbintle Mine

Source Type		Construction Phase	Operational Phase		Closure Phase[(a)]
			Scenario 1	Scenario 2	
Fugitive dust emissions from general construction activities		✓	-	-	-
Fugitive dust emission from drilling[(e)]		-	✓	-	-
Fugitive dust emissions from blasting[(e)]		-	✓	-	-
Fugitive dust emissions from materials handling [(e)]	Excavation	-	✓	-	-
	Tipping from haul trucks	-	✓	✓	-
	Conveyor transfer points	-	✓	✓	-
Fugitive dust emissions from crushing and screening[(e)]	Primary crushing & screening	-	✓	✓	-
	Secondary crushing & screening	-	✓	✓	-
	Tertiary crushing & screening	-	✓	✓	-
Vehicle entrained dust from roads[(e)]	In-pit unpaved haul roads	-	✓	-	-
	Paved access roads	-	✓	✓	-
Fugitive dust emissions from wind erosion[(e)]	Waste disposal sites	-	✓	✓	-
	ROM and product stockpiles	-	✓	✓	-
	Fine tailings disposal facility	-	✓	✓	-

Source Type		Construction Phase	Operational Phase		Closure Phase[a]
			Scenario 1	Scenario 2	
Gaseous emissions	Blasting[b]	-	-	-	-
	Vehicle tailpipe emissions[c]	-	✓	✓	-
	Sinter plant emissions[d]	-	✓	✓	-
	Power generation plant emissions[f]	-	✓	✓	-

Notes:

(a) It was assumed that all processing operations will have ceased by the closure phase of the project. The potential for impacts during this phase will depend on the extent of demolition and rehabilitation efforts during closure and on features which will remain. Information regarding the extent of demolition and/or rehabilitation procedures were limited and therefore not included in the emissions inventory.

(b) Blasting could potentially be a significant source of gaseous emissions at the proposed mine. The duration of an individual blasting episode is however relatively short and usually occurs only once a day and does not normally result in significant impacts (Liebenberg-Enslin et al. , 2006) Gaseous emissions as a result of blasting were therefore not included in the emissions inventory.

(c) Vehicle tailpipe emissions include SO_2, NO_x, CO and diesel particulate matter (DPM).

(d) Sinter plant emissions include PM10, Mn, SO_2 and NO_x.

(e) Includes PM10, TSP and Mn emissions.

(f) Power generation plant emissions include TSP, PM10, SO_2, NO_x and CO.

5.2.1 Fugitive Dust Emissions

5.2.1.1 Construction

The construction phase normally comprises a series of different operations including land clearing, topsoil removal, road grading, material loading and hauling, stockpiling, grading, bulldozing, compaction, (etc.) (Table 5-3). Each of these operations has their own duration and potential for dust generation. It is anticipated 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.

Table 5-3: Typical environmental impacts and associated activities during construction

Impact	Source	Activity
TSP and PM10	Plant site	Clearing of groundcover
		Levelling of area
		Infrastructure edifice (crushers, conveyors, on site unpaved roads, storage areas, administration buildings)
		Wind erosion from topsoil storage piles
		Tipping of topsoil to storage pile
	Unpaved roads	Clearing of vegetation and topsoil
		Loading and unloading of topsoil
		Wind erosion from topsoil storage pile
		Tipping onto topsoil storage pile
		Vehicle entrainment on unpaved road surfaces
	Transport infrastructure	Clearing of vegetation and topsoil
		Levelling of proposed transportation route areas
Gases and particulates	Vehicles	Tailpipe emissions from construction and haul vehicles at the construction sites.

If detailed information regarding the construction phase of the proposed project had been available, the construction process would have been broken down into component operations as shown in Table 5-3, for emissions quantification and dispersion simulations. Due to the lack of detailed information (e.g. number of dozers to be used, size and locations of temporary stockpiles and temporary roads, rate of on-site vehicle activity), emissions were instead estimated on an area wide basis. The quantity of dust emissions was assumed to be proportional to the area of land being worked and the level of construction activity.

In the quantification of releases from the construction phase, use was made of emission factors published by the US-EPA (EPA, 1996), since no local emission factors are available. The approximate emission factors for construction activity operations are given as:

$$E_{TSP} = 2.69\text{Mg/hectare/month of activity}$$

The PM10 fraction is given as ~39% of the US-EPA total suspended particulate factor. It is applicable to construction operations with active large –scale earth moving operations. These emission factors are most applicable to construction operations with (i) medium activity levels, (ii) moderate silt contents, and (iii) semi-arid climates. The emission factor for TSP considers 42 hours of work per week of construction activity.

The total area that would be under construction, including plant and infrastructure areas, was calculated to be in the order of 33 ha. Assuming that construction would occur over about a year and that dust would be controlled through water sprays (75% control efficiency) (NPI, 2001), the calculated annual TSP and PM10 emissions would be in the range of 266 tpa and 104 tpa respectively.

5.2.1.2 *Drilling*

Fugitive dust emissions due to the in-pit drilling operations at the mine were quantified using the Australian NPI single value emission factors for mining (Appendix B). Source specific information that was assumed in the calculation of drilling emissions is presented in Table 5-4. The drill will be equipped with a cyclone and it was assumed to result in 25% control efficiency (NPI, 2001).

Table 5-4: Drilling source specific information

Hours per day	8
Days per year	260
Holes drilled per day	193[(a)]

Notes:

(a) Calculated based on the worst case of 4200 holes/month

5.2.1.3 Blasting

Fugitive dust emissions due to blasting at the opencast mine were quantified using the US EPA predictive emission factor equation for mining (Appendix B). Source specific information that was used in the calculation of blasting emissions is presented in Table 5-5. No mitigation was applied to blasting operations.

Table 5-5: Blasting source specific information

Blasts per Day	1
Blasts per Week	5
Area Blasted per Day (m²)	3040[(a)]

Notes:

(a) Calculated based on planned 15 200 m² blasted per week

5.2.1.4 Materials Handling

Materials handling points at the proposed operation include in-pit excavation operations, tipping of material from trucks and conveyor transfer points. The US EPA AP42 predictive equation (Appendix B) was used to estimate emissions from material transfer operations.

The material moisture content, material throughput rates and assumed control efficiencies used in the calculation of emissions for each point are presented in Table 5-6. Water sprays with a general control efficiency of 70% on material unloaded from trucks and 50% on conveyor transfer points (NPI, 2001) were applied in the estimation of mitigated emissions. Emissions from materials handling points were calculated using the hourly average wind speed of 2.94 m/s measured at Kuruman.

Table 5-6: Materials handling source specific information

Scenario:	Source	Throughput (tons/hour)	Moisture (%)[(a)]
Scenario 1	Open-pit, loading topsoil to truck	228.31	6
	Open-pit, loading waste to truck	1,456.62	6
	Open-pit, loading ore to truck	509.13	5

Scenario:	Source	Throughput (tons/hour)	Moisture (%)[(a)]
	Topsoil stockpile, offloading topsoil from truck	228.31	6
	Waste dump 11a, offloading waste from truck	728.31	6
	Waste dump 11b, offloading waste from truck	728.31	6
	Ore stockpile, offloading ore from truck (UG & OC)	737.44	5
	Primary stockpile, stockpiling ore by conveyor	737.44	5
	Secondary crusher feed stockpile, stockpiling ore by conveyor	737.44	5
	Lumpy Stockpile 5a, stockpiling by conveyor	171.23	5
	Lumpy Stockpile 5b, stockpiling by conveyor	171.23	5
	Loading flask, loading lumpy ore to train	342.47	5
	Loading flask, loading sinter ore to train	114.16	5
	Anthracite offloading from truck	9.13	3.54
	Sinter Stockpile 8a, stockpiling by conveyor	57.08	5
	Sinter Stockpile 8b, stockpiling by conveyor	57.08	5
Scenario 2	Ore stockpile, offloading ore from truck (UG)	228.31	5
	Primary stockpile, stockpiling ore by conveyor	228.31	5
	Secondary crusher feed stockpile, stockpiling ore by conveyor	228.31	5
	Loading flask, loading sinter ore to train	114.16	5
	Anthracite Offloading	9.13	3.54
	Sinter Stockpile 8a	57.08	5
	Sinter Stockpile 8b	57.08	5
	Open-pit rehabilitation, off loading topsoil from truck	9.13	6
	Open-pit rehabilitation off loading waste from truck	57.08	6

Notes:

(a) Obtained from sample analyses at similar operations.

5.2.1.5 Vehicle Entrained Dust from Unpaved Haul Roads

Fugitive dust emissions from unpaved haul roads were calculated using the US EPA predictive emission factor equation (Appendix B) assuming haulage of the material volumes as given in Table 5-1. A mean silt content of 8.4% was used as input in the emission estimations due to the absence of data on-site specific road silt loading data. (The road silt content range for coal mining haul roads is given by the US-EPA as 2.8% to 18%). Off-highway haul trucks with a capacity of 30 tons will be used at the mine. A control efficiency of 90%, achievable through chemical dust suppression, was applied to all the haul roads included in the study.

The following vehicle activities were included:

- Scenario 1:
    - In-pit unpaved haul roads for the transport of ore, waste rock and topsoil; and
    - Haulage of topsoil and waste rock from the pit to the dumps.
- Scenario 2:
    - Haulage of topsoil and waste rock from the dumps to the pit for rehabilitation of the opencast mining area

5.2.1.6 Vehicle Entrained Dust from Paved Access Road

Fugitive dust emissions from the paved road were calculated using the US EPA predictive emission factor equation (Appendix B) assuming the delivery of anthracite and HFO volumes as given in Table 5-1. A mean silt loading of 9.7 g/m² was used as input in the emission estimations due to the absence of data on-site specific road silt loading data. The anthracite and HFO delivery bulk carriers were assumed to have an average weight of 25 tons. A control efficiency of 90%, achievable through the sweeping of the road surface, was applied to all the access road.

5.2.1.7 Crushing and Screening

Crushing and screening plants represent significant dust-generating sources if uncontrolled. Dust fallout in the vicinity of crushers also give rise to the potential for the re-entrained of dust emitted by vehicles or by the wind at a later date. The large percentage of fines in this deposited material enhances the potential for it to become airborne. Fugitive dust emissions due to the crushing and screening operations for mine were quantified using US-EPA single valued emission factors for such operations (Appendix B). The crushing and screening operations for which emissions were estimated are given in Table 5-7, together with the quantities of material being processed. All crushing operations were assumed to be equipped with extraction hoods and fabric filters with a control efficiency of 83%.

Table 5-7: Crushing and screening source specific information

Scenario	Crushing Source	Throughput (tph)	Moisture Content (%)[a]
Scenario 1	Primary Crushing & Screening	737.44	5.00
	Secondary Crushing & Screening	737.44	5.00
	Tertiary Crushing & Screening	171.23	5.00
Scenario 2	Primary Crushing & Screening	228.31	5.00
	Secondary Crushing & Screening	228.31	5.00
	Tertiary Crushing & Screening	171.23	5.00

Notes:

(a) Obtained from sample analyses at similar operations.

5.2.1.8 Wind Erosion

A discussion about the estimation of wind erosion emissions from stockpiles with fine material (diameter less than 2mm) using the ADDAS model is provided in Appendix B. Source parameters used in the emissions estimation and simulations for wind erosion is given in Table 5-8. Since no site specific information was available, particle size analysis from similar operations were used.

NOTE: Emissions from wind erosion were however estimated to be negligibly low and henceforth omitted from the study.

Table 5-8: Parameters pertaining to wind erosion of exposed areas

Scenario	Source	Area (m²)[(a)]	Height (m)	Bulk Density (kg/m³)[(b)]	Moisture Content (%)[(b)]	Roughness Length (m)
Scenario 1 and 2	Fines Stockpile	299,177.00	15	2,240.00	0.5	0.001
	Tailing Dam	422,253.00	25	2,240.00	0.5	0.001
	Topsoil Stockpile	161,583.00	5	1,608.75	6	0.001

Notes:

(a) Areas were estimated from the site layout map.

(b) Obtained from sample analyses at similar mining operations.

5.2.2 Gaseous Vehicle Tailpipe Emissions

Emission factors applied in the calculation of emissions from the off-highway haul trucks are given in Table 5-9 (NPI, 2008). Use was also made of fuel consumption rates obtained from various off-highway truck manufacturers for various operational loads i.e. ***low*** (low gradients and long idling times) to ***high*** (steep gradients and short idling times). The average diesel consumption for the trucks proposed for use at Ntsimbintle was assumed to be 35 ℓ per hour. Gaseous emissions as a result of heavy vehicle activity were estimated based on the number of trips required to transport the material volumes provided in Table 5-1 by truck (capacity 30 tons).

Table 5-9: Emission factors (a) applied in the calculation of vehicle tailpipe emissions

Pollutant	Emission Factor (g/ℓ of fuel)
Diesel Particulates Matter (2.5 µm)	2.08
NO_x	34.1
CO	14.57
SO_2	1.19[(b)]

Notes:

(a) NPI Emission Estimation Technique Manual for Combustion Engines (2008).

(b) Sulphur dioxide emission factor was estimated based on 500 ppm sulphur content for diesel fuel.

5.2.3 Sinter Plant Stack Emissions

The sinter plant will use a wet scrubber to clean off-gas from the sinter strand and a baghouse for the cleaning of gas from the sinter cooler. Emissions from the proposed sinter plant at Ntsimbintle mine were estimated based on the emission limits as described in Section 2.4 (Table 2-1). The stack parameters along with the emission limits used in the calculation of emissions from these sources are provided in Table 5-10.

Table 5-10: Stack parameters for current operations

Parameter	Scrubber Stack	Baghouse Stack
Height (m)	30.00	30.00
Diameter (m)	2.84	2.60
Velocity (m/s)	15.00	15.00
Exit Temp (dC)	40.00	75.00
Flow Rate (Nm³/s)	80.00	80.00
Emission Limit for PM (mg/Nm³)	50	50
Emission Limit for SO_2 (mg/Nm³)	500	500
Emission Limit for NO_x (mg/Nm³)	700	700
PM10 Fraction (%)(a)	100	100
Mn Content (%)(b)	34	34

Notes:

(a) PM emissions assumed to PM10.

(b) From analyses of similar sintering operations.

5.2.4 Power Generation Plant Emissions

Ntsimbintle will employ four 200 kVA (1600 kW) base-load Caterpillar diesel generators. These will be used continuously until the required electricity can be provided by Eskom. The parameters used in the estimation of emissions from the power generation plant, as provided by Metago, are presented in Table 5-11. PM10 emissions were assumed to be 49.6% of TSP emissions (EPA,1995).

Table 5-11: Parameters pertaining to emissions from a single 1600 kW diesel generator

Diesel consumption (liters/annum)	5,750,000.00
Sulphur Content (%)	0.05
Diesel Density (kg/L)	0.85
Exhaust Flow Rate (m^3/min)	453.60
Exit Temperature (°C)	540.00
Exhaust Exit Diameter (m)	0.81
Exit Velocity (m/s)	14.57
NO_x concentration (mg/Nm^3)	3,059.20
CO concentration (mg/Nm^3)	323.30
TSP concentration (mg/Nm^3)	12.60

The release height of the exhaust emissions from the power generation plant was not known at the time of the study. The exhausts from the four generators will connect to a common manifold and pipe outside the building. An appropriate discharge height was calculated using Screen View, the Screening Air Dispersion Model (SCREEN3). The SCREEN model was developed to provide an easy to use method of obtaining pollutant concentration estimates.

The emission rate estimates were modelled for various discharge heights in order to determine the minimum release height required to ensure no ground level exceedances of the relevant air quality standards. A detailed description of the iteration process used to determine the **minimum stack height of 10 m** for the power generation plant is provided in Appendix E.

5.2.5 Summary of Estimated Emissions

Synopses of the estimated emissions as a result of proposed operations at Ntsimbintle for Scenario 1 and 2 as described in the preceding sections are presented in Table 5-10 and Table 5-12 respectively. Source group contributions for unmitigated and mitigated Scenario 1 emissions are presented in Figure 5-3 and Figure 5-4 respectively. Similarly the source group contributions to unmitigated and mitigated Scenario 2 emissions are presented in Figure 5-5 and Figure 5-6.

5.2.5.1 Scenario 1 (opencast and underground mining, processing and beneficiation)

Total **unmitigated PM10** emissions from Scenario 1 were estimated at 4 520 tpa of which 92% were as a result of vehicle entrainment of dust from unpaved haul roads. The total **mitigated PM10** emissions were estimated at 688 tpa, vehicle entrainment and emissions from the sinter plant stacks contributing 60% and 32% to the total, respectively. **Unmitigated** and **mitigated TSP** emissions amounted to 15 100 and 1 790 tpa respectively. Vehicle entrained dust from unpaved haul roads were estimated to be the most significant contributor to unmitigated and mitigated TSP emissions (96 and 82% respectively).

Emissions as a result of vehicle entrainment were estimated to contribute most significantly, 64%, to the total **unmitigated Mn** emissions of 303 tpa, followed by sinter plant emissions at 25%. With **mitigation** measures in place the total **Mn** emissions were estimated to reduce to 104 tpa with the sinter plant emissions contributing 79% to the total.

Estimated **SO_2** and **NO_x** emissions amounted to 1 290 and 2 820 tpa respectively. Sinter plant emissions were estimated to contribute the most significantly to both SO_2 (98%) and NO_x (41%) emissions. **CO** emissions from the power generation plant were estimated to contribute 53% to the total of 173 tpa. Estimated **DPM** as a result of vehicle tailpipe emissions amounted to 10.8 tpa.

5.2.5.2 Scenario 2 (underground mining and rehabilitation, processing and beneficiation)

Total **unmitigated PM10** emissions from Scenario 2 were estimated at 2 230 tpa of which 88% were as a result of vehicle entrainment of dust from unpaved haul roads. The total **mitigated PM10** emissions were estimated at 424 tpa, vehicle entrainment and emissions from the sinter plant stacks contributing 46% and 52% to the total, respectively. **Unmitigated** and **mitigated TSP** emissions amounted to 7 240 and 930 tpa respectively. Vehicle entrained dust from unpaved haul roads were estimated to be the most significant contributor to unmitigated (95%) and mitigated (74%) TSP emissions.

Emissions as a result of the sinter plant were estimated to contribute most significantly, 86%, to the total **unmitigated Mn** emissions of 87.8 tpa. With **mitigation** measures in place the total **Mn** emissions were estimated to reduce to 77.9 tpa with the sinter plant emissions contributing 97% to the total.

Estimated **SO_2** and **NO_x** emissions amounted to 1 280 and 2 720 tpa respectively. Sinter plant emissions were estimated to contribute the most significantly to both SO_2 (98%) and NO_x (65%) emissions. **CO** emissions from the power generation plant were estimated to contribute 70% to the total of 130 tpa. Estimated **DPM** as a result of vehicle tailpipe emissions amounted to 5.11 tpa.

Table 5-12: Scenario 1 - Summary of estimated emissions

Source Group	Unmitigated[(a)] Emissions (tons per annum)							Mitigated Emissions (tons per annum)						
	PM10	TSP	Mn	SO_2	NO_x	DPM	CO	PM10	TSP	Mn	SO_2	NO_x	DPM	CO
Blasting [(a)]	18.0	34.6	1.58	-	-	-	-	18.0	34.6	1.58	-	-	-	-
Crushing & Screening [(b)]	84.5	217	28.7	-	-	-	-	14.4	36.8	4.89	-	-	-	-
Drilling [(c)]	15.6	29.7	1.38	-	-	-	-	11.7	22.3	1.03	-	-	-	-
Materials Handling [(d)]	12.4	26.3	2.49	-	-	-	-	7.02	14.8	1.25	-	-	-	-
Paved Roads [(e)]	3.43	17.9	-	-	-	-	-	0.34	1.79	-	-	-	-	-
Power Generation Plant	1.76	3.55	-	19.6	862	-	91.1	1.76	3.55	-	19.6	862	-	91.1
Sinter Plant Stacks [(f)]	221	221	75.7	1260	1770	-	-	221	221	75.7	1260	1770	-	-
Unpaved Roads [(g)]	4160	14600	193	-	-	-	-	416	1460	19.3	-	-	-	-
Vehicle Tailpipe Emissions [(a)]	-	-	-	6.7	191	10.8	81.8	-	-	-	6.7	191	10.8	81.8
Total Scenario 1 Emissions	**4520**	**15100**	**303**	**1290**	**2820**	**10.8**	**173**	**690**	**1790**	**104**	**1290**	**2820**	**10.8**	**173**

Notes:

(a) No mitigation measures assumed

(b) Crushing and Screening mitigation measures: hooding with fabric filters, 83% control efficiency

(c) Drilling mitigation measures: cyclone, 25% control efficiency

(d) Materials handling mitigation measures: water sprays, 70% control efficiency on truck off-loading, 50% control efficiency on conveyor transfer points

(e) Paved road mitigation measures: sweeper, 90% control efficiency

(f) Sinter plant mitigation measures: scrubber and baghouse

(g) Unpaved road mitigation measures: chemical dust suppressants, 90% control efficiency

Table 5-13: Scenario 2 - Summary of estimated emissions

Source Group	Unmitigated[(a)] Emissions (tons per annum)							Mitigated Emissions (tons per annum)						
	PM10	TSP	Mn	SO_2	NO_x	DPM	CO	PM10	TSP	Mn	SO_2	NO_x	DPM	CO
Crushing & Screening [(b)]	33.6	89.3	11.4	-	-	-	-	5.71	15.2	1.94	-	-	-	-
Materials Handling [(c)]	1.95	4.11	0.65	-	-	-	-	0.68	1.43	0.23	-	-	-	-
Paved Roads [(d)]	3.43	17.90	-	-	-	-	-	0.34	1.79	-	-	-	-	-
Power Generation Plant	1.76	3.55	-	19.6	862	-	91.1	1.76	3.55	-	19.6	862	-	91.1
Sinter Plant Stacks [(e)]	221	221	75.7	1260	1770	-	-	221	221	75.7	1260	1770	-	-
Unpaved Roads [(f)]	1970	6910	-	-	-	-	-	197	691	-	-	-	-	-
Vehicle Tailpipe Emissions [(a)]	-	-	-	3.17	90.6	5.11	38.7	-	-	-	3.17	90.6	5.11	38.7
Total Scenario 1 Emissions	**2230**	**7240**	**87.8**	**1280**	**2720**	**5.11**	**130**	**426**	**934**	**77.9**	**1280**	**2720**	**5.11**	**130**

Notes:

(a) No mitigation measures assumed

(b) Crushing and Screening mitigation measures: hooding with fabric filters, 83% control efficiency

(c) Materials handling mitigation measures: water sprays, 70% control efficiency on truck off-loading, 50% control efficiency on conveyor transfer points

(d) Paved road mitigation measures: sweeper, 90% control efficiency

(e) Sinter plant mitigation measures: scrubber and baghouse

(f) Unpaved road mitigation measures: chemical dust suppressants, 90% control efficiency

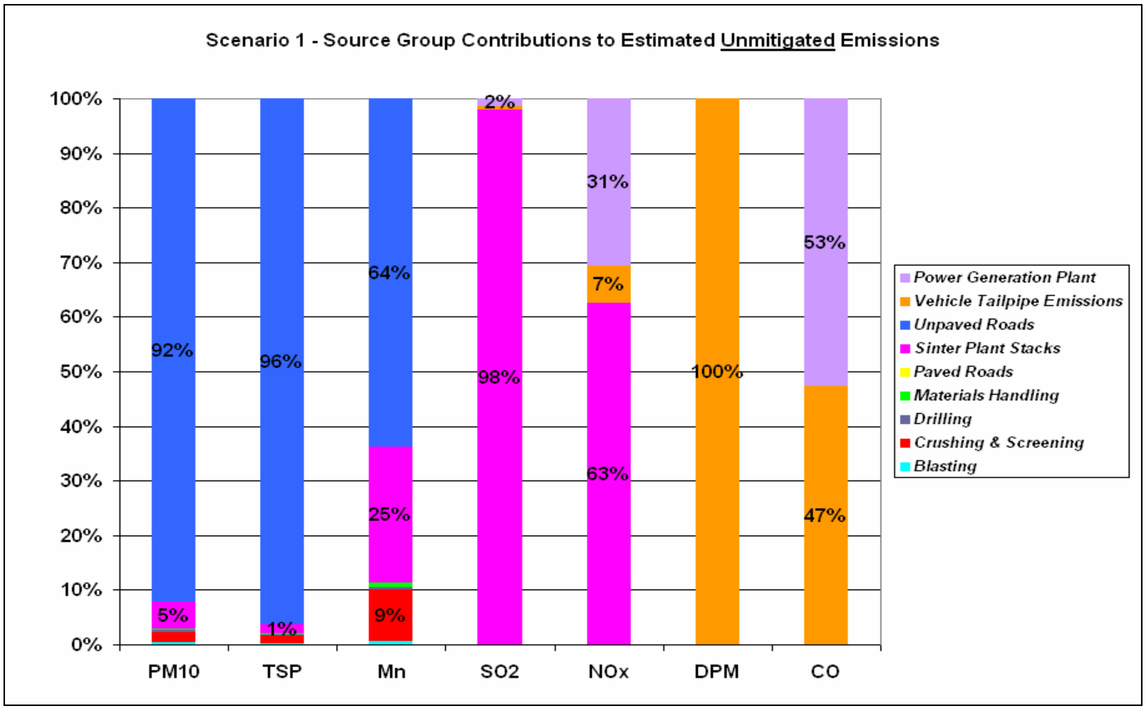

Figure 5-3: **Scenario 1 - Source group contributions to estimated unmitigated emissions**

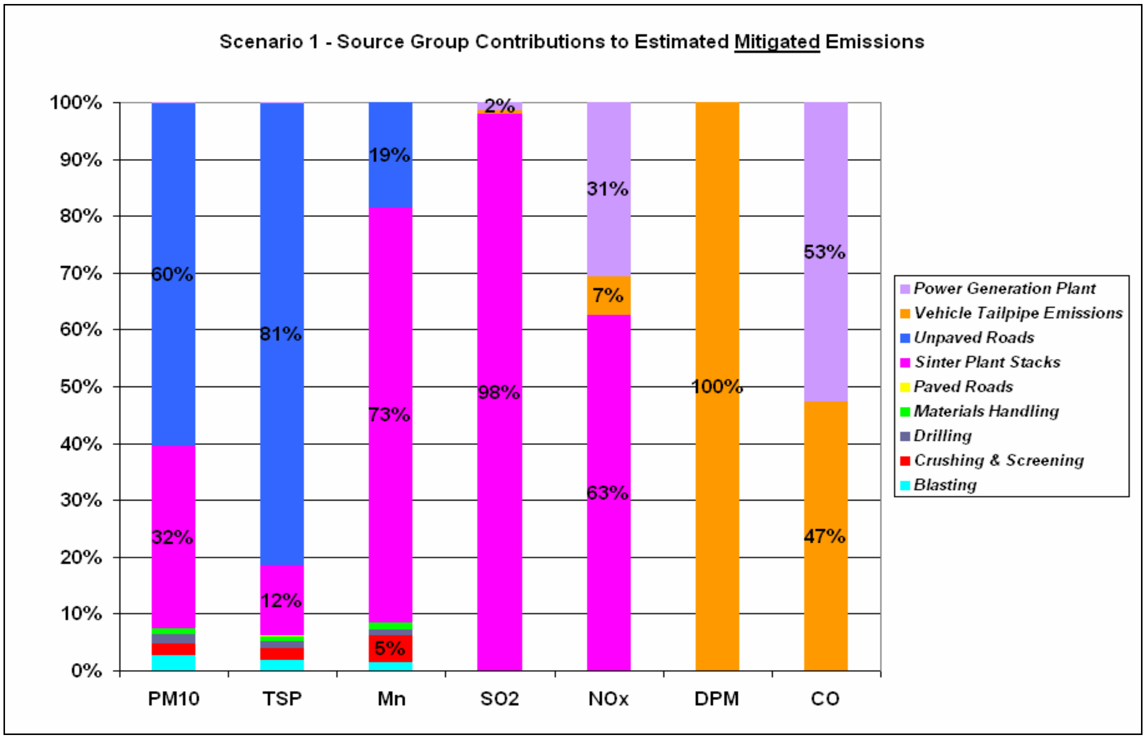

Figure 5-4: **Scenario 1 - Source group contributions to estimated mitigated emissions**

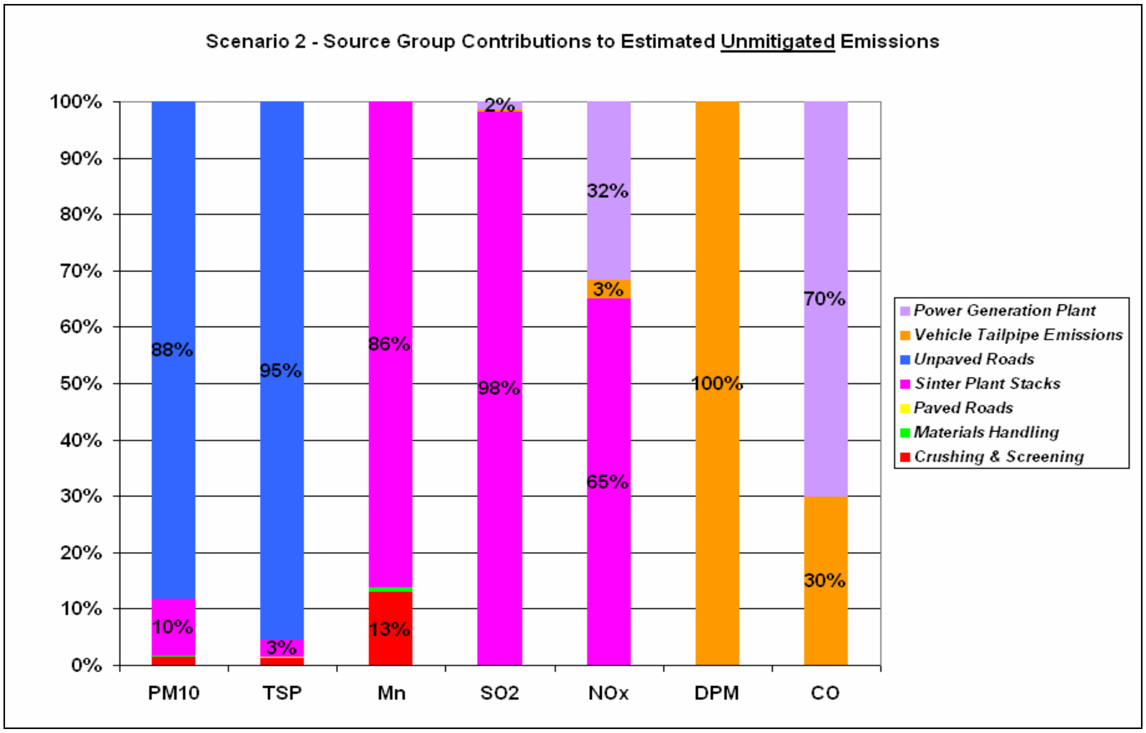

Figure 5-5: **Scenario 2 - Source group contributions to estimated unmitigated emissions**

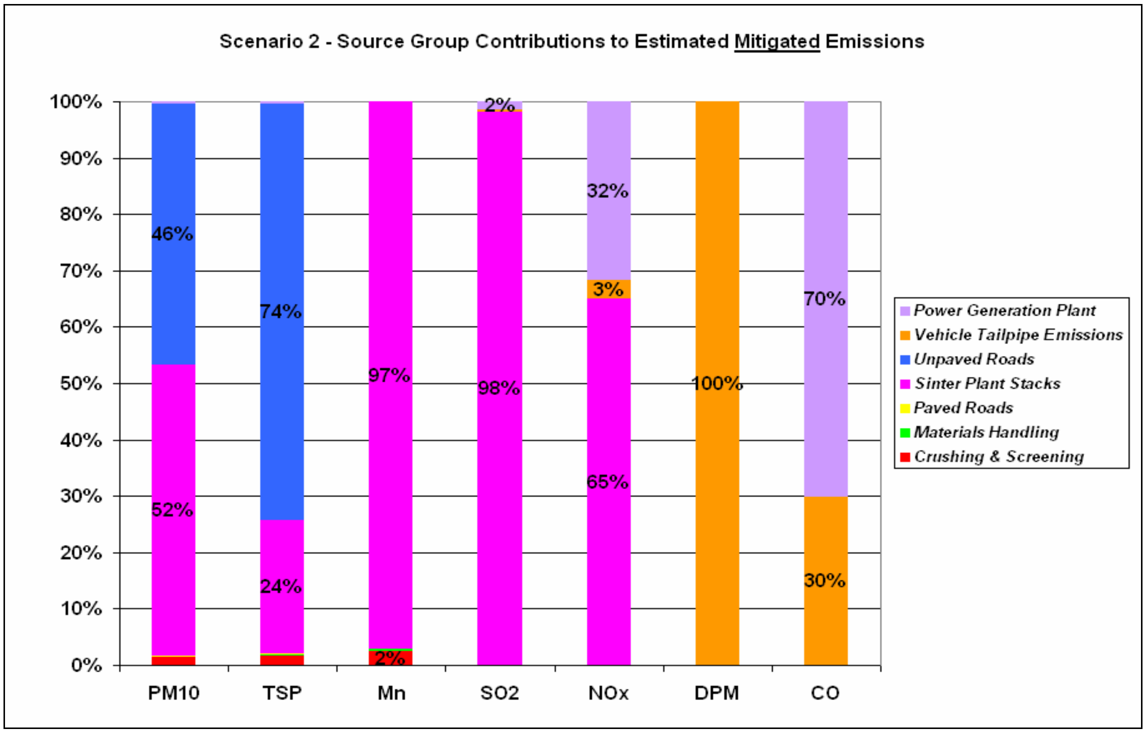

Figure 5-6: **Scenario 2 - Source group contributions to estimated mitigated emissions**

5.3 Dispersion Modelling

5.3.1 Dispersion Model Selection and Data Requirements

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). This model has however been replaced by the new generation AERMOD model and was used in this study.

AERMOD is a model developed under the support of the AMS/EPA Regulatory Model Improvement Committee (AERMIC), whose objective has been to include state-of the-art science in regulatory models (Hanna *et al*). The AERMOD is a dispersion modelling system with three components, namely: AERMOD (AERMIC Dispersion Model), AERMAP (AERMOD terrain pre-processor), and AERMET (AERMOD meteorological pre-processor).

(a) AERMOD is an advanced new-generation model. It is designed to predict pollution concentrations from continuous point, flare, area, line, and volume sources. AERMOD offers new and potentially improved algorithms for plume rise and buoyancy, and the computation of vertical profiles of wind, turbulence and temperature however retains the single straight line trajectory limitation of ISCST3 (Hanna *et al,* 1999).

(b) The AERMET is a meteorological pre-processor for the 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.

(c) The AERMAP is a terrain pre-processor designed to simplify and standardize the input of terrain data for the AERMOD. Input data includes receptor terrain elevation data. The terrain data may be in the form of digital terrain data. The 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 even 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.

5.3.1.1 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:

- No national meteorological database exists.
- Upper air measurements are only taken at 5 locations in South Africa. The South African Weather Services has modelled upper air data for the entire country on half degree intervals.
- Surface meteorological stations seldom measure all the required parameters (such as solar radiation, cloud cover, humidity).

For the purpose of the current study use was made of data recorded the SAWS Kuruman station for the period January 2001 to December 2005 (Section 3).

5.3.1.2 Source Data Requirements

The AERMOD model is able to model point, flare, area, pit, line and volume sources. The sources at Ntsimbintle were grouped and modelled as follows:

- In-pit roads, drilling, blasting and materials handling – modelled as open pit sources;
- Unpaved roads – modelled as area sources;
- Materials handling operations – modelled as volume sources;
- Crushing and screening operations – modelled as volume sources;
- Stacks – modelled as point sources.

5.3.1.3 Modelling Domain

The dispersion of pollutants expected to arise from the proposed operations was modelled for an area covering 20 km (east-west) by 20 km (north-south). The area was divided into a grid matrix with a resolution of 357 m by 357 m, with the site located approximately in the centre of the receptor area. The nearby sensitive receptors identified (Figure 5-7) were included as discrete receptor points. The Ntsimbintle boundary indicated in Figure 5-7 were also included in the dispersion modelling as discreet receptors to facilitate the prediction of maximum off-site concentrations. AERMOD simulates ground-level concentrations for each of the discreet receptor and grid points. Topography was also included in the model setup (Figure 1-2).

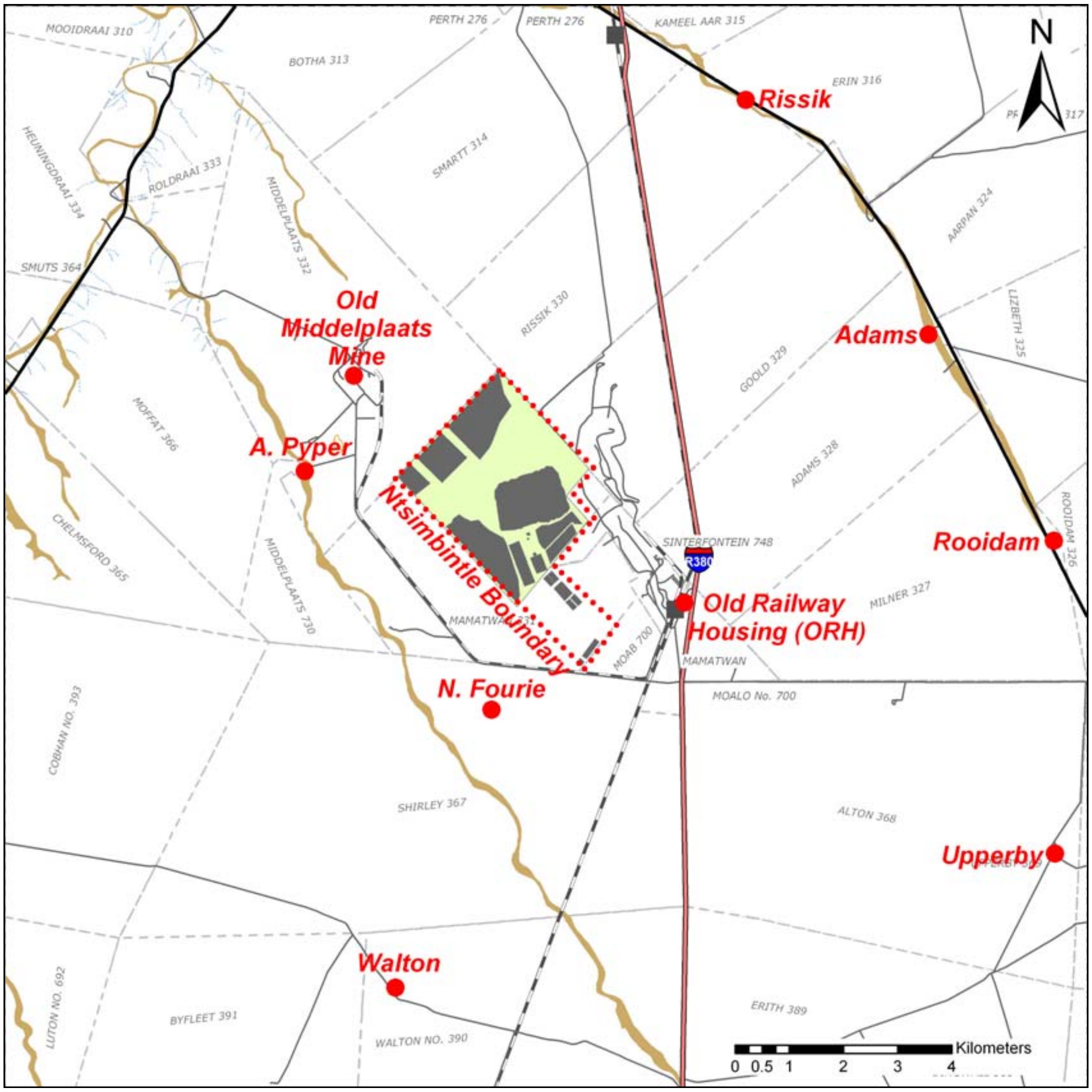

Figure 5-7: **Discreet receptors included in the dispersion modelling**

5.3.2 Dispersion Modelling Results

Dispersion modelling was undertaken to determine highest hourly, highest daily, highest monthly and annual average ground level concentrations for each pollutant. These averaging periods were selected to facilitate the comparison of predicted pollutant concentrations with relevant air quality standards and dustfall limits.

It should be noted that the ground level concentration isopleths depicted present interpolated values from the concentrations predicted by AERMOD for each of the receptor grid points specified. Plots reflecting daily averaging periods contain only the highest predicted ground level concentrations, for those averaging periods, over the entire period for which simulations were undertaken. It is therefore possible that even though a high daily average concentration is predicted to occur at certain locations, that this may only be true for one day of the year.

Scenarios that were included in the dispersion modelling of proposed operations at Ntsimbintle are presented in Table 5-14 along with the appropriate air quality standards and respective figure numbers.

As discussed in Section 4, the potential for cumulative air quality impacts exists in the area proposed for the Ntsimbintle project. It is for this reason that **incremental** impacts associated with Ntsimbintle only and **cumulative** impacts as a result of proposed operations at Ntsimbintle as well as current operations at Mamatwan, were assessed. Due to uncertainty in the exact timeframes associated with operations at UMK, impacts from this mine was not included in the cumulative air quality impact assessment.

Table 5-14: Dispersion modelling scenarios and figure numbers

			Scenario 1 - Unmitigated and Mitigated		Scenario 2 - Unmitigated and Mitigated	
Pollutant	**Averaging Period**	**Proposed SA Ambient Air Quality Standard**[(a)]	**Incremental**[(e)]	**Cumulative**[(f)]	**Incremental**	**Cumulative**
PM10	Annual Average	40 µg/m³	✓ Figure 5-8	✓ Figure 5-10	✓ Figure 5-18	✓ Figure 5-20
	Highest Daily Average	75 µg/m³	✓ Figure 5-9	✓ Figure 5-11	✓ Figure 5-19	✓ Figure 5-21
Mn	Annual Average	-(b)	✓ Figure 5-14	✓ Figure 5-15	✓ Figure 5-24	✓ Figure 5-25
SO_2	Annual Average	50 µg/m³	✓(g)	✓(g)	✓(g)	✓(g)
	Highest Daily Average	125 µg/m³	✓(g)	✓(g)	✓(g)	✓(g)
	Highest Hourly Average	350 µg/m³	✓(g)	✓(g)	✓(g)	✓(g)
NO_x	Annual Average	40 µg/m³	✓(g)	✓(g)	✓(g)	✓(g)
	Highest Hourly Average	200 µg/m³	✓(g)	✓(g)	✓(g)	✓(g)
DPM	Annual Average	5 µg/m³(c)	✓(g)	-	✓(g)	-
CO	Highest Hourly Average	30000 µg/m³	✓(g)	-	✓(g)	-
Dustfall	Maximum Daily Dustfall	-(d)	✓ Figure 5-16	✓ Figure 5-17	✓ Figure 5-26	✓ Figure 5-27

Notes:

(a) See Table 2-2.

(b) No South African standard for manganese. Reference is made to the WHO annual average standard of 0.15 µg/m³.

(c) As for Benzene

(d) SANS dustfall band for residential and light commercial areas (600 mg/m²/day)

(e) Incremental – Predicted concentrations as a result of emissions from Ntsimbintle only

(f) Cumulative – Predicted concentrations as a result of emissions from Ntsimbintle and neighbouring Mamatwan

(g) Predicted concentrations low compared to air quality standards and guidelines, isopleth plots not included

5.4 Compliance Assessment and Health Risk Screening

5.4.1 Scenario 1 (opencast and underground mining, processing, beneficiation and power generation)

5.4.1.1 PM10 Impacts

Table 5-15 gives the incremental and cumulative PM10 ground level concentrations predicted to occur at the various sensitive receptors as a result of proposed Scenario 1 operations.

Exceedances of the proposed SA annual and daily average standards are predicted at the Ntsimbintle boundary for unmitigated and mitigated emissions, incrementally and cumulatively. **Incrementally**, unmitigated emissions from Ntsimbintle are predicted to result exceedances of the proposed daily average standard at A. Pyper, the old Middelplaats mine at N. Fourie. **Cumulative** unmitigated emissions are predicted to result exceedances of the proposed daily average standard at A. Pyper the old railway housing (ORH), the old Middelplaats mine and at N. Fourie. The mitigation measures discussed in Section 5.2 are predicted to, on average, result in an approximate 87% reduction in predicted ground level PM10 concentrations.

The spatial distribution of predicted incremental annual and highest daily average PM10 concentrations are presented in Figure 5-8 and Figure 5-9 respectively. Isopleth plots for predicted cumulative annual and highest daily average PM10 concentrations are presented in Figure 5-10 and Figure 5-11 respectively.

The number of days that the proposed SA daily average PM10 standard is exceeded at the discreet receptors included in the study are presented in Table 5-16. In order to place the predicted impacts into context, reference is made to the European Community's (EC) daily average standard of 50µg/m³ with 35 days of exceedance allowed per calendar year. The distance from the Ntsimbintle operations at which the EC standard is exceeded 35 times per year is illustrated in Figure 5-12 and Figure 5-13.

Table 5-15: Scenario 1 - Predicted PM10 ground level concentrations

Scenario 1 - Predicted PM10 Concentrations (µg/m³)					
Source	**Receptor**	**Unmitigated**		**Mitigated**	
		Annual Average	**Daily Average**	**Annual Average**	**Daily Average**
Incremental	Ntsimbintle Boundary	**3650.00[(c)]**	**7060.00[(c)]**	**366.00[(c)]**	**709.00[(c)]**
	Walton	2.25	30.30	0.26	3.06
	Rissik	4.94	31.70	0.56	3.40
	Adams	1.39	20.60	0.23	2.15
	Rooidam	0.65	15.70	0.11	1.57
	Upperby	0.43	5.14	0.09	1.05
	A. Pyper	16.80	**115.00[(c)]**	1.90	11.80
	Old Railroad Housing	5.67	64.40	0.80	7.43
	Old Middelplaats Mine	**112.00[(c)]**	**269.00[(c)]**	11.90	27.90
	N. Fourie	9.23	**126.00[(c)]**	1.17	12.90
Cumulative	Ntsimbintle Boundary	**3650.00[(c)]**	**7060.00[(c)]**	**370.00[(c)]**	**709.00[(c)]**
	Walton	2.45	30.40	0.46	4.71
	Rissik	5.99	36.30	1.61	10.60
	Adams	2.77	33.80	1.60	21.40
	Rooidam	1.07	20.80	0.53	9.53
	Upperby	0.59	6.76	0.25	3.07
	A. Pyper	17.90	**123.00[(c)]**	3.01	21.40
	Old Railroad Housing	13.70	**94.40[(c)]**	8.85	70.50
	Old Middelplaats Mine	**114.00[(c)]**	**269.00[(c)]**	14.30	30.70
	N. Fourie	10.50	**127.00[(c)]**	2.47	17.00

Notes:

(a) Proposed SA annual average PM10 standard – 40 µg/m³.

(b) Proposed SA daily average PM10 standard – 75 µg/m³.

(c) Predicted ground level concentration exceeds proposed SA PM10 standards.

Table 5-16: Scenario 1 - Predicted days of exceedance of various PM10 standards

Scenario 1 - Predicted days of exceedance of various PM10 standards					
Source	**Receptor**	**Unmitigated**		**Mitigated**	
		EC Daily Average Standard (50 µg/m³)[(a)]	**SA Daily Average Standard (75 µg/m³)**	**EC Daily Average Standard (50 µg/m³)[(a)]**	**SA Daily Average Standard (75 µg/m³)**
Incremental	Ntsimbintle Boundary	350	345	302	295
	Walton	0	0	0	0
	Rissik	0	0	0	0
	Adams	0	0	0	0
	Rooidam	0	0	0	0
	Upperby	0	0	0	0
	A. Pyper	21	8	0	0
	Old Railroad Housing	6	1	0	0
	Old Middelplaats Mine	188	145	0	0
	N. Fourie	10	2	0	0
Cumulative	Ntsimbintle Boundary	350	345	306	295
	Walton	0	0	0	0
	Rissik	0	0	0	0
	Adams	0	0	0	0
	Rooidam	0	0	0	0
	Upperby	0	0	0	0
	A. Pyper	24	8	0	0
	Old Railroad Housing	18	4	8	0
	Old Middelplaats Mine	189	152	0	0
	N. Fourie	11	2	0	0

Notes:

(a) The European Community permits 35 days of exceedance of the 50 µg/m³ daily average PM10 standard.

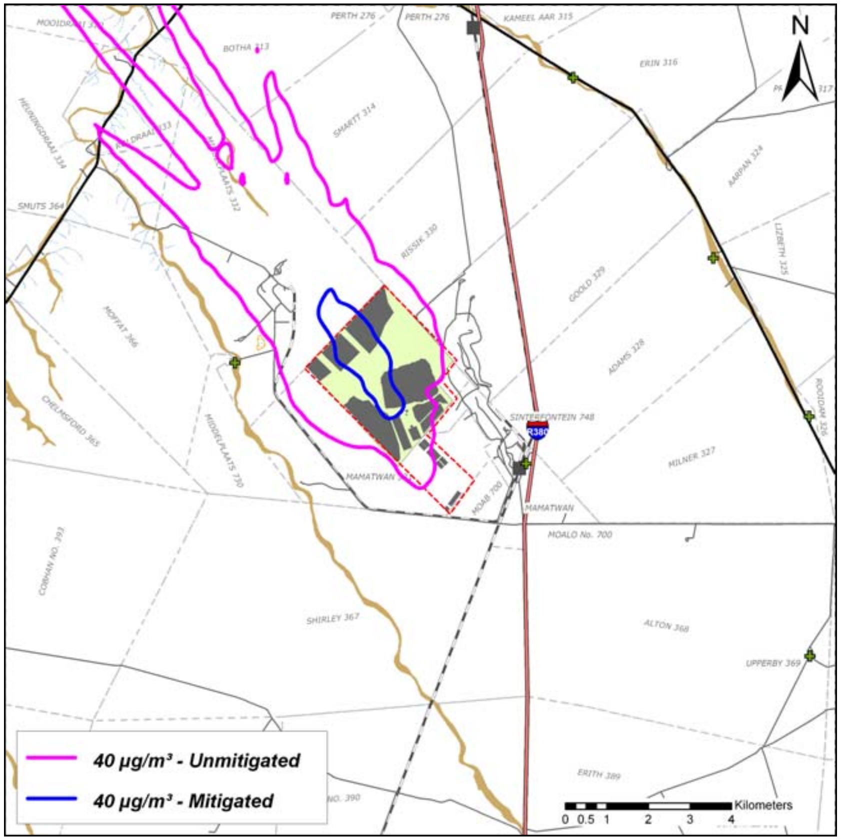

Figure 5-8: Scenario 1 – Predicted incremental annual average PM10 concentrations

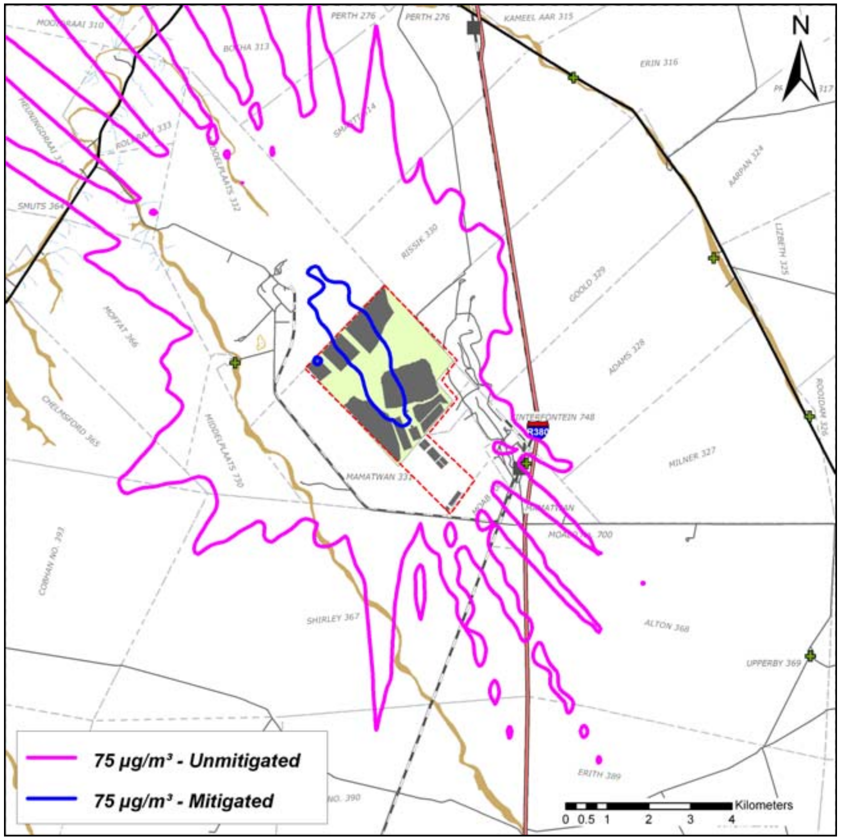

Figure 5-9: Scenario 1 – Predicted incremental highest daily average PM10 concentrations

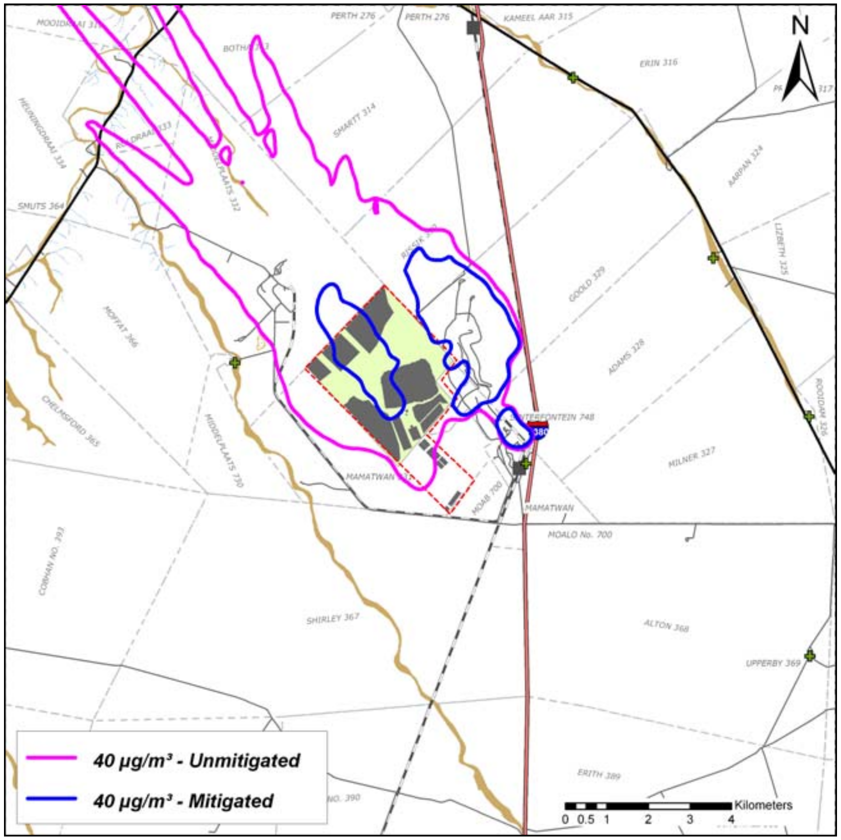

Figure 5-10: Scenario 1 – Predicted cumulative annual average PM10 concentrations

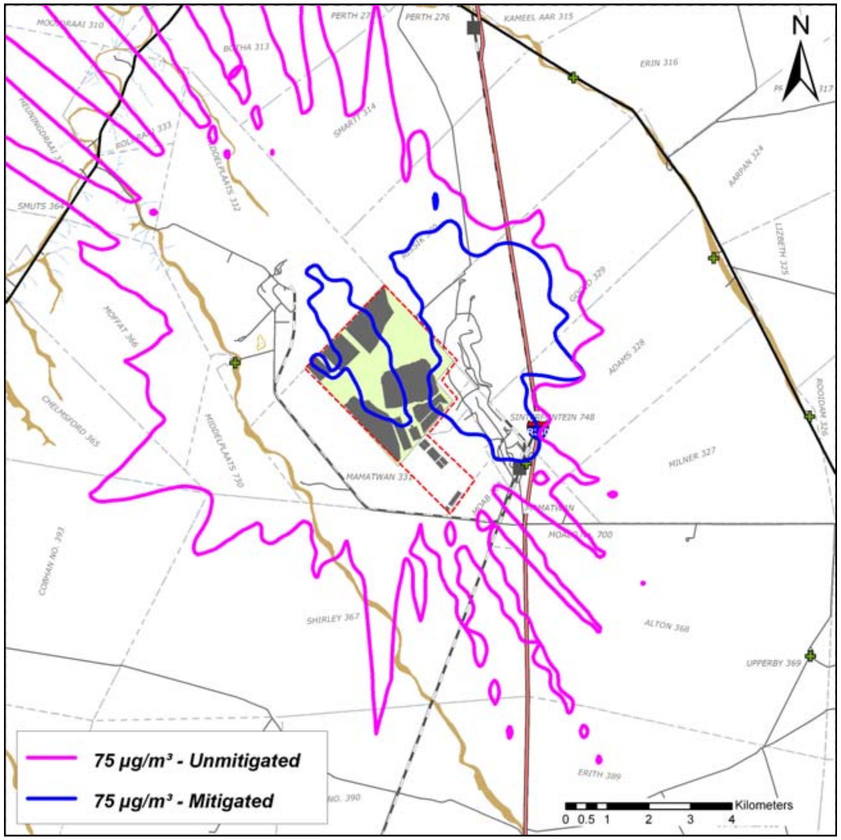

Figure 5-11: Scenario 1 – Predicted cumulative highest daily average PM10 concentrations

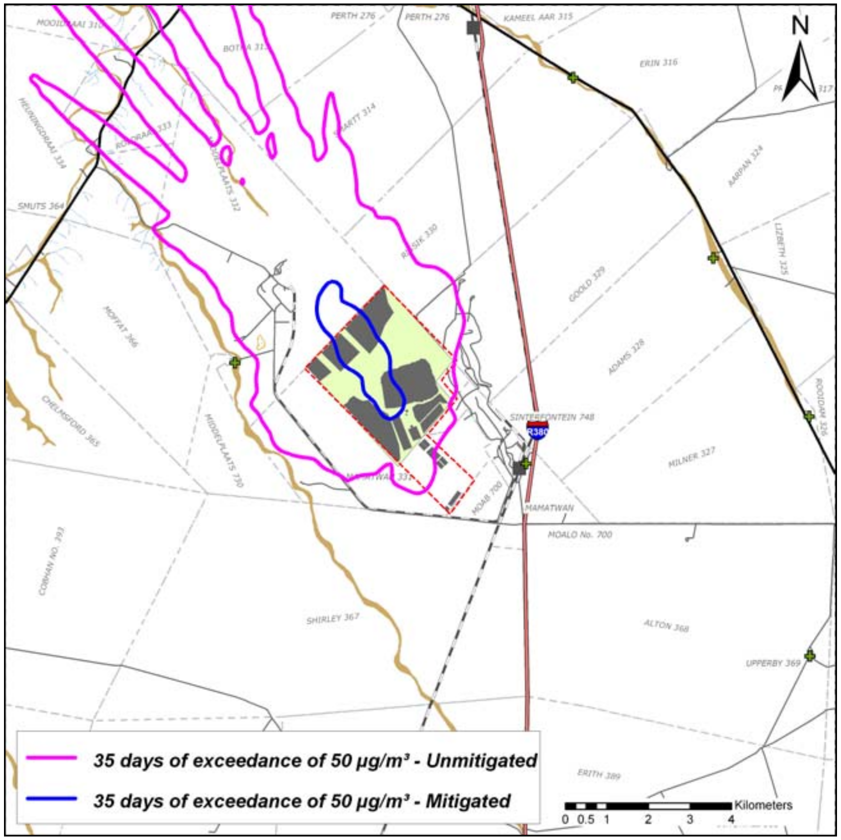

Figure 5-12: Scenario 1, Incremental PM10 - Days of exceedance of 50µg/m³

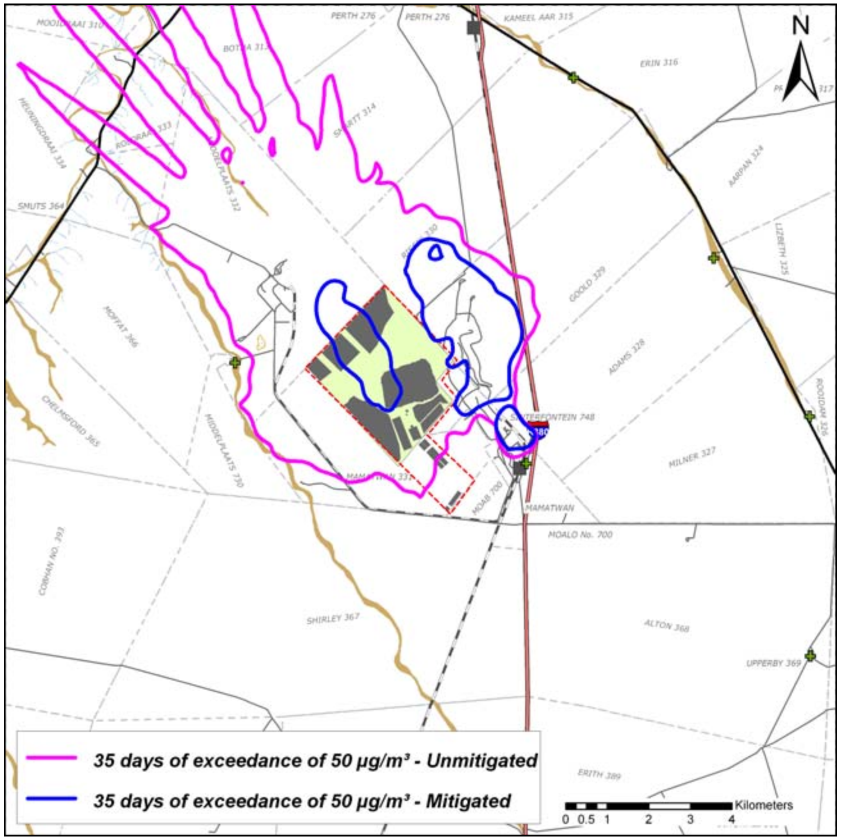

Figure 5-13: Scenario 1, Cumulative PM10 - Days of exceedance of 50µg/m³

5.4.1.2 Manganese Impacts

Table 5-17 gives the incremental and cumulative manganese ground level concentrations predicted to occur at the various sensitive receptors as a result of proposed Scenario 1 operations.

Incrementally, unmitigated emissions are predicted to result in exceedances of the WHO annual average guideline for manganese at the Ntsimbintle boundary, A. Pyper, the ORH, the old Middelplaats mine and N. Fourie. With mitigation measures in place the predicted annual average Mn concentrations exceed the WHO standard at the Ntsimbintle boundary, at the old Middelplaats mine and at N. Fourie. The mitigation measures discussed in Section 5.2 are predicted to result in an average reduction of 69% in predicted incremental Mn concentrations. **Cumulatively**, unmitigated and mitigated emissions are predicted to result in exceedances of the WHO standard at the Ntsimbintle boundary, Rissik, Adams, A. Pyper, the ORH, the old Middelplaats mine and N. Fourie.

Isopleth plots for predicted incremental and cumulative Mn concentrations are presented in Figure 5-14 and Figure 5-15 respectively.

Table 5-17: Scenario 1 - Predicted manganese ground level concentrations

Scenario 1 - Predicted Mn Concentrations (µg/m³)			
Source	**Receptor**	**Unmitigated**	**Mitigated**
		Annual Average[(a)]	**Annual Average[(a)]**
Incremental	Ntsimbintle Boundary	**20.20[(b)]**	**3.64[(b)]**
	Walton	0.09	0.02
	Rissik	0.13	0.03
	Adams	0.08	0.04
	Rooidam	0.05	0.02
	Upperby	0.04	0.02
	A. Pyper	**0.58[(b)]**	0.13
	ORH	**0.37[(b)]**	0.11
	Old Middelplaats Mine	**2.02[(b)]**	**0.40[(b)]**
	N. Fourie	**0.81[(b)]**	**0.16[(b)]**
Cumulative	Ntsimbintle Boundary	**20.70[(b)]**	**9.71[(b)]**
	Walton	0.12	0.05
	Rissik	**0.27[(b)]**	**0.17[(b)]**
	Adams	**0.24[(b)]**	**0.19[(b)]**
	Rooidam	0.09	0.06
	Upperby	0.06	0.04
	A. Pyper	**0.71[(b)]**	**0.26[(b)]**
	ORH	**2.35[(b)]**	**2.09[(b)]**
	Old Middelplaats Mine	**2.36[(b)]**	**0.74[(b)]**
	N. Fourie	**1.00[(b)]**	**0.35[(b)]**

Notes:

(a) WHO annual average Mn guideline – 0.15µg/m³.

(b) Exceeds the WHO guideline.

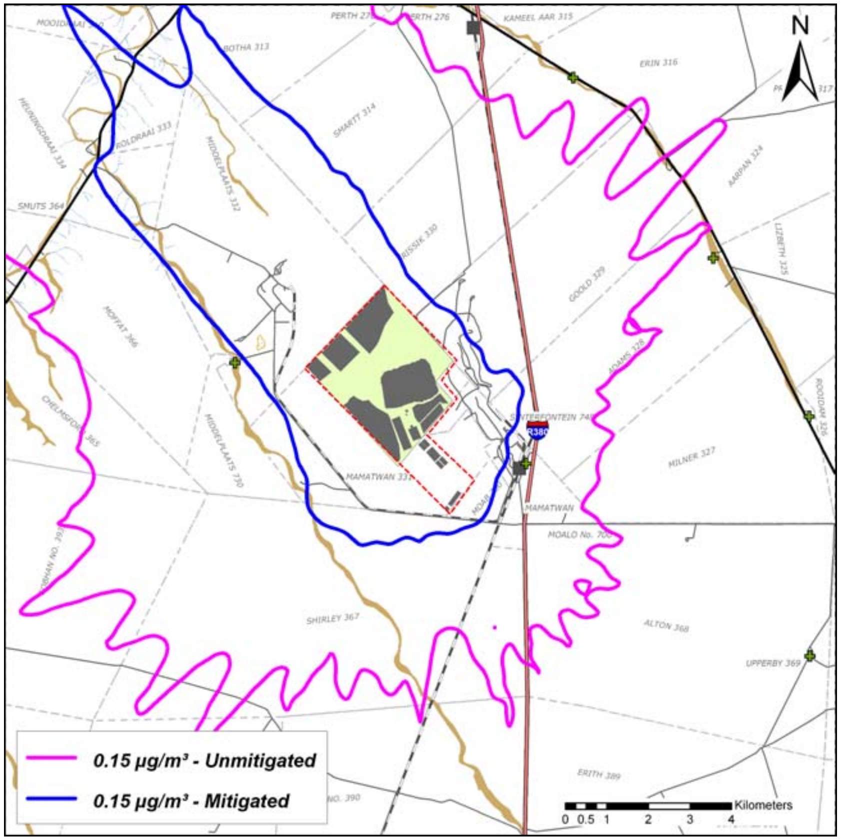

Figure 5-14: Scenario 1 – Predicted incremental annual average PM10 concentrations

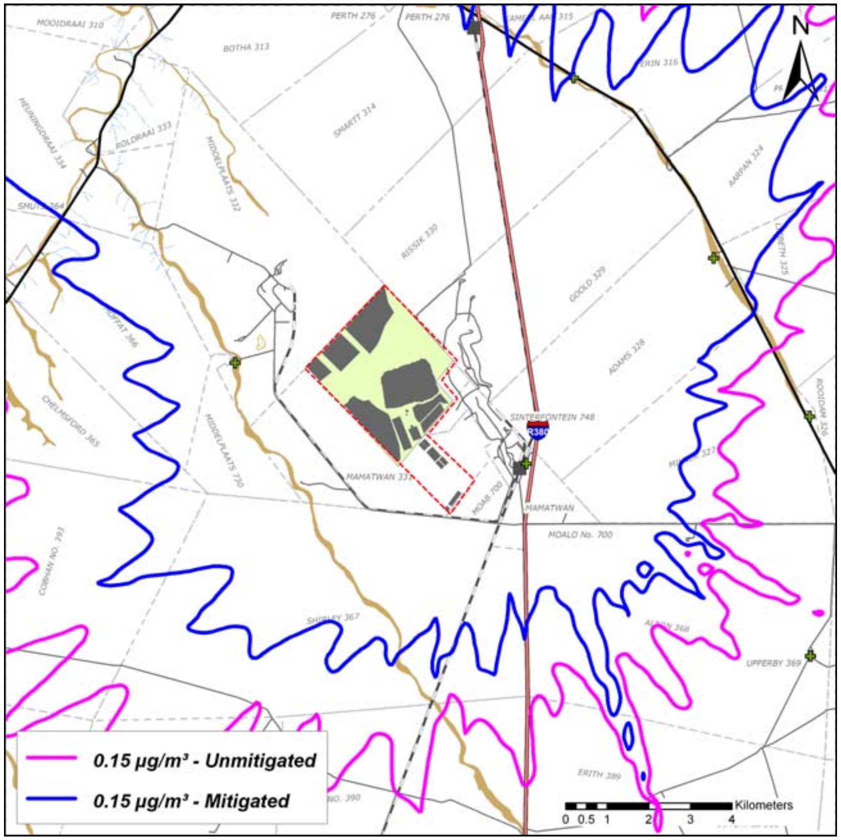

Figure 5-15: Scenario 1 – Predicted cumulative annual average Mn concentrations

5.4.1.3 SO_2 Impacts

Table 5-18 gives the incremental and cumulative SO_2 ground level concentrations predicted to occur at the various sensitive receptors as a result of proposed Scenario 1 operations.

Predicted SO_2 concentrations at the various sensitive receptors are low compared to the SA standards. Only the predicted highest hourly average concentrations at the Ntsimbintle boundary (incrementally and cumulatively) are in exceedance of the proposed SA standard.

5.4.1.4 NO_2 Impacts

Table 5-18 gives the incremental and cumulative NO_2 ground level concentrations predicted to occur at the various sensitive receptors as a result of proposed Scenario 1 operations.

A conservative approach was adopted in the prediction of NO_2 concentrations. It was assumed that at the residential receptors all NO_x emissions would have been converted to NO_2. Since vehicle tailpipe and combustion emissions are the main contributors to predicted DPM concentrations at the boundary it was assumed that only 20% of the NO_x emissions from these vehicles are emitted as NO_2 (Haywood, 1988). Only the predicted highest hourly average concentrations at the Ntsimbintle boundary (incrementally and cumulatively) are in exceedance of the proposed SA standard.

Table 5-18: Scenario 1 - Predicted SO_2 ground level concentrations

Scenario 1 - Predicted SO2 Concentrations (µg/m³)				
Source	**Receptor**	**Annual Average[(a)]**	**Daily Average[(b)]**	**Hourly Average[(c)]**
Incremental	Ntsimbintle Boundary	8.44	50.00	**534.00[(d)]**
	Walton	0.14	1.64	23.30
	Rissik	0.28	2.10	25.80
	Adams	0.55	5.94	51.20
	Rooidam	0.24	2.04	32.30
	Upperby	0.30	4.90	35.50
	A. Pyper	0.69	3.95	24.60
	ORH	1.20	9.22	95.60
	Old Middelplaats Mine	2.04	6.69	23.70
	N. Fourie	0.50	7.49	50.10
Cumulative	Ntsimbintle Boundary	8.69	50.00	**534.00[(d)]**
	Walton	0.17	2.07	24.90
	Rissik	0.35	2.43	25.80
	Adams	0.74	8.27	51.20
	Rooidam	0.35	2.42	32.30
	Upperby	0.37	4.92	35.50
	A. Pyper	0.78	4.81	25.20
	ORH	1.20	9.34	95.60
	Old Middelplaats Mine	2.24	7.59	24.20
	N. Fourie	0.55	7.98	50.20

Notes:

(a) Proposed SA annual SO_2 standard – 50µg/m³.

(b) Proposed SA daily SO_2 standard – 125µg/m³.

(c) Proposed SA hourly SO_2 standard – 350µg/m³.

(d) Predicted ground level concentration exceeds SA SO_2 standards.

Table 5-19: Scenario 1 - Predicted NO_2 ground level concentrations

Scenario 1 - Predicted NO_2 Concentrations (µg/m³)			
Source	**Receptor**	**Annual Average[(a)]**	**Hourly Average[(b)]**
Incremental	Ntsimbintle Boundary	35.10	**219.00**[(c)]
	Walton	0.87	53.10
	Rissik	1.40	103.00
	Adams	0.58	64.80
	Rooidam	0.39	35.80
	Upperby	0.63	56.90
	A. Pyper	3.20	65.10
	ORH	3.37	135.00
	Old Middelplaats Mine	19.70	140.00
	N. Fourie	1.97	148.00
Cumulative	Ntsimbintle Boundary	35.20	**219.00**[(c)]
	Walton	0.95	53.10
	Rissik	1.65	103.00
	Adams	0.72	64.90
	Rooidam	0.48	36.50
	Upperby	0.72	56.90
	A. Pyper	3.31	65.10
	ORH	3.37	135.00
	Old Middelplaats Mine	20.20	140.00
	N. Fourie	2.00	148.00

Notes:

(a) Proposed SA annual NO_2 standard – 40µg/m³.

(b) Proposed SA daily NO_2 standard – 200µg/m³.

(c) Predicted ground level concentration exceeds SA NO_2 standards.

5.4.1.5 DPM Impacts

Table 5-20 gives the incremental DPM ground level concentrations predicted to occur at the various sensitive receptors as a result of proposed Scenario 1 operations. Only the predicted annual average concentrations at the Ntsimbintle boundary is in exceedance of the proposed SA standard for benzene (See section 2.5.3).

Table 5-20: Scenario 1 - Predicted DPM ground level concentrations

Scenario 1 - Predicted DPM Concentrations (µg/m³)	
Receptor	**Annual Average**[(a)]
Ntsimbintle Boundary	**9.45**[(b)]
Walton	0.01
Rissik	0.01
Adams	0.00
Rooidam	0.00
Upperby	0.00
A. Pyper	0.04
Old Railroad Housing	0.01
Old Middelplaats Mine	0.28
N. Fourie	0.02

Notes:

(a) Proposed SA annual Benzene standard – 5µg/m³ (see Section 2.5.3).

(b) Predicted ground level concentration exceeds SA benzene standards.

5.4.1.6 CO Impacts

Table 5-21 presents the incremental CO ground level concentrations predicted to occur at the various sensitive receptors as a result of proposed Scenario 1 operations. The proposed SA standard for CO is not exceeded at any of the discreet receptors included in the study.

Table 5-21: Scenario 1 - Predicted CO ground level concentrations

Scenario 1 - Predicted CO Concentrations (µg/m³)	
Receptor	**Hourly Average[(a)]**
Ntsimbintle Boundary	467.00
Walton	10.70
Rissik	7.83
Adams	7.24
Rooidam	5.51
Upperby	3.02
A. Pyper	21.20
Old Railroad Housing	20.30
Old Middelplaats Mine	29.90
N. Fourie	21.60

Notes:

(a) Proposed SA hourly CO standard – 30 000µg/m³.

5.4.1.7 Dustfall Impacts

Table 5-22 gives the incremental and cumulative dustfall levels predicted to occur at the various sensitive receptors as a result of proposed Scenario 1 unmitigated and mitigated emissions.

Overall the predicted dustfall levels at all the residential discreet receptors were relatively low. Only cumulative unmitigated emissions are predicted to result in dustfall levels in exceedance of 600 mg/m²/day at the Ntsimbintle boundary. Exceedance of this standard is only allowed 3 times a year and should not be exceeded in two consecutive months.

Isopleth plots for predicted incremental and cumulative maximum daily dustfall levels are presented in Figure 5-16 and Figure 5-17 respectively.

Table 5-22: Scenario 1 - Predicted Maximum Dustfall Levels

Scenario 1 - Predicted Maximum Dustfall Levels (mg/m²/day)			
Source	**Receptor**	**Unmitigated**	**Mitigated**
		Maximum Daily	**Maximum Daily**
Incremental	Ntsimbintle Boundary	**756.00**	77.40
	Walton	0.31	0.13
	Rissik	1.23	0.29
	Adams	0.87	0.34
	Rooidam	0.77	0.18
	Upperby	0.33	0.19
	A. Pyper	3.64	0.74
	ORH	4.87	2.52
	Old Middelplaats Mine	12.00	2.10
	N. Fourie	4.00	0.89
Cumulative	Ntsimbintle Boundary	**756.00**	166.00
	Walton	0.40	0.23
	Rissik	1.79	0.84
	Adams	2.05	1.52
	Rooidam	1.10	0.78
	Upperby	0.53	0.40
	A. Pyper	4.14	1.24
	ORH	24.70	22.40
	Old Middelplaats Mine	12.80	2.89
	N. Fourie	4.47	1.36

Notes:

(a) SANS dustfall band for residential and light commercial areas – 600 mg/m²/day.

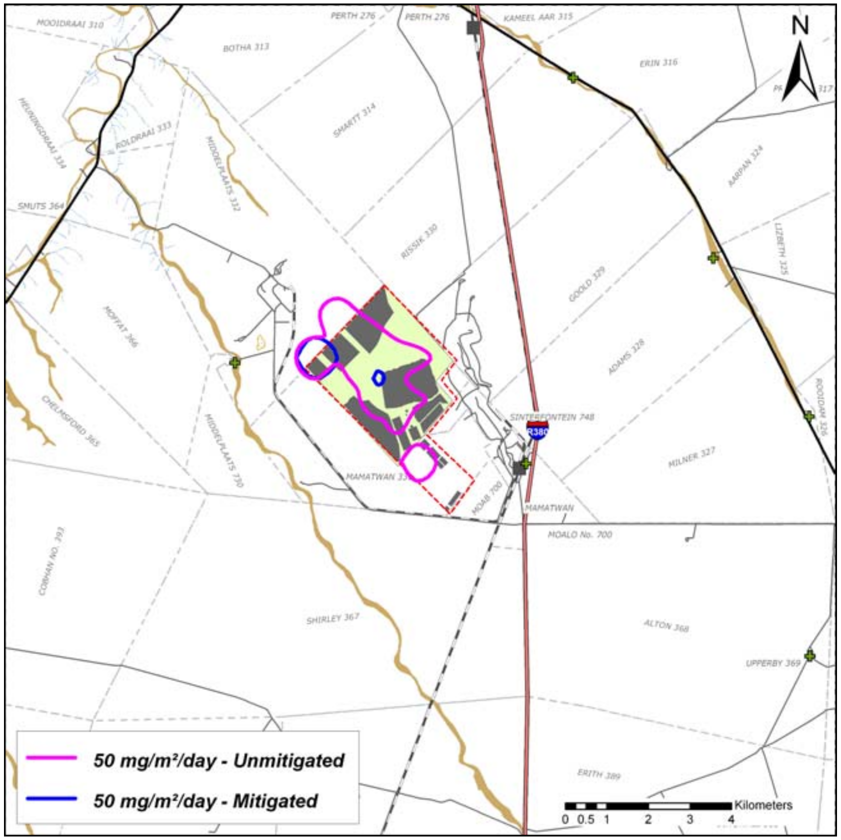

Figure 5-16: Scenario 1 – Predicted incremental maximum daily dustfall levels

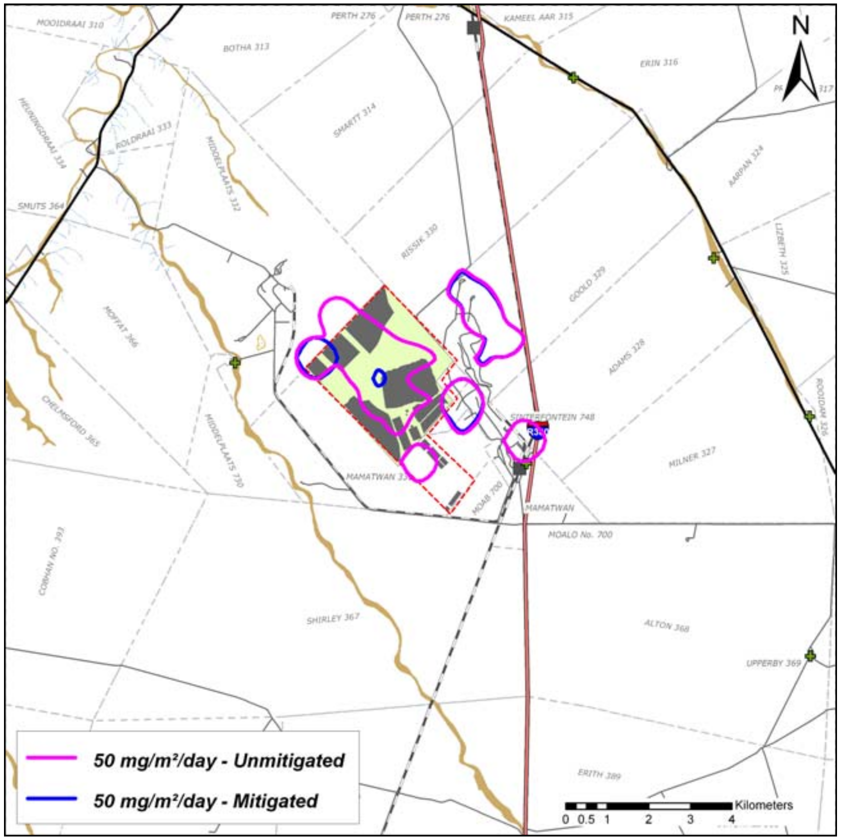

Figure 5-17: Scenario 1 – Predicted cumulative maximum daily dustfall levels

5.4.2 Scenario 2 (underground mining and rehabilitation, processing, beneficiation and power generation)

5.4.2.1 PM10 Impacts

Table 5-23 gives the incremental and cumulative PM10 ground level concentrations predicted to occur at the various sensitive receptors as a result of proposed Scenario 2 operations.

Exceedances of the proposed SA annual and daily average standards are predicted at the Ntsimbintle boundary for unmitigated and mitigated emissions, incrementally and cumulatively. **Incrementally**, unmitigated emissions from Ntsimbintle are predicted to result exceedances of the proposed daily average standard at A. Pyper, the old Middelplaats mine and at N. Fourie. Cumulative unmitigated emissions are predicted to result exceedances of the proposed daily average standard at A. Pyper the old railway housing (ORH), the old Middelplaats mine and at N. Fourie.

Isopleth plots for predicted cumulative annual and highest daily average PM10 concentrations are presented in Figure 5-18 and Figure 5-19 respectively. Isopleth plots for predicted cumulative annual and highest daily average PM10 concentrations are presented in Figure 5-20and Figure 5-21 respectively.

The number of days that the SA daily average PM10 standard is exceeded at the discreet receptors included in the study are presented in Table 5-24. Reference is also made to the European Community's (EC) daily average standard of 50µg/m³ with 35 days of exceedance allowed per calendar year. The distance from the Ntsimbintle operations at which the EC standard is exceeded 35 times per year is illustrated in Figure 5-22 and Figure 5-23.

Table 5-23: Scenario 2 - Predicted PM10 ground level concentrations

Scenario 2 - Predicted PM10 Concentrations (µg/m^3)					
Source	**Receptor**	**Unmitigated**		**Mitigated**	
		Annual Average(a)	**Daily Average(b)**	**Annual Average(a)**	**Daily Average(b)**
Incremental	Ntsimbintle Boundary	**3 610.00(c)**	**6 990.00(c)**	**361.00(c)**	**699.00(c)**
	Walton	2.04	30.10	0.23	3.01
	Rissik	4.30	30.90	0.47	3.17
	Adams	1.15	16.50	0.19	1.66
	Rooidam	0.55	15.70	0.09	1.57
	Upperby	0.34	4.23	0.07	0.91
	A. Pyper	14.80	**105.00(c)**	1.60	10.50
	Old Railroad Housing	4.14	55.50	0.59	6.35
	Old Middelplaats Mine	**102.00(c)**	**245.00(c)**	10.50	24.80
	N. Fourie	7.00	**123.00(c)**	0.82	12.40
Cumulative	Ntsimbintle Boundary	**3 610.00(c)**	**6 990.00(c)**	**365.00(c)**	**699.00(c)**
	Walton	2.24	30.10	0.43	4.48
	Rissik	5.35	31.20	1.53	10.10
	Adams	2.52	29.70	1.56	21.10
	Rooidam	0.97	20.80	0.51	9.52
	Upperby	0.50	6.20	0.24	3.06
	A. Pyper	15.90	**112.00(c)**	2.71	20.60
	Old Railroad Housing	12.20	**84.40(c)**	8.64	69.90
	Old Middelplaats Mine	**104.00(c)**	**245.00(c)**	12.90	28.10
	N. Fourie	8.29	**124.00(c)**	2.12	15.60

Notes:

(a) Proposed SA annual PM10 standard – 40 µg/m^3.

(b) Proposed SA daily PM10 standard – 75 µg/m^3.

(c) Predicted ground level concentration exceeds proposed SA PM10 standards.

Table 5-24: Scenario 2 - Predicted days of exceedance of various PM10 standards

Scenario 2 - Predicted days of exceedance of PM10 standards					
Source	**Receptor**	**Unmitigated**		**Mitigated**	
		EC Daily Average Standard (50 µg/m³)(a)	**SA Daily Average Standard (75 µg/m³)**	**EC Daily Average Standard (50 µg/m³)(a)**	**SA Daily Average Standard (75 µg/m³)**
Incremental	Ntsimbintle Boundary	348	345	300	295
	Walton	0	0	0	0
	Rissik	0	0	0	0
	Adams	0	0	0	0
	Rooidam	0	0	0	0
	Upperby	0	0	0	0
	A. Pyper	18	7	0	0
	Old Railroad Housing	3	1	0	0
	Old Middelplaats Mine	182	127	0	0
	N. Fourie	10	2	0	0
Cumulative	Ntsimbintle Boundary	348	345	305	295
	Walton	0	0	0	0
	Rissik	0	0	0	0
	Adams	0	0	0	0
	Rooidam	0	0	0	0
	Upperby	0	0	0	0
	A. Pyper	20	8	0	0
	Old Railroad Housing	13	2	8	0
	Old Middelplaats Mine	184	134	0	0
	N. Fourie	11	2	0	0

Notes:

(a) The European Community permits 35 days of exceedance of the 50 µg/m³ daily PM10 limit.

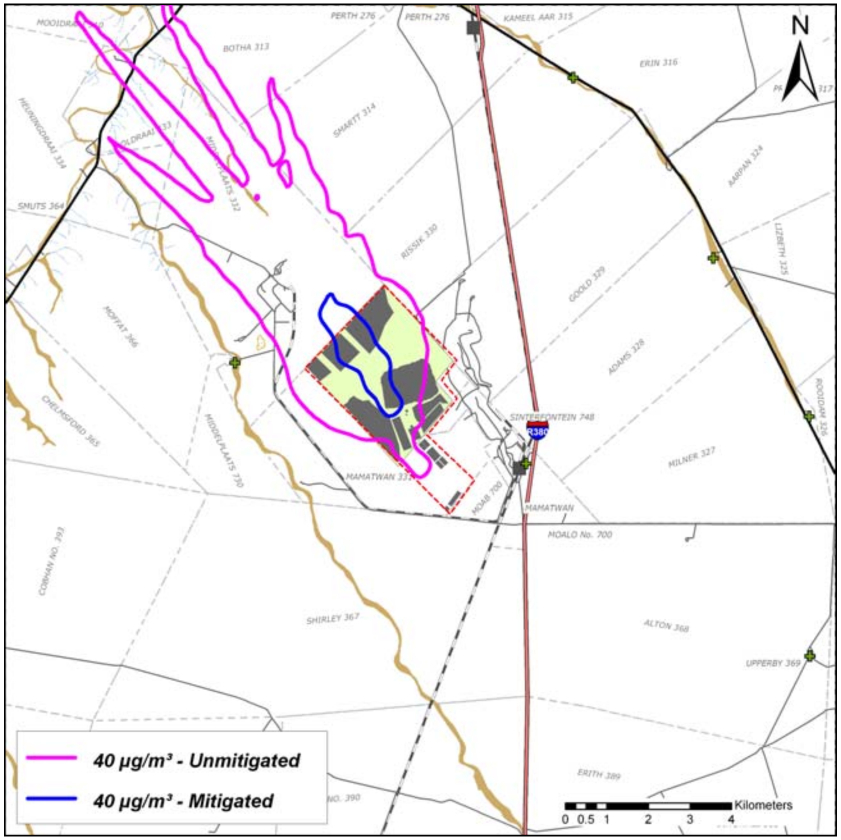

Figure 5-18: Scenario 2 – Predicted incremental annual average PM10 concentrations

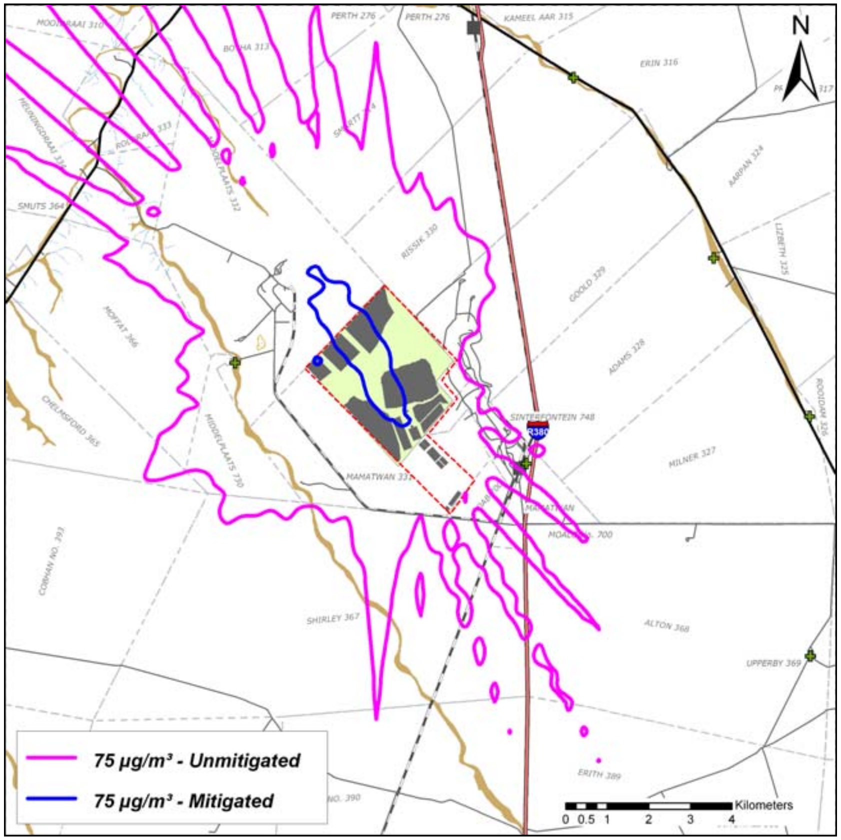

Figure 5-19: Scenario 2 – Predicted incremental highest daily average PM10 concentrations

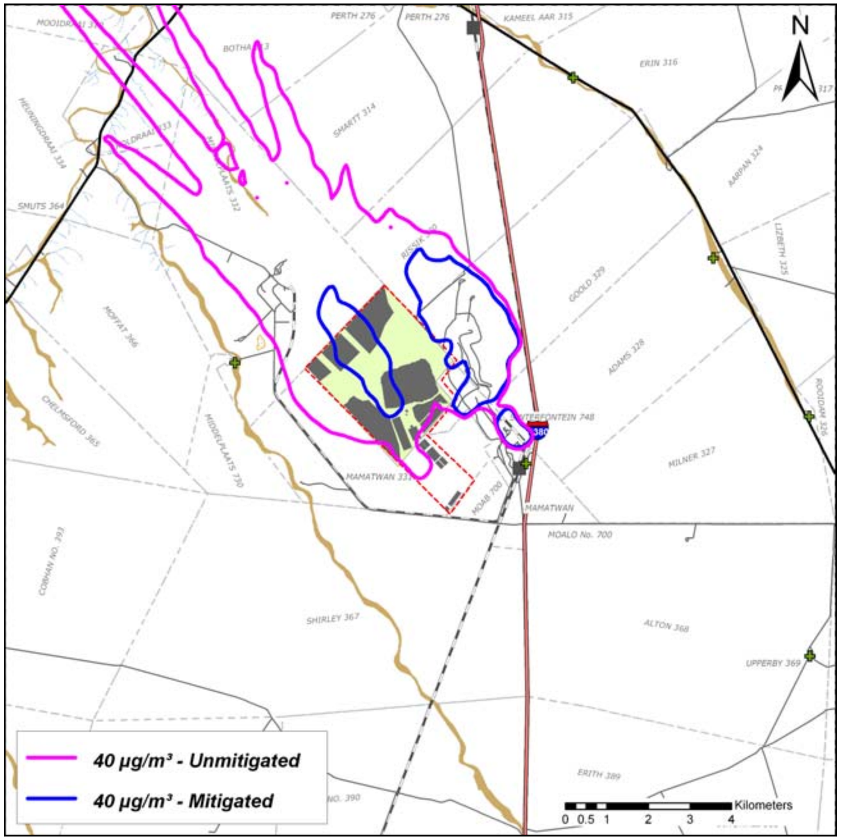

Figure 5-20: Scenario 2 – Predicted cumulative annual average PM10 concentrations

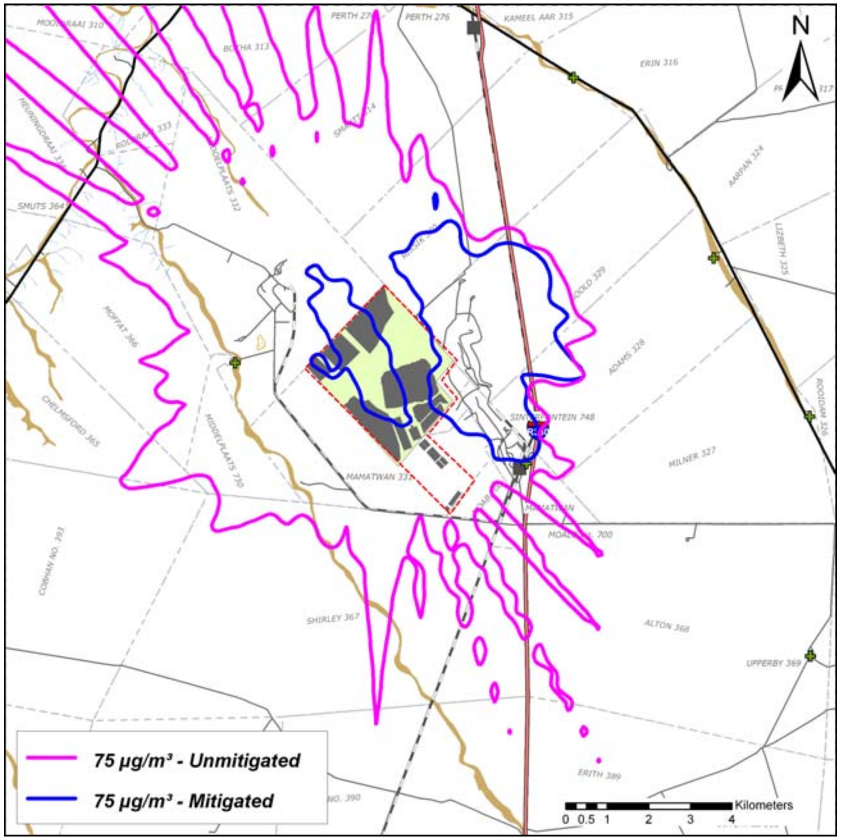

Figure 5-21: Scenario 2 – Predicted cumulative highest daily average PM10 concentrations

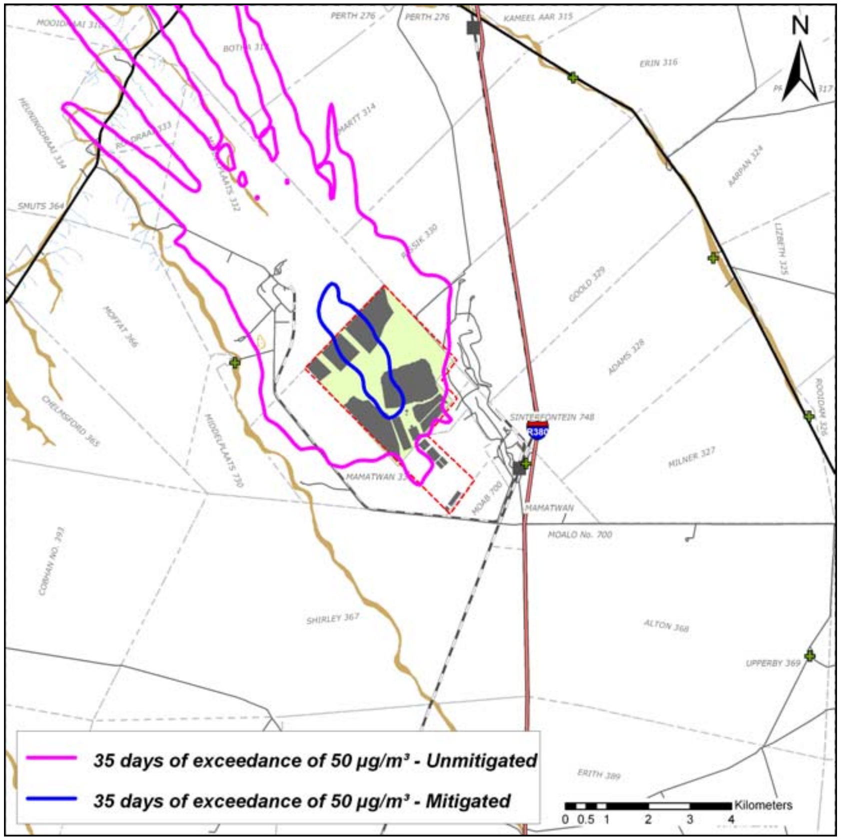

Figure 5-22: Scenario 2, Incremental PM10 - Predicted days of exceedance of 50µg/m³

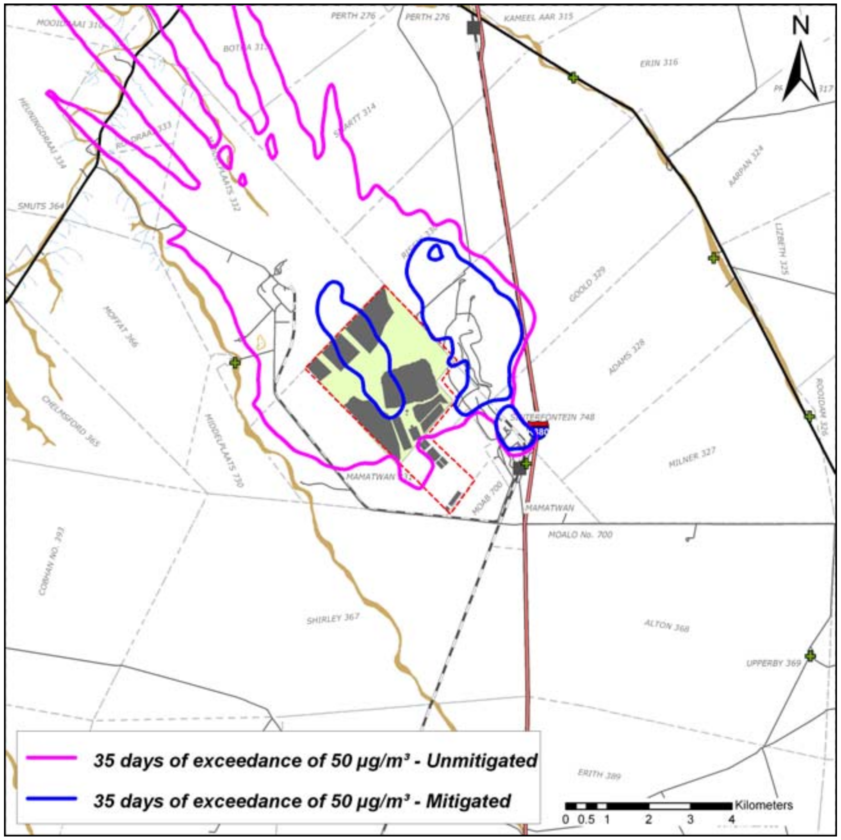

Figure 5-23: Scenario 2, Cumulative PM10 - Predicted days of exceedance of 50µg/m³

5.4.2.2 Manganese Impacts

Table 5-25 gives the incremental and cumulative manganese ground level concentrations predicted to occur at the various sensitive receptors as a result of proposed Scenario 2 operations.

Incrementally, unmitigated emissions are predicted to result in exceedances of the WHO annual average standard for manganese at the Ntsimbintle boundary, A. Pyper, the old Middelplaats mine and N. Fourie. With mitigation measures in place the predicted annual average Mn concentrations exceed the WHO standard at the Ntsimbintle boundary the old Middelplaats mine and N. Fourie. Cumulatively, unmitigated and mitigated emissions are predicted to result in exceedances of the WHO guideline at the Ntsimbintle boundary, Rissik, Adams, A. Pyper the ORH, the old Middelplaats mine and N. Fourie.

Isopleth plots for predicted incremental and cumulative Mn concentrations are presented in Figure 5-24 and Figure 5-25 respectively.

Table 5-25: Scenario 2 - Predicted manganese ground level concentrations

Scenario 2 - Predicted Mn Concentrations (µg/m³)			
Source	**Receptor**	**Unmitigated**	**Mitigated**
		Annual Average[(a)]	**Annual Average[(a)]**
Incremental	Ntsimbintle Boundary	**8.25(b)**	**1.47(b)**
	Walton	0.04	0.01
	Rissik	0.04	0.02
	Adams	0.04	0.03
	Rooidam	0.02	0.01
	Upperby	0.02	0.02
	A. Pyper	**0.20(b)**	0.06
	ORH	0.14	0.07
	Old Middelplaats Mine	**0.57(b)**	**0.18(b)**
	N. Fourie	**0.31(b)**	0.07
Cumulative	Ntsimbintle Boundary	**9.74(b)**	**9.54(b)**
	Walton	0.07	0.05
	Rissik	**0.18(b)**	**0.16(b)**
	Adams	**0.20(b)**	**0.19(b)**
	Rooidam	0.07	0.06
	Upperby	0.04	0.04
	A. Pyper	**0.34(b)**	**0.19(b)**
	ORH	**2.12(b)**	**2.05(b)**
	Old Middelplaats Mine	**0.91(b)**	**0.51(b)**
	N. Fourie	**0.49(b)**	**0.26(b)**

Notes:

(a) WHO annual average Mn guideline – 0.15µg/m³.

(b) Exceeds WHO guideline.

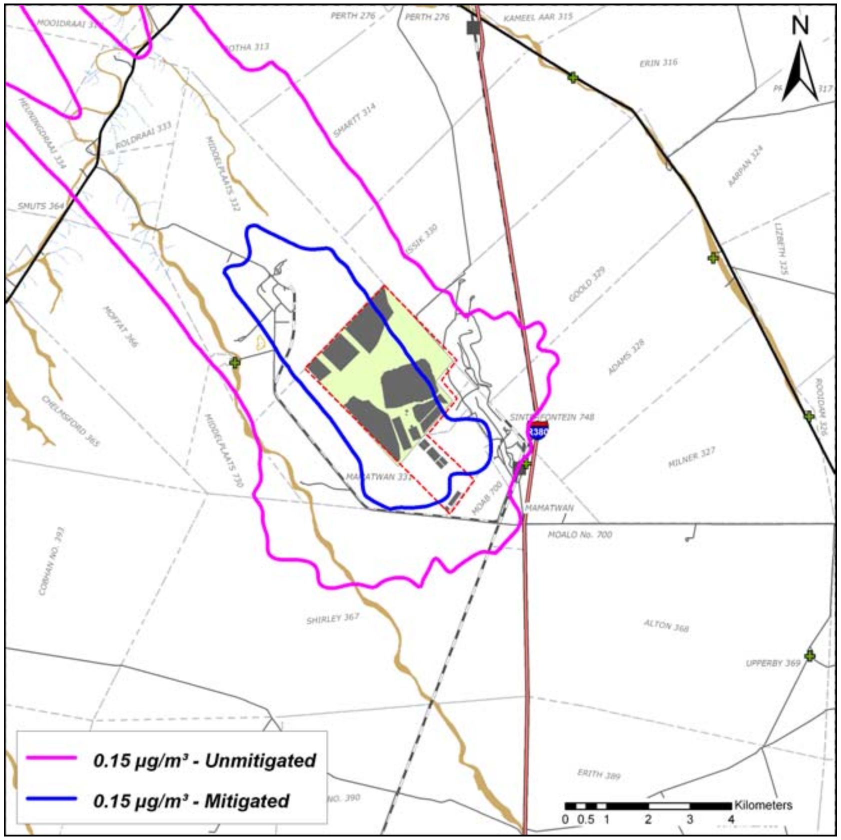

Figure 5-24: **Scenario 2 – Predicted incremental annual average PM10 concentrations**

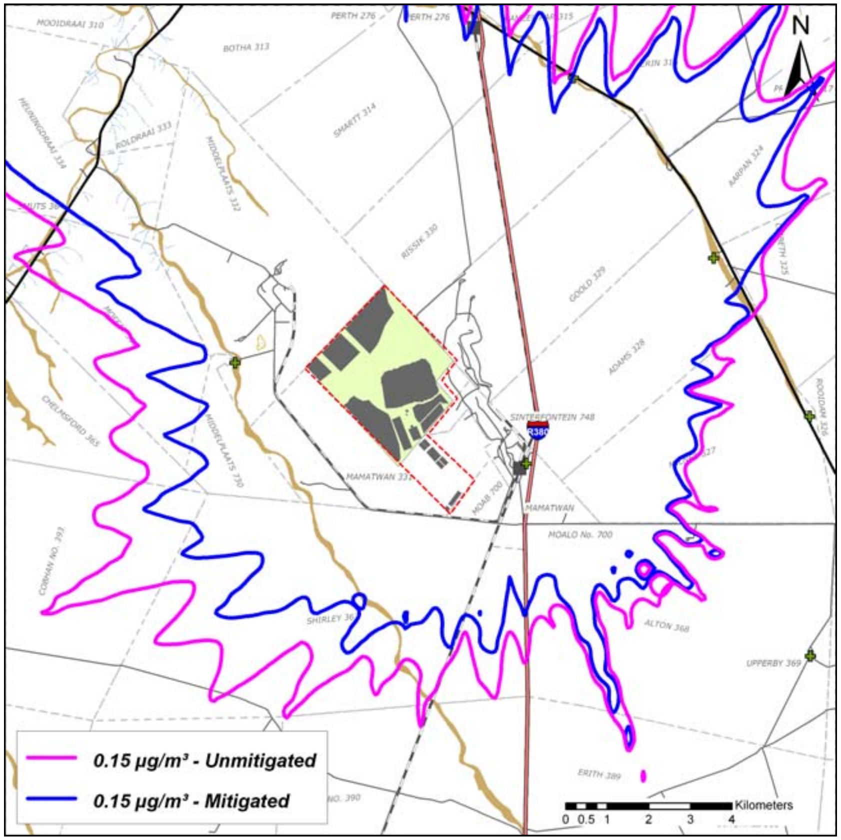

Figure 5-25: **Scenario 2 – Predicted cumulative annual average Mn concentrations**

5.4.2.3 SO_2 Impacts

Table 5-26 gives the incremental and cumulative SO_2 ground level concentrations predicted to occur at the various sensitive receptors as a result of proposed Scenario 2 operations.

Predicted SO_2 concentrations at the various sensitive receptors are low compared to the SA standards. Only the predicted highest hourly average concentrations at the Ntsimbintle boundary (incrementally and cumulatively) are in exceedance of the SA standard.

5.4.2.4 NO_2 Impacts

Table 5-27 gives the incremental and cumulative NO_2 ground level concentrations predicted to occur at the various sensitive receptors as a result of proposed Scenario 2 operations.

A conservative approach was adopted in the prediction of NO_2 concentrations. It was assumed that at the residential receptors all NO_x emissions would have been converted to NO_2. Since vehicle tailpipe emissions are the main contributors to predicted DPM concentrations at the boundary it was assumed that only 20% of the NO_x emissions from these vehicles are emitted as NO_2 (Haywood, 1988). Only the predicted highest hourly average concentrations at the Ntsimbintle boundary (incrementally and cumulatively) are in exceedance of the proposed SA standard.

Table 5-26: Scenario 2 - Predicted SO_2 ground level concentrations

Scenario 2 - Predicted SO2 Concentrations (µg/m³)				
Source	**Receptor**	**Annual Average[(a)]**	**Daily Average[(b)]**	**Hourly Average[(c)]**
Incremental	Ntsimbintle Boundary	8.36	46.80	**521.00[(d)]**
	Walton	0.14	1.60	22.90
	Rissik	0.28	2.11	26.20
	Adams	0.55	5.93	51.00
	Rooidam	0.24	2.05	32.40
	Upperby	0.29	4.77	35.00
	A. Pyper	0.70	3.97	24.90
	ORH	1.20	9.14	94.60
	Old Middelplaats Mine	2.03	6.72	23.80
	N. Fourie	0.50	7.53	50.50
Cumulative	Ntsimbintle Boundary	8.61	46.80	**521.00[(d)]**
	Walton	0.17	2.06	24.70
	Rissik	0.35	2.45	26.20
	Adams	0.74	8.26	51.00
	Rooidam	0.35	2.43	32.40
	Upperby	0.37	4.79	35.00
	A. Pyper	0.78	4.83	25.10
	ORH	1.20	9.25	94.60
	Old Middelplaats Mine	2.23	7.58	23.90
	N. Fourie	0.55	8.00	50.60

Notes:

(a) Proposed SA annual SO_2 standard – 50µg/m³.

(b) Proposed SA daily SO_2 standard – 125µg/m³.

(c) Proposed SA hourly SO_2 standard – 350µg/m³.

(d) Predicted ground level concentration exceeds SA SO_2 standards.

Table 5-27: Scenario 2 - Predicted NO_2 ground level concentrations

Scenario 2 - Predicted NO_2 Concentrations (µg/m³)			
Source	**Receptor**	**Annual Average**[(a)]	**Hourly Average**[(b)]
Incremental	Ntsimbintle Boundary	34.80	**218.00**[(c)]
	Walton	0.57	82.60
	Rissik	0.85	53.40
	Adams	1.39	102.00
	Rooidam	0.58	64.30
	Upperby	0.62	55.50
	A. Pyper	3.15	66.30
	ORH	3.30	133.00
	Old Middelplaats Mine	11.80	90.80
	N. Fourie	2.21	137.00
Cumulative	Ntsimbintle Boundary	34.90	**218.00**[(c)]
	Walton	0.61	82.60
	Rissik	0.93	53.40
	Adams	1.64	102.00
	Rooidam	0.72	64.30
	Upperby	0.71	55.50
	A. Pyper	3.26	66.30
	ORH	3.30	133.00
	Old Middelplaats Mine	12.10	90.80
	N. Fourie	2.27	137.00

Notes:

(a) Proposed SA annual NO_2 standard – 40µg/m³.

(b) Proposed SA daily NO_2 standard – 200µg/m³.

(c) Predicted ground level concentration exceeds SA NO_2 standards.

5.4.2.5 DPM Impacts

Table 5-28 gives the incremental DPM ground level concentrations predicted to occur at the various sensitive receptors as a result of proposed Scenario 2 operations.

Only the predicted annual average concentrations at the Ntsimbintle boundary is in exceedance of the SA standard for benzene (See section 2.5.3).

Table 5-28: Scenario 2 - Predicted DPM ground level concentrations

Scenario 1 - Predicted DPM Concentrations (µg/m³)	
Receptor	**Annual Average[(a)]**
Ntsimbintle Boundary	**9.36[(b)]**
Walton	0.01
Rissik	0.01
Adams	0.00
Rooidam	0.00
Upperby	0.00
A. Pyper	0.04
Old Railroad Housing	0.01
Old Middelplaats Mine	0.26
N. Fourie	0.02

Notes:

(a) Proposed SA annual Benzene standard – 5µg/m³ (see Section 2.5.3).

(b) Predicted ground level concentration exceeds SA benzene standards.

5.4.2.6 CO Impacts

Table 5-29 gives the incremental CO ground level concentrations predicted to occur at the various sensitive receptors as a result of proposed Scenario 2 operations. The SA standard for CO is not exceeded at any of the discreet receptors included in the study.

Table 5-29: Scenario 2 - Predicted CO ground level concentrations

Scenario 2 - Predicted CO Concentrations (µg/m³)	
Receptor	**Hourly Average**[(a)]
Ntsimbintle Boundary	465.00
Walton	10.60
Rissik	6.38
Adams	5.84
Rooidam	5.51
Upperby	3.02
A. Pyper	20.00
Old Railroad Housing	17.60
Old Middelplaats Mine	27.60
N. Fourie	21.40

Notes:

(a) Proposed SA hourly CO standard – 30000µg/m³.

5.4.2.7 Dustfall Impacts

Table 5-30 gives the incremental and cumulative dustfall levels predicted to occur at the various sensitive receptors as a result of proposed Scenario 2 unmitigated and mitigated emissions.

Overall the predicted dustfall levels at all the residential discreet receptors were relatively low. Only cumulative unmitigated emissions are predicted to result in dustfall levels in exceedance of 600 mg/m²/day at the Ntsimbintle boundary. Exceedance of this standard is only allowed 3 times a year and should not be exceeded in two consecutive months.

Isopleth plots for predicted incremental and cumulative maximum daily dustfall levels are presented in Figure 5-26 and Figure 5-27 respectively.

Table 5-30: Scenario 2 - Predicted Maximum Dustfall Levels

Scenario 2 - Predicted Maximum Dustfall Levels (mg/m²/day)			
Source	**Receptor**	**Unmitigated**	**Mitigated**
		Maximum Daily	**Maximum Daily**
Incremental	Ntsimbintle Boundary	**743.00**	75.90
	Walton	0.23	0.12
	Rissik	0.79	0.24
	Adams	0.61	0.31
	Rooidam	0.67	0.17
	Upperby	0.26	0.19
	A. Pyper	2.68	0.62
	ORH	3.76	2.35
	Old Middelplaats Mine	9.04	1.82
	N. Fourie	3.27	0.79
Cumulative	Ntsimbintle Boundary	**744.00**	166.00
	Walton	0.33	0.22
	Rissik	1.34	0.79
	Adams	1.78	1.49
	Rooidam	1.01	0.77
	Upperby	0.47	0.39
	A. Pyper	3.18	1.12
	ORH	23.40	22.20
	Old Middelplaats Mine	9.83	2.59
	N. Fourie	3.74	1.26

Notes:

(a) SANS dustfall band for residential and light commercial areas – 600 mg/m²/day.

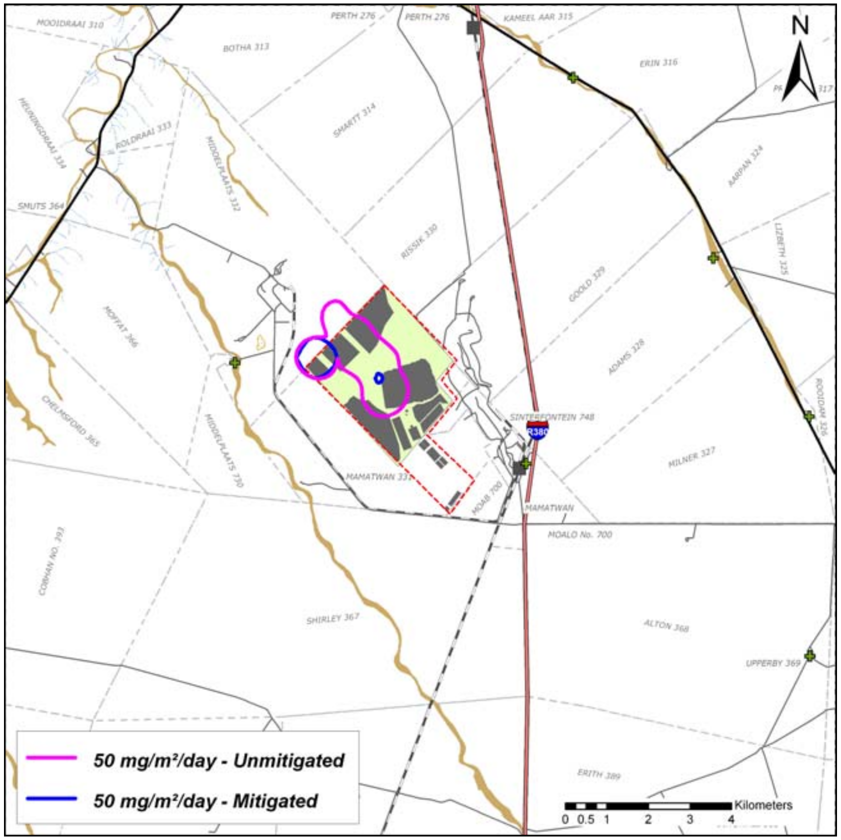

Figure 5-26: Scenario 2 – Predicted incremental maximum daily dustfall levels

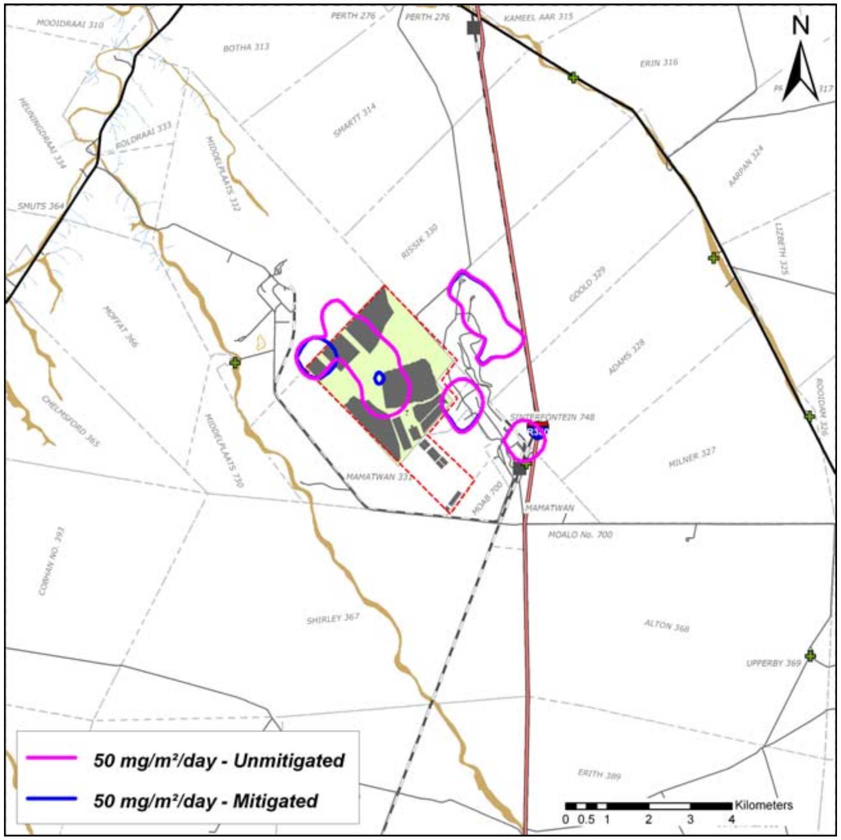

Figure 5-27: Scenario 2 – Predicted cumulative maximum daily dustfall levels

5.5 Source Ranking by Impacts

Ranking source contributions to predicted ground level concentrations can provide valuable insight regarding sources of atmospheric that need to be focussed and can feed into an air quality management plan. Sources are subsequently ranked based on each source group's average contribution to the predicted annual average pollutant concentrations at the various sensitive receptors. The two most significant contributors to the various predicted pollutant concentrations for each Scenario are presented in Table 5-31 along with the average percentage contribution.

From Table 5-31 it is evident that the most significant sources of atmospheric emission based on predicted ground level concentrations are:

- Vehicle entrained dust from unpaved roads;
- Dust as a result from crushing and screening operations;
- Sinter plant stack emissions; and
- Vehicle tailpipe emissions

Table 5-31: Average source group contributions to predicted annual average concentrations

Scenario	Rank	PM10	Mn	SO_2	NO_2	DPM	CO
Scenario 1							
Unmitigated	**#1**	Unpaved Roads (88%)	Crushing & Screening (61%)	Sinter Plant (89%)	Sinter Plant (39%)	Vehicle Tailpipe Emissions (100%)	Vehicle Tailpipe Emissions (68%)
	#2	Crushing & Screening (8%)	Sinter Plant (17%)	Vehicle Tailpipe Emissions (7%)	Power Generation Plant (37%)	-	Power Generation Plant (32%)
Mitigated	**#1**	Unpaved Roads (67%)	Sinter Plant (48%)	Sinter Plant (89%)	Sinter Plant (39%)	Vehicle Tailpipe Emissions (100%)	Vehicle Tailpipe Emissions (68%)
	#2	Sinter Plant (20%)	Crushing & Screening (39%)	Vehicle Tailpipe Emissions (7%)	Power Generation Plant (37%)	-	Power Generation Plant (32%)
Scenario 2							
Unmitigated	**#1**	Unpaved Roads (92%)	Crushing & Screening (60%)	Sinter Plant (89%)	Power Generation Plant (40%)	Vehicle Tailpipe Emissions (100%)	Vehicle Tailpipe Emissions (66%)
	#2	Crushing & Screening (4%)	Sinter Plant (37%)	Vehicle Tailpipe Emissions (7%)	Sinter Plant (38%)	-	Power Generation Plant (34%)
Mitigated	**#1**	Unpaved Roads (71%)	Sinter Plant (68%)	Sinter Plant (89%)	Power Generation Plant (40%)	Vehicle Tailpipe Emissions (100%)	Vehicle Tailpipe Emissions (66%)
	#2	Sinter Plant (24%)	Crushing & Screening (30%)	Vehicle Tailpipe Emissions (7%)	Sinter Plant (38%)	-	Power Generation Plant (34%)

6 CONCLUSIONS

An air quality impact assessment has been undertaken for proposed operations at Ntsimbintle. PM10, manganese, SO_2, NO_x, DPM and CO health impacts as well as nuisance dust impacts for the proposed operations were assessed in order to identify all possible detrimental impacts on the surrounding environment and sensitive receptors.

In order to determine worst case conditions with respect to estimated emissions and predicted impacts four phases in the life of the Ntsimbintle project were considered:

- **Construction phase**: Due to uncertainty as to the exact construction schedule and activities as well as the fact that in general the construction phase is often of short duration, emissions were quantified but not applied in the dispersion modelling.
- **Operational phases**:
    - Scenario 1: Included opencast and underground mining, processing and the beneficiation of manganese ore as well as the power generation plant. The emissions from this scenario were quantified and impacts determined through dispersion modelling.
    - Scenario 2: Included underground mining, the rehabilitation of the open cast mining area, processing and the beneficiation of manganese ore as well as the power generation plant. The emissions from this scenario were quantified and impacts determined through dispersion modelling.
- **Closure phase:** It was assumed that all processing operations will have ceased by the closure phase of the project. The potential for impacts during this phase will depend on the extent of demolition and rehabilitation efforts during closure and on features which will remain. Information regarding the extent of demolition and/or rehabilitation procedures were limited and therefore not included in the emissions inventory or the dispersion modelling.

From the air quality impact assessment it was evident that Scenario 1 (opencast and underground mining, processing and the beneficiation) would constitute the worst case scenario for the Ntsimbintle project. Consequently all conclusions and recommendations were based on this scenario.

Completely unmitigated as well as partially mitigated fugitive dust emissions were determined and assessed in terms of predicted impacts. The mitigation measures that were applied in the mitigated case were as follows:

- Water in combination with chemical dust suppressants on unpaved road surfaces - 90% reduction in PM10, TSP and Mn emissions as a result of vehicle entrainment from unpaved roads
- Sweeper - 90% reduction in PM10, TSP and Mn emissions as a result of vehicle entrainment from paved/treated roads
- Water sprays – 70% and 50% reduction in PM10, TSP and Mn emissions from truck offloading and conveyor transfer points respectively
- Hooding with fabric filters at crushing and screening plants – 83% reduction in PM10, TSP and Mn emissions
- Drill fitted with cyclone – 25% reduction in PM10, TSP and Mn emissions from in-pit drilling

Incremental and cumulative air quality impacts were determined. Incremental concentrations and impacts refer to impacts associated with proposed operations at Ntsimbintle in isolation. Cumulative concentrations and impact refer to impacts associated with proposed operations at Ntsimbintle in addition to impacts associated with current operations at Mamatwan manganese mine.

The main findings of the study, based on worst case emissions and predicted impacts (Scenario 1), were as follows:

6.1 Estimated worst case emissions

- **PM10** emissions:
    - Total **unmitigated PM10** emissions were estimated at 4 520 tpa of which 92% were as a result of vehicle entrainment of dust from unpaved haul roads.
    - The total **mitigated PM10** emissions were estimated at 688 tpa. Vehicle entrainment and emissions from the sinter plant contributed 80% and 32% to the total, respectively.
- **TSP** emissions:

  - Total **unmitigated TSP** emissions amounted to 15 100 tpa of which 96% were as a result of vehicle entrainment of dust from unpaved haul roads.

  - **Mitigated TSP** emissions amounted to 1 790 tpa. Vehicle entrained dust from unpaved haul roads were estimated to be the most significant contributor to mitigated TSP emissions, contributing approximately 82%.

- **Manganese** emissions:

  - Total unmitigated Mn emissions amounted to 303 tpa. Vehicle entrainment was estimated to contribute most significantly, 64%, to the total followed by sinter plant emissions at 25%.

  - With **mitigation** measures in place the total **Mn** emissions were estimated to reduce to 104 tpa with the sinter plant emissions contributing 79% to the total.

- **SO_2** emissions: Total SO_2 emissions were estimated to be 1 290 tpa. Sinter plant emissions were estimated to contribute 98% to the total.

- **NO_x** emissions amounted to 2 820 tpa. Sinter plant emissions were estimated to contribute the most significantly (63%) to NO_x emissions followed by NO_x emissions from the power generation plant (31%).

- Estimated **DPM** as a result of vehicle tailpipe emissions amounted to 10.8 tpa.

- Estimated **CO** amounted to 173 tpa. The power generation plant and vehicle tailpipe emissions contributed 53% and 47% to estimated CO emissions respectively.

6.2 Predicted worst case Impacts

- **PM10** impacts:

  - The predicted annual average and highest daily average **incremental unmitigated** PM10 concentration at the Ntsimbintle boundary were 3650 and 7060 µg/m³ respectively. The proposed annual PM10 standard of 40µg/m³ was exceeded at the Ntsimbintle boundary and the old Middelplaats mine. The proposed daily standard of 75µg/m³ was exceeded at the Ntsimbintle boundary, A. Pyper, the old Middelplaats mine and N. Fourie.

- **Cumulatively** the predicted annual average and highest daily average **unmitigated** PM10 concentrations at the Ntsimbintle boundary were 3650 and 7060 µg/m³ respectively. Exceedance of the proposed annual PM10 standard was predicted the Ntsimbintle boundary and the old Middelplaats mine. Exceedance of the proposed daily PM10 standard was predicted at the Ntsimbintle boundary, A. Pyper, the old railway housing, the old Middelplaats mine and N. Fourie.

- The predicted annual average and highest daily average **incremental mitigated** PM10 concentration at the Ntsimbintle boundary were 366 and 709 µg/m³ respectively. The proposed annual and daily PM10 standards were exceeded at the Ntsimbintle boundary.

- The predicted annual average and highest daily average **cumulative mitigated** PM10 concentration at the Ntsimbintle boundary were 370 and 709 µg/m³ respectively. The proposed annual and daily PM10 standards were exceeded at the Ntsimbintle boundary.

- Mitigation of fugitive dust sources resulted in an average reduction of 87% in predicted PM10 concentrations.

- Vehicle entrained dust from unpaved roads were predicted to result in the most significant unmitigated and mitigated PM10 concentrations contributing, on average, 88% and 67% respectively.

- A summary of predicted annual average and daily average concentrations at the off-site discreet receptors are presented in Figure 6-1 and Figure 6-2.

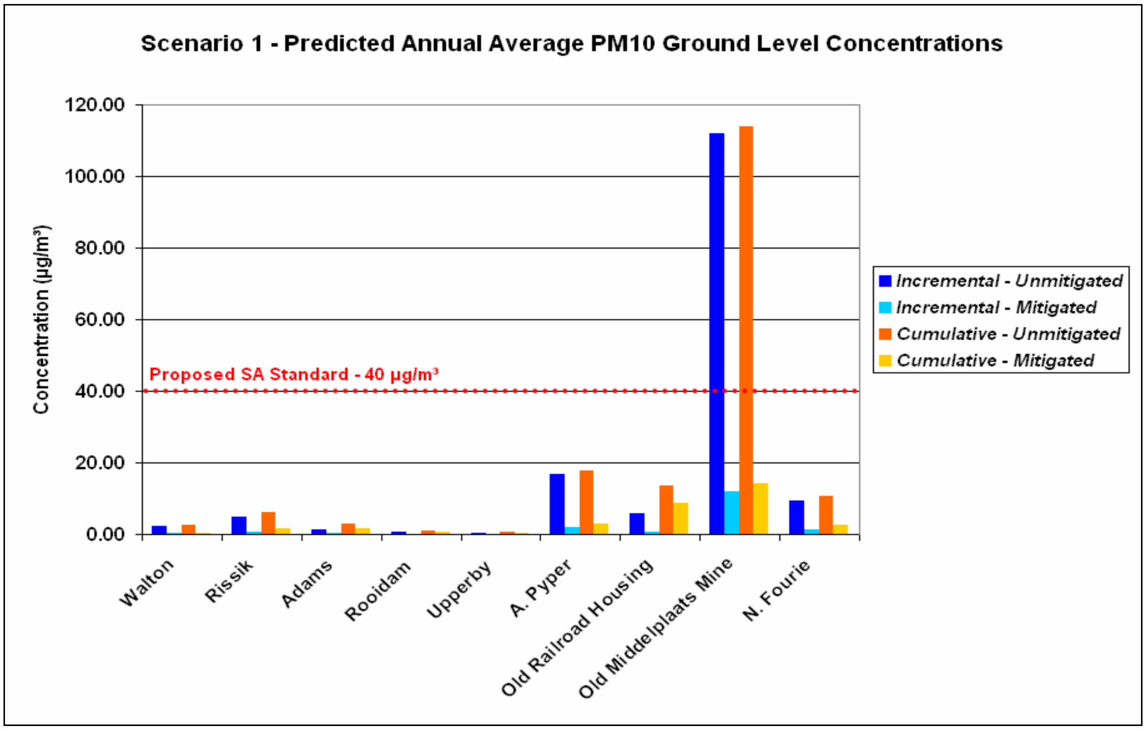

Figure 6-1: **Summary of predicted off-site annual average PM10 concentrations**

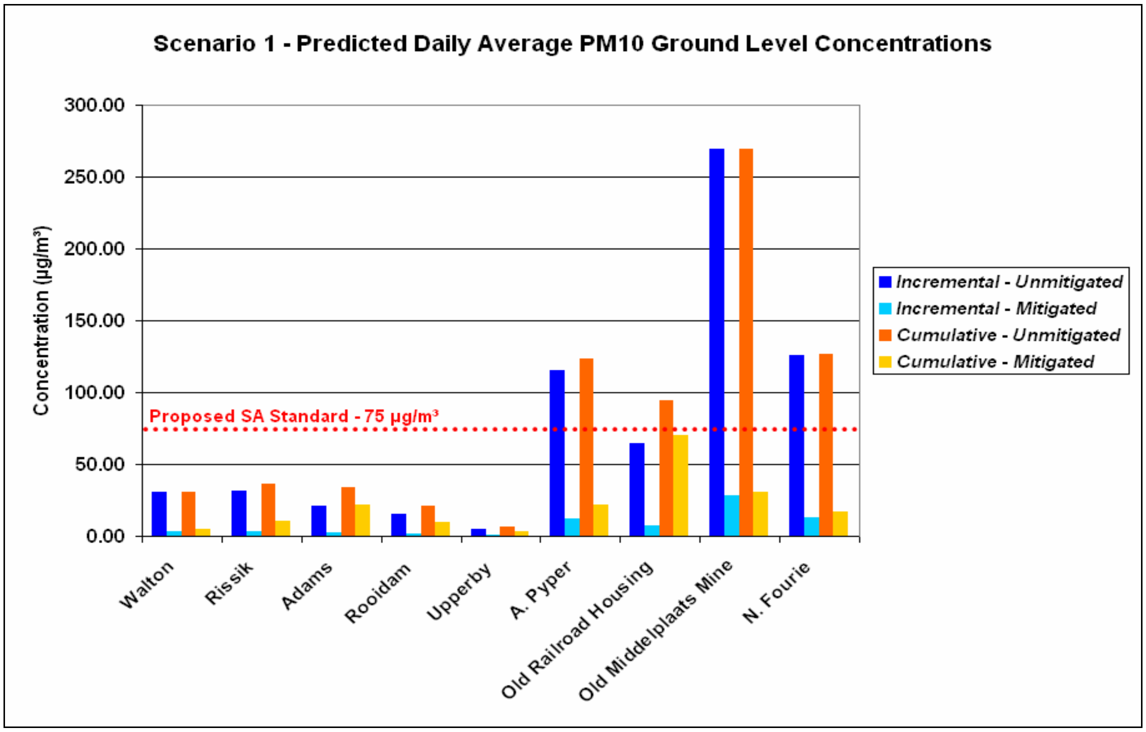

Figure 6-2: **Summary of predicted off-site highest daily average PM10 concentrations**

- **Manganese** impacts:

  - The predicted annual average **incremental unmitigated** Mn concentration at the Ntsimbintle boundary was 20.1µg/m³. The annual WHO guideline of 0.15µg/m³ was exceeded at the Ntsimbintle boundary, A. Pyper, the old railway housing, the old Middelplaats mine and N. Fourie.

  - **Cumulatively** the predicted annual average **unmitigated** Mn concentration at the Ntsimbintle boundary was 20.7µg/m³. Exceedance of the annual WHO guideline was predicted the Ntsimbintle boundary, Rissik, Adams, A. Pyper, the old railway housing, the old Middelplaats mine and N. Fourie.

  - The predicted annual average **incremental mitigated** Mn concentration at the Ntsimbintle boundary was 3.64µg/m³. The annual WHO guideline was exceeded at the Ntsimbintle boundary, the old Middelplaats mine and N. Fourie.

  - The predicted annual average **cumulative mitigated** Mn concentration at the Ntsimbintle boundary was 9.71µg/m³. The annual WHO guideline was exceeded at the Ntsimbintle boundary, Rissik, Adams, A. Pyper, the old railway housing, the old Middelplaats mine and N. Fourie.

  - Mitigation of fugitive dust sources resulted in an average reduction of 69% in predicted Mn concentrations.

  - Manganese dust as a result of crushing and screening operations contributed most significantly, 61%, to predicted unmitigated Mn concentrations. With mitigation measures in place emissions from the sinter plant contributed most significantly to predicted manganese concentrations.

  - A summary of predicted annual average Mn concentrations at the off-site discreet receptors are presented in Figure 6-3

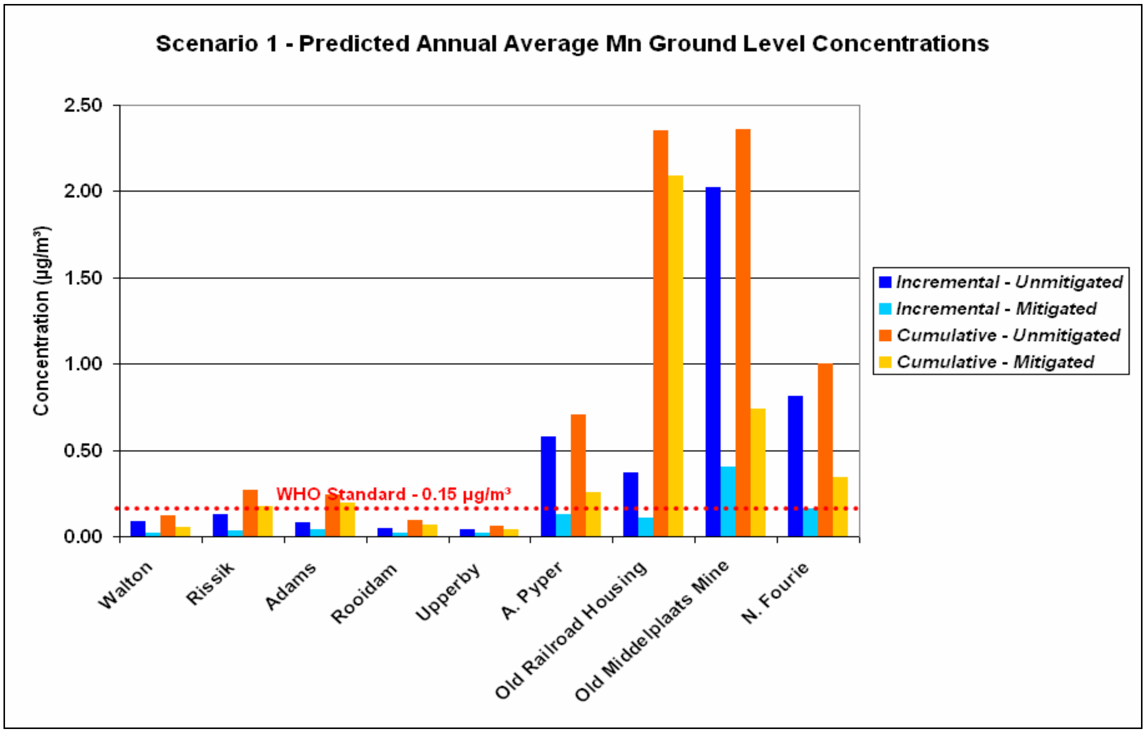

Figure 6-3: **Summary of predicted off-site annual average Mn concentrations**

- **SO_2** impacts:
  - The predicted annual, highest daily and highest hourly average **incremental** SO_2 concentration at the Ntsimbintle boundary was 8.44, 50 and 534 µg/m³ respectively. The proposed hourly SA SO_2 standard of 350µg/m³ was exceeded at the Ntsimbintle boundary.
  - The predicted annual, highest daily and highest hourly average **cumulative** SO_2 concentration at the Ntsimbintle boundary was 8.69, 50 and 534 µg/m³ respectively. Only the proposed SA hourly standard of 350µg/m³ for SO_2 was exceeded at the Ntsimbintle boundary.
  - Sinter plant emissions were estimated to be the most significant contributor, contributing on average 89%, to predicted incremental SO_2 concentrations.
  - A summary of predicted annual, highest daily and highest hourly average SO_2 concentrations at the off-site discreet receptors are presented in Figure 6-4, Figure 6-5 and Figure 6-6 respectively.

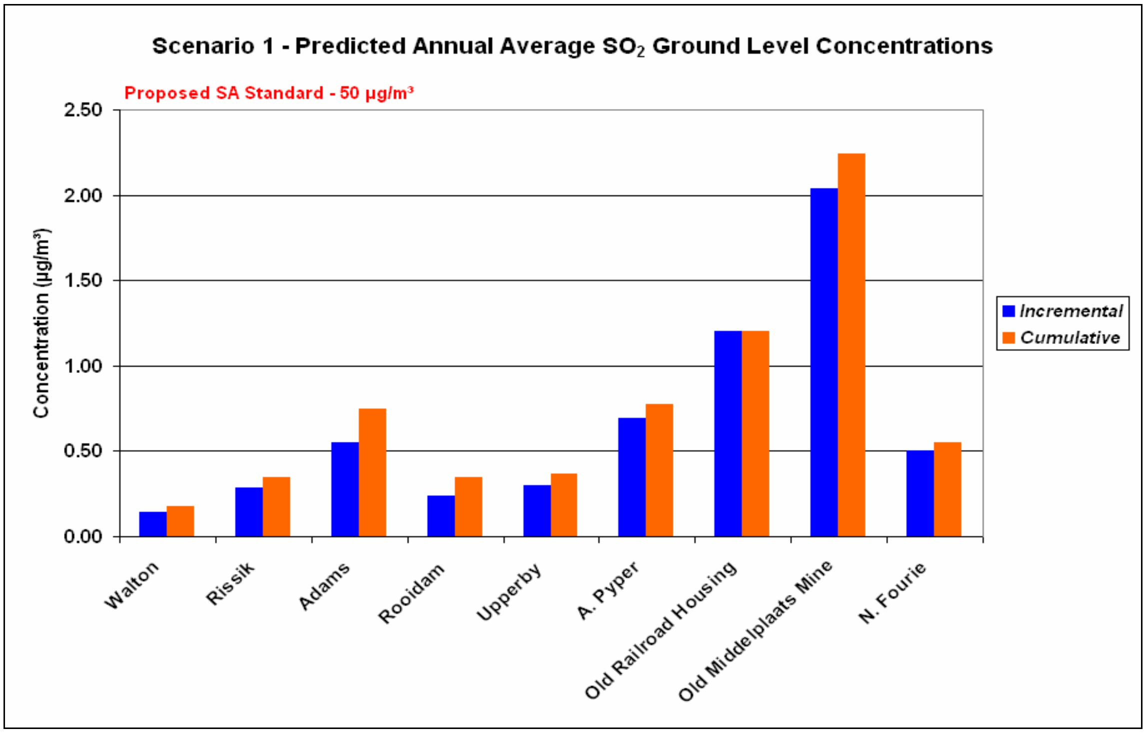

Figure 6-4: Summary of predicted off-site annual average SO_2 concentrations

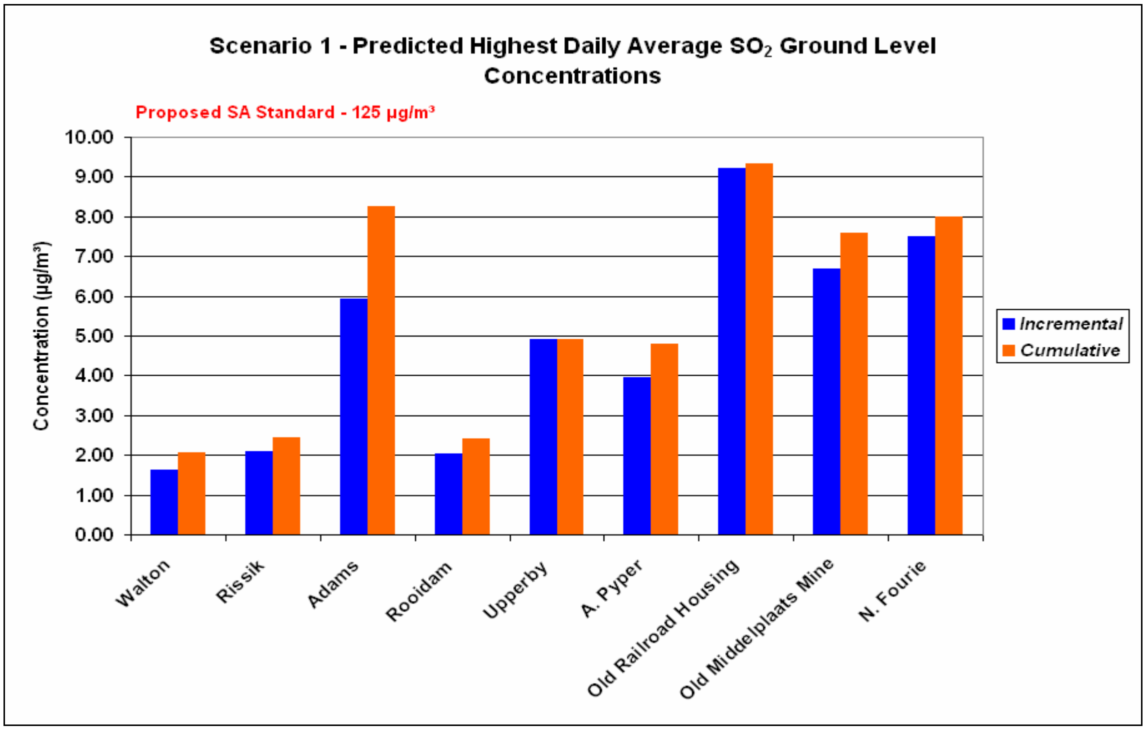

Figure 6-5: Summary of predicted off-site highest daily average SO_2 concentrations

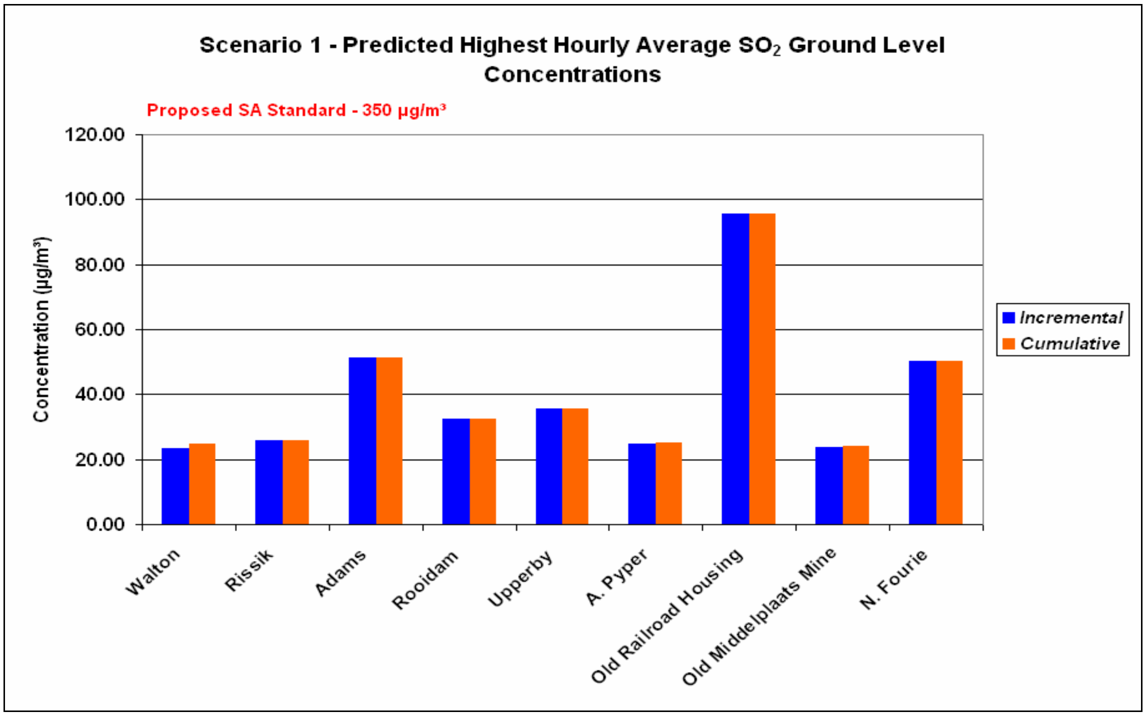

Figure 6-6: **Summary of predicted off-site highest hourly average SO_2 concentrations**

- **NO_2** impacts:
  - The predicted annual and highest hourly average **incremental** NO_2 concentration at the Ntsimbintle boundary was 35.1 and 219 µg/m³ respectively. The proposed hourly SA NO_2 standard of 200µg/m³ was exceeded at the Ntsimbintle boundary.
  - The predicted annual and highest hourly average **cumulative** NO_2 concentration at the Ntsimbintle boundary was 35.2 and 219 µg/m³ respectively. Only the proposed SA hourly standard of 200µg/m³ for NO_2 was exceeded at the Ntsimbintle boundary.
  - Sinter plant emissions were estimated to be the most significant contributor, contributing on average 39%, to predicted incremental NO_2 concentrations.
  - A summary of predicted annual and highest hourly average NO_2 concentrations at the off-site discreet receptors are presented in Figure 6-7 and Figure 6-8 respectively.

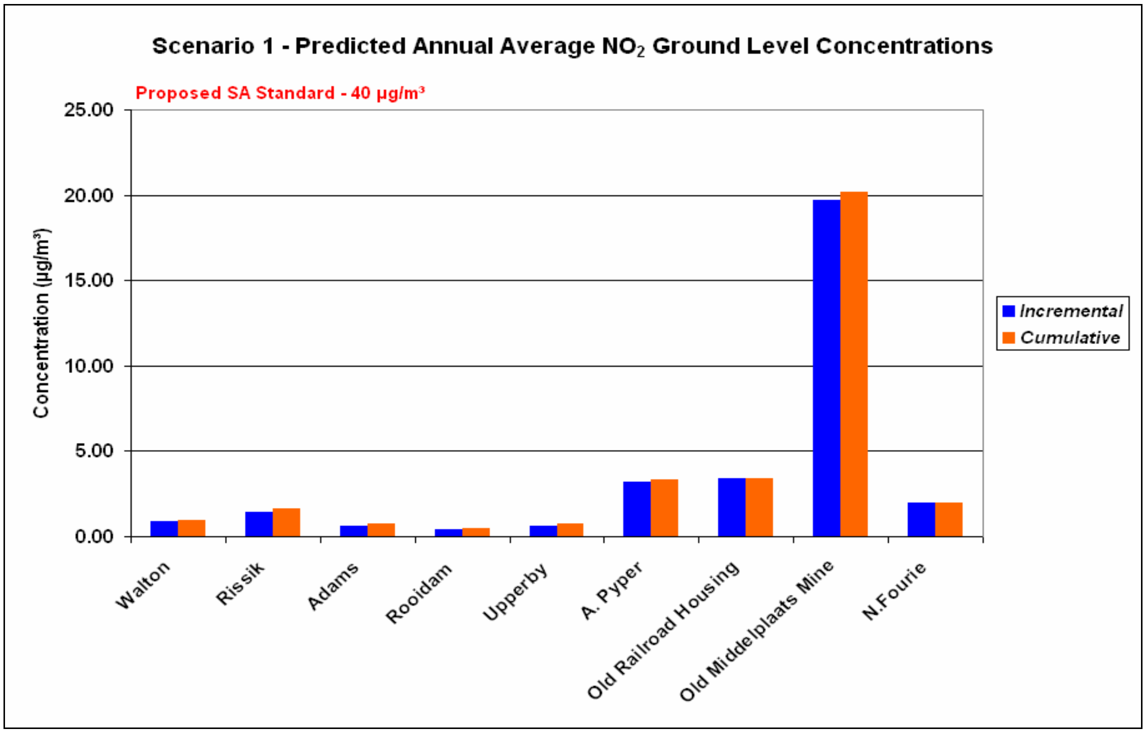

Figure 6-7: Summary of predicted off-site annual average NO_2 concentrations

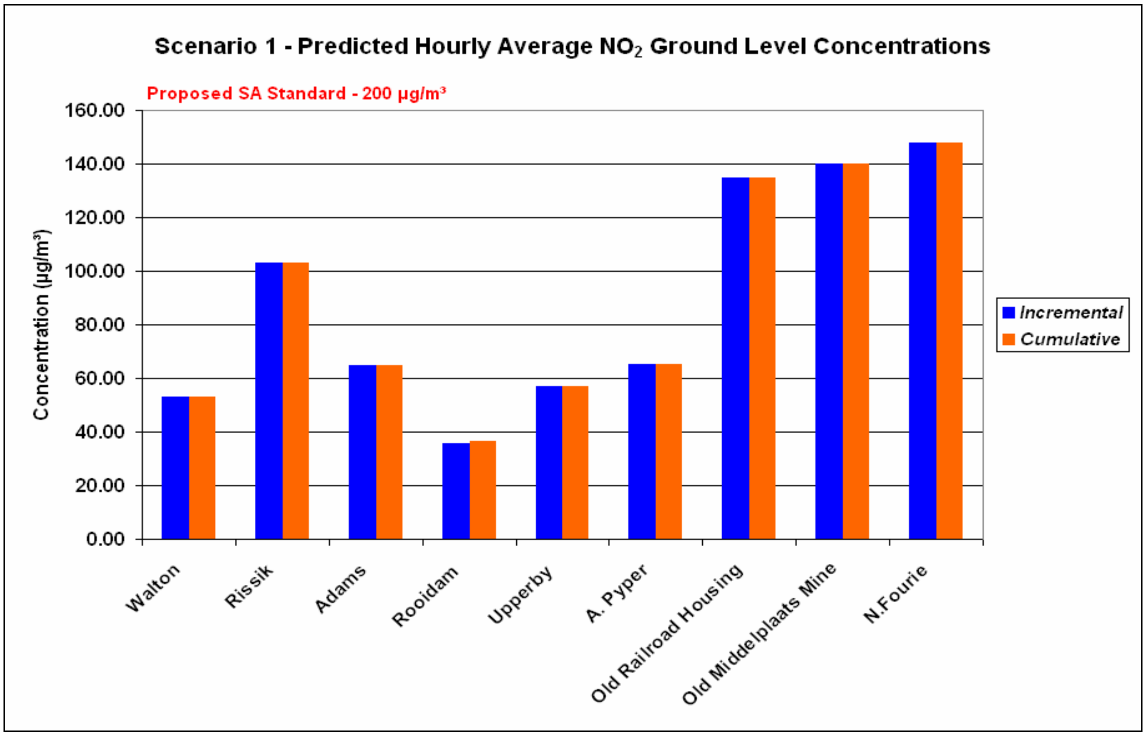

Figure 6-8: Summary of predicted off-site highest hourly average NO_2 concentrations

- **DPM** impacts:
  - The predicted annual average **incremental** DPM concentration at the Ntsimbintle boundary was 9.45µg/m³. The proposed annual SA standard of 5µg/m³ as used in the assessment of DPM impacts was exceeded at the Ntsimbintle boundary.
  - A summary of predicted annual average DPM concentrations at the off-site discreet receptors are presented in Figure 6-9.

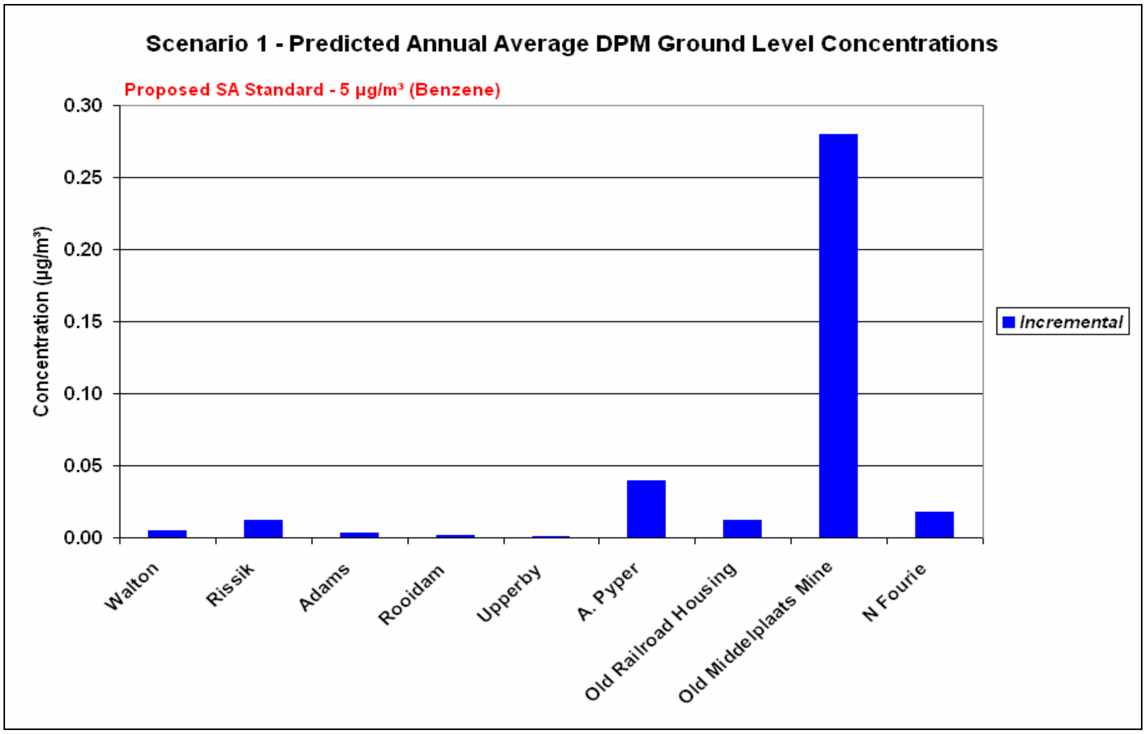

Figure 6-9: **Summary of predicted off-site annual average DPM concentrations**

- **CO** impacts:
  - The predicted highest hourly average **incremental** CO concentration at the Ntsimbintle boundary was 467µg/m³. The proposed hourly SA standard of 30000µg/m³ not exceeded at any of the discreet receptors included in the study.
  - Vehicle tailpipe emissions were estimated to be the most significant contributor, contributing on average 68%, to predicted incremental CO concentrations.

- A summary of predicted highest hourly average CO concentrations at the off-site discreet receptors are presented in Figure 6-10.

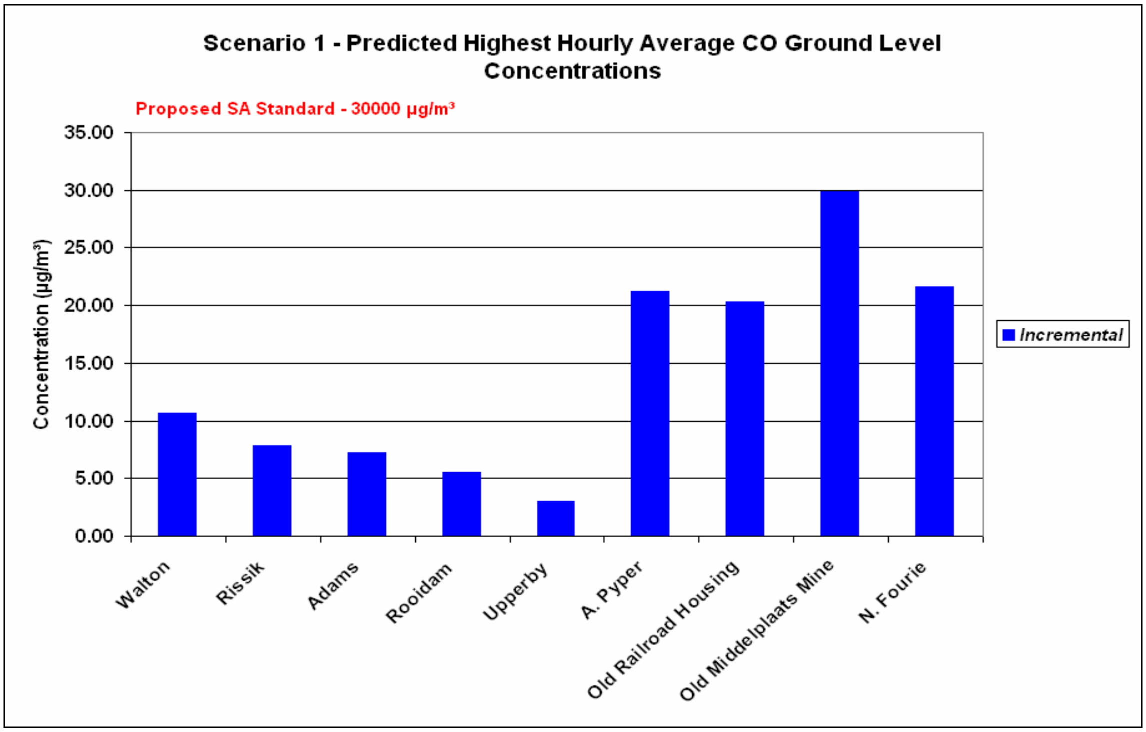

Figure 6-10: Summary of predicted off-site highest hourly average CO concentrations

- **Dustfall** impacts:
  - The predicted maximum daily **incremental unmitigated** dustfall level at the Ntsimbintle boundary was 756mg/m²/day. The SANS residential dustfall band, permissible for residential and light commercial areas, of 600 mg/m²/day was exceeded at the Ntsimbintle boundary.
  - **Cumulatively** the predicted maximum daily **unmitigated** dustfall level at the Ntsimbintle boundary was 756mg/m²/day. The SANS residential dustfall band of 600 mg/m²/day was exceeded at the Ntsimbintle boundary.
  - The predicted maximum daily **incremental mitigated** dustfall level at the Ntsimbintle boundary was 77.4mg/m²/day. The SANS residential dustfall band of 600 mg/m²/day was exceeded at the Ntsimbintle boundary.

- The predicted maximum daily **cumulative mitigated** dustfall level at the Ntsimbintle boundary was 664mg/m²/day. The SANS residential dustfall band of 600 mg/m²/day was exceeded at the Ntsimbintle boundary.

- Mitigation of fugitive dust sources resulted in an average reduction of 66% in predicted incremental dustfall levels.

- A summary of predicted maximum daily dustfall levels at the off-site discreet receptors are presented in Figure 6-11.

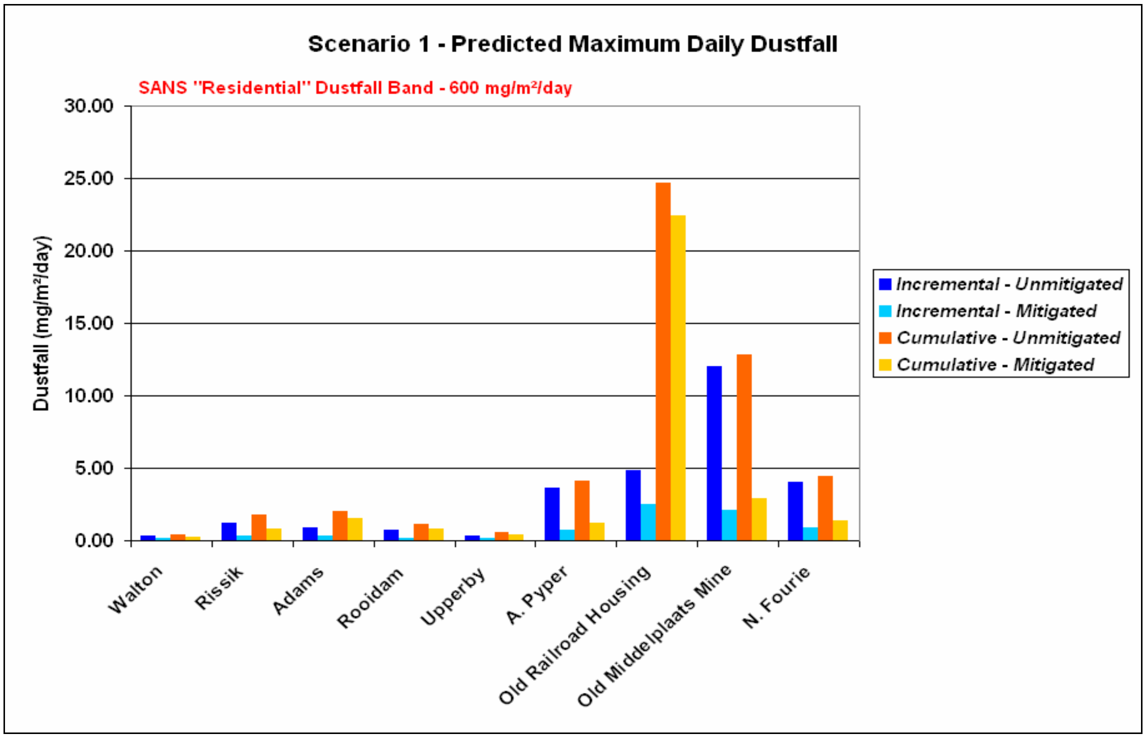

Figure 6-11: Summary of predicted off-site maximum daily dustfall levels

7 AIR QUALITY MANAGEMENT MEASURES AND RECOMMENDATIONS

Based on the conclusions discussed in Section 6, the main objective of the recommendations discussed in this section is to try and ensure that all proposed operations at Ntsimbintle comply with the air quality requirements discussed in Section 2.

Recommendations regarding proposed operations at Ntsimbintle based on worst case emissions and predicted impacts are discussed in subsequent sections.

7.1 Health Risk Assessment

A specialist health risk assessment is required for manganese exposures. Predicted Mn concentrations were compared to international community exposure limits, but most of the Mn exposure in this instance is occupational-related.

The purpose of a human health risk assessment is to consider modelled air concentrations of substances that can cause harm to human health in a site-specific exposure scenario, to quantify human exposure and to predict the potential for adverse health effects in the exposed individuals. Modelled air concentrations of environmental pollutants are required to assess regulatory compliance to air quality regulations and may be used for screening purposes, but that does not constitute a quantitative human health risk assessment. In a health risk assessment the knowledge of toxicology and epidemiology is applied within an internationally accepted health risk assessment paradigm to quantify potential human health risks. In this assessment the risks are contextualised and regulatory authorities are provided with a firm scientific basis to reach conclusions on potential impacts that a source of air contamination may have on the health of neighbouring communities. The assessment not only is in the interest of receptor communities, but it also supports the interest of regulatory authorities and the industry that has to manage its operations and apply mitigation measures, where required (personal communication Dr. W. van Niekerk, Infotox, 2009).

7.2 Mitigation and Management Measures

From the air quality impact assessment it was concluded that potential for health risk primarily exists with regards to predicted PM10 and manganese concentrations. The most significant sources of fugitive dust emission at the proposed Ntsimbintle operation, based on predicted ground level concentrations were:

- Vehicle entrained dust from unpaved roads; and

- Dust as a result from crushing and screening operations

Although gaseous emissions (SO_2 and NO_2) from the sinter plant and vehicle exhausts resulted in exceedances of the short term South African standards at the Ntsimbintle operational boundary, no exceedances were predicted at the off-site sensitive receptors.

The mitigation of dust from unpaved roads as well as other mitigation measures that should be considered for the proposed operations is discussed below.

7.2.1 Vehicle Entrainment on Unpaved Haul Roads

Even with mitigation measures in place on the unpaved roads (water and chemical suppressant with 90% control efficiency) unpaved in-pit and surface haul roads still accounted for 416 tpa (60%) of PM10 emissions and resulted exceedances of the proposed SA standards at the Ntsimbintle operational boundary. To ensure compliance at the boundary it is recommended that additional mitigation measures be considered on all unpaved haul roads where there is vehicle movement.

Three types of measures may be taken to reduce emissions from unpaved roads namely:

- Measures aimed at reducing the extent of unpaved roads, e.g. paving,
- Traffic control measures aimed at reducing the entrainment of material by restricting traffic volumes and reducing vehicle speeds, and
- Measures aimed at binding the surface material or enhancing moisture retention, such as wet suppression and chemical stabilisation (EPA, 1987; Cowhert et al., 1988; APCD, 1995).

It is standard practice at most mines to utilise water trucks on the unpaved roads. It is recommended that water be used in combination with chemical surfactants to reduce the amount of water required to achieve certain control efficiencies. 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. It was shown that 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 will ensure no exceedances at the residential receptors in the area. Should only water be applied, the amount needed to ensure 90% control efficiency on the various haul roads are provided in Table 7-1. This was based on the monthly average evaporation and rainfall data for the Northern Cape (Shulze, 1997).

Traffic control measures aimed at reducing the entrainment of material by restricting traffic volumes and reducing vehicle speeds will not only reduce fugitive dust emissions and therefore predicted PM10 and manganese impacts but also vehicle tailpipe emissions and associated SO_2, NO_2, DPM and CO impacts.

Table 7-1: Average watering rates required on unpaved haul roads

Average watering rates required to ensure 90% reduction in vehicle entrained dust			
Traffic Description	**Trucks per Hour (30 ton capacity)**	**Watering Rate (excluding rainfall)**	**Water Rate (including rainfall)**
In-pit haul roads	146	3.555 litres/m²/hour	3.112 litres/m²/hour
Surface haul roads to the primary crusher	34	0.828 litres/m²/hour	0.725 litres/m²/hour
Surface haul roads to the waste dumps	98	2.386 litres/m²/hour	2.089 litres/m²/hour
Surface haul roads to the topsoil dumps	16	0.390 litres/m²/hour	0.341 litres/m²/hour

7.2.2 Crushing, Screening and Materials Handling 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 7-1. 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. Chemicals mixed into the water will not just save on water consumption but also improve the control efficiency of the application even further.

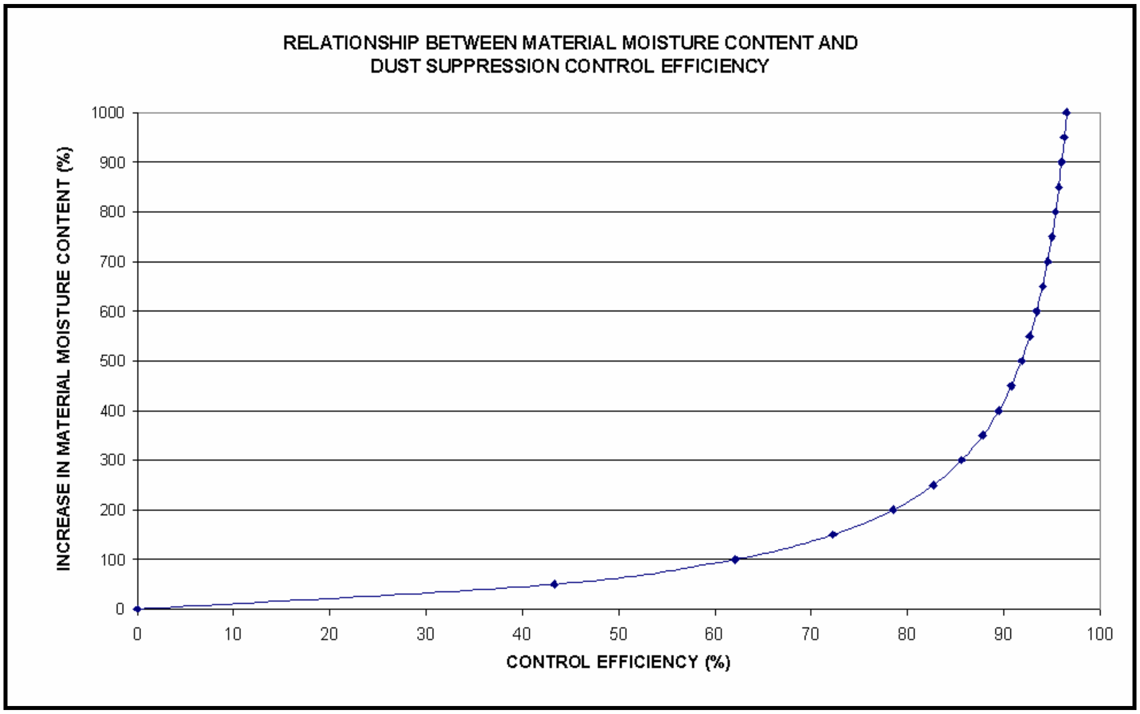

Figure 7-1: **Relationship between the moisture content and dust control efficiency**

The recommendation with regards to crushing and screening operations are the following: **As a minimum**, to reduce predicted unmitigated **maximum** impacts at the Ntsimbintle boundary as a result of **crushing and screening operations only** the predicted annual average PM10 concentration of 57.2µg/m³ needs to reduce to 40µg/m³ (the proposed SA standard) i.e. by 30%. This can be achieved by increasing the moisture content of the material 1.3 fold (i.e. we assumed the ore would have a moisture content of 5%, increasing it 1.3 fold would result in a moisture content of 6.5%).

If a 1 ton per hour throughput at the crusher and an ore moisture content of 5% is assumed, the water within the ore amounts to 0.05 tons per hour. Increasing the moisture content 1.3 fold would result in 0.065 tons per hour of water. The amount of water therefore required is the difference between 0.065 tons per hour (total amount of water required) and 0.05 tons per hour (inherent ore moisture) of 0.015 tons per hour.

To achieve a 30% reduction in crushing and screening emissions, based on the abovementioned assumptions, 15 liters of water is required for every ton of ore that is processed.

7.3 Monitoring Requirements

Performance indicators against which progress may be assessed form the basis for all effective environmental management practices. In the definition of key performance indicators, careful attention is usually paid to ensure that progress towards their achievement is measurable and that the targets set are achievable given available technology and experience. Performance indicators are usually selected to reflect both the source of the emission directly and the impact on the receiving environment.

Based on the impacts predicted as a result of proposed operations at Ntsimbintle on the surrounding environment it is recommended that ambient PM10, SO_2 and NO_2 monitoring be done and a dust fallout monitoring network established as soon as possible for the purpose of defining baseline air quality prior to the start of operations associated with Ntsimbintle.

A monitoring 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.

In addition to air quality monitoring, the absence of local meteorological data necessitates the installation of a meteorological station. Details on what is required with respect to meteorological monitoring are discussed in Section 7.3.4

7.3.1 Dust fallout monitoring

It is recommended that a dust fallout network comprising of at least 5 directional dust fallout buckets be established. The proposed locations of the dust buckets as indicated in Figure 7-2 are:

- **#1:** to determine dustfall directly downwind of the proposed Ntsimbintle operations;
- **#2:** to determine dustfall at the nearest downwind sensitive receptor;
- **#3:** located between topsoil stockpile, waste dumps and tailings facility to determine dustfall as a result of wind erosion;
- **#4:** located adjacent to an unpaved haul road to determine dustfall as a result of vehicle entrainment; and
- **#5:** located within the plant area to determine dustfall as a result of ore processing and beneficiation operations

Dust deposition measurement should be carried out by method ASTM 1739- 98 recommended in SANS 1929-2004. This involves exposure of a standard bucket for a month, with weighing (and chemical analysis e.g. manganese, if necessary) of the dust collected. Again, the changing of the bucket can be done by on-site personnel while the weighing can be carried out at a suitable off-site or on-site laboratory.

7.3.2 Ambient PM10 monitoring

Based on predicted impacts and considering the prevalent wind direction recorded in the area it is recommended that the PM10 ambient monitoring be done at the location indicated in Figure 7-2:

- **#2:** to determine PM10 concentrations at the nearest downwind sensitive receptor;

PM10 measurement can be economically carried out by the use of a “mini hi-vol” apparatus. This consists of a battery-driven flow-controlled sampling pump drawing ambient air through a filter for 24 h. The pre-and post exposure weighting of the filters provides daily average concentration values. The changing of batteries and filters can be carried out by site personnel with a minimum of training, while deployment at regular intervals (every 3 days or so, including weekends) provides a time series free of systematic sampling error, as well as a long-term average value. The filters can be sent to a suitable industrial hygiene laboratory by courier for weighing and metal analysis.

7.3.3 Passive SO_2 and NO_2 sampling

The proposed locations for passive SO_2 and NO_2 sampling as indicted in Figure 7-2 are:

- **#1:** to determine SO_2 and NO_2 concentrations directly downwind of the proposed Ntsimbintle operations;
- **#2:** to determine SO_2 and NO_2 concentrations at the nearest downwind sensitive receptor;
- **#4:** located adjacent to an unpaved haul road to determine SO_2 and NO_2 concentrations as a result of vehicle tailpipe emissions; and
- **#5:** located within the plant area to determine SO_2 and NO_2 concentrations as a result of ore beneficiation operations

Passive or diffusive sampling relies on the unassisted molecular diffusion of gaseous agents (analytes) through a diffusive surface onto an adsorbent. Unlike active (pumped) sampling, passive samplers require no electricity (expensive pumps), have no moving parts, and are simple to use (no pump operation or calibration). After sampling, the adsorbed analytes are desorbed off the adsorbent by solvent or thermal desorption (Sigma-Aldrich, SKC).

Benefits of passive/diffusive sampling:

- Compact, portable, unobtrusive, and inexpensive
- Offers indication of average pollution levels over time periods of 8 hours to weeks/months
- Requires no supervision, is noiseless and can be used in hazardous environments
- Low cost allows for sampling at multiple locations (e.g., for highlighting pollution "hotspots"; or determining long term data trends in a specific geographical area)
- Amenable to personal monitoring (breathing zone), indoor air analysis, and outdoor ambient air analysis.

It must however be recognised that passive samplers are essentially averaging devices that have a lower detection limits. At low ambient concentrations, fairly long sampling times (days to weeks) may be required to obtain meaningful results.

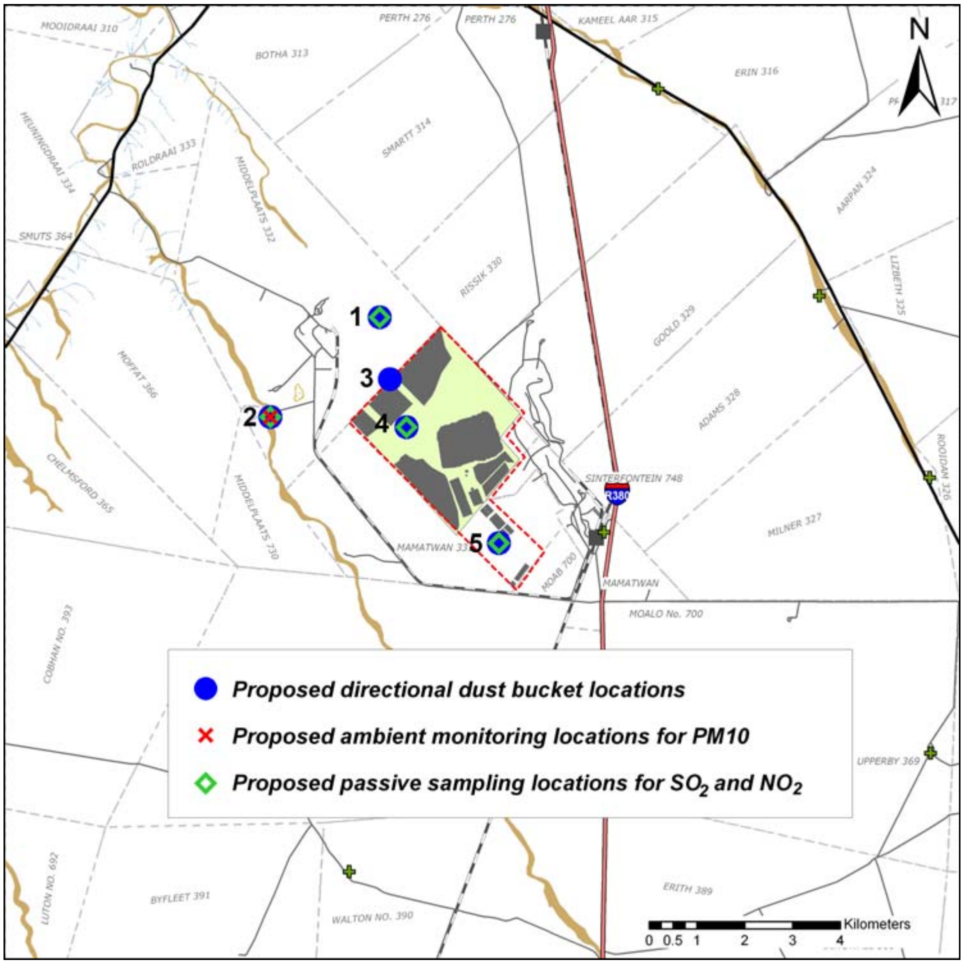

Figure 7-2: **Proposed dust fallout and PM10 monitoring network**

7.3.4 Meteorological Monitoring

Selecting an appropriate site for the weather station is crucial for obtaining accurate meteorological data. The site should typically be representative of the area of interest and away from any obstructions such as buildings and trees. The document published by Campbell Scientific, Inc. (1997) on the siting and installation of the weather station summarises the guidelines from the following publications:

- The State Climatologist (1985). Publication of the American Association of State Climatologists: Heights and Exposure Standards for Sensor on Automated Weather Stations, v. 9, No. 4, October, 1985.

- EPA (1987). On-Site Meteorological Program Guidance for Regulatory Modeling Applications, EPA-450/4-87-013. Office of Air Quality Planning and Standards, Research Triangle Parks, North Carolina 27711.

- WMO (1983). Guide to Meteorological Instruments and Methods of Observation. World Meteorological Organization No. 8, 5th edition, Geneva Switzerland.

As a minimum the following hourly averaged meteorological parameters are required:

- Wind speed;
- Wind direction;
- Ambient Temperature;
- Ambient air pressure;
- Relative humidity;
- Rainfall; and
- Solar radiation

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9 APPENDIX A - REGIONAL CLIMATE & ATMOSPHERIC DISPERSION POTENTIAL

The macro-ventilation characteristics of a region are determined by the nature of the synoptic systems that dominate the circulations of the region, and the nature and frequency of occurrence of alternative systems and weather perturbations over the region. Meso-scale processes affecting the dispersion potential include thermo-topographically induced circulations, the development and dissipation of surface inversions, and the modification of the low-level wind field and stability regime by urban areas.

9.1 Prevailing Synoptic Climatology

Situated in the subtropical high pressure belt, southern Africa is influenced by several high pressure (HP) 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; Taljaard, 1972; Preston-Whyte and Tyson, 1988). The most important of these is the semi-permanent, subtropical continental anticyclones (high pressures) that 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 that can persist at various levels in the atmosphere for long periods.

Seasonal variations in the position and intensity of the high pressure cells determine the extent to which the tropical easterlies and the circumpolar westerly's 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 westerly's expand and displace the upper tropical easterlies equator-ward. 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 anti-cyclonic 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 anti-cyclonic 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 anti-cyclonic subsidence. Anticyclones occur most frequently over the interior during winter months, with a maximum frequency of occurrence of 79% in June and July. During December such anticyclones only occur 11% of the time. Although widespread subsidence dominates the winter months, weather occurs as a result of uplift produced by localized systems.

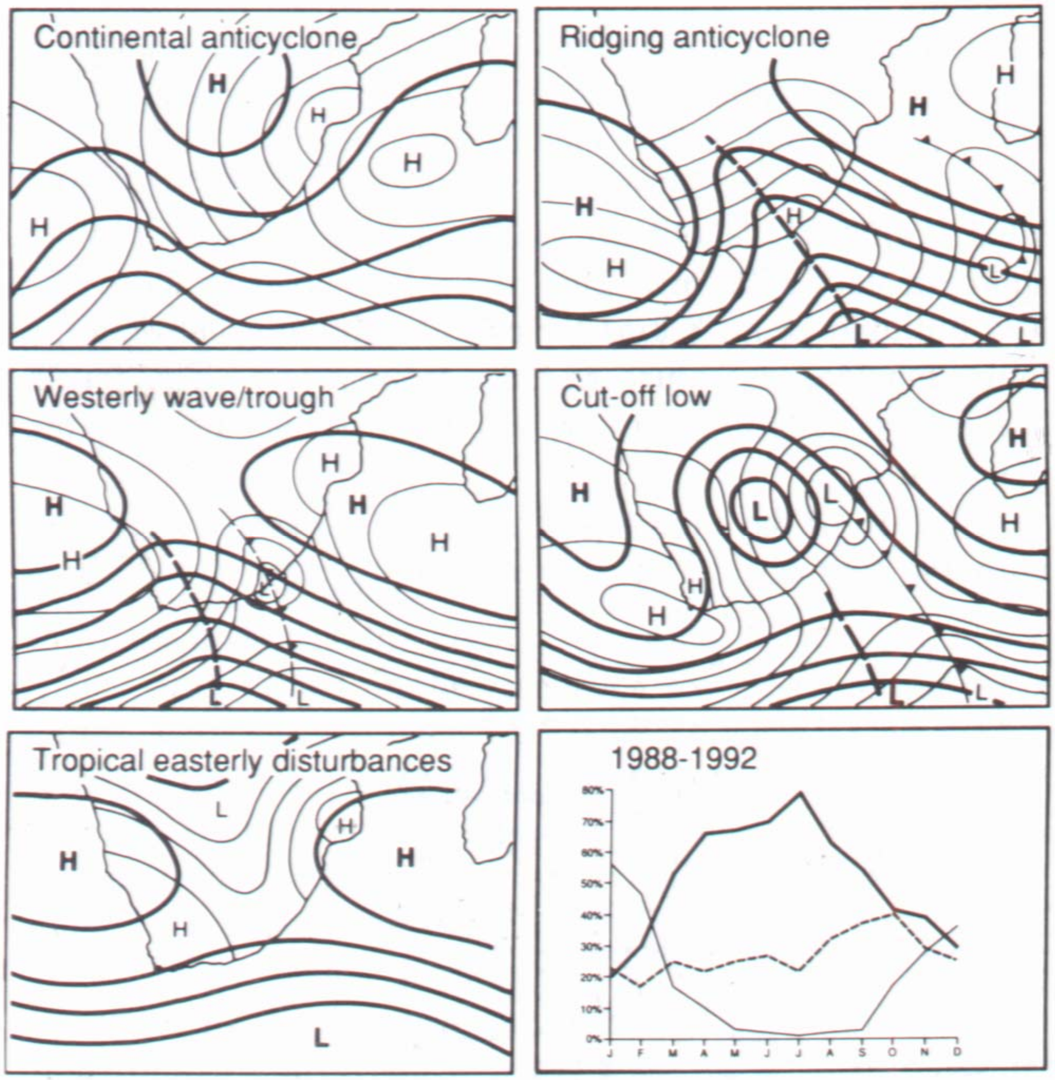

Figure 9-1: Major synoptic circulation types affecting southern Africa

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 that occurs over the interior.

Westerly waves are characterised by concomitant surface convergence and upper-level divergence that 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.

9.2 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 anti-cyclonic 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 anti-cyclonic weather, such as characterize the plateau during winter, result in subsidence inversions which are persistent in time, and continuous over considerable distances.

Multiple elevated inversions occur in the middle to upper troposphere as a result of large-scale anti-cyclonic 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.

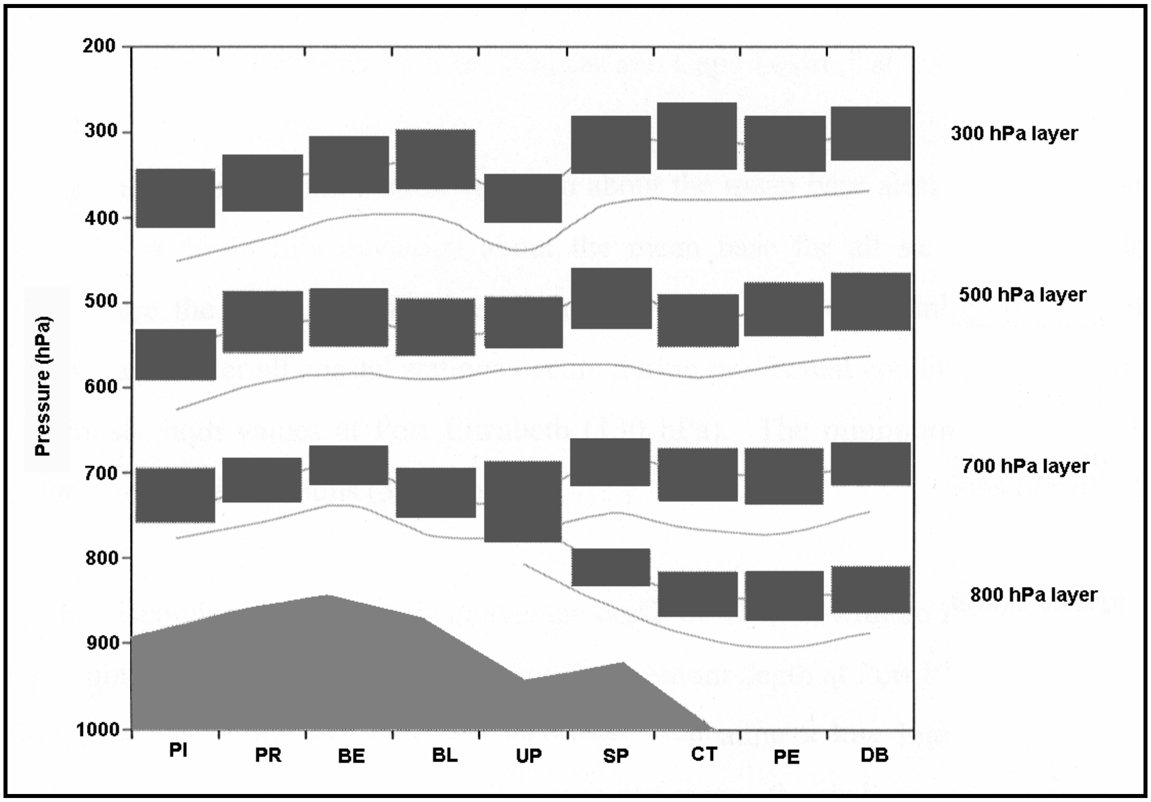

Figure 9-2: **Major synoptic circulation types affecting southern Africa**

In contrast to anti-cyclonic 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, 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.

10 APPENDIX B – FUGITIVE DUST EMISSION FACTORS AND EQUATIONS

10.1 Drilling

Fugitive dust emissions due to the in-pit drilling operations at the mine were quantified using the Australian NPI single valued emission factors for mining given in Table 10-1.

Table 10-1: Australian NPI emission factors for drilling operations

Source	PM10 (kg PM10 / hole drilled)	TSP Emission (kg TSP / hole drilled)
Drilling	0.31	0.59

10.2 Blasting

Fugitive dust emissions due to blasting at the mine were quantified using the US EPA predictive emission factor equation for mining:

$$EF = k \cdot 0.00022 \cdot A^{1.5}$$

where;

E = *emission factor (kg dust / blast)*

k = *particle size multiplier* ($k_{PM10} = 0.52$; $k_{TSP} = 1$)

A = *blast area (m²)*

10.3 Materials Handling

The quantity of dust that will be generated from materials handling operations will depend on various climatic parameters, such as wind speed and precipitation, in addition to non-climatic parameters such as the nature and volume of the material handled. Fine particulates are most readily disaggregated and released to the atmosphere during the material transfer process, as a result of exposure to strong winds. Increases 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. The following US EPA AP42 predictive equation was used to estimate emissions from material transfer operations:

$$E = k \cdot 0.0016 \cdot \left(\frac{U}{2.3}\right)^{1.3} \cdot \left(\frac{M}{2}\right)^{-1.4}$$

where,

E = *Emission factor (kg dust / tons of material transferred)*

U = *mean wind speed (m/s)*

M = *material moisture content (%)*

k = *particle size multiplier* ($k_{PM10} = 0.35$; $k_{TSP} = 0.74$)

10.4 Vehicle Entrained Dust from Unpaved Roads

Vehicle-entrained dust emissions have been found to account for a great portion of fugitive dust emissions from open pit mining operations. The force of the wheels of vehicles travelling on unpaved haul roads causes the 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 act on the road surface after the vehicle has passed. The quantity of dust emissions from unpaved roads varies linearly with the volume of traffic.

The unpaved road size-specific emission factor equation of the US-EPA, used in the quantification of emissions, is given as follows:

$$E = k\left(\frac{s}{12}\right)^{a} \cdot \left(\frac{W}{3}\right)^{b} \cdot 281.9$$

Where,

E = *emissions in lb of particulates per vehicle mile travelled (g/VKT)*

K = *particle size multiplier (dimensionless);*

S = *silt content of road surface material (%);*

W = *mean vehicle weight (tons)*

The particle size multiplier in the equation (k) varies with aerodynamic particle size range and is given as 1.5 for PM10 and 4.9 for total suspended particulates (TSP). The constants a and b are given as 0.9 and 0.45 respectively for PM10 and as 0.7 and 0.45 respectively for TSP.

10.5 Paved Roads

The paved road size-specific emission factor equation of the US-EPA, used in the quantification of emissions, is given as follows:

$$\boxed{E = k\left(\frac{sL}{2}\right)^{0.65} \cdot \left(\frac{W}{3}\right)^{1.5} - C}$$

Where,

E = *emissions in g/VKT*

K = *particle size multiplier (g/VKT);*

sL = *silt loading of road surface material (g/m²);*

W = *mean vehicle weight (tons)*

C = *emission factor for 1980's vehicle fleet exhaust, brake wear and tire wear*

The particle size multiplier in the equation (k) varies with aerodynamic particle size range and is given as 4.6 for PM10 and 24 for total suspended particulates (TSP). The constant C is given as 0.1317 for PM10 and TSP.

10.6 Crushing and Screening

Fugitive dust emissions due to the crushing and screening operations for mine were quantified using US-EPA single valued emission factors for such operations (Table 10-2). These emission factors include emissions from the loading of crusher hoppers and screening.

Table 10-2: 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	0.004	0.01
Secondary crushing	0.04	0.6	0.012	0.03

Notes:

(a) Moisture content less than 4%

(b) Moisture content more than 4%

10.7 Wind Erosion

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 area, 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 contents, 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 calculation of emission rates for various wind speeds and stability classes representative of the simulation period was carried out using the ADDAS model. This model is based on the dust emission model 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.

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:

$$\boxed{E(i) = G(i) \cdot 10^{(0.134 \cdot \% clay - 6)}}$$

For

$$\boxed{G(i) = 0.261 \cdot \left[\frac{P_a}{g} \right] \cdot u^{*3} \cdot (1 + R) \cdot (1 - R^2)}$$

And

$$\boxed{R = \frac{u_*^{\ t}}{u^*}}$$

where,

$E_{(i)}$ = *emission rate (g/m²/s) for particle size class i*

P_a = *air density (g/cm³)*

g = *gravitational acceleration (cm/s³)*

u_*^t = *threshold friction velocity (m/s) for particle size i*

u^* = *friction velocity (m/s)*

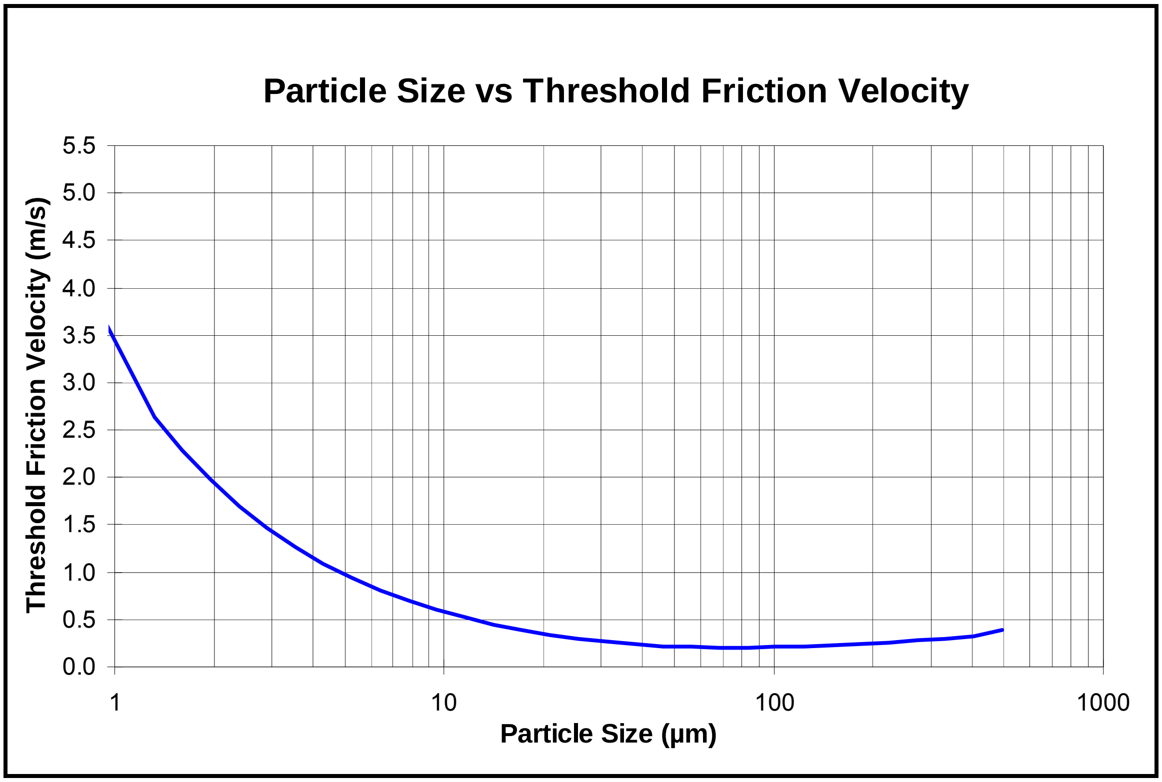

Figure 10-1: Relationship between particle sizes and threshold friction velocities

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 by Marticorena and Bergametti (1995), is illustrated in Figure 10-1.

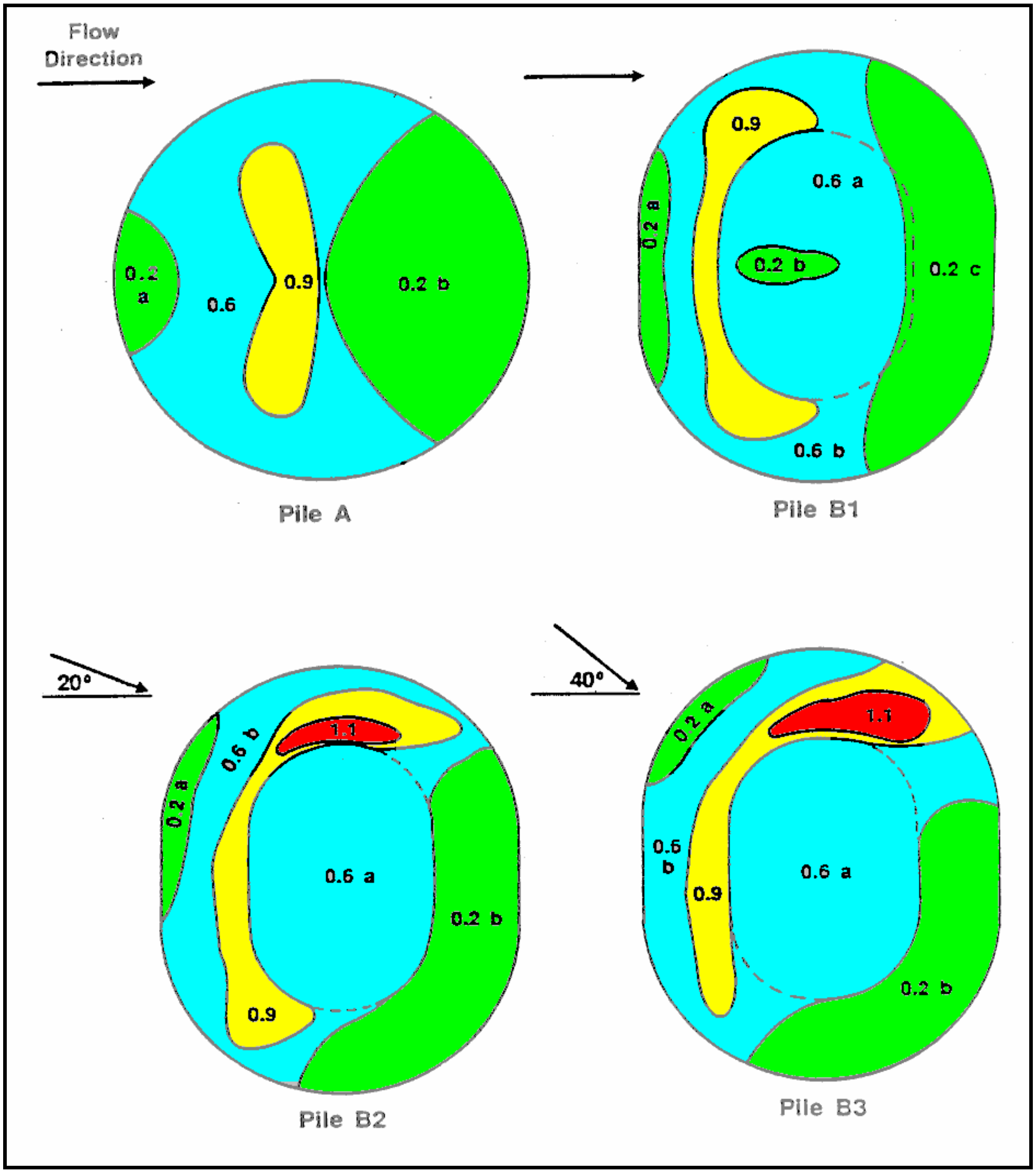

Figure 10-2: **Contours of normalised surface wind speeds**

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):

$$U^* = 0.053 \cdot U_{10}^+$$

(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 area is 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 area. 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 10-2 (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).

11 APPENDIX C – MANGANESE EXPOSURES

The main route of human exposure to manganese is normally in food, primarily in cereals although all foods contain trace amounts of manganese. The typical daily intake of manganese in European and American diets has been reported to vary between 2 and 5 mg/day. Small amounts of manganese typically occur in drinking water (typically daily intake of 10 to 50 µg). The intake of manganese through inhalation of ambient air was estimated by the WHO to be about 2µg/m³, rising to 4 to 6 µg/day in the vicinity of foundries and up to 10 µg near ferromanganese or silicomanganese industries (Levy *et al*., 2004).

When inhaled, manganese that enters the bloodstream passes first to the brain before being processed by the liver. Depending on its ability to cross the blood-brain barrier, this manganese may reach areas of the central nervous system and produce the characteristic neurotoxic effects of manganese. Although manganese is eliminated primarily by biliary excretion, it appears that inhaled manganese may not be as well regulated by this mechanism as is ingested manganese (WHO, 2000).

High occupational exposure to manganese is known to result in severe neurotoxic signs and symptoms, some of which resemble those of idiopathic Parkinson’s diseases (e.g. disturbances in the control of hand movements and the speed of movement). This syndrome, which may also include psychiatric effects, is known as *manganism* (Levy *et al*., 2004). The clinical symptoms associated with manganism, such as movement disorders and neurological dysfunction have not been reported to occur at exposure levels below 5 mg/m³.

Reproductive effects have included a smaller number of children born to manganese-exposed workers compared to matched controls, and various self-reported symptoms of sexual dysfunction. In recent studies at low to moderate occupational exposure levels, respiratory effects have been reflected primarily in self-reported symptoms of respiratory tract illnesses rather than in differences between objective spirometric measurements in manganese-exposed and control workers (WHO, 2000). Although pulmonary effects and adverse effects on the cardiovascular system have been associated with manganese exposure, but neither would be expected at inhalation exposures of 1 mg/m³ or less (Levy *et al*., 2004).

Increasing attention has recently been placed on more subtle, sub-clinical neurobehavioral / neuron-toxicological effects that may occur at much lower levels of occupational exposure (e.g. deterioration in motor function and co-ordination. According to Levy *et al* (2004) it is considered overall that these small non-clinical neuron-motor effects do represent biologically significant events of relevant to human health.

It is possible that the compensatory or reserve capacity of certain neurological mechanisms may be stressed by manganese exposure earlier in life, with manifestations of impairments only becoming evident much later, perhaps at a geriatric stage. One reason for the latter concern is that Parkinson’s disease is typically a geriatric disease, in which the symptoms are only seen when the loss of brain cells that produce dopamine (which is also apparently involved in manganese toxicity) reaches 80% or more. Indeed, some neurologists think that a long latency period of perhaps several decades may precede various parkinsonian syndromes. These points lead to a concern that if manganese reduces the compensatory or reserve capacity of the nervous system, Parkinson-type effects might occur earlier in life than they would otherwise (WHO, 2000).

Given the involvement of the dopaminergic system and extrapyramidal motor system in both Parkinson’s disease and manganism, symptoms of the two diseases are somewhat similar, and several writers have suggested the possibility of a common etiology. Nevertheless, many neurological specialists make a clear distinction in the etiologies and clinical features of Parkinson’s disease and manganism (WHO, 2000).

Most people who inhale manganese are involved in jobs where they are exposed to the metal. There is a possibility that people can be exposed to manganese in the air if they live near a plant that uses manganese, or if they live in a high traffic area and the automobiles burn manganese in the gasoline. A recent study showed that people who inhaled manganese from the air and who had high levels of manganese in their blood showed signs of neurological problems that were similar to those reported in occupationally-exposed persons. The neurological problems were most significant in the people aged 50 years and older (ASTD, 2003).

12 APPENDIX D – AIR QUALITY ISSUES RAISED BY INTERESTED AND AFFECTED PARTIES

12.1 Comment 1 – The effects of Mining on the Micro-Climate

Comment: The issue of long term micro-climate change should be investigated as part of the studies carried out for the project, as the cumulative effect which could be attributable to the increase in mines in the area.

Raised by: A. Pyper

Date: 20/10/2008

Response: As the variables affecting climate are regional or even global in scale (atmospheric circulation patterns, the atmospheric radiation balance etc.) it is unlikely that mining on a local or sub-regional scale will have noticeable climatological effects. In order to undertake an investigation to determine potential changes in the micro-climate of the area surrounding the proposed mine a site specific meteorological baseline characterisation could be done. This would require long term historical as well as on-site meteorological data neither of which is available at present. It has however been recommended that a meteorological station be installed in the area (Section 7.3.4) as soon as possible.

12.2 Comment 2 – Micro-climate Investigation

Comment: I am of the opinion that a credible investigation into the effects of the proposed project on the micro-climate must be undertaken.

Raised by: A. Pyper

Date: 20/10/2008

Response: See response to Comment 1 (Section 12.1)

12.3 Comment 3 – Global Warming

Comment: Air pollution due to dust from the mines causes global warming.

Raised by: M. A. Kruger

Date: 18/10/2008

Response: The effects of particulate matter in the atmosphere on the global radiation balance are the subject of considerable difference of opinion among atmospheric scientists. Opinions about the effect vary between a negative (decreasing) effect on warming (due to the blocking of incoming short-wave radiation) to a positive (increasing) effect (due to decreased albedo from ice and snow surfaces soiled by soot deposition). However, it is generally agreed that these effects are caused by sources of particulate orders of magnitude larger than those from mining viz. volcanic activity, biomass burning on a continental scale and global industrial activity. If there is an effect from mining, its effect would in all probability be negligible compared to the above, and the effect is therefore not considered in this report.

12.4 Comment 4 – Dust and its Effects on Plant Growth

Comment: An increase in dust emissions from dirt roads resulting from an increase in traffic pollutes the air and affects plant growth.

Raised by: M. A. Kruger

Date: 18/10/2008

Response: Unlike sulphur dioxide and oxides of nitrogen, limited information is available on the effects of dust on vegetation. 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 robust quantitative, and that dose-response information is lacking (CEPA, 1998).

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 stomatal apertures. The chemical composition of the dust particles can also affect the plant and have indirect effects on the soil pH and ionic composition. There are three ways particles can deposit upon leaf:

- by sedimentation under the influence of gravity;
- by impaction under the influence of eddy currents; and,
- by deposition under the influence of precipitation.

For fine particulates (diameter les 10 µm) the impaction is efficient and is likely to affect the retentive mechanism of the plant. The magnitude of the effect will mainly be determined by the deposition rate under conditions of variable microclimates. Due to the reduction in light transmission on the surface of the plant leaf due to dust deposition, photosynthetic processes are affected. Particle accumulation on leaf surfaces may also cause plants to become more susceptible to other stresses. Relatively high deposition rates (from 1000 to 7000 mg/m^2 for up to 130 days) of cement dust on cereals, have resulted in decreased respiration, catalase activity, oil content and overall yields (CEPA, 1998).

Fugitive dust emissions from unpaved roads are dependent on the extent of traffic on the road. Dust fallout as a result of on-site roads is however predicted to be localised and was found to be around 750 mg/m^2/day (unmitigated emission) and 70 mg/m^2/day (mitigated emissions). Off site public dirt roads were not included in the study. Data on the direct effect of dust are often linked to a specific source, and prediction of the effect in this specific case would have a high uncertainty. Proposals to reduce the amount of dust generated have however been included in the specialist report (Section 7.2.1).

13 APPENDIX E – POWER GENERATION PLANT STACK HEIGHT CALCULATIONS

The release height of the exhaust emissions from the power generation plant was not known at the time of the study. The exhausts from the four generators will connect to a common manifold and pipe outside the building. An appropriate discharge height was calculated using Screen View, the Screening Air Dispersion Model (SCREEN3). The SCREEN model was developed to provide an easy to use method of obtaining pollutant concentration estimates.

As NO_x emissions from the power generation plant proved to be most significant (Section 5.2.5) it was used to determine the minimum release height required to ensure no ground level exceedances of the proposed South African hourly NO_2 standard. To be conservative, it was assumed that 30% of the NO_x would be emitted as NO_2 (Heywood, 1988).

The NO_x emission rate of 27.3 g/s were modelled at various release heights. Stack parameters as presented in Table 13-1 were applied in the modelling.

Table 13-1: Parameters pertaining to emissions from a single 1600 kW diesel generator

Diesel consumption (liters/annum)	5,750,000.00
Sulphur Content (%)	0.05
Diesel Density (kg/L)	0.85
Exhaust Flow Rate (m^3/min)	453.60
Exit Temperature (°C)	540.00
Exhaust Exit Diameter (m)	0.81
Exit Velocity (m/s)	14.57
NO_x concentration (mg/Nm^3)	3,059.20

A summary of the maximum hourly average NO_2 concentration and the distance from the source at which it was predicted are provided in Table 13-2. The change in predicted NO_2 ground level concentrations as a function of stack height and distance from the source are graphically presented in Figure 13-1. As evident from Table 13-2 and Figure 13-1 a stack height of 10 m will not result in ground level concentrations in exceedance of 200µg/m³ (the proposed hourly SA standard).

As a minimum it was decided to use a release height of 10m for the proposed power generation plant.

Table 13-2: PGP release heights and maximum predicted ground level concentrations

Emission Release Height (m)	Maximum NO_2 Ground Level Concentration[a] (µg/m³)	Distance From Source (m)
2	**705**[b]	127
4	**459**[b]	165
6	**322**[b]	202
8	**239**[b]	241
10	183	279
12	146	278

Notes:

(a) Proposed SA daily NO_2 standard – 200µg/m³.

(b) Predicted ground level concentration exceeds SA NO_2 standards.

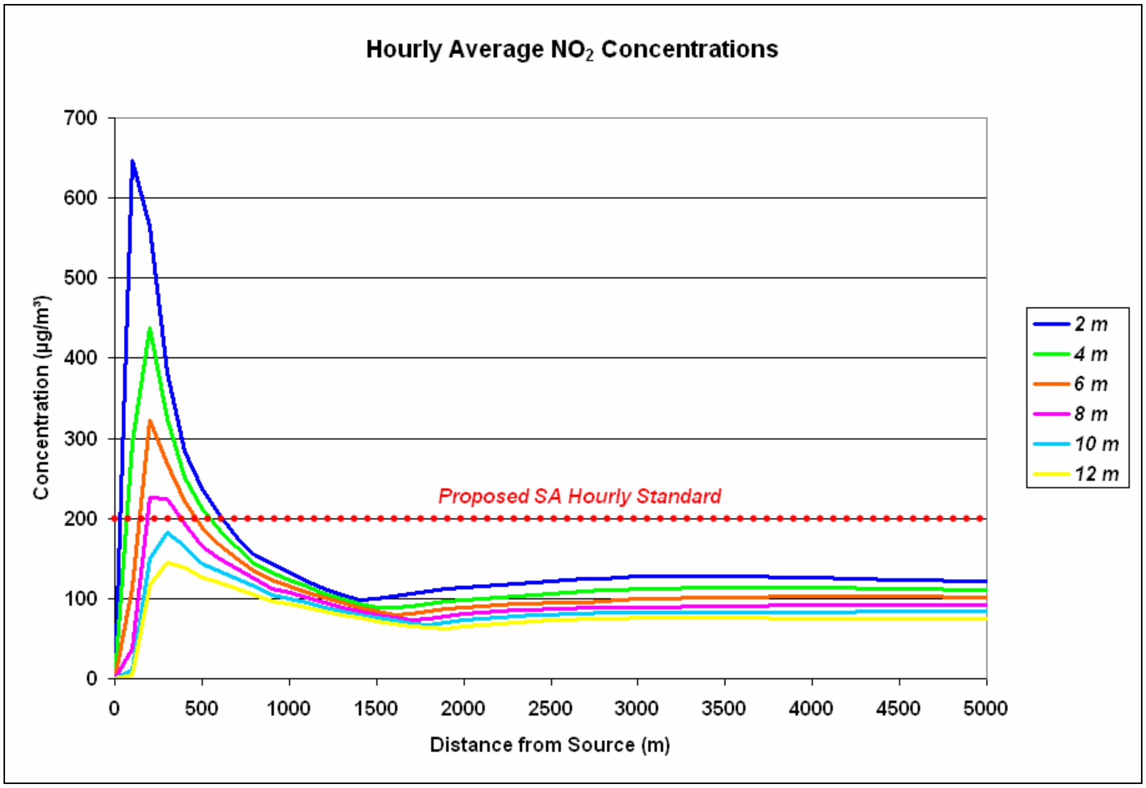

Figure 13-1: Predicted hourly ground level NO_2 concentrations for various stack heights