Appendix D8

Air Quality Specialist Report for Mine Waste Solutions - Kareerand Expansion Project

- Airshed, 2020

Air Quality Specialist Report for Mine Waste Solutions - Kareerand Expansion Project

Project done on behalf of **Mine Waste Solutions**

Report Compiled by
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Report Details

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Report Title	Air Quality Specialist Report for Mine Waste Solutions - Kareerand Expansion Project
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Client	Mine Waste Solutions
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Reviewed by	Hanlie Liebenberg-Enslin, PhD (Geography) (University of Johannesburg) Terri Bird, Pr. Sci. Nat., PhD (University of Witwatersrand)
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Revision Record

Revision Number	Date	Section Revised	Reason for Revision
Draft	4 January 2019		Original for client comment
Final v1	28 February 2019		With client comments
Final v2	30 May 2019	Section 7 Section 13	Additional simulations using final topography GHG emissions due to mobile equipment operation
Final v3	6 June 2019	Section 1	Update of the project background
Final v4	22 July 2019	Section 3 All Sections	Updated process description With additional client comments
Final v5	22 April 2020	All Sections	Update of the project background Updated legislation New meteorological data Recent dustfall data included Updated simulations using new meteorological data Addition of GHG emissions due to electricity consumption
Final v6	30 April 2020	Section 5 Section 18	Inclusion of client comments

Competency Profiles

Report author: N A Shackleton (née Gresse), Pr. Sci. Nat., BSc Hons - Meteorology (University of Pretoria)

Natasha Shackleton started her professional career in Air Quality in 2011 when she joined Airshed Planning Professionals (Pty) Ltd after completing her Undergraduate Degree at the University of Pretoria in Science. In 2011 she completed her Honours Degree at the University of Pretoria in Meteorology. Natasha is also a member of the South African Society for Atmospheric Sciences (SASAS) and is a registered Professional Natural Scientist with the South African Council for Natural Scientific Professions (SACNASP) (registration no. 116335). She is currently undertaking her MSc: Applied Science (Environmental Technology) through the University of Pretoria.

Natasha has worked on several air quality specialist studies between 2011 and 2020. She has experience in the various components including emissions quantification for a range of source types, simulations using a range of dispersion models, impacts assessment and health risk screening assessments. Her project experience range over various countries in Africa, providing her with an inclusive knowledge base of international legislation and requirements pertaining to air quality. Whilst most of his working experience has been in South Africa, a number of investigations were made in countries elsewhere, including Burkina Faso, Guinea, Ghana, Madagascar, Mozambique, Namibia, Suriname, Tanzania, Zimbabwe and Zambia.

Report reviewer: Dr Hanlie 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 was 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 in 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. Hanlie was the project manager on a number of ground-breaking air quality management plan (AQMP) projects between 2008 and 2013 and the principal air quality specialist on regional environmental assessments. Her project experience range over various countries in Africa, providing her with an inclusive knowledge base of international legislation and requirements pertaining to air quality.

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

Report reviewer: Dr Theresa (Terri) Bird, Pr. Sci. Nat., PhD (University of the Witwatersrand)

Dr Terri Bird holds a PhD from the School of Animal, Plant and Environmental Sciences, University of the Witwatersrand, Johannesburg. The focus of her doctoral research was on the impact of sulfur and nitrogen deposition on the soil and waters of the Mpumalanga Highveld. Since March 2012 she has been employed at Airshed Planning Professionals (Pty) Ltd. In this time, she has been involved in air quality impact assessments for various mining operations (including coal, mineral sand, diamond and platinum mines) as well as coal-fired power station ash disposal facilities. She has been a team member on the development of Air Quality Management Plans, both provincial and for specific industries. Recent projects include assessing the impact of Postponement and/or Exemption of Emission Standards for various Listed Activities.

NEMA EIA Regulation (2014, as amended), Appendix 6

NEMA Regulations (2017) - Appendix 6	Relevant section in report
Details of the specialist who prepared the report.	Report Details (page i)
The expertise of that person to compile a specialist report including curriculum vitae.	Competency Profiles Section 15: Appendix A: Authors' Curriculum Vitae (page 15-1)
A declaration that the person is independent in a form as may be specified by the competent authority.	Report Details (page i)
An indication of the scope of, and the purpose for which, the report was prepared.	Section 1.1: Background (page 1-1) Section 1.2: Terms of Reference (page 1-7)
An indication of quality and age of base data used.	Section 2.1: Literature Review (page 2-2) Section 2.2: Data Gathering (page 2-2) Section 2.6: Assumptions and Limitation (page 2-6) Section 5.2: Atmospheric Dispersion Potential (page 5-1) Section 5.3: Existing Air Quality (page 5-7)
A description of existing impacts on the site, cumulative impacts of the proposed development and levels of acceptable change.	Section 5.3: Existing Air Quality (page 5-7) Section 7.2: Assessment of Impact – Current Operations (page 7-3) Section 9: Impact Assessment: Cumulative (page 9-1) Section 4: Applicable Legislation (page 4-1)
The date and season of the site investigation and the relevance of the season to the outcome of the assessment.	Section 2.2: Data Gathering (page 2-2) Description of the current land use in the region, simulations undertaken for the current operations and meteorological data included used in the study are considered representative of all seasons. Section 5.2: Atmospheric Dispersion Potential (page 5-1) Section 5.3: Existing Air Quality (page 5-7)
A description of the methodology adopted in preparing the report or carrying out the specialised process.	Section 2: Methodology (page 2-1)
The specific identified sensitivity of the site related to the activity and its associated structures and infrastructure.	Section 5: Air Quality Baseline (page 5-1)
An identification of any areas to be avoided, including buffers.	Not applicable
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.	Figure 1-1, Table 2-3 and Section 5.1: Affected Environment (page 5-1)
A description of any assumptions made and any uncertainties or gaps in knowledge.	Section 2.6: Assumptions and Limitation (page 2-6)
A description of the findings and potential implications of such findings on the impact of the proposed activity, including identified alternatives, on the environment.	Section 6: Impact Assessment: Construction Phase (page 6-1) Section 7: Impact Assessment: Operational Phase (page 7-1)
Any mitigation measures for inclusion in the EMPr.	Section 11: Dust Management (page 11-1)
Any conditions for inclusion in the environmental authorisation	Section 11: Dust Management (page 11-1)
Any monitoring requirements for inclusion in the EMPr or environmental authorisation.	Section 11: Dust Management (page 11-1)
A reasoned opinion as to whether the proposed activity or portions thereof should be authorised.	Section 12: Findings and Recommendations (page 12-1)

NEMA Regulations (2017) - Appendix 6	Relevant section in report
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 EMPr, and where applicable, the closure plan.	Section 12: Findings and Recommendations (page 12-1)
A description of any consultation process that was undertaken during the course of carrying out the study.	Not applicable.
A summary and copies if any comments that were received during any consultation process.	Section 20: Appendix F: Comments/Issues/Concerns Raised
Any other information requested by the competent authority.	None

Executive Summary

Mine Waste Solutions (MWS), also known as Chemwes (Pty) Ltd (Chemwes), has been in business since 1964, and conducts its operations over a large area of land to the east of Klerksdorp (Figure 1-1), within the area of jurisdiction of the City of Matlosana and JB Marks Local Municipalities (LM), which fall within the Dr Kenneth Kaunda District Municipality (DM) in the North-West Province. The MWS/Chemwes Operations are located primarily to the south of the N12, east of the town of Stilfontein. The closest town is Khuma, located about 3 km northwest of the facility, and other nearby towns include Stilfontein (10 km from facility) and Klerksdorp (19 km from facility).

The operations at Mine Waste Solutions entail the collection and reprocessing of mine tailings that were previously deposited on tailings storage facilities (TSFs) in order to extract gold and uranium. High pressure water cannons are used to slurry the tailings on the Source TSFs, then slurry is pumped by a number of pump stations and pipelines to the MWS/Chemwes Processing Plant, and the residues from the Processing Plants are pumped to the Kareerand TSF. Once an old Source TSF has been completely recovered, it is cleaned-up and rehabilitated.

The Kareerand TSF was designed with an operating life of 14 years, taking the facility to 2025, and total design capacity of 352 million tonnes. Subsequent to commissioning of the TSF, AngloGold Ashanti (AGA) acquired MWS and increased the tailings production target by an additional 485 million tonnes, which necessitates the operations to continue until 2042, which will require operations to continue until 2042. The additional tailings therefore require extension of the design life of the TSF.

This project entails the expansion of the current Kareerand TSF to accommodate the increased tailings and final design capacity, along with additional pump stations and pipelines. The TSF expansion is proposed on the western edge of the current facility, and the final height of the combined facility (both expansion and current) will be 122m. The expansion footprint will add about 380 hectares (ha) to the TSF.

The expansion of the existing TSF will enable the re-mining of tailings dams and deposition of the tailings in a new facility complete with appropriate seepage mitigation measures and resultantly reduce the total seepage into the Vaal River.

The project will support concurrent rehabilitation of the existing TSF and the expansion TSF, thereby reducing the risk of windborne dust and storm water management. Removing and consolidating all the tailings in the KOSH (Klerksdorp, Orkney, Stilfontein and Hartebeestfontein) area on a single mega-tailings storage facility will in the long term, positively impact the surrounding environment and Vaal River.

Specialist studies have been commissioned to assess the impacts of the TSF expansion on all aspects of biophysical and socio-economic receptors within the area. Mitigation, management, and rehabilitation designs are informed by a team of specialists and engineers.

Airshed Planning Professionals (Pty) Ltd was appointed by MWS to undertake an Air Quality Impact Assessment (AQIA) and Climate Change Impact Assessment (CCIA) as part of the Environmental Impact Assessment (EIA) to identify key aspects that may have significant air quality impacts during the various project phases. As such the report conforms to the amended regulated format requirements for specialist reports as per the Appendix 6 of EIA Regulations (Government Gazette No. 40772, 7 April 2017). This report covers the impact assessment for the expansion of the Kareerand TSF (the project).

The scope of work had to include the following:

- Identify and describe the existing air quality of the project area, as well as climatic patterns and features (i.e. the baseline);
- Assess (model) the impact on air quality (specifically particulate matter), human health and biota resulting from the proposed TSF expansion (including impacts associated with the construction, operations, decommissioning and post-closure phases of the project);
- Identify and describe potential cumulative air quality impacts resulting from the proposed project in relation to proposed and existing developments in the surrounding area;
- Recommend mitigation measures to minimise impacts and/or optimise benefits associated with the project;
- Recommend a monitoring campaign to ensure the correct implementation and adequacy of recommenced mitigation measures, if applicable;
- Make recommendations for rehabilitation and closure planning;
- Estimate the greenhouse gas (GHG) emissions during construction, operation and decommissioning of the project compared to the global and national emission inventory; and compared to international benchmarks for the project;
- Determine the robustness of the project with the impact of climate change over the lifetime of the project considered; and
- Ascertain the vulnerability to climate change of communities in the immediate vicinity of the project.

The main findings of the baseline assessment were:

- Air quality sensitive receptors (AQSRs) identified in the vicinity of the existing Kareerand TSF and expansion area are those of Khuma Township; Village Main Reef Mine; various farm and property owners; the chicken farm; the nearby supermarket; and Midvaal Water Company.
- Two years of measured meteorological data was used from the on-site located west of the existing Kareerand TSF. The area is dominated by winds from the north-north-east. The north-north-westerly wind direction is associated with strong winds of above 6 m/s.
- The main sources likely to contribute to baseline particulate matter (PM) emissions include mining operations, industrial operations, vehicle entrained dust from local roads, vehicle exhaust and windblown dust from exposed areas.
- Other sources of PM include farm activities, occasional biomass burning and household fuel burning in the residential areas of Stilfontein, Klerksdorp, Khuma Township and Village Main Reef Mine.
- A comprehensive fallout dust measurements dataset was provided for the area from 2009 to 2019; although AGA has been undertaking dustfall sampling in the area for longer. The fallout dust data for sites near the Project area (Kareerand) were considered relevant to this study and analysis of the data was undertaken and included in this report. The National Dust Control Regulations (NDCR) limit for residential areas of 600 mg/m^2-day was not exceeded at any of the residential sites. SA NDCR limit for non-residential areas of 1 200 mg/m^2-day was exceeded once at three sites (see Appendix C).
    - Tailings South East - July 2015
    - Tailings - October 2015
- Simulations for the 2013 AGA Vaal River (VR) and MWS operations were undertaken in a 2014/2015 study. Some of these operations are no longer being undertaken by AGA and is also likely a conservative estimate of potential impacts in the region. The main findings of the 2014/2015 study were as follows:
    - Particulate matter with diameter of less than 10 µm (PM_{10}) and particulate matter with diameter of less than 2.5 µm ($PM_{2.5}$) concentrations complied at the AQSRs over the short- and long-term. Both in the vicinity of Kareerand and other operations in the region.

- Dustfall rates were below the NDCR limit for residential areas at the AQSRs. Both in the vicinity of Kareerand and other operations in the region.

The main findings of the current impact assessment are as follows:

- PM emissions will be released during the construction, operational, decommissioning and closure phases. Operational phase air quality impacts were assessed quantitatively whereas construction and decommissioning phase impacts were assessed qualitatively due to limited information on these activities.
- Construction phase:
  - The significance of construction related inhalation health and nuisance impacts are likely to have a “low” risk; however, using the GCS (Pty) Ltd (GCS) ranking methodology the impacts are “moderate” risk without and with mitigation. This is mainly due to the high likelihood in the significance ranking which increases the risk rating. The likelihood is significantly inflated since the activity assessed is governed by legislation.
- Future operational phase:
  - PM (total suspended particulates [TSP], PM_{10} and $PM_{2.5}$) emissions and impacts were quantified.
  - PM_{10} and $PM_{2.5}$ concentrations are within compliance off-site and at all the AQSRs over the short- and long-term.
  - Dustfall rates above the NDCR limits for residential areas at some AQSRs occurred for one month based on the meteorological data used. High winds occurred over two consecutive days where a secondary development associated with a frontal system arose. The rest of the data showed dustfall rates below the NDCR limit for residential areas at all AQSRs. Dustfall rates are below non-residential areas at all of the AQSRs.
  - The significance of operations related to inhalation health and nuisance impacts are likely to be “low” risk; however, using the GCS ranking methodology the impacts are “moderate” risk without and with mitigation. This is mainly due to the high likelihood in the significance ranking which increases the risk rating. The likelihood is significantly inflated since the activity assessed is governed by legislation.
- Decommissioning and closure phases:
  - The significance of decommissioning operations related inhalation health and nuisance impacts are likely “low”; however, according to the GCS ranking methodology the risk is “moderate” without and with mitigation.
  - The significance of closure operations related inhalation health and nuisance impacts are likely “low”; however, using the GCS ranking methodology the risk is “moderate” without and with mitigation.
  - The likelihood in the significance ranking is high which increases the risk rating. The likelihood is excessive since the activity assessed is governed by legislation.

To ensure the lowest possible impact on AQSRs and environment it is recommended that the air quality management plan as set out in this report should be adopted. This includes:

- Management of the Kareerand TSF; resulting in the mitigation of associated air quality impacts;
- Ambient air quality monitoring; and
- Continuation of the record keeping and community liaison procedures. The facility is ISO14001:2015 accredited. Procedures are in place to log, record and to respond to public complaints related to environmental management. A Community Environmental Forum has been in place since 2014, meeting on quarterly basis, where key environmental performance i.e. dust management is discussed.

The main findings of the GHG and climate change assessment:

- The carbon dioxide equivalent (CO_2-e) (scope 1) emissions for construction is approximately 6 809 tonnes per annum (tpa).

- The CO_2-e emissions for future operations will increase by approximately 4 369 tpa from the current operations.
- The GHG emissions from the project are relatively low and will not likely result in a noteworthy contribution to climate change on their own.
- The project and the community are likely to be negatively impacted by climate change due to increased temperatures and possible water shortages (decreased rainfall and possible increased evaporation).

Climate change recommendations:

- The following is recommended to reduce the impacts of climate change on the project and the community:
  - Additional support infrastructure can reduce the climate change impact on the staff and project, for example ensuring adequate water supply for staff and reducing on-site water usage as much as possible.
  - MWS could initiate a community development program if one is not already in place.
- The following is recommended to reduce the GHG emissions from project:
  - Ensuring the vehicles and equipment are maintained through an effective inspection and maintenance program.
  - Limiting the removal of vegetation and ensuring adequate and appropriate (i.e. with a focus on indigenous species) re-vegetation or addition of vegetation surrounding the project. Vegetation acts as a carbon sink.

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List of Abbreviations

AGA	AngloGold Ashanti Limited
Airshed	Airshed Planning Professionals (Pty) Ltd
APPA	Atmospheric Pollution Prevention Act
CO	Carbon monoxide
DEA	Department of Environmental Affairs
DoE	Department of Energy
DTU	Technical University of Denmark
EIA	Environmental Impact Assessment
EMPr	Environmental Management Programme
g	Gram
g/s	Gram per second
GCS	GCS (Pty) Ltd
IPCC	Intergovernmental Panel on Climate Change
m	Metre
m^2	Metre squared
m^3	Metre cubed
m/s	Metres per second
MWS	Mine Waste Solutions
NMES	National Minimum Emission Standards
NAAQ Limit	National Ambient Air Quality Limit concentration
NAAQS	National Ambient Air Quality Standards (as a combination of the NAAQ Limit and the allowable frequency of exceedance)
NEMA	National Environmental Management Act
NEM:AQA	National Environmental Management: Air Quality Act
NO	Nitrogen oxide
NO_2	Nitrogen dioxide
NO_x	Oxides of nitrogen
O_3	Ozone
PM	Particulate matter
PM_{10}	Particulate matter with diameter of less than 10 µm
$PM_{2.5}$	Particulate matter with diameter of less than 2.5 µm
SANEDI	South African National Energy Development Institute
SO_2	Sulphur dioxide
TSF	Tailings Storage Facility
US EPA	United States Environmental Protection Agency
VR	Vaal River
µ	micro
°C	Degrees Celsius

Glossary

Air-shed	An area, bounded by topographical features, within which airborne contaminants can be retained for an extended period
Albedo[1]	The ratio of reflected flux density to incident flux density, referenced to some surface. Albedos commonly tend to be broadband ratios, usually referring either to the entire spectrum of solar radiation, or just to the visible portion. More precise work requires the use of spectral albedos, referenced to specific wavelengths. Visible albedos of natural surfaces range from low values of ~0.04 for calm, deep water and overhead sun, to > 0.8 for fresh snow or thick clouds. Many surfaces show an increase in albedo with increasing solar zenith angle.
Algorithm	A mathematical process or set of rules used for calculation or problem-solving, which is usually undertaken by a computer
Atmospheric dispersion model	A mathematical representation of the physics governing the dispersion of pollutants in the atmosphere
Atmospheric stability	A measure of the propensity for vertical motion in the atmosphere
Baseline	Information gathered at the beginning of a study which describes the environment prior to development of a project and against which predicted changes (impacts) are measured.
Calm / stagnation	A period when wind speeds of less than 0.5 m/s persist
Cartesian grid	A co-ordinate system whose axes are straight lines intersecting at right angles
Causality	The relationship between cause and effect
Closure Phase	This stage of the project includes the period of aftercare and maintenance after the decommissioning phase
Configuring a model	Setting the parameters within a model to perform the desired task
Construction Phase	The stage of project development comprising site preparation as well as all construction activities associated with the development.
Cumulative Impacts	Direct and indirect impacts that act together with current or future potential impacts of other activities or proposed activities in the area/region that affect the same resources and/or receptors.
Dispersion	The lowering of the concentration of pollutants by the combined processes of advection and diffusion
Environment	The external circumstances, conditions and objects that affect the existence of an individual, organism or group. These circumstances include biophysical, social, economic, historical and cultural aspects.
Environmental Authorisation	Permission granted by the competent authority for the applicant to undertake listed activities in terms of the NEMA EIA Regulations, 2014.
Environmental Impact Assessment	A process of evaluating the environmental and socio-economic consequences of a proposed course of action or project.
Environmental Impact Assessment Report	The report produced to relay the information gathered and assessments undertaken during the Environmental Impact Assessment.
Environmental Management Programme	A description of the means (the environmental specification) to achieve environmental objectives and targets during all stages of a specific proposed activity.

[1] Definition from American Meteorological Society's glossary of meteorology

Impact	A change to the existing environment, either adverse or beneficial, that is directly or indirectly due to the development of the project and its associated activities.
Mitigation measures	Design or management measures that are intended to minimise or enhance an impact, depending on the desired effect. These measures are ideally incorporated into a design at an early stage.
Operational Phase	The stage of the works following the Construction Phase, during which the development will function or be used as anticipated in the Environmental Authorisation.
Specialist study	A study into a particular aspect of the environment, undertaken by an expert in that discipline.
Stakeholders	All parties affected by and/or able to influence a project, often those in a position of authority and/or representing others.

Air Quality Specialist Report for Mine Waste Solutions - Kareerand Expansion Project

1 INTRODUCTION

1.1 Background

Mine Waste Solutions (MWS), also known as Chemwes (Pty) Ltd (Chemwes), has been in business since 1964, and conducts its operations over a large area of land to the east of Klerksdorp (Figure 1-1), within the area of jurisdiction of the City of Matlosana and JB Marks Local Municipalities (LM), which fall within the Dr Kenneth Kaunda District Municipality (DM) in the North-West Province. The MWS/Chemwes Operations are located primarily to the south of the N12, east of the town of Stilfontein. The closest town is Khuma, located about 3 km northwest of the facility, and other nearby towns include Stilfontein (10 km from facility) and Klerksdorp (19 km from facility).

The operations at MWS entail the collection and reprocessing of mine tailings that were previously deposited on tailings storage facilities (TSFs) in order to extract gold and uranium. High pressure water cannons are used to slurry the tailings on the Source TSFs, then slurry is pumped by a number of pump stations and pipelines to the MWS/Chemwes Processing Plant (indicated in dark green in Figure 1-2), and the residues from the Processing Plants are pumped to the Kareerand TSF (indicated in yellow in Figure 1-2). Once an old Source TSF has been completely recovered, it is cleaned-up and rehabilitated. See Figure 1-2 for an overview of the existing infrastructure used for this process.

The Kareerand TSF was designed with an operating life of 14 years, taking the facility to 2025, and total design capacity of 352 million tonnes. Subsequent to commissioning of the TSF, AngloGold Ashanti (AGA) acquired MWS and tailings production target has increased by an additional 485 million tonnes, which will require operations to continue until 2042. The additional tailings therefore require extension of the design life of the TSF.

This project entails the expansion of the current Kareerand TSF to accommodate the increased tailings and final design capacity, along with additional pump stations and pipelines. The TSF expansion is proposed on the western edge of the current facility, and the final height of the combined facility (both expansion and current) will be 122m. The expansion footprint will add about 380 hectares (ha) to the TSF. Figure 1-3 depicts the site layout of all additional infrastructure across the operational footprint, while Figure 1-4 depicts the TSF expansion and its associated infrastructure.

The expansion of the existing TSF will enable the re-mining of tailings dams and deposition of the tailings in a new facility complete with appropriate seepage mitigation measures and resultantly reduce the total seepage into the Vaal River.

The project will support concurrent rehabilitation of the existing TSF and the expansion TSF, thereby reducing the risk of windborne dust and storm water management. Removing and consolidating all the tailings in the KOSH (Klerksdorp, Orkney, Stilfontein and Hartebeestfontein) area on a single mega-tailings storage facility will in the long term, positively impact the surrounding environment and Vaal River.

Specialist studies have been commissioned to assess the impacts of the TSF expansion on all aspects of biophysical and socio-economic receptors within the area. Mitigation, management, and rehabilitation designs are informed by a team of specialists and engineers.

Airshed Planning Professionals (Pty) Ltd was appointed by MWS to undertake an Air Quality Impact Assessment (AQIA) and Climate Change Impact Assessment (CCIA) as part of the Environmental Impact Assessment (EIA) to identify key aspects that may have significant air quality impacts during the various project phases. As such the report conforms to the amended regulated format requirements for specialist reports as per Appendix 6 of the EIA Regulations (Government Notice [GN] R982 as amended by GN 326, 7 April 2017 and GN 706, 13 July 2018). This report covers the impact assessment for the expansion of the Kareerand TSF (the project).

The locality of Kareerand TSF, in relation to Vaal River (VR), the remainder of MWS operations and surrounding residentials areas (within North West and Free State Provinces), is shown in Figure 1-1.

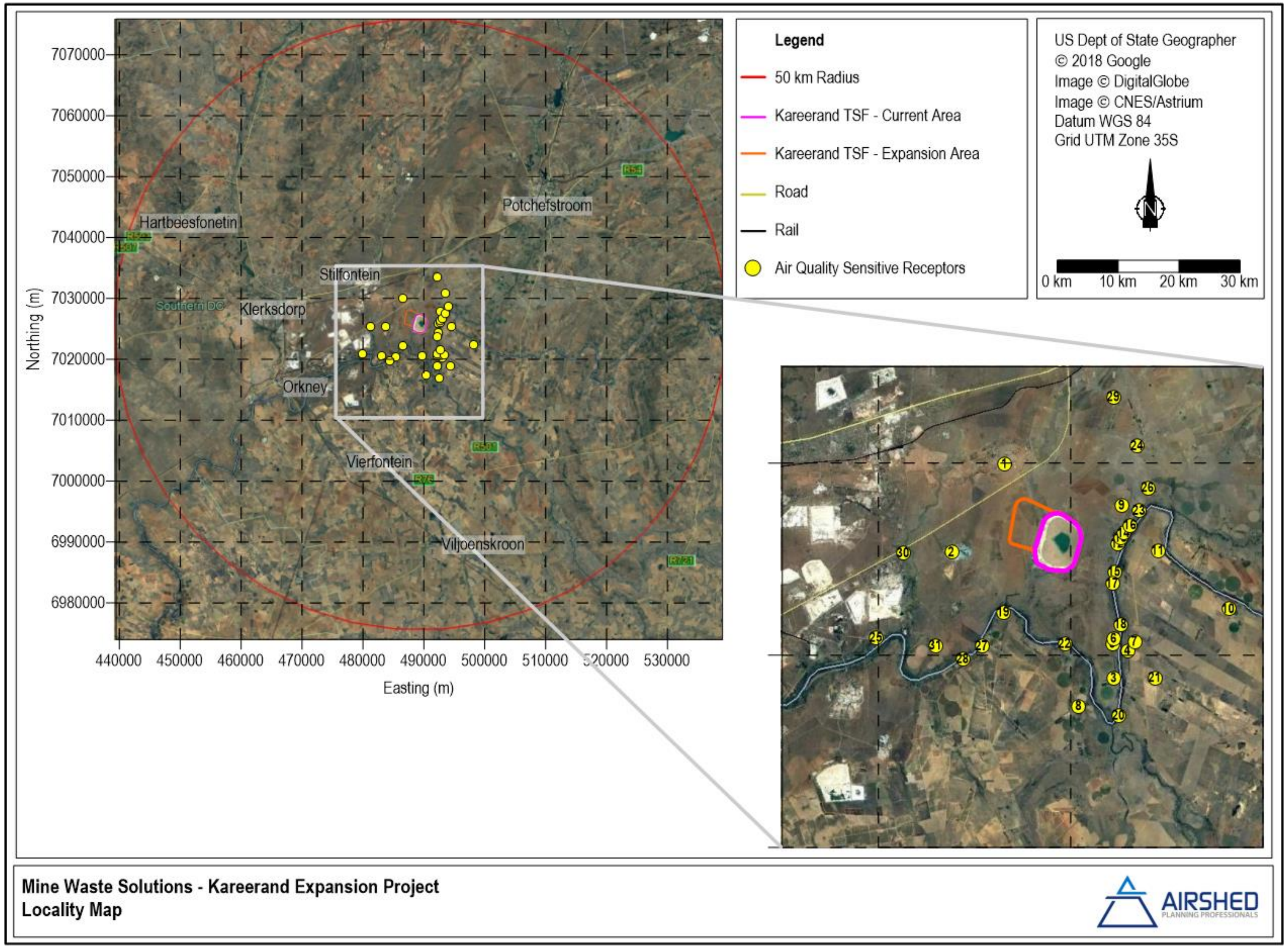

Figure 1-1: Location of Kareerand TSF and sensitive receptors included in the simulations

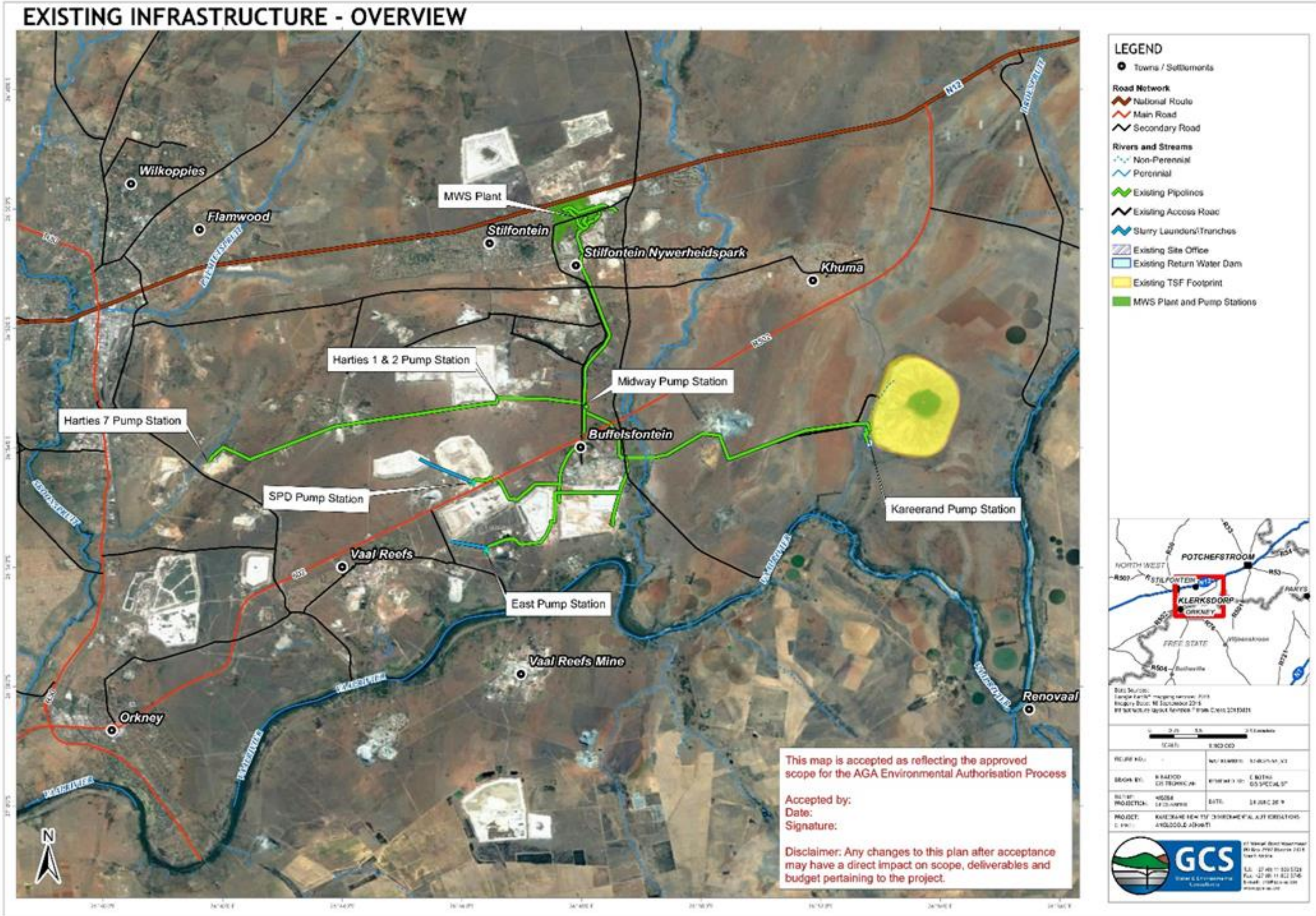

Figure 1-2: Existing infrastructure

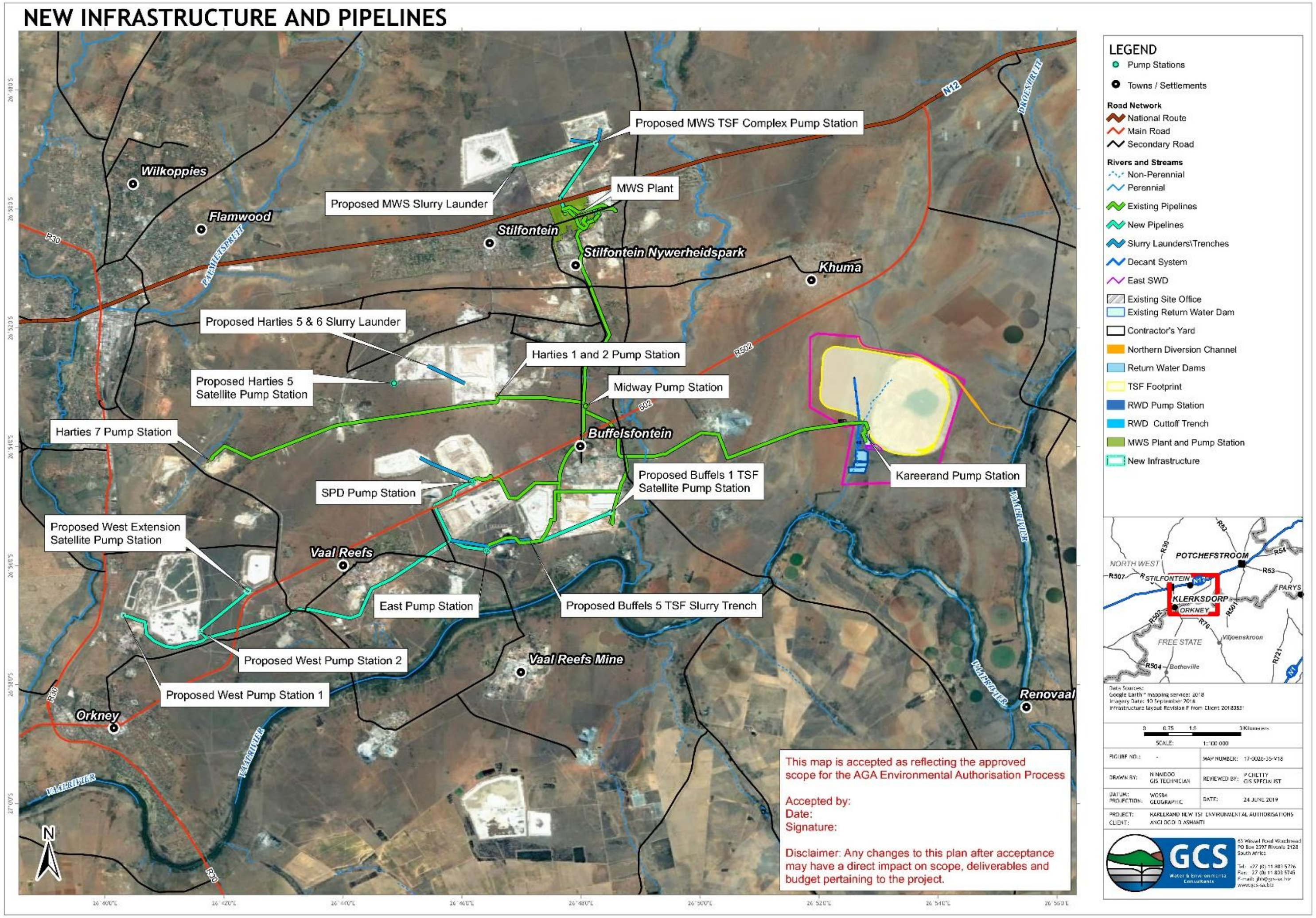

Figure 1-3: Site layout across operational footprint and TSF expansion footprint. The new infrastructure is noted by the word "proposed", and the new pipelines are indicated in bright blue (as opposed to existing pipelines indicated in green)

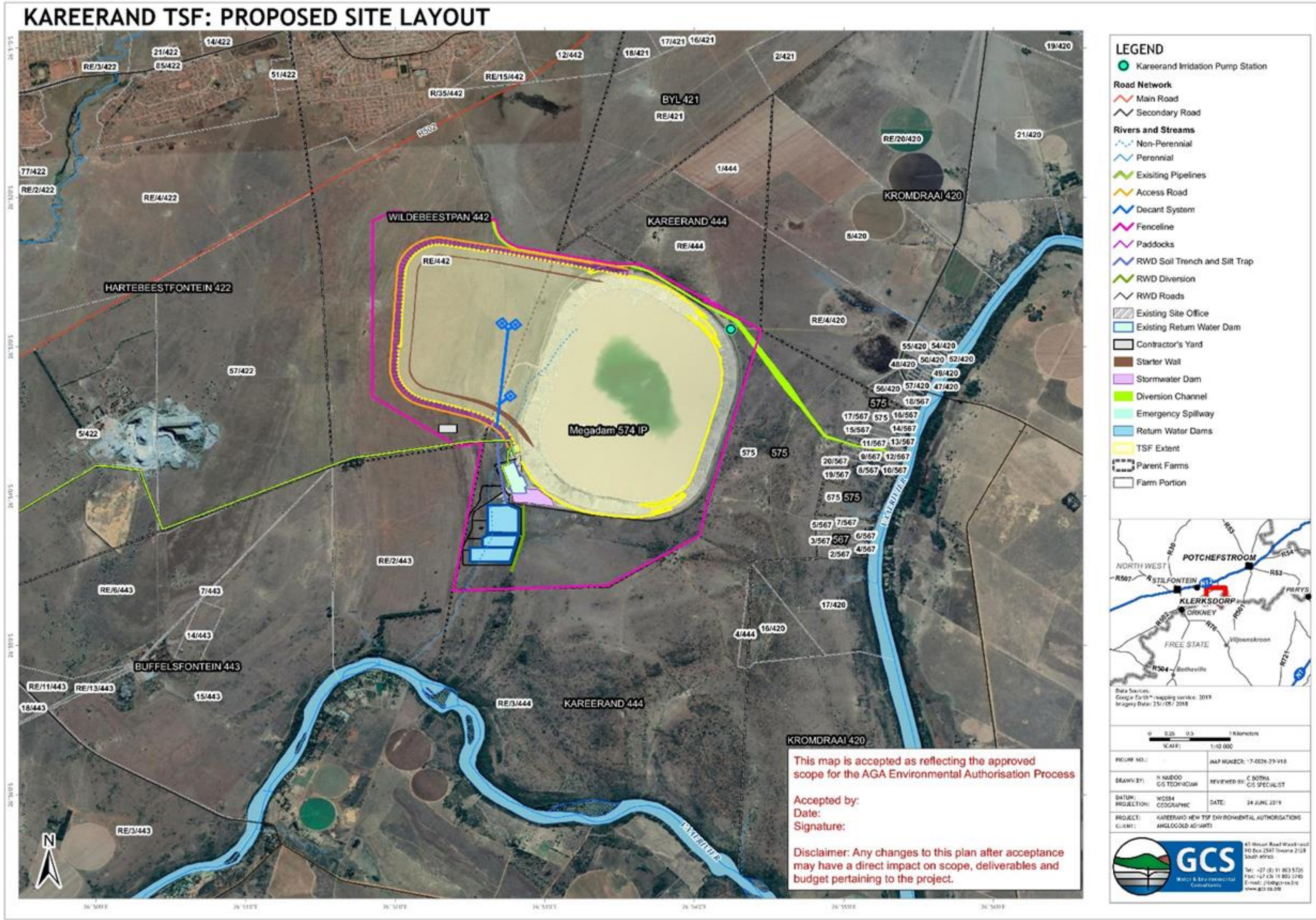

Figure 1-4: TSF expansion site layout in detail, including associated infrastructure

1.2 Terms of Reference

The specific terms of reference for the overall project are as follows:

- Identify and describe the existing air quality of the project area, as well as climatic patterns and features (i.e. the baseline);
- Assess (model) the impact on air quality (specifically particulate matter), human health and biota resulting from the proposed TSF expansion (including impacts associated with the construction, operations, decommissioning and post-closure phases of the project);
- Identify and describe potential cumulative air quality impacts resulting from the proposed project in relation to proposed and existing developments in the surrounding area;
- Recommend mitigation measures to minimise impacts and/or optimise benefits associated with the project;
- Recommend a monitoring campaign to ensure the correct implementation and adequacy of recommenced mitigation measures, if applicable;
- Make recommendations for rehabilitation and closure planning;
- Estimate the greenhouse gas (GHG) emissions during construction, operation and decommissioning of the project compared to the global and national emission inventory; and compared to international benchmarks for the project;
- Determine the robustness of the project with the impact of climate change over the lifetime of the project considered; and
- Ascertain the vulnerability to climate change of communities in the immediate vicinity of the project.

1.3 Report Structure

Section	Description	Page
1 - Introduction	An introduction to the study including a description of the project and the scope of work.	1-1
2 - Methodology	A detailed description of the study methodology is given in this section along with all limitations and assumptions relevant to it.	2-1
3 - Project Description	The project operations (current and proposed) are described.	3-1
4 - Applicable Legislation	A summary of applicable environmental legislation is presented	4-1
5 - Air Quality Baseline	A description of the receiving environment is given. It addresses AQSRs, dispersion potential as well as baseline air quality.	5-1
6 - Impact Assessment: Construction Phase	Impact discussion and significance ranking based on specialist knowledge.	6-1
7 - Impact Assessment: Operational Phase	Emissions and modelling results and assessment of air quality impacts.	7-1
8 Impact Assessment: Decommissioning and Closure Phases	Impact discussion and significance ranking based on specialist knowledge.	8-1
9 - Impact Assessment: Cumulative	Impact discussion based on specialist knowledge and simulation results.	9-1
10 - Impact Assessment: No Go Option	Discussion of the No-Go option.	10-1
11 - Dust Management	Detailed discussion on recommended mitigation, management and monitoring.	11-1
12 - Findings and Recommendations	The main findings of the study and recommendations of mitigation, management and monitoring.	12-1
13 - Greenhouse Gas Emission Statement	A discussion of GHG legislation, literature, potential operations' emissions and likely impacts.	13-1

2 METHODOLOGY

The air quality study includes both baseline and predicted impact assessment. The baseline characterisation includes the following enabling tasks:

- Identification of existing sources of emission and characterization of ambient air quality and dustfall levels in the study area;
  - A quantitative assessment of baseline VR and MWS air quality was possible due to the availability of a previous study dispersion simulations (study done in 2014/2015 and based on 2013 emissions inventory).
  - The remainder of the baseline air quality is qualitative.
- It is important to have a good understanding of the meteorological parameters governing the rate and extent of dilution and transportation of air pollutants that are generated by the proposed project. The primary meteorological parameters to obtain from measurement include wind speed, wind direction and ambient temperature. Other meteorological parameters that influence the air concentration levels include rainfall (washout) and a measure of atmospheric stability. The latter quantities are normally not measured and are derived from other parameters such as the vertical height temperature difference or the standard deviation of wind direction. The depth of the atmosphere in which the pollutants are able to mix is similarly derived from other meteorological parameters by means of mathematical parameterizations.
  - The first step was therefore to source any on-site meteorological observations. As a minimum this data had to include hourly averaged wind speed, wind direction and ambient air temperature.
  - Two years of hourly sequential data was available from the AGA operated Kareerand weather station; at the time that the final dispersion simulations commenced. With data availability above 90%, the AGA operated Kareerand weather station was used to construct wind roses, general climatic information such as diurnal temperature variations, atmospheric stability estimates and for dispersion modelling.
  - Rainfall data from AGA operated stations were analysed. The Klerksdorp data was used to describe the rainfall pattern in the area.
  - The South Africa Weather Service (SAWS) weather station located in Klerksdorp (more than 20 km from project site) measures wind speed, wind direction, temperature, rainfall, relative humidity, and barometric pressure. These parameters are current but taking into consideration the topography, land-use and landforms surrounding Kareerand TSF, the station may be located too far away to provide an accurate representation of the meteorology near Kareerand TSF.
  - Measurements of wind direction from the AGA operated Klerksdorp station appeared erroneous with the wind originating from one sector.
- Potential air pollution sensitive receptors within the study area were identified and georeferenced for detailed analysis of the impact assessment calculations.

The impact assessment followed with the tasks below:

- The dispersion modelling was executed as per *The Regulations Regarding Air Dispersion Modelling* (GN 533 in Gazette No 37804, 11 July 2014). Three *Levels of Assessment* are defined in the Regulations. Level 2 was deemed adequate. These are described under Section 4.3.
- Preparation of the model control options and input files for the AERMOD dispersion modelling suite. This included the compilation of:
  - terrain information (topography, land use, albedo and surface roughness);
  - source layout; and
  - grid and receptor definitions.
- Preparation of hourly average meteorological data for the wind field and atmospheric dispersion model.

- Preparation of an emissions inventory (particulates) for the current and proposed Kareerand TSF operations, including fugitive sources[2] of windblown dust. Ideally, the emission rates should be based on actual measurements, but since this is not possible for the proposed project, emission factors are used.
- For the current Kareerand TSF study, simulations were conducted using the AERMOD dispersion modelling suite, which allowed the calculations of the current ambient inhalable concentrations (PM_{10} and $PM_{2.5}$) and dust fallout as well as the predicted expanded TSF impacts. The highest daily and annual concentrations and total daily dust deposition were calculated.
- The legislative and regulatory context, including emission limits and guidelines, ambient air quality guidelines and dustfall classifications were used to assess the impact and recommend additional emission controls, mitigation measures and air quality management plans to maintain the impact of air pollution to acceptable limits in the study area. The model results were analysed against the National Ambient Air Quality Standards (NAAQS) and National Dust Control Regulations (NDCR).

2.1 Literature Review

The following reports were utilised to obtain relevant information on the local meteorological and current air quality information, as well as to identify the possible air pollutants that may originate from the project and may have an impact in the study area.

- Liebenberg-Enslin, H. and Fletcher, D. (2015). Baseline Air Quality Specialist Report update for the AngloGold Ashanti Vaal River and Mine Waste Solutions - located on the border of the Free State and Northwest Province, Report No.: 13AGA01, Report Version: Final Rev1, Airshed Planning Professionals (Pty) Ltd, Midrand.

2.2 Data Gathering

All project information required to calculate emissions for proposed operations was provided by MWS and GCS (Pty) Ltd (GCS) via electronic mail and at the site visit conducted in November 2017.

Dustfall rates data was acquired from AGA and analysed for inclusion in this report and for simulation results verification. The following data sources were consulted, primarily for their observations of meteorological parameters including wind speed, wind direction, ambient air temperature and rainfall data:

- SAWS Klerksdorp weather station (2011-2013);
- AGA Klerksdorp weather station (2016);
- AGA Kareerand TSF weather station (2018 and 2019); and
- WRF model data (2014-2016), see Appendix H for comparison with measured data.

2.3 Data Analysis for Air Dispersion Modelling

2.3.1 AERMOD Modelling Suite

As per the National Code of Practice for Air Dispersion Modelling use was made of the US EPA approved AERMOD atmospheric dispersion modelling suite for the simulation of ambient air pollutant concentrations and dustfall rates. AERMOD is a Gaussian plume model, best used for near-field applications where the steady-state meteorology assumption is most

[2] Fugitive particulate matter (PM) emissions will be released to atmosphere during these activities. Fugitive emissions refer to emissions that are spatially distributed over a wide area and not confined to a specific discharge point as would be the case for process related emissions (IFC, 2007).

likely to apply. The AERMOD model is one of the most widely used Gaussian plume model. AERMOD is a model developed with the support of the AMS/EPA Regulatory Model Improvement Committee (AERMIC), whose objective was 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 which 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 spatially varying wind fields, due to topography or other factors cannot be included. Input data types required for the AERMOD model includes source data, meteorological data (pre-processed by the AERMET model), terrain data (pre-processed by the AERMAP model) and information on the nature of the receptor grid.

The components of the AERMOD modelling suite are summarised in Table 2-1; however, only AERMOD contain the simulation engines to calculate the dispersion and removal mechanisms of pollutants released into this boundary layer. The other codes are mainly used to assist with the preparation of input and output data. Table 2-1 also includes the development versions of each of the codes used in the investigation.

Table 2-1: Summary description of AERMOD model suite with versions used in the investigation

Module	Interface Version	Executable	Description
AERMOD	Breeze v9.0.0.23	(US) EPA 19191	Gaussian plume dispersion model.
AERMET	Breeze v7.9.0.3	(US) EPA 18081	Meteorological pre-processor for creating AERMOD compatible formats.
AERMAP	Breeze v9.0.0.23	(US) EPA 18081	Topographical pre-processor for creating digital elevation data in a format compatible with the AERMOD control file.

The execution phase (i.e. dispersion modelling and analyses) involves gathering specific information regarding the emission source(s) and site(s) to be assessed, and subsequently the actual simulation of the emission sources and determination of impact significance. The information gathering included:

- Source information: emission rate, source extents and release height;
- Site information: site layout, terrain information, and land use data;
- Meteorological data: a minimum of wind speed, wind direction, temperature, and sensible heat flux or Monin-Obukhov length; and
- Receptor information: locations using discrete receptors and/or gridded receptors.

2.3.1 Meteorological Requirements

An understanding of the atmospheric dispersion potential of the area is essential to an air quality impact assessment. Use was made of measured on-site data from the Kareerand TSF weather station. The AERMOD output covered a 37.5 km (east-west) by 30.5 km (north-south) area containing the current and proposed Kareerand TSF operational area for 2018 and 2019.

2.3.2 Topographical and Land Use Data

For operational scenario with current topography readily available terrain and land use data was obtained from the United States Geological Survey (USGS) via the Earth Explorer website (U.S. Department of the Interior, U.S. Geological Survey, 2018). Use was made of Shuttle Radar Topography Mission (SRTM) (30 m, 1 arc-sec) data and Global Land Cover Characterisation (GLCC) data for Africa. For operational scenario with future (final) topography, terrain data was obtained from GCS.

2.3.3 Receptor Grid

The dispersion of pollutants expected to arise from current and proposed operations was simulated for an area covering 37.5 km (east-west) by 30.5 km (north-south). The area was divided into a grid matrix with a resolution of 100 m. AERMOD calculates ground-level concentrations and dustfall rates at each grid point. The grid details used in dispersion modelling are given in Table 2-2. The discrete receptors data included in the dispersion model input is shown in Table 2-3.

Table 2-2: Simulation domain

Simulation domain	
South-western corner of simulation domain	461 281.88 m (Easting); 7 007 570 m (Northing)
Domain size	37.5 x 30.5 km
Projection	Grid: UTM Zone 35S, Datum: WGS-84
Resolution	100 m

Table 2-3: Individual air quality sensitive receptors included as discrete receptors points

Receptor ID	Receptor name	Longitude	Latitude
1	Khuma Township	26.86498	-26.8521
2	Village Main Reef Mine	26.83695	-26.8935
3	Farm Owner 1	26.92199	-26.9525
4	Farm Owner 2	26.92919	-26.9398
5	Farm Owner 3	26.92133	-26.9365
6	Farm Owner 4	26.92208	-26.934
7	Farm Owner 5	26.93289	-26.9355
8	Farm Owner 6	26.90357	-26.9658
9	Farm Owner 7	26.92629	-26.8715
10	Farm Owner 8	26.9821	-26.9202
11	Farm Owner 9	26.94511	-26.8928
12	Vaal River - Property Owners 1	26.9239	-26.8894
13	Vaal River - Property Owners 2	26.92582	-26.8867
14	Vaal River - Property Owners 3	26.92722	-26.8846
15	Vaal River - Property Owners 4	26.92237	-26.9028
16	Vaal River - Property Owners 5	26.93061	-26.8808
17	Vaal River - Property Owners 6	26.92127	-26.9082
18	Vaal River - Property Owners 7	26.92564	-26.9273

Receptor ID	Receptor name	Longitude	Latitude
19	Vaal River - Property Owners 8	26.86419	-26.9216
20	Vaal River - Property Owner 9	26.92457	-26.9702
21	Chicken Farm A	26.94347	-26.9525
22	Vaal River Property Owners	26.89625	-26.9365
23	Vaal River - Property Owners 10	26.93526	-26.874
24	Supermarket / Garage	26.93426	-26.8436
25	Midvaal Water Company	26.79745	-26.9336
26	Farm Homestead A	26.939837	-26.863266
27	Clementia Wedding Venue	26.85278	-26.937576
28	Wawiel Park Holiday Resort	26.842846	-26.943617
29	Chicken Farm B	26.921934	-26.820628
30	Farm Homestead B	26.8118	-26.893809
31	Farm Homestead C	26.8286	-26.937201

2.3.4 Dispersion results

The dispersion model uses the specific input data to run various algorithms to estimate the dispersion of pollutants between the source and receptor. The model output is in the form of a simulated time-averaged concentration at the receptor. These simulated concentrations are added to suitable background concentrations and compared with the relevant ambient air quality standard or guideline. The post-processing of air concentrations at discrete receptors as well as the regular grid points includes the calculation of various percentiles, specifically the 99^{th} percentile, which corresponds to the requirements of the NAAQS.

Ground level concentration (GLC) isopleth plots presented in this report depict interpolated values from the concentrations simulated by AERMOD for each of the receptor grid points specified. Plots reflecting daily averaging periods contain only the 99.73th percentile of simulated ground level concentrations, for those averaging periods, over the entire period for which simulations were undertaken. It is therefore possible that even though a high daily average concentration is simulated at certain locations, this may only be true for one day during the period. Typically, NAAQS apply to areas where the Occupational Health and Safety regulations do not apply, thus outside the mine property or lease area. Ambient air quality guidelines and standards are therefore not occupational health indicators but applicable to areas where the general public has access i.e. off-site.

2.3.5 Uncertainty of Modelled Results

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

The stochastic uncertainty includes all errors or uncertainties in data such as source variability, observed concentrations, and meteorological data. Even if the field instrument accuracy is excellent, there can still be large uncertainties due to unrepresentative placement of the instrument (or taking of a sample for analysis). Model evaluation studies suggest that the data input error term is often a major contributor to total uncertainty. Even in the best tracer studies, the source emissions are known only with an accuracy of ±5%, which translates directly into a minimum error of that magnitude in the model predictions.

It is also well known that wind direction errors are the major cause of poor agreement, especially for relatively short-term predictions (minutes to hours) and long downwind distances. All the above factors contribute to the inaccuracies not associated with the mathematical models themselves.

A disadvantage of the model is that spatial varying wind fields, due to topography or other factors cannot be included. Although the model has been shown to be an improvement on the ISC model, especially short-term predictions, the range of uncertainty of the model predictions is -50% to 200%. The accuracy improves with fairly strong wind speeds and during neutral atmospheric conditions.

In quantifying the uncertainty of the modelled results for this assessment, measured ambient data was required which was not available for this study.

2.4 Impact Assessment

Potential impacts of the proposed project were identified based on the baseline data, project description, review of other studies for similar projects and professional experience. The significance of the impacts was assessed using the prescribed GCS impact rating methodology provided. The significance of an impact is defined as a combination of the consequence of the impact occurring and the probability that the impact will occur. The impact significance was rated for unmitigated operations and assuming the effective implementation of design mitigation measures.

The severity of the impact was selected based on the following:

i. Disastrous / extremely harmful / within a regulated sensitive area
    - (5) - Short term and long-term NAAQS exceeded at AQSRs.

ii. Great / harmful
    - (4) - Short term NAAQS exceeded at AQSRs.

iii. Significant / slightly harmful
    - (3) – Short term NAAQ limit exceeded at AQSRs.

iv. Small / potentially harmful
    - (2) – NDCR limit for non-residential and/or residential areas exceeded at AQSRs for more than two months or for two consecutive months.

v. Insignificant / non-harmful
    - (1) - No exceedances of assessment criteria at AQSRs.

2.5 Mitigation and Management Recommendations

Practical mitigation and optimisation measures that can be implemented effectively to reduce or enhance the significance of impacts were identified.

2.6 Assumptions and Limitations

The study is based on a few assumptions and is subject to certain limitations, which should be borne in mind when considering information presented in this report. The validity of the findings of the study is not expected to be affected by these assumptions and limitations:

1. All project information required to calculate emissions for proposed operations was provided by MWS and GCS.

2. The EIA will be completed by GCS on behalf of MWS. For this reason, the impact significance of the project was determined based on the GCS impact significance methodology. This ranking methodology inflated the risk of the air quality impacts. The use of this methodology resulted in realistic consequence but unreasonably high likelihood. The likelihood is significantly inflated since the activity assessed is governed by legislation.
3. The baseline air quality is based on the modelling undertaken in 2014/2015 which accounted for 2013 VR and MWS operations. As the VR underground mining operations have ceased and MWS operations are similar, the current ambient air quality and dustfall rates may differ slightly near the shafts, plants, other TSFs and waste dumps. It is unlikely that there will be significant contribution from the other operations on sensitive receptors surrounding the Kareerand TSF.
4. The impact of the construction and operational phases were determined quantitatively through emissions calculation and but not through simulation. Decommissioning phase impacts are expected to be similar or somewhat less significant than construction phase impacts. Mitigation and management measures recommended for the construction and operational phases are however also applicable to the decommissioning phase. No impacts are expected post-closure provided the rehabilitation of final landforms is successful.
5. Meteorology:
    a. It was noted in the previous VR and MWS studies that the South African Weather Service (SAWS) Klerksdorp weather station data did not appear accurate. Based on the location of Kareerand TSF in relation to this station; as well as considering the topography, land-use and landforms (other TSFs and waste dumps) in the area which can all affect the local meteorology, it was decided to use the measured meteorological data for the weather station at Kareerand TSF. The data for the period January 2018 to December 2019 was used in the dispersion modelling.
    b. The National Code of Practice for Air Dispersion Modelling described in the Regulations regarding air dispersion modelling (GN 533; 11 July 2014) prescribes the use of a minimum of one year of on-site data or at least three years of appropriate off-site data for use in Level 2 and 3 assessments. It also states that the meteorological data must be for a period no older than five years to the year of assessment. The dataset period is within the timeframe recommended by the National Code of Practice for Air Dispersion Modelling being of two years (on-site) data less than five years old during the assessment period (2020).
6. Greenhouse gas (GHG):
    a. Scope 1 and Scope 2, carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) emissions were calculated for the construction phase and operational phase;
    b. Scope 1 and Scope 2 emissions were converted to CO_2 equivalent (CO_2-e) emissions for the construction phase and operational phase; and
    c. Modelling was not included in the scope of work.
7. Particulate matter, with reference to Total Particulate Matter (TSP), PM_{10} (Particulate matter with an aerodynamic dimeter less than 10 µm) and $PM_{2.5}$ (particulate matter with an aerodynamic dimeter less than 2.5 µm) is the main pollutant of concern from the current and proposed expanded Kareerand TSF. The AGA PM_{10} ambient monitoring station located near the VR Offices, some 15 km from the Kareerand TSF had poor data availability (erroneous data) and could not be used. $PM_{2.5}$ is not presently sampled in the project area.
8. Emissions:
    a. The impact assessment was limited to airborne particulates (including TSP, PM_{10} and $PM_{2.5}$). These pollutants are regulated under NAAQS and considered key pollutants released by the operations associated with the expansion of the Kareerand TSF.
    b. The quantification of sources of emission was restricted to the current Kareerand TSF operations and the expansion project. Other existing sources of emission within the area were identified. A study was completed in 2015 (using 2013 data) for the VR and MWS operations and the emissions from this study

are discussed. The VR and MWS emissions inventory is being updated for the 2020 operations. Other companies' mining operations, farming activities, domestic fires, vehicle exhaust emissions and dust entrained by vehicles on public roads were not quantified as part of the Project's emissions inventory and simulations.

c. Site specific particle size, moisture and silt content data were available.
d. For the estimation of windblown dust emissions, use was made of the Airborne Dust Dispersion Model from Area Sources (ADDAS) (Burger, Held, & Snow, 1997).

Other assumptions made in the report are explicitly stated in the relevant sections.

3 PROJECT DESCRIPTION

3.1 New Infrastructure

The proposed project will make use of the existing facilities as well as additional supporting infrastructure.

The details of the infrastructure which forms part of the expansion of the TSF are as follows (Figure 1-4):

- TSF expansion TSF Footprint
    - TSF will be expanded by 380 Ha
- Fences Fenceline
    - 2.4 m high game fence with appropriate signage will be installed around the perimeter of the new TSF (length of new fence = 7 km)
    - This will tie into the existing fence and is the same type of fence
- New main access road and perimeter access road Access Road
    - 8 m wide gravel access road around perimeter of TSF, to the RWDs (return water dams), pump stations (western perimeter of TSF extension) and offices
    - Total combined distance of new roads will be 11 km
    - Access ramps provide access onto tailings dam
- Topsoil bund wall
    - A bund wall will be constructed around the TSF, next to the access road
    - The wall will be 6 m at highest point and 2 m at lowest point, crest width is 8 m
    - The bund wall will also be used as access road on northern side of TSF
- Stormwater diversion channels Diversion Channel RWD Diversion
    - A trench on the northern side of the TSF, 6 km in length, to divert clean storm water running from the north, towards the east in the direction of the Vaal River
        - Trapezoidal in shape with side slopes of 1v:2h and base width of 9m.
        - Designed to accommodate the 1:50 year storm event
        - Peak flow velocity will be 125 m^3/s during 1:50 year storm events
    - A second unlined trench next to the RWD will divert clean storm water runoff away from the RWD and solution trench and prevent it from mixing with the dirty water
    - Diversion channels will assist to minimise the water quality impact from the TSF
- Delivery pipeline
    - Three steel 500 mm tailings delivery pipes located at the toe of the facility (western edge); 13.5 km in total length
    - Will deliver slurry to the northern, western and southern side of the TSF extension
- Solution trench
    - Trench lined with 100 mm thick mesh reinforced concrete
    - Around northern, western and southern side of TSF
    - Will convey decant water and storm water from the side slopes, filter discharge (seepage water) from the outer drains and surface runoff from the side slopes to the RWD.

- Seepage and dirty water collector sump
  - Constructed on northern side of TSF
  - Will collect seepage water and dirty storm water running off the TSF walls from solution trench before it is pumped back to the north-western corner
- Catchment paddocks Paddocks
  - Constructed around perimeter of facility at final outer wall toe location
  - Constructed using material from solution trench excavations and paddock basins; will be nominally compacted
  - Paddocks will be 50 m long and 20 m wide
  - Designed to contain run-off from a 1:50 year storm event
- Starter wall Starter Wall
  - The starter wall will contain tailings deposition during early development of TSF
  - Constructed using clay-based material from basin or other construction areas
- Drainage system
  - Under drainage system located within TSF footprint, consisting of toe, intermediate and central drains and drain outlets
  - Filter drain system consisting of a trench lined with Geofabric, which prevents the ingress of fine clay / sand particles into drain, thus preventing clogging
  - Drain outlets constructed at approximately 50-100m intervals to collect seepage water from filter drains and convey it to solution trench
  - The existing drain outlets will connect to a collector drain system then discharge into the solution trench on the southern flank where the two facilities connect.
- Decant system
  - Gravity pipe decant system to ensure water does not accumulate on top of TSF
  - Includes permanent double intake structure and intermediate intake structures
  - Intermediate penstock intake structures positioned at different elevations along the penstock outlet pipeline
    - Ensure effective decanting of supernatant water during the development phase of TSF
    - Minimise delay in water returned to the reclamation sites
- Catwalk
  - Timber catwalk and floating walkway structure for access from pool wall to penstock intermediate and permanent intake structures respectively
- Energy dissipater
  - Concrete energy dissipater box where penstock outlet pipe daylights
  - Should reduce velocity of water from penstock before it flows into silt trap
- Silt trap RWD Soil Trench and Silt Trap
  - Concrete-lined silt trap with twin compartments between penstock outlet and RWD
  - Should reduce volume of suspended solids flowing into RWD
- Storm water dam Stormwater Dam
  - Storm water dam will be located between TSF and RWDs and will contain dirty water running off the TSF
  - Capacity will be 155 000 m^3 and will cover 6.6 Ha
- RWD and related infrastructure Return Water Dams

- New RWDs with a combined capacity of 837 000 m³ (area of 60 Ha), south of the TSF and existing RWD complex
    - RWD will have three compartments (one for operation, the other two for dirty water containment)
    - Will be lined with double HDPE liner system and leakage-detection material (Hi-drain); double liner will consist of 2 mm geomembrane and 1.5 HDPE geomembrane
- Contractors yard Contractor's Yard
    - Contractor's yard will be located on the south western side of the TSF extent on the right of the access road travelling south.
    - Contractor's yard will include the following infrastructure: site office, workshop, fuel storage facilities, wash bays, change houses, septic tanks.
- Pump Stations
    - Three main pump stations: one at the MWS complex, two at the outlying western TSFs
    - Three satellite pump stations: one at the Harties TSFs (probably at a later stage), one at the outlying western TSFs and one at the Buffels TSFs
- Process water pipelines New Pipelines
    - Extended from the existing SPD and East Complex pump stations to the western outlying TSFs
    - Connecting MWS TSFs and MWS plant
- Slurry pipelines New Pipelines
    - Extended from the existing SPD and East Complex pump stations to the western outlying TSFs
    - Connecting MWS TSFs and MWS plant
- Slurry launders Slurry Launders\Trenches
    - Connecting the Buffels TSF to the East Complex pump station
    - Connecting Harties TSFs with the Harties 1 & 2 pump station
    - Connecting MWS TSFs to the proposed MWS pump station

The additional infrastructure required across the operational footprint will include new pump stations, new satellite pump stations, slurry launders and connecting slurry and process water pipelines. As indicated in Figure 1-3, in the centre of operations, existing infrastructure (pump stations and main slurry and process water pipelines) will be utilised to process adjacent resources. Buffels 5 TSF will be connected to the East Complex Pump Station via a new slurry trench and Buffels 1 TSF will be pumped via a satellite pump station to the Buffels 5 TSF slurry trench feed. At the Harties 1 & 2 Pump Station, located centre to north of Figure 2, Harties 5 & 6 TSF will be directed via a slurry launder to the pump station and may require, at a later date, a satellite pump station to aid in reclamation of tailings that cannot be gravity fed. In the west, three new pump stations (West Pump Station 1, West Pump Station 2 and a satellite pump station) will be constructed, with main slurry and process water pipelines extended from the existing SPD and East Complex Pump Stations in the east to the west, allowing for the use of the SPD and East Complex Pump Stations as booster pump stations. In the north, the MWS 4 & 5 TSF's will be reclaimed and directed to a new pump station via slurry launders. New process water and slurry piping will be installed between the MWS 4 & 5 Pump Station and the MWS plant. In total, three new main pump stations and three new satellite pump stations will be built.

3.2 NEMA Listed and Specified Activities

The activities which will take place as part of the expansion of the Kareerand TSF trigger listed activities in terms of the Environmental Management Act, 1998 (Act No. 107 of 1998) (NEMA), as contained in the 2014 Environmental Impact Assessment (EIA) Regulations, as amended in 2017 and 2018. The identified listed activities are presented in the Table 3-1. Due to the listed activities triggered under Listing Notice 2, a Scoping and Environmental Impact Reporting (S&EIR) process is required in order to obtain the necessary Environmental Authorisation (EA) in terms of the NEMA.

Table 3-1: NEMA listed activities identified

Listing Notice	Activity No	Activity description	Project activity which triggers the Listed Activity:
Listing Notice 1: Government Notice R983 in Government Gazette 38282 of 4 December 2014 and amended by: • **GN 327 GG 40772 20170407 w.e.f. 7 April 2017** • **GN 706 GG 41766 20180713 w.e.f. 13 July 2018**			
LN1	12	The development of- (i) dams or weirs, where the dam or weir, including infrastructure and water surface area, exceeds 100 square metres; or (ii) infrastructure or structures with a physical footprint of 100 square metres or more; where such development occurs- (a) within a watercourse; (b) in front of a development setback; or (c) if no development setback exists, within 32 metres of a watercourse, measured from the edge of a watercourse	New RWDs = 60.6 Ha will occur over the site of a small watercourse Development of the TSF within the watercourse Development of new pump stations
LN1	19	The infilling or depositing of any material of more than 10 cubic metres into, or the dredging, excavation, removal or moving of soil, sand, shells, shell grit, pebbles or rock of more than 10 cubic metres from a watercourse	TSF expansion will be conducted on the site of a small watercourse
LN1	24	The development of a road- (i) for which an environmental authorisation was obtained for the route determination in terms of activity 5 in Government Notice 387 of 2006 or activity 18 in Government Notice 545 of 2010; or (ii) with a reserve wider than 13,5 meters, or where no reserve exists where the road is wider than 8 metres	The development of 8 m wide access roads to the TSF. The combined distance of the new roads will be 11 km.
LN1	28	Residential, mixed, retail, commercial, industrial or institutional developments where such land was used for agriculture, game farming, equestrian purposes or afforestation on or after 01 April 1998 and where such development: (i) will occur inside an urban area, where the total land to be developed is bigger than 5 hectares; or	Commercial development which will occur on land that was used for agriculture; TSF and associated dams will be 473 Ha in size, plus the footprint of the six (6) pump stations (unknown at this stage).

Listing Notice	Activity No	Activity description	Project activity which triggers the Listed Activity:
		(ii) will occur outside an urban area, where the total land to be developed is bigger than 1 hectare; excluding where such land has already been developed for residential, mixed, retail, commercial, industrial or institutional purposes.	
LN1	31	The decommissioning of existing facilities, structures or infrastructure for- (i) any development and related operation activity or activities listed in this Notice, Listing Notice 2 of 2014 or Listing Notice 3 of 2014	During the first ten years of the expansion operation, some of the pump stations and associated infrastructure will be decommissioned.
LN1	46	The expansion and related operation of infrastructure for the bulk transportation of sewage, effluent, process water, waste water, return water, industrial discharge or slimes where the existing infrastructure- (i) has an internal diameter of 0,36 metres or more; or (ii) has a peak throughput of 120 litres per second or more; and (a) where the facility or infrastructure is expanded by more than 1 000 metres in length; or (b) where the throughput capacity of the facility or infrastructure will be increased by 10% or more	Process water and slurry pipelines will range from 0.5 m to 0.6 m in diameter and pipeline network will be cumulatively expanded by approximately 30 km.
LN1	48	The expansion of- (i) infrastructure or structures where the physical footprint is expanded by 100 square metres or more	The TSF expansion footprint will be approximately 380 Ha; expansion will occur over a small watercourse.
Listing Notice 2: Government Notice R984 in Government Gazette 38282 of 4 December 2014 and amended by: • **GN 327 GG 40772 20170407 w.e.f. 7 April 2017** • **GN 706 GG 41766 20180713 w.e.f. 13 July 2018**			
LN2	15	The clearance of an area of 20 hectares or more of indigenous vegetation, excluding where such clearance of indigenous vegetation is required for- (i) the undertaking of a linear activity; or	The total footprint that will be cleared for the proposed project is approximately 473 Ha + footprints of six (6) pump stations (unknown at this stage)

Listing Notice	Activity No	Activity description	Project activity which triggers the Listed Activity:
		(ii) maintenance purposes undertaken in accordance with a maintenance management plan.	

3.3 Identification of Potential Air Pollution Impacts

Air emissions during the current and future activities will result from a variety of air emission sources, which include bulldozing, scraping, material transfer, wheel entrainment, vehicle exhaust tailpipe and processing activities. Airborne particulates are the most significant of these emissions and may contain airborne particulate sizes up to about 100 micron in diameter. Particles of sizes larger than about 75 micron tend to deposit out of the plume relatively nearby their source of emission. Particles less than about 20 micron, on the other hand, can be carried for considerable distances before depositing out. Dust emissions are produced from the mechanical movement of large volumes of material, as well as by the movement of mobile equipment and trucks, both within the areas being reclaimed and along the unsealed roadways adjacent to these areas. Dust particles, especially the very fine particles, will potentially be harmful to human health, may create amenity issues and might result in soiling of buildings, structures and other objects at nearby residences. Particle fallout in significant quantities can also negatively impact vegetation due to the reduction in photosynthesis.

4 Applicable Legislation

Prior to assessing the impact of proposed activities on human health and the environment, reference needs to be made to the air quality regulations governing the calculation and impact of such operations i.e. reporting requirements, emission standards, ambient air quality standards and dust control regulations.

Emission standards are generally provided for point sources, specify the amount of the pollutant acceptable in an emission stream and are often based on proven efficiencies of air pollution control equipment. Air quality guidelines and standards are fundamental to effective air quality management, providing the link between the source of atmospheric emissions and the user of that air at the downstream receptor site. The ambient air quality standards and guideline values indicate safe daily exposure levels for the majority of the population, including the very young and the elderly, throughout an individual's lifetime. Air quality guidelines and standards are normally given for specific averaging or exposure periods.

This section summarises legislation for particulate matter (PM) concentrations and dustfall. The National Atmospheric Emission Reporting Regulations, Regulations regarding Air Dispersion Modelling, NAAQS and National Dust Control Regulations (NDCR) are relevant to the extension of the Kareerand TSF and are discussed below.

4.1 Emissions Standards

The NEM:AQA (Act No. 39 of 2004 as amended) mandates the Minister of Environment to publish a list of activities which result in atmospheric emissions and consequently cause significant detrimental effects on the environment, human health and social welfare, economic conditions, ecological conditions or cultural heritage. All scheduled processes as previously stipulated under the Air Pollution Prevention Act (APPA) are included as listed activities with additional activities added to the list. The updated Listed Activities and Minimum National Emission Standards (MES) were published in 2013 (GN 893, in Government Gazette No. 37054) as amended by GN 551, 12 June 2015; GN 1207, 81 October 2018 and GN 687, 22 May 2019).

Although MWS has an existing AEL (renewal process currently underway), the extension of the Kareerand TSF would not fall under any listed activities nor require an AEL thus national minimum emission standards (NMES), AELs and AIRs are not discussed in this section.

4.2 Atmospheric Emissions Reporting Regulations

The National Atmospheric Emission Reporting Regulations (GN R283 in Government Gazette No. 38633) came into effect on 2 April 2015. The purpose of the regulations is to regulate 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). The NAEIS is a component of the South African Air Quality Information System (SAAQIS). Its objective is to provide all stakeholders with relevant, up to date and accurate information on South Africa's emissions profile for informed decision making.

Emission sources and data providers are classified according to groups. As the MWS operations would be classified under Group A ("Listed activity published in terms of section 21(1) of the Act"), so would the Project. Emission reports from this group must be made in the format required for NAEIS and if applicable should be in accordance with the AEL.

As per the regulations, MWS and/or their data provider are registered on the NAEIS system as they are currently operating. Data providers must inform the relevant authority of changes if there are any:

- Change in registration details;
- Transfer of ownership; or
- Activities being discontinued.

A data provider must submit the required information for the preceding calendar year to the NAEIS by 31 March of each year. Records of data submitted must be kept for a period of 5 years and must be made available for inspection by the relevant authority. AGA/MWS have been reporting on their emissions inventories since this legislation was instituted.

The relevant authority must request a data provider, in writing to verify the information submitted if the information is incomplete or incorrect. The data provider then has 60 days to verify the information. If the verified information is incorrect or incomplete the relevant authority must instruct a data provider, in writing, to submit supporting documentation prepared by an independent person. The relevant authority cannot be held liable for cost of the verification of data. A person guilty of an offence in terms of section 13 of these regulations is liable for penalties.

4.3 Atmospheric Dispersion Modelling Regulations

Air dispersion modelling provides a cost-effective means for assessing the impact of air emission sources, the major focus of which is to determine compliance with the relevant ambient air quality standards. Dispersion modelling provides a versatile means of assessing various emission options for the management of emissions from existing or proposed installations. Regulations regarding Air Dispersion Modelling were promulgated in GN 533, in Government Gazette No. 37804; 11 July 2014, and recommend a suite of dispersion models to be applied for regulatory practices as well as guidance on modelling input requirements, protocols and procedures to be followed. The Regulations regarding Air Dispersion Modelling are applicable –

(a) in the development of an air quality management plan, as contemplated in *Chapter 3* of the NEMAQA;
(b) in the development of a priority area air quality management plan, as contemplated in *Section 19* of the NEMAQA;
(c) in the development of an AIR, as contemplated in *Section 30* of the NEMAQA; and,
(d) in the development of a specialist air quality impact assessment study, as contemplated in *Chapter 5* of the NEMAQA.

Three *Levels of Assessment* are defined in the Regulations. The three levels are:

- Level 1: where worst-case air quality impacts are assessed using simpler screening models
- Level 2: for assessment of air quality impacts as part of license application or amendment processes, where impacts are the greatest within a few kilometres downwind (less than 50km)
- Level 3: require more sophisticated dispersion models (and corresponding input data, resources and model operator expertise) in situation:
    - where a detailed understanding of air quality impacts, in time and space, is required;
    - where it is important to account for causality effects, calms, non-linear plume trajectories, spatial variations in turbulent mixing, multiple source types & chemical transformations;
    - when conducting permitting and/or environmental assessment process for large industrial developments that have considerable social, economic and environmental consequences;

- when evaluating air quality management approaches involving multi-source, multi-sector contributions from permitted and non-permitted sources in an air-shed; or,
- when assessing contaminants resulting from non-linear processes (e.g. deposition, ground-level O3, particulate formation, visibility).

The first step in the dispersion modelling exercise requires a clear objective of the modelling exercise and thereby gives clear direction to the choice of the dispersion model most suited for the purpose. Accordingly, Level 2 was deemed appropriate.

4.4 South African National Ambient Air Quality Standards

Criteria pollutants are considered those pollutants most commonly found in the atmosphere, that have proven detrimental health effects when inhaled and are regulated by ambient air quality criteria. These generally include carbon monoxide (CO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), PM_{10}, $PM_{2.5}$, and ground level ozone (O_3).

The initial NAAQS were published for comment in the Government Gazette on 9 June 2007. The revised NAAQS were subsequently published for comment in the Government Gazette on the 13th of March 2009. The final revised NAAQS were published in the Government Gazette on the 24th of December 2009 (GN 1210, Government Gazette 32816) and additional standards for particulate matter less than 2.5 µm in aerodynamic diameter ($PM_{2.5}$) were published on the 29th June 2012 (GN 486, Government Gazette no. 35463). SA NAAQSs for the criteria pollutants assessed in this study are listed in Table 4-1.

Table 4-1: National Ambient Air Quality Standards

Pollutant	Averaging Period	Concentration (µg/m^3)	Permitted Frequency of Exceedance	Compliance Date
$PM_{2.5}$	24-hour	40	4	1 January 2016 till 31 December 2029 (currently enforceable)
	24-hour	25	4	1 January 2030
	1 year	20	-	1 January 2016 till 31 December 2029 (currently enforceable)
	1 year	15	-	1 January 2030
PM_{10}	24-hour	75	4	Currently enforceable
	1 year	40	-	Currently enforceable

4.5 National Dust Control Regulations

The NDCR were published on 1 November 2013 (GN R827 in Government Gazette No. 36974). The purpose of the regulations is to prescribe general measures for the control of dust in all areas including residential and non-residential areas. The standard for acceptable dustfall rates for residential and non-residential areas is set out in Table 4-2. According to these regulations the dustfall at the boundary or beyond the boundary of the premises where it originates cannot exceed 600 mg/m²- day in residential and light commercial areas; or 1 200 mg/m²-day in areas other than residential and light commercial areas.

In addition to the dust fall limits, the NDCR prescribe monitoring procedures and reporting requirements. This will be based on the measuring reference method ASTM 01739 averaged over 30 days.

Table 4-2: Acceptable dust fall rates

Restriction Area	Dust-fall rate (D) (mg/m²-day, 30-day average)	Permitted frequency of exceeding dust fall rate
Residential	D < 600	Two within a year, not sequential months
Non-residential	600 < D < 1 200	Two within a year, not sequential months

Note: The method to be used for measuring dustfall rate and the guideline for locating sampling points shall be ASTM D1739: 1970, or equivalent method approved by any internationally recognized body

4.6 Screening criteria for animals and vegetation

Limited information is available on the impact of dust on vegetation and grazing quality. While there is little direct evidence of the impact of dustfall on vegetation in the South African context, a review of European studies has shown the potential for reduced growth and photosynthetic activity in sunflower and cotton plants exposed to dust fall rates greater than 400 mg/m²- day (Farmer, 1993). In addition, there is anecdotal evidence to indicate that over extended periods, high dustfall levels in grazing lands can soil vegetation and this can impact the teeth of livestock (Farmer, 1993).

5 Air Quality Baseline

5.1 Affected Environment

MWS operations are located directly east of the town of Stilfontein, approximately 8 km east of Klerksdorp and 15 km north east of Orkney. These operations include gold and uranium processing plants and one operating TSF namely Kareerand. Buffelsfontein 1, 3, 4 & 5 and Hartebeesfontein 1/2, Hartebeesfontein 7 and Ellaton are in the process of being reclaimed. MWS (Chemwes) 4 & 5 and Hartebeesfontein 5/6 are dormant. Several TSF footprints have been cleared: MWS (Chemwes) 2 & 3, Flannagan and the New Klerksdorp Gold Estates (NKGE) TSFs.

The land use in the area comprises primarily of mining and agriculture. Aside from the residential areas near the Kareerand TSF, no other environmental sensitive areas have been identified. Table 2-3 is a summary of the nearby individual sensitive receptors that may be influenced by air pollution emissions from the proposed Project. These receptors are also depicted in Figure 1-1.

5.2 Atmospheric Dispersion Potential

Meteorological mechanisms direct the dispersion, transformation and eventual removal of pollutants from the atmosphere. The extent to which pollution will accumulate or disperse in the atmosphere is dependent on the degree of thermal and mechanical turbulence within the earth's boundary layer. This dispersion comprises vertical and horizontal components of motion. The stability of the atmosphere and the depth of the surface-mixing layer define the vertical component. The horizontal dispersion of pollution in the boundary layer is primarily a function of the wind field. The wind speed determines both the distance of downwind transport and the rate of dilution because of plume 'stretching'. The generation of mechanical turbulence is similarly a function of wind speed, in combination with surface roughness. The wind direction, and variability in wind direction, determines the general path pollutants will follow, and the extent of crosswind spreading. The pollution concentration levels therefore fluctuate in response to changes in atmospheric stability, to concurrent variations in the mixing depth, and to shifts in the wind field (Tiwary & Colls, 2010).

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

Use was made of measured on-site data from the Kareerand TSF weather station. Two years of hourly sequential data was available from the AGA operated Kareerand weather station; at the time that the final dispersion simulations commenced. With data availability above 90%, the AGA operated Kareerand weather station was used to construct wind roses, general climatic information such as diurnal temperature variations, atmospheric stability estimates and for dispersion modelling.

5.2.1 Local Wind Field

The vertical dispersion of pollution is largely a function of the wind field. The wind speed determines both the distance of downward transport and the rate of dilution of pollutants. The generation of mechanical turbulence is similarly a function of wind speed, in combination with surface roughness (Tiwary & Colls, 2010).

The 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 between 6 and 7 m/s. The dotted circles provide information regarding the frequency of occurrence of wind speed and direction categories. The frequency with which calms occurred, i.e. periods during which the wind speed was below 1 m/s are also indicated.

To avoid the overly conservative concentration estimates being made by AERMOD, it is recommended in the Regulations Regarding Dispersion Modelling (Government Gazette No. 37804; 11 July 2014) that all wind speeds greater than/equal to the anemometer starting threshold (AST) and less than 1 m/s be replaced with the value of 1 m/s. This approach was undertaken and 15% of the wind speeds were replaced with 1 m/s.

The period wind field and diurnal variability in the wind field are shown in Figure 5-1, while the seasonal variations are shown in Figure 5-2. The wind field is dominated by winds from the north-northeast. The strongest winds (>6 m/s) occurred mostly from the north-west and north-north-west. Calm conditions occurred 0.4% of the time (for 70 hours), with the average wind speed over the period of 3.06 m/s. Wind speeds increased during the day with a slight decrease in calm conditions (0.32% during the day to 0.48% during the night). Strong winds in excess of 6 m/s occurred most frequently during spring months. Calm conditions occurred most frequently during the winter months.

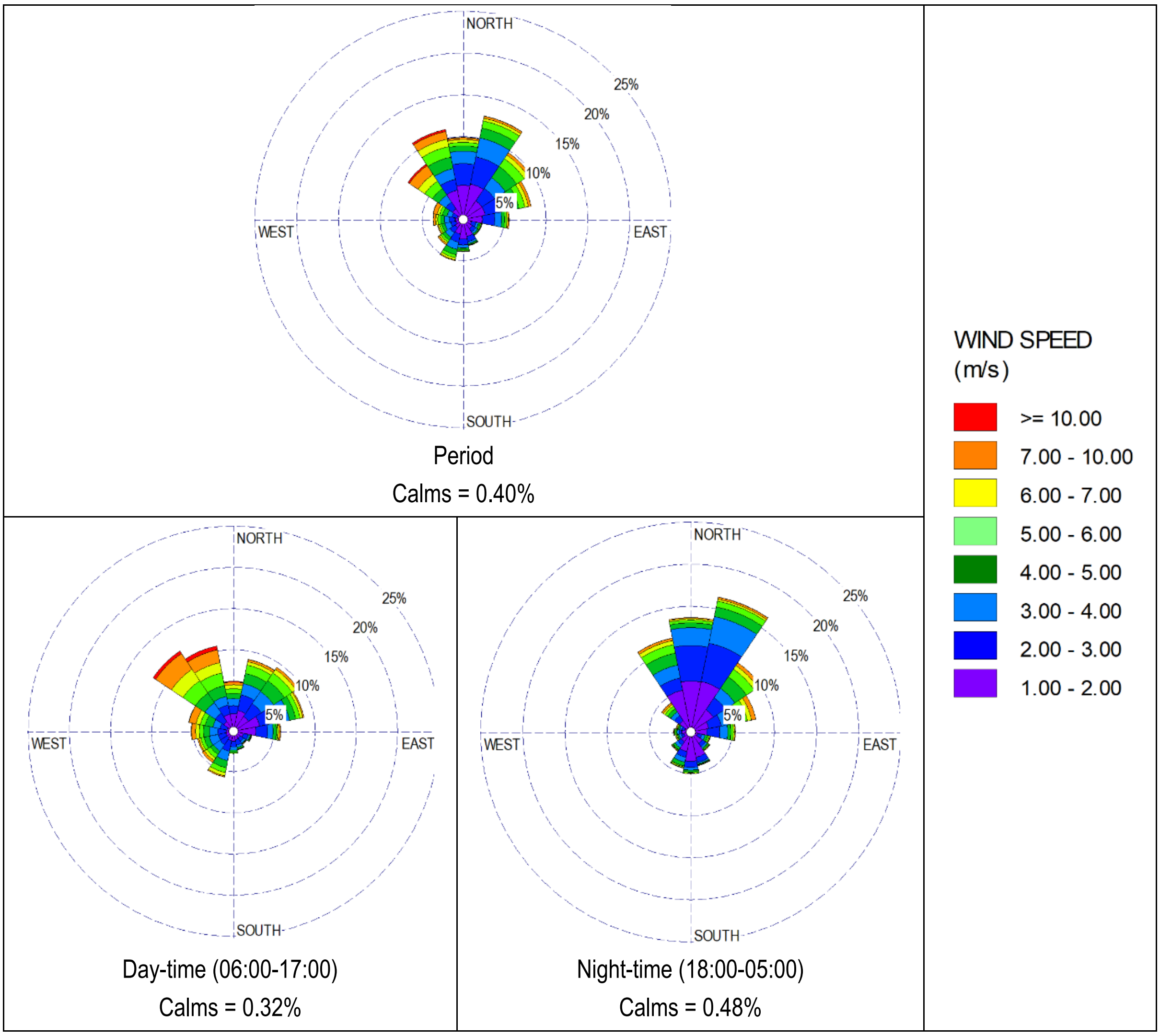

Figure 5-1: Period, day- and night-time wind roses (measured data, January 2018 to December 2019)

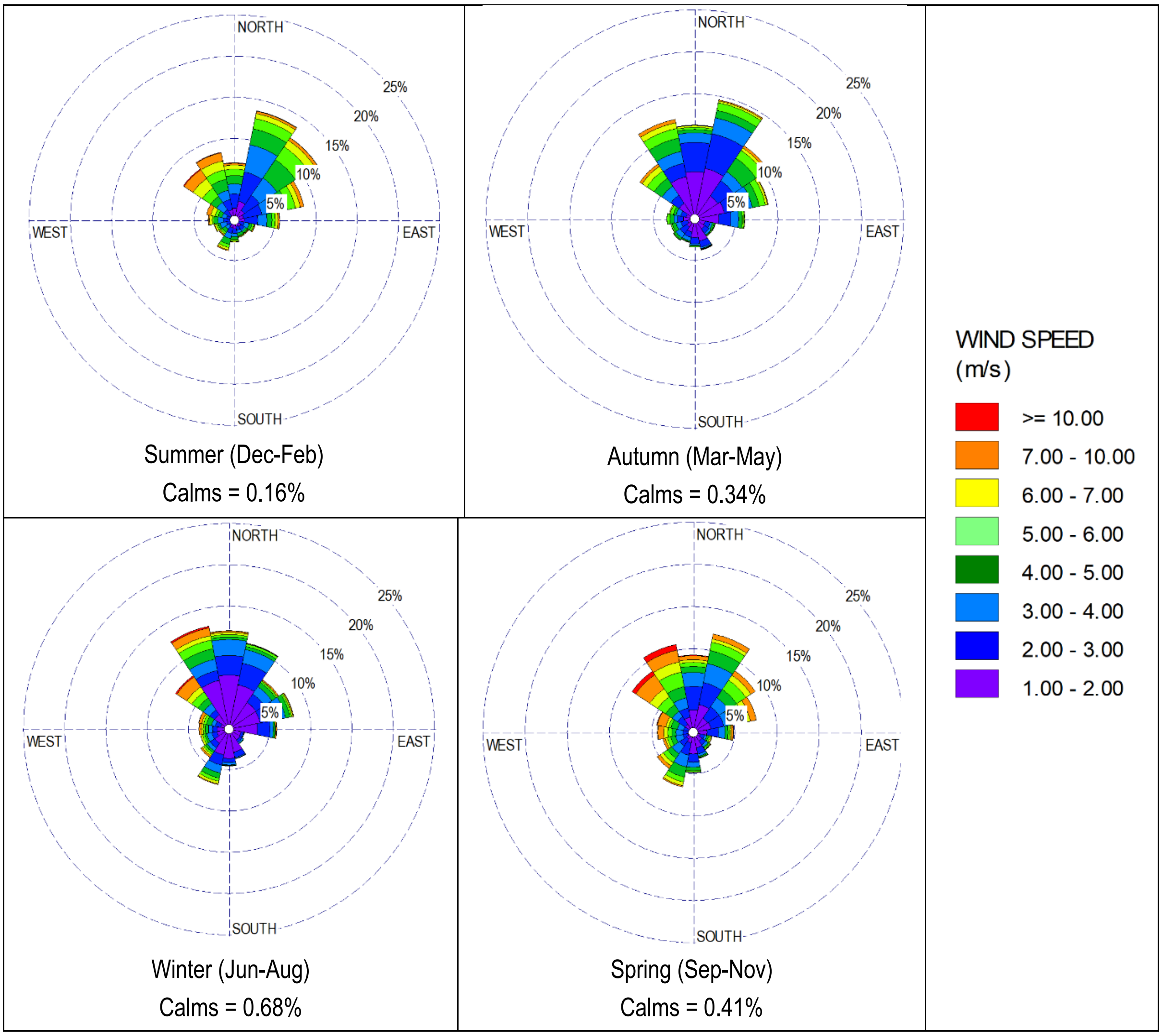

Figure 5-2: Seasonal wind roses (measured data, January 2018 to December 2019)

5.2.2 Ambient Temperature

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

Monthly mean, maximum and minimum temperatures are given in Table 5-1. Diurnal temperature variability is presented in Figure 5-3. Temperatures ranged between -6°C and 38°C. The highest temperatures occurred in December and the lowest in June and July. During the day, temperatures increase to reach maximum at around 14:00 in the afternoon. Ambient air temperature decreases to reach a minimum at around 06:00 i.e. just before sunrise.

Table 5-1: Monthly temperature summary (measured data, January 2018 to December 2019)

Monthly Minimum, Maximum and Average Temperatures (°C)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly Average	24	22	21	17	13	9	9	15	17	21	23	23
Hourly Maximum	37	33	34	28	28	26	27	29	34	36	37	38
Hourly Minimum	10	11	10	4	-1	-6	-6	-3	-3	3	5	10

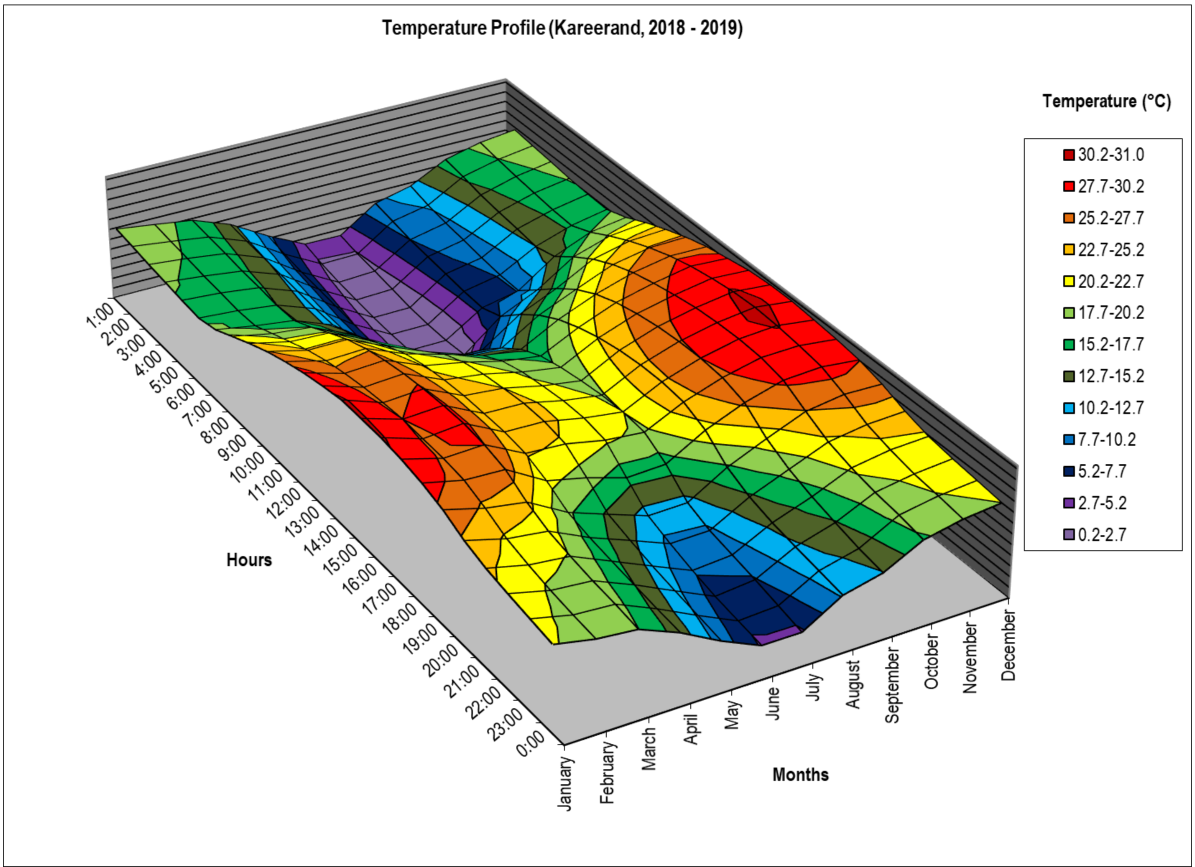

Figure 5-3: Diurnal temperature profile (measured data, January 2018 to December 2019)

5.2.3 Atmospheric Stability

The new generation air dispersion models differ from the models traditionally used in a number of 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 Obukhov length (often referred to as the Monin-Obukhov length).

The 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 daytime, the atmospheric boundary layer is characterised by thermal turbulence due to the heating of the earth's surface. 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 lower dilution potential.

Diurnal variation in atmospheric stability, as calculated from measured data, and described by the inverse Obukhov length and the boundary layer depth is provided in Figure 5-4. The highest concentrations for ground level, or near-ground level releases from non-wind dependent sources would occur during weak wind speeds and stable (night-time) atmospheric conditions. For elevated releases, unstable conditions can result in very high concentrations of poorly diluted emissions close to the stack. This is called *looping* (Figure 5-4 (c)) and occurs mostly during daytime hours. Neutral conditions disperse the plume fairly equally in both the vertical and horizontal planes and the plume shape is referred to as *coning* (Figure 5-4 (b)). Stable conditions prevent the plume from mixing vertically, although it can still spread horizontally and is called *fanning* (Figure 5-4 (a)) (Tiwary & Colls, 2010). For ground level releases such as fugitive dust the highest ground level concentrations will occur during stable night-time conditions.

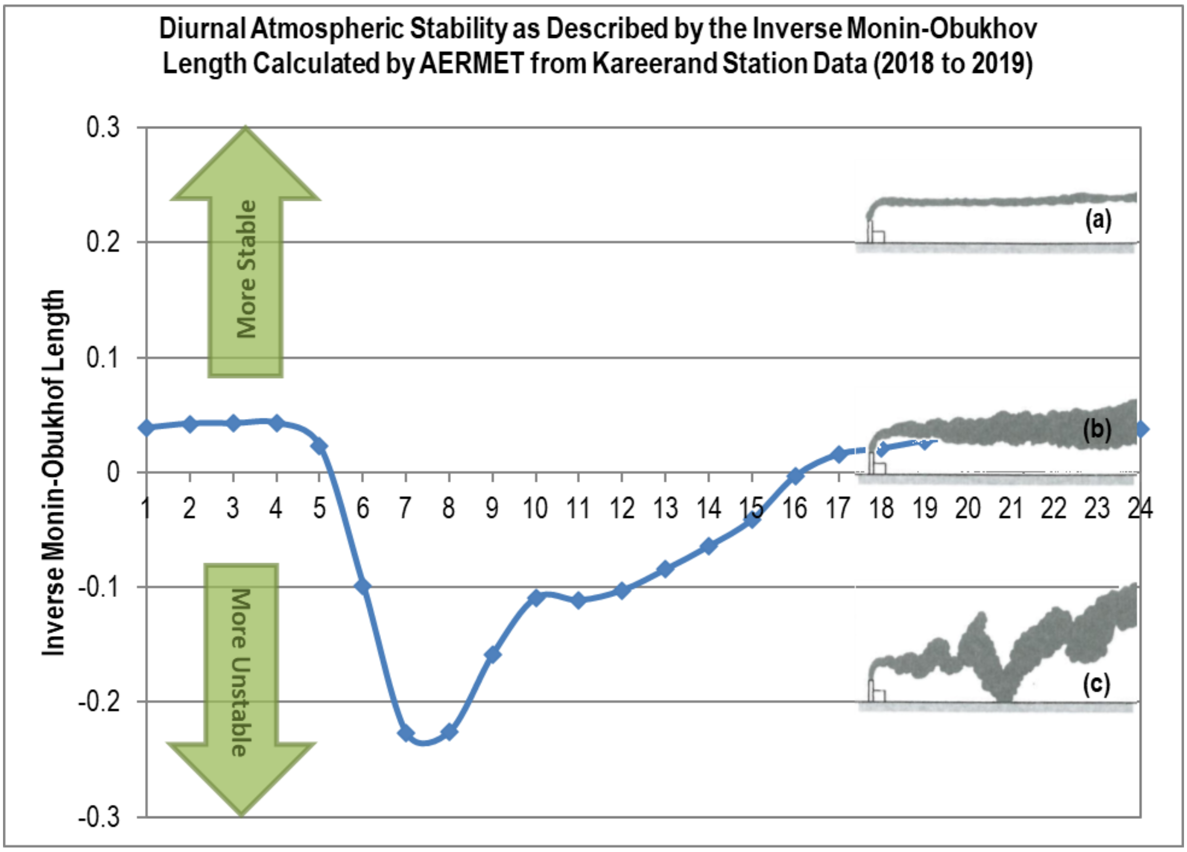

Figure 5-4: Diurnal atmospheric stability (AERMET processed measured data, January 2018 to December 2019)

5.2.4 Precipitation

Rainfall is important to air pollution studies since it represents an effective removal mechanism of atmospheric pollutants. Monthly rainfall obtained from the measured Klerksdorp station data is presented in Figure 5-5. Total annual rainfall from January 2016 to December 2016 amount to 479 mm. The model simulations did not include rainfall data.

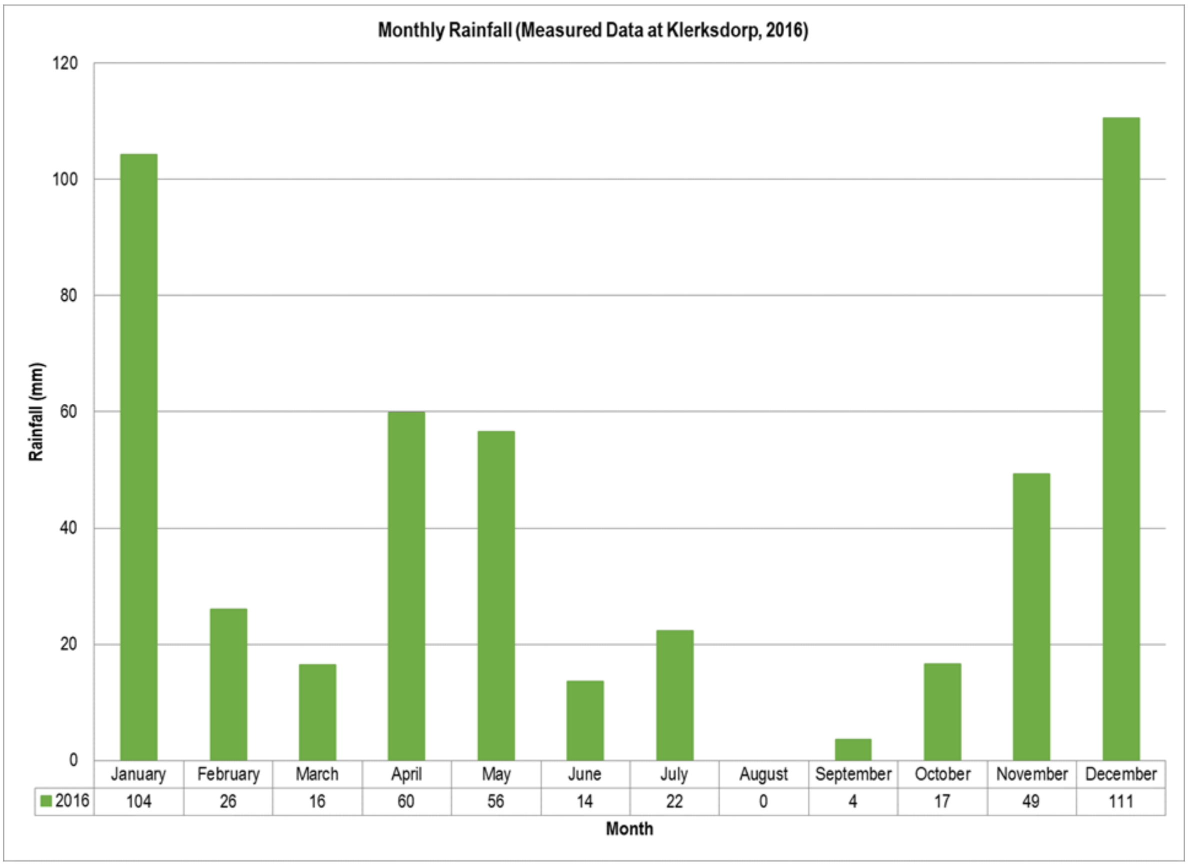

Figure 5-5: Monthly rainfall (measured data at Klerksdorp, January 2016 to December 2016)

5.3 Existing Air Quality

The current air quality in the study area is mostly influenced by mining activities at the VR, MWS and other companies' mining operations, as well as farming activities, domestic fires, vehicle exhaust emissions and dust entrained by vehicles. These emission sources vary from activities that generate relatively course airborne particulates (such as farmland preparation, dust from paved and unpaved roads, and the mine sites) to fine PM such as that emitted by vehicle exhausts, diesel power generators and processing operations. Other sources of PM include occasional fires in the residential areas and farm activities. Emissions from unpaved roads constitute a major source of emissions to the atmosphere in South Africa. When a vehicle travels on an unpaved road, the force of the wheels on the road surface causes pulverization of surface material. Particles are lifted and dropped from the rolling wheels, and the road surface is exposed to strong turbulent air shear with the surface. The turbulent wake behind the vehicle continues to act on the road surface after the vehicle has passed. Dust emissions from unpaved roads are a function of vehicle traffic and the silt loading on the roads. Emissions from paved roads are significantly less than those originating from unpaved roads, however they do contribute to the particulate load of the atmosphere. Particulate emissions occur whenever vehicles travel over a paved surface. The fugitive dust emissions are due to the re-suspension of loose material on the road surface. Emissions generated by wind erosion are dependent on the frequency of disturbance of the erodible surface. Every time that a surface is disturbed e.g. by mining, agriculture and/or grazing activities, its erosion potential is restored.

5.3.1 Sampled Dustfall Rates

Dust fallout sampling has been undertaken near Kareerand for some time and the Kareerand network was expanded in 2012 and then again in 2015. The current Kareerand network includes at seven locations in accordance with ASTM D1739 (1970).

Figure 5-6 acquired from the February 2020 dustfall report created by Skyside shows the locations of the Kareerand units. Results of the sampling campaign available to date are summarised in Table 5-2. Appendix C includes the dustfall graphs for 2009 to 2019.

Table 5-2: Summary of dustfall rates

Pollutant	Data source	Compliance Assessment
Dustfall	Results of dustfall sampling at seven locations for the period June 2009 to December 2019. Data availability for all Kareerand units: • Wouter de Wet = 100% • Kareerand TSF = 98% • Chubby Chicks 7 = 96% • Tailings North West = 98% • Tailings South East = 100% • Tailings = 99% • Tailings South = 99% • Tailings North = 98% • Umfula Eco Estate = 100%	SA NDCR limit for residential areas of 600 mg/m^2-day was not exceeded at any of the residential sites. SA NDCR limit for non-residential areas of 1 200 mg/m^2-day was exceeded once at three sites (see Appendix C). • Tailings South East - July 2015 • Tailings - October 2015

Figure 5-6: Kareerand dustfall monitoring network

5.3.2 Simulation Results for Regional Operations Based on the 2014/2015 Assessment Undertaken for AngloGold Ashanti

An air quality assessment was undertaken in 2014/2015 for the AGA VR and MWS operations, for the period of 2011 to 2013 using SAWS Klerksdorp meteorological data (including wind speed, wind direction and temperature). PM_{10} and TSP were included in the assessment. A summary of the findings, results and images for the assessment can be found in this section with detail on the emissions inventory provided in Appendix D.

The 2014/2015 assessment provides an insight into potential PM impacts as a result of the operations within the region. Impacts are expected to have decreased since 2013 due to changes in production, full reclamation of some of the TSFs and discontinuation of some operations. It is noted that changes in ownership may have also resulted in a change in operational procedures and throughput volumes of some of the sources included in the 2014/2015 assessment, however, the scale of impact of these changes is unknown.

The 2014/2015 dispersion modelling was undertaken to determine daily and annual average ground level concentrations of $PM_{2.5}$ and PM_{10} as well as daily dustfall rates. The averaging periods were selected to facilitate the comparison of simulated pollutant concentrations/dustfall with relevant NAAQS and NDCR, respectively.

The isopleth plots to follow depict the simulated $PM_{2.5}$ andPM_{10} concentrations as well as dustfall rates. $PM_{2.5}$ and PM_{10} concentrations are screened against the relative NAAQS as provided in Table 4-1. Dustfall is screened against the NDCR as set out in Table 4-2.

Simulations indicate exceedances of the current daily $PM_{2.5}$ NAAQS off-site. Figure 5-7 shows the frequency of exceedance of the simulated 24-hour average $PM_{2.5}$ concentrations, where a small area in the vicinity of the AGA Plant, north of Sulphur Paydam 1 and at the No. 9 Gold Plant exceeds the current NAAQS. Simulated annual average $PM_{2.5}$ concentrations (see Figure 5-8) do not exceed the current NAAQS.

The area over which simulated daily PM_{10} concentrations exceed the NAAQS limit value of 75 µg/m^3 more than the permitted 4 days per year is depicted in Figure 5-9. The area of exceedance is largely within quadrants to the north east and south-east quadrants of the AGA Plant. The area of exceedance extends approximately 2.5 km south of the plant's southern boundary, while the Sulphur Paydam, East Complex, Southeast Complex, Buffels 5 and Vaal Reef's mine plant all exceed within 1 km of their respective boundaries. Simulated annual average PM_{10} concentrations (see Figure 5-10) exceed the NAAQS of 40 µg/m^3. The areas of exceedance extend approximately 1 km south of the Buffels TSF, AngloGold Ashanti plant and Vaal Reef plant's southern boundary.

Simulated dustfall rates are depicted in Figure 5-11. The NDCR limit for residential areas (600 mg/m^2-day) is reached at the East Complex, Sulphur Paydam and Buffels TSFs, this being associated with their close proximity to one another amalgamating the particulate impact potential. This same region is the largest area where the NDCR limit for non-residentials areas (1 200 mg/m^2-day) is likely to be reached. The industrial limit is not reached at any sensitive receptor, or residential area included in the study. Other TSFs where the residential and industrial limit values are reached include the West Complex, Kopanang and Kareerand TSFs.

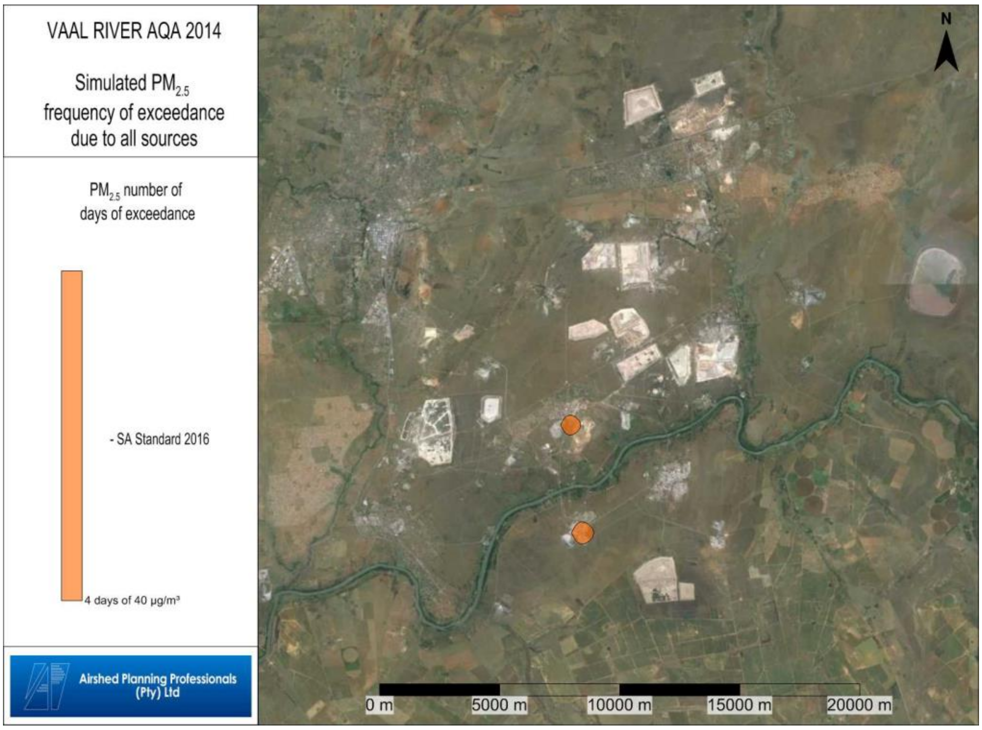

Figure 5-7: Simulated $PM_{2.5}$ Frequency of Exceedance (Jan. 2011 - Dec. 2013)

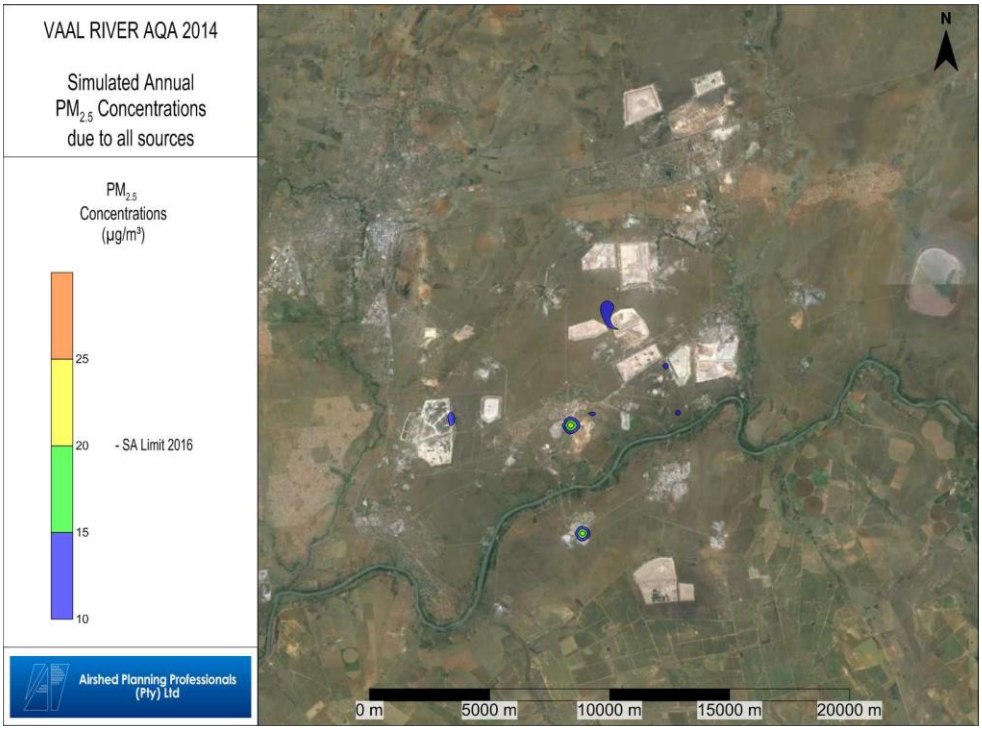

Figure 5-8: Simulated $PM_{2.5}$ annual average concentration (Jan. 2011 - Dec. 2013)

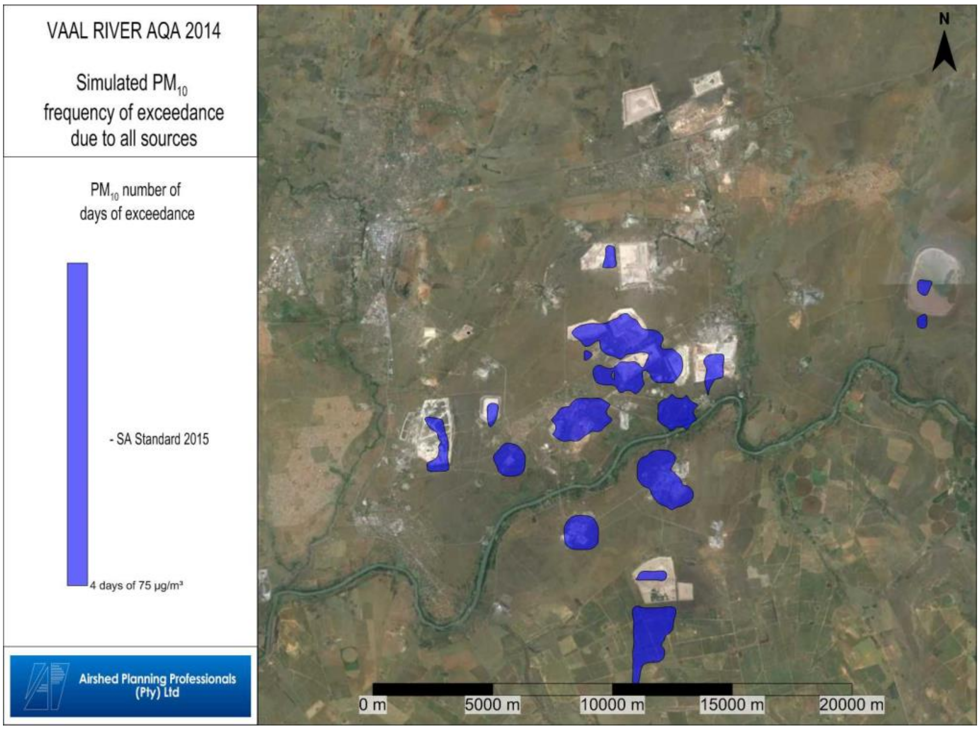

Figure 5-9: Simulated PM_{10} Frequency of Exceedance (Jan. 2011 - Dec. 2013)

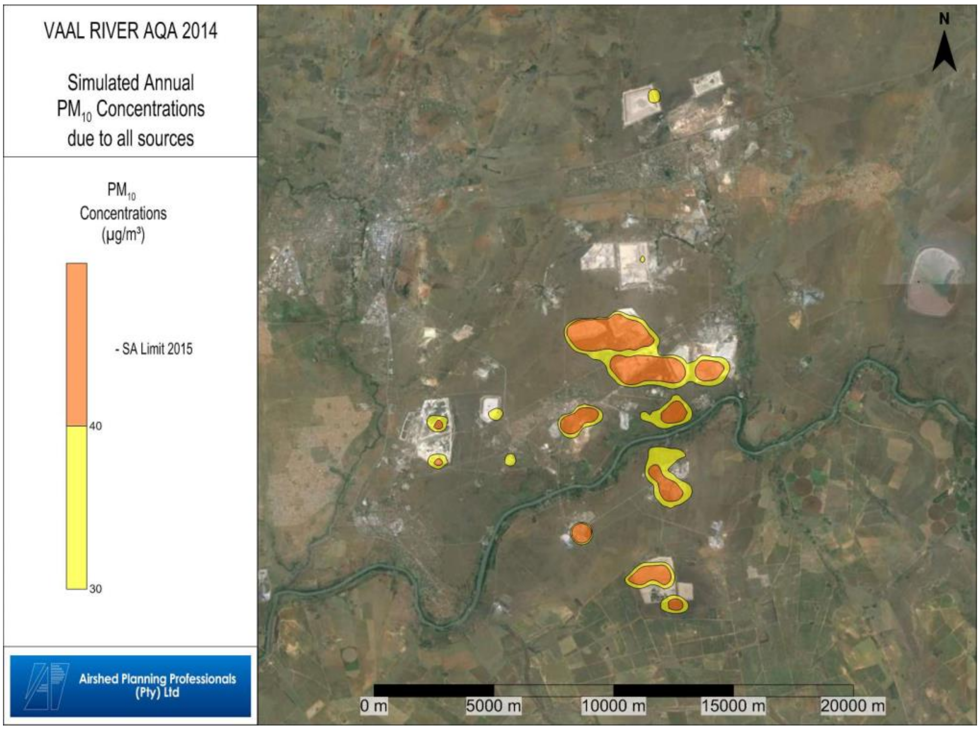

Figure 5-10: Simulated PM_{10} annual average concentration (Jan. 2011 - Dec. 2013)

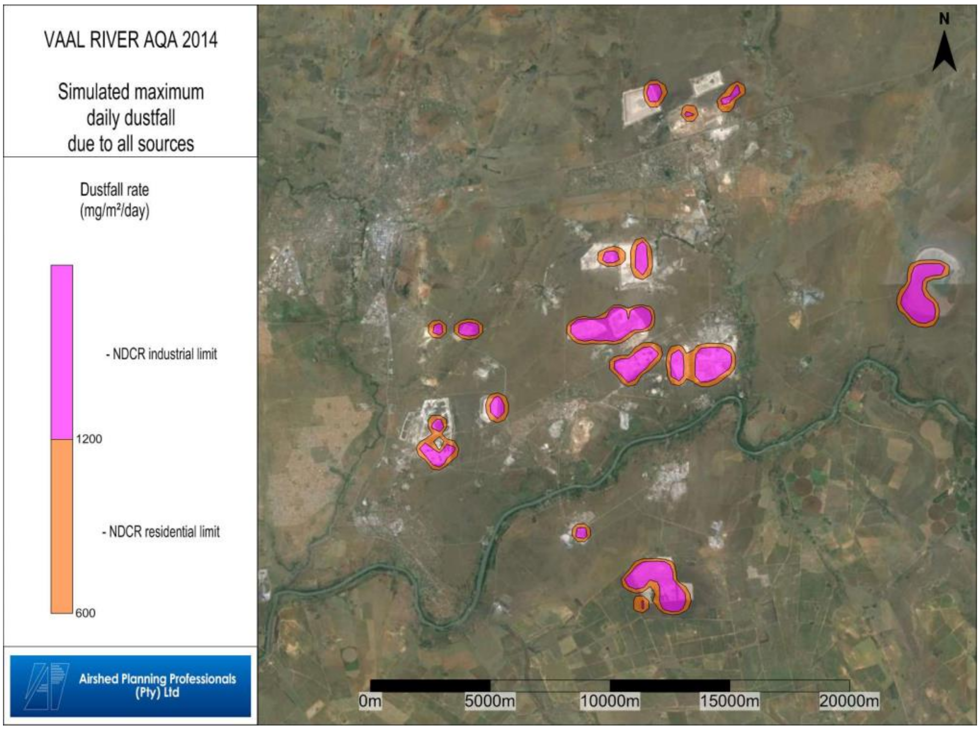

Figure 5-11: Simulated maximum daily dustfall rates (Jan. 2011 - Dec. 2013)

6 Impact Assessment: Construction Phase

6.1 Emissions Inventory for Construction Phase

During the construction phase several facilities need to be upgraded including the pipelines, storm water infrastructure and TSF service roads. The following activities will take place:

- Site establishment of construction phase facilities;
- Clearing of vegetation;
- Stripping and stockpiling of soil resources and earthworks;
- Collection, storage and removal of construction related waste;
- Construction of all infrastructure required for the operational phase; and
- Operation of mechanical equipment.

A summary of sources quantified, emissions estimation techniques applied, and source input parameters are summarised in Table 6-1 and the summary of estimated particulate emissions is provided in Table 6-2.

Table 6-1: Emission estimation techniques and parameters for construction

Source Group	Emission Estimation Technique	Input Parameters/Notes
General construction	US EPA emission factor (US EPA, 1995) $EF = k \cdot 2.69$ Where EF is the emission factor in t/ha-month k is the particle size multiplier (k_{TSP} – 1, k_{PM10} – 0.35, $k_{PM2.5}$ – 0.18)	A total infrastructure/disturbed area of ~400 ha was estimated from the site layout map. It was assumed that 25% of this area would be under construction at any given point in time. It is assumed that roads will likely be unpaved for most of the construction period. **Hours of operation:** 5 days per week (6 days when required), 12-hours per day (06H00 – 18H00) **Design mitigation:** None **Additional mitigation:** Dust management and water sprays
Construction equipment	NPI single valued emission factors (ADE, 2008) for: Excavator Bulldozer Tractor Crane Front End Loader	**Operating power:** Excavator – 304 kW Bulldozer – 114 kW Tractor – 60.8 kW Crane – 76 kW Front End Loader – 57 kW **Hours of operation:** 5 days per week (6 days when required), 12-hours per day (06H00 – 18H00) **Design Mitigation:** None

Table 6-2: Summary of estimated particulate emissions in tons per annum for construction

Source Group	Estimated UNMITIGATED Particulate Emissions (tpa)			Estimated MITIGATED Particulate Emissions (tpa)		
	$PM_{2.5}$	PM_{10}	TSP	$PM_{2.5}$	PM_{10}	TSP
General Construction	4.00	8.00	22.9	2.00	4.00	11.4
Mobile Construction Equipment	1.75	1.75	1.75	-	-	-

6.2 Assessment of Impact – Construction

Dispersion modelling for the construction phase was considered to be unrepresentative of the actual activities that will result in dust and gaseous emissions. It is not anticipated that the various construction activities will result in higher $PM_{2.5}$ and PM_{10} GLCs and dustfall rates than the operational phase activities. The temporary nature of the construction activities will likely reduce the significance of the potential impacts. The main pollutants of concern are PM. A qualitative assessment of the PM_{10}, $PM_{2.5}$ and TSP impacts during construction operations is discussed below.

The CGS ranking methodology results in an unreasonably high likelihood since the activity is governed by legislation. The high likelihood significantly inflates the risk of the impacts. The severity of the impact was selected based on the criteria as set out in Section 2.4.

Two potential direct construction phase impacts on the air quality of the area were identified:

- A1: Potential impact on human health from increased pollutant concentrations associated with construction activities;
- A2: Increased nuisance dustfall rates associated with construction activities;

A1 would likely impact on human health whereas A2 would impact on amenities.

6.2.1 Impact A1: Potential for Impacts on Human Health from Increased Pollutant Concentrations Associated with General Construction Activities

The sources of emissions would include site establishment in proposed additional operating areas; vegetation clearing; stripping and stockpiling of topsoil and other earthworks; collection, storage and removal of construction related waste; the construction of all required infrastructure; and the operation of mechanical equipment. It is unlikely that the long-term and short-term NAAQS will be exceeded at AQSRs (with and without mitigation). The construction operations are likely to last for less than two years.

Unmitigated PM_{10} and $PM_{2.5}$ emissions in the project area will *very seldom* result in an *insignificant negative* impact on *human health* in the *medium-term* in the *study area*. The risk is likely LOW; however, using the GCS impact rating methodology, the environmental risk of this impact is MODERATE; without and with mitigation applied.

6.2.2 Impact A2: Increased Nuisance Dustfall Rates Associated with General Construction Activities

The sources of emissions would include site establishment in proposed additional operating areas; vegetation clearing; stripping and stockpiling of topsoil and other earthworks; collection, storage and removal of construction related waste; the construction of all required infrastructure; and the operation of mechanical equipment. It is unlikely that the NDCR limit for residential areas will be exceeded at AQSRs (with and without mitigation). The construction operations are likely to last for less than two years.

Unmitigated TSP emissions in the project area will *very seldom* result in an *insignificant negative* impact on *amenitie*s in the *medium-term* in the *study area*. The risk is likely LOW; however, using the GCS rating methodology the environmental risk of this impact is MODERATE; without and with mitigation applied.

Table 6-3: Health risk impact significance summary table for the construction operations

	Severity	Spatial Scale	Duration	**Consequence**	Frequency of Activity	Frequency of Impact	Legal	Detection	**Likelihood**	**Risk**
Without mitigation	1	1	3	**5**	5	1	5	4	**15**	**75** **Moderate**
<u>Recommended mitigation measures:</u> **Reduction of fugitive PM emissions through the watering of roads, stockpiles and inactive open areas and the use of screens.** **Reductions of vehicle exhaust emissions through the use of better quality diesel; and inspection and maintenance programs.**										
With mitigation	1	1	3	**5**	5	1	5	4	**15**	**75** **Moderate**

Table 6-4: Nuisance impact significance summary table for the construction operations

	Severity	Spatial Scale	Duration	**Consequence**	Frequency of Activity	Frequency of Impact	Legal	Detection	**Likelihood**	**Risk**
Without mitigation	1	1	3	**5**	5	1	5	1	**12**	**60** **Moderate**
<u>Recommended mitigation measures:</u> **Reduction of fugitive PM emissions through the watering of roads, stockpiles and inactive open areas and the use of screens.** **Reductions of vehicle exhaust emissions through the use of better quality diesel; and inspection and maintenance programs.**										
With mitigation	1	1	3	**5**	5	1	5	1	**12**	**60** **Moderate**

7 IMPACT ASSESSMENT: OPERATIONAL PHASE

7.1 Emissions Inventory

Expected sources of atmospheric emissions during the operational phase include:

- Particulate emissions from vehicle entrainment along the existing unpaved access road;
- Particulate emissions from vehicles' exhaust; and
- Particulate emissions from concurrent rehabilitation equipment operating on the TSF area;
- Particulate emissions from concurrent rehabilitation equipment exhaust; and
- Particulate emissions from wind-blown dust from additional TSF area.

The current volume of vehicles (included in the baseline) travelling along the existing access road is not expected to change during the future operations, thus they have been quantified to avoid duplication. There will be additional equipment active on the TSF area due to the concurrent rehabilitation during the future operations. The operations of this equipment are highly variable making it difficult to estimate emissions for the entrainment on the TSF area, so instead the rehabilitation emission factor was determined using the general construction emission factor. The rehabilitation equipment exhaust emissions have also been estimated.

Wind erosion is a complex process, including three different phases of particle entrainment, transport and deposition. It is primarily influenced by atmospheric conditions (e.g. wind, precipitation and temperature), soil properties (e.g. soil texture, composition and aggregation), land-surface characteristics (e.g. topography, moisture, aerodynamic roughness length, vegetation and non-erodible elements) and land-use practice (e.g. farming, grazing and mining) (Shao, 2008).

Windblown dust (WBD) generates from natural and anthropogenic sources. For wind erosion to occur, the wind speed needs to exceed a certain threshold, called the friction velocity. This relates to gravity and the inter-particle cohesion that resists removal. Surface properties such as soil texture, soil moisture and vegetation cover influence the removal potential. Conversely, the friction velocity or wind shear at the surface is related to atmospheric flow conditions and surface aerodynamic properties. Thus, for particles to become airborne the wind shear at the surface must exceed the gravitational and cohesive forces acting upon them, called the threshold friction velocity (Shao, 2008). 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 the friction velocity.

Literature indicates a friction velocity of 9 m/s to initiate erosion from two gold tailings storage facilities in in New Brunswick and Ontario, Canada (Mian & Yanful, 2003). A case study conducted for a gold tailings facility in South Africa, indicated dust mobilisation for wind speeds above 3 m/s (dust flux), with most dust emissions when winds exceeded between 6.7 and 8.8 m/s, depending on the surface conditions (Liebenberg-Enslin, 2014). Wind speed data used in this study indicate exceedances of 8.8 m/s for 5% of the time and emissions resulted from wind speeds exceeding 9.8 m/s (3%).

Sources of emissions generally associated with these TSFs include windblown dust and radon gas. A summary of emission sources quantified, estimation techniques applied, and source input parameters is included in Table 7-2.

Table 7-1: Tailings content and particles size distribution for three particle size bins of $PM_{2.5}$, PM_{10} and PM_{75} (CSIR Climate Studies, 2016)

Source	Clay (<2 µm) (%)	Silt (2-63 µm) (%)	Sand (63-2000 µm) (%)	Normalised percentage of $p_m(d)$ fractions		
				$PM_{2.5}$ (d < 2.5 µm)	PM_{10} (d < 10 µm)	PM_{75} (d < 75 µm)
TSF	2.35	57.75	39.90	3.56	13.34	83.10

Emission quantification was done using the in-house modelled ADDAS (Burger, Held, & Snow, 1997); (Burger L. W., 2010). This model is based on the dust emission scheme of Marticorena & Bergametti (1995) and Shao et al. (2011). For the purpose of this study, the Marticorena & Bergametti (1995) dust flux model 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. A summary of estimated particulate emissions in tonnes per annum (tpa) associated with the current Kareerand TSF and future Kareerand TSF operations is provided in Table 7-3.

Table 7-2: Emission estimation techniques and parameters

Source Group	Emission Estimation Technique	Input Parameters and Activities
Kareerand TSF wind erosion	**<u>Windblown dust</u>** The calculation of a windblown dust emission rate for every hour of 2018 AND 2019 was carried out using the ADDAS model, which is based on the dust emission model proposed by Marticorena & Bergametti (1995). A literature review on the model is provided in Appendix C. **<u>Radon gas</u>** Airshed modelled a unit release rate of radon gas and the Radiation Protection Specialist will assess the potential impact from the TSF on the receiving environment.	**<u>Windblown dust</u>** Exposed area was included in emission estimations based on project layouts and google earth images: • Current Kareerand TSF = 550 ha (it is estimated that between 80 and 100 ha is wet) • Future Kareerand TSF = 898 ha **<u>Radon gas</u>** The assumption is made that radon is released from the entire surface area of a source, irrespective of any physical parameters or mitigation measures which could affect the release of particulates. For the radon modelling, moisture content of the tailings and vegetation cover <u>was not</u> taken into consideration. The following areas were modelled for the radon gas: • Current Kareerand TSF = 550 ha • Future Kareerand TSF = 898 ha
Future concurrent rehabilitation operations	US EPA general construction emission factor (US EPA, 1995) $EF = k \cdot 2.69$ Where EF is the emission factor in t/ha-month k is the particle size multiplier (k_{TSP} – 1, k_{PM10} – 0.35, $k_{PM2.5}$ – 0.18)	A total disturbed area of ~950 ha was assumed. It was assumed that 10% of this area would be under rehabilitation at any given point in time. The active rehabilitation area will be exposed and uncovered. **Hours of operation:** 7 days per week, 12-hours per day (06H00 – 18H00) **Design mitigation:** None **Additional mitigation:** Dust management, netting, vegetation and water sprays
Future concurrent rehabilitation equipment exhaust	NPI single valued emission factors (ADE, 2008) for:	**Operating power per type:** Excavator – 304 kW

Source Group	Emission Estimation Technique	Input Parameters and Activities
	3 x Excavators 2 x Bulldozers 2 x Loaders 1 x Grader 17 x Dump trucks	Bulldozer – 114 kW Loader – 57 kW Grader – 76 kW Dump truck – 210 kW **Hours of operation:** 7 days per week, 12-hours per day (06H00 – 18H00) **Design Mitigation:** None

Dispersion modelling was completed for "*current*" which includes the wind-blown dust from the current Kareerand TSF area; and "*future*" which includes the wind-blown dust from the future Kareerand TSF (current plus expansion area). For the "future" there are two scenarios that were included. "Future with current topography" makes use of the current terrain data as input into the model, this would be indicative of the initial years of operation. "Future with final topography" makes use of the future terrain data as input into the model, this would be indicative of the final years of operation. Since the rehabilitation equipment operational area is not consistent throughout operation of the TSF, dispersion modelling is likely to unrepresentative of the actual rehabilitation activities. The emissions from the rehabilitation operations were estimated to be minimal in comparison to wind erosion.

Table 7-3: Summary of estimated particulate emissions in tonnes per annum

Source Group	Simulated Period[(c)]	Estimated UNMITIGATED Particulate Emissions (tpa)			Estimated MITIGATED Particulate Emissions (tpa)[(a)]		
		$PM_{2.5}$	PM_{10}	TSP	$PM_{2.5}$	PM_{10}	TSP
Current Kareerend TSF wind erosion[(b)]	2018	120	282	1 516	98.5	230	1 241
	2019	14.0	32.8	165	11.5	26.9	135
Future Kareerand TSF wind erosion[(b)]	2018	198	459	2 473	-	-	-
	2019	22.9	53.5	296			
Future rehabilitation		23.9	23.9	23.9	-	-	-
Future rehabilitation equipment exhaust		18.8	18.8	18.8	-	-	-

Notes:

(a) Estimated emissions when considering that 100 ha is wet

(b) Threshold wind speed was determined to be approximately 8.8 m/s. Thus when winds speeds are 8.8 m/s or higher, emissions are expected to occur.

(c) Rehabilitation related emissions are based on constant emission factors used and will not vary annually.

7.2 Assessment of Impact – Current Operations

Simulation results of windblown dust emissions from the current Kareerand TSF area are discussed in this section. Isopleth plots have been included even though the assessment criteria were not exceeded. The simulation results are for the erosion of the Kareerand TSF by wind only and do not include any other source contributions in the area.

7.2.1 Inhalable particulate matter (PM_{10})

Simulated annual average PM_{10} concentrations do not exceed the NAAQS of 40 µg/m³ (Figure 7-1). The 24-hour NAAQS (4 days of exceedance of 75 µg/m³) are exceeded on Kareerand TSF but not at any AQSRs (Figure 7-2). The NAAQS are intended to indicate safe daily exposure levels for the majority of the population, including the very young and the elderly, throughout an individual's lifetime. Simulated results show that the short-term NAAQS are exceeded only at the TSF and not at any of the AQSRs, thus the simulated operations are unlikely to be a significant risk to human health at the surrounding receptors.

7.2.2 Respirable particulate matter ($PM_{2.5}$)

Simulated annual average $PM_{2.5}$ concentrations do not exceed the NAAQS of 20 µg/m^3 (Figure 7-3). The 24-hour NAAQS (4 days of exceedance of 40 µg/m^3) are exceeded only on the TSF and not at any AQSRs (Figure 7-4). Simulated results show that the short-term NAAQS are exceeded only at the TSF and not at any of the AQSRs; thus, the simulated operations are not likely to be a significant risk to human health at the surrounding receptors.

7.2.3 Fallout Dust

Based on the highest monthly simulated dustfall rates, the daily average dustfall rate exceeds the NDCR residential limit of 600 mg/m²-day at one of the AQSRs (Vaal River - Property Owners 8) and are close to 600 mg/m²-day at two others (Figure 7-5). Based on the highest monthly simulated dustfall rates, the daily average dustfall rate exceeds the NDCR residential limit of 600 mg/m²-day but not at any of the AQSRs (Figure 7-6). The entire area covered by the isopleths are areas in which the natural vegetation and farming crops may be affected. Dust fallout is associated with nuisance impacts – it reduces the appearance of and personal satisfaction gained from amenities. Based on simulations there was likely to be dustfall rates higher than the NDCR residential limit at one AQSRs during September 2018 (Vaal River - Property Owners 8), but the dustfall rates would have been in compliance with NDCR for residential areas as it does not exceed for consecutive months or more than three months in a year at this receptor. The September 2018 meteorological data showed a high frequency of wind speeds above 7 m/s from the north-north-westerly sectors as well as the north-north-easterly sector on the 5th and 6th of September 2018. The wind rose for September 2018 is shown in Figure 7-7 and for the 5th and 6th of September 2018 in Figure 7-8. An article in a South African Weather Service WeatherSMART News describes a secondary development associated with a frontal system around this period that may have contributed to the high wind speeds and the measured wind directions (Heyneke & Phatudi, 2019).

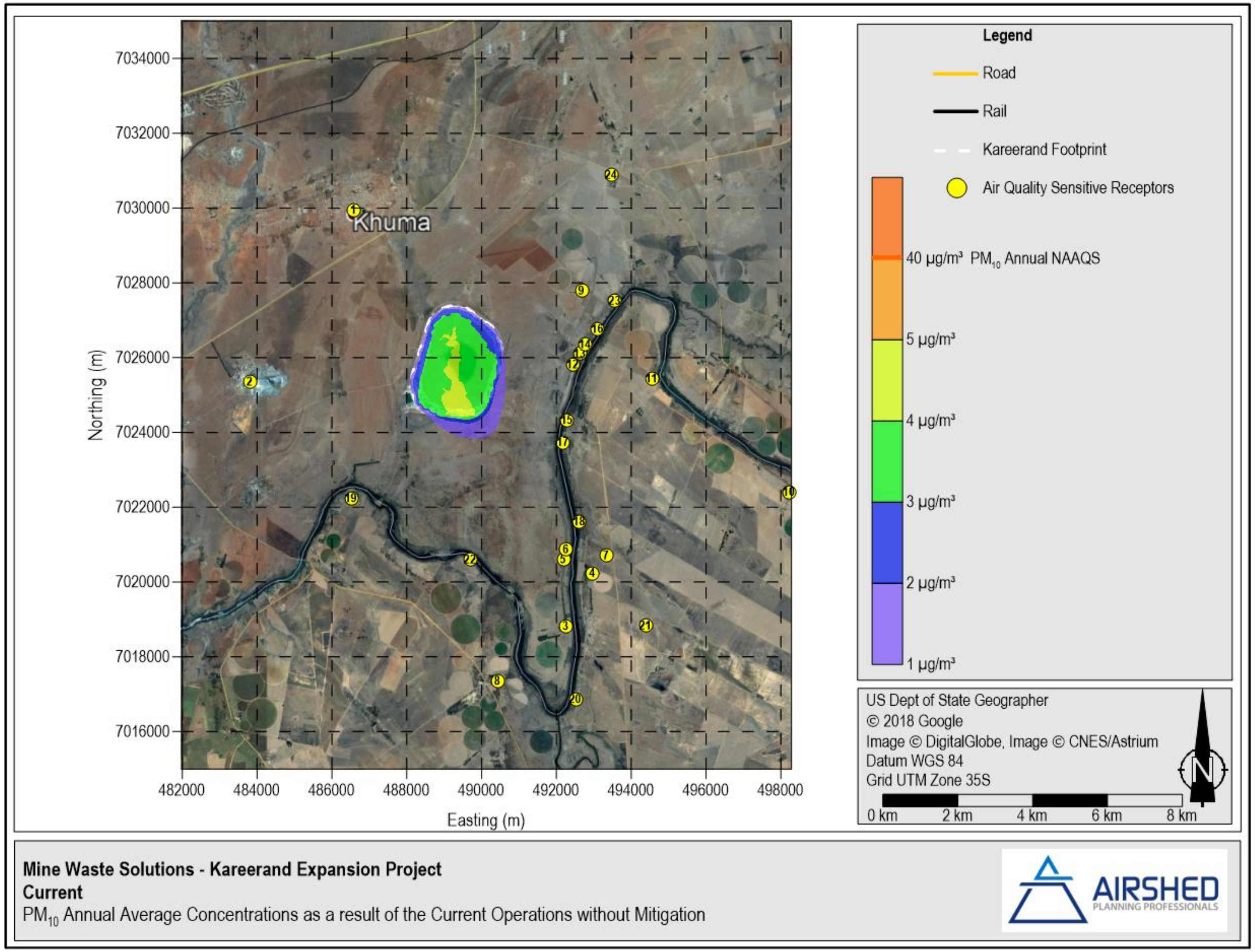

Figure 7-1: Current: simulated annual average PM_{10} concentrations

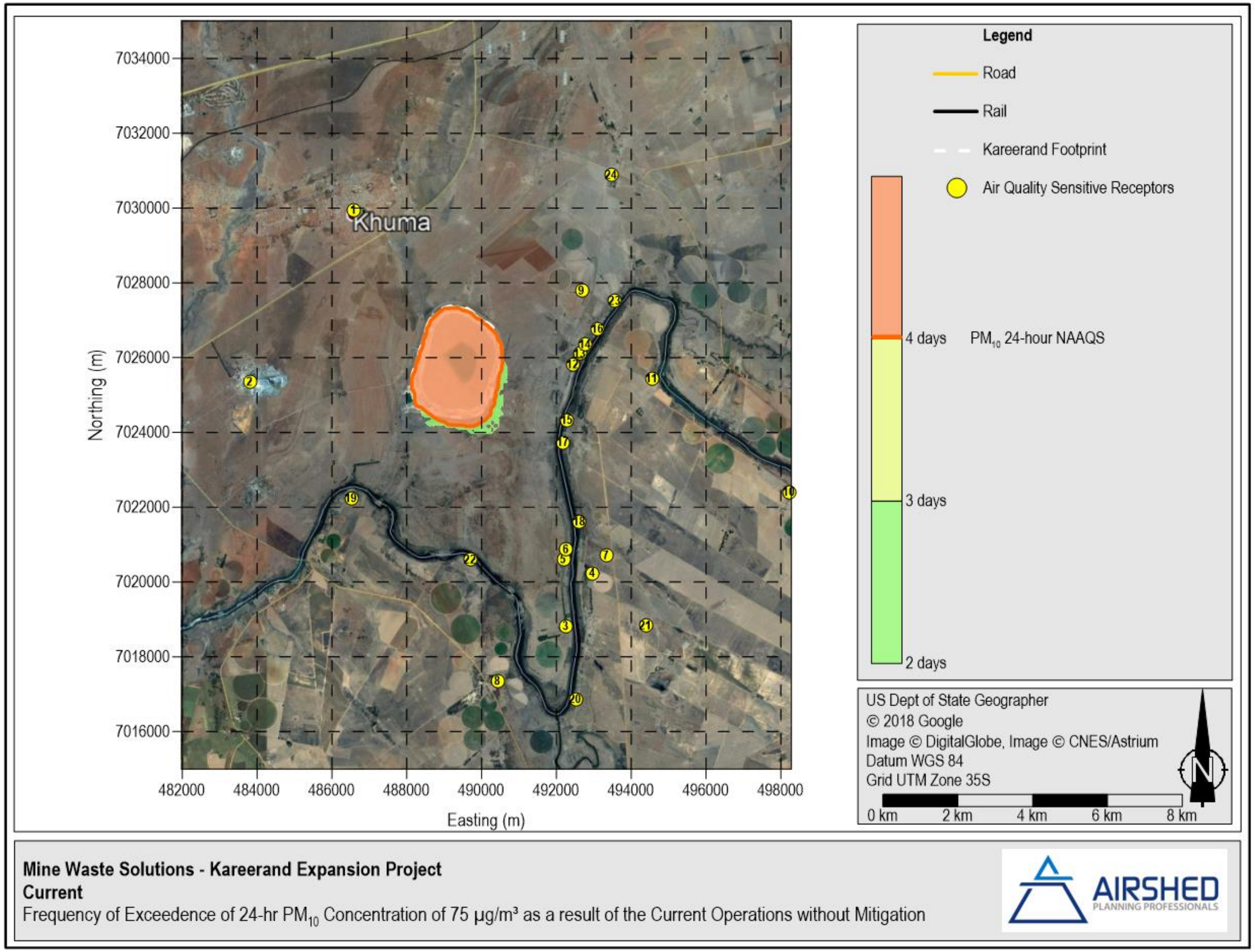

Figure 7-2: Current: frequency of exceedance of the 24-hour average PM_{10} NAAQS limit of 75 µg/m³

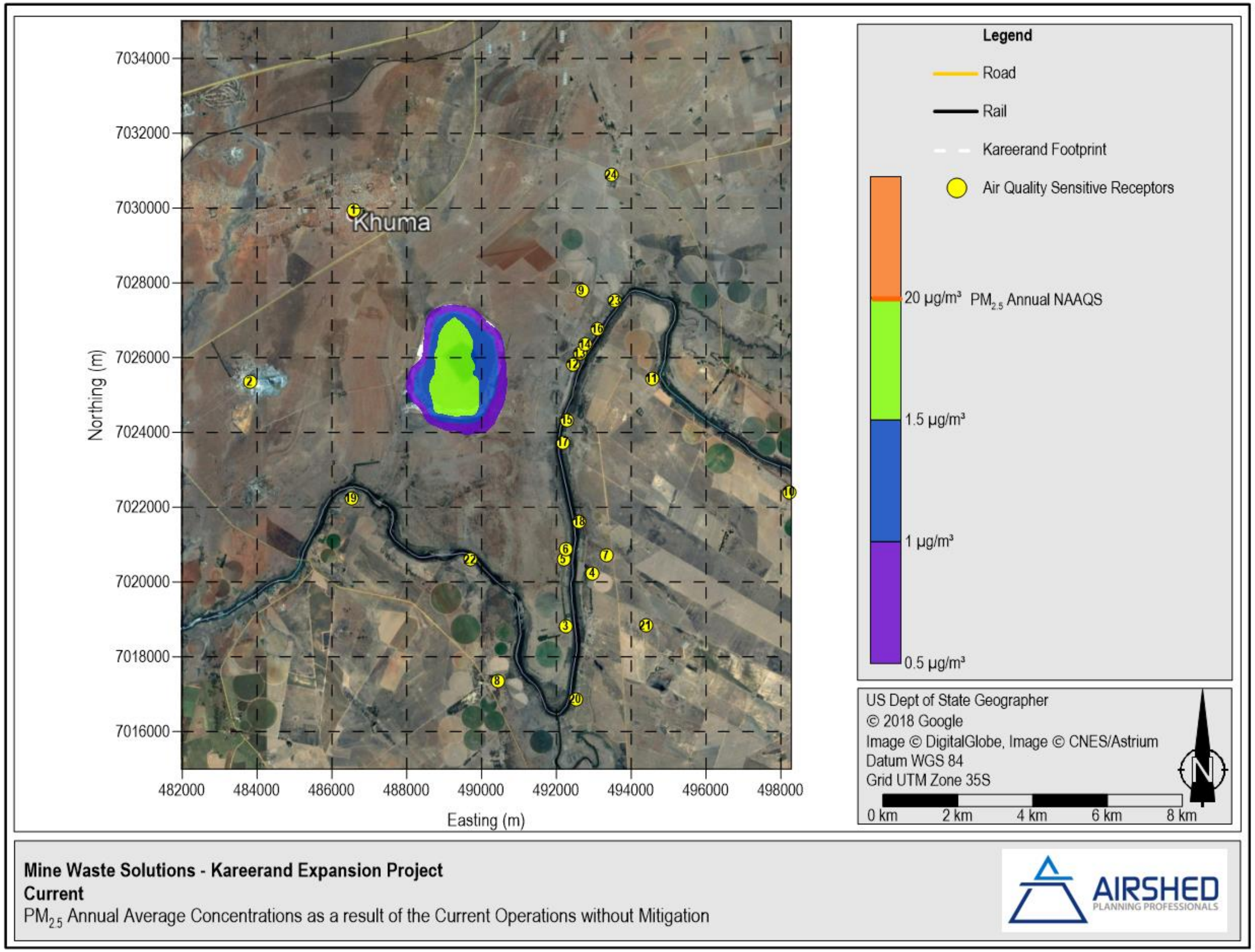

Figure 7-3: Current: simulated annual average $PM_{2.5}$ concentrations

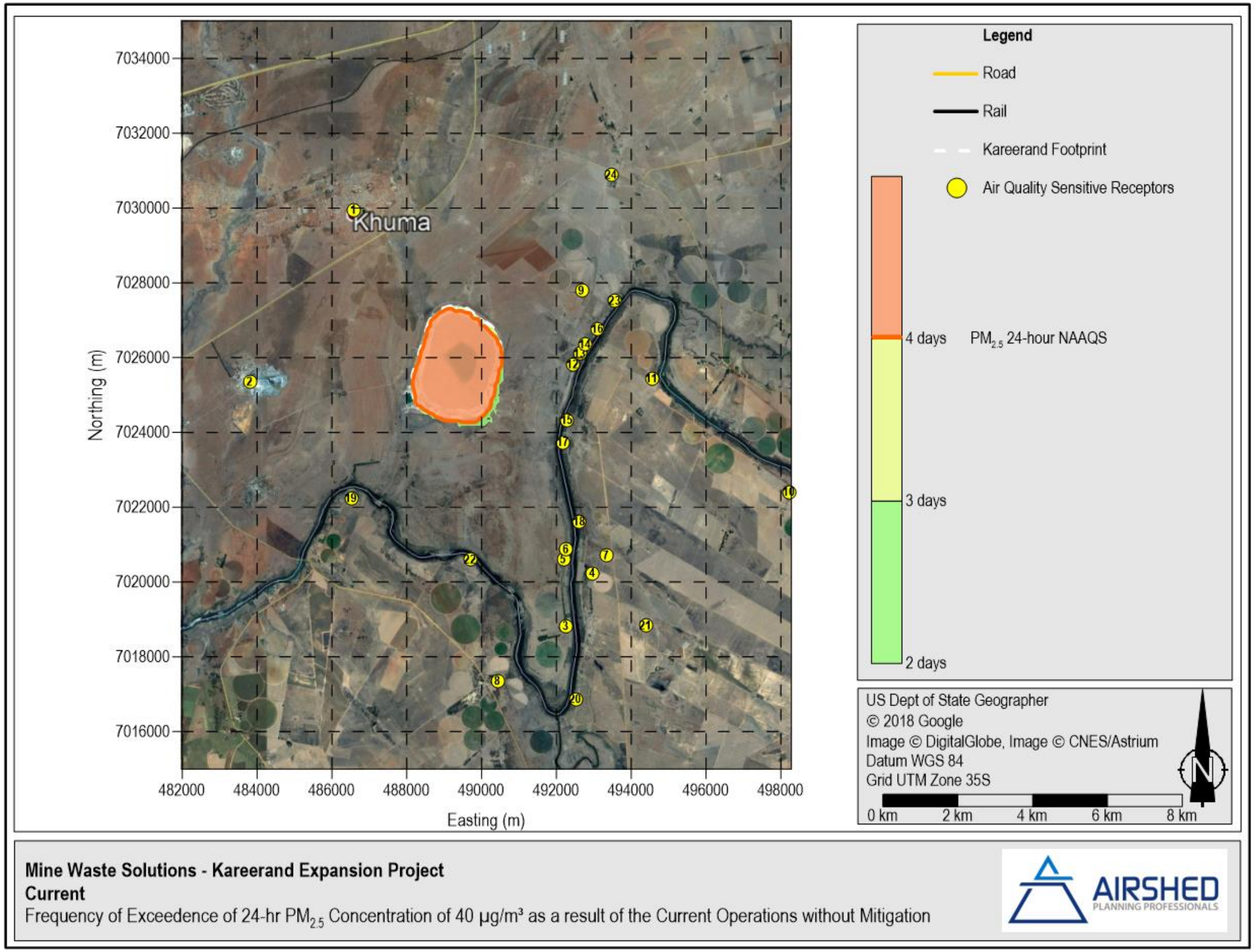

Figure 7-4: Current: frequency of exceedance of the 24-hour average PM$_{2.5}$ NAAQS limit of 40 µg/m³

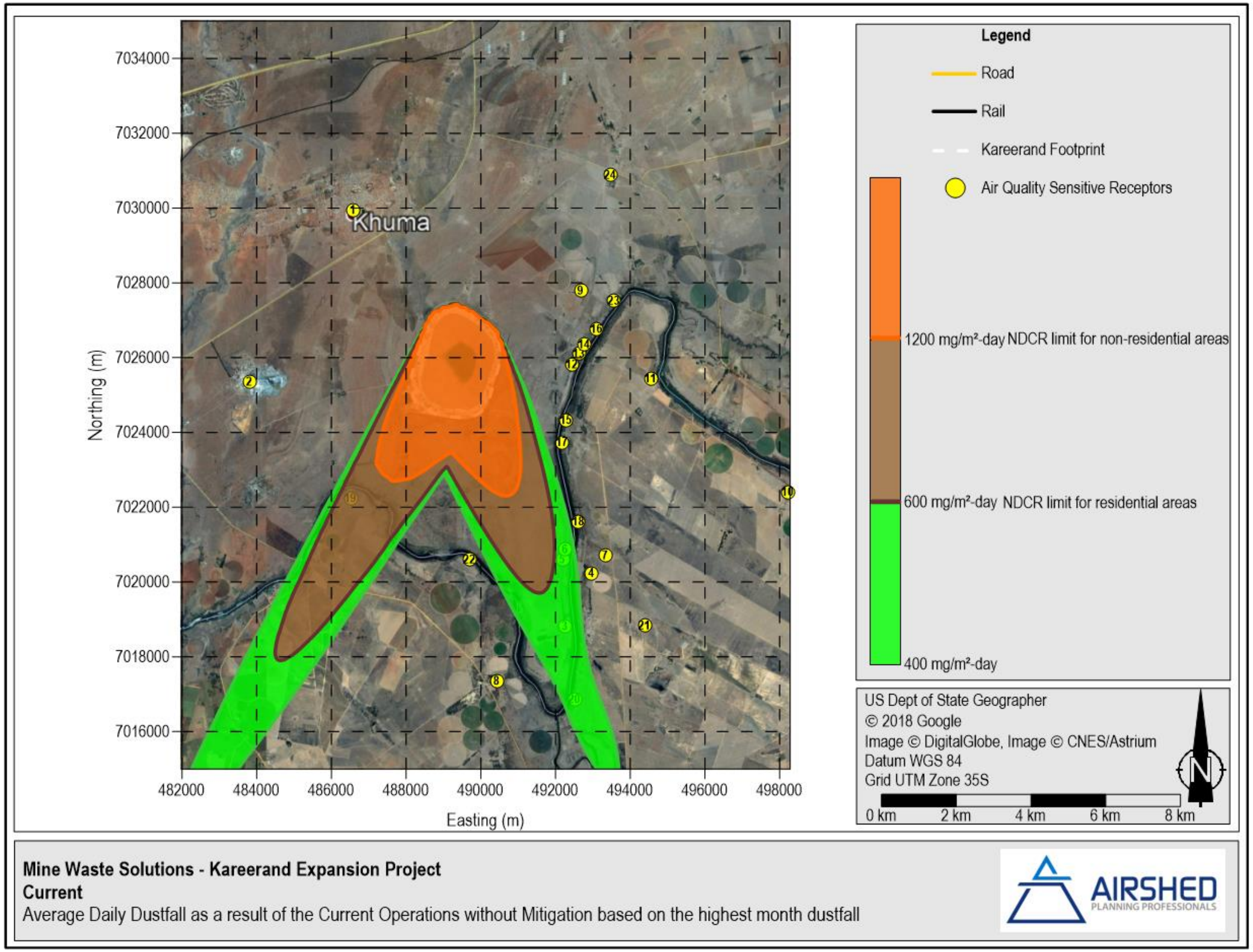

Figure 7-5: Current: average daily dustfall rates based on simulated highest monthly dust fallout

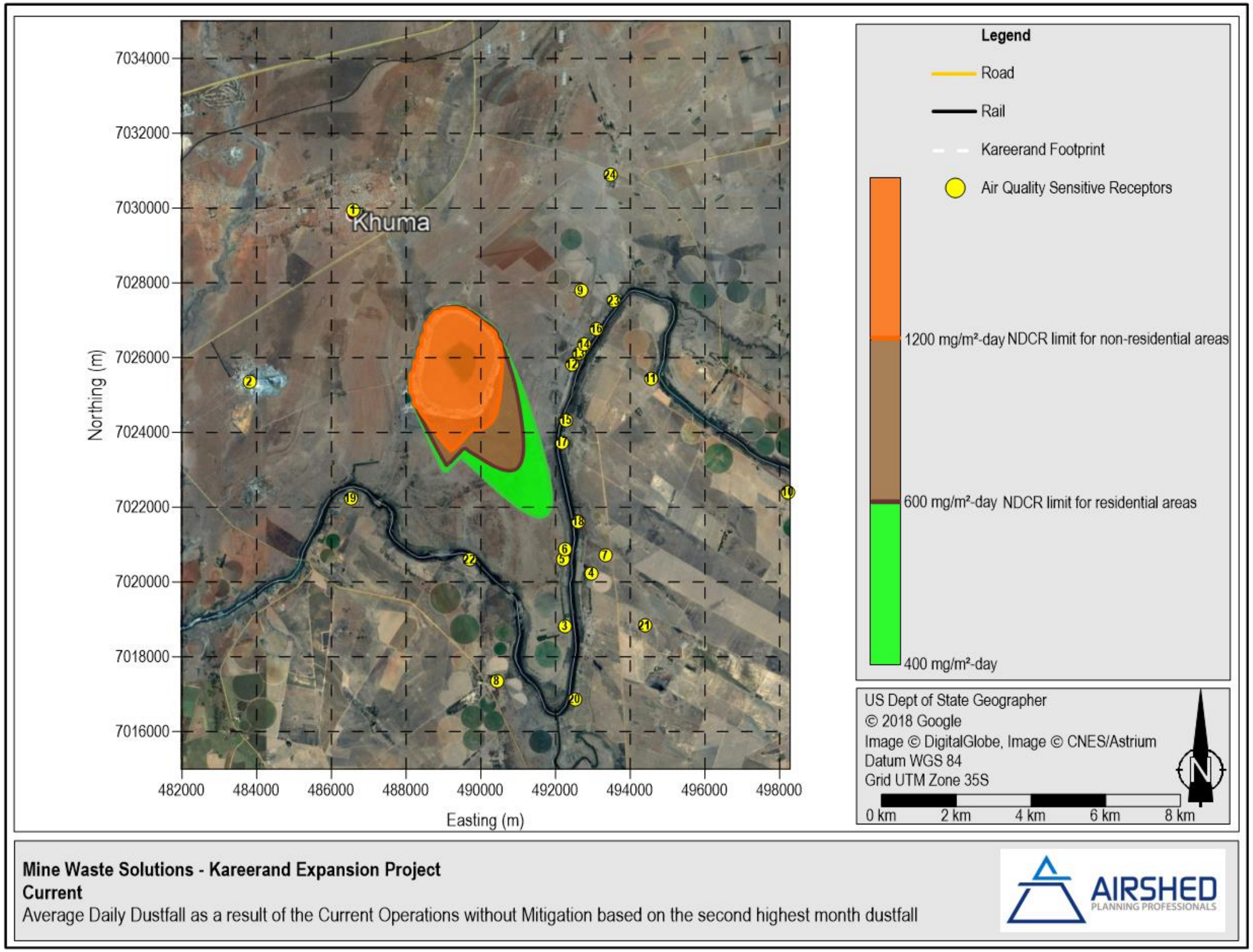

Figure 7-6: Current: average daily dustfall rates based on simulated second highest monthly dust fallout

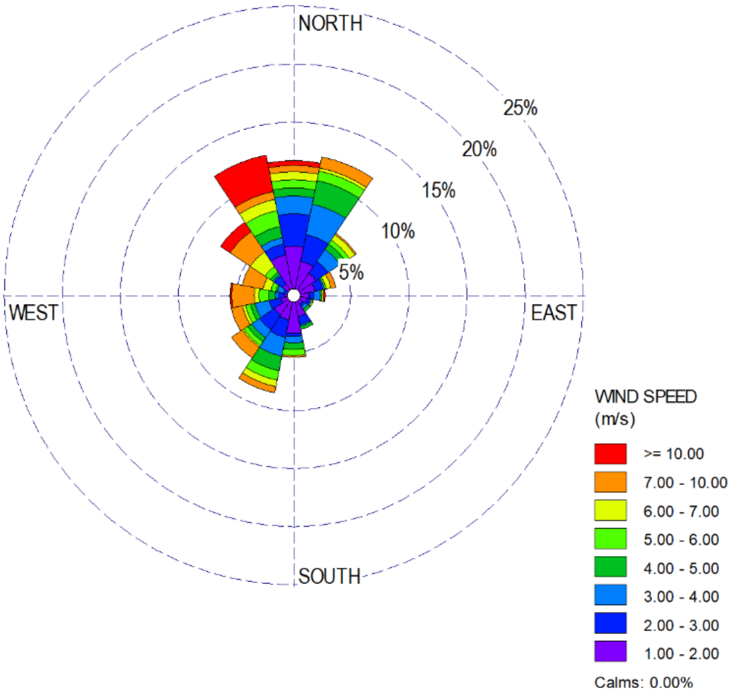

Figure 7-7: Wind rose for September 2018

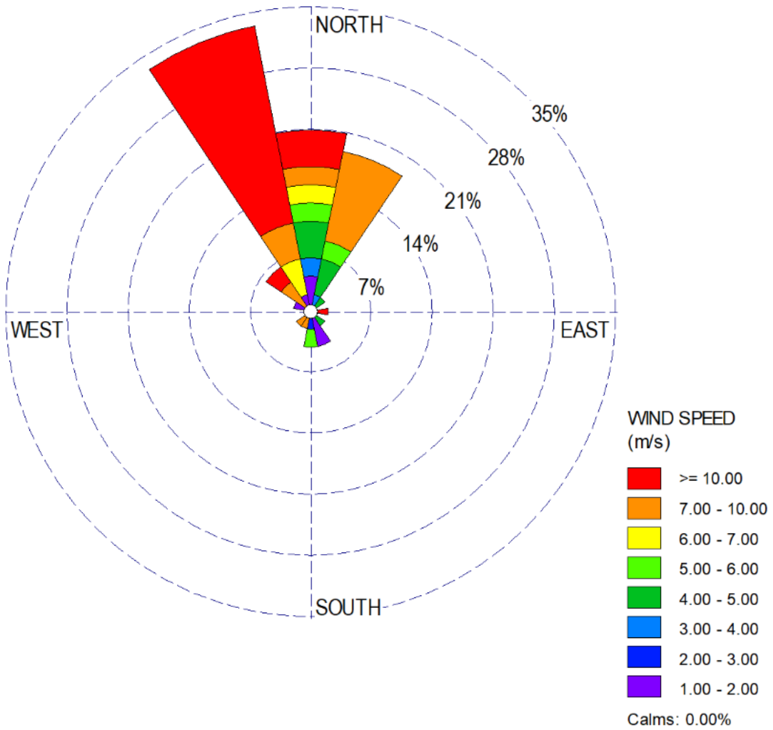

Figure 7-8: Wind rose for 5th and 6th September 2018

7.3 Assessment of Impact – Future (Current and Expansion Area) with Current Topography

Simulation results of windblown dust emissions for future operations (current Kareerand TSF and expansion area) using the current terrain data are discussed in this section. Isopleth plots have been included even if the simulated pollutant concentrations do not exceed the assessment criteria (NAAQS and NDCR).

7.3.1 Inhalable particulate matter (PM_{10})

Simulated annual average PM_{10} concentrations do not exceed the NAAQS of 40 µg/m^3 (Figure 7-9). The 24-hour NAAQS (4 days of exceedance of 75 µg/m^3) are only exceeded just beyond the expanded TSF but not at any AQSRs (Figure 7-10). Since the simulated results show that the NAAQS are not exceeded at any of the AQSRs included, there is not a significant risk to human health at these receptors as a result of the future Kareerand TSF operations.

7.3.2 Respirable particulate matter ($PM_{2.5}$)

Simulated annual average $PM_{2.5}$ concentrations do not exceed the NAAQS of 20 µg/m^3 (Figure 7-3). The current 24-hour NAAQS (4 days of exceedance of 40 µg/m^3) and future 24-hour NAAQS (4 days of exceedance of 25 µg/m^3) are only exceeded just beyond the expanded TSF but not at any of the AQSRs (Figure 7-13). Simulated results show that the NAAQS are exceeded within the TSF footprint or just beyond which suggests that there is not a significant risk to human health at the surrounding AQSRs.

7.3.3 Fallout Dust

Based on the highest monthly simulated dustfall rates, the daily average dustfall rate exceeds the NDCR residential limit of 600 mg/m²-day at five of the AQSRs (Figure 7-14). Based on the highest monthly simulated dustfall rates, the 24-hr average dustfall rates exceed the NDCR residential limit of 600 mg/m²-day but not at any of the AQSRs (Figure 7-15). The entire area covered by the isopleths are areas in which the natural vegetation and farming crops may be affected. Based on simulations there was likely to be dustfall rates higher than the NDCR residential limit at five AQSRs during September 2018, but the dustfall rates would have been in compliance with NDCR for residential areas as it does not exceed for consecutive months or more than three months in a year at this receptor. The likely reason for the high daily dustfall rates during September 2018 is discussed in section 7.2.3.

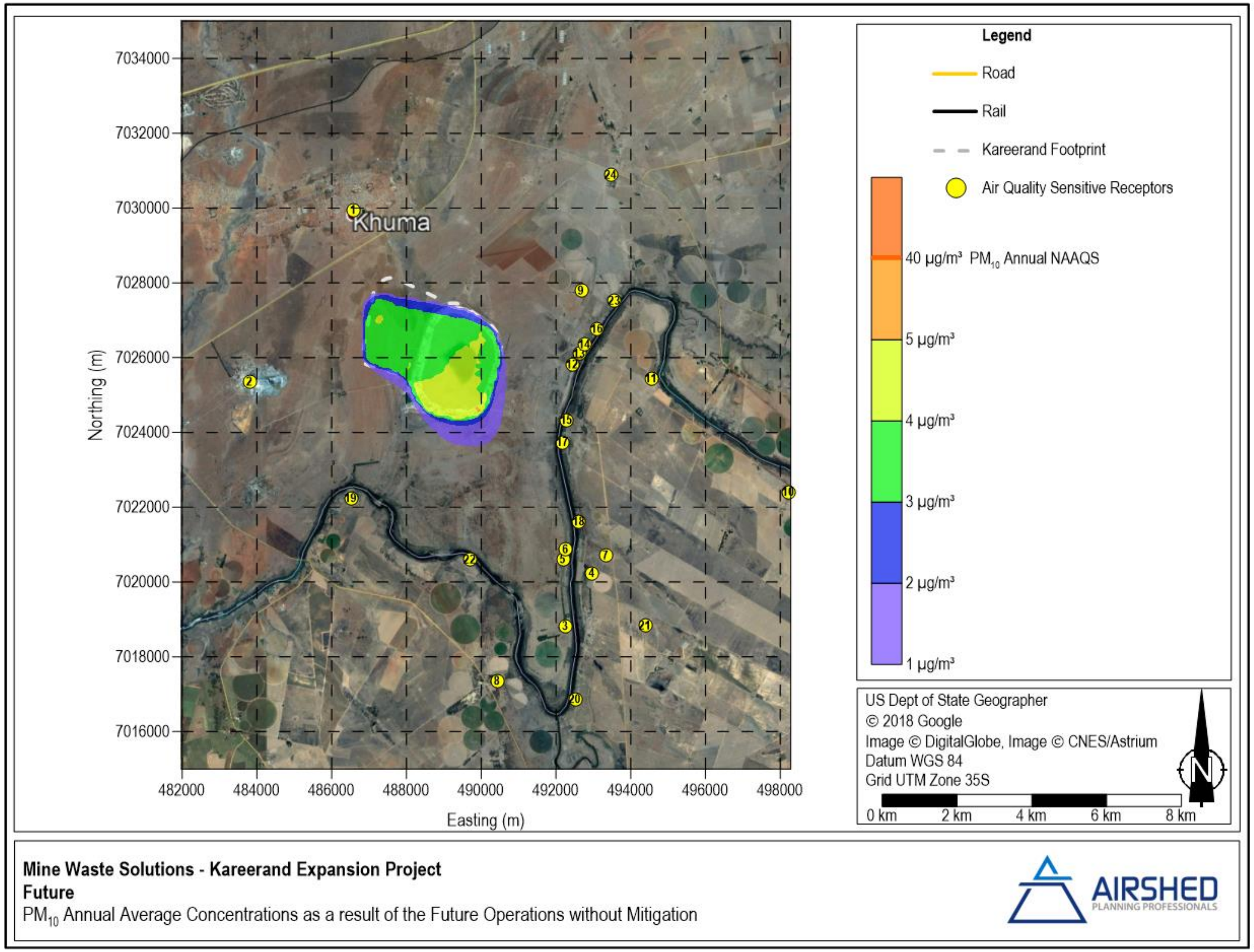

Figure 7-9: Future: simulated annual average PM_{10} concentrations

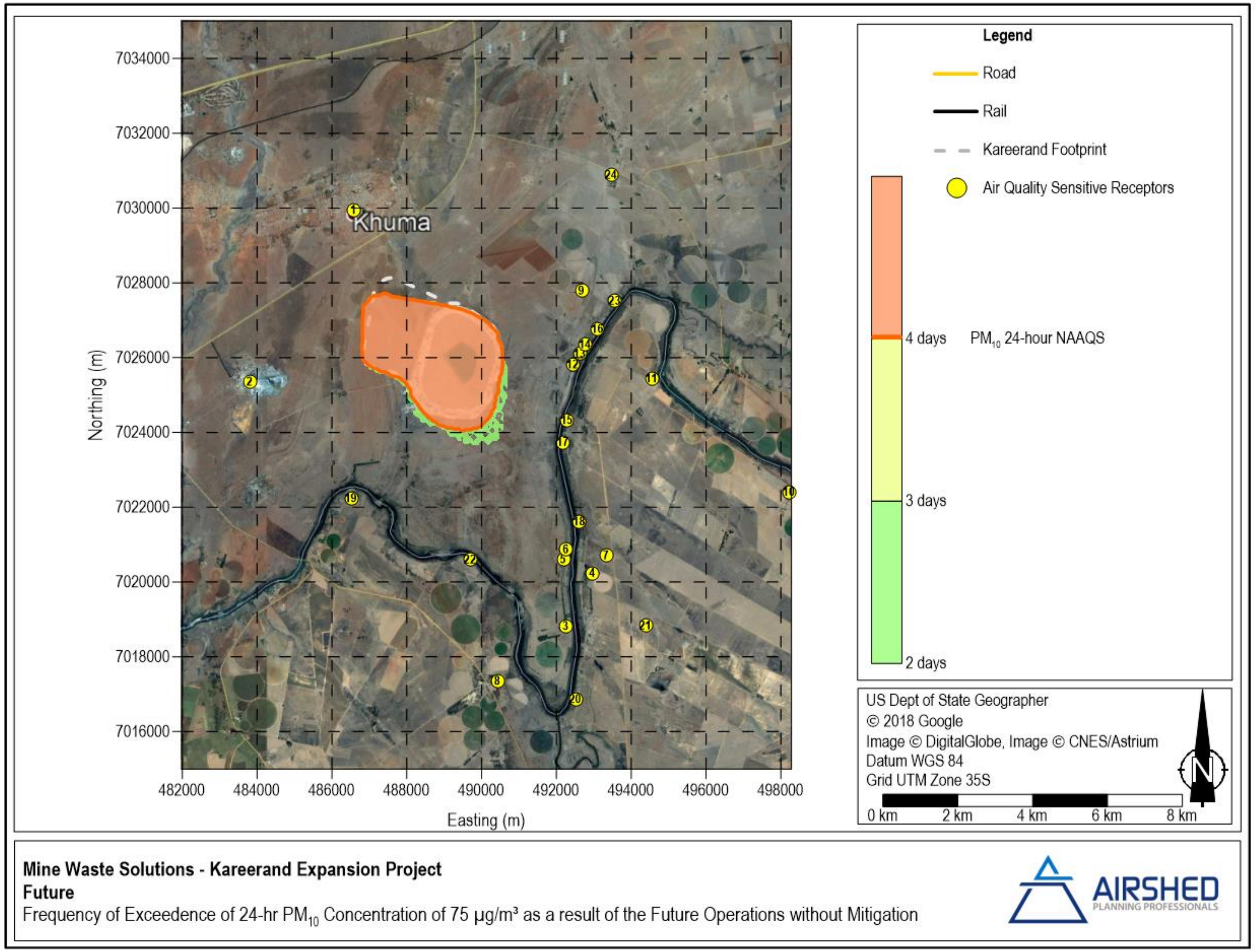

Figure 7-10: Future: frequency of exceedance of the 24-hour average PM_{10} NAAQS limit of 75 µg/m³

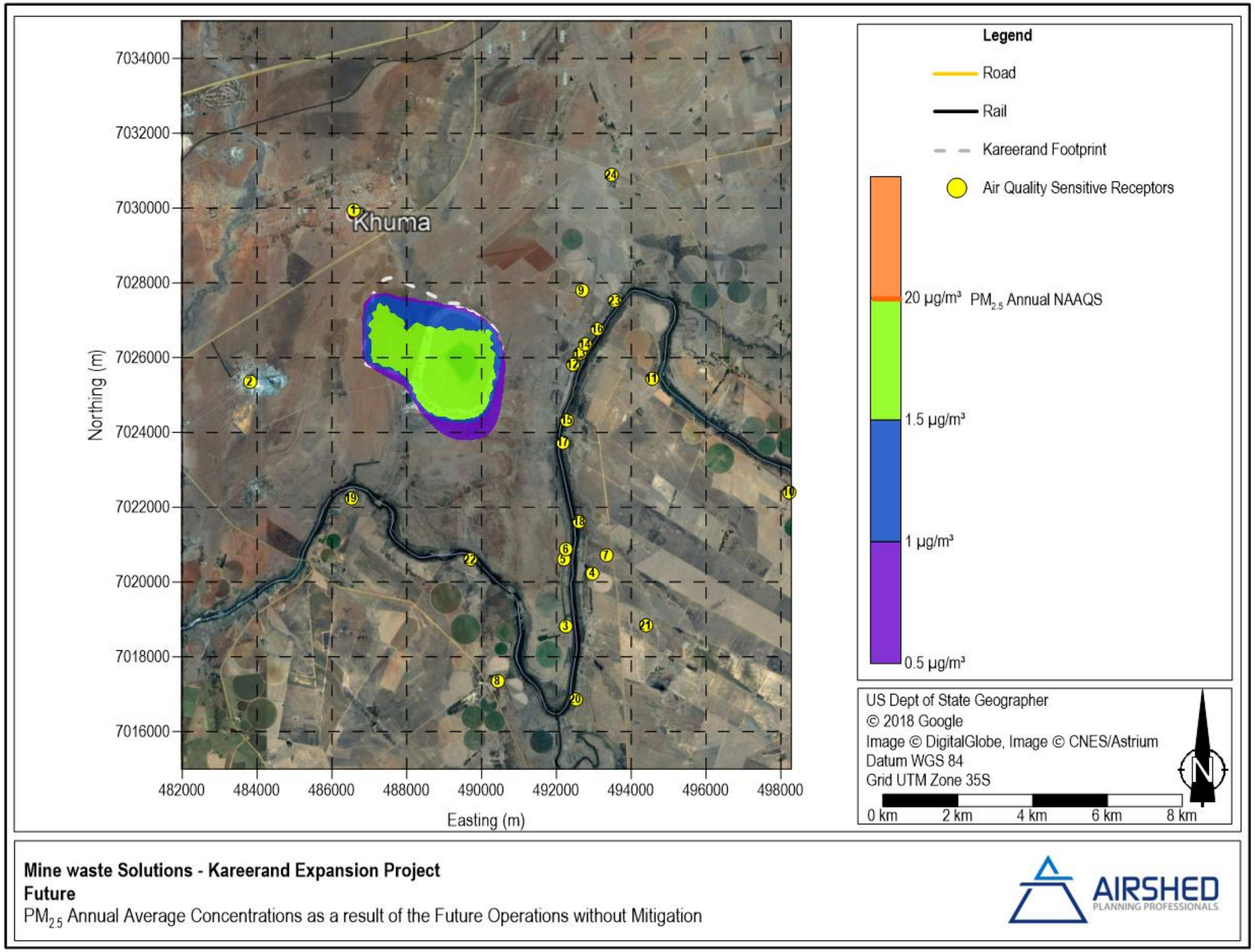

Figure 7-11: Future: simulated annual average $PM_{2.5}$ concentrations

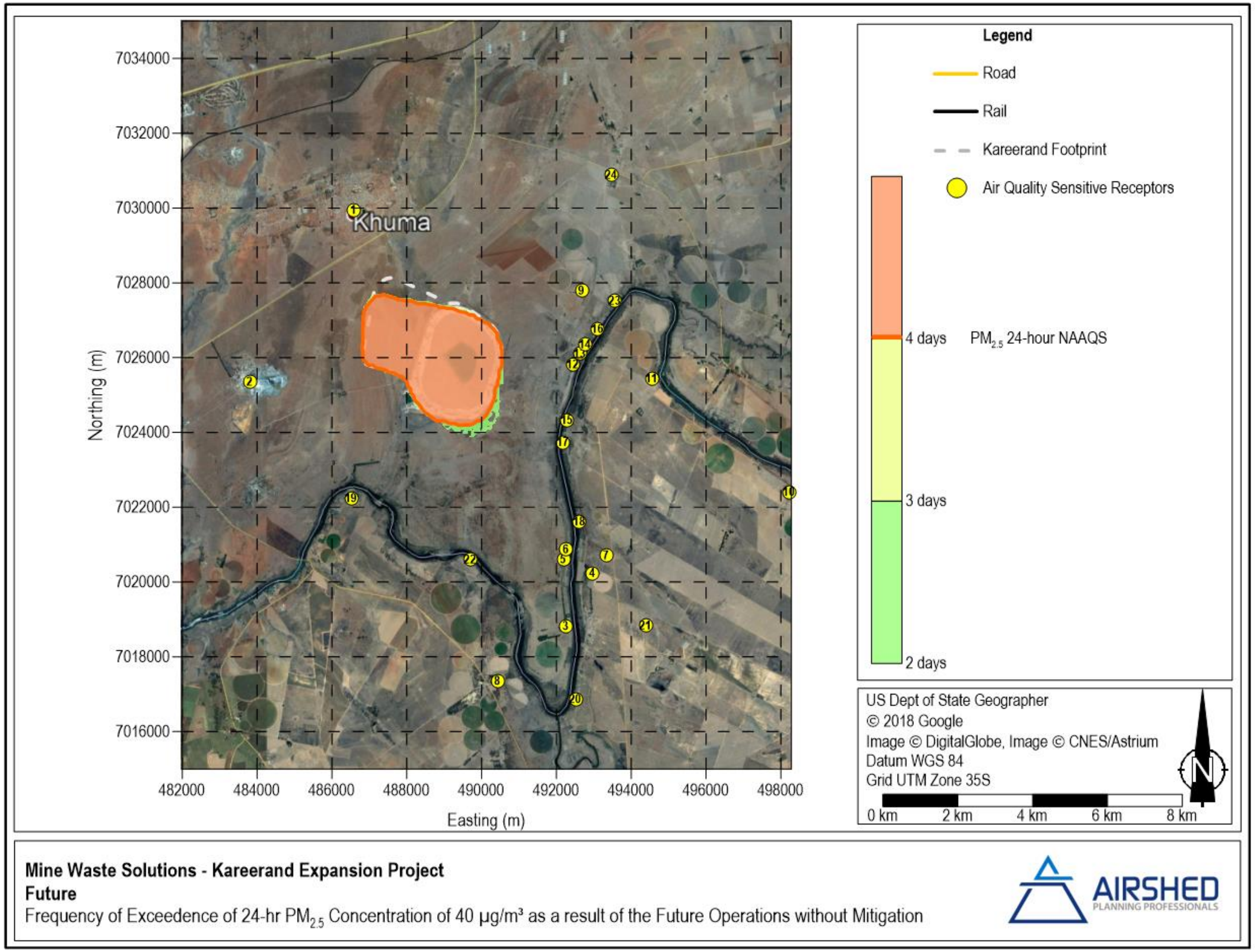

Figure 7-12: Future: frequency of exceedance of the 24-hour average $PM_{2.5}$ NAAQS limit of 40 µg/m³

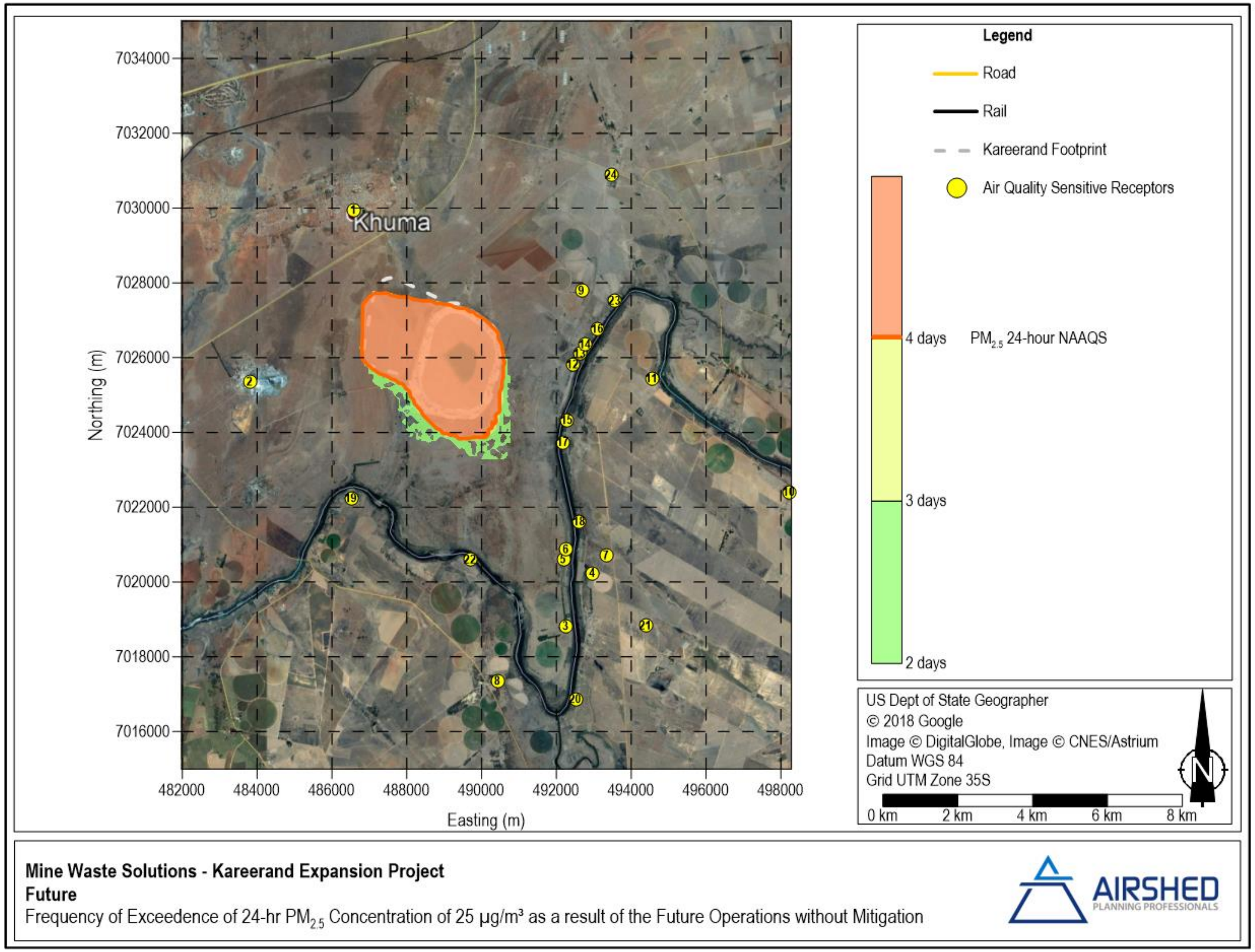

Figure 7-13: Future: frequency of exceedance of the 24-hour average $PM_{2.5}$ NAAQS limit of 25 µg/m³

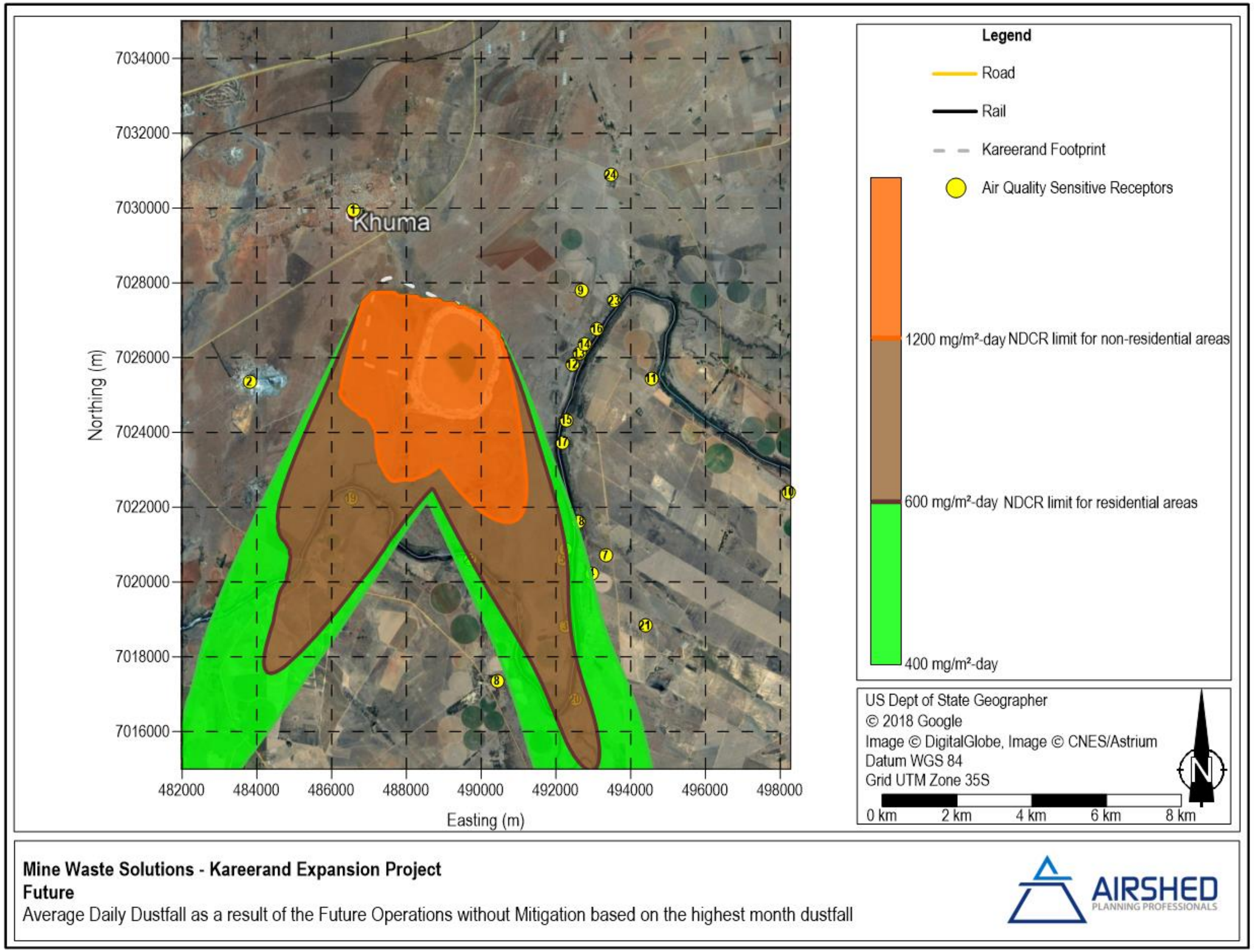

Figure 7-14: Future: average daily dustfall rates based on simulated highest monthly dust fallout

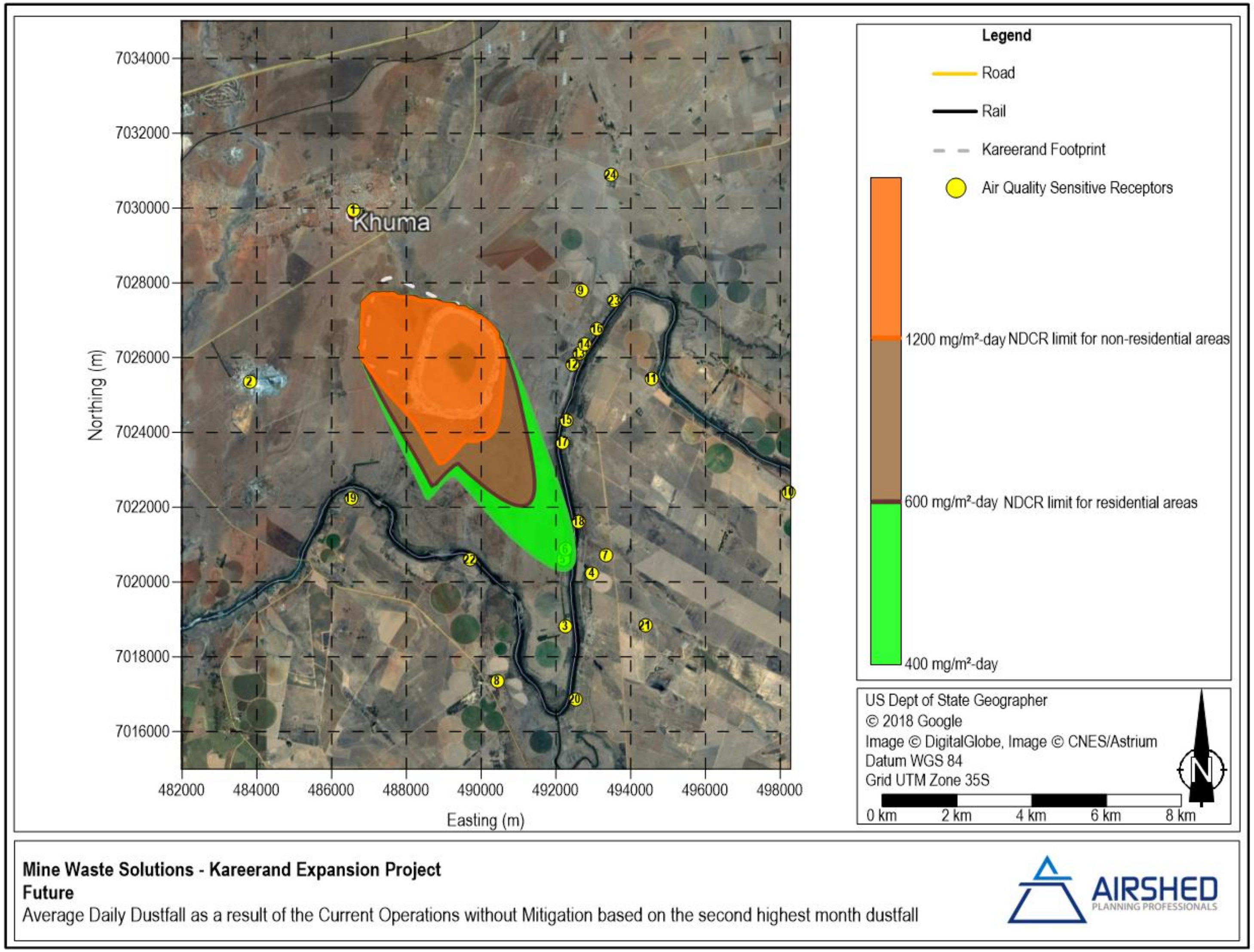

Figure 7-15: Future: average daily dustfall rates based on simulated second highest monthly dust fallout

7.4 Assessment of Impact – Future (Current and Expansion Area) with Final Topography

Simulation results of windblown dust emissions for future operations (current Kareerand TSF and expansion area) using the future terrain data are discussed in this section. Isopleth plots have been included even if the simulated pollutant concentrations do not exceed the assessment criteria (NAAQS and NDCR).

7.4.1 Inhalable Particulate Matter (PM_{10})

Simulated annual average PM_{10} concentrations do not exceed the NAAQS of 40 $\mu g/m^3$ (Figure 7-16). The 24-hour NAAQS (4 days of exceedance of 75 $\mu g/m^3$) are only exceeded at the expanded TSF but not at any AQSRs (Figure 7-17). Since the simulated results show that the NAAQS are not exceeded at any of the AQSRs included, there is not a significant risk to human health at these receptors as a result of the future Kareerand TSF operations.

7.4.2 Respirable Particulate Matter ($PM_{2.5}$)

Simulated annual average $PM_{2.5}$ concentrations do not exceed the NAAQS of 20 $\mu g/m^3$ (Figure 7-18). The 24-hour NAAQS (4 days of exceedance of 40 $\mu g/m^3$) are only exceeded at the expanded TSF but not at any of the AQSRs (Figure 7-19). The future 24-hour NAAQS (4 days of exceedance of 25 $\mu g/m^3$) are only exceeded just beyond the expanded TSF but not at any of the AQSRs (Figure 7-19). Simulated results show that the NAAQS are exceeded within the TSF footprint only which suggests that there is not a significant risk to human health at the surrounding AQSRs.

7.4.3 Fallout Dust

Based on the highest monthly simulated dustfall rates, the daily average dustfall rate exceeds the NDCR residential limit of 600 mg/m^2-day at six of the AQSRs (Figure 7-21). Based on the highest monthly simulated dustfall rates, the daily average dustfall rate exceeds the NDCR residential limit of 600 mg/m^2-day but not at any of the AQSRs (Figure 7-22). The entire area covered by the isopleths are areas in which the natural vegetation and farming crops may be affected. Based on simulations there was likely to be dustfall rates higher than the NDCR residential limit at six AQSRs during September 2018 but the dustfall rates would have been in compliance with NDCR for residential areas as it does not exceed for consecutive months or more than three months in a year at this receptor. The likely reason for the high daily dustfall rates during September 2018 is discussed in section 7.2.3.

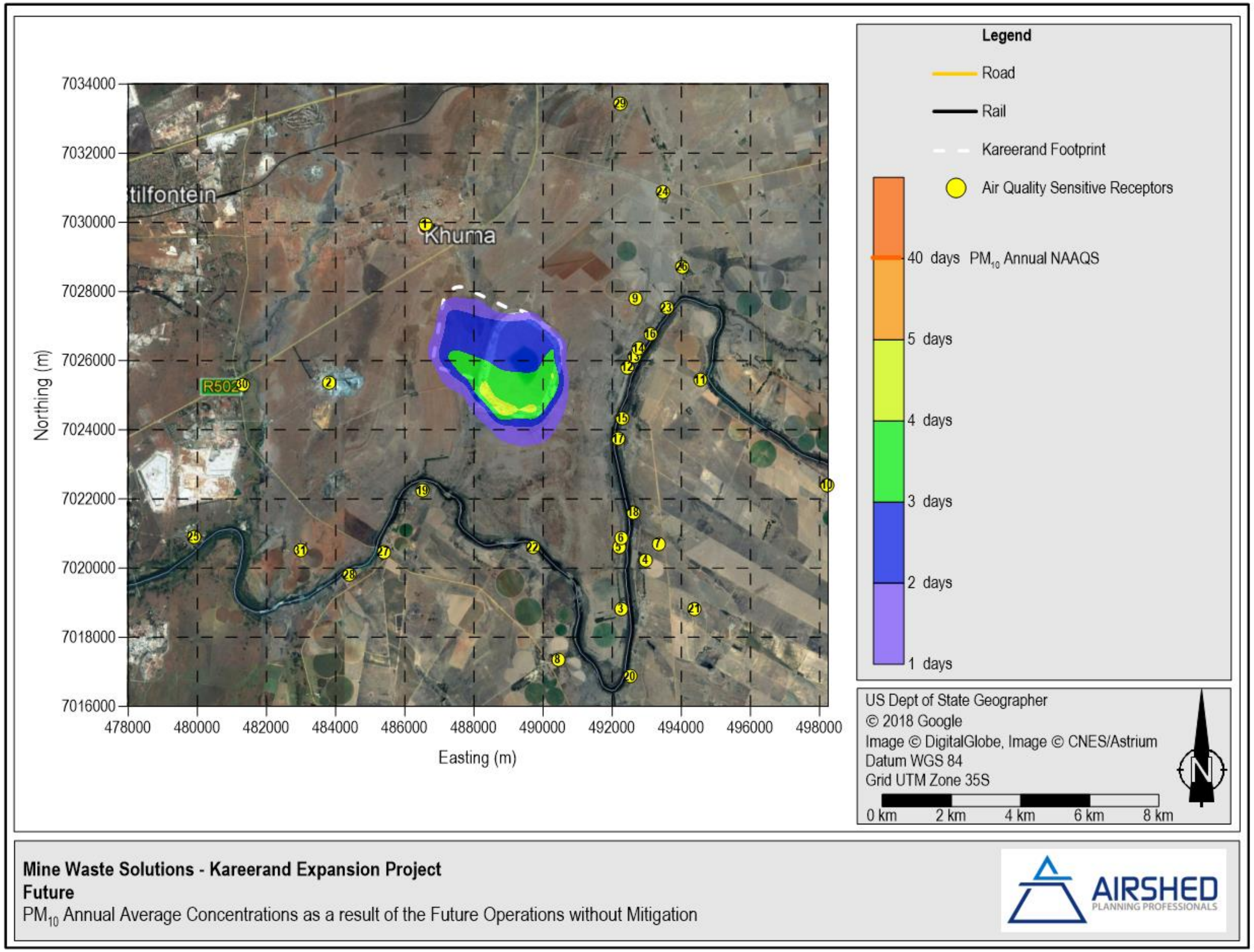

Figure 7-16: Future: simulated annual average PM_{10} concentrations

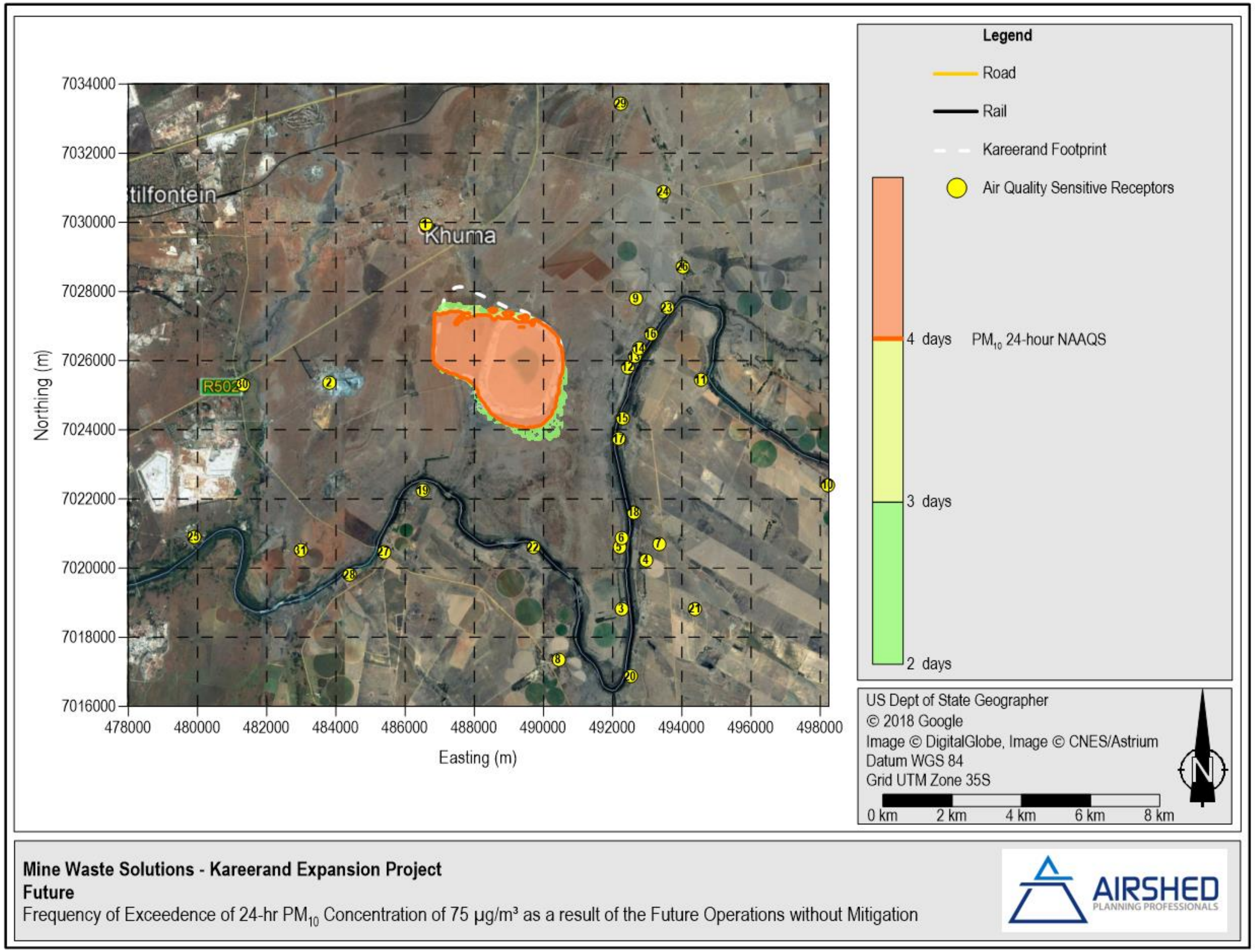

Figure 7-17: Future: frequency of exceedance of the 24-hour average PM_{10} NAAQS limit of 75 µg/m^3

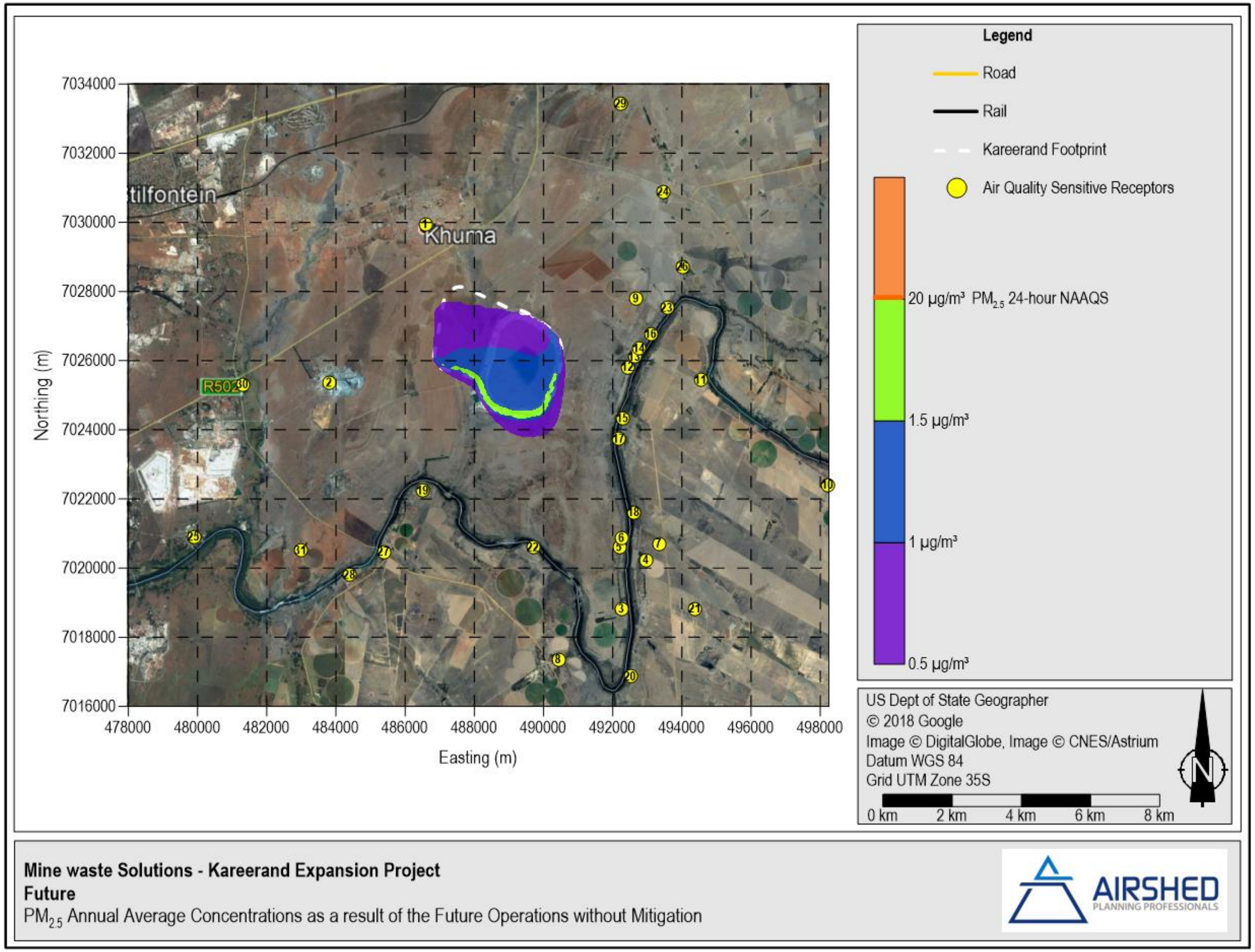

Figure 7-18: Future: simulated annual average $PM_{2.5}$ concentrations

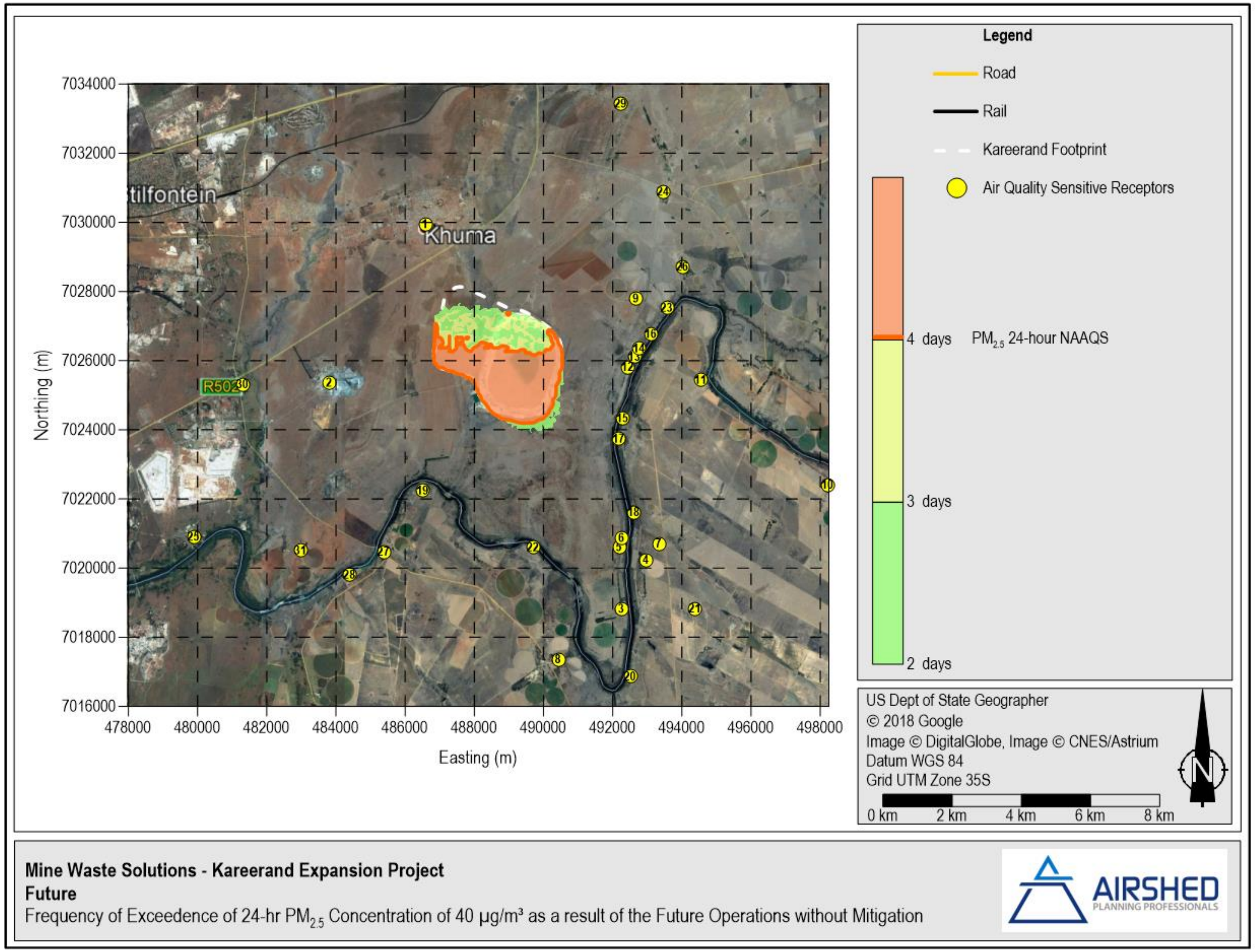

Figure 7-19: Future: frequency of exceedance of the 24-hour average $PM_{2.5}$ NAAQS limit of 40 µg/m³

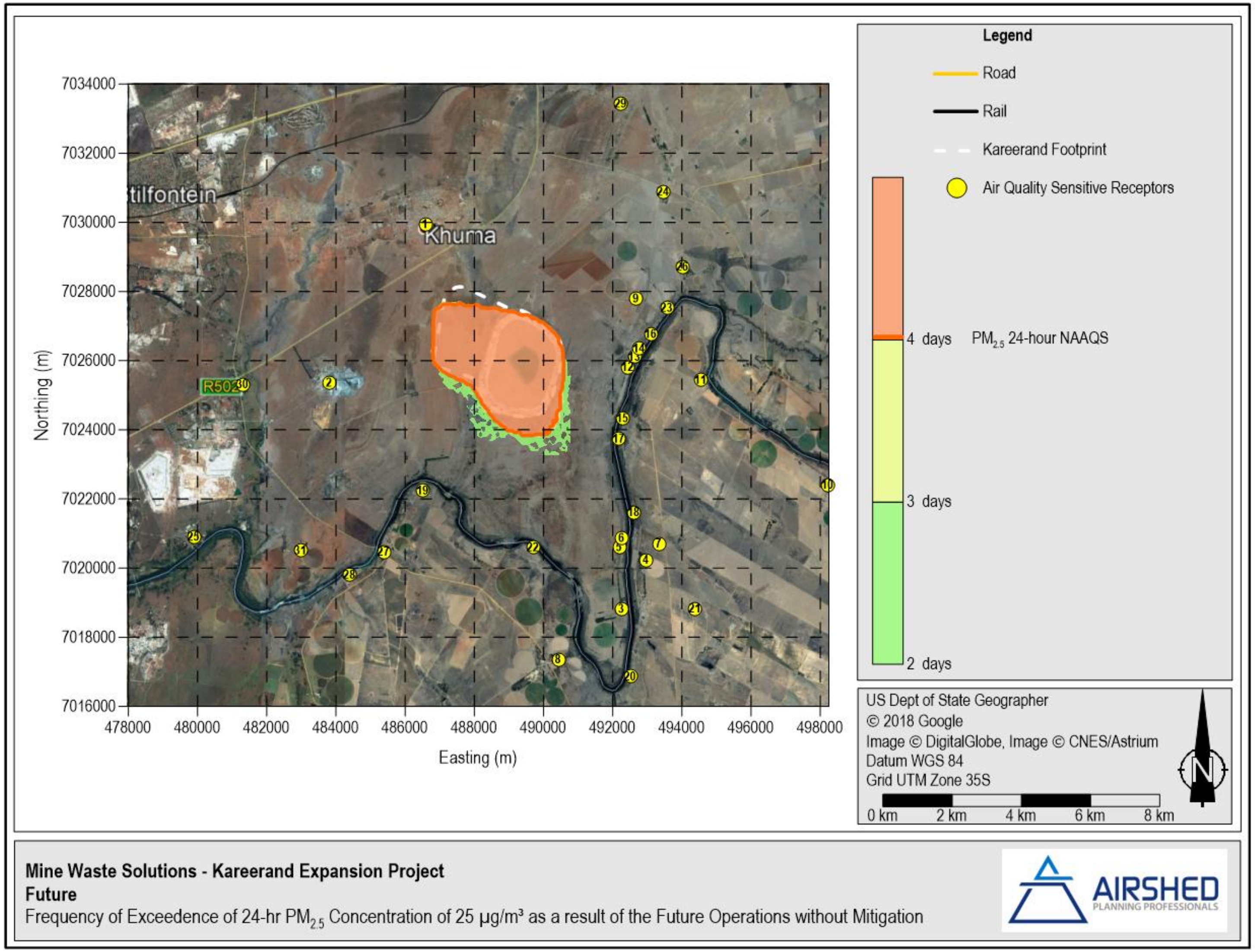

Figure 7-20: Future: frequency of exceedance of the 24-hour average $PM_{2.5}$ NAAQS limit of 25 µg/m³

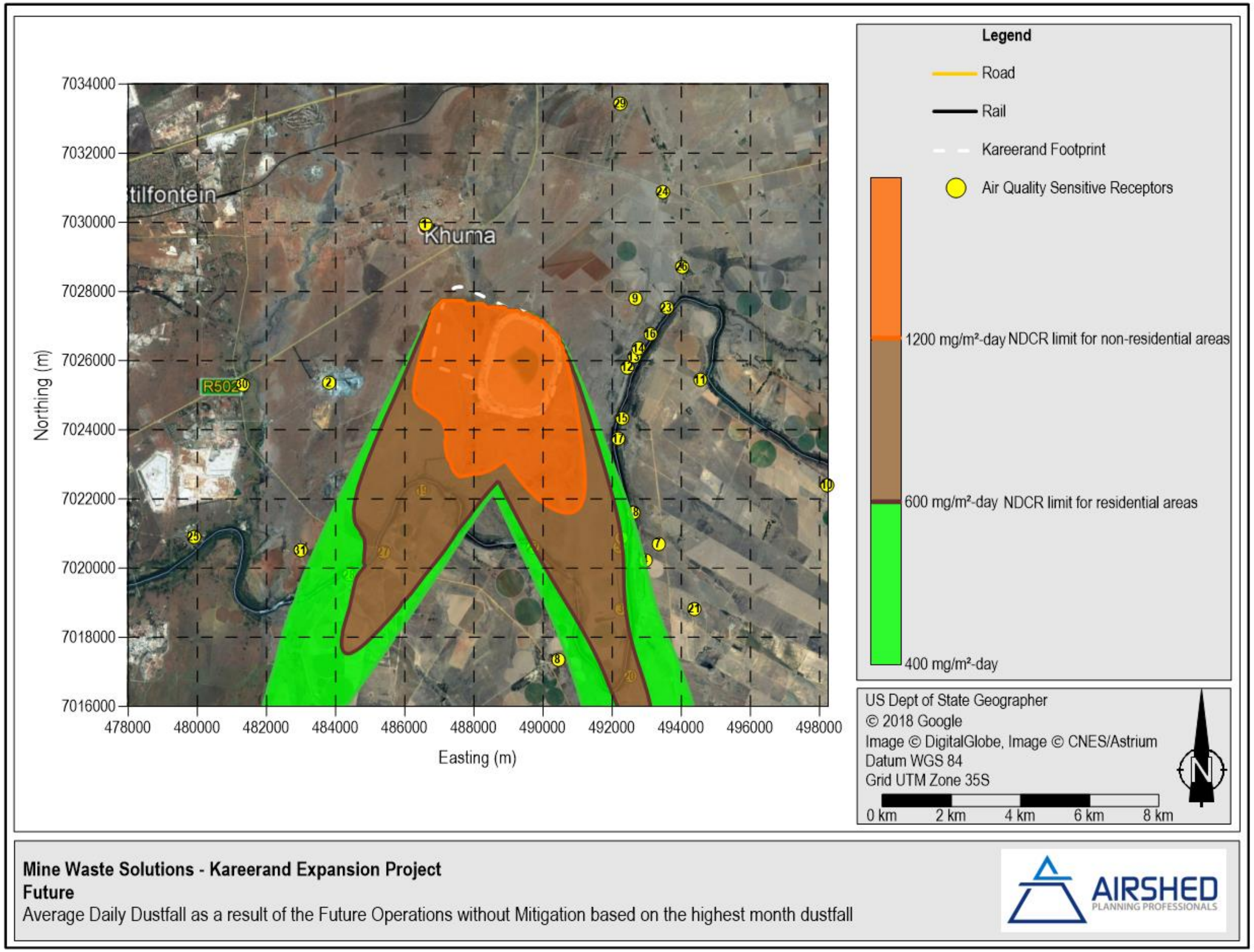

Figure 7-21: Future: average daily dustfall rates based on simulated highest monthly dust fallout

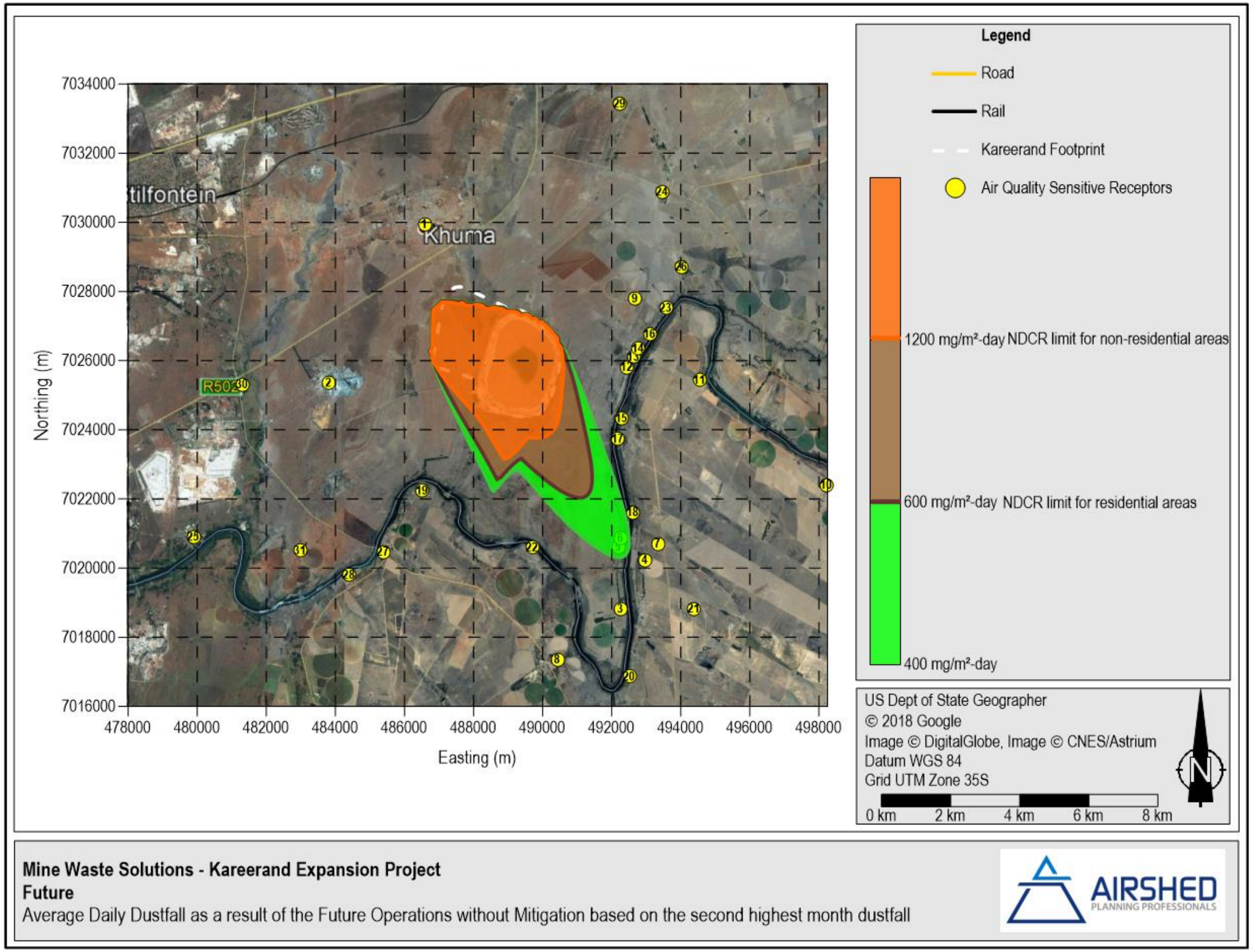

Figure 7-22: Future: average daily dustfall rates based on simulated second highest monthly dust fallout

7.5 Impact Significance Rating

Non-compliance of PM_{10} and $PM_{2.5}$ concentrations could result in human health impacts. The main pollutants of concern were determined to be PM (including TSP, PM_{10} and $PM_{2.5}$). A quantitative assessment of the potential impacts from PM_{10}, $PM_{2.5}$ and dust fallout (TSP) during the operational phase is discussed below. The GCS ranking methodology results in an unreasonably high likelihood since the activity is governed by legislation. The high likelihood significantly inflates the risk of the impacts. The severity of the impact was selected based on the criteria as set out in Section 2.4.

Two potential direct operational phase impacts on the air quality of the area were identified:

- B1: Potential impact on human health from increased pollutant concentrations during future Kareerand TSF operations;
- B2: Increased nuisance dustfall rates associated with future Kareerand TSF operations.

7.5.1 Potential Impact B1: Potential Impact on Human Health from Increased Pollutant Concentrations Caused by Activities Associated with the Future Kareerand TSF

Unmitigated PM_{10} emissions in the project area will *seldom* result in an *insignificant negative* impact on *human health* in the *long-term* in the *study area*. The risk is likely LOW; however, using the GCS impact rating methodology, the environmental risk of this impact is MODERATE; without and with mitigation applied.

7.5.2 Potential Impact B2: Increased Nuisance Dustfall Rates Associated with the Future Kareerand TSF

Based on 24 months of simulated results, only one month had high dustfall in exceedance of the NDCR limit for residential areas at AQSRs which could be attributed to a meteorological event that is not a common occurrence; thus, unmitigated TSP emissions in the project area will *seldom* result in an *insignificant negative* impact on *amenitie*s in the *long-term* in the *study area*. The risk is likely LOW; however, when using the GCS methodology, the environmental risk of this impact is MODERATE; without and with mitigation applied.

Table 7-4: Health risk impact significance summary table for the future Kareerand TSF

	Severity	Spatial Scale	Duration	**Consequence**	Frequency of Activity	Frequency of Impact	Legal	Detection	**Likelihood**	**Risk**
Without mitigation	1	1	4	**6**	5	1	5	4	**15**	**90** **Moderate**
<u>Recommended mitigation measures:</u> **Vegetation and/or nets of side slopes.**										
With mitigation	1	1	4	**6**	5	1	5	4	**15**	**90** **Moderate**

Table 7-5: Nuisance impact significance summary table for the future Kareerand TSF

	Severity	Spatial Scale	Duration	**Consequence**	Frequency of Activity	Frequency of Impact	Legal	Detection	**Likelihood**	**Risk**
Without mitigation	1	1	4	**6**	5	1	5	1	**12**	**72** **Moderate**
<u>Recommended mitigation measures:</u> **Vegetation and/or nets of side slopes.**										
With mitigation	1	1	4	**6**	5	1	5	1	**12**	**72** **Moderate**

8 IMPACT ASSESSMENT: DECOMMISSIONING AND CLOSURE PHASES

8.1 Increase in Pollutant Concentrations and Dustfall Rates

It is assumed that all operations will have ceased by the decommissioning phase. It is expected that all surface infrastructure will be demolished and removed except for roads which will remain for public use. It is also expected that the TSF surface will be covered with topsoil and vegetated.

The potential for air quality impacts during the decommissioning phase will depend on the extent of demolition and rehabilitation efforts during decommissioning and on features which will remain.
The likely activities associated with the decommissioning phase of the operations are:

- infrastructure removal/demolition;
- topsoil recovered from stockpiles for rehabilitation and re-vegetation of surroundings;
- vehicle entrainment on unpaved road surfaces during rehabilitation. Once that is done, vehicle activity associated with MWS should cease; and
- exhaust emissions from vehicles utilised during the closure phase. Once that is done, vehicle activity associated with MWS should cease;

The closure phase includes the period of aftercare and maintenance after the decommissioning phase. During this phase rehabilitated areas are checked and maintained. The activities that may be included are irregular and minimal vehicle entrainment on roads and vehicle exhaust emissions when the property is checked up on.

8.2 Assessment of Impact

Insufficient data was available for the decommissioning and closure phases thus dispersion modelling for the actual activities that will result in dust emissions could not be undertaken. It is not anticipated that the various activities would result in higher $PM_{2.5}$ and PM_{10}, GLCs and dustfall rates than the operational phase activities. The temporary nature of the decommissioning activities would likely reduce the significance of the potential impacts. The minimal activities during closure will likely result in insignificant potential impacts. A qualitative assessment of decommissioning and closure operations from the PM_{10} and TSP impacts perspective is discussed below.

Two potential direct decommissioning phase impacts on the air quality of the area were identified:

- C1: Potential impact on human health from pollutant concentrations associated with decommissioning activities;
- C2: Nuisance dustfall rates associated with decommissioning activities;

Two potential direct closure phase impacts on the air quality of the area were identified:

- D1: Potential impact on human health from pollutant concentrations associated with closure activities;
- D2: Nuisance dustfall rates associated with closure activities;

C1 and D1 would likely impact on human health whereas C2 and D2 would impact on amenities.

8.2.1 Potential Impact C1: Potential Impact on Human Health from Pollutant Concentrations Associated with Decommissioning Activities

The sources of emissions would include the demolition of infrastructure and removal of material; topsoil reclaiming and covering of exposed areas; re-vegetation; and the operation of mechanical equipment. It is unlikely that the long-term and short-term NAAQS will be exceeded at AQSRs with mitigation in place, but it is probable that the short-term NAAQS limits will likely be exceeded in the case of unmitigated operations.

Unmitigated PM_{10} emissions in the project area will *seldom* result in an *insignificant negative* impact on *human health* in the *medium-term* in the *study area*. The risk is likely LOW; however, using the GCS impact rating methodology, the environmental risk of this impact is MODERATE; without and with mitigation applied.

8.2.2 Potential Impact C2: Nuisance Dustfall Rates Associated with Decommissioning Activities

The sources of emissions would include the demolition of infrastructure and removal of material; topsoil reclaiming and covering of exposed areas; re-vegetation; and the operation of mechanical equipment. It is probable that the NDCR limit for residential areas will not be exceeded at AQSRs (with and without mitigation).

Unmitigated TSP emissions in the project area will *very seldom* result in an *insignificant negative* impact on *amenitie*s in the *medium-term* in the *study area*. The risk is likely LOW; however, using the GCS impact rating methodology, the environmental risk of this impact is MODERATE; without and with mitigation applied.

8.2.3 Potential Impact D1: Impaired Human Health from Pollutant Concentrations Associated with Closure Activities

The sources of emissions would include the site inspections and where necessary the addition of topsoil and vegetation; and the operation of mechanical equipment. It is unlikely that the long-term and short-term NAAQS will be exceeded at AQSRs (with and without mitigation). The operations will likely occur for less more than 1 year but less than 10 years.

Unmitigated PM_{10} emissions in the project area will *seldom* result in an *insignificant negative* impact on *human health* in the *medium-term* in the *study area*. The risk is likely LOW; however, using the GCS impact rating methodology, the environmental risk of this impact is MODERATE; without and with mitigation applied.

8.2.4 Potential Impact D2: Nuisance Dustfall Rates Associated with Closure Activities

The sources of emissions would include the site inspections and where necessary the addition of topsoil and vegetation; and the operation of mechanical equipment. It is probable that the NDCR limit for residential areas will not be exceeded at AQSRs (with and without mitigation). The operations will likely occur for less more than 1 year but less than 10 years.

Unmitigated TSP emissions in the project area will *seldom* result in an *insignificant negative* impact on *amenitie*s in the *medium-term* in the *study area*. The risk is likely LOW; however, using the GCS impact rating methodology, the environmental risk of this impact is MODERATE; without and with mitigation applied.

Table 8-1: Health risk impact significance summary table for the decommissioning operations

	Severity	Spatial Scale	Duration	**Consequence**	Frequency of Activity	Frequency of Impact	Legal	Detection	**Likelihood**	**Risk**
Without mitigation	3	1	3	**6**	5	2	5	4	**16**	**96** **Moderate**
Recommended mitigation measures: **Reduction of fugitive PM emissions through the watering of roads and the use of screens.** **Reductions of vehicle exhaust emissions through the use of better quality diesel; and inspection and maintenance programs.**										
With mitigation	1	1	3	**5**	5	1	5	4	**15**	**75** **Moderate**

Table 8-2: Nuisance impact significance summary table for the decommissioning operations

	Severity	Spatial Scale	Duration	**Consequence**	Frequency of Activity	Frequency of Impact	Legal	Detection	**Likelihood**	**Risk**
Without mitigation	1	1	3	**5**	5	1	5	1	**12**	**60** **Moderate**
Recommended mitigation measures: **Reduction of fugitive PM emissions through the watering of roads, stockpiles and inactive open areas and the use of screens.** **Reductions of vehicle exhaust emissions through the use of better quality diesel; and inspection and maintenance programs.**										
With mitigation	1	1	3	**5**	5	1	5	1	**12**	**60** **Moderate**

Table 8-3: Health risk impact significance summary table for the closure operations

	Severity	Spatial Scale	Duration	**Consequence**	Frequency of Activity	Frequency of Impact	Legal	Detection	**Likelihood**	**Risk**
Without mitigation	1	1	3	**5**	5	1	5	4	**15**	**75** **Moderate**
Recommended mitigation measures:										

	Severity	Spatial Scale	Duration	**Consequence**	Frequency of Activity	Frequency of Impact	Legal	Detection	**Likelihood**	**Risk**
Reductions of vehicle exhaust emissions through the use of better quality diesel; and inspection and maintenance programs.										
With mitigation	1	1	3	**5**	5	1	5	4	**15**	**75** **Moderate**

Table 8-4: Nuisance impact significance summary table for the closure operations

	Severity	Spatial Scale	Duration	**Consequence**	Frequency of Activity	Frequency of Impact	Legal	Detection	**Likelihood**	**Risk**
Without mitigation	1	1	3	**5**	5	1	5	1	**12**	**60** **Moderate**
Recommended mitigation measures: **Reductions of vehicle exhaust emissions through the use of better quality diesel; and inspection and maintenance programs.**										
With mitigation	1	1	3	**5**	5	1	5	1	**12**	**60** **Moderate**

9 IMPACT ASSESSMENT: CUMULATIVE

9.1 Elevated Pollutant Concentrations and Dustfall Rates

Land use in the region includes residences, farming, mining, industry and wilderness. The mining operations (MWS as well as other companies), farming activities, domestic fires, vehicle exhaust emissions and dust entrained by vehicles on public roads without the addition of the proposed operations will likely result in elevated ambient air pollutant concentrations and dustfall rates compared to an area where there are no anthropogenic emission sources. The simulated impacts from the VR and MWS operations are discussed in Section 5.3 and are likely to be the greatest contributor to ambient air quality in close proximity to the Kareerand TSF operational areas. It is difficult to predict the location and contribution of the sources from residences, farming and wilderness to existing air quality, but it is unlikely these sources will result in NAAQS being exceeded, at least in the long-term.

The potential cumulative scenario includes the following atmospheric emissions:

a. Particulate emissions from VR and MWS operations;
b. Miscellaneous fugitive dust sources including vehicle entrainment on roads and wind-blown dust from open areas;
c. Particulate emissions from vehicle exhaust emissions;
d. Particulate emissions from household fuel burning; and
e. Particulate emissions from biomass burning (e.g. wild fires).

Based on the simulated results there is not likely to be any exceedances of the NAAQS at AQSRs near Kareerand.

10 IMPACT ASSESSMENT: NO GO OPTION

10.1 Potential State of the Air Quality

Should the no go option be embarked on, only the existing activities will occur in the area without the addition of the Kareerand TSF expansion area operations. Thus, the potential for an increase in ambient air pollutant concentrations and dustfall rates is small. The current site operations are also likely to cease at some stage and the ambient air quality will improve. There is the possibility of a gradual reduction in ambient air quality in close proximity to the MWS operations should there be any additional farming operations, vehicle entrainment on roads, wind-blown dust from open areas, vehicle exhaust, household fuel burning and biomass burning.

11 DUST MANAGEMENT PLAN

Based on the findings of the impact assessment, the following mitigation, management and monitoring recommendations are made.

11.1 Air Quality Management Objectives

The main objective of the proposed air quality management measures for the project is to ensure that operations at the facility cumulatively result in ambient air concentrations that are within the relevant ambient air quality criteria off-site. In order to define site specific management objectives, the main sources of pollution needed to be identified.

11.1.1 Source Specific Management and Mitigation Measures

Windblown dust is the main source of pollution from the proposed project.

11.1.1.1 Windblown dust control options

Main techniques adopted to reduce windblown dust potential include source extent reduction, source improvement and surface treatment methods:

- Source extent reduction:
    - Disturbed area reduction – planned through deposition on one area at a time.
    - Disturbance frequency reduction – planned through continuous revegetation and rehabilitation.
    - Dust spillage prevention and/or removal.
- Source Improvement:
    - Disturbed area wind exposure reduction, e.g. vegetation on side slopes, wind fences/nets at source areas. Erosion losses from grassed slopes measured by (Blight, 1989) was found to be in the order of 80% less compared to uncontrolled slopes.

A combination of the above measures must be applied to the operations to ensure exposed areas are kept free of dry fine materials.

11.1.2 Source Monitoring

It should be noted that the data provider will be required to continue reporting annual emissions on the NAEIS system. Dustfall monitoring near sources can be an effective mechanism in determining the main emission sources and the continuation of the current network is suggested.

11.1.3 Ambient Air Quality Monitoring

Ambient air quality monitoring can serve to meet various objectives, such as:

- Compliance monitoring;
- Validate dispersion model results;
- Use as input for health risk assessment;
- Assist in source apportionment;
- Temporal trend analysis;

- Spatial trend analysis;
- Source quantification; and,
- Tracking progress made by control measures.

It is recommended that, as a minimum continuous dustfall sampling continue to be conducted as part of the project's air quality management plan. The current sampling network locations should be sufficient.

11.1.3.1 Dustfall Sampling

The ASTM method covers the procedure of dustfall collection and its measurement and employs a simple device consisting of a cylindrical container (not less than 150 mm in diameter) exposed for one calendar month (30 ±2 days). Even though the method provides for a dry bucket, de-ionised (distilled) water can be added to ensure the dust remains trapped in the bucket. The bucket stand includes a wind shield at the level of the rim of the bucket to provide an aerodynamic shield. The bucket holder is connected to a 2 m galvanized steel pole, which is either planted and cemented or directly attached to a fence post (Figure 11-1). This allows for a variety of placement options for the fallout samplers. Two buckets are usually provided for each dust bucket stand. Thus, after the first month, the buckets get exchanged with the second set.

Collected sampled are sent to an accredited laboratory for gravimetric analysis. At the laboratory, each sample will be rinsed with clean water to remove residue from the sides, and the contents filtered through a coarse (>1 mm) filter to remove insects and other course organic detritus. The sample is then filtered through a pre-weighed paper filter to remove the insoluble fraction. This residue and filter are dried, and gravimetrically analysed to determine total dustfall.

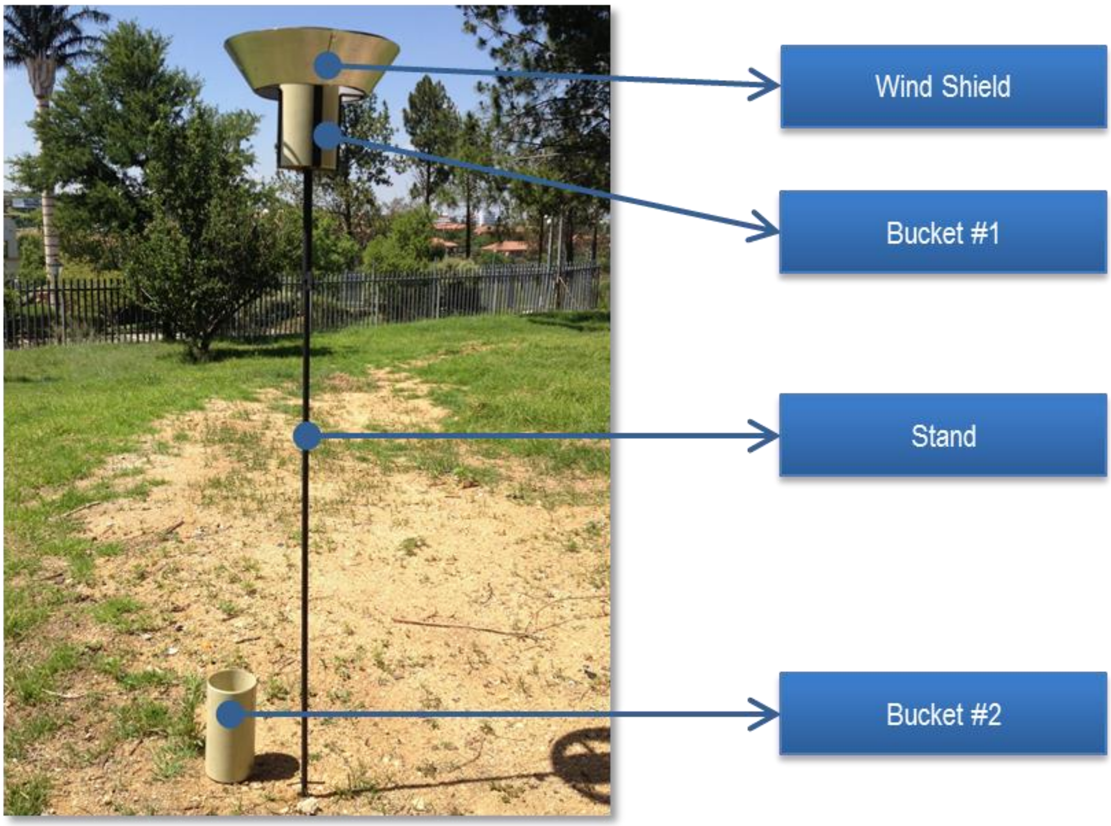

Figure 11-1: Dustfall collection unit example

11.2 Record-keeping, Environmental Reporting and Community Liaison

11.2.1 Periodic Inspections and Audits

Periodic inspections and external audits are essential for progress measurement, evaluation and reporting purposes. It is recommended that site inspections and progress reporting be undertaken at regular intervals (at least quarterly), with annual environmental audits being conducted. Annual environmental audits should be continued at least until closure. Results from site inspections and monitoring efforts should be combined to determine progress against source- and receptor-based performance indicators. Progress should be reported to all interested and affected parties, including authorities and persons affected by pollution.

The criteria to be taken into account in the inspections and audits must be made transparent by way of minimum requirement checklists included in the management plan. Corrective action or the implementation of contingency measures must be proposed to the stakeholder forum in the event that progress towards targets is indicated by the quarterly/annual reviews to be unsatisfactory.

11.2.2 Liaison Strategy for Communication with I&APs

Stakeholder forums provide possibly the most effective mechanisms for information dissemination and consultation. Management plans should stipulate specific intervals at which forums will be held and provide information on how people will be notified of such meetings. For operations in which un-rehabilitated or partly rehabilitated impoundments are located in close proximity (within 3 km) from community areas, it is recommended that such meetings be scheduled and held at least on a bi-annual basis. A complaints register must be kept at all times.

11.2.3 Financial Provision

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

12 FINDINGS AND RECOMMENDATIONS

12.1 Main Findings

An air quality impact assessment was conducted for activities proposed as part of the Kareerand TSF expansion. The main objective of this study was to establish baseline air quality in the study area and to quantify the extent to which ambient pollutant levels will change as a result of the proposed expansion operations. The baseline and impact study then informed the air quality management and mitigation measures recommended as part of the Air Quality Management Plan (AQMP). This section summarises the main findings of the baseline and impact assessments.

The main findings of the baseline assessment are:

- The significant AQSRs are those of Khuma Township; Village Main Reef Mine; various farm and property owners; the chicken farm; the nearby supermarket/garage; and Midvaal Water Company.
- The main sources likely to contribute to baseline PM emissions include mining operations, industrial operations, vehicle entrained dust from local roads, vehicle exhaust and windblown dust from exposed areas on existing TSFs.
- Other sources of PM include farm activities, occasional biomass burning and household fuel burning in the residential areas of Stilfontein, Klerksdorp, Khuma Township and Village Main Reef Mine.
- The area is dominated by winds from the north-north-west and north. These wind directions are also associated with strong winds of above 6 m/s. Wind speeds exceeding 9.8 m/s, likely to result in high dust emissions, occurred for 3% of the time.
- A comprehensive fallout dust measurements dataset was provided for the area from 2009 to 2019; although AGA has been undertaking dustfall sampling in the area for longer. The fallout dust data for sites near the Project area (Kareerand TSF Expansion) were considered relevant to this study and analysis of the data was undertaken and included in this report. The National Dust Control Regulations (NDCR) limit for residential areas of 600 mg/m^2-day was not exceeded at any of the residential sites. SA NDCR limit for non-residential areas of 1 200 mg/m^2-day was exceeded once at three sites (see Appendix C).
    - Tailings South East - July 2015
    - Tailings - October 2015
- Simulations for the 2013 AGA Vaal River (VR) and MWS operations were undertaken in a 2014/2015 study. Some of these operations are no longer being undertaken by AGA and is also likely a conservative estimate of potential impacts in the region. The main findings of the 2014/2015 study were as follows:
    - Particulate matter with diameter of less than 10 µm (PM_{10}) and particulate matter with diameter of less than 2.5 µm ($PM_{2.5}$) concentrations complied at the AQSRs over the short- and long-term. Both in the vicinity of Kareerand and other operations in the region.
    - Dustfall rates were below the NDCR limit for residential areas at the AQSRs. Both in the vicinity of Kareerand and other operations in the region.

The main findings of the impact assessment are as follows:

- Construction phase:
    - The significance of construction related inhalation health and nuisance impacts are likely to have a "low" risk; however, using the GCS ranking methodology the impacts are "moderate" risk without and with mitigation. This is mainly due to the high likelihood in the significance ranking which increases the risk rating. The likelihood is significantly inflated since the activity assessed is governed by legislation.
- Future operational phase:
    - PM (TSP, PM_{10} and $PM_{2.5}$) emissions and impacts were quantified.

- PM_{10} and $PM_{2.5}$ concentrations are within compliance off-site and al all the AQSRs over the short- and long-term.
- Dustfall rates above the NDCR limits for residential areas at some AQSRs occurred for one month based on the meteorological data used. High winds occurred over two consecutive days where a secondary development associated with a frontal system arose. The rest of the data showed dustfall rates below the NDCR limit for residential areas at all AQSRs. Dustfall rates are below non-residential areas at all of the AQSRs.
- The significance of operations related inhalation health and nuisance impacts are likely to be “low” risk; however, using the GCS ranking methodology the impacts are “moderate” risk without and with mitigation. This is mainly due to the high likelihood in the significance ranking which increases the risk rating. The likelihood is significantly inflated since the activity assessed is governed by legislation.

- Decommissioning and closure phases:
  - The significance of decommissioning operations related inhalation health and nuisance impacts are likely “low”; however, according to the GCS ranking methodology the risk is “moderate” without and with mitigation.
  - The significance of closure operations related inhalation health and nuisance impacts are likely “low”; however, using the GCS ranking methodology the risk is “moderate” without and with mitigation.
  - The likelihood in the significance ranking is high which increases the risk rating. The likelihood is excessive since the activity assessed is governed by legislation.

12.2 Air Quality Recommendations

To ensure the lowest possible impact on AQSRs and environment it is recommended that the air quality management plan as set out in this report should be adopted. This includes:

- The on-going management of the Kareerand TSF; resulting in the mitigation of associated air quality impacts;
- Ambient air quality monitoring; and
- Continuation of the record keeping and community liaison procedures. The facility is ISO14001 accredited. Procedures are in place to log, record and to respond to public complaints related to environmental management. A Community Environmental Forum has been in place since 2014, meeting on quarterly basis, where key performance i.e. dust management is discussed.

Based on these findings and provided the measures recommended are in place, it is the specialist opinion that the project may be authorised.

13 GREENHOUSE GAS EMISSION STATEMENT

13.1 Introduction

13.1.1 The greenhouse effects

Greenhouse gases are "those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of thermal infrared radiation emitted by the Earth's surface, the atmosphere itself, and by clouds. This property causes the greenhouse effect. Water vapour (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) and ozone (O_3) are the primary greenhouse gases in the Earth's atmosphere. Moreover, there are a number of entirely human-made greenhouse gases in the atmosphere, such as the halocarbons and other chlorine and bromine containing substances, dealt with under the Montreal Protocol. Beside CO_2, N_2O and CH_4, the Kyoto Protocol deals with the greenhouse gases sulphur hexafluoride (SF_6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) (IPCC, 2007). Human activities since the beginning of the Industrial Revolution (taken as the year 1750) have produced a 40% increase in the atmospheric concentration of carbon dioxide, from 280 ppm in 1750 to 406 ppm in early 2017 (NOAA, 2017). This increase has occurred despite the uptake of a large portion of the emissions by various natural "sinks" involved in the carbon cycle (NOAA, 2017). Anthropogenic carbon dioxide (CO_2) emissions (i.e., emissions produced by human activities) come from combustion of fossil fuels, principally coal, oil, and natural gas, along with deforestation, soil erosion and animal agriculture (IPCC, 2007).

13.1.2 International agreements

In 1992, countries joined an international treaty, the United Nations Framework Convention on Climate Change, (UNFCCC) as a framework for international cooperation to combat climate change by limiting average global temperature increases and the resulting climate change, and coping with impacts that were, by then, inevitable.

By 1995, countries launched negotiations to strengthen the global response to climate change, and, two years later, adopted the Kyoto Protocol. The Kyoto Protocol legally binds developed country parties to emission reduction targets. The Protocol's first commitment period started in 2008 and ended in 2012. As agreed in Doha in 2012, the second commitment period began on 1 January 2013 and will end in 2020 (UNFCCC, 2017) but due to lack of ratification has not come into force.

The Paris Agreement (2016) builds upon the Convention and – for the first time – brings all nations into a common cause to undertake ambitious efforts to combat climate change and adapt to its effects, with enhanced support to assist developing countries to do so. As such, it charts a new course in the global climate effort.

The Paris Agreement's central aim is to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius. Additionally, the agreement aims to strengthen the ability of countries to deal with the impacts of climate change. To reach these ambitious goals, appropriate financial flows, a new technology framework and an enhanced capacity building framework will be put in place, thus supporting action by developing countries and the most vulnerable countries, in line with their own national objectives.

The Paris Agreement requires all Parties to put forward their best efforts through "nationally determined contributions" (NDCs) and to strengthen these efforts in the years ahead. This includes requirements that all Parties report regularly on their emissions and on their implementation efforts.

In 2018, Parties will take stock of the collective efforts in relation to progress towards the goal set in the Paris Agreement and to inform the preparation of NDCs. There will also be a global stocktake every 5 years to assess the collective progress towards achieving the purpose of the Agreement and to inform further individual actions by Parties.

As of August 2017, 158 Parties of the 197 Parties to the UNFCCC Convention, including South Africa, had ratified the Paris agreement. South Africa submitted its intended NDC (INDC) to the UNFCCC on 25 September 2016.

13.2 The Project

MWS owns and operates the Kareerand TSF as part of the MWS operations in North-West Province of South Africa, near Stilfontein. The current operation is recovery of gold, uranium and sulphuric acid from the reprocessing of existing TSFs in the area. MWS proposes to extend the current Kareerand TSF footprint ("the Project"). The current power requirements will be sufficient for the expanded Kareerand TSF operations and no change will be made to the equipment fleet due to the Kareerand TSF extension.

13.3 Methodology

13.3.1 Impact Assessment Methodology

As the emission of greenhouse gases has a global impact, it is not feasible to follow the normal impact assessment methodology viz. comparing the state of the physical environment after implementation of the project to the condition of the physical environment prior to its implementation. Instead, this report will assess the following

(i) The GHG emissions during the construction, operation and decommissioning of the project compared to the global and South African emission inventory and to international benchmarks for the project.
(ii) The impact of climate change over the lifetime of the project taking the robustness of the project into account.
(iii) The vulnerability of communities in the immediate vicinity of the project to climate change.

13.3.1.1 Carbon Footprint Methodology

The Carbon Footprint is an indication of the greenhouse gases estimated to be emitted directly and/or indirectly by an organisation, facility or product. It can be estimated from

$$Carbon\ emissions = Activity\ information * emission\ factor * GWP$$

where

- *Activity information* relates to the activity that causes the emissions
- *emission factor* refers to the amount of GHG emitted per unit of activity
- *GWP* or global warming potential is the potential of an emitted gas to cause global warming relative to CO_2. This converts the emissions of all GHGs to the equivalent amount of CO_2 or CO_2-e.

For combustion processes, the emission factor is often calculated from a carbon mass balance, where the combustion of each unit mass of carbon in the fuel leads to an equivalent emission of 3.67 mass units of CO_2 (from 44/12, the ratio of molecular weight of CO_2 to that of carbon).

13.3.1.1.1 Scope of Carbon Footprint

This report considers Scope 1 emissions, which are the emissions directly attributable to the project, as well as Scope 2 emissions, which are the emissions associated with bought-in electricity over the lifetime of the project. Scope 3 emissions, which consider the "embedded" carbon in bought-in materials, are not considered here, in line with the guidelines provided by the International Finance Corporation (IFC, 2012)

13.4 Description of the Baseline

13.4.1 South African Climate Change Literature and Legislation

13.4.1.1 National Climate Change Response Policy 2011

South Africa ratified the UNFCCC in August 1997 and acceded to the Kyoto protocol in 2002, with effect from 2005. However, since South Africa is an Annex 1 country it implies no binding commitment to cap or reduce GHG emissions.

The National Climate Change Response White Paper stated that in responding to climate change, South Africa has two objectives: to manage the inevitable climate change impacts and to contribute to the global effort in stabilising GHG emissions at a level that avoids dangerous anthropogenic interference with the climate system. The White Paper proposes mitigation actions, especially a departure from coal-intensive electricity generation, be implemented in the short- and medium-term to match the GHG trajectory range. Peak GHG emissions are expected between 2020 and 2025 before a decade long plateau period and subsequent reductions in GHG emissions.

The White Paper also highlighted the co-benefit of reducing GHG emissions by improving air quality and reducing respiratory diseases by reducing ambient particulate matter, ozone and SO_2 concentrations to levels in compliance with NAAQS by 2020. In order to achieve these objectives, the DEA has appointed a service provider to establish a national GHG emissions inventory, which will report through SAAQIS.

13.4.1.2 Intended Nationally Determined Contribution

The South African Intended Nationally Determined Contribution (INDC) submission was completed in 2015. This was undertaken to comply with decision 1/CP.19 and 1/CP.20 of the Conference of the Parties to the UNFCC. This document describes South Africa's INDC on adaptation, mitigation and finance and investment necessities to undertake the resolutions.

As part of the adaption portion the following goals have been assembled:

1. Goal 1: Development and implementation of a National Adaption Plan. The implementation of this will also result in the implementation of the National Climate Change Response Plan (NCCRP) as per the 2011 policy.
2. Goal 2: In the development of national, sub-national and sector strategy framework, climate concerns must be taken into consideration.
3. Goal 3: An official institutional function for climate change response planning and implementation needs to be assembled.
4. Goal 4: The creation of an early warning, vulnerability and adaptation monitoring system
5. Goal 5: Develop policy regarding vulnerability assessment and adaptation needs.
6. Goal 6: Disclosure of undertakings and costs with regards to past adaptation strategies.

As part of the mitigation portion the following have been or can be implemented:

- The approval of 79 (5 243 MW) renewable energy Independent Power Producer (IPP) projects as part of a Renewable Energy Independent Power Producer Procurement Programme (REI4P). An additional 6 300 MW is being deliberated.
- A "Green Fund" has been created to back green economy initiatives. This fund will be increased in the future to sustain and improve successful initiatives.
- It is intended that by 2050 electricity will be decarbonised.
- Carbon Capture and Sequestration (or Carbon Capture and Storage) (CCS) which is discussed in more detail in the mitigation section.
- To support the use of electric and hybrid electric vehicles.
- Reduction of emissions can be achieved through the use of energy efficient lighting; variable speed drives and efficient motors; energy efficient appliances; solar water heaters; electric and hybrid electric vehicles; solar PV; wind power; CCS; and advanced bio-energy.

13.4.1.3 Greenhouse Gas Emissions

Regulations pertaining to GHG reporting using the NAEIS were published on 3 April 2017 (GN 257 in Government Gazette 40762). 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 South African Greenhouse Gas Emission Reporting System (SAGERS) web-based monitoring and reporting system will 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 South African Atmospheric Emission Licensing and Inventory Portal (SAAELIP).

The DEFF 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. Technical guidelines for GHG emission estimation have been issued.

Also, the Carbon Tax Act (Act 15 of 2019) includes details on the imposition of a tax on the CO_2-e of GHG emissions. Certain production processes indicated in Annexure A of the Declaration of Greenhouse Gases as Priority Pollutants (GN 710 in GG 40966, 21 July 2017) with GHG in excess of 0.1 Mt, measured as CO_2-e, are required to submit a pollution prevention plan to the Minister for approval. The Astron Energy Refinery is required to report CO_2-e emissions annually as the operations are listed under Annexure A of the Declaration (Production and/or refining of crude oil) and GHG emission rates exceed 0.1 Mt per year.

13.4.2 South African Energy supply

Coal provides in the order of 70% of the primary energy supply to the SA economy, with in excess of 90% of the electricity being generated from coal combustion. South Africa is thus regarded as having a carbon-intensive energy economy.

13.4.2.1 Planning framework

The 1998 White Paper on the Energy Policy of the Republic of South Africa covered both supply and demand of energy for the next decade and made specific provision for independent suppliers of energy to enter the market. No additional capacity ensued during the decade 1998 to 2008, leading to the 'load shedding' of 2008 and the subsequent short-term interventions to ensure stability of supply. The 2011 Integrated Resource Plan (IRP) (DOE, 2011) provided a planning basis for the period up to 2030 and made provision for the supply of energy (including renewable energy) by independent producers, as well as 9600 MW of nuclear energy over that period. An update of the IRP is in progress at the date of this report but has not been officially adopted; the drafts have attracted considerable criticism regarding the cost and greenhouse gas implications as part of the public participation process, including a report by the CSIR arguing for a much larger use of renewable sources (CSIR, 2016).

13.4.2.2 Additional energy supply

Seventy-nine renewable energy Independent Power Producer (IPP) projects have been approved and several others are being deliberated as part of a Renewable Energy Independent Power Producer Procurement Programme (REI4P).

13.4.3 GHG Inventories

13.4.3.1 National GHG Emissions Inventory

South Africa is perceived as a global climate change contributor and is undertaking steps to mitigate and adapt to the changing climate. DEA is categorised as the lead climate change institution and is required to coordinate and manage climate related information such as development of mitigation, monitoring, adaption and evaluation strategies (DEA, 2014a). This includes the establishment and updating of the National GHG Inventory. The National Greenhouse Gas Improvement Programme (GHGIP) has been initiated; it includes sector specific targets to improve methodology and emission factors used for the different sectors as well as the availability of data.

The 2000 to 2010 National GHG Inventory was prepared using the 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines (IPCC, 2006). According to the National GHG Inventory (DEA, 2014a) the 2010 total GHG emissions were estimated at approximately 544.314 million metric tonnes CO_2-e (excluding Forestry and Other Land Use (FOLU)). This was a 21.1% increase from the 2000 total GHG emissions (excluding FOLU). FOLU is estimated to be a net carbon sink which reduces the 2010 GHG emissions to 518.239 million metric tonnes CO_2-e. The assessment (excluding FOLU) showed the main sectors contributing to GHG emissions in 2010 to be the energy industries (solid fuels); road transport; manufacturing industry and construction (solid fuels); and energy industries (liquid fuels). In 2010 the energy industry contributed 78.7% to the total GHG emissions (excluding FOLU), this increased by 3.6% from 2000.

The DEA is working together with local sectors to develop country specific emissions factors in certain areas; however, in the interim the 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.

13.4.3.2 GHG Emission Inventory for the sector

The MWS operations would most likely fall under the category of “industry” for the global GHG inventory and “manufacturing industries and construction” for the national GHG inventory. According to the “mitigation of climate change” document as part of the IPCC fifth Assessment Report (AR5) (IPCC, 2014) the 2010 global GHG emissions were 49 (±4.5) Gt CO_2-e, 21% (10 Gt CO_2-e) of which is as a result of industry. The South African category contributes approximately 41.117 million metric tonnes CO_2-e (excluding and including FOLU).

13.5 Effects of Climate Change on the Region

13.5.1.1 Climate Change Reference Atlas

In 2017 the SAWS published an updated Climate Change Reference Atlas (CCRA) based on Global Climate Change Models (GCMs) projections. It must be noted that as with all atmospheric models there is the possibility of inaccuracies in the results as a result of the model’s physics and accuracy of input data; for this reason, an ensemble of models’ projections is used to determine the potential change in near-surface temperatures and rainfall depicted in the CCRA. The projections are for to 30-year periods described as the near future (2036 to 2065) and the far future (2066 to 2095). Projected changes are defined relative to a historical 30-year period (1976 to 2005). The Rossby Centre regional model (RCA4) was used in the predictions for the CCRA which included the input of nine GCMs results. The RCA4 model was used to improve the spatial resolution to 0.44° x 0.44°- the finest resolution GCMs in the ensemble were run at resolutions of 1.4° x 1.4° and 1.8° x 1.2°.

Two trajectories are included based on the four Representative Concentration Pathways (RCPs) discussed in the IPCC’s fifth assessment report (AR5) (IPCC, 2013). RCPs are defined by their influence to atmospheric radiative forcing in the year 2100. RCP4.5 represents an addition to the radiation budget of 4.5 W/m^2 as a result of an increase in GHGs. The two RCPs selected were RCP4.5 representing the medium-to-low pathway and RCP8.5 representing the high pathway. RCP4.5 is based on a CO_2 concentration of 560 ppm and RCP8.5 on 950 ppm by 2100. RCP4.5 is based on if current interventions to reduce GHG emissions being sustained (after 2100 the concentration is expected to stabilise or even decrease). RCP8.5 is based on if no interventions to reduce GHG emissions being implemented (after 2100 the concentration is expected to continue to increase).

13.5.1.1.1 RCP4.5 trajectory

Based on the median, for the region in which the Kareerand TSF and AQSRs discussed are situated, the annual average near surface temperatures (2 m above ground) are expected to increase by between 1°C and 2.5°C for the near future and between 2.5°C and 3°C for the far future. The seasonal average temperatures are expected to increase for all seasons. The total annual rainfall is expected to decrease by between 0 mm and 10 mm for the near future and the far future. For the near future the total seasonal rainfall is expected to increase in summer, remain the same or slightly increase for autumn. Winter total rainfall is expected to decrease and spring to stay the same or decrease slightly for near future. The total seasonal rainfall is expected to remain the same or slightly decrease for summer, winter and spring for the far future. Autumn total rainfall is expected to increase for the far future.

13.5.1.1.2 RCP8.5 trajectory

Based on the median, the region in which the Kareerand TSF and AQSRs discussed are situated, the annual average near surface temperatures (2 m above ground) are expected to increase by between 2.5°C and 3°C for the near future and between

4.5°C and 5°C for the far future. The seasonal average temperatures are expected to increase for all seasons. The total annual rainfall is expected to decrease by between 0 mm and 10 mm for the near future and far future. For the near future the total seasonal rainfall is expected to increase for summer and remain the same or slightly increase for autumn and spring. Winter total rainfall is expected to decrease for the near future. The total seasonal rainfall is expected to decrease for autumn and winter for the far future. Spring and summer total rainfall is expected to increase for the far future.

13.6 Impact Assessment: The Project's Carbon Footprint

13.6.1 The Project's GHG Emissions

For the construction and the future operations operations, scope 1 and scope 2 are applicable. The future scope 1 emissions based on the annual fuel use will likely not change from the current VR and MWS scope 1 emissions. For the future scope 2 emissions based on the approximate electricity requirements there will be no change from the current scope 2 emissions. Ultimately there will be no project specific GHG emissions during the operational phase. For the decommissioning operations scope 1 and scope 2 are also applicable but available data is insufficient to determine construction operations GHG emissions.

13.6.1.1 Carbon Sequestration and Carbon Sink

Accounting for the uptake of carbon by plants, soils and water is referred to as *carbon sequestration* and these sources are commonly referred to as *carbon sinks*. Quantifying the rate of carbon sequestration is however not a trivial task requiring detailed information on the geographical location, climate (specifically temperature and humidity) and species dominance (Ravin & Raine, 2007).

Photosynthesis is the main sequestration process in forests and in soils. Carbon is absorbed as fixed carbon into the roots, trunk, branches and leaves and during the shedding of leaves, but is emitted – although at a reduced percentage – from foliage and when biomass decays. Several factors also determine the amount of carbon absorbed by trees such as species, size and age. Mature trees, for example, will absorb more carbon than saplings (Ravin & Raine, 2007).

Aspects required in order to calculate the carbon stack change in the pool (in tons of Carbon per year) include the climate, the type of forest or vegetation removed and the type to be re-introduced, and management measures. Soil type also has different absorption and release ratios that need to be included. This level of information was not available for the quantification of carbon sequestration for the project.

There will be an initial carbon sink loss due to the vegetation removal for the expansion area. As operations progress, the previously cleared areas that form part of VR and MWS will be rehabilitated resulting in a carbon sink gain. Even assuming rehabilitation uses the same indigenous vegetation, the carbon balance will not be completely restored. There may also be potential soil degradation due to stockpiling. The main CO_2 contribution from the project will therefore be based on the clearing of vegetation.

13.6.1.2 Construction

Comparison of the results of this section with the figures obtained for the operational period will indicate that the GHG emissions during construction do not constitute a material fraction of the overall emissions; fairly rudimentary estimation methods were therefore considered sufficient for this sub-section.

Scope 1: This includes clearing of the area (assumed to be grassland. The IPCC methodology (IPCC, 2006) assumes a cropland carbon stock of 6.1 tonne C/ha. For the construction period, approximately 362 hectares (ha) will be denuded for the construction of the TSF. To account for additional service road surfaces and other possible laydown space, a total of 400 ha land clearance was assumed for the calculations. Assuming all carbon eventually reports to the atmosphere as CO_2, it is therefore calculated that a total of 2 440 tonne of CO_2 would be released. The IPCC provides default emission factors for diesel in kg CO_2/unit energy content, while the density and calorific values are available from a number of standard engineering databases (Table 13-1). The United States Environmental Protection Agency (US EPA) provides default emission factors for distillate fuel oil no. 2 (diesel) powered off-road heavy vehicles in kg CO_2/gallon (US) (Table 13-2). The emissions may vary slightly depending on the calorific value of the diesel. Using the values in Table 13-1 and Table 13-2, the emission factor can be calculated per litre or gallon of fuel used, which allows calculation of the total emissions directly from proposed fuel use. The estimated amount of fuel (diesel) used per annum by mobile equipment is 1 605 240 litres (424 059 gallons (US)).

A summary of the greenhouse gas emissions is provided in Table 13-3. The total CO_2 (equivalent) emissions of approximately 6 809 tonnes per annum (tpa) should be seen in the perspective of the annual South African emission rate of GHG, which is approximately 518.239 million metric tonnes CO_2-e. The calculated CO_2-e emissions from the construction operations therefore contribute less than 0.0013% to the total of South African GHG emissions, 0.02% of the total "manufacturing industries and construction" sector.

Table 13-1: Calculation of liquid fuel-related CO_2 emission factors for vehicles

Type of fuel	CO_2 emission factor kg/TJ	Density kg/m³	Calorific value kJ/kg	Emission factor kg CO_2/litre fuel
Diesel	74100	840	43 400	2.701

Table 13-2: Vehicles - liquid fuel-related methane and nitrous oxide emission factors

Type of fuel	Density kg/m³	Emission factor g CH_4/gallon	Emission factor g N_2O/gallon
Diesel	840	0.58	0.26

Table 13-3: Summary of estimated greenhouse gas emissions for the construction operations

Source Group	CO_2	CH_4 as CO_2-e	N_2O as CO_2-e	Total CO_2-e	CO_2
	tpa	tpa	tpa	tpa	%
Mobile Equipment Exhaust	4330	6	33	**4369**	64%
Clearing	2440	-	-	**2440**	36%
Total	***6770***	***6***	***33***	***6809***	***100%***

13.6.1.3 Operations

The main sources of GHG due to current VR and MWS operations are the mobile and stationary equipment consuming diesel, paraffin and coal (scope 1) and the electricity usage (scope 2). The scope 1 sources of GHG as well as the emission quantities will change slightly for future operations; thus, the Project will have additional operational GHG emissions.

Scope 1: The IPCC provides default emission factors for diesel in kg CO_2/unit energy content, while the density and calorific values are available from a number of standard engineering databases (Table 13-1). The United States Environmental

Protection Agency (US EPA) provides default emission factors for distillate fuel oil no. 2 (diesel) powered off-road heavy vehicles in kg CO_2/gallon (US) (Table 13-2). Using the values in Table 13-1 and Table 13-2, the emission factor can be calculated per litre or gallon of fuel used, which allows calculation of the total emissions directly from proposed fuel use. The estimated amount of fuel (diesel) used per annum by mobile equipment is 1 605 240 litres (424 059 gallons (US)).

Scope 2: These emissions are related to purchased energy, heat or steam and can be calculated from the average South African emission factor published annually by Eskom in its integrated report. The emission factors for the last four years are given in Table 13-4. This allows the scope 2 emissions to be calculated directly from electricity consumption from the Eskom or local authority account. The median of 0.99 tonnes CO_2/MWh was used in the calculations. The average annual electricity usage for Kareerand TSF based on 2018 and 2019 data is 37 000 258 kWh.

Table 13-4: Eskom electricity emission factors

Year	Emission Factor (tonnes CO_2/MWh)	Source
2015/2016	1.00	Eskom 2016 Integrated Report
2016/2017	0.98	Eskom 2017 Integrated Report
2017/2018	0.97	Eskom 2018 Integrated Report
2018/2019	1.04	Eskom 2019 Integrated Report
Median	0.99	

A summary of the greenhouse gas emissions for scope1 and scope 2 is provided in Table 13-5. The total CO_2 (equivalent) emissions of approximately 40 999 tpa should be seen in the perspective of the annual South African emission rate of GHG, which is approximately 518.239 million metric tonnes CO_2-e. The calculated CO_2-e emissions from the construction operations therefore contribute approximately 0.008% to the total of South African GHG emissions, 0.1% of the total "manufacturing industries and construction" sector.

Table 13-5: Summary of estimated greenhouse gas emissions for the current operations

Source Group	CO_2	CH_4 as CO_2-e	N_2O as CO_2-e	Total CO_2-e	CO_2
	tpa	tpa	tpa	tpa	%
Mobile Equipment Exhaust	4 330	6	33	**4 369**	11%
Electricity Usage	36 630	-	-	**36 630**	89%
Total	***40 960***	***6***	***33***	***40 999***	***100%***

13.6.1.4 Decommissioning

There is insufficient data at this point to determine the decommissioning GHG emissions.

13.6.2 The Project's GHG Impact

13.6.2.1 Magnitude

The GHG emissions from the project will be relatively low and will not likely result in a noteworthy contribution to climate change on its own.

13.6.2.2 Impact on the sector

With the future operations there will be additions to the equipment fleet, likely to result in an increase in scope 1 emissions from the MWS operations. This would therefore change the “manufacturing industry and construction” sector’s total annual CO_2-e emissions, increasing it by approximately 4 369 tpa. The project contribution towards the 2010 total “manufacturing industries and construction” sector CO_2-e emissions is 0.01%.

13.6.2.3 Impact on the National Inventory

The clearing of vegetation (even though the TSF will likely be re-vegetated at some stage) will result in a carbon sink loss and an increase towards the national GHG inventory. With the construction and future operations, there will also be additions to the equipment fleet and will likely result in an increase in scope 1 emissions from the MWS operations; therefore, changing the national inventory’s total annual CO_2-e emissions by approximately 6 809 tpa during the construction phase and only 4 369 tpa during operations.

13.6.2.4 Alignment with national policy

Most of the South African policy is still draft or in the planning phase; however, as from the next NAEIS reporting period MWS will have to start reporting on GHG emissions.

13.7 Impact Assessment: Potential Effect of Climate Change on the Project

The most significant of the discussed climate change impacts on the project would be as a result of:

- Temperature increase,
- Possible reduction in rainfall.

13.7.1 Temperature

With the increase in temperature there is the likelihood of an increase in discomfort, possibility of heat related illness (such as heat exhaustion, heat cramps, and heat stroke). Both these have the potential to negatively affect staff performance and productivity. There is also the increased change in the overheating of equipment/machinery with effects on production. Finally, there is the possibility of increased evaporation and thus the need for increased use of water for mitigation and process operations.

13.7.2 Rainfall

The decrease in rainfall can result in reduced water supply.

13.8 Impact Assessment: Potential Effect of Climate Change on the Community

From the discussed climate change impacts, all aspects would likely have a significant effect on the surrounding communities.

13.8.1 Temperature

With the increase in temperature there is the likelihood of an increase in discomfort and possibility of heat related illness (such as heat exhaustion, heat cramps, and heat stroke). There is also the possibility of increased evaporation which in conjunction with the decrease in rainfall can result in water shortage. This does not only negatively affect the community's water supply but can reduce the crop yields and affect livestock (agriculture) resulting in a food security issue.

13.8.2 Rainfall

As discussed above the decrease in rainfall can result in the following effects:

- Reduced water supply
- A negative impact on food security

13.9 Adaptation and Management Measures

Climate change management includes both mitigation and adaptation. The main aim of mitigation is to stabilise or reduce GHG concentrations as a result of anthropogenic activities. This is achievable by lessening sources (emissions) and/or enhancing sinks through human intervention.

13.9.1.1 Project adaptation and mitigation measures

13.9.1.2 General

Additional support infrastructure can reduce the climate change impact on the staff and project, for example ensuring adequate water supply for staff and reducing on-site water usage as much as possible. MWS could initiate a community development program if one is not already in place.

13.9.1.2.1 Scope 1 (technology/sector-specific)

One way to keep GHG emissions to a minimum would be to ensure there is minimal fuel use, this can be achieved by ensuring the vehicles and equipment is maintained through an effective inspection and maintenance program. A measure of reducing the project's impact is to limit the removal of vegetation and to ensure that that as much as possible revegetation occurs and possibly even the addition of vegetation to the surrounding project area.

13.9.1.2.2 Scope 2

Carbon Capture and Storage (CCS) is a way of mitigating the contribution of fossil fuel emissions to global warming, based on capturing CO_2 from large point sources such as power stations and storing it. CCS involves carbon dioxide being concentrated through various options and then stored permanently.

The best researched carbon dioxide option is geological storage: This method involves injecting carbon dioxide directly into underground geological formations. Oil fields, gas fields, saline formations, un-mineable coal seams, and saline-filled basalt formations have been suggested as storage sites. Various physical (e.g. highly impermeable rock) and geochemical trapping mechanisms would prevent the CO_2 from escaping to the surface. The CSIR undertook a study into the potential for CO_2 storage in South Africa (2004). The study concluded that the storage of CO_2 in depleted gas fields, coal mines or gold mines is very limited. Deep saline reservoirs offer the highest potential for the geological storage of CO_2. The Karoo Super Group sediments offer the highest potential, and within that, the Vryheid Formation in the north and the Katberg Formation near Burgersdorp/Molteno offer the biggest potential. However, due to a lack of information about the porosity and permeability of these of reservoirs, significant work is required before CO_2 sequestration into geological formations will be possible (CSIR, 2004).

The South African CCS Atlas identified at a theoretical level that South Africa had about 150 Gigatons (Gt) of storage capacity. Less than 2% of this is onshore.

A significant limitation of CCS is its energy penalty. The technology is expected to use between 10 – 40 % of the energy produced by a power station to capture the CO_2 (IPCC, 2005). Wide scale adoption of CCS may erase efficiency gains of the last 50 years and increase resource consumption by one third. However, even taking the fuel penalty into account, overall levels of CO_2 abatement remain high, at approximately 80 - 90% compared to a plant without CCS.

13.10 Conclusions and recommendation

- The CO_2-e (scope 1) emissions for construction is approximately 6 809 tpa therefore contributing less than 0.01% to the total of South Africa’s GHG emissions and 0.02% of the total “manufacturing industry and construction” sector.
- The CO_2-e (scope 1) emissions for project associated operations is approximately 4 369 tpa therefore contributing less than 0.01% to the total of South Africa’s GHG emissions and 0.01% of the total “manufacturing industry and construction” sector.
- The GHG emissions from the project are low and will not likely result in a noteworthy contribution to climate change on their own.
- The project and the community are likely to be negatively impacted by climate change due to increased temperatures and possible water shortages (decreased rainfall and possible increased evaporation).
- The following is recommended to reduce the impacts of climate change on the project and the community:
    - Additional support infrastructure can reduce the climate change impact on the staff and project, for example ensuring adequate water supply for staff and reducing on-site water usage as much as possible.
    - MWS could initiate a community development program if one is not already in place.
- The following is recommended to reduce the GHG emissions from project:
    - Ensuring the vehicles and equipment are maintained through an effective inspection and maintenance program.
    - Limiting the removal or vegetation and ensuring adequate re-vegetation or addition of vegetation surrounding the project. Vegetation acts as a carbon sink.

14 REFERENCES

ADE. (2008). *Emission Estimation Technique Manual for Combustion Engines. Version 3.* Australian Depertment of the Environment.

Blight, G. E. (1989). Erosion Losses from the Surfaces of Gold-tailings Dams. *Journal of the South African Institute of Mining and Metallurgy, vol. 89 (1)*, 23-29.

Burger, L. W. (2010). Complexities in the Estimation of Emissions and Impacts of Wind generated fugitive dust. *Proceedings of the National Association for Clean Air Conference.* Polokwane: NACA.

Burger, L., Held, G. S., & Snow, N. H. (1997). *Revised User's Manual for the Airborne Dust Dispersion Model from Area Sources (ADDAS).* Eskom TSI Report No. TRR/T97?066.

CERC. (2004). *ADMS Urban Training. Version 2. Unit A.*

CSIR. (2016). *Council for Scientific and Industrial Research Report 20170331-CSIR-EC-ESPO-REP-DOE-1.1A Rev 1.1.* Pretoria: Council for Scientific and Industrial Research.

DEA. (2014a). *GHG Inventory for South Africa 2000 -2010.* Department of Environmental Affairs.

Department of National Treasury. (2013). *Carbon Tax Policy Paper.*

DOE. (2011, March 25). *Integrated Resource Plan for Electricity 2010-2030 Revision 2.* Retrieved from RSA Department of Energy: http://www.energy.gov.za/IRP/irp%20files/IRP2010_2030_Final_Report_20110325.pdf

Farmer, A. M. (1993). The Effects of Dust on Vegetation – A Review. *Environmental Pollution, 79*, 63-75.

Goldreich, Y., & Tyson, P. (1988). Diurnal and Inter-Diurnal Variations in Large-Scale Atmospheric Turbulence over Southern Africa. *South African Geographical Journal*, 48-56.

Government Gazette. (2014, July 11). Regulations Regarding Air Dispersion Modelling. *Regulations Prescribing the Format of the Atmospheric Impact Report, 37804*.

Hanna, S. R., Egan, B. A., Purdum, J., & Wagler, J. (1999). *Evaluation of ISC3, AERMOD, and ADMS Dispersion Models with Observations from Five Field Sites.*

Heyneke, E., & Phatudi, T. (2019, February). Veld Fire North of Reitz; Free State: 5 September 2018. *WeatherSMART News*, pp. 14-20.

IFC. (2007). *General Environmental, Health and Safety Guidelines.* World Bank Group.

IFC. (2012). *Performance Standard 3 Resource Efficiency and Pollution Prevention.* Retrieved from International Finance Corporation: https://www.ifc.org/wps/wcm/connect/25356f8049a78eeeb804faa8c6a8312a/PS3_English_2012.pdf?MOD=AJPERE

IPCC. (2006). *2006 IPCC Guidelines for National Greenhouse Gas Inventories.* Retrieved from Intergovernmental Panel on Climate Change: http://www.ipcc-nggip.iges.or.jp/public/2006gl/

IPCC. (2007). *Intergovernmental Panel on Climate Change 4th Assessment Report.* Retrieved from Intergovernmental Panel on Climate Change: http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_appendix.pdf

IPCC. (2013). *Intergovernmental Panel on Climate Change 5th Assessment Report.* Retrieved from Intergovernmental Panel on Climate Change: https://www.ipcc.ch/report/ar5/

IPCC. (2014). *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the IPCC.* Intergovernmental Panel on Climate Change. Cambridge, United Kingdom and New York, USA: Cambridge University Press. Retrieved from https://www.ipcc.ch/report/ar5/wg3/

Jongikhaya, W. (2015, August 6). Technical Guidelines for Monitoring, Reporting and Verification of Greenhouse Gas Emissions by Industry.

Liebenberg-Enslin, H. (2014). *A Functional Dependence Analysis of Wind Erosion Modelling System Parameters to Determine a Practical Approach* (PhD Thesis ed.). Johannesburg: University of Johannesburg.

Marticorena, B., & Bergametti, G. (1995). Modelling the Atmospheric Dust Cycle. 1. Design of a Soil-Derived Dust Emission Scheme. *Journal of Geophysical Research*, 100, 16 415 - 16430.

Mian, M., & Yanful, E. (2003). Tailings erosion and resuspension in two mine tailings ponds due to wind waves. *Advances in Environmental Research*, 745-765.

NOAA. (2017, August). *Earth System Research Laboratory Global Monitoring Division.* Retrieved from National Oceanic and Atmospheric Administration: https://www.esrl.noaa.gov/gmd/ccgg/trends/global.html

Shao, Y. (2008). *Physics and Modelling of Wind Erosion* (2nd revised and expanded edition ed.). Berlin: Springer.

Shao, Y., Ishizuka, M., Mikami, M., & Leys, J. F. (2011). Parameterization of size resolved dust emission and validation with measurements. *Journal of Geophysical Research*, 116.

Tiwary, A., & Colls, J. (2010). *Air Pollution: Measurement, Modelling and Mitigation.*

Tiwary, A., & Colls, J. (2010). *Air pollution: measurement, monitoring and mitigation* (3rd Edition ed.). Oxon: Routledge.

U.S. Department of the Interior, U.S. Geological Survey. (2018, February 2). *Digital Elevation: SRTM 1 Arc-Second Global*. Retrieved from EarthExplorer: http://earthexplorer.usgs.gov

UNFCCC. (2017). *United Nations Framework Convention on Climate Change e-Handbook* . Retrieved from United Nations Framework Convention on Climate Change: http://bigpicture.unfccc.int/

US EPA. (1995). *AP 42, 5th Edition, Volume 1, Chapter 13: Miscellaneous, 13.2.3 Heavy Construction Operations.*

US EPA. (2006). *AP 42, 5th Edition, Volume 1, Chapter13: Miscellaneous Sources, 13.2.4 Introduction to Fugitive Dust Sources, Aggragate Handling and Storage Piles.* Retrieved from https://www3.epa.gov/ttn/chief/ap42/ch13/final/c13s0204.pdf

15 APPENDIX A: AUTHORS' CURRICULUM VITAE AND SACNASP CERTIFICATE

CURRICULUM VITAE	NATASHA ANNE SHACKLETON

CURRICULUM VITAE

Name	Natasha Anne Shackleton (née Gresse)
Date of Birth	12 September 1988
Nationality	South African
Identification Number	880912 0054 081
Passport Number	A05514095
Employer	Airshed Planning Professionals (Pty) Ltd
Position	Senior Consultant
Profession	Meteorologist employed as an Air Quality and Noise Consultant
Years with Firm	9
E-mail Address	natasha@airshed.co.za
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MEMBERSHIP OF SOCIETIES

- Registered Professional Natural Scientist (Registration Number 116335) with South African Council for Natural Scientific Professions (SACNASP), 2018 to present.
- National Association for Clean Air (NACA), 2011 to present
- South African Society for Atmospheric Sciences (SASAS), 2016 to present.
- American Meteorological Society (AMS), 2017 and 2018.
- Golden Key International Honour Society, 2011 to present.

EXPERIENCE

Natasha has several years of experience in air quality and noise impact assessments and management. She is an employee of Airshed Planning Professionals (Pty) Ltd and is tasked with completing air, noise, greenhouse gas and climate change studies involving ambient measurements; meteorological data processing and preparation; the compilation of emission inventories; undertaking of air dispersion and noise propagation modelling; impact and compliance assessment using her substantial knowledge of South African and international legislation and requirements pertaining to air quality and noise; air quality, noise, greenhouse gas and climate change management plan preparation and report writing. Many of her projects within various countries in Africa required international financing, providing her with an inclusive knowledge base of IFC guidelines and requirements pertaining to air quality.

PROJECTS COMPETED IN VARIOUS SECTORS ARE LISTED BELOW:

Mining Sector

- Coal mining: Argent Colliery, Commissiekraal Coal Mine, Estima Coal Project (Mozambique), Grootegeluk Coal Mine, Matla Coal Mine, Rietvlei Coal Mine, Vierfontein Coal Mine.
- Metalliferous mines: AngloGold Ashanti, Atlantic Sands, Bakubung Platinum Mine, Bannerman Uranium Mine (Namibia), Consol Industrial Minerals, Gold Fields' South Deep Gold Mine, Kitumba Copper Project (Zambia), Lehating Manganese Mine, Lesego Platinum Mine, Lofdal Mining Project (Namibia), Marula Platinum Mine, Maseve Platinum Mine, Mkuju River Uranium Project (Tanzania), Namakwa Sands Quartz Rejects Disposal and Mine, Otjikoto Gold Project (Namibia), Otjikoto Gold Mine's Wolfshag Project (Namibia), Pan Palladium Project, Perkoa Zinc Project (Burkina Faso), Storm Mountain Diamonds (Lesotho), Tete Iron Ore Project / Tete Steel and Vanadium Project (Mozambique), Thabazimbi Iron Ore's Infinity Project, Toliara Sands Project (Madagascar), Tormin Mineral Sands Mine, Trekkopje Uranium Mine (Namibia), Tri-K Project (Guinea), Tschudi Copper Mine (Namibia), Wayland Iron Ore Project, Zulti South Project, Impala Platinum Rustenburg Mine and Smelter.
- Quarries: AfriSam Saldanha Cement Project Limestone Quarry, Bundu Mining, Tete Iron Ore Project / Tete Steel and Vanadium Project (Mozambique).

Industrial Sector

AfriSam Saldanha Project; CAH Chlorine Caustic Soda and HCl Plant, Consol Industrial Minerals, Corobrik Driefontein, Metal Concentrators SA Paarden Eiland, Namakwa Sands Dryer, Otavi Rebar Manufacturing, Phakisa Project, Pan Palladium Project, PPC Riebeeck Cement, Rare Earth Elements Saldanha Separation Plant, Saldanha Steel, Siyanda Project, Tete Iron Ore Project / Tete Steel and Vanadium Project (Mozambique), Tri-K Project (Guinea), Tormin Mineral Sands MSP, Tronox Namakwa Sands Smelter, Tronox Namakwa Sands UMM Plant, Tronox Namakwa Sands MSP, ZMY Steel Recycling Plant, Nyanza TiO_2 Pilot Plant, Musina-Makhado SEZ, West African Resources Sanbrado Project (Burkina Faso), Impala Platinum Rustenburg Mine and Smelter.

Power Generation, Oil and Gas

H2 Energy Power Station, Hwange Thermal Power Station Project (Zimbabwe), Ibhubesi Gas Project, Expansion of Staatsolie Power Company, Suriname Operations (Suriname), Tri-K Project (Guinea), Tete Iron Ore Project / Tete Steel and Vanadium Project (Mozambique).

Waste Disposal and Treatment Sector

Fishwater Flats Waste Water Treatment Works, Khutala Water Treatment Project, Moz Environmental Industrial Landfill (Mozambique), Wolverand Crematorium.

Petroleum Sector

Chevron Refinery, Exol Oil Refinery, Puma South Africa's Fuel Storage Facility, Oilkol Depot, Astron Energy Cape Town Refinery.

Transport and Logistics Sector

Saldanha Port Project.

Ambient Air Quality and Noise Sampling/Monitoring

Gravimetric particulate matter (PM) sampling, Dustfall sampling, Passive diffusive gaseous pollutant sampling, Continuous ambient air quality monitoring, Environmental noise sampling.

SOFTWARE PROFICIENCY

Software utilised in conducting air and noise studies:

- WRPLOT (wind & pollution rose generation);
- OpenAir (ambient and meteorological data processing)
- ScreenView (screening model);
- AERMOD suite (air dispersion model);
- ADMS (air dispersion model);
- CALPUFF suite (air dispersion model);
- GRAL system (air dispersion model);
- TANKS (emission estimation model);
- GasSim (emission estimation model);
- DataKustic CadnaA (noise propagation model);

- CONCAWE (noise propagation model); and
- SANS 10201 (calculating and predicting road traffic noise).

EDUCATION

- 2016 to present - MSc: Applied Science (Environmental Technology) student at the University of Pretoria (Faculty of Engineering, Built Environment and Information Technology), Pretoria. Currently undertaking studies. Supervisor: Dr G Kornelius.
- 2010 to 2011 - BSc Honours (Meteorology) student at the University of Pretoria (Faculty of Natural and Agricultural Sciences), Pretoria. Completed 30 November 2011. Degree issued/conferred 13 April 2012. Research project supervisor: Dr S Venkataraman.
- 2007 to 2010 - BSc student at the University of Pretoria (Faculty of Natural and Agricultural Sciences), Pretoria. Completed 30 June 2010. Degree issued/conferred 2 September 2010.

CONFERENCES ATTENDED, ARTICLES PUBLISHED AND COURSES COMPLETED

- Conference: Innovation Bridge and Science Forum South Africa (December 2019), attended.
- Conference: NACA (October 2018), attended and presented a paper (Correlating Dust Concentration Measurements aloft with Opencast Mining Surface Operations).
- Conference: NACA (October 2017), attended and presented a paper (Correlating Dust Concentration Measurements aloft with Opencast Mining Surface Operations).
- Published Article: Beukes, JP; Van Zyl, PG; Sofiev, M; Soares, J; Liebenberg-Enslin, H; Shackleton, N; Sundstrom, AM (2018). The use of satellite observations of fire radiative power to estimate the availabilities (activity patterns) of pyrometallurgical smelters. Journal of the Southern African Institute of Mining and Metallurgy, 118(6), 619-624., co-author.
- Undergraduate courses passed: computer literacy (word processing, spreadsheet processing, Microsoft power point, Microsoft publisher, use of Internet and Microsoft front page); MATLAB; ArcGIS 9.0.; ERDAS Image; Aan Arbor; IDRISI TAIGA; GRADS; TITAN; SUMO 3.00; and Danny Rosenfeld 2007-01.

COUNTRIES OF WORK EXPERIENCE

South Africa, Botswana, Burkina Faso, Guinea, Lesotho, Mozambique, Madagascar, Namibia, Suriname, Tanzania, Zambia and Zimbabwe.

LANGUAGES

Language	Proficiency
English	Full professional proficiency
Afrikaans	Limited working proficiency

REFERENCES

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Dr Gerrit Kornelius	Associate of Airshed Planning Professionals	+27 82 925 9569 gerrit@airshed.co.za
Dr Lucian Burger	Director at Airshed Planning Professionals	+27 11 805 1940 lucian@airshed.co.za
Dr Hanlie Liebenberg-Enslin	Managing Director at Airshed Planning Professionals	+27 11 805 1940 hanlie@airshed.co.za

CERTIFICATION

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

22/04/2020

SACNASP

South African Council for Natural Scientific Professions

herewith certifies that

Natasha Anne Shackleton

Registration Number: 116335

is a registered scientist

in terms of section 20(3) of the Natural Scientific Professions Act, 2003
(Act 27 of 2003)
in the following fields(s) of practice (Schedule 1 of the Act)

Physical Science (Professional Natural Scientist)

Effective **6 June 2018** Expires **31 March 2021**

Botha
Chairperson

Chief Executive Officer

To verify this certificate scan this code

16 APPENDIX B: COMPETENCIES FOR PERFORMING AIR DISPERSION MODELLING

All modelling tasks were performed by competent personnel. Table 16-1 is a summary of competency requirements. Apart from the necessary technical skills required for the calculations, personnel competency also include the correct attitude, behaviour, motive and other personal characteristic that are essential to perform the assigned job on time and with the required diligence as deemed necessary for the successful completion of the project.

The project technical team included a principal scientist with relevant experience of more than 15 years and one senior scientist with 9 years relevant experience. The principal scientist managed and directed the project.

Verification of modelling results was conducted by the principal scientist. The latter function requires a thorough knowledge of the

- meteorological parameters that influence the atmospheric dispersion processes and
- atmospheric chemical transformations that some pollutants may undergo during the dispersion process.

In addition, the project team included another senior staff member as an additional reviewer.

Table 16-1: Competencies for Performing Air Dispersion Modelling

Competency	Task, Knowledge and Experience
Context	Communication with field workers, technicians, laboratories, engineers and scientists and project managers during the process is important to the success of the model
	Familiar with terminology, principles and interactions
	Record keeping is important to support the accountability of the model - Understanding of data collection methods and technologies
Knowledge	Meteorology: Obtain, review and interpret meteorological data Understanding of meteorological impacts on pollutants Ability to identify and describe soil, water, drainage and terrain conditions Understanding of their interaction Familiarity with surface roughness` Ability to identify good and bad data points/sets Understanding of how to deal with incomplete/missing meteorological data
	Atmospheric Dispersion models Select appropriate dispersion model Prepare and execute dispersion model Understanding of model input parameters Interpret results of model
	Chemical and physical interactions of atmospheric pollutants Familiarity with fate and transport of pollutants in air Interaction of primary pollutants with other substances (natural or industrial) to form secondary pollutants
	Information relevant to the model Identify potential pollution (emission) sources and rates Gather physical information on sources such as location, stack height and diameter

Competency	Task, Knowledge and Experience
	Gather operating information on sources such as mass flow rates, stack top temperature, velocity or volumetric flow rate Calculate emission rates based on collected information Identify land use (urban/rural) Identify land cover/terrain characteristics Identify the receptor grid/site
	Legislation, regulations and guidelines in regard to National Environment Management: Air Quality Act (Act No 39 of 2004), including Minimum Emissions Standards (Section 21 of Act) National Atmospheric Emissions Reporting Regulations regarding Air Dispersion Modelling National Ambient Air Quality Standards Atmospheric Impact Report (AIR)
Abilities	Ability to read and understand map information
	Ability to prepare reports and documents as necessary
	Ability to review reports to ensure accuracy, clarity and completeness
	Communication skills
	Team skills

17 APPENDIX C: DUST FALLOUT GRAPHS

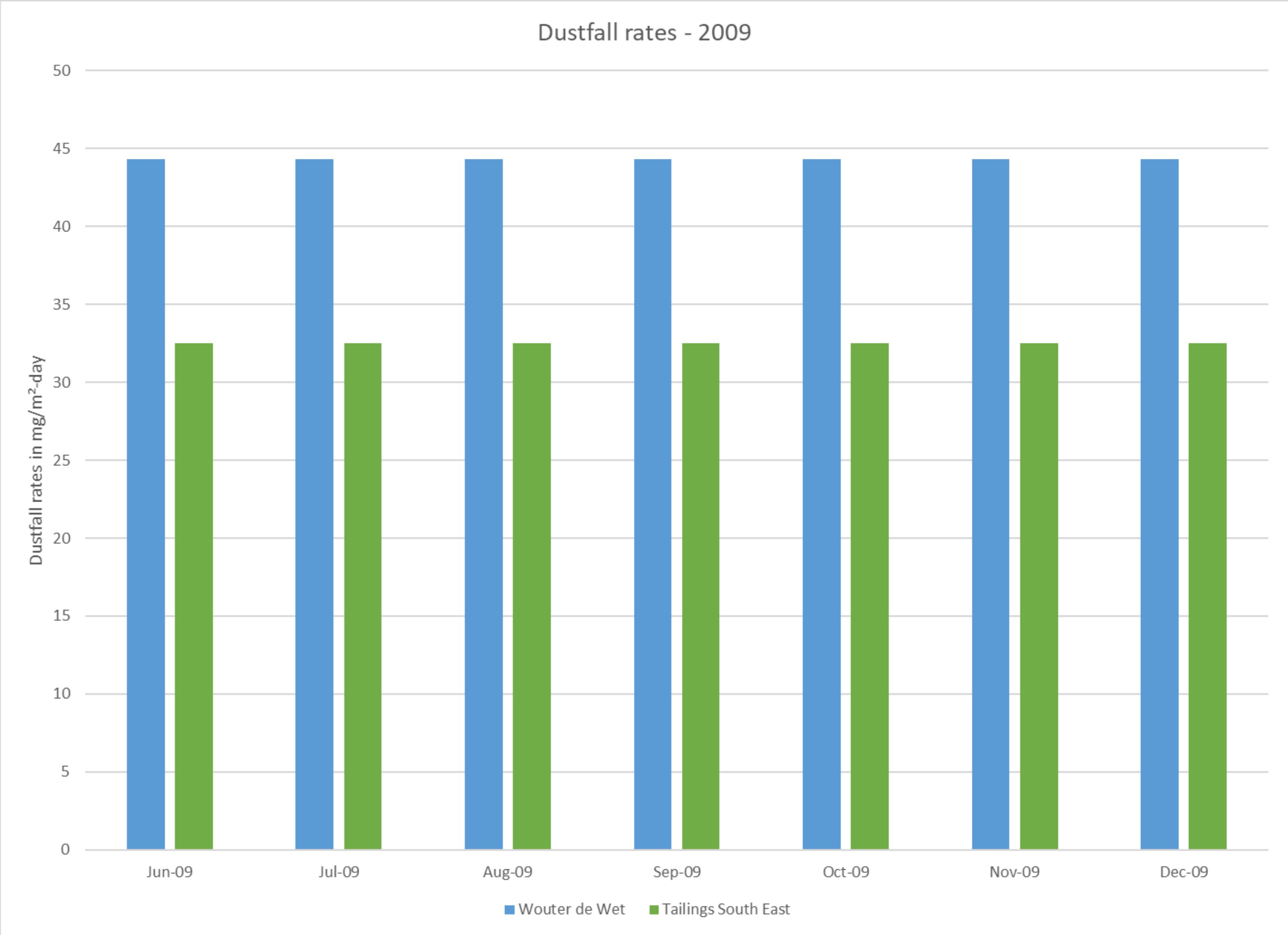

Figure 17-1: Dustfall rates for June 2009 to December 2009

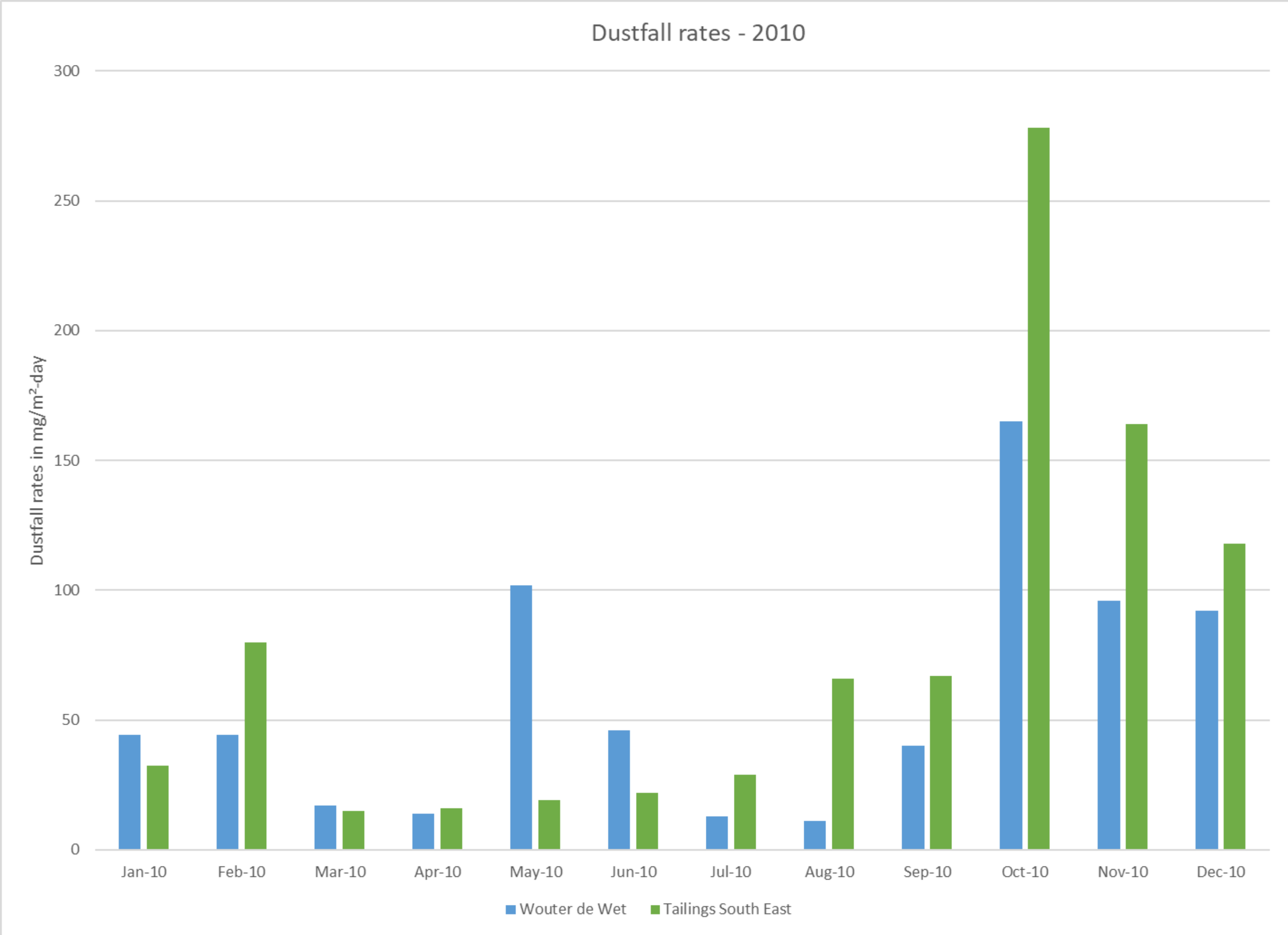

Figure 17-2: Dustfall rates for January 2010 to December 2010

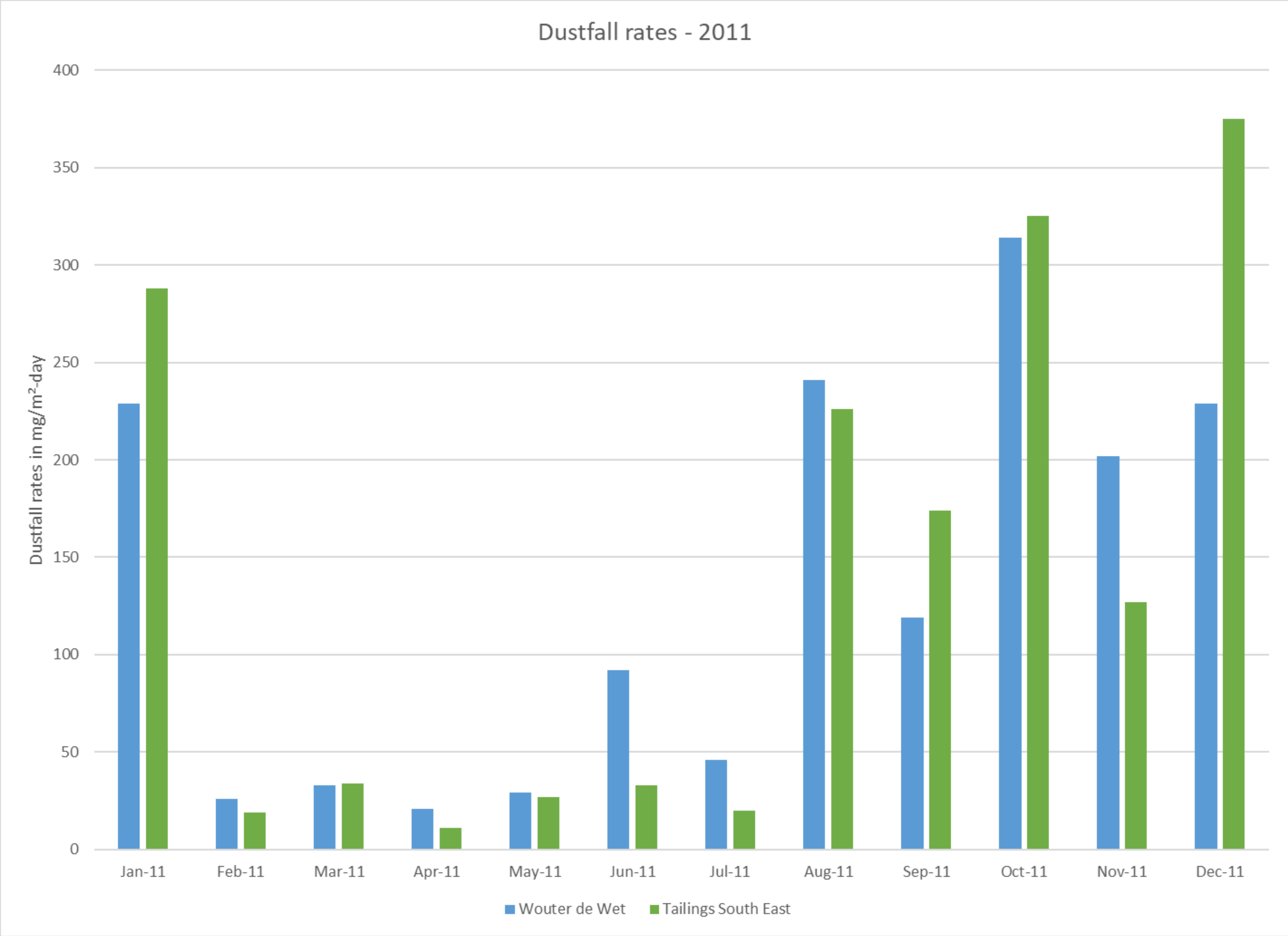

Figure 17-3: Dustfall rates for January 2011 to December 2011

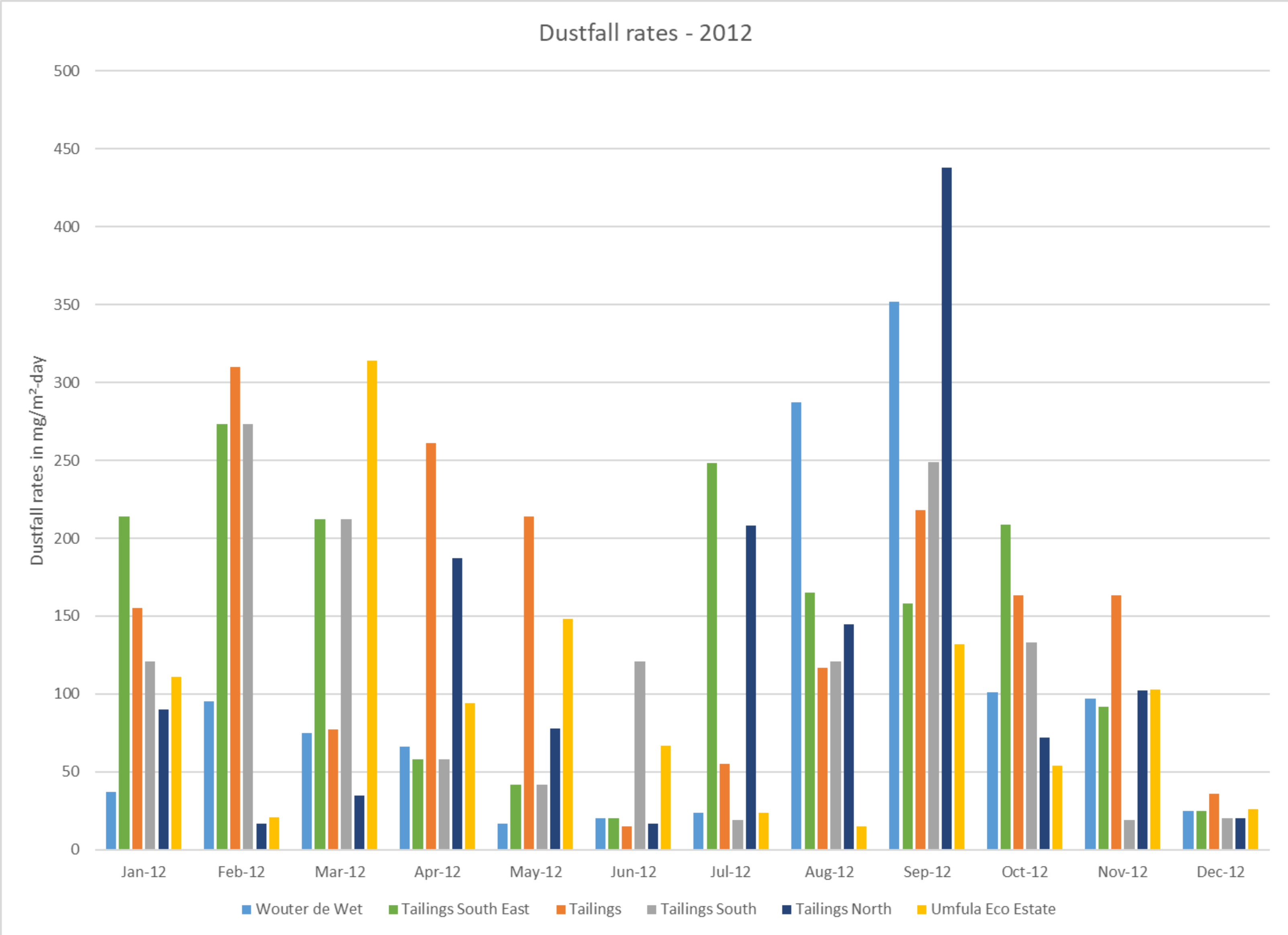

Figure 17-4: Dustfall rates for January 2012 to December 2012

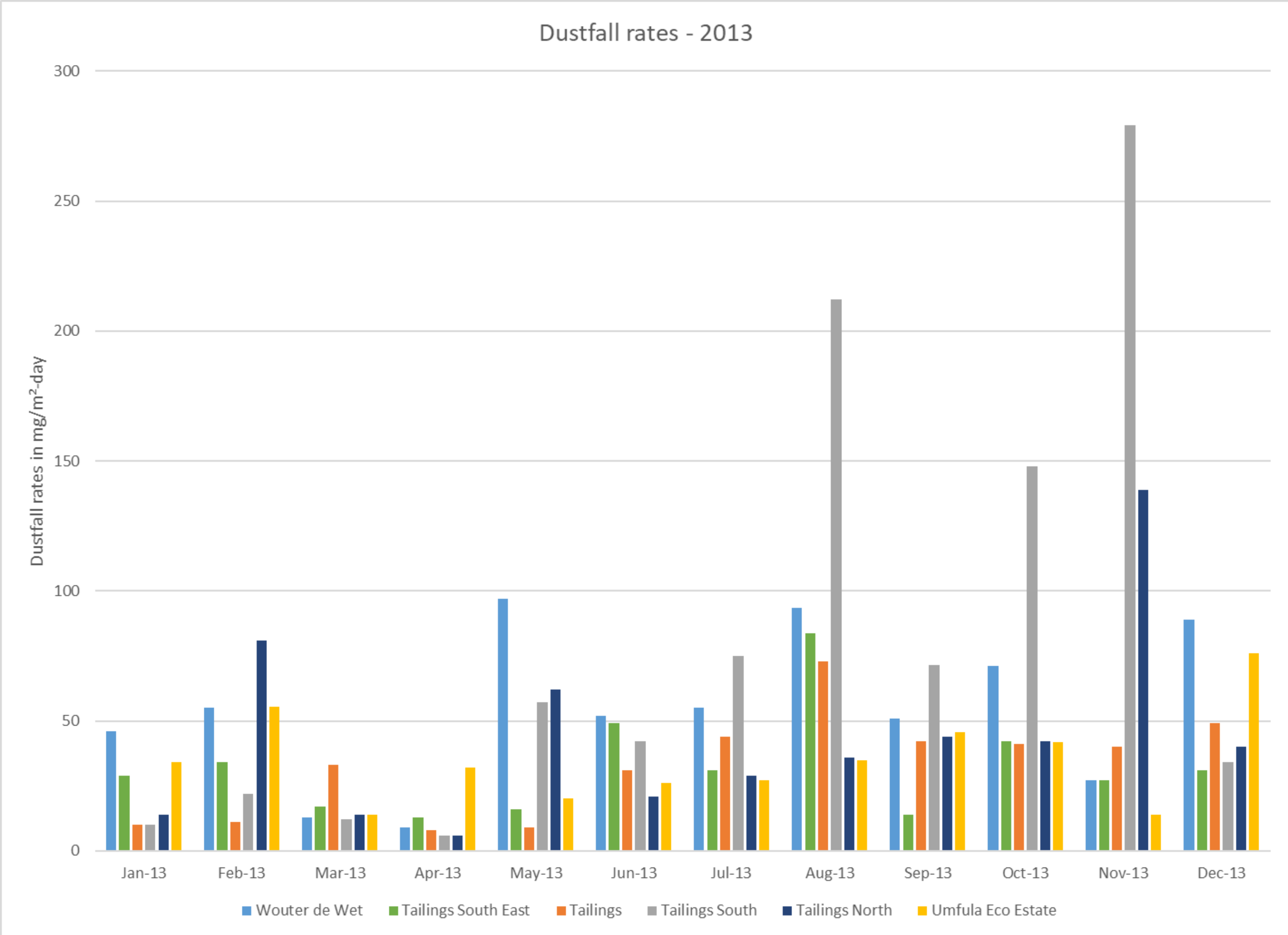

Figure 17-5: Dustfall rates for January 2013 to December 2013

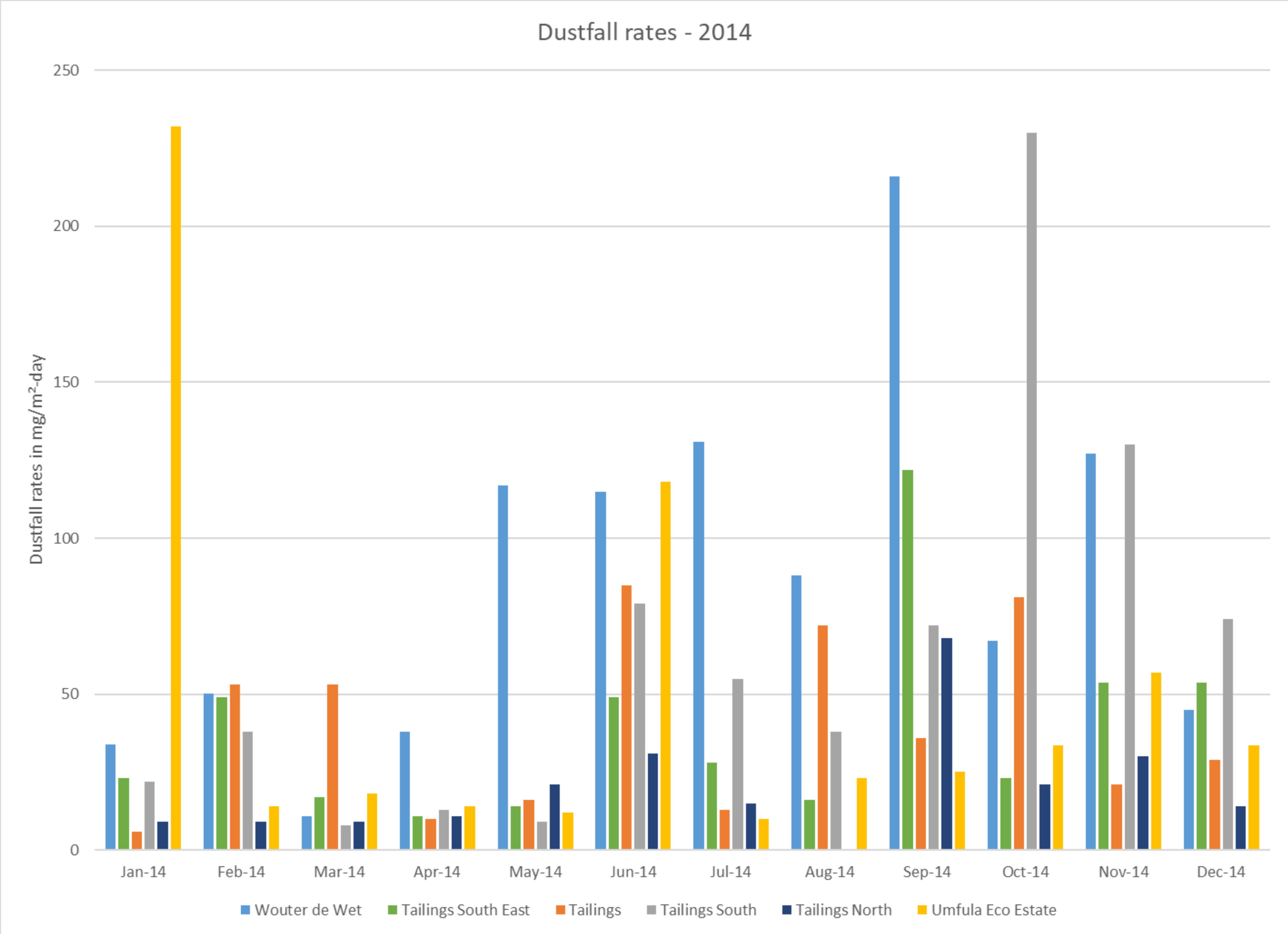

Figure 17-6: Dustfall rates for January 2014 to December 2014

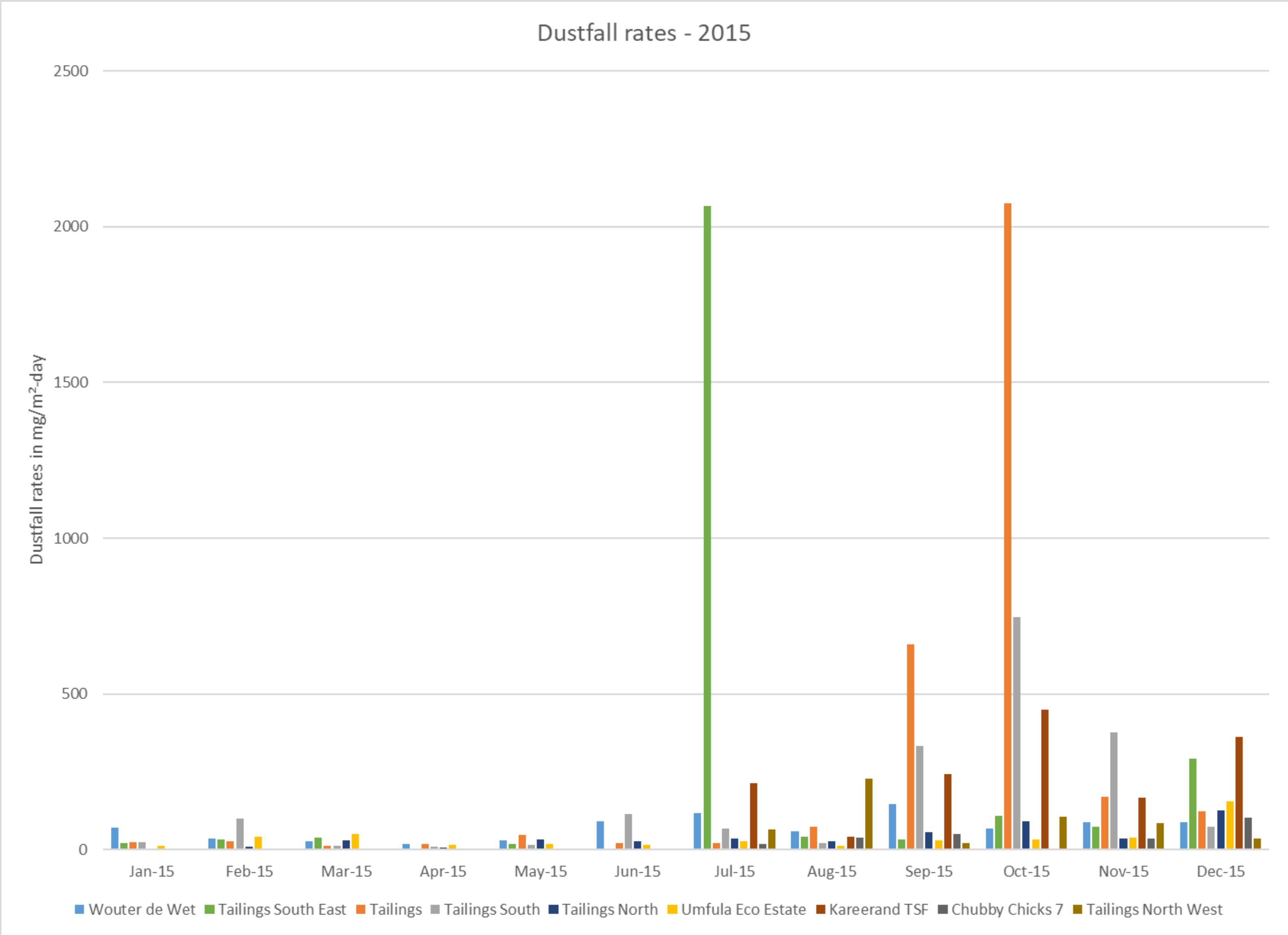

Figure 17-7: Dustfall rates for January 2015 to December 2015

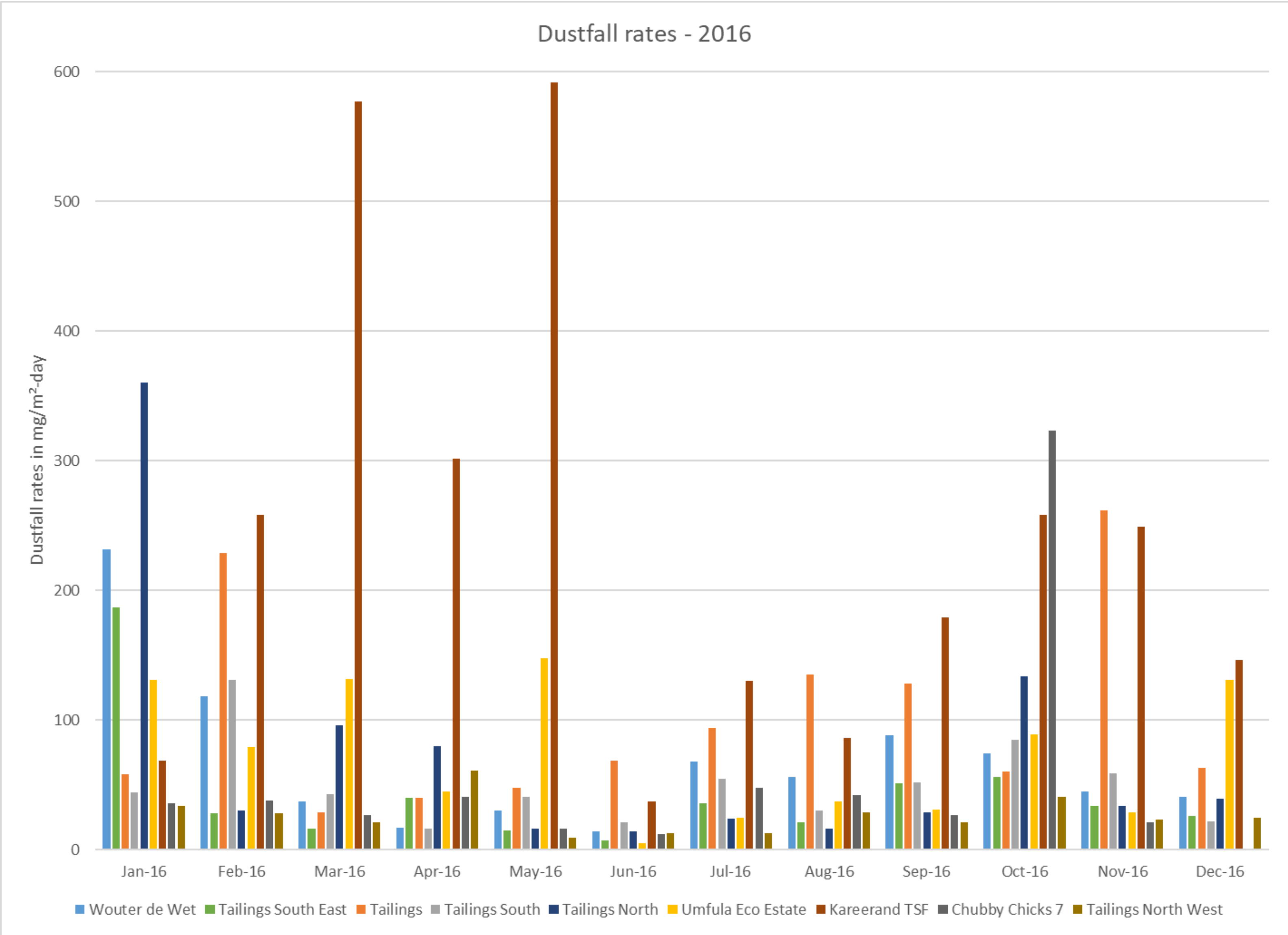

Figure 17-8: Dustfall rates for January 2016 to December 2016

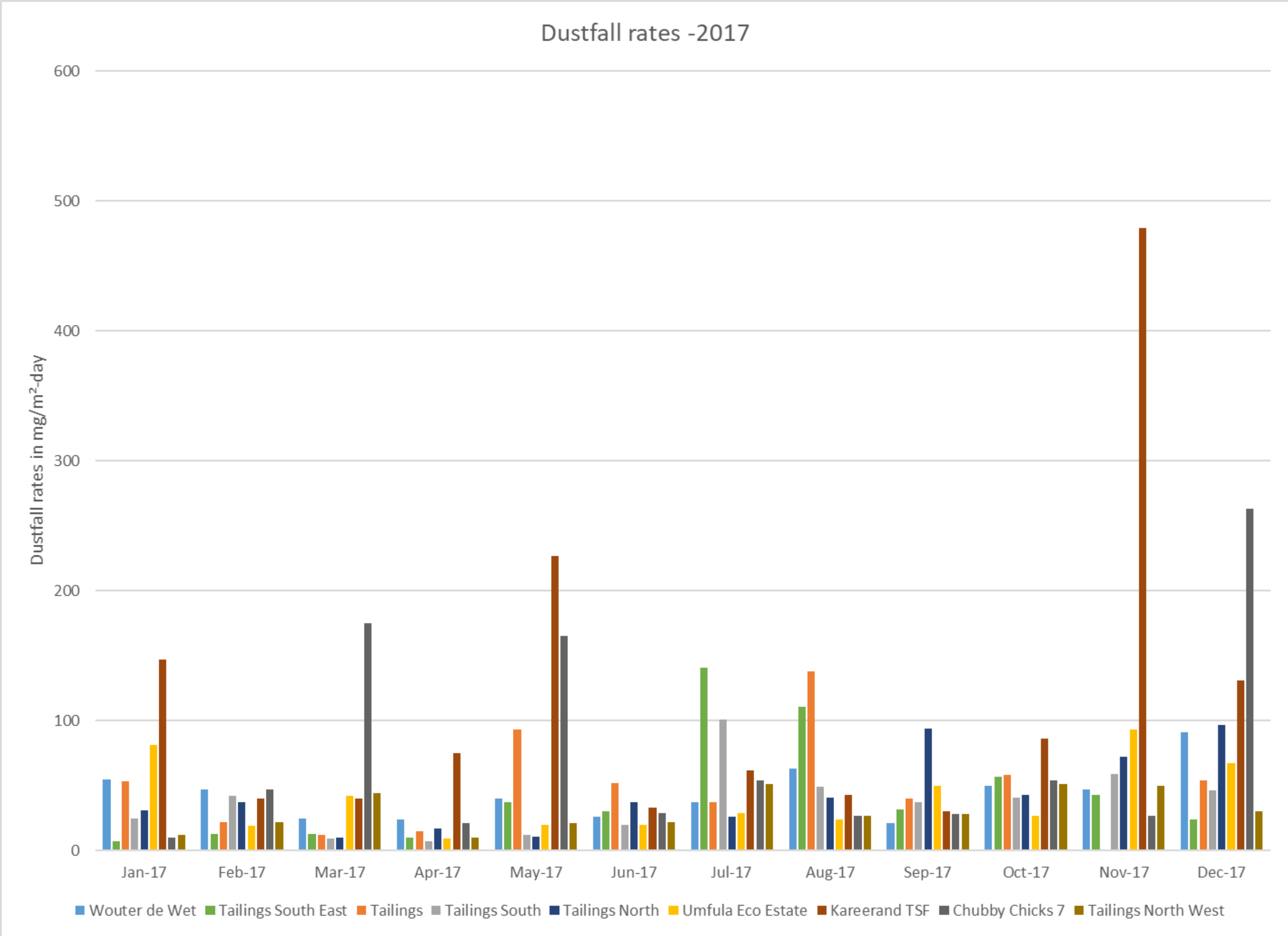

Figure 17-9: Dustfall rates for January 2017 to December 2017

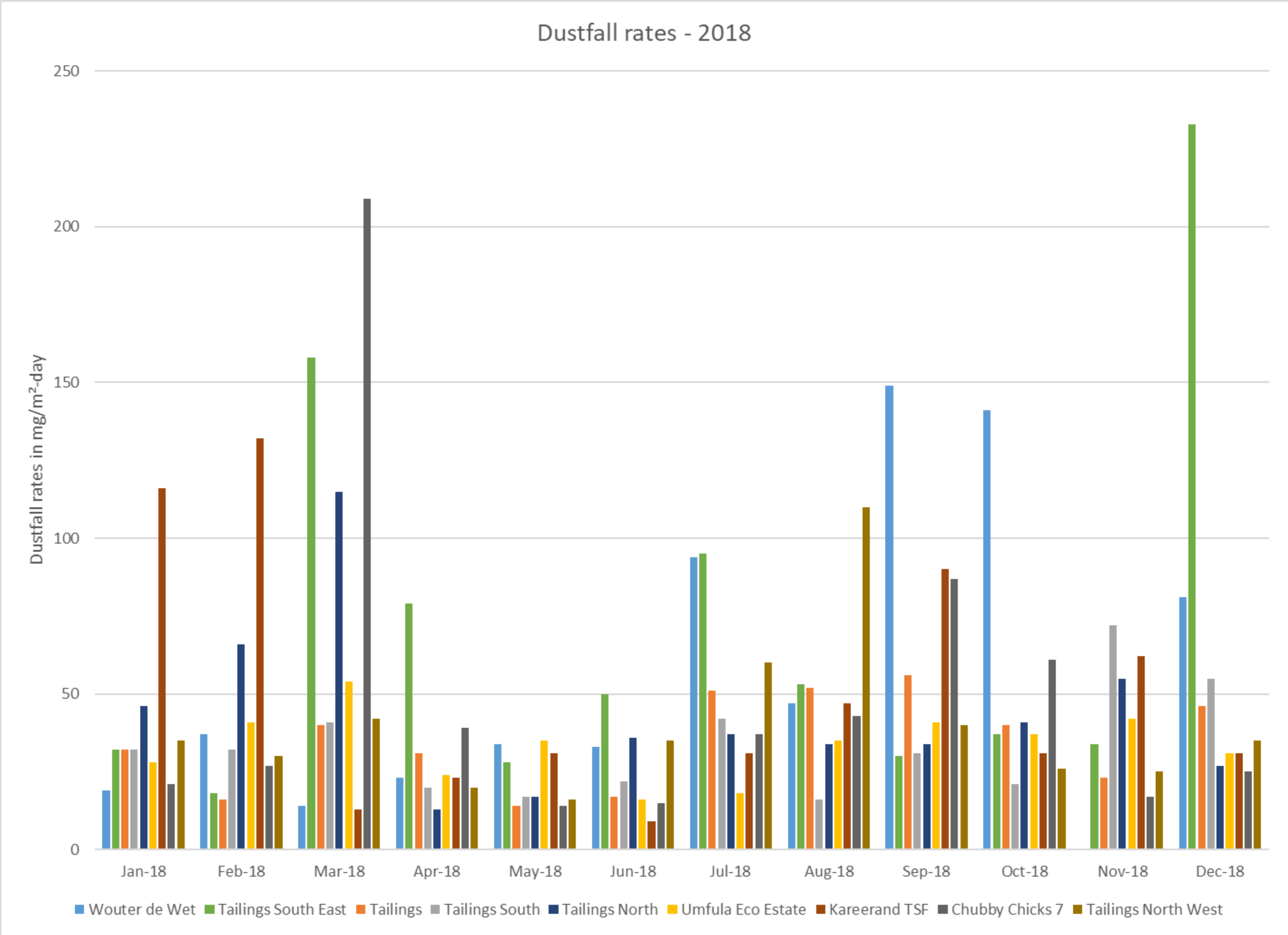

Figure 17-10: Dustfall rates for January 2018 to December 2018

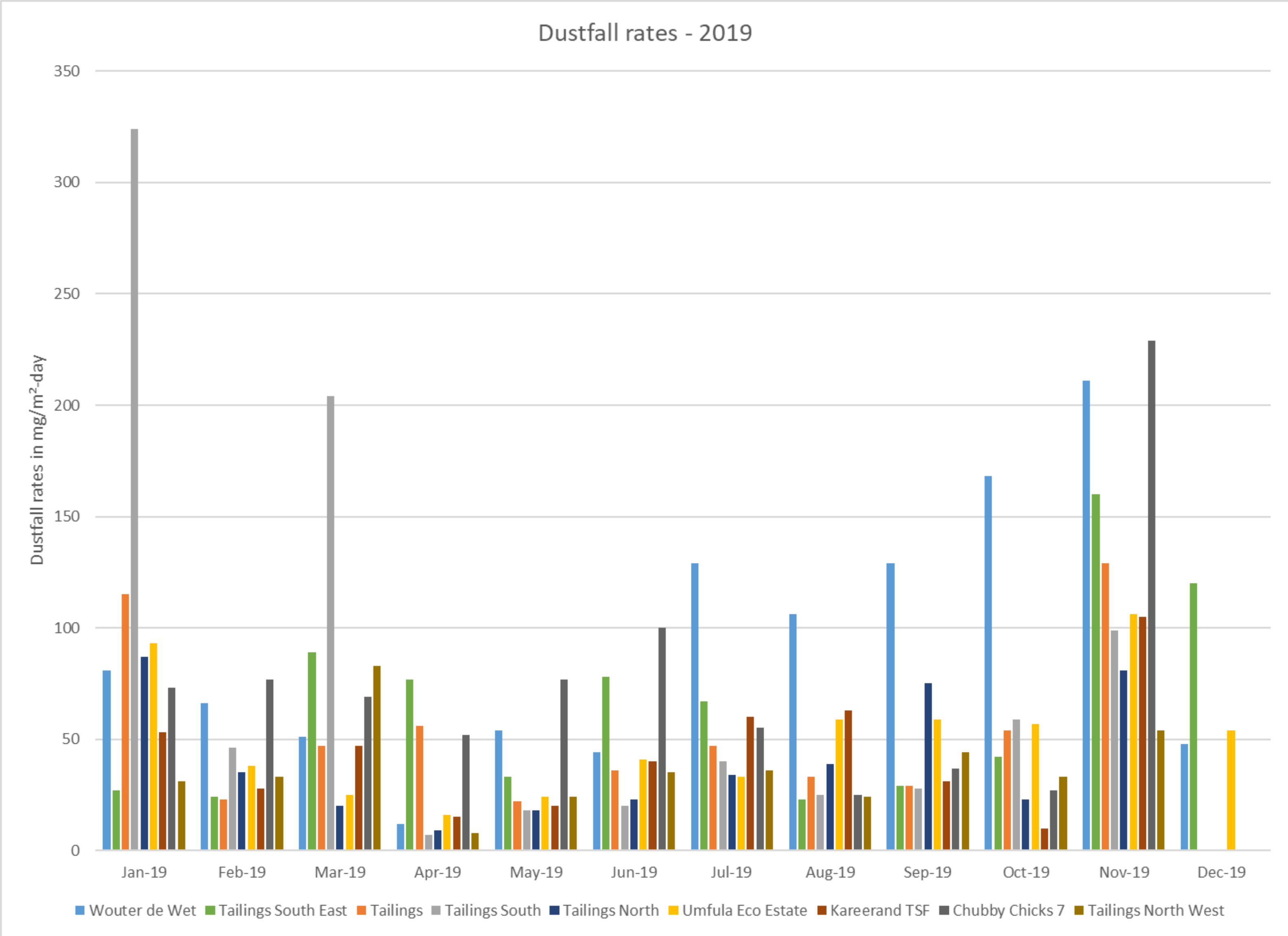

Figure 17-11: Dustfall rates for January 2019 to December 2019

18 APPENDIX D: VAAL RIVER AND MINE WASTE SOLUTION EMISSIONS INVENTORY FOR THE 2014/2015 STUDY

This section describes the information used in the 2014/2015 assessment which provides an insight into potential PM impacts as a result of the operations within the region. As stated previously the impacts are expected to have decreased since 2013 due to changes in production, full reclamation of some of the TSFs and discontinuation of some operations. It should also be noted that changes in ownership may have also resulted in a change in operational procedures and throughput volumes of some of the sources included in the 2014/2015 assessment, however, the scale of impact of these changes is unknown.

18.1 Point source emissions

Noligwa and Kopanang Gold Plant emissions were based on the 2004 emissions inventory and were assumed to be unchanged at the time of the 20147/2015 assessment and the point source parameters are depicted in Table 18-2. Similarly, South Uranium Plant emission rates were based on the 2004 inventory.

Noligwa Gold Plant comprises of crushing (primary and secondary), two smelter baghouse stacks, two calcine furnace stacks, electrowinning cell extractor and three carbon regenerator kilns. South Uranium plant includes an ADU stack, a boiler stack (re-sampled 2010) and lime baghouse stack with Kopanang Gold Plant only comprising a carbon regeneration kiln stack.

Both Noligwa and Kopanang Gold Plants are now owned by Harmony Gold (Harmony) which may have resulted in a change in operational procedures and throughput volumes, however, these changes are unknown.

Emissions from the ventilation shafts could not be determined – no measured data exist and the quantification of emissions requires detailed information on underground equipment fuel use and operational times. The ventilation shafts are not regarded a significant source of particulate emissions. MWS operations do not have any ventilation shafts related to it and AGA no longer undertakes any underground mining and thus no operations of ventilation shafts.

18.2 Windblown dust emission quantification

Wind erosion is a complex process, including three different phases of particle entrainment, transport and deposition. It is primarily influenced by atmospheric conditions (e.g. wind, precipitation and temperature), soil properties (e.g. soil texture, composition and aggregation), land-surface characteristics (e.g. topography, moisture, aerodynamic roughness length, vegetation and non-erodible elements) and land-use practice (e.g. farming, grazing and mining) (Shao, 2008).

Windblown dust generates from natural and anthropogenic sources. For wind erosion to occur, the wind speed needs to exceed a certain threshold, called the friction velocity. This relates to gravity and the inter-particle cohesion that resists removal. Surface properties such as soil texture, soil moisture and vegetation cover influence the removal potential. Conversely, the friction velocity or wind shear at the surface is related to atmospheric flow conditions and surface aerodynamic properties. Thus, for particles to become airborne the wind shear at the surface must exceed the gravitational and cohesive forces acting upon them, called the threshold friction velocity (Shao, 2008).

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.

The Vaal River operations consist of the Mispah Complex (now owned by Harmony), East Complex and West Complex. For the current assessment, the tailings parameters as provided (Table 4-3) and particle size distributions from a previous study conducted by the University of Johannesburg were used. At the time of the 2014/2015 assessment, the particle size distribution was available for the six TSFs (West Extension, West Complex, South East, East Complex, South Complex, Sulphur Paydam and Mispah TSFs) and is visually presented in Figure 4-1 with the various particle size bins provided in Table 4-1. From the particle size distribution graph it is evident that the Sulphur Dam has primarily courser material with the South Complex and Western Complex comprising mainly fine material.

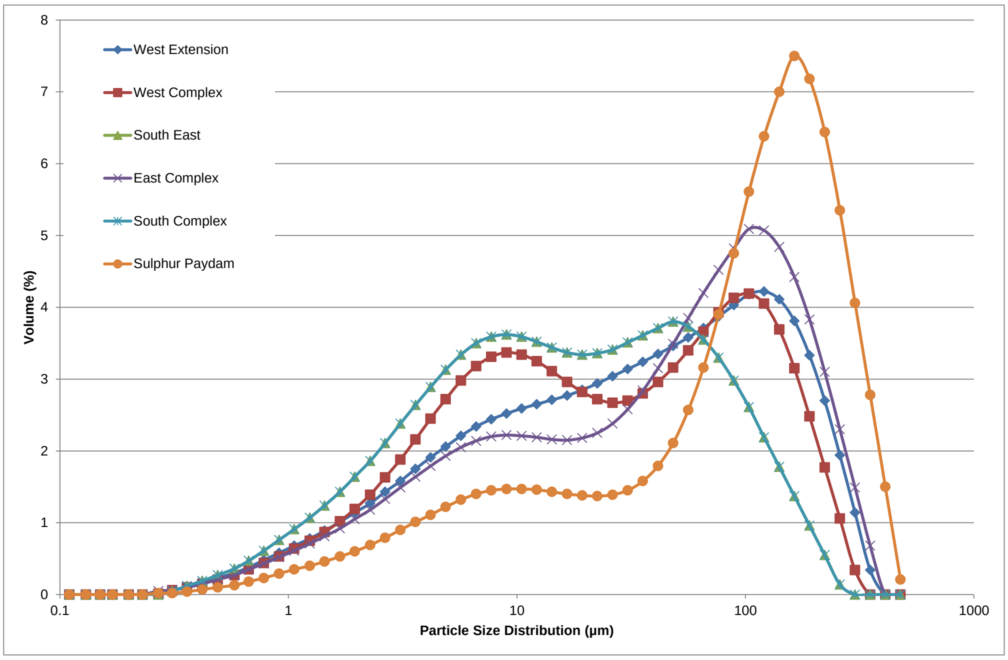

Figure 18-1: Particle size distribution for the West Extension, West Complex, South East, East Complex, South Complex, Sulphur Paydam and Mispah TSFs at the Vaal River operations

Table 18-1: Lognormal particles size distribution for three particle size bins of $PM_{2.5}$, PM_{10} and PM_{75} for the six TSFs

Source	Modes	Clay (<2 µm)	Silt	Sand	Percentage of $p_m(d)$ fractions		
					$PM_{2.5}$	PM_{10}	PM_{75}
		(%)	(%)	(%)	(d < 2.5 µm)	(d < 10 µm)	(d < 75 µm)
West Extension	TSF1	6.8	59.5	33.7	0.08	0.29	0.70
West Complex	TSF2	6.6	64.6	28.8	0.08	0.34	0.74
South East	TSF3	9.1	75.0	15.9	0.11	0.41	0.87
East Complex	TSF4	6.2	53.6	40.2	0.07	0.26	0.64
South Complex	TSF5	9.1	75.0	15.9	0.11	0.41	0.87
Sulphur Dam	TSF6	3.4	33.9	62.7	0.04	0.16	0.41

The TSFs included in the 2014/2015 study are visually represented as follows:

West complex and West extension	Figure 18-2
East complex, Southeast complex and Sulphur pay dams	Figure 18-3
Mispah and Kopanang[(a)]	Figure 18-4
Harties 1, 2, 5 and 6	Figure 18-5
Harties 7 and Ellaton	Figure 18-6

Buffels 1, 2, 3, 4 and 5	Figure 18-7
MWS CW dam 2, 4 and 5	Figure 18-8
Kareerand	Figure 18-9

Notes: (a) Now owned and operated by Harmony

The red lines in the above-mentioned images portray the relevant road network included in the modelling scenarios, while the yellow highlighted areas in each figure represent the modelled area of each respective TSF available to wind erosion. The areas highlighted are based on a study conducted by AngloGold Ashanti and were digitised directly into the model based on these results.

18.3 Area source emissions

Vehicle entrainment from unpaved roads often presents a significant source of particulate emissions. For the purpose of this assessment, roads were modelled as line area sources. Vehicle entrainment of dust is dependent on the silt content of the road surface (fraction of road surface material less than 75 µm in diameter), the size and weight of the average vehicle utilizing the road as well the frequency that the vehicle is upon the road. A summary of emissions included in simulations for this road network are provided in Table 18-5. The roads are visually represented in Figure 18-11.

Waste rock dumps were included as sources of Radon emissions but were not included as sources of windblown dust since the WRDs resulted in very low particulate emissions. The location and size of these WRDs are shown in Table 18-4 and Figure 18-10.

18.4 Volume source emissions

Materials handling points were included in the model as volume sources for the VR operations. At the AngloGold Ashanti plant this included materials handling activities such as ore transfer between the mill bins and off-loading of lime from transport vehicles. Materials handling activities include ore tipping from transport vehicles. Information pertaining to volume sources included in this assessment is given in Table 18-6.

Table 18-2: Stack parameters for point sources associated with the 2014/2015 assessment operations

Business Unit	Source Name	Source ID	X-Coord	Y-Coord	elevation (m)	stk height (m)	exit temp (K)	exit velocity (m/s)	stk diam (m)	TSP (tpa)	PM_{10} (tpa)	$PM_{2.5}$ (tpa)
Noligwa Gold Plant[a][b]	Smelter baghouse 1 (resampled 2010)	8GSBH1	478 204	7 017 993	1300	5	353.15	3.97	0.5	0.04	0.04	0.04
	Smelter baghouse 2	8GSBH2	478 197	7 017 994	1300	5	366.15	3.86	0.545	-	-	-
	Calcine Furnace at wall outside furnace building (resampled 2010)	8GCalc1	478 233	7 017 984	1300	10	334.15	17.46	0.5	-	-	-
	Calcine Furnace at sample preparation area	8GCalc2	478 292	7 017 930	1300	5	303.15	20.62	0.51	558.54	209.45	209.45
	Electrowinning cell extractor	8GElect	478 254	7 018 109	1300	10	288.15	6.587	0.57	0.38	0.38	0.38
	Carbon regeneration - 3 kilns	8GCgen	478 299	7 018 038	1300	10	823.15	6.1	0.2	-	-	-
South Uranium Plant	ADU stack	8UADU	477 921	7 017 529	1300	10	290.15	15.578	0.56	-	-	-
	Boiler stacks (resampled 2010)	8Uboil	477 645	7 017 372	1300	20	459.15	8.361	2.05	0.08	0.08	0.08
	Lime baghouse stack	8Ulimes	477 633	7 017 516	1300	10.65	293.15	1.51	0.45	0.08	0.08	0.08
Kopanang Gold Plant[b]	Carbon regeneration - 1 kiln	9GCgen	474 674	7 015 607	1300	10	823.15	6.1	0.2	0.11	0.11	0.11
Chemical Laboratories	AA extraction	Vlab1	467 094	7 017 502	1300	3	293	3.3	0.6	0.02	0.02	0.02
	Electric furnace room extraction	Vlab2	467 094	7 017 502	1300	3	332	4.5	1	0.08	0.08	0.08
	Crusher room extraction BH1	Vlab3	467 094	7 017 502	1300	3	301	9.97	0.6	0.83	0.83	0.83
	Crusher room extraction BH2	Vlab4	467 094	7 017 502	1300	3	294	16.6	0.8	0.89	0.89	0.89
	U-prep lab extraction baghouse (gold deslagging process)	Vlab5	467 094	7 017 502	1300	3	296	5.1	0.5	0.53	0.53	0.53
	Fluxing room extraction baghouse	Vlab6	467 094	7 017 502	1300	3	294	4.9	0.8	0.04	0.04	0.04
	Tub loading extractor	Vlab7	467 094	7 017 502	1300	4	295	6.37	0.4	-	-	-
	Water lab extraction	Vlab8	467 094	7 017 502	1300	4	293	15.09	0.53	-	-	-
	Radical lab extraction blue pipe	Vlab9	467 094	7 017 502	1300	3	296	14.7	0.39	-	-	-

Business Unit	Source Name	Source ID	X-Coord	Y-Coord	elevation (m)	stk height (m)	exit temp (K)	exit velocity (m/s)	stk diam (m)	TSP (tpa)	PM_{10} (tpa)	$PM_{2.5}$ (tpa)
	Radical lab galv. Duct	Vlab10	467 094	7 017 502	1300	3	296	3.3	0.52	-	-	-

Notes: (a) Updated as per E.S.S.A. report (August 2010).

(b) Now owned by Harmony

(c) Assumed $PM_{2.5}$ and PM_{10} to be the same as TSP

Table 18-3: Wind erosion area sources and respective emissions associated with 2014/2015 assessment operations

Business Unit	Source Name	Source ID	X-Coord	Y-Coord	Elevation (m)	Release Ht (m)	Total Area [a] (ha)	Active Area[b] (ha)	Moisture content[c] (%)	Particle density [d] (kg/m³)	Roughness Length[d] (m)	Friction Velocity [e] (m/s)	Side Slopes [f] (%)	TSP (tpa)	PM_{10} [g] (tpa)
Tailings & Land	VR West Extension TSF	TSF1	470858	7021350	1600	30	425.5	35.2	1	2625	0.0003	0.5	20	175.6	44.5
	West complex TSFs	TSF2	467736	7020731	1600	15	91.4	101.3	1	2625	0.0003	0.5	70	506.7	143.2
	South East	TSF3	474308	7024225	1600	40	104.3	88.8	1	2625	0.00012	0.51	5	1134.5	331.4
	East Complex	TSF4	476208	7022576	1600	45	143.5	111.0	1	2625	0.00012	0.51	50	429.1	107.9
	Sulphur Paydam 1	TSF5	476222	7023932	1600	30	181.5	59.3	1	2625	0.00012	0.51	30	757.7	221.4
	Sulphur Paydam 2	TSF6	476226	7023925	1600	20		46.4	1	2625	0.00012	0.64	40	48.2	11.6
	Mispah 1[g]	TSF7	476728	7013675	1600	35	266.5	119.5	1	2625	0.00012	0.51	20	597.7	168.9
	Mispah 2[g]	TSF8	476911	7013281	1600	20		68.8	1	2625	0.00012	0.51	30	265.9	66.9
	Kopanang Pay dam[g]	TSF9	478576	7013317	1600	15	44.8	44.8	1	2625	0.00012	0.51	0	223.6	56.7

	Harties 1 and 2	TSF10	476925	7027630	1600	20	212.7	106.5	1	2625	0.00012	0.51	50	411.9	103.5
	Harties 5 and 6	TSF11	474931	7026645	1600	30	135.5	41.5	1	2625	0.00012	0.51	60	160.3	40.3
	Harties 7 - slimes	TSF12	470496	7024273	1600	15	38.4	13.8	1	2625	0.00012	0.51	40	69.0	17.5
	Harties 7 - footprint	TSF13	469863	7023787	1600	15		13.5	1	2625	0.00012	0.51	30	67.1	17.0
	Ellaton - slimes	TSF14	468432	7024138	1600	15	19.4	11.2	1	2625	0.00012	0.51	0	55.7	14.1
	Ellaton - footprint	TSF15	468428	7024145	1600	15		5.7	1	2625	0.00012	0.51	0	28.3	7.2
	Buffelsfontein B1	TSF16	480649	7023413	1600	15	238.3	48.6	1	2625	0.00012	0.51	10	187.9	47.2
	Buffelsfontein B2	TSF17	479585	7023397	1600	15		55.6	1	2625	0.00012	0.51	90	214.9	54.0
	Buffelsfontein B3	TSF18	479533	7022625	1600	15		50.4	1	2625	0.00012	0.51	90	195.0	49.0
	Buffelsfontein B4	TSF19	480302	7022619	166	15		30.4	1	2625	0.00012	0.51	0	117.7	29.6
	Buffelsfontein B5	TSF20	478793	7021770	1600	60	115.8	76.7	1	2625	0.00012	0.51	50	296.6	74.6
	MWS Dam 2 - plus spilloff	TSF21	478909	7032968	1600	25	258.2	86.9	1	2625	0.00012	0.51	50	335.9	84.5
	MWS Dam 4	TSF22	480074	7034811	1600	25	94.8	9.8	1	2625	0.00012	0.51	70	48.8	12.4
	MWS Dam 5	TSF23	477416	7034244	1600	45	194	64.4	1	2625	0.00012	0.51	60	321.4	81.4
	Kareerand Part 1, 2 & 3	TSF24	490532	7025904	1600	20	286.9	286.9	1	2625	0.00012	0.51	50	1109.4	278.9

Notes: (a) Used for the modelling of radon.

(b) Taken from Aerial Photographs depicting active surface (non-vegetated, wind erodible) area provided by AngloGold Ashanti.

(c) Moisture content assumed to be 1% (given as 0%).

(d) From similar gold tailing dams.

(e) Estimated from the 2009 UJ sampling campaign based on equation 6, Appendix A.

(f) Percentage vegetated.

(f) Calculations for $PM_{2.5}$ emissions from wind erosion were zero.

(g) Now owned by Harmony.

Table 18-4: Waste rock dump areas and locations associated with 2014/2015 assessment operations

Business Unit	Source Name	X-Coord	Y-Coord	Elevation	Total Area [(a)]	Particulate emissions
				(m)	(ha)	(tpa)
Waste Rock Dumps & Land	1#WRD	473653	7019728	1600	38.7	Negligible
	2#WRD	476485	7020005	1600	29.4	Negligible
	3#WRD	471771	7018505	1600	21.4	Negligible
	4#WRD	470776	7022359	1600	28.3	Negligible
	5#WRD	476222	7023105	1600	15.0	Negligible
	Kopanang WRD[(b)]	474109	7015121	1600	54.9	Negligible
	Moab WRD[(b)]	480249	7015609	1600	37.3	Negligible
	Noligwa WRD[(b)]	478648	7017153	1600	55.8	Negligible

Notes: (a) total footprint area of WRD.

(b) now owned by Harmony.

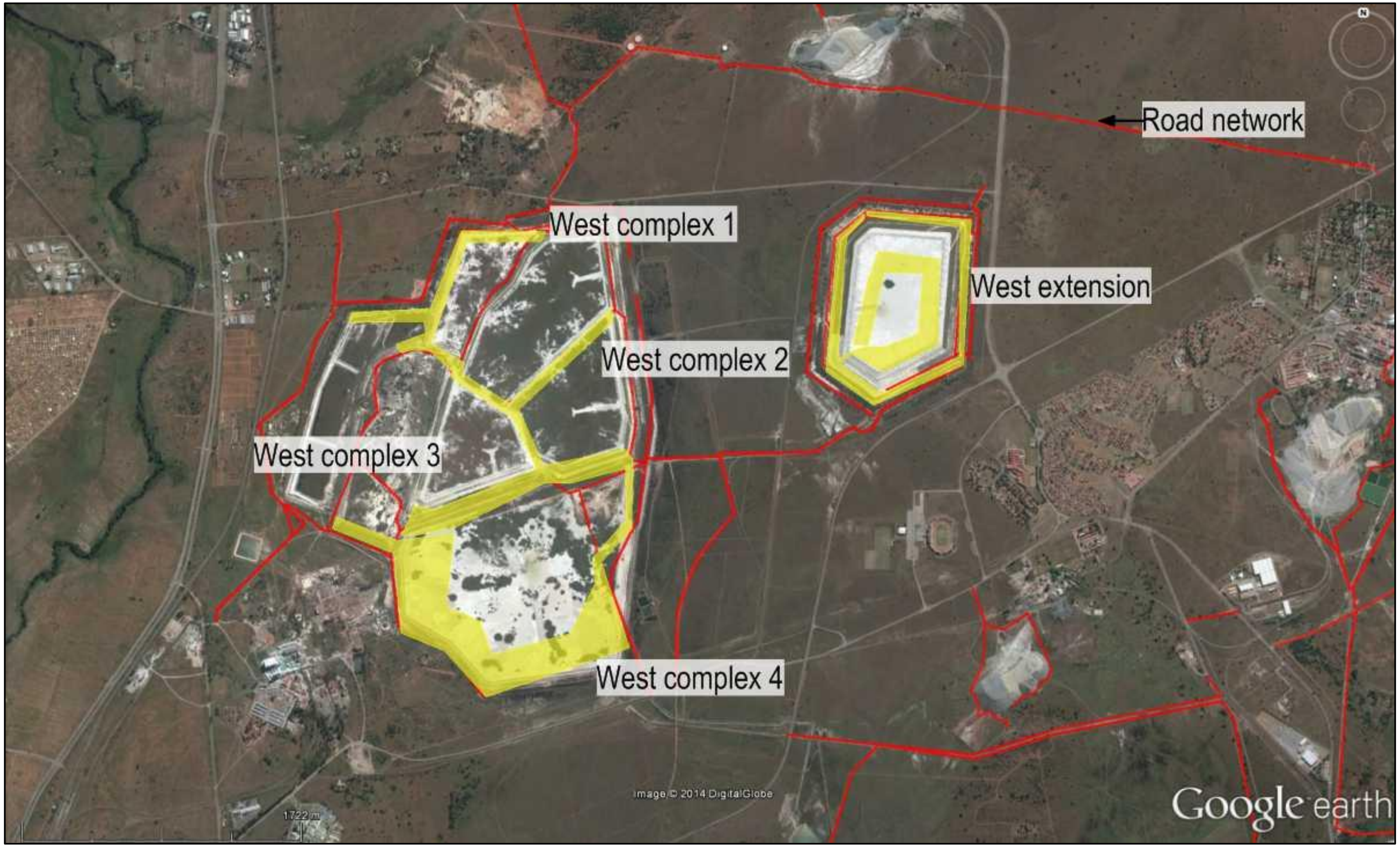

Figure 18-2: West Extension and West complex TSFs. Wind erodible area highlighted in yellow

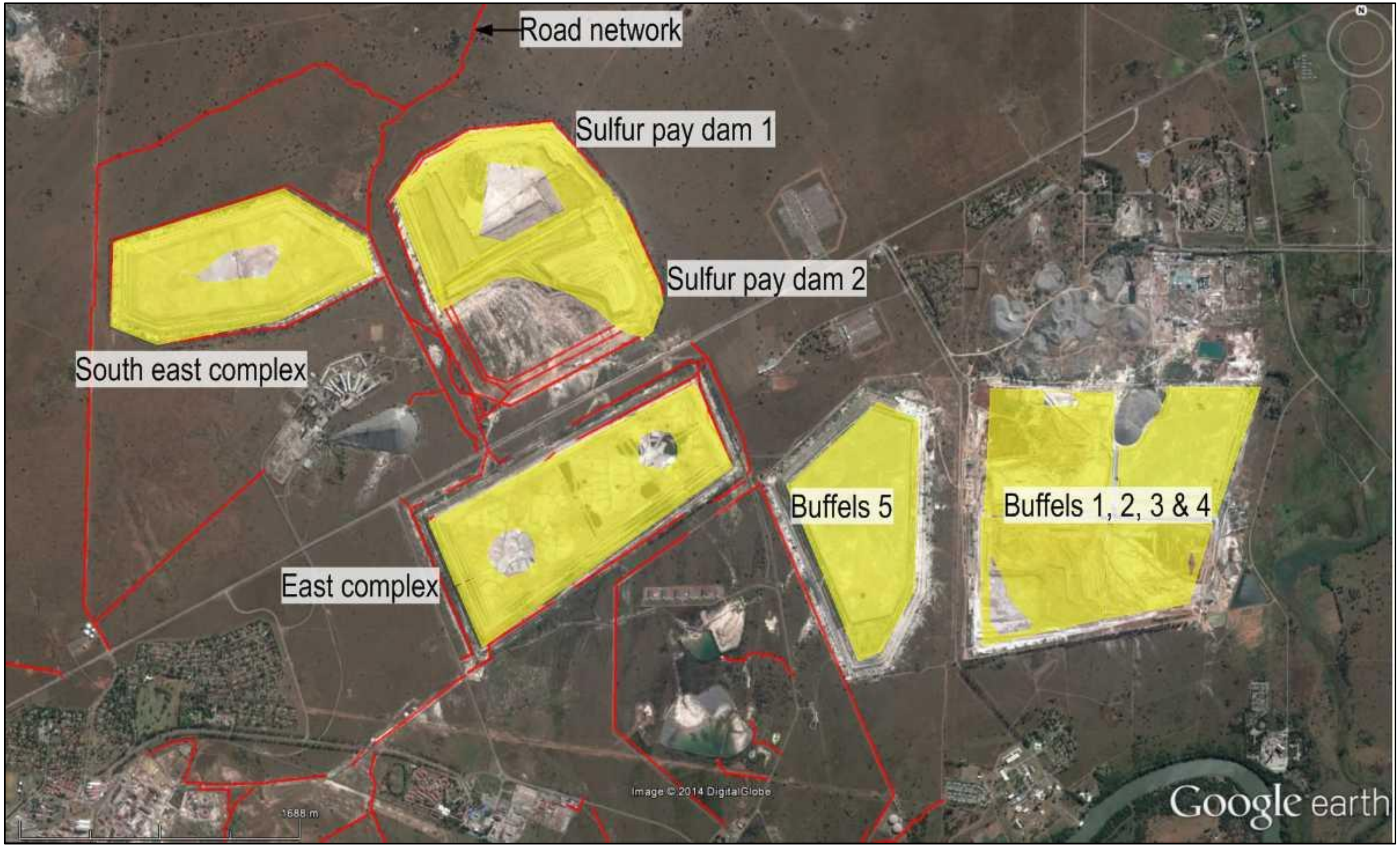

Figure 18-3: East complex, South east complex and Sulphur pay dams TSFs. Wind erodible area highlighted in yellow

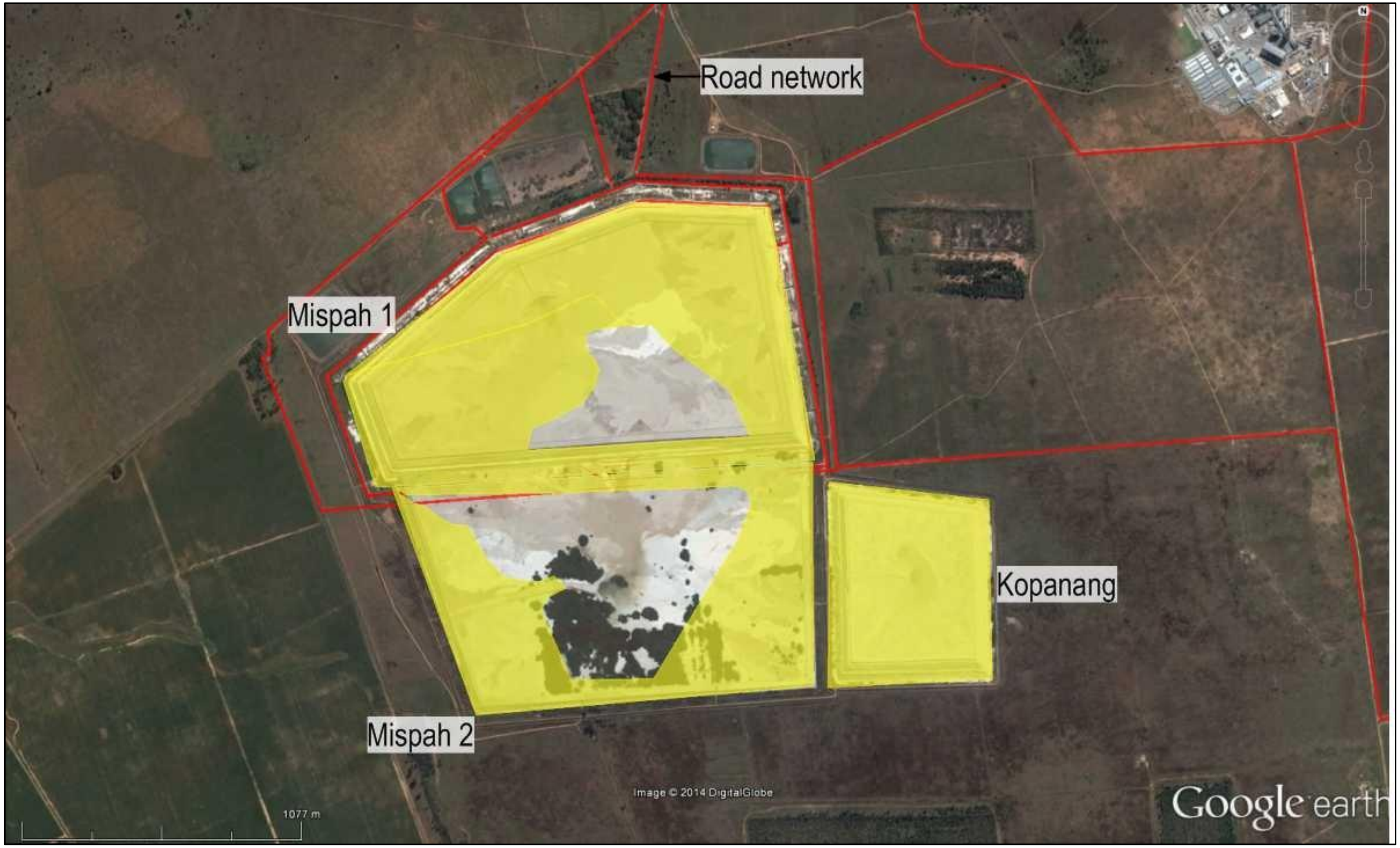

Figure 18-4: Mispah and Kopanang TSFs, now owned by Harmony. Wind erodible area highlighted in yellow

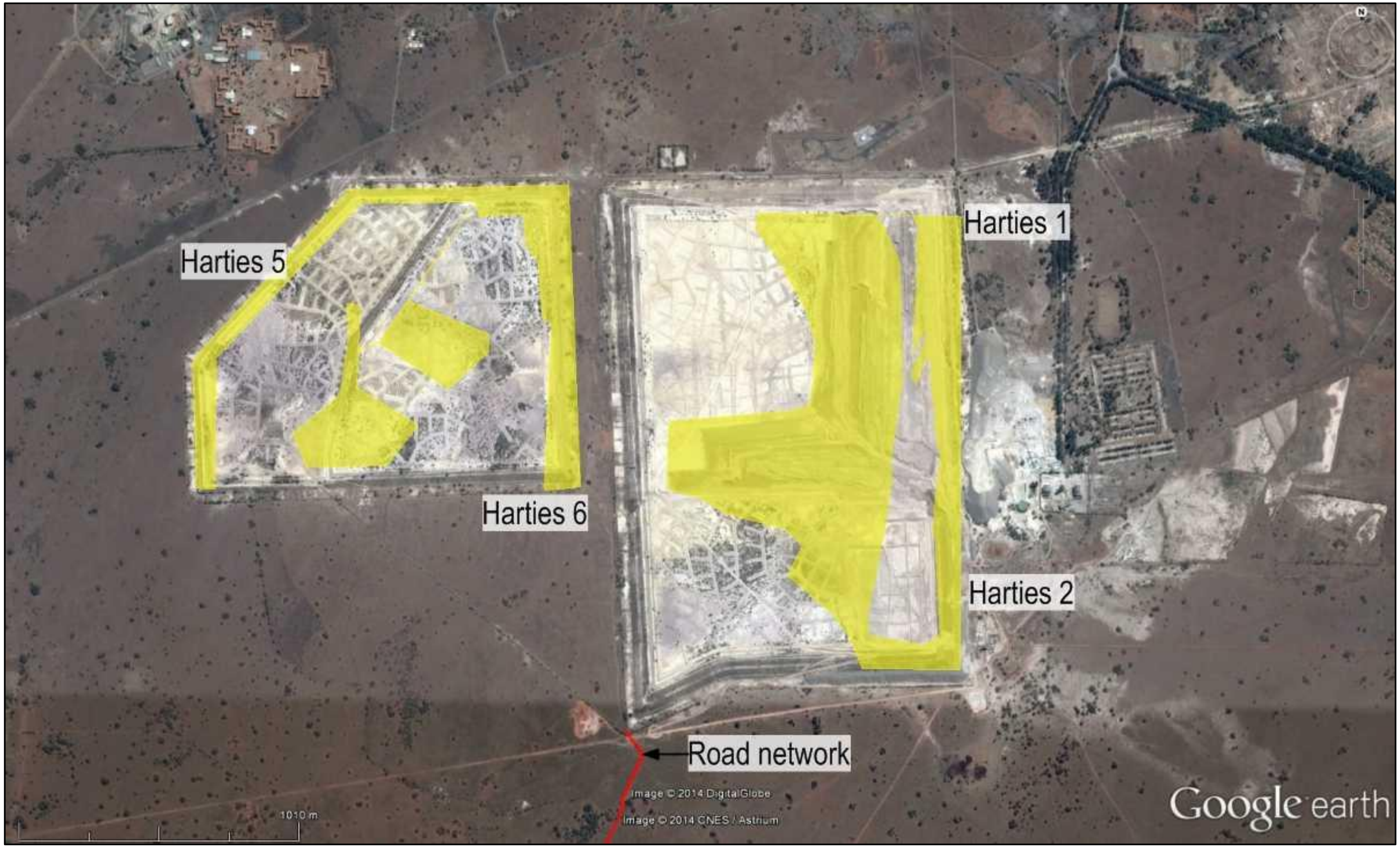

Figure 18-5: Harties 1, 2, 5 and 6 TSFs. Wind erodible area highlighted in yellow

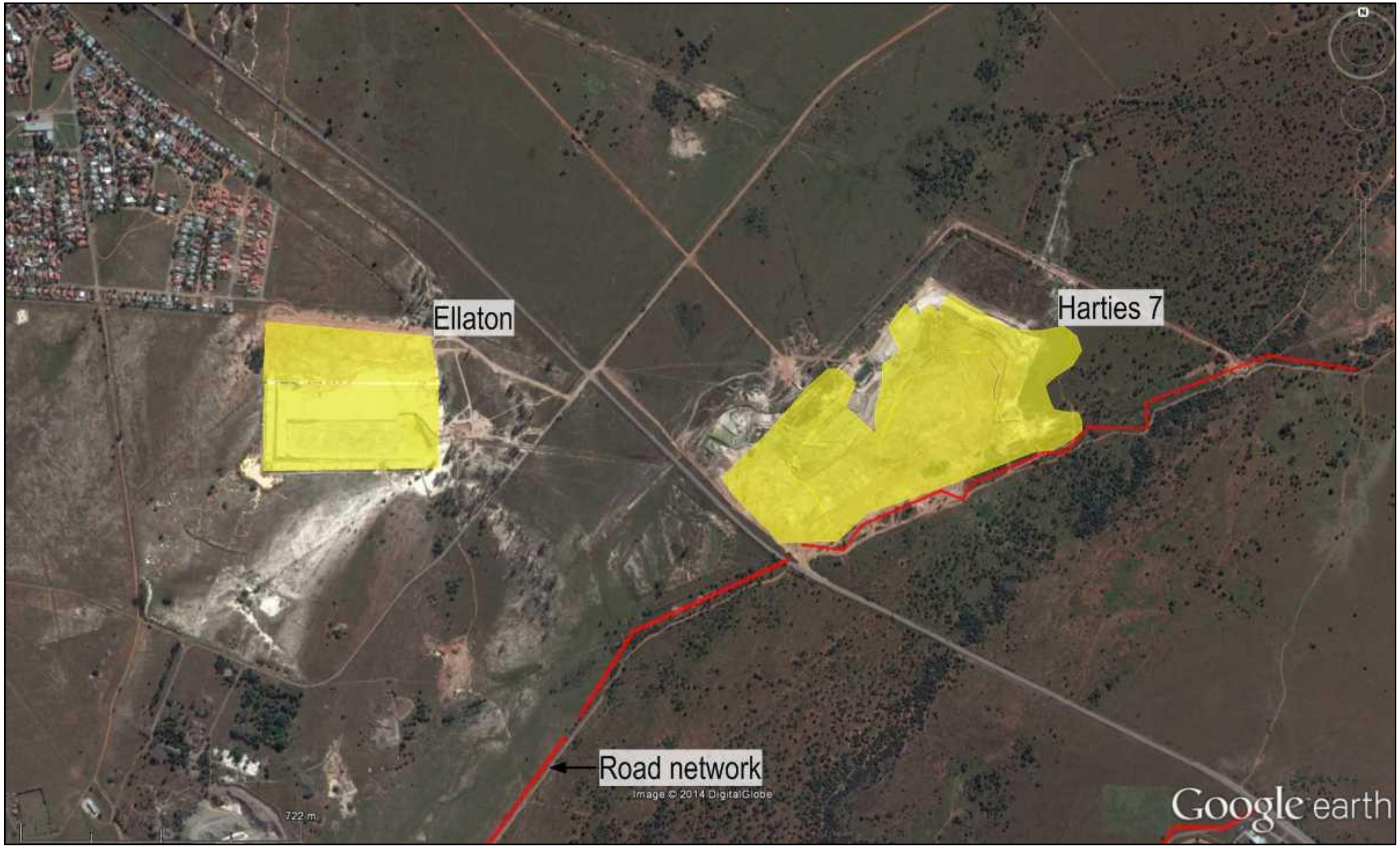

Figure 18-6: Harties 7 and Ellaton TSFs. Wind erodible area highlighted in yellow

Figure 18-7: Buffels 1, 2, 3, 4 and 5 TSFs. Wind erodible area highlighted in yellow

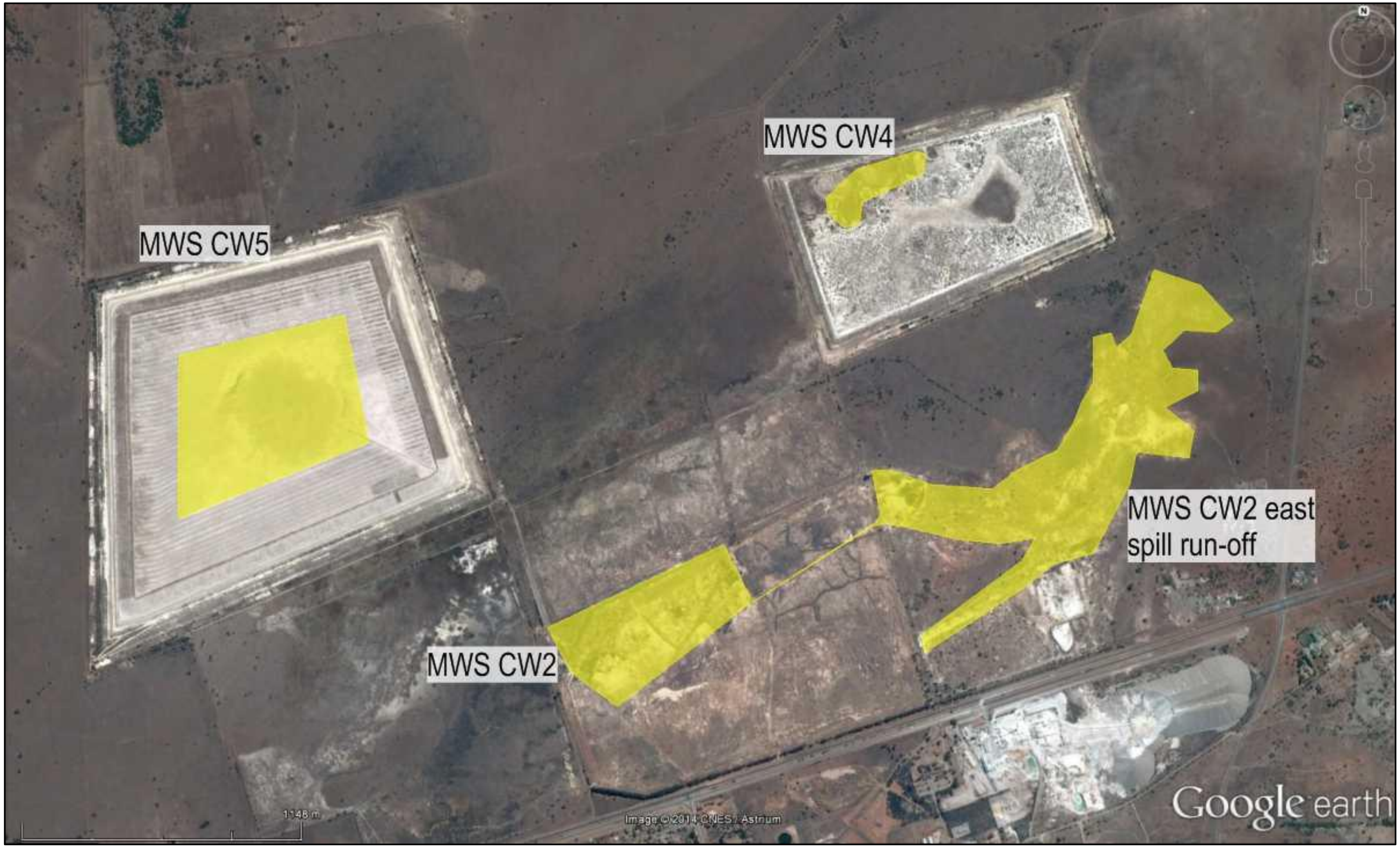

Figure 18-8: MWS CW TSFs. Wind erodible area highlighted in yellow

Figure 18-9: Kareerand TSF. Wind erodible area highlighted in yellow

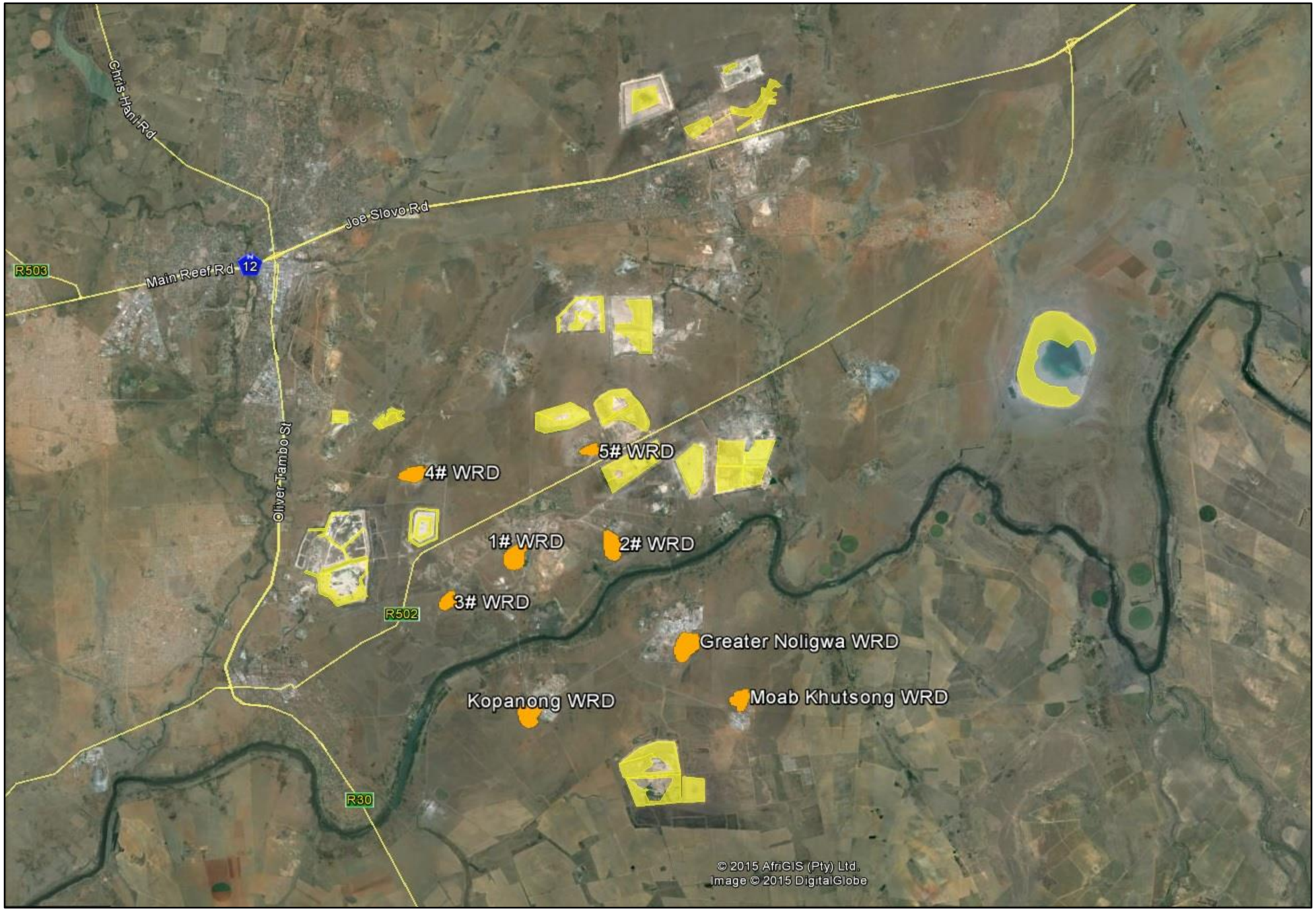

Figure 18-10: Vaal River waste rock dumps and TSFs

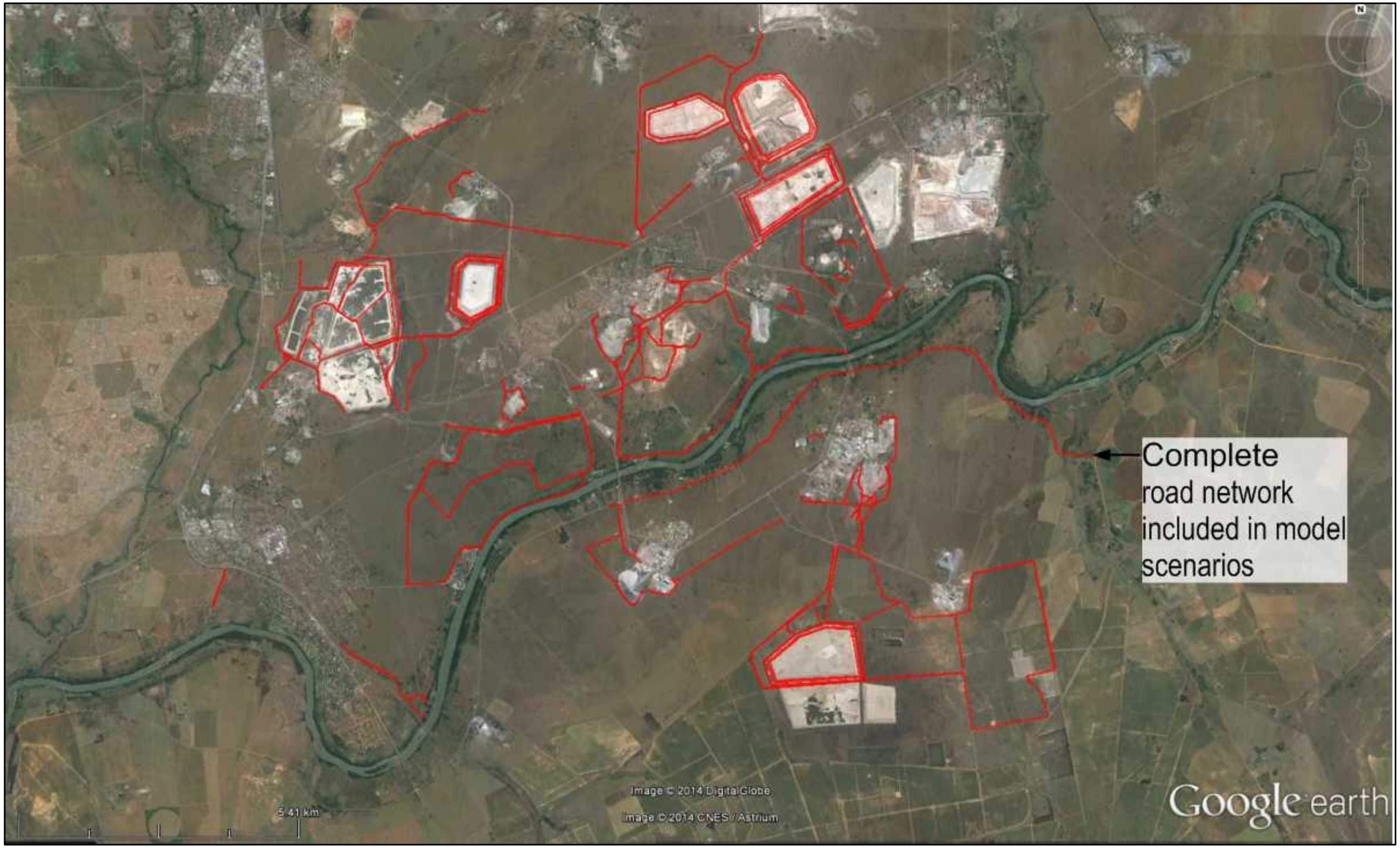

Figure 18-11: Road network included in the 2014/2015 modelling scenario

Table 18-5: Summary of road area sources and respective emissions associated with 2014/2015 assessment operations [a]

Business Unit	Source Name	Source ID	Silt content of road material	Average Vehicle Weight	No. of Trips per day	Road Length	Width	Area of Road Segment (as to be modelled)	Estimated VKT	$PM_{2.5}$ Emissions[b]	PM_{10} Emissions	TSP Emissions
			%	(tons)		(km)	(m)	(m^2)	(km)	(tpa)	(tpa)	(tpa)
Vaal River Tailings & Land	Primary Roads	PRD	11	20	119	23.74	7	100 525	145	2.0	19.5	70.1
	Secondary Roads	SRD	11	14	151	58.66	6	1 034 975	261	26.3	260.8	313.3
	Tertiary Roads	TRD	11	3	50	58.28	5	409 873	88	15.8	72.6	247.3
	TSF Roads	TSFRD	11	2	216	52.06	4	250 537	417	8.7	47.7	125.6

Notes: (a) Detailed table of roads and associated emission rates are provided in Appendix A, Table 8-3.

(b) It was assumed that all $PM_{2.5}$ would be the same as PM_{10} as a conservative approach

Table 18-6: Volume sources and respective emissions associated with the 2014/2015 assessment operations[a][b]

Business Unit	Source Name	Source ID	X-Coord	Y-Coord	elevation	release height	lateral dimension	vertical dimension	TSP	PM_{10}[b]
					(m)	(m)	(m)	(m)	(tpa)	(tpa)
Noligwa Gold Plant -	Ore storage bins / stockpile	8GOrebin	477 903	7 018 156	1300	5	1.4	1.16	89.76	38.81
	Ore transfer to screen bins	8GTrans1	478 449	7 018 189	1300	5	1.4	1.16	10.56	4.49
	Ore transfer to mill bins	8GTrans2	478 253	7 017 872	1300	5	1.4	1.16	10.56	4.49
	Lime off-loading	8Ulimef	477 633	7 017 516	1300	3	1.4	1.4	0.23	0.08

Business Unit	Source Name	Source ID	X-Coord	Y-Coord	elevation	release height	lateral dimension	vertical dimension	TSP	PM_{10} (b)
					(m)	(m)	(m)	(m)	(tpa)	(tpa)
- South Uranium Plant	Coal off-loading & loading	8Ucoal	477 630	7 017 463	1300	3	1.4	1.4	0.07	0.02
	Ash handling (FEL)	8Uash	477 550	7 017 334	1300	3	1.4	1.4	0.05	0.02
Kopanang Gold Plant	Lime off-loading	9Glimef	474 756	7 015 610	1300	3	1.4	1.4	0.02	0.01
	Ore to mill feedbins	9Gore2	474 809	7 015 573	1300	3	1.4	1.4	27.48	9.62

Notes: (a) Now owned by Harmony

(b) It was assumed that all $PM_{2.5}$ would be the same as PM_{10} as a conservative approach

19 APPENDIX E: DESCRIPTION OF WIND EROSION ESTIMATION TECHNIQUE

Emission quantification was done using the in-house modelled ADDAS (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. Site specific particle size distribution data, 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 US 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.

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 calculated using referenced methodologies (Liebenberg-Enslin, 2014).

For the purpose of this study, the MB95 dust flux model as schematically represented in Figure 19-1 is used.

Meteorological data from the WRF model, run for the years 2014, 2015 and 2016, were extracted for locations close to each of the TSF and used to determine the friction velocity and threshold friction velocity. Parameters of importance include wind speed, wind direction and temperature.

The relationship between particle sizes ranging between 1 µm and 500 µm and threshold friction velocities (0.24 m/s to 3.5 m/s), estimated based on the equations proposed by (Marticorena & Bergametti, 1995), is illustrated in Figure 19-2. The wind speed variation over the storage piles is based on the work of Cowherd et al. (1988). With the aid of physical modelling, the US EPA has shown that the frontal face of an elevated pile (i.e. windward side) is exposed to wind speeds of the same order as the approach wind speed at the top of the pile. The ratios of surface wind speed (us) to approach wind speed (ur), derived from wind tunnel studies for two representative pile shapes, are illustrated in Figure 19-2 (viz. a conical pile, and an oval pile with a flat top and 37° side slope). The contours of normalised surface wind speeds are indicated for the oval, flat top pile for various pile orientations to the prevailing direction of airflow (the higher the ratio, the greater the wind exposure potential). These flow patterns are only applicable with piles that have a height to base ratio of more than 0.25.

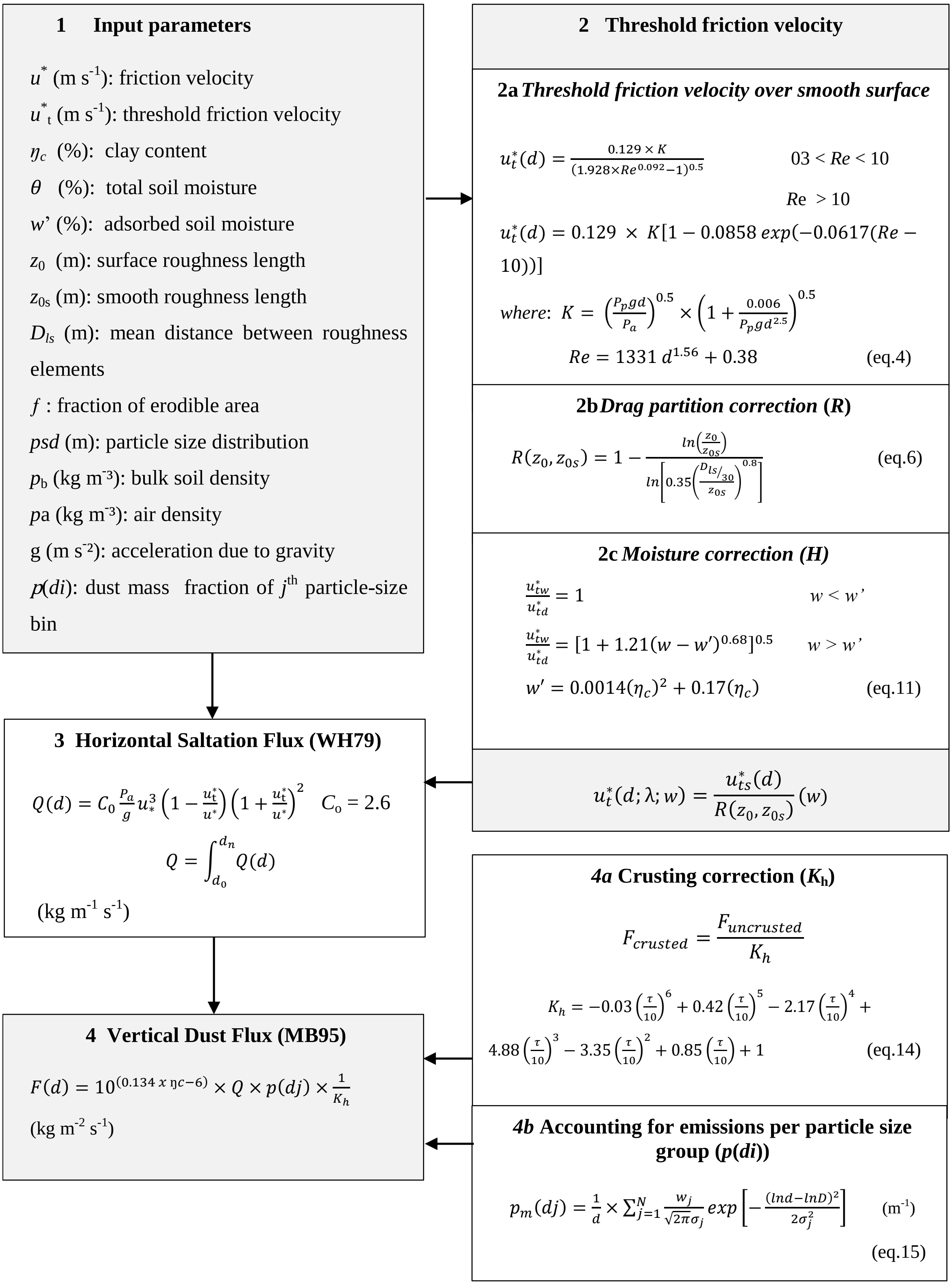

Figure 19-1: Schematic diagram of parameterisation options and input parameters for the Marticorena and Bergametti (1995) dust flux scheme (Liebenberg-Enslin, 2014)

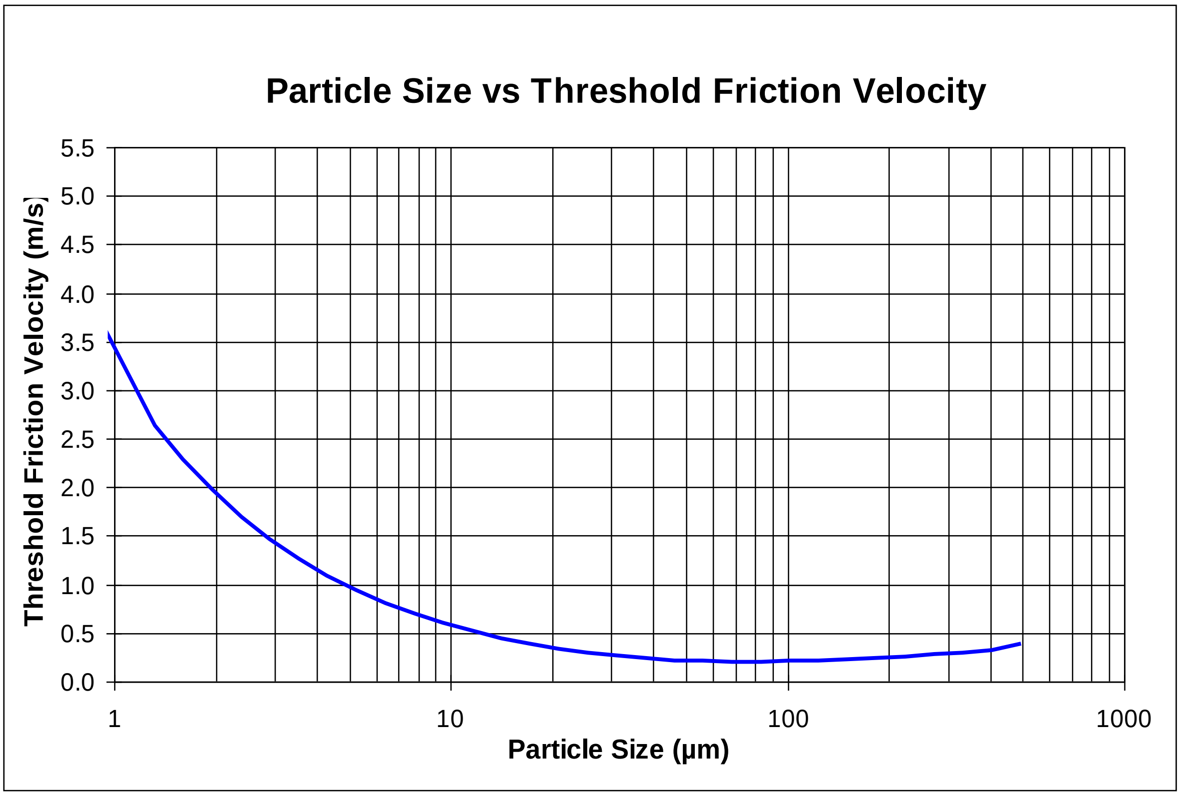

Figure 19-2: Relationship between particle sizes and threshold friction velocities using the calculation method proposed by Marticorena and Bergametti (1995)

20 APPENDIX F: COMMENTS/ISSUES/CONCERNS RAISED

The Comments/Issues/Concerns raised during the initial Public Participation Period are provided in the Table 20-1 with responses and reference to the sections where these issues or concerns have been addressed.

Table 20-1: Comments and responses table

Issue/Concern	Contributor	Date of Contribution	Means of Contribution	Response
Will a climate change specialist assessment be conducted for this application? It is recommended that a climate change assessment be conducted for this application.	Mariette Liefferink - Federation for Sustainable Environment (FSE)	1 November 2019	Focus Meeting	The climate change assessment is included in Section 13.
What is the current height of Kareerand as planning is to extend the TSF to 122 m? What will dust impact be when at full height (122 m)?	Etienne Rood – Tims Haven	20 January 2020	Email Correspondence	This is discussed in Section 7.4, specifically 7.4.3 and Section 7.5.2.
DUST **In terms of the Draft Scoping Report we are informed that:** • **Only dustfall rates measured near the project site were available for analysis (page 41).** • **The current air quality in the study area is mostly influenced by farming activities, domestic fires, vehicle exhaust emissions and dust entrained by vehicles. No reference is made to the dust fallout from the existing Kareerand TSF and its risks to human health (respiratory and cardiovascular diseases), the environment, wildlife and water, which is surprising since it is well established in scientific literature that the dust from environmental exposure**	Mariette Liefferink - Federation for Sustainable Environment (FSE)	2 February 2020	Email Correspondence	The Air Quality Specialist report includes all the receptors that were provided to all specialists by AGA/MWS. The most distant being 8 km away from the expanded TSF. The National Dust Control Regulations (NDCR) provide levels which the impacts should be screened against. These have been used to depict the impacts as well as a 400 mg/m²-day for agricultural areas (from literature). There will be instances when high wind speeds occur that the dust will be visible and can travel a further distance than during lower winds but it would be unlikely that these conditions prevail for a day or more, in potential instances where this may occur for a day or longer it is usually associated with extreme or irregular weather events. The nuisance limits are based on dust deposition within a day from a monthly total. Measured dustfall rates are discussed in section 5.3.1, past simulated impacts are discussed in 5.3.2. The dustfall rates as a result of the current TSF

Issue/Concern	Contributor	Date of Contribution	Means of Contribution	Response
to tailings particulate matter (PM) through water*, food and inhalation may present a significant risk for wildlife, ecosystems as well as for individuals living around mining areas, especially children, the elderly and individuals with existing health problems. Epidemiologic studies have indicated that living near mining waste is a major risk factor for exposure to metals as a result of dust fallout. * (Stormwater drainage systems, into which windblown dust from adjacent slimes dams is flushed by run-off from sealed surfaces are also likely to constitute a major source of potential water pollution. Based on (conservative) assumptions regarding the affected surface area and average deposition rates of dust from adjacent slimes dams, it was estimated that approx. 10 tons of (particle-bound) uranium per year are flushed by stormwater into receiving watercourses.) The DSR informs us that: • **The final height of the existing and expanded facility will be 122 meters.** • **The current TSF and the proposed expansion will store 837 tons of tailings.** **The existing Kareerand TSF is the source of significant dust fallout according to testimonies and eyewitness accounts by mining affected communities. It can logically be inferred that the expanded facility will contribute significantly to the**				are discussed in section 7.2.3 , the initiation of the expansion in section 7.3.3 and the dustfall rates as a result of the final TSF (at 122 m) can be found in section 7.4.3.

Issue/Concern	Contributor	Date of Contribution	Means of Contribution	Response
existing dust fallout. Research found that fall-out - as deposition or nuisance dust - exceeds a 1000 m distance from the TSF source. Because of the combined height of the existing TSF and expanded Kareerand TSF these distances can be expected to be much further.				
The Applicant and its EAP should, in its assessment, mitigation and management measures, recognise the significant challenges regarding dust management of gold TSFs. Research identified the following challenges: • **monitoring networks;** • **monitoring methods;** • **deposition standards;** • **financial provisions;** • **technical skills and capacity;** • **lack of specific dust management plans within air quality management plans;** • **limited regulation and enforcement;** • **limited information and participation of government,** • **lack of participation of interested and affected parties as well as;** • **lack of specialists' expertise.** **It is common cause that dust fallout has a significant impact on human health. A large number of epidemiological studies have been conducted globally over the last two decades and associations between ambient particulate matter and excesses in daily mortality and morbidity were observed. Dust fallout furthermore hassignificant impacts on eco-**	Mariette Liefferink - Federation for Sustainable Environment (FSE)	2 February 2020	Email Correspondence	Section 11 includes the potential management measures. Ultimately MWS will have to settle on a final management plan based on the feasibility of the measures suggested. The air quality study was limited to the inhalation pathway and more detailed potential health impacts based on the air quality modelling results will be included in the other relevant specialist reports.

Issue/Concern	Contributor	Date of Contribution	Means of Contribution	Response
systems and results in losses in crop and livestock productivity. In view of the above-mentioned risks, we call for a dust management plan (from the commencement of the Project and not only after the standard is transgressed) and not merely a dust monitoring plan. The 2019 proposed amendments to the 2013 National Dust Control Regulations require the use of windshields, tailored to allow for tolerance ranges for the bucket diameter (150mm ± 30mm); a minimum ratio of depth to diameter (1:2); a height of a sampler above ground (2m±0.2m uncertainty) and the method should allow for both wet and dry sampling (algae control – biocide). We would expect that the Applicant will comply with the above-mentioned requirements. The FSE recommends the establishment of a community forum within Stilfontein/Kareerand area to report on and address exceedances because of the following identified weakness: • **Reliance on the air quality officer's action on dust sources** • **Averaging period of monitoring weakens quick response to short-term episodes/activities** • **Approach not suitable to deal timeously to complaints (due to the 3 months of submission of a plan required)** • **Implementation of control measures only after approval. The findings and directives by the South African Human Rights Commission in terms of its Report on the**				

Issue/Concern	Contributor	Date of Contribution	Means of Contribution	Response
National Hearing of the Underlying SocioEconomic Impacts of Mining Affected Communities to the DMR and the DEA also has relevance, namely: "The DMR together with the DEA must jointly report on the measures taken to streamline the control of the cumulative air pollution impacts on mining operations. This report must outline the mechanisms that have been put in place for collation, verification and dissemination of information between stakeholders in relation to impacts reported and/or interventions undertaken in relation to air quality." And, • **"Overall the mining sector is riddled with challenges related to land, housing, water, the environment and the absence of sufficient participation mechanisms and access to information.** • **"Non-compliance, the failure to monitor compliance, poor enforcement, and a severe lack of coordination amongst especially government stakeholders exacerbate the socio-economic challenges faced by mining-affected communities.** • **"It is crucial that government ensures that communities are able to participate meaningfully in mining-related activities and influence decisions that detrimentally impact their enjoyment of constitutionally guaranteed rights and general wellbeing.**				

Issue/Concern	Contributor	Date of Contribution	Means of Contribution	Response

• "The State must do more to include communities in reporting and monitoring mechanisms." Of relevance too are the following the fact that the dust contains a wide spectrum of metals, in toxic concentrations as well and radioactive metals. We refer in this regard to the subjoined findings:
• "The two major airborne risks will be due to airborne radon and windblown dust.
• "The major primary pathways by which contamination can enter the environment from a mine site are:
  ○ the airborne pathway, where radon gas and windblown dust disperse outwards from mine sites".
  ○ air-quality, with particular reference to dust pollution from MRAs (including radioactive dust)."
• "Three main issues relating to MRAs located in Gauteng have been identified, namely:
  ○ "… significant radiation exposure can occur in the surroundings of mining legacies, due to:
  ○ Inhalation of Rn-222 daughter nuclides from radon emissions				

Issue/Concern	Contributor	Date of Contribution	Means of Contribution	Response
of desiccated water storage dams and slimes dams. ○ **The inhalation of contaminated dust generated by wind erosion from these objects, and** ○ **The contamination of agricultural crop (pasture, vegetables) by the deposition of radioactive dust particles, which can cause considerable dose contributions via ingestion".**				
Our plants are not growing – they are dying because of the TSF.	Puleng Silvia Nkash - Khuma Community	5 February 2020	Public Meeting	Potential effects on plants may occur when dustfall rates are above 400 mg/m²-day but this based on a literature survey for other areas and crop types. More detail are included in section 4.6 and section 7.
We worry for our kids and their health	Puleng Silvia Nkash - Khuma Community	5 February 2020	Public Meeting	More details on the potential impact areas are discussed in section 7. The air quality study was limited to the inhalation pathway for criteria pollutants and more detailed potential health impacts based on the air quality modelling results will be included in the other relevant specialist reports.
Air pollution caused by chemicals from the TSF is a serious concern. The TSF is a health hazard to the environment of Khuma. In the event of a serious spill the people in Ext 7 will be mostly affected, followed by the rest of the Khuma community. While the TSF is extended, can something be done to prevent such dangers? Can a wall be constructed between the TSF and the Khuma community?	Puleng Nkash - Puleng Nkash	5 February 2020	Comment Sheet	More details on the potential impact areas are discussed in section 7. The air quality study was limited to the inhalation pathway for criteria pollutants and more detailed potential health impacts based on the air quality modelling results will be included in the other relevant specialist reports.

Issue/Concern	Contributor	Date of Contribution	Means of Contribution	Response
The waste on the TSF is compromising our health.	Kefilwe Segomoco, Bonolo Segomoco, Kgothatso Moepadira, Siphokazi Jobela, Kgomotso Manoto, Meita Molekane, Elizabeth Molekane, Gloria Dineo Monoto Khuma - Khuma community (Ext 7)	5 February 2020	Comment Sheet	More details on the potential impact areas are discussed in section 7.
Considering the planned height of 122m, significant air considered as an alternative storage option underground.	Friedemann Essrich – Private landowner	17 February 2020	Comment Sheet	More details on the potential impact areas are discussed in section 7.
These mine dumps are spewing poisonous materials into the atmosphere and people living close to them have presented with a range of serious illness that have been linked to these toxic wastes. The submission details the type of wastes, e.g. heavy metals in water containing uranium, zinc, arsenic, selenium, sulphur and lithium traces and dust containing a mixture of chemicals like arsenic and cyanide that that polluted water and air and that can cause various health issues from brain damage to skin cancers. **Khuma is one of the contaminated areas outside Stilfontein. Some winter mornings the dust in the air makes it impossible to continue driving. This**				More details on the potential impact areas are discussed in section 7. The air quality study was limited to the inhalation pathway for criteria pollutants and more detailed potential health impacts based on the air quality modelling results will be included in the other relevant specialist reports.

Issue/Concern	Contributor	Date of Contribution	Means of Contribution	Response
situation is caused by the tailings in our area including all the relics from the old mines. **David van Wyk a lead researcher was quoted in the submission on the dangers to exposures to chemical substances and heavy metals.** **Information of the Ellen Glen Special Needs Centre was provided (why it was established and its status) describing the reason for the disabilities in the children as a direct result of the exposure to toxic wastes.**				
Implement dust suppression and control measures in all stages of the project	SM Lesupi - Municipal Manager, Dr Kenneth Kaunda District Municipality	10 Feb 2020 (received 28 Feb 2020)	Written Communication	Section 11 includes the potential management measures. Ultimately MWS will have to settle on a final management plan based on the feasibility of the measures suggested.

21 Appendix G: Impact Significance Methodology

The **significance** of an impact is defined as a combination of the **consequence** of the impact occurring and the **likelihood** that the impact will occur. The criteria used to determine impact consequence and likelihood are presented in the tables below (Table 21-1 to Table 21-7). Each impact identified was rated according the expected magnitude, duration, scale and probability of the impact (Table 21-8).

Each impact identified will be assessed in terms of scale (spatial scale), magnitude (severity) and duration (temporal scale). Consequence is then determined as follows:

Consequence = Severity + Spatial Scale + Duration

Table 21-1: Severity

Insignificant / non-harmful	1
Small / potentially harmful	2
Significant / slightly harmful	3
Great / harmful	4
Disastrous / extremely harmful / within a regulated sensitive area	5

Table 21-2: Spatial Scale - How big is the area that the aspect is impacting on?

Area specific (at impact site)	1
Whole site (entire surface right)	2
Local (within 5km)	3
Regional / neighboring areas (5km to 50km)	4
National	5

Table 21-3: Duration

One day to one month (immediate)	1
One month to one year (Short term)	2
One year to 10 years (medium term)	3
Life of the activity (long term)	4
Beyond life of the activity (permanent)	5

The Risk of the activity is then calculated based on frequency of the activity and impact, how easily it can be detected and whether the activity is governed by legislation. Thus:

Likelihood = Frequency of activity + frequency of impact + legal issues + detection

Table 21-4: Frequency of the activity - How often do you do the specific activity?

Annually or less	1
6 monthly	2
Monthly	3
Weekly	4
Daily	5

Table 21-5: Frequency of the incident/impact - How often does the activity impact on the environment?

Almost never / almost impossible / >20%	1
Very seldom / highly unlikely / >40%	2
Infrequent / unlikely / seldom / >60%	3
Often / regularly / likely / possible / >80%	4
Daily / highly likely / definitely / >100%	5

Table 21-6: Legal Issues - How is the activity governed by legislation?

No legislation	1
Fully covered by legislation	5

Table 21-7: Detection - How quickly/easily can the impacts/risks of the activity be detected on the environment, people and property?

Immediately	1
Without much effort	2
Need some effort	3
Remote and difficult to observe	4
Covered	5

The risk is then based on the consequence and likelihood.

Risk = Consequence x likelihood

Environmental effects will be rated as either of high, moderate or low significance on the basis provided in Table 21-8.

Table 21-8: Impact Ratings

RATING	CLASS
1 – 55	(L) Low Risk
56 – 169	M) Moderate Risk
170 – 600	(H) High Risk

22 APPENDIX H: METEOROLOGICAL DATA COMPARISON

Figure 22-1 shows the difference in locality of the two meteorological data points. The point extracted for WRF data is shown by the yellow sun while the location of the Kareerand TSF measured data is shown by the blue cloud, the purple line is the MWS plant boundary and the TSF to the east of the Kareerand station is the current Kareerand TSF

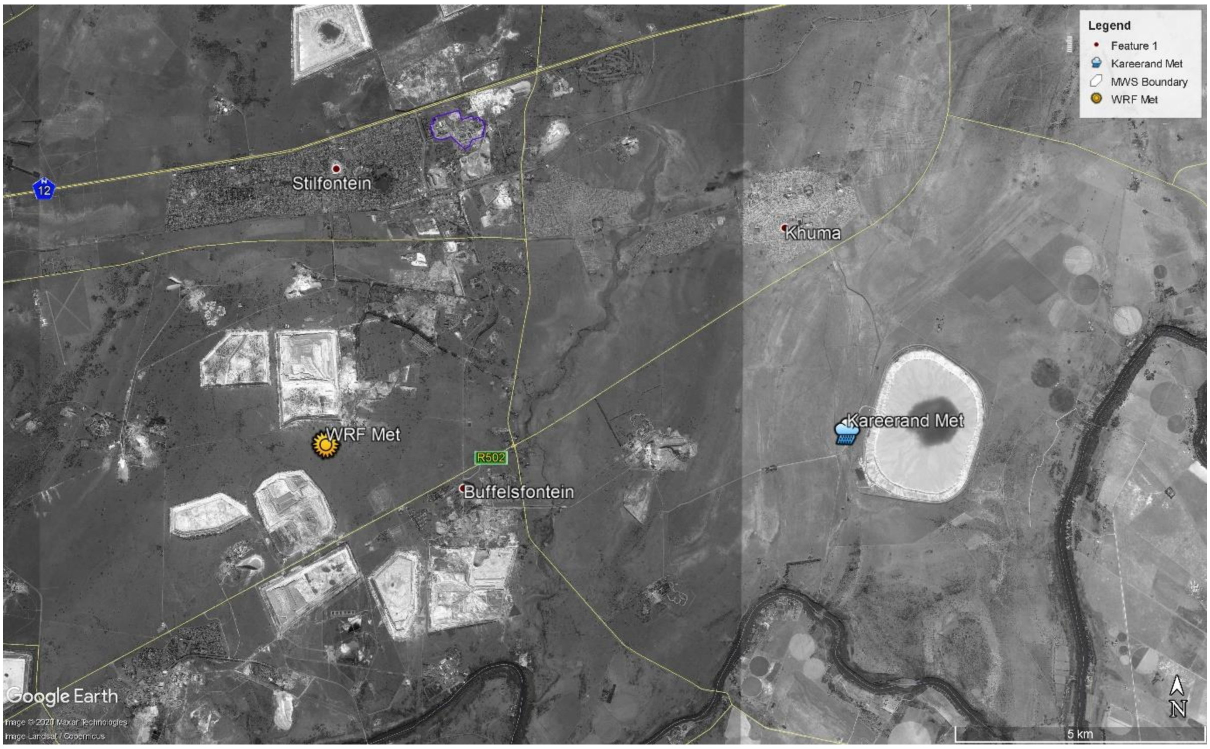

Figure 22-1: Map showing the locations for the two datasets

22.1 Local Wind Field

The wind data varies slightly with WRF data having higher wind speeds and the most dominant sector being north-north-westerly whereas the measured data has more dominant winds from the north-north-east.

22.1.1 WRF Data

The period wind field and diurnal variability in the wind field are shown in Figure 22-2, while the seasonal variations are shown in Figure 22-3. The wind field is dominated by winds from the north-northwest. The strongest winds (>6 m/s) occurred mostly from the north-west, north-north-west and north. Calm conditions occurred approximately 4% of the time, with the average wind speed over the period of 3.9 m/s. Wind speeds increased during the day with a slight decrease in calm conditions (from 4.5% during the day to 4% during the night). Strong winds in excess of 6 m/s occurred most frequently during spring months. Calm conditions occurred most frequently during autumn and winter months.

22.1.2 Measured Data

The period wind field and diurnal variability in the wind field are shown in Figure 5-1, while the seasonal variations are shown in Figure 5-2. The wind field is dominated by winds from the north-northeast. The strongest winds (>6 m/s) occurred mostly from the north-west and north-north-west. Calm conditions occurred 0.4% of the time (for 70 hours), with the average wind speed over the period of 3.06 m/s. Wind speeds increased during the day with a slight decrease in calm conditions (0.32% during the day to 0.48% during the night). Strong winds in excess of 6 m/s occurred most frequently during spring months. Calm conditions occurred most frequently during the winter months.

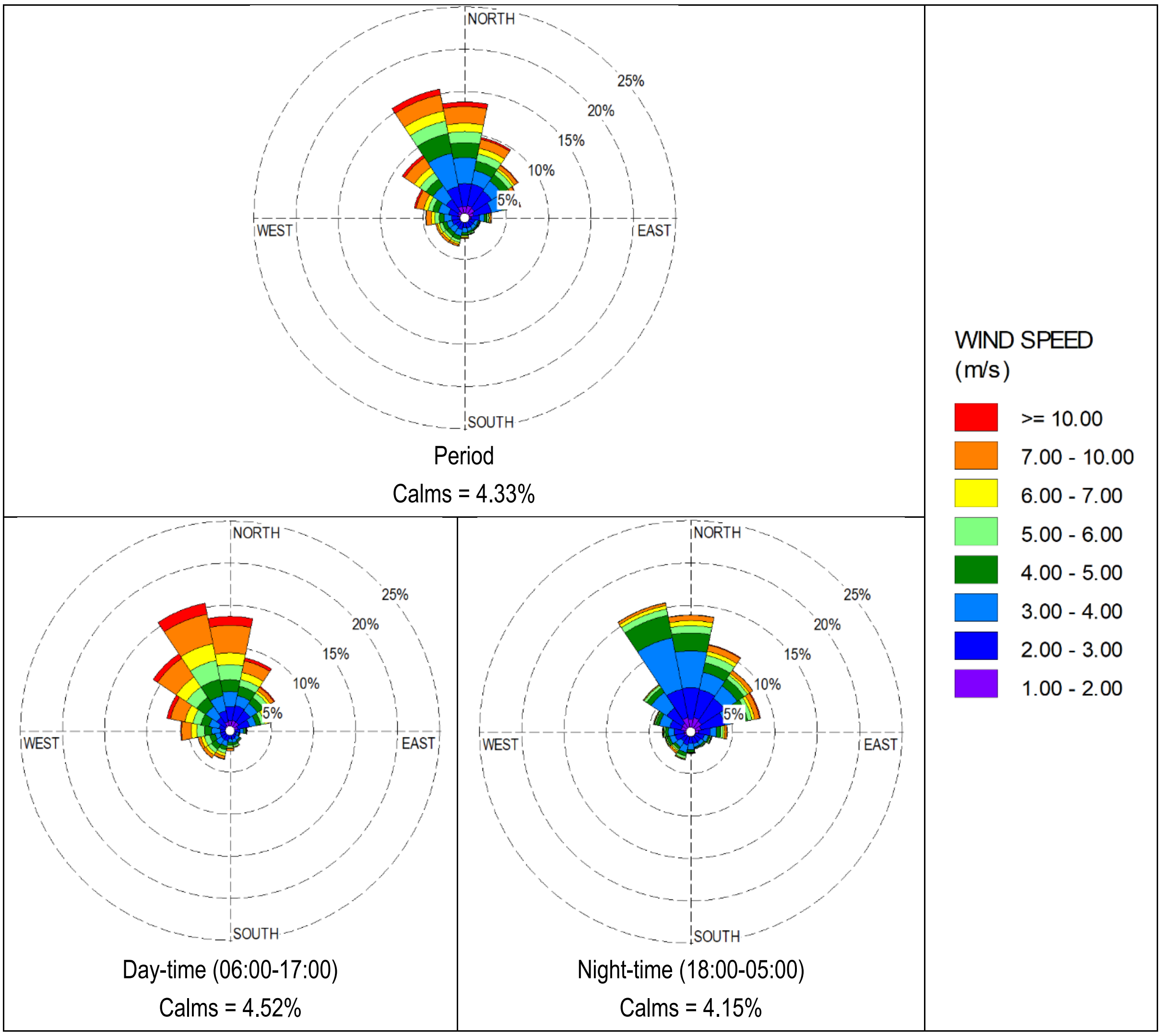

Figure 22-2: Period, day- and night-time wind roses (WRF data, January 2014 to December 2016)

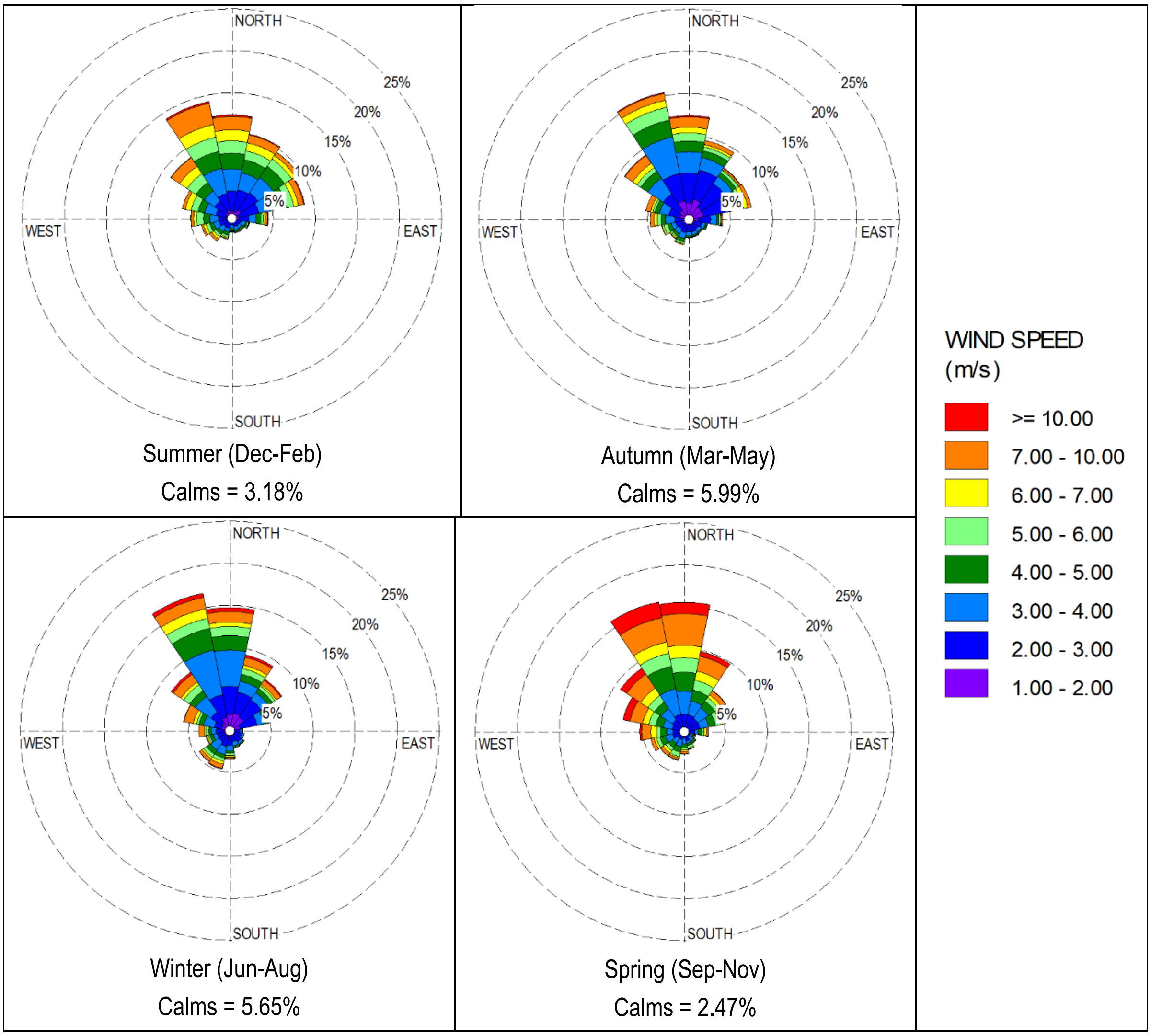

Figure 22-3: Seasonal wind roses (WRF data, January 2014 to December 2016)

22.2 Ambient Temperature

The temperatures measured are slightly lower than WRF data.

22.2.1 WRF Data

Monthly mean, maximum and minimum temperatures are given in Table 22-1. Diurnal temperature variability is presented in Figure 22-4: Diurnal temperature profile (WRF data, January 2014 to December 2016). Temperatures ranged between -4 °C and 41 °C. The highest temperatures occurred in January and the lowest in June.

22.2.2 Measured Data

Monthly mean, maximum and minimum temperatures are given in Table 5-1. Diurnal temperature variability is presented in Figure 5-3. Temperatures ranged between -6 °C and 38 °C. The highest temperatures occurred in December and the lowest in June and July.

Table 22-1: Monthly temperature summary (WRF data, January 2014 to December 2016)

Monthly Minimum, Maximum and Average Temperatures (°C)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly Average	24	23	21	18	15	11	11	15	19	22	22	25
Hourly Maximum	41	37	35	34	30	27	25	32	35	37	38	39
Hourly Minimum	11	7	4	2	2	-4	-3	-3	1	1	4	12

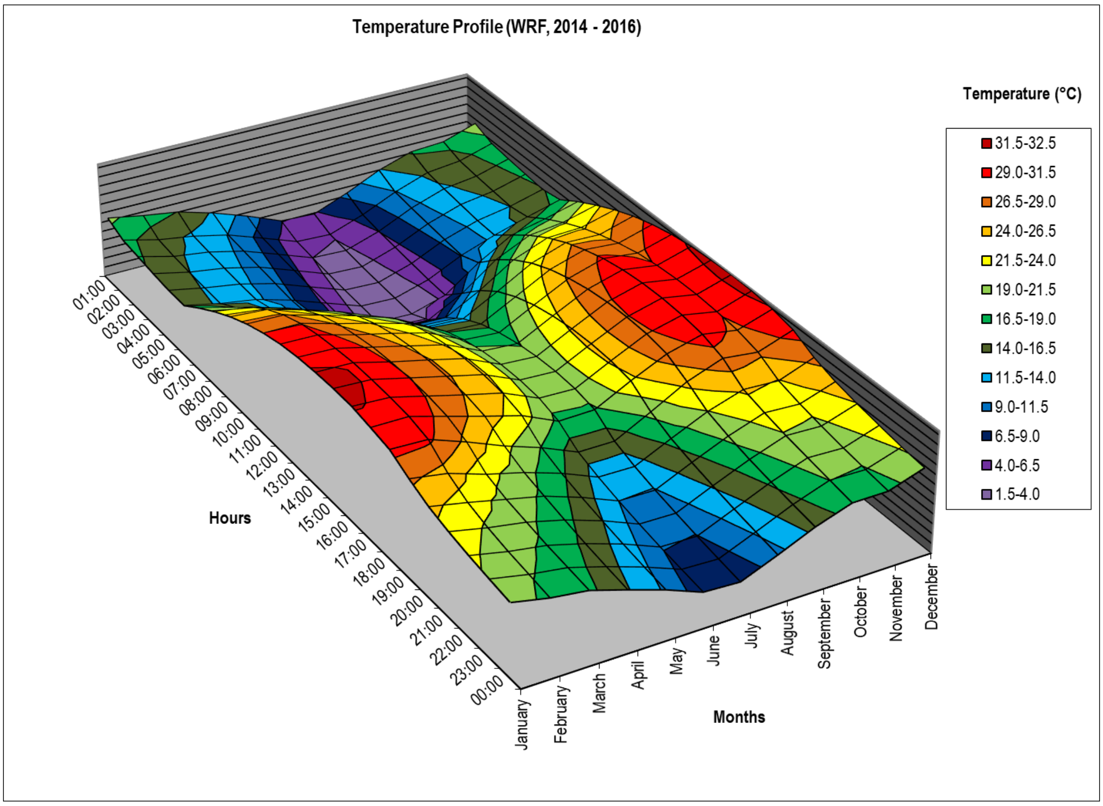

Figure 22-4: Diurnal temperature profile (WRF data, January 2014 to December 2016)

22.3 Atmospheric Stability

The highest concentrations for ground level, or near-ground level releases from wind dependent sources would occur during stable (night-time) atmospheric conditions. Stable (night-time) conditions occur for a longer period based on the measured data that that of the WRF data allowing.

22.3.1 WRF Data

Diurnal variation in atmospheric stability, as calculated from measured data, and described by the inverse Obukhov length and the boundary layer depth is provided in Figure 22-5.

22.3.2 Measured Data

Diurnal variation in atmospheric stability, as calculated from measured data, and described by the inverse Obukhov length and the boundary layer depth is provided in Figure 5-4.

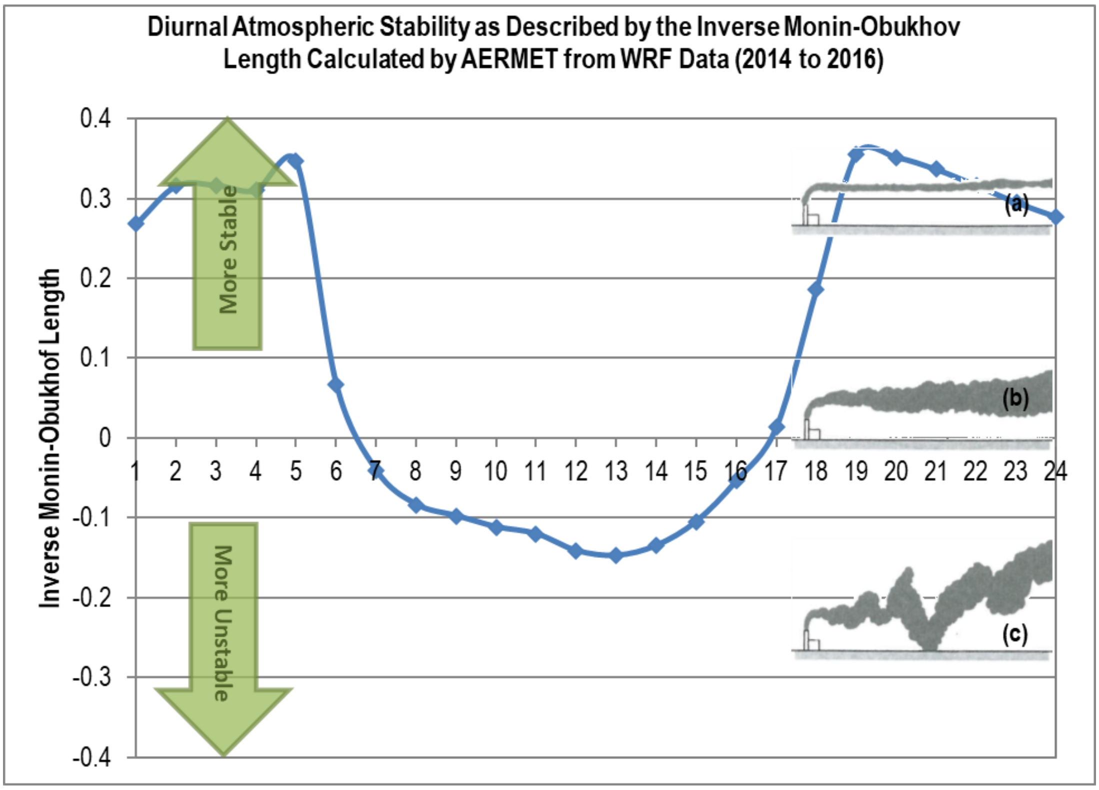

Figure 22-5: Diurnal atmospheric stability (AERMET processed WRF data, January 2014 to December 2016)