Air Quality Impact Assessment for the Tshipi Borwa Manganese Mine Closure Option

Project done on behalf of **SLR Consulting (Africa)(Pty) Ltd**

Report compiled by:
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Report Details

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Assisted by	Rochelle Bornman, MPhil. GIS and Remote Sensing (University of Cambridge)
Notice	Airshed Planning Professionals (Pty) Ltd is a consulting company located in Midrand, South Africa, specialising in all aspects of air quality, ranging from nearby neighbourhood concerns to regional air pollution impacts as well as noise impact assessments. The company originated in 1990 as Environmental Management Services, which amalgamated with its sister company, Matrix Environmental Consultants, in 2003.
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Revision Record

Revision Number	Date	Reason for Revision
Draft Rev0	7 June 2019	Draft for SLR review
Final Rev1	8 July 2019	Addressed SLR comments
Final Rev2	18 July 2019	Addressed client comments

Competency Profiles

Report author: H Liebenberg-Enslin (PhD Geography (University of Johannesburg)

Hanlie Liebenberg-Enslin started her professional career in Air Quality Management in 2000 when she joined Environmental Management Services (EMS) after completing her Master's Degree at the University of Johannesburg (then RAU) in the same field. She is one of the founding members of Airshed Planning Professionals in 2003 where she has worked as a company Director until she took over as Managing Director in May 2013.

She has extensive experience on the various components of air quality management including emissions quantification for a range of source types, using different dispersion models, and conducting impact assessments and health risk screening assessments. Hanlie was the project manager on a number of ground-breaking air quality management plan (AQMP) projects and the principal air quality specialist on regional environmental assessments. Her work experience, although mostly in South Africa, range over various countries in Africa, including extensive experience in Namibia, providing her with an inclusive knowledge base of international legislation and requirements pertaining to air quality.

Hanlie has lectured several Air Quality Management Courses and is actively involved in the International Union of Air Pollution Prevention and Environmental Protection Associations (IUAPPA) and the South African National Association for Clean Air (NACA), where she served as President for both organisations. Being an avid student, she received her PhD from the University of Johannesburg in June 2014, specialising in Aeolian dust transport.

The CV of Hanlie Liebenberg-Enslin is provided in Appendix A.

Specialist Declaration

I, Hanlie Liebenberg-Enslin, as the appointed independent air quality specialist for the Tshipi Borwa Manganese Mine Closure Option, hereby declare that I:

- acted as the independent specialist in this Environmental Clearance Certificate application;
- performed the work relating to the application in an objective manner;
- regard the information contained in this report as it relates to my specialist input/study to be true and correct,
- do not have and will not have any financial interest in the undertaking of the activity, other than remuneration for work performed in terms of the Environmental Impact Assessment;
- declare that there are no circumstances that may compromise my objectivity in performing such work;
- have expertise in conducting the specialist report relevant to this application;
- have no, and will not engage in, conflicting interests in the undertaking of the activity;
- have no vested interest in the proposed activity proceeding;
- undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing the decision of the competent authority; and
- all the particulars furnished by us in this specialist input/study are true and correct.

Signature of the specialist:

Name of Specialists: Hanlie Liebenberg-Enslin

Date: 18 July 2019

NEMA Regulation (2014), Appendix 6

NEMA Regulations (2018) - Appendix 6		Relevant section in report
1.a)	Details of the specialist who prepared the report.	Report details (page ii)
	The expertise of that person to compile a specialist report including curriculum vitae.	Report details (page ii) Appendix A
1.b)	A declaration that the person is independent in a form as may be specified by the competent authority.	Report details (page ii)
1.c)	An indication of the scope of, and the purpose for which, the report was prepared.	Executive Summary Section 1.1: Terms of Reference
	An indication of the quality and age of base data used for the specialist report.	Section 3.2: Atmospheric Dispersion Potential Section 3.3: Baseline Air Quality
	A description of existing impacts on the site, cumulative impacts of the proposed development and levels of acceptable change.	Section 3.3: Baseline Air Quality Section 4.2.3: Dispersion Modelling Results Section 4.2.4: Cumulative Impacts
1.d)	The duration date and season of the site investigation and the relevance of the season to the outcome of the assessment.	Section 3.2: Atmospheric Dispersion Potential Section 3.3: Baseline Air Quality
1.e)	A description of the methodology adopted in preparing the report or carrying out the specialised process inclusive of equipment and modelling used.	Executive Summary Section 1.3: Assumptions and Limitations Section 4.2.1: Emissions Quantification Section 4.2.2: Atmospheric Dispersion Modelling
1.f)	Details of an assessment of the specific identified sensitivity of the site related to the proposed activity or activities and its associated structures and infrastructure inclusive of a site plan identifying site alternatives.	Section 3.1: Site Description
1.g)	An identification of any areas to be avoided, including buffers.	Not applicable
1.h)	A map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers.	Section 3.1: Site Description
1.i)	A description of any assumptions made and any uncertainties or gaps in knowledge.	Section 1.3: Assumptions and Limitations
1.j)	A description of the findings and potential implications of such findings on the impact of the proposed activity or activities.	Section 4.2.3: Dispersion Modelling Results Section 4.2.4: Cumulative Impacts Section 4.3: Alternative Closure Phase Options
1.k)	Any mitigation measures for inclusion in the environmental management programme report	Section 4.4: Management and Mitigation Measures
1.l)	Any conditions for inclusion in the environmental authorisation	Section 4.4: Management and Mitigation Measures
1.m)	Any monitoring requirements for inclusion in the environmental management programme report or environmental authorisation.	Section 4.4: Management and Mitigation Measures
1.n)	A reasoned opinion as to whether the proposed activity, activities or portions thereof should be authorised.	Section 6: Conclusion and Recommendations
	A reasoned opinion regarding the acceptability of the proposed activity or activities.	Section 6: Conclusion and Recommendations
	If the opinion is that the proposed activity or portions thereof should be authorised, any avoidance, management and mitigation measures that should be included in the environmental management programme report, and where applicable, the closure plan.	Section 4.4: Management and Mitigation Measures Section 6.3: Recommendations

NEMA Regulations (2018) - Appendix 6		Relevant section in report
1.o)	A description of any consultation process that was undertaken during the course of carrying out the study.	Not applicable
1.p)	A summary and copies if any comments that were received during any consultation process.	Not applicable
1.q)	Any other information requested by the competent authority.	Not applicable.

Abbreviations

Airshed	Airshed Planning Professionals (Pty) Ltd
AQA	Air Quality Act
DPM	Diesel Particulate Matter
EIA	Environmental Impact Assessment
EMP	Environmental Management Program
EMPR	Environmental Management Program Report
GHG	Greenhouse Gas
Ha	hectare
MES	Minimum Emission Standards
Mn	Manganese
m	metre
m^2	metre squared
m/s	metre per second
$mg/m^2/day$	Milligram per metre squared per day
NAAQS	National Ambient Air Quality Standards
NAEIS	National Atmospheric Emissions Inventory System
NAERR	National Atmospheric Emission Reporting Regulations
NDCR	National Dust Control Regulations
NPI	National Pollutant Inventory (Australia)
PM_{10}	Particulate Matter with an aerodynamic diameter of less than 10µ
$PM_{2.5}$	Particulate Matter with an aerodynamic diameter of less than 2.5µ
PPP	Pollution Prevention Plans
SAAQIS	South African Air Quality Information System
SANS	South African National Standards
tpa	tonnes per annum
tpd	tonnes per day
TSP	Total Suspended Particles
US-EPA	United States Environmental Protection Agency
WHO	World Health Organisation
WRD	Waste Rock Dump
°C	Degrees Celsius
$\mu g/m^3$	Microgram per cubic metre

Executive Summary

Airshed Planning Professionals (Pty) Ltd was appointed by SLR Consulting (Africa) (Pty) Ltd to assess the potential for air quality related impacts on the surrounding environment and human health from the proposed mine closure option. This will be used in the amendment of the approved Environmental Impact Assessment (EIA) and Environmental Management Programme Report (EMPR).

Tshipi Mine's approved closure commitment is to restore the surface to pre-mining status which includes complete backfilling of the open pit. Tshipi Mine is investigating alternative closure options. The preferred option is In-pit Dumping only (i.e. no backfill following mine closure) and this is the option that has been assessed. This option implies the following:

- the waste rock dumps (WRDs) will be rehabilitated concurrent with mining operations; and
- no loading, hauling and tipping of waste rock activities will occur.

The prevailing wind field at the mine is from the south-south-east and south with most of strong winds from the west. Frequent winds also occur from the north. During the day winds are more frequent from the westerly and the northerly sectors, with the strongest winds directly from the west. The wind shifts during the night to south-south-easterly and southerly winds.

Dustfall collected at five locations at and around the mine over a period of 16 months indicate high dust fallout levels, exceeding the National Dust Control Regulation (NDCR) limit for non-residential areas of 1 200 mg/m²/day regularly. Ambient PM_{10} concentrations regularly exceeded the National Ambient Air Quality 24-hour limit of 75 µg/m³, indicating the likelihood of non-compliance with the NAAQS.

The air quality impact assessment conducted in 2009 for the then proposed Ntsimbintle Mine (now Tshipi Borwa) assessed the potential health and nuisance impacts from PM_{10}, manganese (Mn), SO_2, NOx, Diesel Particulate Matter (DPM) and CO due to the mining operations based on the then approved infrastructure layout. Vehicle entrained dust from unpaved roads were the main source of PM_{10} concentrations with crushing and screening contributing most significantly to manganese ground level concentrations. Gaseous emissions were most likely to result from the Sinter Plant, which has not been established yet.

The main findings from the **air quality assessment** of the proposed mine closure option at the Tshipi Borwa Manganese Mine are as follow:

- The main sources of emissions during the proposed closure phase is windblown dust from the WRDs. The main pollutants of concern are $PM_{2.5}$, PM_{10} and TSP.
- Unmitigated windblown dust emissions from the four WRDs are 32.20 tpa for $PM_{2.5}$, 359.22 tpa for PM_{10} and 1 039.33 tpa for TSP. By covering/ controlling 80% of the areas, the resulting reduction in emissions is 99%.
- Unmitigated PM_{10} daily GLCs due to windblown dust from the WRDs are in compliance off-site, only exceeding the daily NAAQS of 75 µg/m³ on-site at the WRDs. Annual average concentrations comply on- and off-site. The impact significance is LOW. With mitigation in place (vegetation and revegetation) the impact significance reduces to VERY LOW.
- Unmitigated $PM_{2.5}$ daily GLCs due to windblown dust from the WRDs are low and well within compliance off-site with the only on-site exceedances at West_WRD. Annual average concentrations comply on- and off-site. The impact significance is LOW. With mitigation in place (vegetation and revegetation) the impact significance reduces to VERY

LOW.

- Unmitigated maximum daily dustfall rates are below the NDCR residential limit (600 mg/m²/day) off-site, and below the non-residential limit of 1 200 mg/m²/day on-site. The impact significance is LOW. With mitigation in place (vegetation and revegetation) the impact significance reduces to VERY LOW.
- The highest annual average manganese GLC due to unmitigated windblown dust from the WRDs is 0.03 µg/m³, falling well below the WHO annual average manganese guideline of 0.15 µg/m³. The impact significance is VERY LOW.
- At the time of closure, all operations at Tshipi Mine would have ceased, with farming activities and vehicles travelling on the paved and unpaved roads the only remaining contributors to PM concentrations and dustfall. The air quality around Tshipi Mine is likely to improve significantly by closure phase.

Conclusion

PM_{10} and $PM_{2.5}$ ground level concentrations and dust fallout rates off-site and at nearby AQSRs due to the closure phase option will be significantly lower than during the operational phase. With mitigation measures in place, such as vegetation and revegetation of exposed areas, these impacts would reduce even further, resulting in a very low significance. Significant decreases in SO_2, NO_2, Mn and CO are foreseen. DPM concentrations are also likely to decrease.

Recommendations

For the WRDs the same mitigation scenarios can be applied:

- Operational (up to 2048): 90% CE on the "baseline" exposed areas, to reflect revegetation (medium term).
- Long-term Scenario (closure and post-closure): 100% CE on all exposed surfaces (assumption being that all are fully vegetated).
- Continue with the current dustfall monitoring network throughout the closure phase.
- Should aggregate crushing be implemented, ensure placement of the crusher as far away from the sensitive receptors as possible.

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1 INTRODUCTION

Tshipi é Ntle Manganese Mining (Pty) Ltd (Tshipi) currently operates the Tshipi Borwa open pit manganese mine located on the farms Mamatwan 331 and Moab 700, approximately 18 km south of Hotazel in the Joe Morolong Local Municipality and the John Taolo Gaetsewe District Municipality in the Northern Cape Province. Tshipi currently holds the following authorisations:

- A mining right (NC/30/5/1/2/2/0206MR) issued by the Department of Mineral Resources (DMR);
- An Environmental Management Programme report (EMPr) approved by the DMR;
- An environmental authorisation (NC/30/5/1/2/2/206/000083 EM) issued by the DMR; and
- A Water Use Licence (IWUL) (10/D41K/AGJ/1735) issued by the Department of Water and Sanitation.

Key mine infrastructure includes an open pit, haul roads, run-of mine ore tip, a primary crusher, a secondary crushing and screening plant, various stockpiles for crushed and product ore, a train load-out facility, a private siding, offices, workshops, warehouses and ancillary buildings, an access control facility, various access roads, diesel generator house, electrical reticulation, clean and dirty water storage dams, water reticulation pipelines and drains, topsoil stockpiles and waste rock dumps. The mine has an anticipated life of mine of approximately 25 years and has been operational since 2012.

The approved EMPr commits Tshipi to restore the surface to pre-mining state of wilderness and grazing and requires that the open pit is backfilled. Recent operation optimisation investigations indicate that when considering environmental, socio-economic, technical, commercial and legal factors, and, completely backfilling the open pits is sub-optimal. An alternative closure and rehabilitation strategy offers:

- The opportunities for enhanced biodiversity habitats with a different backfill approach particularly in terms of topographic variety and access to surface water;
- The opportunities for enhanced land use increase with access to surface water;
- An alternative closure option will allow for earlier rehabilitation of waste rock dumps; and
- Completely backfilling the open pit is likely to sterilise an underground resource located to the north of the current approved open pit. The associated loss of employment, procurement, taxes and foreign exchange earnings is significant and will be a material net loss to the region and the country;

Tshipi is therefore proposing to change the current closure commitment to achieve a more sustainable and optimised outcome. In this regard, the proposed project focusses on:

- Concurrent backfill only i.e. in-pit dumping during mining operations only;
- Sloping and rehabilitation of waste rock dumps remaining on surface with no loading, hauling and tipping of waste rock activities;
- Access to readily available future water supply; and
- Optimisation of the surface landforms and partially backfilled pit from a biodiversity, rehabilitation, land use and pollution prevention perspective.

Airshed Planning Professionals (Pty) Ltd was appointed by SLR Consulting (Africa) (Pty) Ltd to assess the potential for air quality related impacts on the surrounding environment and human health from the proposed mine closure option. This will be used to amend the approved EIA EMPR.

1.1 Terms of Reference

The scope of work includes:

- A review and identification of legal requirements pertaining to air quality;
- A desktop study of the receiving atmospheric environment (baseline) incl.:
  - the identification of air quality sensitive receptors;
  - an analysis of regional climate and site-specific atmospheric dispersion taking into account local meteorology, land-use and topography; and
  - analysis and assessment of existing (baseline) ambient air quality data (if available).
- The establishment of the proposed closure option emissions;
- Atmospheric dispersion simulations for proposed closure option (pre- and post-mitigation);
- A human health risk and nuisance impact screening assessment based on dispersion simulation results;
- The identification of air quality management measures based on the findings of the compliance and impact assessment; and
- An Air Quality Impact Assessment (AQIA) Report in the prescribed specialist report format.

1.2 Brief process description

1.2.1 Current Mining Operations

Mining operations include open pit mining methods (drilling, blasting and excavation of ore and waste rock), with haul roads linking the pit with the surrounding waste rock dumps (WRDs) and crushing and screening plant. Ore is hauled from the open pit and tipped at the run-of-mine (ROM) stockpile from where it is sent to the primary crusher, and to the secondary crushing and screening plant. Waste rock is hauled from the pit to three existing WRDs – Northern-; Western- and Eastern WRDs. Other infrastructure includes a train load-out facility, a private siding, topsoil stockpiles, product stockpiles, railway line and buildings.

Amendments to the Environmental Impact Assessment (EIA) and Environmental Management Programme Report (EMPR) included the extension of the East WRD in a south-easterly direction to join with the Mamatwan (Sinterfontein) WRD and essentially fill the narrow void between these two WRDs, and the extension of the West WRD in a south-westerly direction onto the remaining extent of Portion 8 of the farm Mamatwan 331. The construction of an overhead powerline and sub-station along the boundary of Portion 8 was also applied as well as the construction of an overland conveyor system from the existing crushing and screening plant to the existing manganese product stockpiles. A decision from the regulatory authorities is still pending for these amendments.

A sinter plant has been approved in the mine's approved EMP but is yet to be established.

The approved mine layout plan is provided in Figure 1 with a summary of the current mining operations provided in Table 1. It is important to note that this also illustrates infrastructure associated with the pending amendment application (WRD extensions and overhead powerline and sub-station), and as such this infrastructure is currently not located on site.

Table 1: Current Mining activities at Tshipi Borwa Mine with associated pollutants

Activity	Associated pollutants
Mining Operations	
Drilling and blasting	Particulate matter (PM)[a], sulfur dioxide (SO_2); oxides of nitrogen (NOx); carbon monoxide (CO); and carbon dioxide (CO_2)[b]
Excavation of ore and waste	mostly PM, gaseous emissions from mining equipment (PM, SO_2; NOx; CO; CO_2)
Removal and stockpiling of topsoil during pit expansion	mostly PM, gaseous emissions from excavation equipment (PM, SO_2; NOx; CO; CO_2)
Haulage of materials	PM from road surfaces and windblown dust from trucks, gaseous emissions from truck exhaust (PM, SO_2; NOx; CO; CO_2)
WRDs (Top_WRD; North_WRD; West_WRD and East_WRD)	PM from tipping and windblown dust, gaseous emissions from truck exhaust (PM, SO_2; NOx; CO; CO_2)
Primary crushing and screening	mostly PM, gaseous emissions from machinery (PM, SO_2; NOx; CO; CO_2)
Processing Operations	
Secondary crushing and screening	mostly PM, gaseous emissions from machinery (PM, SO_2; NOx; CO; CO_2)
Support Functions	
Back-up diesel power generators	PM, metals[c][d], NOx, SO_2, CO, TVOC, polycyclic aromatic hydrocarbons (PAH), toxic equivalent quantities (TEQ)
Other Activities	
Transportation of product	gaseous emissions from truck exhaust (PM, SO_2; NOx; CO; CO_2)
Explosives magazine	gaseous emissions from open burning (PM, SO_2; NOx; CO; CO_2)

Notes: [a] Particulate matter (PM) comprises a mixture of organic and inorganic substances, ranging in size and shape and can be divided into coarse and fine particulate matter. Total Suspended Particulates (TSP) represents the coarse fraction >10μm, with particulate matter with an aerodynamic diameter of less than 10μm (PM_{10}) and particulate matter with an aerodynamic diameter of less than 2.5μm ($PM_{2.5}$) falling into the finer inhalable fraction. TSP is associated with dust fallout (nuisance dust) whereas PM_{10} and $PM_{2.5}$ are considered a health concern.

[b] CO_2 and methane are greenhouse gasses (GHG).

[c] Metals include antimony, arsenic, beryllium, boron, cadmium, chromium(III), chromium(VI), cobalt, copper, fluoride, lead, manganese, mercury, nickel, selenium, zinc.

[d] All metals in [c] except antimony, boron, cobalt, fluoride, chromium(VI).

1.2.2 Mine Closure Options

The initial mine closure plan included backfilling of the open pit. Alternative closure options have been considered in a preliminary options analysis: partial backfill to the post closure groundwater rebound level, in pit dumping only, and no backfill or in pit dumping (Figure 2).

In-pit dumping is the preferred closure option to be assessed. The understanding is during the closure phase most of the in-pit dumping would be completed, leaving the WRDs and other exposed surfaces to be rehabilitated. It is further assumed that most of the WRD side slopes and some surface areas would be rehabilitated during the operational phase. Thus, during closure phase the main sources of air pollution remaining would be small exposed surfaces at the WRDs and some intermitted vehicle and materials handling activities associated with the rehabilitation of these exposed areas.

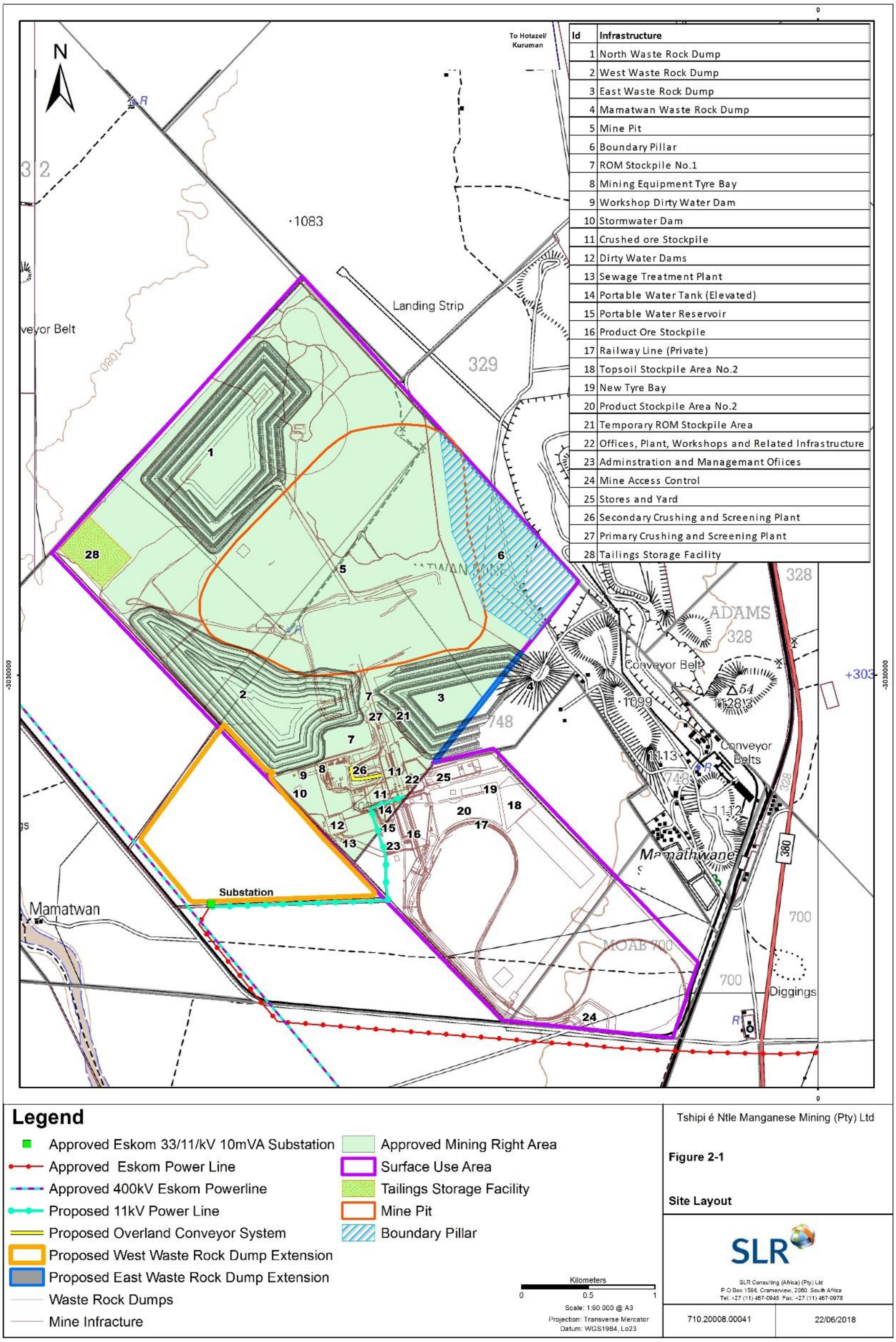


Figure 1: Approved Tshipi Borwa Mine Infrastructure Layout (SLR, 2017)

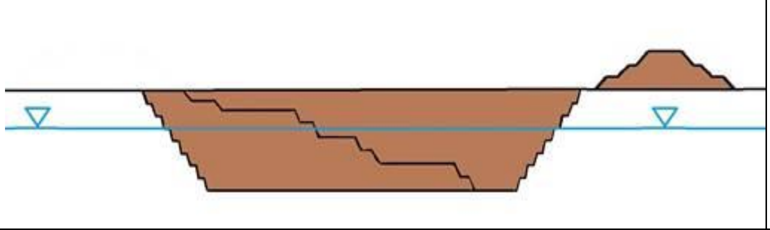
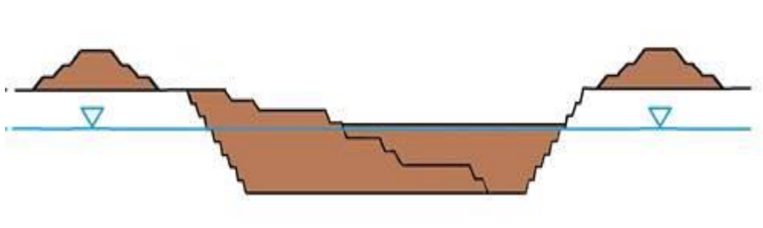
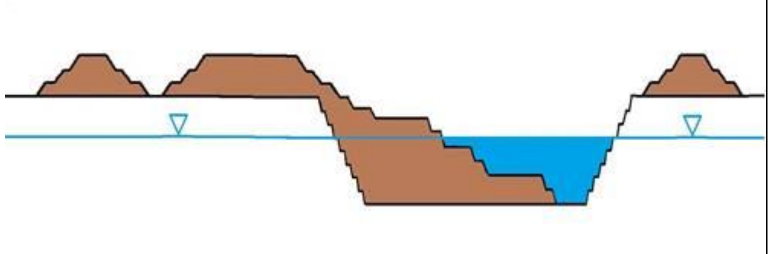
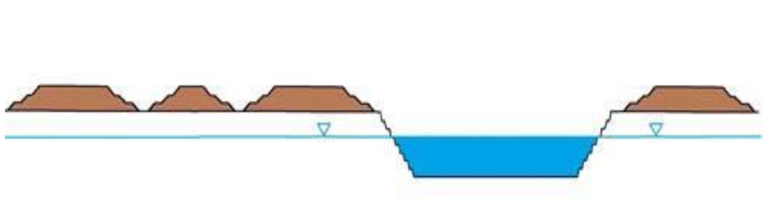
Options considered	Illustration	Detail
Complete backfill		Backfill of the final pit void post mining to original ground level, before rehabilitation of the surface as per the current approved EMPr.
Partial backfill		Backfill of the final pit void post mining to a level just above the rebound water-table level, approximately 50m below original ground level, before rehabilitation of the surface.
Concurrent backfill (in-pit dumping)		Backfill of the pit void concurrent with mining only, also called in-pit dumping, which results in a final pit void which will be 'made safe' (profiled) before rehabilitation of the surface.
No backfill		No backfill of the pit either concurrent with mining or post mining i.e. all waste rock to surface dumps. The pit side-walls and end-walls will only be 'made safe'.

Figure 2: The four closure options that were considered

The anticipated WRD sizes are provided in Table 2 and the final pit void in shown in Figure 3.

Table 2: Expected WRD sizes at end of Life of Mine (2048)

Source	ID	Volume (m^3)
West Dump	West_WRD	37.72 million m^3
East Dump	East_WRD	19.28 million m^3
Portion8 Dump	Top_WRD	59.12 milllion m^3
North Dump	North_WRD	45.59 million m^3
In-pit dumping volume	In_PIT	222.35 million m^3 of in-pit dumping (of which 139.02 million m^3 is below NGL, and 83.33 million m^3 is above NGL).

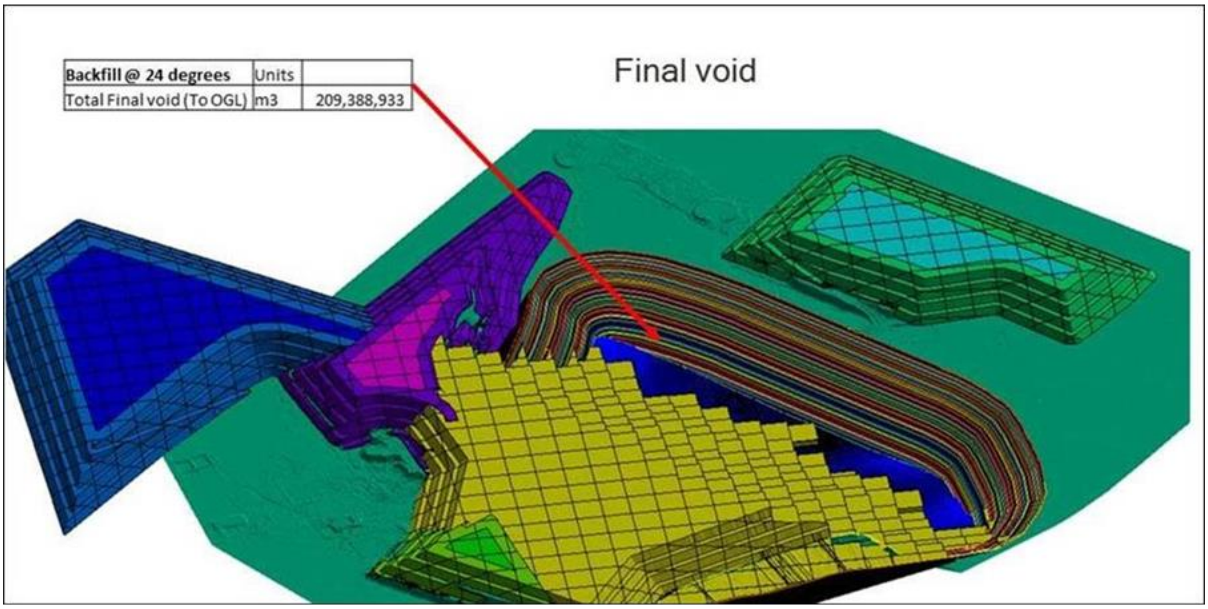


Figure 3: Conceptual layout of concurrent backfilling

1.3 Assumptions and Limitations

The main assumptions, exclusions and limitations are summarized below:

- Meteorological data: No onsite meteorological data was available and modelled MM5 data for the study site was obtained for the period January 2015 – December 2016.
- Tshipi Mine operates a dustfall network comprising of five (5) single dustfall units and five (5) directional dustfall units. Since results from the directional units cannot be compared to the NDCR limits, and only results from the single dustfall units are reported on. Monthly dustfall results were provided for the period January 2017 to April 2018, with no monthly results thereafter. The annual report for 2018 was made available but only reported on the minimum; average and maximum rates.
- PM_{10} is also measured at and around the mine and results were made available for the period October 2015 to May 2018, but with no data provided for the remainder of 2018 and for 2019.
- Current Mining Operations:
  - The current mining operations were not assessed. The impact assessment conducted as part of the 2009 EIA was regarded representative of the current mining operations, including a discussion on the WRD expansions and additional infrastructure addressed in the EIA/EMPR revisions in 2016 and 2018.
  - It was further assumed that in-pit dumping occurs concurrently with the current mining operations and that this would have ceased during the closure phase.
- Closure Option:
  - It was assumed that during closure, windblown dust from the remaining WRDs would be the main source of air pollution. It is likely that there will be intermittent truck activities and materials handling as part of the final rehabilitation, but these could not be quantified and were qualitatively described. The quantification of sources of emission was for Project activities only. Background sources were not included.
  - It was further assumed that in-pit dumping occurs concurrently with the current mining operations and that this would have ceased during the closure phase.

- It was assumed that the tailings storage facility will not be on-site at the time of closure.
- The windblown emissions from the WRDs were based on particle size distribution data obtained from material samples taken at the West_WRD and the East_WRD. For the remaining dumps the average particle size distribution was applied.
- Gaseous emissions from vehicle exhaust and other auxiliary equipment were not quantified as the impacts from these sources are usually localized and unlikely to exceed health screening limits outside the project area. The main pollutant of concern from the closure phase is particulate matter.
- The impact assessment was limited to airborne particulate (including TSP, PM_{10} and $PM_{2.5}$).
- There will always be some degree of uncertainty in any geophysical model, but it is desirable to structure the model in such a way to minimize 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. Nevertheless, dispersion modelling is generally accepted as a necessary and valuable tool in air quality management.

2 LEGAL REVIEW

The Air Quality Impact Assessment as part of the EIA conducted for the Ntsimbintle Manganese Mining Operations (Tshipi Borwa Manganese Mine) was done in April 2009. Subsequently, there have been additions and changes to the National Environmental Management: Air Quality Act (Act no.39 of 2004). The Act commenced with on 11 September 2005 as published in the Government Gazette on 9 September 2005 with sections omitted from the implementation (Sections 21, 22, 36 to 49, 51(1)(e),51(1)(f), 51(3), 60 and 61). The Act was fully implemented on 1 April 2010, including Section 21 on the Listed Activities and Minimum National Emission Standards (MES) with the revised MES published on 22 November 2013 (Government Gazette 37054, Notice No. 893). Amendments to the Act, primarily pertaining to administrative aspects, were published in 2014 (Government Gazette 37666, Notice No. 390 on 14 May 2014).

Air quality legislation that came into play after April 2009 that is relevant to the project is provided in Table 2.

Table 3: Legislation applicable to the project

Air Quality Legislation	Implementation/ revision dates	Reference	Affected Project Activity
National Framework	updated Dec 2012	Government Gazette 37078, 29 Nov 2013	Industry legal responsibilities
Section 21 – Listed Activities	Implemented: 1 April 2010 Revised: 2013 Amendments: 2015	Government Gazette 37054, 22 Nov 2013 Government Gazette 38863, 12 Jun 2015	Sinter Plant (still to be established)
National Ambient Air Quality Standards (NAAQS)	24 December 2009 29 July 2012	Government Gazette 32816, 24 Dec 2009 Government Gazette 35463, 29 Jun 2012	PM_{10} and $PM_{2.5}$ ground level concentrations as a result from the mining activities
National Dust Control Regulations (NDCR)	1 November 2013	Government Gazette 37054, 22 Nov 2013	Dust fallout rates as a result from the mining activities
National Atmospheric Emission Reporting Regulations (NAERR)	2 April 2015	Government Gazette 3863, 2 Apr 2015	Emissions reporting on mining operations Emissions reporting on Listed Activity (Sinter Plant to be established)
Regulation on Administrative Fines and Air quality offsets guideline	18 March 2016	Government Gazette 39833, 18 Mar 2016	Sinter Plant to be established will require an AEL
Declare Greenhouse Gas (GHG) as priority pollutants	Draft in 2016	Government Gazette 40996, 21 Jul 2017	N.A. [(a)]
National Pollution Prevention Plans (PPP) regulations	Draft in 2016	Government Gazette 40996, 21 July 2017	N.A.[(a)]
National Greenhouse Gas (GHG) Emission Reporting Regulations	3 April 2017	Government Gazette 40762, 3 April 2017	Mining and quarrying to report on all stationary combustion emissions above 10 MW(th)

Notes: (a) only apply to direct emission of GHG in excess of 0.1 Megatonnes (Mt) annually measured as carbon dioxide equivalents (CO_2-eq)

2.1 National Framework

The National Framework (first published in Government Gazette Notice No. 30284 of 11 September 2007) was updated in 2013) and provides national norms and standards for air quality management to ensure compliance. 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 measurement 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 have further responsibilities, including:
    - Making application for an 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.
    - Section 51 of the Air Quality Act lists possible offences according to the requirements of the Act with Section 52 providing for penalties in the case of offences.

2.2 Listed activities

At the time of the 2009 EIA, Minimum Emission Standards (MES) were still in the process of being developed and the study evaluated emissions against the then proposed MES for the ferromanganese industry. Sinter Plants fall under Category 4: Metallurgical Industry and requires an Atmospheric Emission License (AEL) to operate. There are two sets of MES applicable to:

- *New Plants* (plant or process where the application in terms of NEMA was made on or after 1 April 2010); and
- *Existing Plants* (plant or process that was legally authorised to operate before 1 April 2010 or where an application in terms of NEMA was made before 1 April 2010).

The sinter plant has not been established yet, thus no Atmospheric Emissions License is required.

2.3 National Ambient Air Quality Standards

The South African Bureau of Standards (SABS) assisted the Department of Environmental Affairs (DEA) in the development of ambient air quality standards. National Ambient Air Quality Standards (NAAQS) were determined based on international best practice for $PM_{2.5}$ PM_{10}, SO_2, NO_2, ozone (O_3), CO, lead (Pb) and benzene. The NAAQS were published in the Government Gazette (no. 32816) on 24 December 2009, thus after the 2009 EIA was competed. NAAQS for $PM_{2.5}$ was published on 29 July 2012. The NAAQS for are listed in Table 4.

Table 4: South African national ambient air quality standards (Government Gazette 32816, 2009)

Pollutant	Averaging Period	Limit Value ($\mu g/m^3$)	Limit Value (ppb)	Frequency of Exceedance	Compliance Date
Benzene	1 year	10	-	0	Immediate – 31 Dec 2014
	1 year	5	-	0	1 Jan 2015
CO	1 hour	30 000	26 000	88	Immediate
	8 hour[(a)]	10 000	8 700	11	Immediate
NO_2	1 hour	200	106	88	Immediate
	1 year	40	21	0	Immediate
PM_{10}	24 hour	75	-	4	1 Jan 2015
	1 year	40	-	0	1 Jan 2015
$PM_{2.5}$	24 hour	40	-	4	1 Jan 2016 – 31 Dec 2029
	24 hour	25	-	4	1 Jan 2030
	1 year	20	-	0	1 Jan 2016 – 31 Dec 2029
	1 year	15	-	0	1 Jan 2030
SO_2	10 minutes	500	191	526	Immediate
	1 hour	350	134	88	Immediate
	24 hour	125	48	4	Immediate
	1 year	50	19	0	Immediate

2.4 National Regulations for Dust Deposition

South Africa's Draft National Dust Control Regulations were published on the 27 May 2011 with the dust fallout standards passed and subsequently published on the 1st of November 2013 (Government Gazette No. 36974). These are called the National Dust Control Regulations (NDCR). The purpose of the regulations is to prescribe general measures for the control of dust in all areas including residential and light commercial areas. SA NDCRs that were published on the 1st of November 2013. Acceptable dustfall rates according to the regulation are summarised in Table 5.

Table 5: Acceptable dustfall rates

Restriction areas	Dustfall rate (D) in mg/m^2-day over a 30 day average	Permitted frequency of exceedance
Residential areas	D < 600	Two within a year, not sequential months.
Non-residential areas	600 < D < 1 200	Two within a year, not sequential months.

The regulation also specifies that the method to be used for measuring dustfall and the guideline for locating sampling points shall be ASTM D1739 (1970), or equivalent method approved by any internationally recognized body. It is important to note that dustfall is assessed for nuisance impact and not inhalation health impact.

2.5 National Atmospheric Emission Reporting Regulations (NAERR)

The National Atmospheric Emission Reporting Regulations (NAERR) was published on the 2nd of April 2015 by the Minister of Environmental Affairs. The regulation aims to standardize the reporting of data and information from an identified point, non-point and mobile sources of atmospheric emissions to an internet-based National Atmospheric Emissions Inventory System (NAEIS), towards the compilation of atmospheric emission inventories (DEA , 2015).

Annexure 1 of the NAERR classify **mines** (holders of a mining right or permit in terms of the Mineral and Petroleum Resources Development Act, 2002 (Act No. 28 of 2002)) as a data provider under **Group C**. **Listed Activity** as published in terms of Section 21(1) of the AQA falls under **Group A**.

Sections of the regulation that applies to data providers are summarized below.

With regards to registration, the regulation stipulates that:

(a) A person classified as a data provider must register on the NAEIS within 30 days from the date upon which these Regulations came into effect;

(b) A person classified as a data provider and who commences with an activity or activities classified as emission source in terms of the regulation 4(1) after the commencement of these Regulations, must register on the NAEIS within 30 days after commencing with such an activity or activities.

With regards to reporting and record keeping, the regulation stipulates that:

(a) A data provider must submit the required information for the preceding calendar year, as specified in Annexure 1 to these Regulations, to the NAEIS by 31 March of each calendar year.

(b) A data provider must keep a record of the information submitted to the NAEIS for five years and such record must, on request, be made available for inspection by the relevant authority.

With regards to verification of information, the regulation requires data providers to verify requested information within 60 days after receiving the written request from the relevant authority.

2.6 Greenhouse Gas Emissions

Greenhouse gasses – CO_2, CH_4, N_2O, HFCs, PFCs and SF_6 – have been declared priority pollutants under Section 29(1) of the Air Quality Act (Government Gazette 37421 of 14 March 2014). The declaration provides a list of sources and activities including (i) fuel combustion (both stationary and mobile), (ii) fugitive emission from fuels, (iii) industrial processes and other product use, (iv) agriculture; forestry and other land use and (v) waste management. GHGs in excess of 0.1 Megatons or more, measured as CO_2-e, is required to submit a pollution prevention plan to the Minister for approval.

Regulations pertaining to GHG reporting using the NAEIS was published on 3 April 2017 (Government Gazette 40762, Notice 275 of 2017). The South African mandatory reporting guidelines focus on the reporting of Scope 1 emissions only. The South African mandatory reporting guidelines focus on the reporting of Scope 1 emissions only. The three broad scopes for estimating GHG are:

- Scope 1: All direct GHG emissions.

- Scope 2: Indirect GHG emissions from consumption of purchased electricity, heat or steam.
- Scope 3: Other indirect emissions, such as the extraction and production of purchased materials and fuels, transport-related activities in vehicles not owned or controlled by the reporting entity, electricity-related activities not covered in Scope 2, outsourced activities, waste disposal, etc.

The NAEIS web-based monitoring and reporting system will also be used to collect GHG information in a standard format for comparison and analyses. The system forms part of the National Atmospheric Emission Inventory component of SAAELIP and South African Air Quality Information System (SAAQIS).

The DEA is working together with local sectors to develop country specific emissions factors in certain areas; however, in the interim the Intergovernmental Panel on Climate Change's (IPCC) default emission figures may be used to populate the SAAQIS GHG emission factor database. These country specific emission factors will replace some of the default IPCC emission factors. It has been indicated that these factors will only be published towards the end of 2015 (Jongikhaya, 2015). For this assessment, IPCC emission factors have been used.

A draft carbon tax bill was introduced for a further round of public consultation. The Carbon Tax Policy Paper (CTPP) (Department of National Treasury, 2013) stated consideration will be given to sectors where the potential for emissions reduction is limited. Also, in draft is that GHG in excess of 0.1 Mt, measured as CO_{2-eq}, is required to submit a pollution prevention plan to the Minister for approval.

3 DESCRIPTION OF THE RECEIVING ENVIRONMENT

3.1 Site Description

Tshipi Borwa Manganese Mine is situated adjacent to the Mamatwan Mine, approximately 15 km south of Hotazel, 40 km north of Khatu and 43 km west of Kuruman. The site is surrounded by farmland used for grazing. Air quality sensitive receptors (AQSRs) in the immediate vicinity of the mine, as identified in the 2009 study, include a farmhouse (N Fourie) 1.5 km south of the mine and a farmhouse (D van den Berg) is 1 km to the south west. The Farmhouse of A Pyper is about 2 km west of the mine. Farm workers also residence on the farm Middelplaats 332 located approximately 2 km north west from the mine. There is a solar farm about 3 km to the north-east from the mine, with Mamatwan Mine in-between.

Operating mines located in relatively close proximity to Tshipi Borwa Manganese Mine include Mamatwan opencast mine directly to the east, and United Manganese of Kalahari (UMK) Mine 4 km to the north. Both these mines have on-site sintering (Krause & Liebenberg-Enslin, 2009). Another large opencast mine in the area is Sishen Iron Ore Mine, located 33 km to the south of Tshipi Borwa Manganese Mine. Closed or dormant mines include Middelplaats, Adams, Smartt and Perth.

The area surrounding the site is mostly flat with ridges to the west (about 40 km away) and to the east (about 20 km away). Within a 10 km radius around the mine the terrain is fairly flat with s slight slope from the southeast to the northwest.

The identified AQSRs and other mines are shown in Figure 4.

3.2 Atmospheric Dispersion Potential

Physical and meteorological mechanisms govern the dispersion, transformation, and eventual removal of pollutants from the atmosphere. The analysis of hourly average meteorological data is necessary to facilitate a comprehensive understanding of the dispersion potential of the site. Parameters useful in describing the dispersion and dilution potential of the site i.e. wind speed, wind direction, temperature and atmospheric stability, are subsequently discussed.

Weather data from the on-site weather station were only available for the last six months of 2016 (July – December). In the 2009 study (Krause & Liebenberg-Enslin, 2009)., use was made of the South African Weather Services (SAWS) Kuruman Weather Station (located approximately 43 km to the west of Tshipi Borwa Manganese Mine). More recent data (1 January 2015 – 31 December 2017) from the same station was obtained for inclusion in the report. The data availability varied between the years with poor data availability of 63% (specifically on the wind field) in 2015 but good data availability of 93% and 90% for 2016 and 2017, respectively.

3.2.1 Surface Wind Field

The wind field determines both the distance of downward transport and the rate of dilution of pollutants. The generation of mechanical turbulence is a function of the wind speed, in combination with the surface roughness. The wind field for the study area is described with the use of wind roses. Wind roses comprise 16 spokes, which represent the directions from which winds blew during a specific period. The colours used in the wind roses below, reflect the different categories of wind speeds; the yellow area, for example, representing winds in between 4 and 5 m/s. The dotted circles provide information regarding the frequency of occurrence of wind speed and direction categories. Calm conditions are periods when the wind speed was below 1 m/s. These low values can be due to “meteorological” calm conditions when there is no air movement; or, when there may be wind, but it is below the anemometer starting threshold.

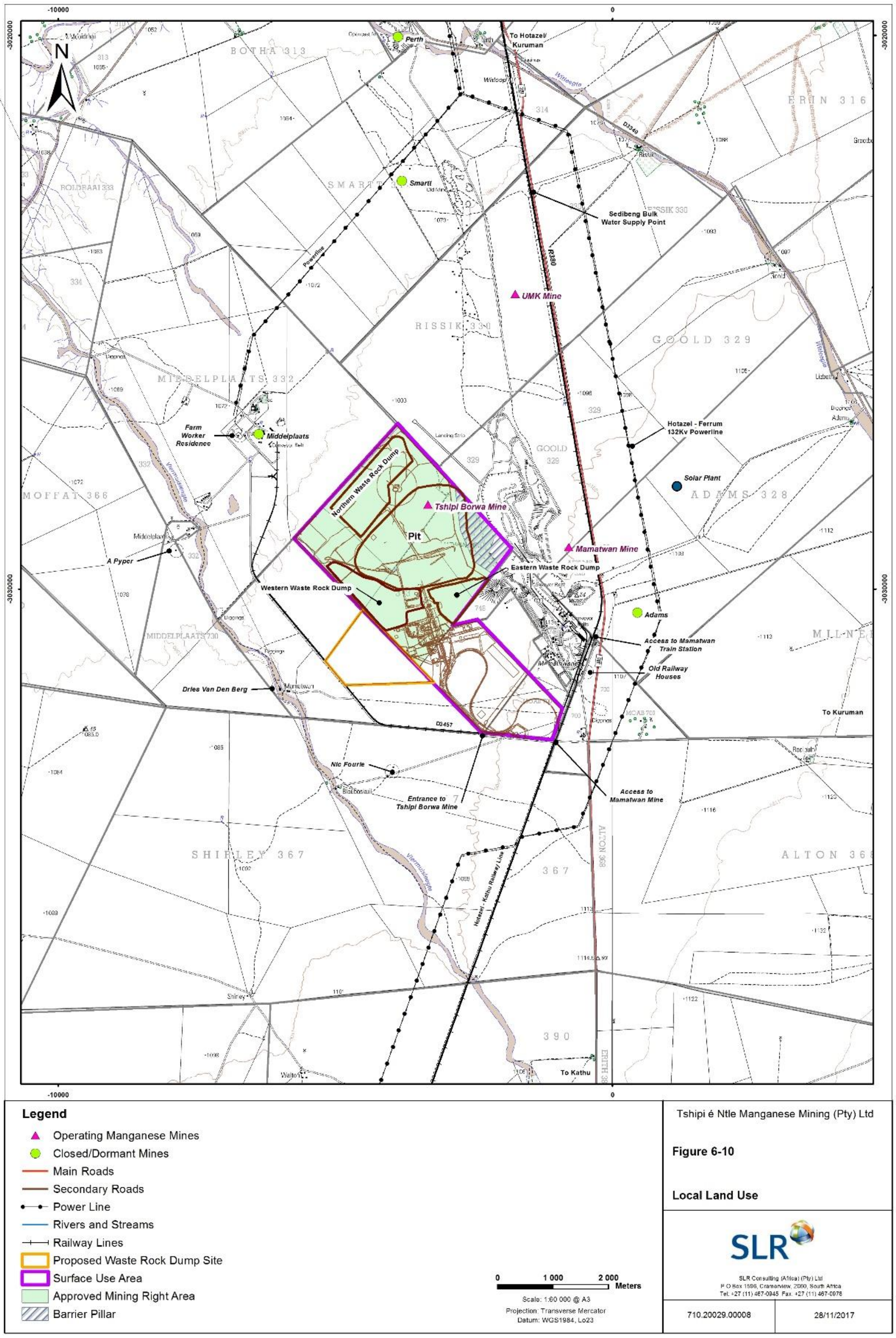


Figure 4: Air quality sensitive receptors near the Tshipi Borwa Manganese Mine

The annual average wind roses for the years 2015, 2016 and 2017 are shown in Figure 5 with the period average wind field (2015-2017) and diurnal variability in the wind field provided in Figure 6. The predominant wind direction is from the south-south-east and south with most of strong winds from the west. Frequent winds also occur from the north. Over the three-year period, the frequency of occurrence of south-south-easterly wind is between 12% and 17%, with winds with a westerly component occurring approximately 15% of the time. Winds occur less frequently from the easterly sector. The year 2015 had low data availability for wind speed and wind direction (63%), which may account for the seemingly less frequent winds from the south-south-east.

As shown in Figure 6, during the day winds are more frequent from the westerly and the northerly sectors, with the strongest winds directly from the west. The wind shifts during the night-time to dominantly south-south-easterly and southerly winds. Day-time calms occurred for 9% of the time, with night-time calms for 24% of the time.

The prevailing wind field is similar to the data used in the 2009 study, with a slight shift in the overall wind field from south-east and south-south-east (2001-2005 data) to the south-south-east and south (2015-2017). Similarly, the 2001-2005 Kuruman data had more prevalent north-westerly winds with a shift to more westerly winds in the later dataset.

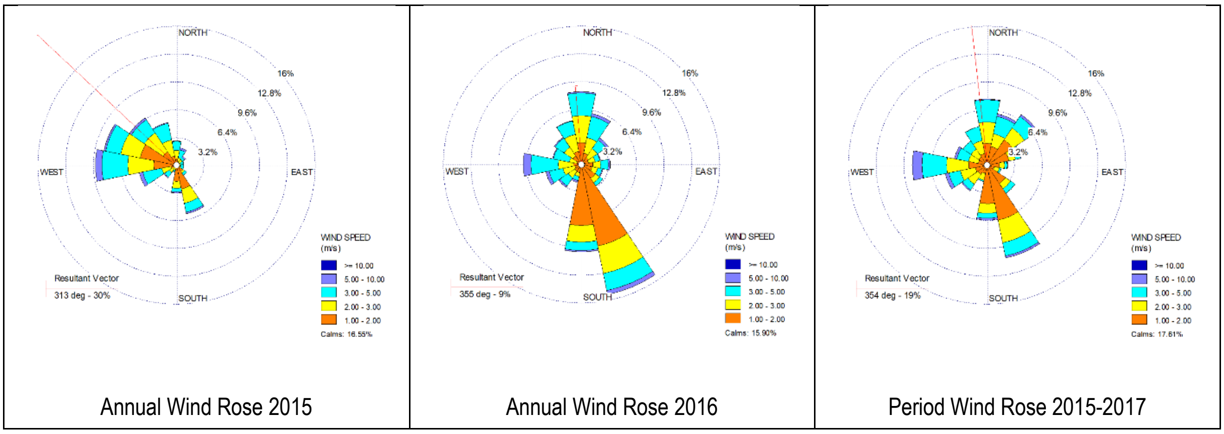


Figure 5: Period and annual wind roses (SAWS Kuruman data; 2015, 2016 and 2017)

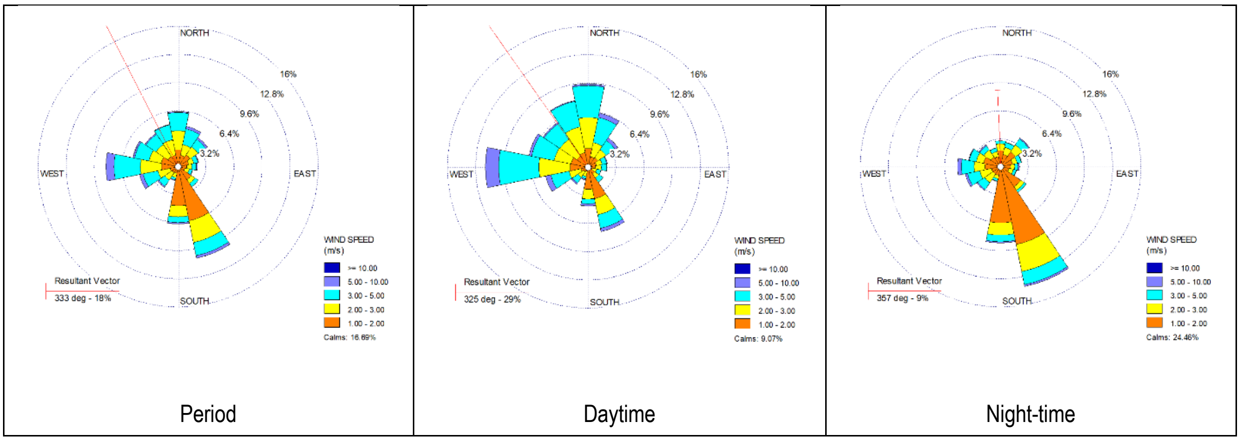


Figure 6: Period, daytime and nigh-time wind roses (SAWS Kuruman data; 2015 to 2017)

According to the Beaufort wind force scale (https://www.metoffice.gov.uk/guide/weather/marine/beaufort-scale), wind speeds between 6-8 m/s equates to a moderate breeze, with wind speeds between 14-17 m/s near gale force winds. Based on the three years of SAWS data, wind speeds exceeding 6 m/s occurred for only 1% of the time, with a maximum wind speed of 10 m/s. The average wind speed over the three years was 2.06 m/s. Calm conditions (wind speeds < 1 m/s) occurred for

17% of the time (Figure 7). The US EPA indicates a friction velocity of 5.4 m/s to initiate erosion from a coal storage piles (US EPA, 2006) and Mian & Yanful (2003). Thus, the likelihood exists for wind erosion to occur from open and exposed surfaces, with loose fine material, when the wind speed exceeds at least 5.4 m/s. Wind speeds exceeding 5.4 m/s occurred only for 2% over the three years (2015 -2017).

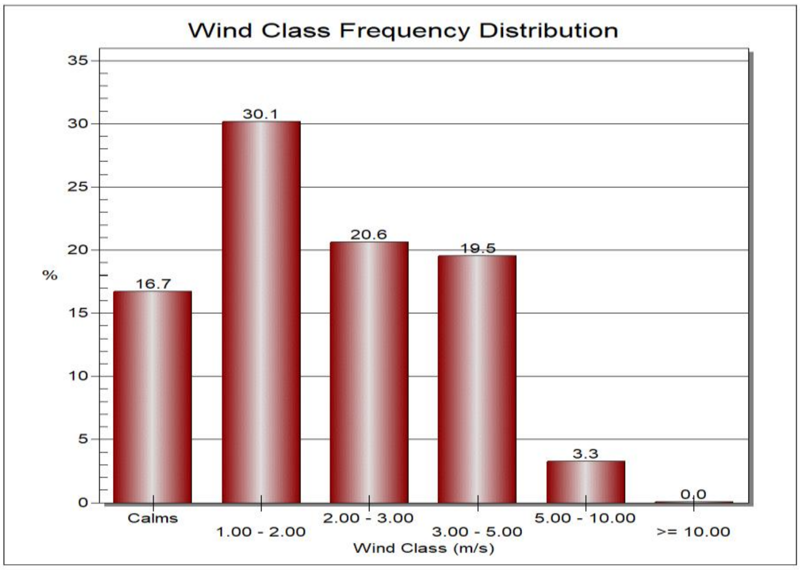


Figure 7: Wind speed categories (SAWS Kuruman data; 2015 to 2017)

3.2.2 Temperature

Air temperature is important, both for determining the effect of plume buoyancy (the larger the temperature difference between the plume and the ambient air, the higher a pollution plume is able to rise and determining the development of the mixing and inversion layers. The monthly temperature pattern is provided in Table 6. The area experience hot temperatures above 22°C during summer. Winter temperatures are relatively low especially in the months of June to August. Average daily maximum temperatures range between 43°C in January to 25°C in June, with daily minima between -4.2°C in August to 10°C in January.

Table 6: Minimum, average and maximum temperatures (SAWS Kuruman data; 2015 to 2017)

	Jan	Feb	March	April	May	June	July	Aug	Sep	Oct	Nov	Dec
Min	10.1	10	6.4	3.3	2	-3.2	-3.9	-4.2	2.2	2.7	4.3	9.6
Ave	25.1	24.3	22.2	17.9	14.0	10.7	10.8	13.8	18.5	21.7	23.5	26.4
Max	42.6	38.8	35.6	35.3	28.8	25.3	27.1	31.3	34.7	38.5	39.5	39.9

3.2.3 Precipitation

Precipitation is important to air pollution studies since it represents an effective removal mechanism for atmospheric pollutants and inhibits dust generation potentials. Monthly rainfall for Kuruman is shown in Figure 8. Months wherein the most rain occurred ranged between October and May. The most rain was received during the months of January and February in 2017, and April 2016. Total rainfall during 2015 was 397.6 mm, 821.6 mm in 2016 and 498.4 mm in 2017.

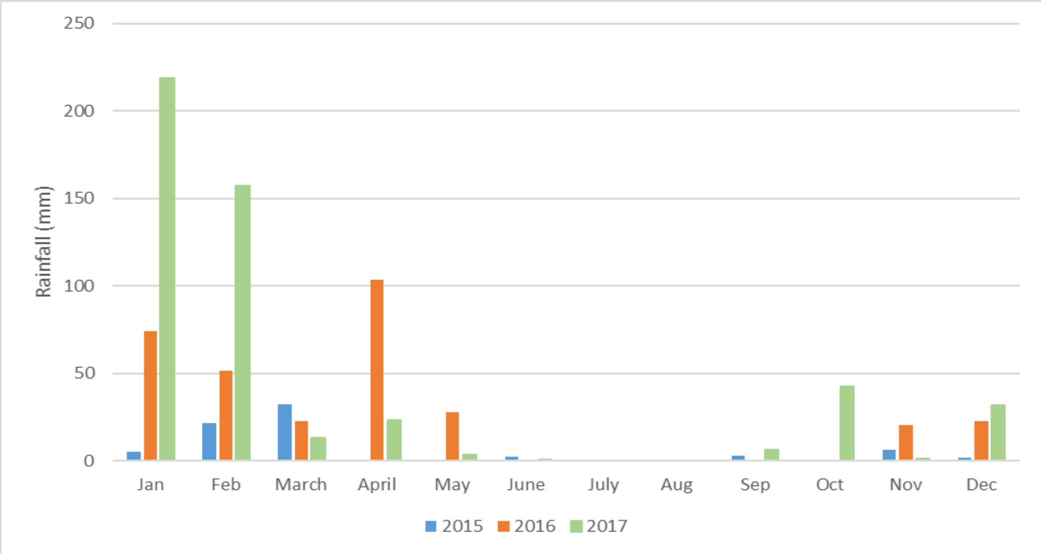


Figure 8: Monthly precipitation (SAWS Kuruman data; 2015 to 2017)

3.2.4 Atmospheric Stability

The new generation air dispersion models differ from the models traditionally used in several aspects, the most important of which are the description of atmospheric stability as a continuum rather than discrete classes. The atmospheric boundary layer properties are therefore described by two parameters; the boundary layer depth and the Monin-Obukhov length, rather than in terms of the single parameter Pasquill Class. The Monin-Obukhov length (L_{MO}) provides a measure of the importance of buoyancy generated by the heating of the ground and mechanical mixing generated by the frictional effect of the earth's surface. Physically, it can be thought of as representing the depth of the boundary layer within which mechanical mixing is the dominant form of turbulence generation (CERC, 2004).

The atmospheric boundary layer constitutes the first few hundred metres of the atmosphere. During the daytime, the atmospheric boundary layer is characterised by thermal turbulence due to the heating of the earth's surface and the predominance of an unstable layer. In unstable conditions, ground level pollution is readily dispersed thereby reducing ground level concentrations. Night-times are characterised by weak vertical mixing and the predominance of a stable layer. These conditions are normally associated with low wind speeds and less dilution potential. During windy and/or cloudy conditions, the atmosphere is normally neutral (which causes sound scattering in the presence of mechanical turbulence).

Atmospheric stability is frequently categorised into one of six stability classes – these are briefly described in Table 7. For low level releases, such as activities associated with mining operations, the highest ground level concentrations would occur during weak wind speeds and stable (night-time) atmospheric conditions. However, windblown dust is likely to occur under high winds (neutral conditions).

Table 7: Atmospheric stability classes and percentage occurrence (SAWS Kuruman data; 2015 to 2017)

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

3.3 Baseline Air Quality

3.3.1 Dustfall Monitoring network

A dustfall monitoring network is in place at Tshipi Mine, comprising of five directional dustfall units (DW-01 to DW-5) as shown in Figure 8. Data is also reported for five single dust fallout units (SW-01 to SW-05), and it is assumed these are located alongside the directional units (coordinates and descriptions supplied in Table 8). Since the NDCRs are based on single dustfalll units following the ASTM D1739 method, the directional units cannot be compared to the NDCR limits. Dustfall results for the period January 2017 to May 2018 for the single units are provided in Table 9. From the data, it is evident that the dustfall is high at and around the mine, exceeding the NDCR for non-residential areas of 1 200 mg/m²/day, often.

Table 8: Location of Single Dustfall Units and applicable NDCRs

Dustfall Unit	Description	Latitude	Longitude	NDCR
SB-01	Main Security Gate 27	27°24'22.58"S	22°58'52.17"E	Non-residential
SB-02	Mining Offices	27°23'26.15"S	22°57'54.38"E	Non-residential
SB-03	Tshipi Main Office	27°23'35.98"S	22°58'2.04"E	Non-residential
SB-04	Processing Plant	27°23'26.70"S	22°58'23.28"E	Non-residential
SB-05	Silo	27°23'44.78"S	22°58'15.09"E	Non-residential

Table 9: Dustfall rates from the single duistfall units at Tshipi Borwa Manganese Mine

Start date	End date	Days Exposed	Dustfall rates (mg/m²/day)				
			SB-01	SB-02	SB-03	SB-04	SB-05
11/01/2017	27/02/2017	47	-	1 075	676	1 097	636
27/02/2017	30/03/2017	31	-	1 473	1 343	1 480	1 266
30/03/2017	02/05/2017	33	-	1 375	1 193	1 642	1 119
02/05/2017	30/05/2017	28	-	841	725	771	940
30/05/2017	28/06/2017	29	-	2 003	1 069	1 336	826
28/06/2017	27/07/2017	29	-	1 338	833	1 147	632
27/07/2017	31/08/2017	35	1 680	2 234	1 333	1 539	-
31/08/2017	03/10/2017	33	1 248	2 245	1 618	1 369	-
03/10/2017	30/10/2017	27	831	1 238	726	932	-
30/10/2017	29/11/2017	30	1 325	1 209	866	930	-
29/11/2017	14/12/2017	15	1 495	1 095	1 051	944	1 420
14/12/2017	15/02/2018	63	-	1 933	1 234	1 371	1 162
15/02/2018	19/04/2018	63	-	2 290	930	1 150	594

Notes: Highlighted cells indicate exceedances of the NDCR non-residential limit of 1 200 mg/m²/day

Only minimum, maximum and average dustfall rates were provided for the single dustfall units for the period 14 December 2017 to 13 December 2018. These dustfall rates are provided in Table 10. Based on these, the minimum dustfall rate for SB-01 exceeded the residential limit of 600 mg/m²/day, but the remaining units were within the non-residential limit of 1 200 mg/m²/day. However, all maximum rates exceeded the applicable NDCR limits at all locations.

Table 10: Minimum, average and maximum dustfall rates from the single dustfall units for period 14 December 2017 to 13 December 2018

	Dustfall rates (mg/m²/day)				
	SB-01	SB-02	SB-03	SB-04	SB-05
Minimum	694.4	532.3	783.7	820.4	681.4
Average	983.0	1 129.5	1 185.8	1 330.4	950.5
Maximum	1 405.2	1 616.8	1 936.5	1 795.6	1 522.4

3.3.2 *PM_{10} Sampling*

PM_{10} sampling campaigns have been on-going since October 2015 at the dustfall locations and next to the Silo. The 24-hour results from the eight campaigns indicate elevated PM_{10} levels around the mine, exceeding the 24-hour NAAQS of 75 µg/m³ for all the campaigns (days sampled) at almost all the locations. The sampling campaigns only covered a single day in 2015, five (5) days in 2017 and two (2) days in 2018, thus compliance evaluation is not possible – the NAAQS allows 4 days in a calendar year where the standard can be exceeded. It is therefore likely that the ambient air quality around the mine is in non-compliance with the NAAQS since most sampled days exceeded the 24-hour limit. No data was made available after May 2018.

Table 11: PM_{10} daily concentrations at Tshipi Borwa Manganese Mine

Date	SB-01	SB-02	SB-03	SB-04	SB-05	Next to Silo
Oct-15	125	93.7	541.7	187.5	ND	1 218.7
May-17	256.9	423.6	0	381.9	809	329.9
Aug-17	73	181	660	160	1316	233
Sep-17	253.5	180.6	211.8	ND	ND	69.4
Oct-17	288.2	430.6	468.7	291.7	83.3	72.9
Dec-17	135.4	93.8	215.3	111.1	784.7	180.6
Feb-18	93.75	0	135.42	208.33	114.58	291.67
May-18	552.08	114.58	187.5	708.33	239.58	625

Notes: ND is No Data. The NAAQS for PM_{10} 24-hour is 75 µg/m³ not to be exceeded for more than 4 days in a year.

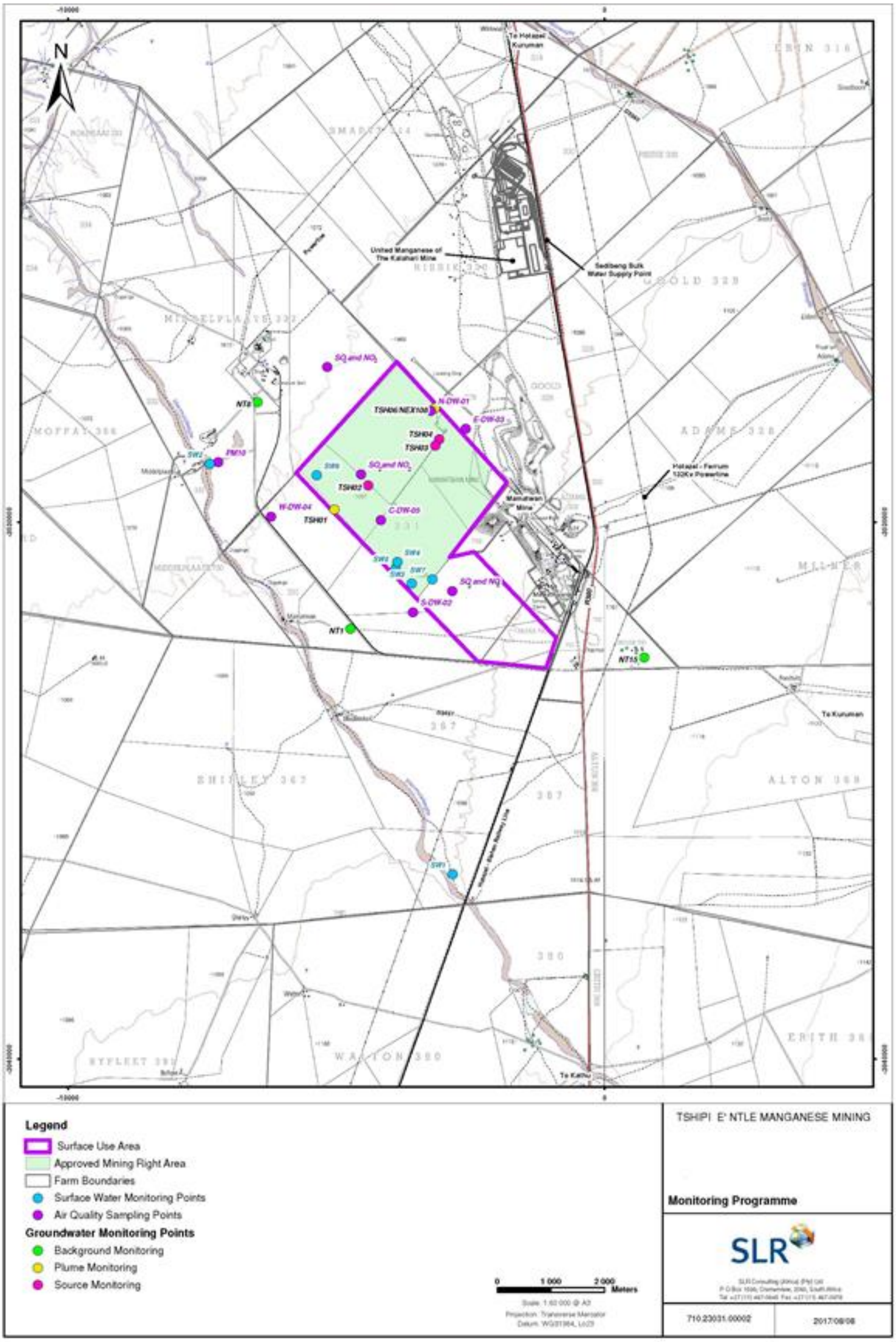


Figure 9: Monitoring Network at Tshipi Borwa Manganese Mine

4 AIR QUALITY IMPACT ASSESSMENT

4.1 Current Mining Operations

The air quality impact assessment conducted for the then proposed Ntsimbintle Mine (now Tshipi Borwa) assessed the potential health and nuisance impacts from PM_{10}, manganese (Mn), SO_2, NOx, Diesel Particulate Matter (DPM) and CO due to the mining operations per the approved infrastructure layout (Figure 1).

The main findings from the April 2009 air quality impact assessment 1 can be summarised as follows:

- **PM_{10} ground level concentrations**: The modelled annual average and highest daily average incremental and cumulative unmitigated PM_{10} concentrations at the Ntsimbintle boundary were well above the NAAQSs. The annual NAAQS of 40 µg/m³ was exceeded at the Ntsimbintle boundary and the old Middelplaats mine. The daily NAAQS of 75 µg/m³ was exceeded at the Ntsimbintle boundary and a number of identified sensitive receptors (A. Pyper, the old Middelplaats mine and N. Fourie). Mitigation of fugitive dust sources resulted in an average reduction of 87% in predicted PM_{10} concentrations, with only exceedances of the annual and daily PM_{10} NAAQS at the mine boundary and not at any of the sensitive receptors.

  Vehicle entrained dust from unpaved roads were the main source resulting in unmitigated and mitigated PM_{10} concentrations contributing, on average, 88% and 67% respectively to the total PM_{10} ground level concentrations.

- **Manganese ground level concentrations**: The modelled annual average incremental unmitigated Mn concentration at the Ntsimbintle boundary was 20.1 µg/m³ and the cumulative concentration was 20.7 µg/m³ compared to the annual World Health Organisation (WHO) guideline of 0.15 µg/m³. Exceedances were also predicted at A. Pyper, the old railway housing, the old Middelplaats mine and N. Fourie. With mitigation in place the impact reduced on average by 69%.

  Manganese dust as a result of crushing and screening operations contributed most significantly, 61%, to the predicted unmitigated Mn concentrations. With mitigation measures in place, emissions from the sinter plant contributed most significantly to predicted manganese concentrations. The sinter plant has not been established.

- **SO_2 ground level concentrations**: The modelled annual, highest daily and highest hourly average incremental and cumulative SO_2 concentrations at the Ntsimbintle boundary were below the NAAQSs for annual and daily averages but exceeded the hourly limit at the Ntsimbintle boundary but not at any of the sensitive receptors.

  Sinter plant emissions were estimated to be the most significant contributor, contributing on average 89%, to predicted incremental SO_2 concentrations. The sinter plant has, however, not been established.

- **NO_2 ground level concentrations**: The modelled annual and highest hourly average incremental and cumulative NO_2 concentrations at the Ntsimbintle boundary was below the NAAQS for annual averages but marginally exceeded the hourly limit at the Ntsimbintle boundary but not at any of the sensitive receptors.

  Sinter plant emissions were estimated to be the most significant contributor, contributing on average 39%, to predicted incremental NO_2 concentrations. The sinter plant has not been established.

- **Diesel Particulate Matter (DPM) ground level concentrations**: The modelled annual average incremental DPM concentration at the Ntsimbintle boundary was above the SANS annual limit of 5 µg/m³, but not at the sensitive receptors.

- **CO ground level concentrations**: Modelled highest hourly average incremental CO concentration at the Ntsimbintle boundary and at any of the discreet receptors was well below the NAAQS.

- **Dustfall impacts**: The modelled maximum daily incremental unmitigated dustfall level at the Ntsimbintle boundary was above the NDCR residential dustfall limit, but within the non-residential limit. With mitigation in place the impacts reduced.

- The potential implications of the proposed changes to the current mining operations that have been assessed during 2016 and 2018, can be summarised as follows:
- Impacts associated with current and proposed mining operations not assessed during the 2009 air quality impact assessment include:
  - Infrastructure changes as proposed in 2017 (Liebenberg-Enslin, 2017) would likely result in increased PM_{10} ground level concentrations and dust fallout rates specifically to the west and north-west of the mine mainly due to the increase of fugitive dust sources. No increases in SO_2, NO_2, Mn and CO are foreseen. DPM concentrations might increase due to the increased truck activity but it is unlikely to exceed the guideline.
  - Infrastructure changes as proposed in 2018 (Liebenberg-Enslin, 2018), where the West WRD and the East WRD are to be extended, would likely result in increased PM_{10} and $PM_{2.5}$ ground level concentrations and dust fallout rates off-site and at nearby AQSRs from the construction and operation of the West WRD extension. With mitigation measures in place these impacts should be limited and localised resulting in a low significance. Increased impacts from the East WRD extension and the overland conveyor are likely to be insignificant. No increases in SO_2, NO_2, Mn and CO are foreseen. DPM concentrations might increase due to the increased truck activity but it is unlikely to exceed the guideline.

4.2 Closure Option Impact Assessment

As discussed under Section 1.2.2, in-pit dumping is the preferred closure option. All the in-pit dumping will be done during the operational phase with no loading, hauling and tipping of waste rock activities, leaving windblown dust from exposed WRD surfaces as the main air pollution sources. This section describes the quantification of windblown dust from the WRDs and the potential impact on the surrounding environment.

4.2.1 Emissions Quantification

Windblown particulates from exposed mine waste facilities can result in significant dust emissions with high particulate concentrations near the source locations, potentially affecting both the environment and human health.

4.2.1.1 Methodology

Emission quantification from these types of sources was obtained using the in-house ADDAS model (Burger *et al.,* 1997; Burger, 2010; Liebenberg-Enslin, 2014). This model is based on the dust emission scheme of Marticorena and Bergametti (1995) (referred to as MB95 from this point forward) and Shao *et al.*, 2011 (referred to as SH11). A study conducted by Liebenberg-Enslin (2014) set out to establish a best practice prescription for modelling aeolian dust emissions from mine tailings storage facilities (TSFs). Site-specific particle size distribution data, and bulk density and moisture content were used in the dust flux schemes of MB95, and SH11, to test the effects on a local scale. This was done by coupling these schemes with the U.S. EPA regulatory Gaussian plume AERMOD dispersion model for the simulation of ground level concentrations resulting from aeolian dust from mine tailings facilities. Simulated ambient near surface concentrations were validated with ambient monitoring data for the same period as used in the model. Coupling the dust flux schemes with a regulatory Gaussian plume model provided simulated ground level PM_{10} concentrations in good agreement with measured data. For this study, the MB95 dust flux model, as schematically represented in Figure 10, was used.

The model inputs include material particle density, moisture content, particle size distribution, and site-specific surface characteristics such as whether the source is active or undisturbed. All input parameters that were not measured as part of this work, have been drawn from or were calculated using referenced methodologies (Liebenberg-Enslin, 2014).

Facilities prone to wind erosion during the closure option include: i) Top_WRD; ii) West_WRD; iii) East_WRD; and iv) North_WRD. The TSF was assumed not to be on-site during closure. Quantification of windblown dust from these facilities used site-specific sources parameters obtained from samples taken at East_WRD and West_WRD (i.e. particle size distribution, moisture and silt content, and particle density) and on-site weather data.

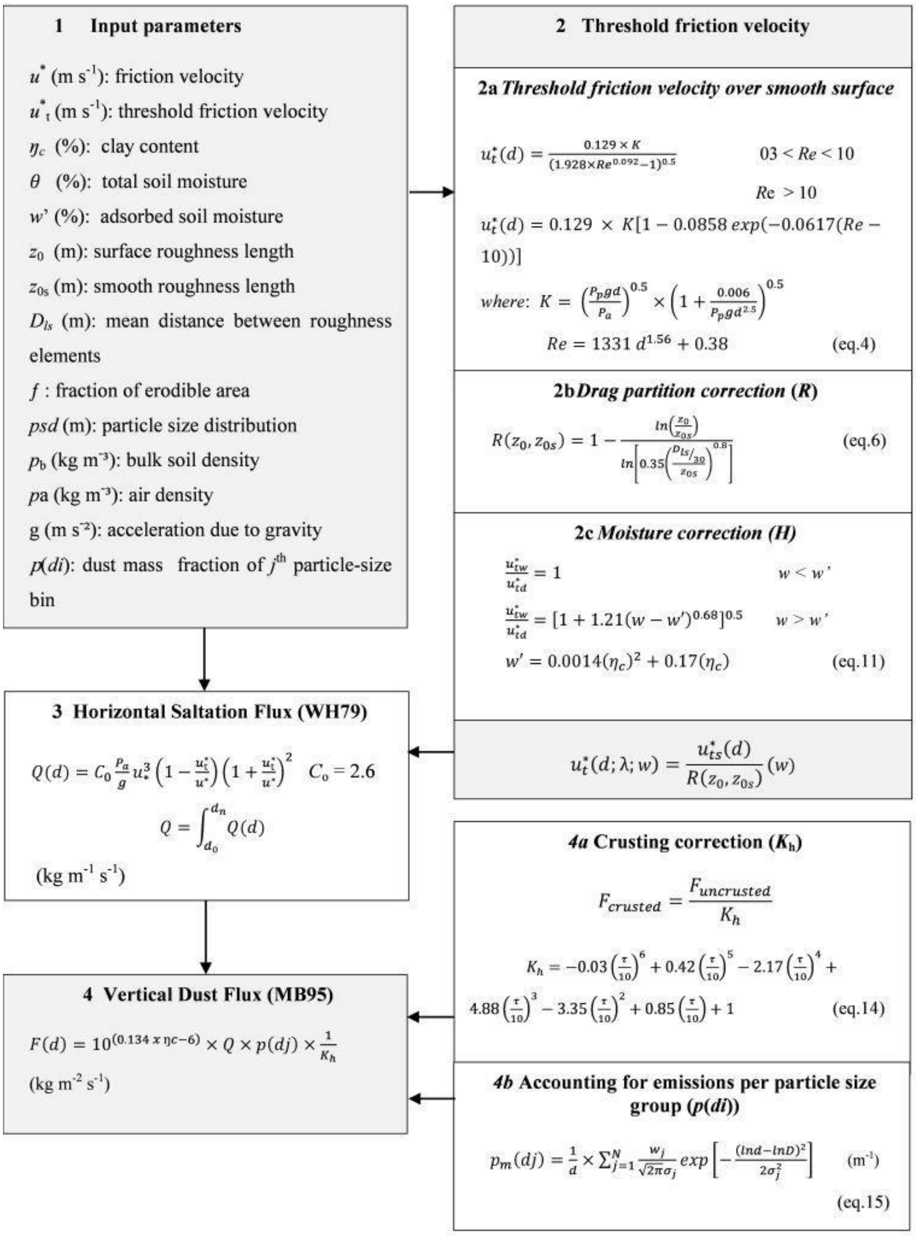


Figure 10: Schematic diagram of parameterization options and input parameters for the Marticorena and Bergametti (1995) dust flux scheme (see Liebenberg-Enslin, 2014)

4.2.1.2 Results

Clay, silt and sand fractions as listed in Table 12 are in accordance to the typical soil classification provided by Friedman & Sanders (1978), where clay is defined as d<2 µm. The clay content ranges between 0% (West_WRD) and 1% (East_WRD), with silt ranging from 35% (West_WRD) to 88% (East_WRD). The sand fraction is between 65% (West_WRD) and 11% (East_WRD).

The percentage within each of the fractions for $PM_{2.5}$, PM_{10} and PM_{75} is provided in Table 12. This provides an indication of the amount of these fractions likely to be eroded. These fractions were normalised for up to 75 µm and provided as the total within each fraction (cumulative). $PM_{2.5}$ fraction is small on average, ranging between 0% (West_WRD) and 3% (East_WRD). The PM_{10} fraction ranges between 12% (West_WRD) and 29% (East_WRD) with the PM_{75} fractions between 88% (West_WRD) and 68% (East_WRD).

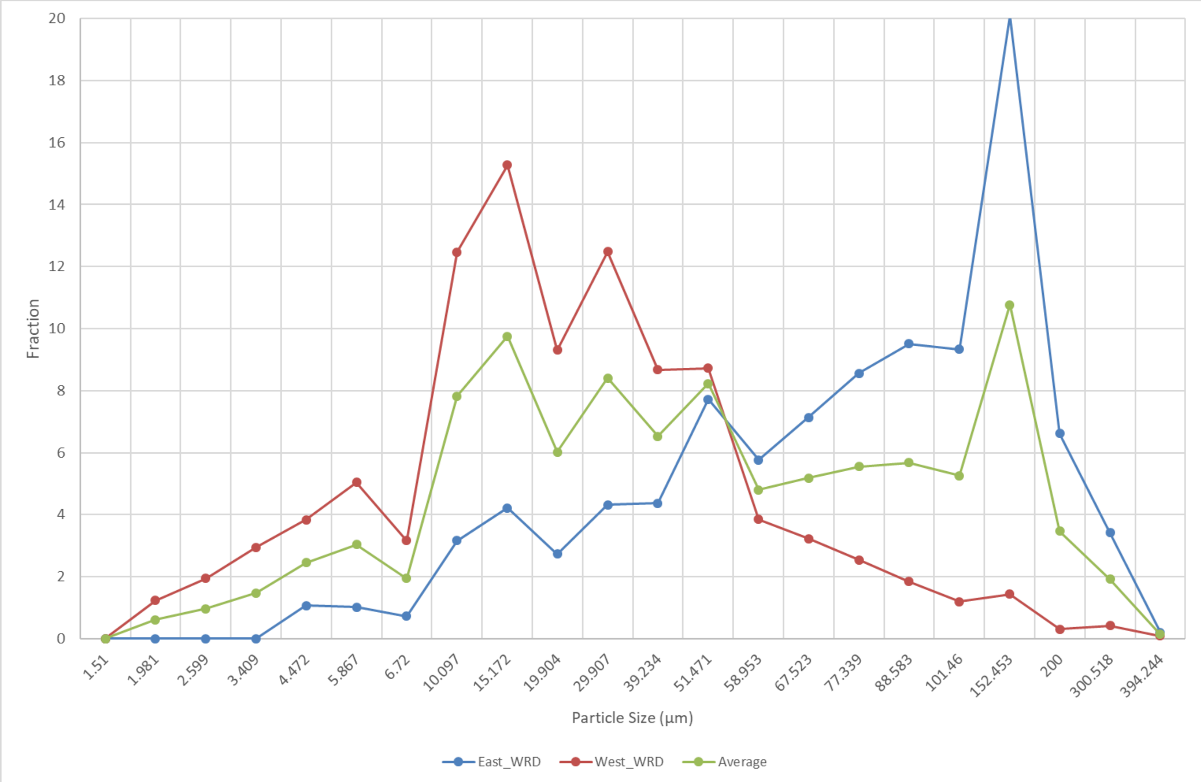


Figure 11: Particle size distribution of the two samples taken from West_WRD and East_WRD at Tshipi Mine

Table 12: Particle size distribution for three particle size bins of $PM_{2.5}$, PM_{10} and PM_{75} from the two samples taken from West_WRD and East_WRD

Source	Clay	Silt	Sand	Normalised percentage of $p_m(d)$ fractions		
	(<2 µm)	(2-63 µm)	(63-2000 µm)	$PM_{2.5}$	PM_{10}	PM_{75}
	(%)	(%)	(%)	(d < 2.5 µm)	(d < 10 µm)	(d < 75 µm)
West_WRD	0%	35%	65%	0%	12%	88%
East_WRD	1%	88%	11%	3%	29%	68%
Average	0%	0%	0%	2%	20%	78%

The US EPA indicates a friction velocity of 5.4 m/s to initiate erosion from a coal storage piles (US EPA, 2006) and Mian & Yanful (2003) calculated a wind speed in excess of 9 m/s is required to initiate wind erosion from two tailings storage facilities in in New Brunswick and Ontario, Canada. Thus, the likelihood exists for wind erosion to occur from open and exposed surfaces, with loose fine material, when the wind speed exceeds at least 5.4 m/s. As a conservative approach, lower wind speeds were selected to result in wind erosion from the WRDs as shown in

Table 13. The windblown emissions were modelled as hourly emission rates resulting in an emission rate only when the wind speed exceeded these threshold wind speeds. Thus, the modelled concentrations should reflect a similar temporal variation as in measured data, with highest concentrations under high wind speeds.

Table 13: Soil loss due to wind erosion for the areas evaluated

Windblown Dust Area	Area size (m²)	PSD sampling point	Emissions (tpa)			Threshold Wind speed (m/s)	Percentage emission rate hours (%)
			$PM_{2.5}$	PM_{10}	TSP		
Top_WRD	202 848.00	Average of West_WRD & East_WRD	2.74	32.91	99.59	4.3	6%
North_WRD	1 096 504.00		14.80	177.88	538.33	4.3	6%
West_WRD	863 924.00	West_WRD	14.66	147.56	397.29	3.9	10%
East_WRD	9 252.00	East_WRD	0.00	0.87	4.12	4.5	5%
TOTAL			**32.20**	**359.22**	**1 039.33**	-	-

4.2.1.3 Metal Analysis

The same samples used for psd analysis were used for Inductively Coupled Plasma Mass Spectrometry (ICP/MS) analysis for elemental content (8 elements). Samples were analysed at Biograde, an accredited Laboratory in Pretoria, South Africa. The main elements in the PM_{10} were iron (Fe), magnesium (Mg) and manganese (Mn). The other elements made up a small portion.

Table 14: ICP Metal Results for the West_WRD and East_WRD

Metal		West_WRD	East_WRD
		mg/kg	mg/kg
Chromium	Cr	37	20
Copper	Cu	41	12
Iron	Fe	33 535	13 089
Magnesium	Mg	12 589	3 679
Manganese	Mn	2 532	570
Nickel	Ni	66	39
Lead	Pb	5	5
Zinc	Zn	23	12

4.2.2 Atmospheric Dispersion Modelling

To assess impact on human health and the environment the following important aspects need to be considered:

- The criteria against which impacts are assessed (Section 2.3 and 2.4);
- The potential of the atmosphere to disperse and dilute pollutants emitted by the project (Section 3.2**Error! Reference source not found.**);
- The AQSRs in the vicinity of the proposed mine (Section 3.1); and
- The methodology followed in determining ambient pollutant concentrations and dustfall rates (Section 4.2.2).

The impact of the proposed closure phase on the atmospheric environment was determined through the simulation of ambient pollutant concentrations. Dispersion models simulate ambient pollutant concentrations as a function of source configurations, emission strengths and meteorological characteristics, thus providing a useful tool to ascertain the spatial and temporal patterns in the ground level concentrations arising from the emissions of various sources. Increasing reliance has been placed on concentration estimates from models as the primary basis for environmental and health impact assessments, risk assessments and emission control requirements. It is therefore important to carefully select a dispersion model for the purpose.

4.2.2.1 Dispersion Model Selection

Gaussian-plume models are best used for near-field applications where the steady-state meteorology assumption is most likely to apply. One of the most widely used Gaussian plume model is the US EPA AERMOD model that was used in this study. AERMOD is a model developed with the support of AERMIC, whose objective has been to include state-of the-art science in regulatory models (Hanna, Egan, Purdum, & Wagler, 1999). 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).

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. AERMET is a meteorological pre-processor for AERMOD. Input data can come from hourly cloud cover observations, surface meteorological observations and twice-a-day upper air soundings. Output includes surface meteorological observations and parameters and vertical profiles of several atmospheric parameters. AERMAP is a terrain pre-processor designed to simplify and standardise the input of terrain data for AERMOD. Input data includes receptor terrain elevation data. The terrain data may be in the form of digital terrain data. The output includes, for each receptor, location and height scale, which are elevations used for the computation of air flow around hills.

A disadvantage of the model is that spatial varying wind fields, due to topography or other factors cannot be included. Input data types required for the AERMOD model include: Source data, meteorological data (pre-processed by the AERMET model), terrain data, information on the nature of the receptor grid and pre-development or background pollutant concentrations or dustfall rates. Version 7.9 of AERMOD and its pre-processors were used in the study.

4.2.2.2 Meteorological Requirements

For the current study, use was made of modelled MM5 data for the study site for the period 2015-2017 (Section 3.2).

4.2.2.3 Source Data Requirements

The AERMOD model can model point, jet, area, line and volume sources. Sources were modelled as follows:

- Windblown dust from WRDs – modelled as area sources.

4.2.2.4 Modelling Domain

The dispersion of pollutants expected to arise from proposed activities was modelled for an area covering 12 km (east-west) by 12 km (north-south). The area was divided into a grid matrix with a resolution of 100 m by 100 m, with the project located centrally. AERMOD calculates ground-level (1.5 m above ground level) concentrations and dustfall rates at each grid and discrete receptor points (AQSRs).

4.2.3 Dispersion Modelling Results

Dispersion modelling was undertaken to determine highest daily and annual average ground level PM concentrations. Averaging periods were selected to facilitate the comparison of predicted pollutant concentrations to relevant ambient air quality and inhalation health criteria as well as dustfall regulations.

Pollutants with the potential to result in human health impacts which are assessed in this study include $PM_{2.5}$ and PM_{10}. Dustfall is assessed for its nuisance potential. Results are primarily provided in form of isopleths to present areas of exceedance of assessment criteria. Ground level concentration or dustfall isopleths presented in this section depict interpolated values from the concentrations simulated by AERMOD for each of the receptor grid points specified.

Isopleth plots reflect the incremental ground level concentrations (GLCs) for $PM_{2.5}$ and PM_{10} where exceedances of the relevant NAAQSs were simulated.

It should also be noted that ambient air quality criteria apply to areas where the Occupational Health and Safety regulations do not apply, thus outside the mining area. Ambient air quality criteria are therefore not occupational health indicators but applicable to areas where the general public has access i.e. off-site.

4.2.3.1 PM_{10}

The simulated highest daily PM_{10} concentrations for the closure phase are provided in Figure 12.

The main findings are:

- PM_{10} daily GLCs due to windblown dust from the WRDs, with no mitigation in place, are likely to be in compliance off-site. The only exceedances of the daily NAAQS of 75 µg/m³ occur at the WRDs.
- PM_{10} annual average concentrations are very low, and not shown on Figure 12. These concentrations are well below the NAAQS (40 µg/m³).

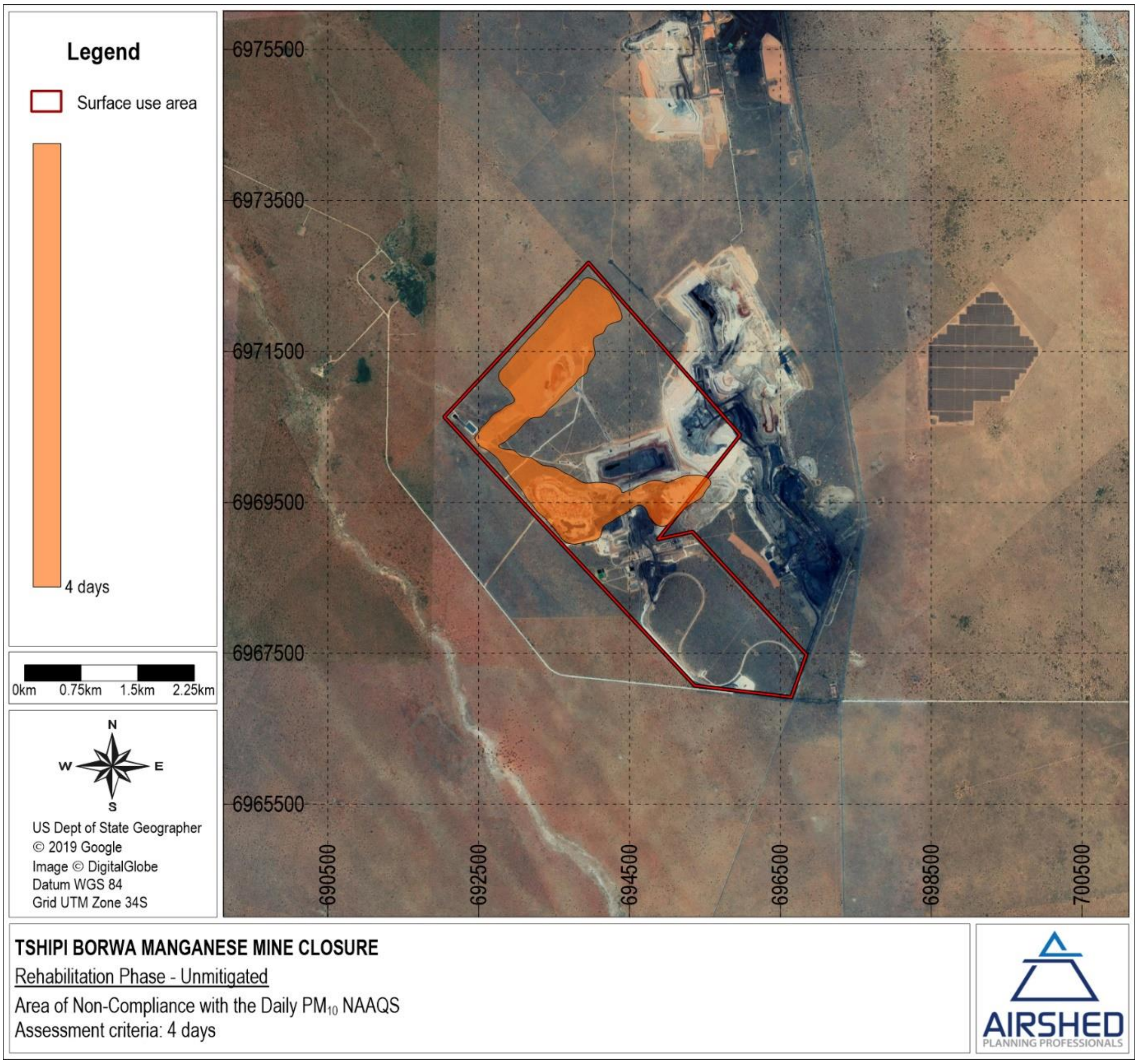


Figure 12: Area of non-compliance of daily PM_{10} NAAQS due to <u>unmitigated</u> emissions

4.2.3.2 $PM_{2.5}$

The simulated highest daily $PM_{2.5}$ concentrations for the closure phase are provided in Figure 13.

The main findings are:

- $PM_{2.5}$ daily GLCs due to windblown dust from the WRDs, with no mitigation in place, are low and within compliance off-site. The only exceedances of the daily 2030 NAAQS of 25 µg/m³ occur at West_WRD.
- $PM_{2.5}$ annual average concentrations are very low, and not shown on Figure 12. These concentrations are well below the NAAQS of 15 µg/m³.

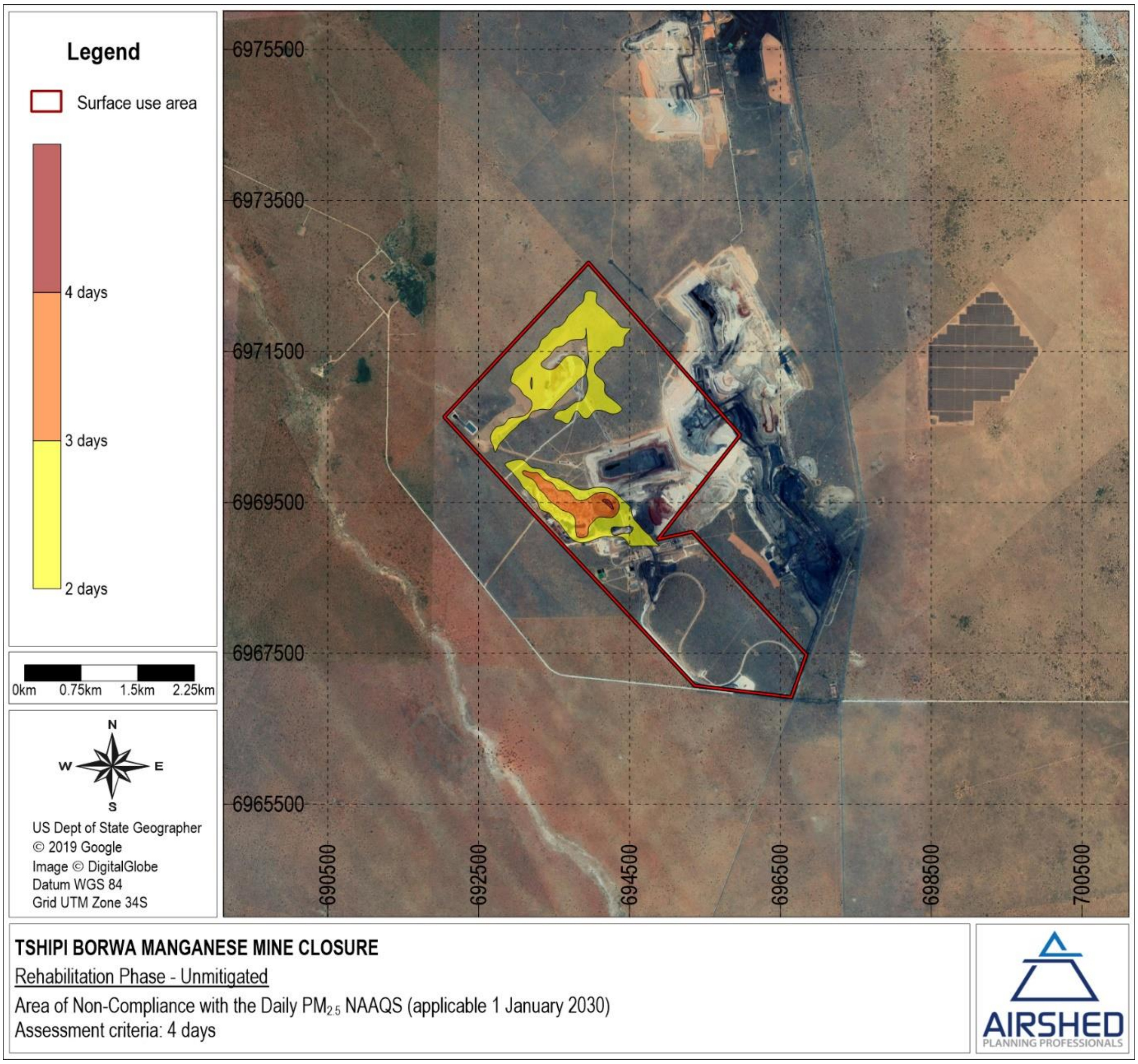


Figure 13: Area of non-compliance of daily $PM_{2.5}$ NAAQS due to unmitigated emissions

4.2.3.3 Dust fallout

The simulated daily dustfall rates for the closure phase are provided in Figure 14.

The main findings are:

- Maximum daily dustfall rates, for unmitigated closure operations, are likely to be in compliance with the NDCR residential limit (600 mg/m²/day) off -site. On-site the dustfall rates are below the non-residential limit of 1 200 mg/m²/day only exceeding the residential limit on the WRDs.

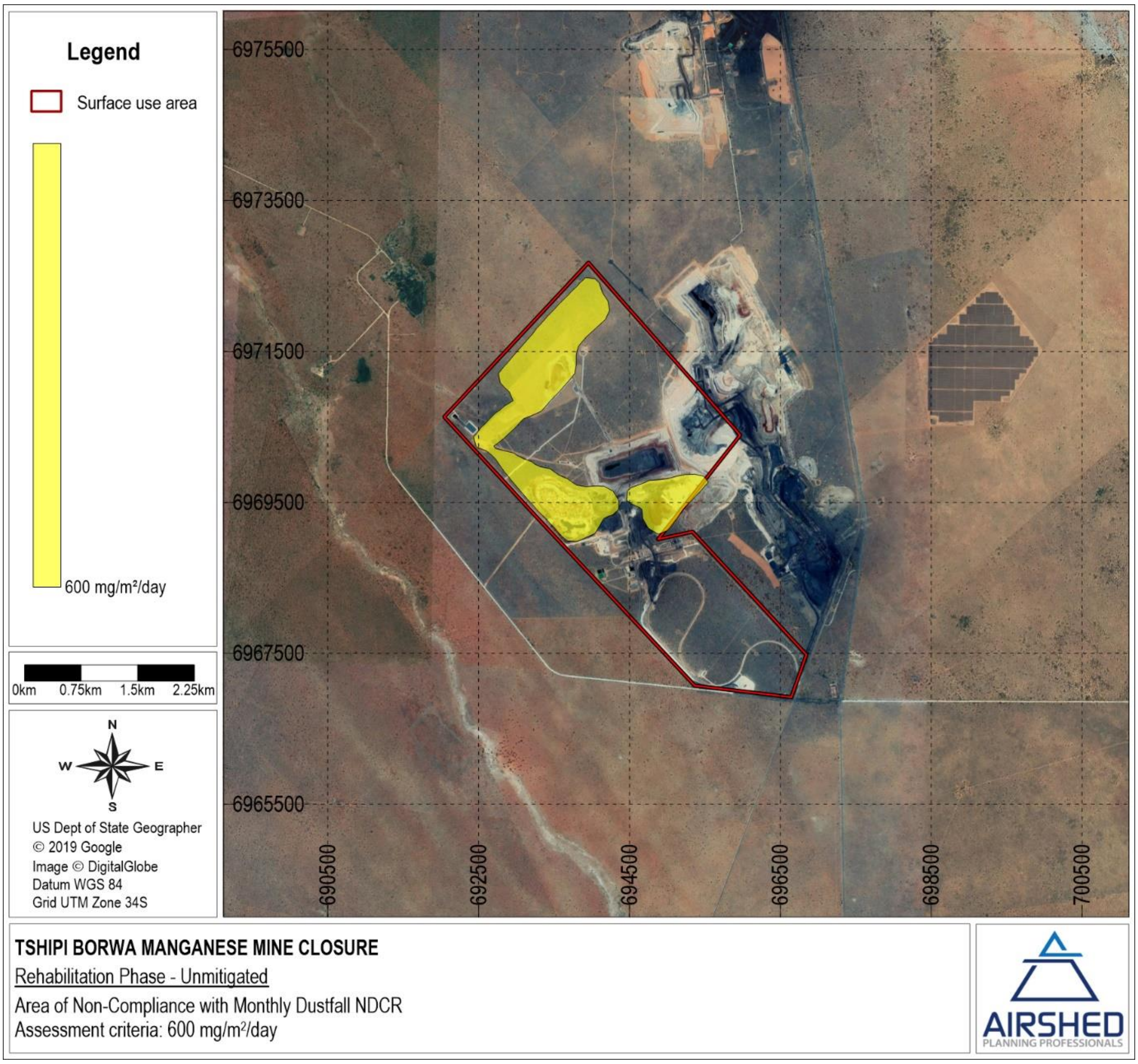


Figure 14: Simulated dustfall deposition rates due to due to unmitigated emissions

4.2.3.4 Manganese Impacts

Manganese within the waste rock samples taken ranged between 0.25% (West_WRD) and 0.06% (East_WRD). When simulated the highest annual average concentration is 0.03 µg/m³, which is below the WHO annual average manganese guideline of 0.15 µg/m³. This the significance of manganese impacts during closure phase is low.

4.2.4 Cumulative Impacts

At the time of closure, all operations at Tshipi Mine would have ceased leaving only other sources in the region to contribute to cumulative particulate concentrations and dustfall rates. Mamatwan Mine, adjacent to Tshipi Mine is likely to cease operations by 2035 (https://www.south32.net/docs/default-source/all-financial-results/reports-and-presentations/mamatwan-site-tour-2016.pdf?sfvrsn=2ba37bd2_8). This leaves the main contributors to PM concentrations and dustfall in the immediate vicinity of the mine to be the farming activities and vehicles travelling on the paved and unpaved roads. These sources are already part of the background PM concentrations and dust fallout and would result in significantly lower ambient particulate concentrations and dust fallout than is currently the case. The air quality around Tshipi Mine is likely to improve significantly by closure phase.

4.3 Alternative Closure Phase Options

Other closure phase options considered include partial backfill to the post closure groundwater rebound level, in pit dumping only, and no backfill or in pit dumping (Figure 2). For options 1 (complete backfill) and 2 (partial backfill), in pit dumping will continue after closure and this is likely to result in higher air quality impacts compared to options 3 (concurrent in-pit dumping) and 4 (no backfill and no in-pit dumping). The potential for air quality impacts between options 1 and 2 after closure are regarded similar, with slight changes due to the volumes of WRDs and exposed areas. All closure options would however result in significantly lower air pollution levels than the operational phase.

There is an additional option of post closure aggregate rock crushing. This is likely to last longer for option 4 where all WRDs will provide available material for crushing, and the shortest for option 1 where most waste rock will be moved into the pit. The impacts on air quality from this option would thus be the most significant (based on duration) for option 4, followed by similar impacts from options 2 and 3, and the least significant from option 1.

4.4 Management and Mitigation Measures

4.4.1 Emission reduction

The Australian National Pollution Inventory (NPI, 2012) states the following control efficiencies (CE) for wind erosion:

- 40% for vegetation established but not demonstrated to be self-sustaining. (Weed control and grazing control.)
- 60% for secondary rehabilitation.
- 90% for revegetation.
- 100% for fully rehabilitated (release) vegetation.

For the WRDs the same mitigation scenarios can be applied:

- <u>Operational (up to 2048)</u>: 90% CE on the "baseline" exposed areas, to reflect revegetation (medium term).
- <u>Long-term Scenario (closure and post-closure)</u>: 100% CE on all exposed surfaces (assumption being that all are fully vegetated).

A 99% reduction in windblown dust emissions have been achieved by applying an 80% control on the WRDs (Table 15). Thus, the proposed mitigation scenarios are regarded feasible.

Table 15: Windblown dust emission reduction due to WRD rehabilitation

Source	Emission Rates (tpa)						Percentage Reduction		
	Unmitigated			Mitigated					
	$PM_{2.5}$	PM_{10}	TSP	$PM_{2.5}$	PM_{10}	TSP	$PM_{2.5}$	PM_{10}	TSP
Top_WRD	2.74	32.91	99.59	0.03	0.32	1.06	**99%**	**99%**	**99%**
North_WRD	14.80	177.88	538.33	0.14	1.72	5.73	**99%**	**99%**	**99%**
West_WRD	14.66	147.56	397.29	0.11	1.15	3.30	**99%**	**99%**	**99%**
East_WRD	0.00	0.87	4.12	0.00	0.01	0.05	**99%**	**99%**	**99%**

- Any binding properties would reduce the potential for wind erosion from the WRDs. One of the most effective measures of minimizing wind erosion emissions is re-vegetation. The control efficiency of vegetation is given as 40% for non-sustaining vegetation and 90% for re-vegetation. Secondary rehabilitation would up the control efficiency to 60% for non-sustaining vegetation (NPI, 2012). Windblown dust from the WRDs should be controlled through.

4.4.2 Post-Closure

Post-closure should not result in any significant air quality impacts assuming that the WRDs have been fully vegetated and rehabilitated.

5 IMPACT SIGNIFICANCE

The significance of air quality impacts was assessed according to a generic impact significance rating methodology. Refer to Appendix B of this report for the methodology.

The potential for health risk impacts from PM_{10} and $PM_{2.5}$ are provided in
Table 16. The environmental significance of these impacts is LOW; with mitigation applied it would reduce further to remain LOW.

Table 16: Health risk impact significance summary table for the proposed Closure Phase as a result of PM_{10} and $PM_{2.5}$

Criteria	Without Mitigation	With Mitigation
Intensity	Low	Low
Duration	Long term (a)	Medium
Extent	Local	Local
Loss of resource	Medium	Medium
Probability	Probable	Probable
Confidence	Medium	Medium
Significance	LOW (b)	VERY LOW (c)
Cumulative significance	LOW	LOW
Nature of cumulative impact	Other activities that may contribute to the cumulative risk impact include farming activities, paved and unpaved roads.	
Degree in which impact can be reversed	Partially reversable	Partially reversable
Degree to which impact may cause irreplaceable loss of resources	Low	Low
Degree to which impact can be mitigated	High	-
Recommended mitigation measures: Vegetation and re-vegetation of entire WRDs and exposed surfaces		-

Notes: (a) where the impact will cease after the operational life of the activity

(b) of ***low intensity*** at a ***local level*** in the ***long term***

(c) of ***low intensity*** at a ***local level*** and endure in the ***medium term***

The significance rating for manganese impacts is provided in Table 17. The environmental significance of these impacts is LOW; with mitigation applied it would reduce further to VERY LOW.

Table 17: Health risk impact significance summary table for the proposed Closure Phase as a result of Manganese

Criteria	Without Mitigation	With Mitigation
Intensity	Low	Low
Duration	Long term	Medium
Extent	Local	Local
Loss of resource	Medium	Medium
Probability	Probable	Probable

Criteria	Without Mitigation	With Mitigation
Confidence	Medium	Medium
Significance	LOW (a)	VERY LOW (b)
Cumulative significance	LOW	LOW
Nature of cumulative impact	Other activities that may contribute to the cumulative risk impact include farming activities, paved and unpaved roads.	
Degree in which impact can be reversed	Partially reversable	Partially reversable
Degree to which impact may cause irreplaceable loss of resources	Low	Low
Degree to which impact can be mitigated	High	-
Recommended mitigation measures: Vegetation and re-vegetation of entire WRDs and exposed surfaces		-

Notes: (a) of ***low intensity*** at a ***local level*** in the ***long term***

(b) of ***low intensity*** at a ***local level*** and endure in the ***medium term***

The potential for nuisance impacts from dust fallout are provided in Table 18. The environmental significance of this impact is LOW; with mitigation applied it would reduce further to remain LOW.

Table 18: Nuisance impact significance summary table for the project

Criteria	Without Mitigation	With Mitigation
Intensity	Low	Low
Duration	Long term	Medium
Extent	Local	Local
Loss of resource	Medium	Medium
Probability	Probable	Probable
Confidence	Medium	Medium
Significance	LOW (a)	VERY LOW (b)
Cumulative significance	LOW	LOW
Nature of cumulative impact	Other activities that may contribute to the cumulative risk impact include farming activities, paved and unpaved roads	
Degree in which impact can be reversed	Partially reversable	Partially reversable
Degree to which impact may cause irreplaceable loss of resources	Low	Low
Degree to which impact can be mitigated	High	-
Recommended mitigation measures: Vegetation and re-vegetation of entire WRDs and exposed surfaces		-

Notes: (a) of ***low intensity*** at a ***local level*** in the ***long term***

(b) of ***low intensity*** at a ***local level*** and endure in the ***medium term***

6 CONCLUSION AND RECOMMENDATIONS

6.1 Main Findings

The main findings from the assessment of the closure options at Tshipi Borwa Manganese Mine are as follow:

- The main sources of emissions during the proposed closure phase is windblown dust from the WRDs. The main pollutants of concern are $PM_{2.5}$, PM_{10} and TSP.
- Unmitigated windblown dust emissions from the four WRDs are 32.20 tpa for $PM_{2.5}$, 359.22 tpa for PM_{10} and 1 039.33 tpa for TSP. By covering/ controlling 80% of the areas, the resulting reduction in emissions is 99%.
- Unmitigated PM_{10} daily GLCs due to windblown dust from the WRDs are in compliance off-site, only exceeding the daily NAAQS of 75 µg/m³ on-site at the WRDs. Annual average concentrations comply on- and off-site. The impact significance is LOW. With mitigation in place (vegetation and revegetation) the impact significance reduces to VERY LOW.
- Unmitigated $PM_{2.5}$ daily GLCs due to windblown dust from the WRDs are low and well within compliance off-site with the only on-site exceedances at West_WRD. Annual average concentrations comply on- and off-site. The impact significance is LOW. With mitigation in place (vegetation and revegetation) the impact significance reduces to VERY LOW.
- Unmitigated maximum daily dustfall rates are below the NDCR residential limit (600 mg/m²/day) off-site, and below the non-residential limit of 1 200 mg/m²/day on-site. The impact significance is LOW. With mitigation in place (vegetation and revegetation) the impact significance reduces to VERY LOW.
- The highest annual average manganese GLC due to unmitigated windblown dust from the WRDs is 0.03 µg/m³, falling well below the WHO annual average manganese guideline of 0.15 µg/m³. The impact significance is VERY LOW.
- At the time of closure, all operations at Tshipi Mine would have ceased, with farming activities and vehicles travelling on the paved and unpaved roads the only remaining contributors to PM concentrations and dustfall. The air quality around Tshipi Mine is likely to improve significantly by closure phase.

6.2 Conclusion

PM_{10} and $PM_{2.5}$ ground level concentrations and dust fallout rates off-site and at nearby AQSRs due to the closure phase option will be significantly lower than during the operational phase. With mitigation measures in place, such as vegetation and revegetation of exposed areas, these impacts would reduce even further, resulting in a very low significance. Significant decreases in SO_2, NO_2, Mn and CO are foreseen. DPM concentrations are also likely to decrease.

6.3 Recommendations

For the WRDs the same mitigation scenarios can be applied:

- Operational (up to 2048): 90% CE on the "baseline" exposed areas, to reflect revegetation (medium term).
- Long-term Scenario (closure and post-closure): 100% CE on all exposed surfaces (assumption being that all are fully vegetated).
- Continue with the current dustfall monitoring network throughout the closure phase.
- Should aggregate crushing be implemented, ensure placement of the crusher as far away from the sensitive receptors as possible.

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8 APPENDIX A - SPECIALIST CURRICULUM VITAE

CURRICULUM VITAE — HANLIE LIEBENBERG-ENSLIN

FULL CURRICULUM VITAE

Name of Firm	Airshed Planning Professionals (Pty) Ltd
Name of Staff	Hanlie Liebenberg-Enslin
Profession	Managing Director / Air Quality Scientist
Date of Birth	09 January 1971
Years with Firm/ entity	19 years
Nationalities	South African

MEMBERSHIP OF PROFESSIONAL SOCIETIES

- International Union of Air Pollution Prevention and Environmental Protection Associations (IUAPPA) – President 2010–2013, Board member 2013-present
- Member of the National Association for Clean Air (NACA) - President 2008-2010, NACA Council member 2010 –2014

KEY QUALIFICATIONS

Hanlie Liebenberg-Enslin started her professional career in Air Quality Management in 2000 when she joined Environmental Management Services (EMS) after completing her Master's Degree at the University of Johannesburg (then Rand Afrikaans University) in the same field. She is one of the founding members of Airshed Planning Professionals in 2003 where she has worked as a company Director until May 2013 when she was appointed as Managing Director. She has extensive experience on the various components of air quality management including emissions quantification for a range of source types, simulations using a range of dispersion models, impacts assessment and health risk screening assessments. She has worked all over Africa and has an inclusive knowledge base of international legislation and requirements pertaining to air quality.

She has developed technical and specialist skills in various modelling packages including the industrial source complex models (ISCST3 and SCREEN3), EPA Regulatory Models (AERMOD and AERMET), UK Gaussian plume model (ADMS), EPA Regulatory puff based model (CALPUFF and CALMET), puff based HAWK model and line based models such as CALINE. Her experience with emission models includes Tanks 4.0 (for the quantification of tank emissions) and GasSim (for the quantification of landfill emissions).

Having worked on projects throughout Africa (i.e. South Africa, Mozambique, Botswana, Namibia, Malawi, Kenya, Mali, Democratic Republic of Congo, Tanzania, Madagascar, Guinea and Mauritania) Hanlie has developed a broad experience base. She has a good understanding of the laws and regulations associated with ambient air quality and emission limits in South Africa and various other African countries, as well as the World Bank Guidelines, European Community Limits and World Health Organisation.

Being an avid student, she received her PhD in 2014, specialising in Aeolian dust transport. Hanlie is also actively involved in the National Association for Clean Air and is their representative at the International Union of Air Pollution Prevention and Environmental Protection Associations.

RELEVANT EXPERIENCE

Air Quality Management Plans and Strategies

Provincial Air Quality Management Plan for the Limpopo Province (March 2013); Mauritius Road Development Agency Proposed Road Decongestion Programme (July 2013); Transport Air Quality Management Plan for the Gauteng Province (February 2012); Gauteng Green Strategy (2011); Air Quality and Radiation Assessment for the Erongo Region Namibia as part of a Strategic Environmental Assessment (June, 2010); Vaal Triangle Airshed Priority Area AQMP (March, 2009); Gauteng Provincial AQMP (January 2009); North West Province AQMP (2008); City of Tshwane AQMP (April 2006); North West Environment Outlook 2008 (December 2007); Ambient Monitoring Network for the North West Province (February 2007); Spatial Development Framework Review for the City of uMhlathuze (August 2006); Ambient Particulate Pollution Management System (Anglo Platinum Rustenburg):

Hanlie has also been the Project Director on all the listed Air Quality Management plan developments.

Mining and Ore Handling

Hanlie has undertaken numerous air quality impact assessments and management plans for coal, platinum, uranium, copper, cobalt, chromium, fluorspar, bauxite and mineral sands mines. These include air quality impact assessments for: Trekkopje Uranium Mine near Swakopmund; Bannerman Uranium Project; Langer Heinrich Uranium Mine, Valencia Uranium Mine, Etango (Husab) Project, Rössing South Uranium Mine (Namibia); Sishen Iron Ore Mine (Kathu); Kolomela Iron Ore Mine (Postmasburg); Thabazimbi Iron ore Mine (Thabazimbi); UKM Manganese Mine (Hotazel); Everest Platinum Mine (Steelpoort); Murowa Diamond Mine (Zimbabwe); Jwaneng Diamond Mine (Botswana); Sadiola Gold Mine (Mali); North Mara Gold Mine (Tanzania); Tselentis Coal mine (Breyeton); Lime Quarries (De Hoek, Dwaalboom, Slurry); Beesting Colliery (Ogies); Anglo Coal Opencast Coal Mine (Heidelberg); Klippan Colliery (Belfast); Beesting Colliery (Ogies); Xstrata Coal Tweefontein Mine (Witbank); Xstrata Coal Spitskop Mine (Hendrina); Middelburg Colliery (Middelburg); Klipspruit Project (Ogies); Rustenburg Platinum Mine (Rustenburg); Impala Platinum (Rustenburg); Buffelsfontein Gold Mine (Stilfontein); Kroondal Platinum Mine (Kroondal); Lonmin Platinum Mine (Mooinooi); Rhovan Vanadium (Brits); Macauvlei Colliery (Vereeniging); Voorspoed Gold Mine (Kroonstad); Pilanesberg Platinum Mine (Pilanesberg); Kao Diamond Mine (Lesotho); Modder East Gold Mine (Brakpan); Modderfontein Mines (Brakpan); Bulyanhulu North Mara Gold Mine (Tanzania); Gold Mine (Tanzania); Zimbiwa Crusher Plant (Brakpan); RBM Zulti South Titanium mining (Richards Bay); Premier Diamond Mine (Cullinan).

Metal Recovery

Air quality impact assessments have been carried out for Smelterco Operations (Kitwe, Zimbia); Waterval Smelter (Amplats, Rustenburg); Hernic Ferrochroime Smelter (Brits); Rhovan Ferrovanadium (Brits); Impala Platinum (Rustenburg); Impala Platinum (Springs); Transvaal Ferrochrome (now IFM, Mooinooi), Lonmin Platinum (Mooinooi); Xstrata Ferrochrome Project Lion (Steelpoort); ArcelorMittal South Africa (Vandebijlpark, Vereeniging, Pretoria, Newcastle, Saldanha); Hexavalent Chrome Xstrata (Rustenburg); Portland Cement Plant (DeHoek, Slurry, Dwaalboom, Hercules, Port Eelizabeth); Vantech Plant (Steelpoort); Bulyanhulu Gold Smelter (Tanzania), Sadiola Gold Recovery Plant (Mali); RBM Smelter Complex (Richards Bay); Chibuto Heavy Minerals Smelter (Mozambique); Moma Heavy Minerals Smelter (Mozambique); Boguchansky Aluminium Plant (Russia); Xstrata Chrome CMI Plant (Lydenburg); SCAW Metals (Germiston).

Chemical Industry

Comprehensive air quality impact assessments have been completed for AECI (Pty) Ltd Operations (Modderfontein); Kynoch Fertilizer (Potchefstroom), Foskor (Richards Bay) and Omnia (Rustenburg).

Petrochemical Industry

Numerous air quality impact assessments have been completed for SASOL operations (Sasolburg); Sapref Refinery (Durban); Health risk assessment of Island View Tank Farm (Durban Harbour).

Pulp and Paper Industry

Air quality studies have been undertaken or the expansion of Mondi Richards Bay, Multi-Boiler Project for Mondi Merebank (Durban), impact assessments for Sappi Stanger, Sappi Enstra (Springs), Sappi Ngodwana (Nelspruit) and Pulp United (Richards Bay).

Power Generation

Air quality impact assessments have been completed for numerous Eskom coal fired power station studies including the Coal 3 Power Project near Lephalale, Komati Power Station and Lethabo Power Stations. In addition to Eskom's coal fired power stations, projects have been completed for the proposed Mmamabula Energy Project (Botswana); Morupule Power Plant (Botswana) and NamPower Erongo Power Project (Namibia).

Apart from Eskom projects, heavy fuel oil power station assessments have also been completed in Kenya (Rabai Power Station) and Namibia (Arandis Power Plant).

Waste Disposal

Air quality impact assessments, including odour and carcinogenic and non-carcinogenic pollutants were undertaken for the proposed Coega Waste Disposal Facility (Port Elizabeth); Boitshepi Waste Disposal Site (Vanderbijlpak); Umdloti Waste Water Treatment Plant (Durban).

Cement Manufacturing

Impact assessments for ambient air quality have been completed for the PPC Cement Alternative Fuels Project (which included the assessment of the cement manufacturing plants in the North West Province, Gauteng and Western).

Vehicle emissions

Platinum Highway (N1 to Zeerust); Gauteng Development Zone (Johannesburg); Gauteng Department of Roads and Transport (Transport Air Quality Management Plan); Mauritius Road Development Agency (Proposed Road Decongestion Programme); South African Petroleum Industry Association (Impact Urban Air Quality).

Government Strategy Projects

Hanlie was the project Director on the APPA Registration Certificate Review Project for Department of Environmental Affairs (DEA); Green Strategy for Gauteng (2011).

EDUCATION

Ph.D Geography	University of Johannesburg, RSA (2014) Title: *A functional dependence analysis of wind erosion modelling system parameters to determine a practical approach for wind erosion assessments*
M.Sc Geography and Environmental Management	University of Johannesburg, RSA (1999) Title: *Air Pollution Population Exposure Evaluation in the Vaal Triangle using GIS*
B.Sc Hons. Geography	University of Johannesburg, RSA (1995) GIS & Environmental Management
B.Sc Geography and Geology	University of Johannesburg, RSA (1994) Geography and Geology

ADDITIONAL COURSES AND ACADEMIC REVIEWS

External Examiner (May 2018)	MSc Candidate: Ms A Quta Characterisation of Particulate Matter and Some Pollutant Gasses in the City of Tshwane Department of Environmental Sciences, University of South Africa
External Examiner (December 2017)	MSc Candidate: Ms B Wernecke Ambient and Indoor Particulate Matter Concentrations on the Mpumalanga Highveld Faculty of Natural and Agricultural Sciences, North-West University
External Examiner (January 2016)	MSc Candidate: Ms M Grobler Evaluating the costs and benefits associated with the reduction in SO_2 emissions from Industrial activities on the Highveld of South Africa Department of Chemical Engineering, University of Pretoria
External Examiner (August 2014)	MSc Candidate: Ms Seneca Naidoo Quantification of emissions generated from domestic fuel burning activities from townships in Johannesburg Faculty of Science, University of the Witwatersrand
Air Quality Law– Lecturer (2012 - 2016)	Environmental Law course: Centre of Environmental Management.
Air Quality law for Mining – Lecturer (2014)	Environmental Law course: Centre of Environmental Management.
Air Quality Management – Lecturer (2006 -2012)	Air Quality Management Short Course: NACA and University of Johannesburg, University of Pretoria and University of the North West
ESRI SA (1999)	ARCINFO course at GIMS: Introduction to ARCINFO 7 course
ESRI SA (1998)	ARCVIEW course at GIMS: Advanced ARCVIEW 3.1 course

COUNTRIES OF WORK EXPERIENCE

South Africa, Mozambique, Botswana, Namibia, Malawi, Mauritius, Kenya, Mali, Zimbabwe, Democratic Republic of Congo, Tanzania, Zambia, Madagascar, Guinea, Russia, Mauritania and Saudi Arabia.

EMPLOYMENT RECORD

March 2003 - Present

Airshed Planning Professionals (Pty) Ltd, (previously known as Environmental Management Services cc until March 2003), Managing Director and Principal Air Quality Scientist, Midrand, South Africa.

January 2000 – February 2003

Environmental Management Services CC, Senior Air Quality Scientist.

May 1998 – December 1999

Independent Broadcasting Authority (IBA), GIS Analyst and Demographer.

February 1997 – April 1998

GIS Business Solutions (PQ Africa), GIS Analyst

January 1996 – December 1996

Annegarn Environmental Research (AER), Student Researcher

LANGUAGES

	Speak	Read	Write
English	Excellent	Excellent	Excellent
Afrikaans	Excellent	Excellent	Excellent

CONFERENCE AND WORKSHOP PRESENTATIONS AND PAPERS

- Understanding the Atmospheric Circulations that lead to high particulate matter concentrations on the west coast of Namibia. Hanlie Liebenberg-Enslin, Hannes Rauntenbach, Reneé von Gruenewaldt, and Lucian Burger. Clean Air Journal, 27, 2, 2017, 66-74.
- Cooperation on Air Pollution in Southern Africa: Issues and Opportunities. SLCPs: Regional Actions on Climate and Air Pollution. Liebenberg-Enslin, H. 17th IUAPPA World Clean Air Congress and 9th CAA Better Air Quality Conference. Clean Air for Cities - Perspectives and Solutions. 29 August - 2 September 2016, Busan Exhibition and Convention Center, Busan, South Korea.

- A Best Practice prescription for quantifying wind-blown dust emissions from Gold Mine Tailings Storage Facilities. Liebenberg-Enslin, H., Annegarn, H.J., and Burger, L.W. VIII International Conference on Aeolian Research, Lanzhou, China. 21-25 July 2014.

- Quantifying and modelling wind-blown dust emissions from gold mine tailings storage facilities. Liebenberg-Enslin, H. and Annegarn, H.J. 9th International Conference on Mine Closure, Sandton Convention Centre, 1-3 October 2014.

- Gauteng Transport Air Quality Management Plan. Liebenberg-Enslin, H., Krause,N., Burger, L.W., Fitton, J. and Modisamongwe, D. National Association for Clean Air Annual Conference, Rustenburg. 31 October to 2 November 2012. Peer reviewed.

- Developing an Air Quality Management Plan: Lessons from Limpopo. Bird, T.; Liebenberg-Enslin, H., von Gruenewaldt, R., Modisamongwe, D. National Association for Clean Air Annual Conference, Rustenburg. 31 October to 2 November 2012. Peer reviewed.

- Modelling of wind eroded dust transport in the Erongo Region, Namibia, H. Liebenberg-Enslin, N Krause and H.J. Annegarn. National Association for Clean Air (NACA) Conference, October 2010. Polokwane.

- The lack of inter-discipline integration into the EIA process-defining environmental specialist synergies. H. Liebenberg-Enslin and LW Burger. IAIA SA Annual Conference, 21-25 August 2010. Workshop Presentation. Not Peer Reviewed.

- A Critical Evaluation of Air Quality Management in South Africa, H Liebenberg-Enslin. National Association for Clean Air (NACA) IUAPPA Conference, 1-3 October 2008. Nelspuit.

- Vaal Triangle Priority Area Air Quality Management Plan – Baseline Characterisation, R.G. Thomas, H Liebenberg-Enslin, N Walton and M van Nierop. National Association for Clean Air (NACA) conference, October 2007, Vanderbijl Park.

- Air Quality Management plan as a tool to inform spatial development frameworks – City of uMhlathuze, Richards Bay, H Liebenberg-Enslin and T Jordan. National Association for Clean Air (NACA) conference, 29 – 30 September 2005, Cape Town.

CERTIFICATION

I, the undersigned, certify that to the best of my knowledge and belief, these data correctly describe me, my qualifications, and my experience.

26/04/2019

Full name of staff member: Hanlie Liebenberg-Enslin

9 APPENDIX B: IMPACT SIGNIFICANCE METHODOLOGY

Specialists must consider ten rating scales when assessing potential impacts. These include:

- Extent of impact;
- Duration of impact;
- Intensity of impact;
- Status of impact;
- Probability of impact occurring;
- Degree of confidence of assessment;
- Significance of impact;
- Degree to which a resource is lost;
- Degree to which impact can be mitigated; and
- Reversibility of impact.

In assigning significance ratings to potential impacts before and after mitigation specialists are instructed to follow the approach presented below:

1. The core criteria for determining significance ratings are "extent" (Section 0), "duration" (Section 9.2) and "intensity" (Section 9.1). The preliminary significance ratings for combinations of these three criteria are given in Section 9.4.
2. Additional criteria to be considered, which could "increase" the significance rating if deemed justified by the specialist, with motivation, are the following:
   - Permanent / irreversible impacts (as distinct from long-term, reversible impacts);
   - Potentially substantial cumulative effects (see Item 9 below); and
   - High level of risk or uncertainty, with potentially substantial negative consequences.
3. Additional criteria to be considered, which could "decrease" the significance rating if deemed justified by the specialist, with motivation, is the following:
   - Improbable impact, where confidence level in prediction is high.
4. The status of an impact is used to describe whether the impact will have a negative, positive or neutral effect on the surrounding environment. An impact may therefore be negative, positive (or referred to as a benefit) or neutral (Section 9.5).
5. Describe the degree to which a resource is impacted (Section 9.4).
6. Describe the impact in terms of the probability of the impact occurring (Section 9.6) and the degree of confidence in the impact predictions, based on the availability of information and specialist knowledge (Section 9.7).
7. When assigning significance ratings to impacts *after mitigation*, the specialist needs to:
   - First, consider probable changes in intensity, extent and duration of the impact after mitigation, assuming effective implementation of mitigation measures, leading to a revised significance rating; and
   - Then moderate the significance rating after taking into account the likelihood of proposed mitigation measures being effectively implemented. Consider:
     - Any potentially significant risks or uncertainties associated with the effectiveness of mitigation measures;
     - The technical and financial ability of the proponent to implement the measure; and
     - The commitment of the proponent to implementing the measure or guarantee over time that the measures would be implemented.
8. Describe the degree to which an impact can be mitigated or enhanced (Section 0) and reversed (Section 9.10).
9. The cumulative impacts of a project should also be considered. "Cumulative impacts" refer to the impact of an activity that may become significant when added to the existing activities currently taking place within the surrounding environment.
10. Where applicable, assess the degree to which an impact may cause irreplaceable loss of a resource. A resource assists in the functioning of human or natural systems, i.e. specific vegetation, minerals, water, agricultural land, etc.

The significance ratings are based on largely objective criteria and inform decision-making at a project level as opposed to a local community level. In some instances, therefore, whilst the significance rating of potential impacts might be "low" or "very low", the importance of these impacts to local communities or individuals might be extremely high. The importance which I&APs attach to impacts must be taken into consideration, and recommendations should be made as to ways of avoiding or minimising these negative impacts through project design, selection of appropriate alternatives and / or management.

The relationship between the significance ratings after mitigation and decision-making can be broadly defined as follows (see below):

Significance rating	Effect on decision-making
INSIGNIFICANT; VERY LOW; LOW	Will not have an influence on the decision to proceed with the proposed project, provided that recommended measures to mitigate negative impacts are implemented.
MEDIUM	Should influence the decision to proceed with the proposed project, provided that recommended measures to mitigate negative impacts are implemented.
HIGH; VERY HIGH	Would strongly influence the decision to proceed with the proposed project.

9.1 Intensity

"Intensity" establishes whether the impact would be destructive or benign.

Rating	Description
ZERO TO VERY LOW	Where the impact affects the environment in such a way that natural, cultural and social functions and processes are not affected.
LOW	Where the impact affects the environment in such a way that natural, cultural and social functions and processes continue, albeit in a slightly modified way.
MEDIUM	Where the affected environment is altered, but natural, cultural and social functions and processes continue, albeit in a modified way.
HIGH	Where natural, cultural and social functions or processes are altered to the extent that it will temporarily or permanently cease.

9.2 Duration

"Duration" gives an indication of how long the impact would occur.

Rating	Description
SHORT-TERM	0 - 5 years
MEDIUM-TERM	5 - 15 years
LONG-TERM	Where the impact will cease after the operational life of the activity, either because of natural processes or by human intervention.
PERMANENT	Where mitigation either by natural processes or by human intervention will not occur in such a way or in such time span that the impact can be considered transient.

9.3 Extent

"Extent" defines the physical extent or spatial scale of the impact.

Rating	Description
LOCAL	Extending only as far as the activity, limited to the site and its immediate surroundings. Specialist studies to specify extent.
REGIONAL	Western Cape. Specialist studies to specify extent.
NATIONAL	South Africa
INTERNATIONAL	

9.4 Loss of Resources

"Loss of resource" refers to the degree to which a resource is permanently affected by the activity, i.e. the degree to which a resource is irreplaceable.

Rating	Description
LOW	Where the activity results in a loss of a particular resource but where the natural, cultural and social functions and processes are not affected.
MEDIUM	Where the loss of a resource occurs, but natural, cultural and social functions and processes continue, albeit in a modified way.
HIGH	Where the activity results in an irreplaceable loss of a resource.

9.5 Status of Impact

The status of an impact is used to describe whether the impact would have a negative, positive or zero effect on the affected environment. An impact may therefore be negative, positive (or referred to as a benefit) or neutral.

9.6 Probability

"Probability" describes the likelihood of the impact occurring.

Rating	Description
IMPROBABLE	Where the possibility of the impact to materialise is very low either because of design or historic experience.
PROBABLE	Where there is a distinct possibility that the impact will occur.
HIGHLY PROBABLE	Where it is most likely that the impact will occur.
DEFINITE	Where the impact will occur regardless of any prevention measures.

9.7 Degree of Confidence

This indicates the degree of confidence in the impact predictions, based on the availability of information and specialist knowledge.

Rating	Description
HIGH	Greater than 70% sure of impact prediction.
MEDIUM	Between 35% and 70% sure of impact prediction.

LOW	Less than 35% sure of impact prediction.

9.8 Significance

"Significance" attempts to evaluate the importance of a particular impact, and in doing so incorporates the above three scales (i.e. extent, duration and intensity).

Rating	Description
VERY HIGH	Impacts could be EITHER: of ***high intensity*** at a ***regional level*** and endure in the ***long term***[1]; OR of ***high intensity*** at a ***national level*** in the ***medium term***; OR of ***medium intensity*** at a ***national level*** in the ***long term.***
HIGH	Impacts could be EITHER: of ***high intensity*** at a ***regional level*** and endure in the ***medium term***; OR of ***high intensity*** at a ***national level*** in the ***short term***; OR of ***medium intensity*** at a ***national level*** in the ***medium term;*** OR of ***low intensity*** at a ***national level*** in the ***long term***; OR of ***high intensity*** at a ***local level*** in the ***long term***; OR of ***medium intensity*** at a ***regional level*** in the ***long term.***
MEDIUM	Impacts could be EITHER: of ***high intensity*** at a ***local level*** and endure in the ***medium term***; OR of ***medium intensity*** at a ***regional level*** in the ***medium term***; OR of ***high intensity*** at a ***regional level*** in the ***short term***; OR of ***medium intensity*** at a ***national level*** in the ***short term***; OR of ***medium intensity*** at a ***local level*** in the ***long term***; OR of ***low intensity*** at a ***national level*** in the ***medium term;*** OR of ***low intensity*** at a ***regional level*** in the ***long term.***
LOW	Impacts could be EITHER of ***low intensity*** at a ***regional level*** and endure in the ***medium term***; OR of ***low intensity*** at a ***national level*** in the ***short term***; OR of ***high intensity*** at a ***local level*** and endure in the ***short term***; OR of ***medium intensity*** at a ***regional level*** in the ***short term***; OR of ***low intensity*** at a ***local level*** in the ***long term***; OR of ***medium intensity*** at a ***local level*** and endure in the ***medium term.***
VERY LOW	Impacts could be EITHER of ***low intensity*** at a ***local level*** and endure in the ***medium term***; OR of ***low intensity*** at a ***regional level*** and endure in the ***short term***; OR of ***low to medium intensity*** at a ***local level*** and endure in the ***short term.***
INSIGNIFICANT	Impacts with: ***Zero to very low intensity*** with any combination of extent and duration.
UNKNOWN	In certain cases it may not be possible to determine the significance of an impact.

[1] For any impact that is considered to be "Permanent" apply the "Long-Term" rating.

9.9 Degree to which an Impact Can Be Mitigated

This indicates the degree to which an impact can be reduced / enhanced.

Rating	Description
NONE	No change in impact after mitigation.
VERY LOW	Where the significance rating stays the same, but where mitigation will reduce the intensity of the impact.
LOW	Where the significance rating drops by one level, after mitigation.
MEDIUM	Where the significance rating drops by two to three levels, after mitigation.
HIGH	Where the significance rating drops by more than three levels, after mitigation.

9.10 Reversibility of An Impact

This refers to the degree to which an impact can be reversed.

Rating	Description
IRREVERSIBLE	Where the impact is permanent.
PARTIALLY REVERSIBLE	Where the impact can be partially reversed.
FULLY REVERSIBLE	Where the impact can be completely reversed.