Air Quality Impact Assessment for the proposed Kimberley Rehabilitation and Development Project – Roodepan Quarry and Clay Brick Facility

Project done on behalf of **Ndi Geological Consulting Services**

Project Compiled by:
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Revision Record

Revision Number	**Date**	**Reason for Revision**
Rev 0	September 2020	Draft for client review

Competency Profiles

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

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

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

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

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

Specialist Declaration

I, Hanlie Liebenberg-Enslin, as the appointed independent air quality specialist for the Rehabilitation and Development Project activities, hereby declare that I:

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

Signature of the specialist:
Name of Specialists: Hanlie Liebenberg-Enslin
Date: 10 September 2020

NEMA Regulation (2017), Appendix 6

NEMA Regulations (2017) - Appendix 6		Relevant section in report
1.a)	Details of the specialist who prepared the report.	Report details (page ii)
	The expertise of that person to compile a specialist report including curriculum vitae.	Report details (page ii) Appendix A
1.b)	A declaration that the person is independent in a form as may be specified by the competent authority.	Report details (page ii)
1.c)	An indication of the scope of, and the purpose for which, the report was prepared.	Executive Summary Section 1: Introduction
	An indication of the quality and age of base data used for the specialist report.	Section 3.2: Influencing Meteorological Conditions Section 3.4: Status Quo of Air Quality
	A description of existing impacts on the site, cumulative impacts of the proposed development and levels of acceptable change.	No baseline air quality information available. Cannot assess cumulative impacts. Likely pollutants addressed om Section 3.3: Pollutants of Concern and Associated Health Impacts
1.d)	The duration date and season of the site investigation and the relevance of the season to the outcome of the assessment.	Section 3.2: Influencing Meteorological Conditions Section 3.4: Status Quo of Air Quality
1.e)	A description of the methodology adopted in preparing the report or carrying out the specialised process inclusive of equipment and modelling used.	Section 1.1: Brief Process Description Section 1.2: Air Quality Impact Assessment Approach Section 1.3: Exclusions and Assumptions
1.f)	Details of an assessment of the specific identified sensitivity of the site related to the proposed activity or activities and its associated structures and infrastructure inclusive of a site plan identifying site alternatives.	Section 3.1: Site Description Section 4: Air Quality Impact Assessment Section 5: Impact Evaluation
1.g)	An identification of any areas to be avoided, including buffers.	Not applicable
1.h)	A map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers.	Section 3.1: Site Description Section 4.3: Dispersion Modelling Results for the Roodepan Quarry and Clay Brick facility
1.i)	A description of any assumptions made and any uncertainties or gaps in knowledge.	Section 1.3: Exclusions and Assumptions
1.j)	A description of the findings and potential implications of such findings on the impact of the proposed activity or activities.	Section 4: Air Quality Impact Assessment
1.k)	Any mitigation measures for inclusion in the environmental management programme report	Section 7.3: Recommendations
1.l)	Any conditions for inclusion in the environmental authorisation	Section 7.2: Conclusion Section 7.3: Recommendations
1.m)	Any monitoring requirements for inclusion in the environmental management programme report or environmental authorisation.	Section 7.3: Recommendations
1.n)	A reasoned opinion as to whether the proposed activity, activities or portions thereof should be authorised.	Section 7.2: Conclusion
	A reasoned opinion regarding the acceptability of the proposed activity or activities.	Section 7: Conclusion and Recommendations
	If the opinion is that the proposed activity or portions thereof should be authorised, any avoidance, management and mitigation measures that should be included in the environmental management programme report, and where applicable, the closure plan.	Section 7.3: Recommendations
1.o)	A description of any consultation process that was undertaken during the course of carrying out the study.	Not applicable
1.p)	A summary and copies if any comments that were received during any consultation process.	Not applicable
1.q)	Any other information requested by the competent authority.	Not applicable.

Abbreviations

°C	Degrees Celsius
µg/m³	Microgram per cubic metre
AEL	Atmospheric Emissions License
AIR	air quality impact
Airshed	Airshed Planning Professionals (Pty) Ltd
AQA	Air Quality Act
AQSR	air quality sensitive receptors
CC	Climate Change
CE	control efficiency
CO_2	carbon dioxide
CO_2eq	carbon dioxide equivalent
COHb	carboxyhaemoglobin
COPD	chronic obstructive pulmonary disease
DEA	Department of Environmental Affairs
DEFF	Department of Environment, Forestry and Fisheries
EIA	Environmental Impact Assessment
FELs	front-end-loaders
FEV1	volume over one second
GHG	greenhouse gas emissions
GLCs	ground level concentrations
HAP	hazardous air pollutants
HC	hydrocarbons
IPCC	Intergovernmental Panel on Climate Change's
KRD	Kimberley Rehabilitation and Development
m	metre
m/s	Metre per second
m^2	Metre squared
Mamsl	mean sea level
MES	Minimum Emission Standards
$mg/m^2/day$	Milligram per metre squared per day
NAAQS	National Ambient Air Quality Standards
NAEIS	National Atmospheric Emissions Inventory System
NAERR	National Atmospheric Emission Reporting Regulations
NDCR	National Dust Control Regulations
NEM:AQA	National Environmental Management: Air Quality Act
NOx	oxides of nitrogen
NPI	National Pollutant Inventory (Australia)
O_3	ozone
OEHHA	Environmental Health Hazard Assessments
PM_{10}	Particulate Matter with an aerodynamic diameter of less than 10m
$PM_{2.5}$	Particulate Matter with an aerodynamic diameter of less than 2.5m
RfCs	Inhalation reference concentrations
SAAELIP	South African Atmospheric Emission Licensing & Inventory Portal
SAAQIS	South African Air Quality Information System

SABS	South African Bureau of Standards
SANS	South African National Standards
SAWS	South African Weather Services
SO_2	sulfur dioxide
SO_3	sulfur trioxide
tpa	Tonnes per annum
TSP	Total Suspended Particles
UDDF	Urban Design and Development Framework
US EPA	United States Environmental Protection Agency
VOCs	Volatile Organic Compounds
WB	World Bank Group
WHO	World Health Organisation

Executive Summary

Kimberley Rehabilitation and Development (KRD) proposes mixed-use developments (residential and commercial, etc.) for three sites in Kimberley, namely the BMW, Colville and St Augustine sites. The BMW and St Augustine sites are located in the central part of Kimberley with Colville more to the north-east. The area to the east of the BMW and St Augustine sites is commercially zoned with residential areas to the south, east and north. The Colville site is to the north and surrounded by residential areas. Two quarries, namely Roodepan Quarry to the north of Kimberley and Vooruitzigt Quarry located to the west, will be developed to provide building material for the three mixed-use sites. In addition, a Clay Brick Facility is planned at Roodepan Quarry and a Cement Brick Facility at Vooruitzigt Quarry.

Airshed Planning Professionals (Pty) Ltd was appointed by Ndi Geological Consulting Services to conduct a basic air quality assessment for the three mixed-use sites (BMW, Colville and St Augustine) and an air quality impact assessment for the two quarry sites (Vooruitzigt Quarry and Roodepan Quarry) including the Brick Making Facilities. The main objective of the study is to assess the potential for air quality related impacts on the surrounding environment and human health from these proposed operations. The current study constitutes the baseline and preliminary screening assessment of the proposed project.

Limited information was available at the time of the screening assessment, with no information on the actual quarry operations, the type of Clay Brick facility, the type of Cement Brick facility or detail on the developments at each of the mixed-use sites. Use was made of Google Earth and Google Maps to determine the air quality sensitive receptors (AQSR) around these developments and of the South African Weather Services (SAWS) meteorological data for Kimberley to determine the potential areas of impact from the various activities. A quantitative impact assessment will be conducted for the two Quarries and the Clay- and Cement Brick facilities.

This report assessed the potential for air quality impacts from the planned mixed-use development zones and an air quality impact assessment for the Roodepan quarry and Brick Making Facility.

Main Findings

The findings from the baseline screening assessment can be summarised as follows:

- Meteorological data was obtained from the SAWS station in Kimberley for the period Jan 2015 – Jun 2020. The prevailing wind field in the area is northerly, north-northeasterly and to a lesser extent from the west-southwest and southwest. The average wind speed recorded was 3.6 m/s with a maximum of 15 m/s. The threshold wind speed of 5.4 m/s required for windblown dust to occur, was exceeded for 19% of the time. There was no significant variation in the prevailing wind fields between the seasons, with northerly winds prevailing throughout and a slight change in the frequency of north-northwesterly to north-northeasterly winds which are more prominent in summer and spring and less in winter and autumn. Temperatures ranged between -1°C (June 2018) to 42.5°C (January 2016), with the highest temperatures in summer and the lowest in winter. Kimberley falls within the summer rainfall area with an average annual rainfall of 328 mm recorded.
- No ambient air quality data could be found for Kimberley. Given the activities within the region which include primarily mining operations, vehicles and trucks on gravel roads, agricultural field tilling and windblown dust from exposed surfaces, the main pollutants are expected to be PM_{10} and $PM_{2.5}$. Background concentrations for the Kimberley area are however not known.
- Activities identified that will give rise to air pollutants include:

  - **Mixed-use sites**: air quality related impacts will primarily be from construction activities such as land clearing activities, including removal of waste rock and surface levelling (grading and scraping), crushing and handling of clay material, and the off-loading and handling of building materials (bricks, cement, etc.) on-site. Once the sites are developed, there might be an increase in road traffic contributing to increased vehicle tailpipe emissions.
  - **Roodepan Quarry and Clay Brick facility**: clay brick production will result in the most significant emissions, with particulate emissions deriving from mixing and blending of the raw materials, grinding and firing. The firing will also give rise to SO_2, NO_2, CO and VOCs. Gaseous emissions will result from mobile equipment and vehicle tailpipe emissions on-site. At the time of the assessment, the preferred clay brick making technology was Clamp Kilns, but this was subsequently changed to Zig-Zag Kilns which would result in significantly less particulate emissions due to the zig-zag design causing the deposition of particulates as a result of the continuous change in flue gas, and a flue gas scrubber.
- The main pollutant of concern is particulate matter (TSP, PM_{10} and $PM_{2.5}$). Particulate matter emissions would result from all the planned activities including construction at the mixed-use sites and operations at the Roodepan Quarry (manufacturing of clay bricks). Gaseous emissions (SO_2, NO_2, CO and VOC) would result from vehicle tailpipe emissions – truck activity at the quarry and trucks transporting the clay material from the mixed-use sites to the quarry, as well as from diesel powered equipment at the sites. The Clay Brick facility will emit particulate emissions as well as SO_2, NO_2.

The findings from the impact assessment are as follows:

- **Construction** normally comprises a series of different operations including land clearing, topsoil removal, road grading, etc., with particulate matter the main pollutants of concern from these activities. During construction, the extent of dust emissions would vary substantially from day to day depending on the level of activity, the specific operations, and the prevailing meteorological conditions, and how close these activities are to AQSRs. Construction in this context was thus taken to only include the site preparation at Roodepan Quarry for the Clay Brick facility i.e. construction of site infrastructure. Due to the temporary nature of construction operations, and the localised scale of these activities, the impacts are expected to have a **Medium-High** (for $PM_{2.5}$ and PM_{10} without mitigation) to **Medium-Low** (with mitigation) significance. No baseline data was available, with cumulative impacts expected to increase in proximity of these activities but only for the duration of the activities.
- **Operations** were taken to include the Clay Brick manufacturing at Roodepan Quarry, and the crushing, handling and transport of the clay material at the mixed-use sites. The main pollutants of concern from these sites are particulate matter (TSP, PM_{10} and $PM_{2.5}$), with the main contributing source at Roodepan Quarry the Clamp Kilns (59% of TSP; 70% of PM_{10} and 92% of $PM_{2.5}$) and vehicle entrained dust from the paved roads being the main contributor from the mixed-use sites (95% of TSP; 88% of PM_{10} and 92% of $PM_{2.5}$).
  - Simulated (design) mitigated PM_{10} GLCs resulted in exceedances of the daily NAAQSs at the nearest AQSR and the Roodepan Quarry boundary. Annual average PM_{10} GLCs, as well as the daily and annual $PM_{2.5}$ GLCs were within the NAAQSs. Due to the potential for exceedances, the significance is regarded to be **High** with the design-mitigation in place but would reduce to **Medium-High** with the Zig-Zag kiln technology.
  - Simulated impacts from gaseous emissions (SO_2, NO_2, CO and VOCs) were well within the respective NAAQSs at all AQSRs. With the impacts limited to the site, the significance of the impacts is **Medium-High** for SO_2 and Medium low for NO_2, CO and VOCs. With mitigation in place the severity, footprint and duration would reduce resulting a **Medium-Low** significance for all.

  - Dustfall rates from the Clay Brick facility were limited to the site, and likely to result in **Medium-High** significance impacts when (design) mitigation is applied and would reduce to **Medium-Low** with additional mitigation in place.
  - For the mixed-use sites, the significance from PM_{10} and $PM_{2.5}$, as well as dustfall impacts is regarded to be **Medium-High** due to the proximity of AQSRs to the roads to be used by the trucks transporting the clay material. With mitigation in place, the significance could reduce to **Medium-Low.**
  - No baseline data was available for a **cumulative assessment**. Based on the existing sources of pollution in the region, particulates are expected to be the main pollutant of concern and would likely result in higher impacts at the AQSRs close to the various project activities. With the recommended additional mitigation measures applied, these cumulative impacts could remain at the project specific significance ratings.
  - Once the mixed-use sites have been developed, and all activities at the Roodepan Quarry and Clay Brick facility cease, the significance should reduce, and the air quality should return to pre-project status. There is a possibility for higher gaseous concentrations due increases in traffic around the mixed-use sites once these are developed.
- GHG emissions were quantified for the operations using the estimated diesel and coal usage. In the quantification of emissions use was made of the 2006 IPCC guidelines and South Africa's carbon dioxide equivalent (CO_2eq) emission factors (kg/tonne of fuel consumed, or kg/litre of fuel consumed). GHG emission rates are reported as tCO_2eq. The total GHG emissions for the Roodepan Clay Brick Facility and mixed-use sites is 43 242 CO_2eq tpa. This is well below the 100 000 tCO_2eq annually and thus do not require the submission of a pollution prevention plan.

Conclusion

The air quality impact assessment from the Clay Brick facility is regarded representative since the Clamp Kilns, although resulting in higher emission rates than the Zig-Zag kiln technology, were modelled as point sources due to the buoyancy of the emissions. The Zig-Zag kiln technology could however, if fitted with a flue gas scrubber and designed to meet the Minimum Emission Standards, result in an overall significance rating of **Medium-Low**. Once the design for the Zig-Zag kilns are finalized, the dispersion model would need to be rerun to determine the impacts from this technology. It is further assumed that the brick making operations will only last for the duration of the construction of the mixed-use development sites. It can thus be concluded from the impact assessment that the planned development operations could have a **Medium-Low** significance on the surrounding environment and human health with the required mitigation measures in place.

Recommendations

- During the operations at the Clay Brick facility, the following mitigation measures should be implemented:
  - Limiting the speed of on-site trucks; limiting unnecessary travelling of vehicles on untreated roads.
  - Access road to be paved.
  - Water sprays on all on-site unpaved roads (at least 50% control efficiency).
  - Water sprays, or other dust control measures, at all material transfer points to ensure at least 50% control efficiency.
  - Screening of clay should be enclosed to ensure at least 50% control efficiency.
  - The Zig-Zag technology should include a flue gas scrubber.
  - Screening of clay material, blending and the brick kilns to be located on the eastern side of the Roodepan Quarry, furthest away from residences, with limited site activity on the western side.
- Operations at the mixed-use sites should be mitigated through water sprays and activities should be visually assessed – where dust is visible, additional water sprays should be applied. The main source on-site would be the

crushers, with trucks transporting the clay to the Roodepan Quarry required to be covered to reduce the potential for spills and windblown dust from the trucks.

- Monitoring requirements:
  - Continuous sampling of PM_{10} and $PM_{2.5}$ concentrations on the western boundary of the quarry, closest to the AQSRs for the duration of the clay brick manufacturing.
  - Dustfall collection for the duration of the clay brick manufacturing comprising of four (4) single dustfall units, one in each of the four main wind directions – north, west, east and south.
  - Bi-annual passive sampling of NO_x, SO_2 and VOCs at the four (4) dustfall locations.

Table of Contents

List of Tables

List of Figures

1 INTRODUCTION

Kimberley Rehabilitation and Development (KRD) is in the process of compiling a detailed Urban Design and Development Framework (UDDF) for Kimberley in the Northern Cape. The development is to include three sites: BMW, Colville and St Augustine for mixed-use (residential and commercial, etc.) and two sites: Vooruitzigt Quarry and Roodepan Quarry that will be used to mine and process waste rock to be used in the construction of the mixed-use sites. In addition, a Clay Brick Facility is planned at Roodepan Quarry and a Cement Brick Facility at Vooruitzigt Quarry. The sites are indicated in Figure 1.

An air quality impact assessment is required for the quarries and brickmaking facilities as part of the Environmental Impact Assessment (EIA). Airshed Planning Professionals (Pty) Ltd was appointed by Ndi Geological Consulting Services to conduct a qualitative air quality assessment for the three mixed-use sites (BMW, Colville and St Augustine) and an air quality impact assessment for the two quarry sites (Vooruitzigt Quarry and Roodepan Quarry) including the Brick Making Facilities. The Clay Brick Facility is a Listed Activity according to the National Environmental Management: Air Quality Act (NEM:AQA, Act no.39 of 2004) and will require an Atmospheric Emissions License (AEL) to operate. The main objective of the study is to assess the potential for air quality related impacts on the surrounding environment and human health from these proposed processes, and to provide an opinion on the process with the least likely long-term air quality impact.

This report includes the qualitative assessment of the three mixed-use sites and the quantitative impact assessment for the Roodepan Quarry and Clay Brick facility. The air quality impact assessment for the Vooruitzigt Quarry is provided in a separate report.

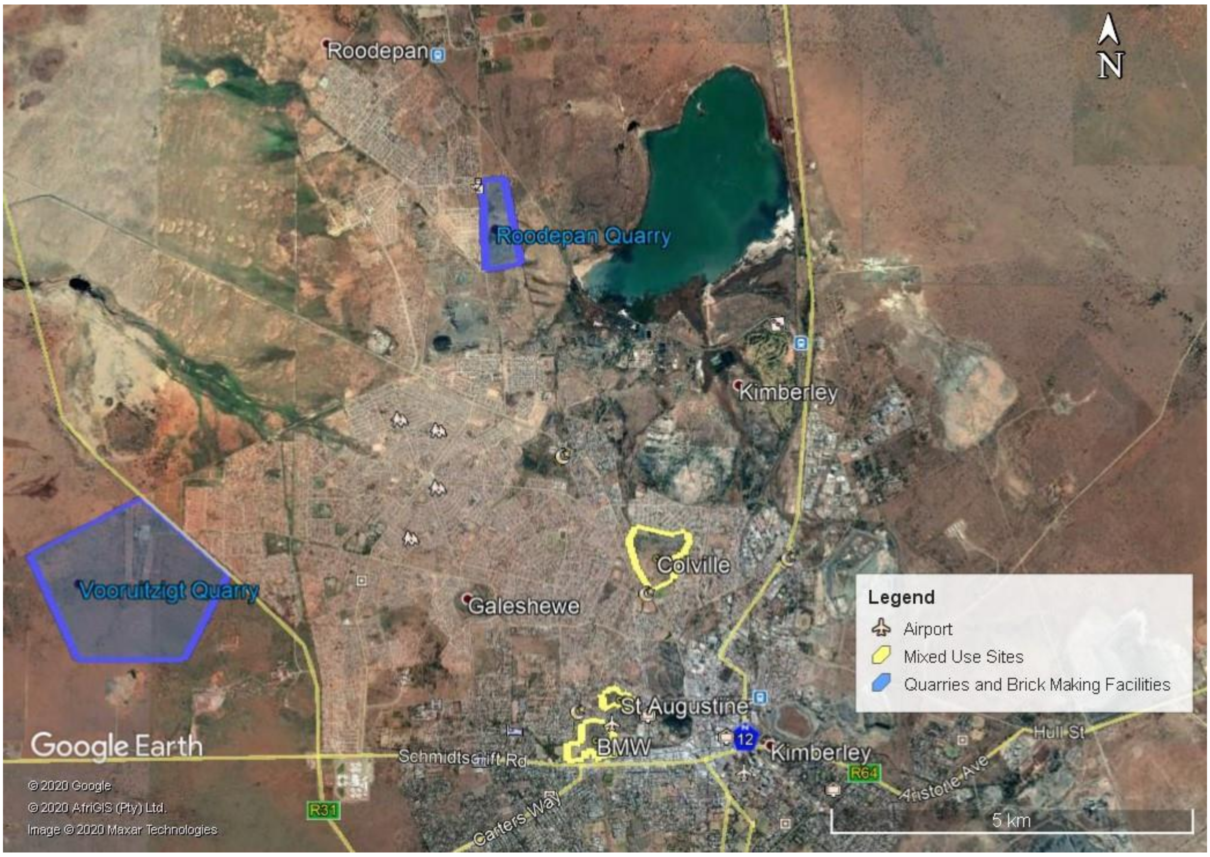

Figure 1: Location of the KRD Sites

1.1 Brief Process Description

The various components of the project are shown in Figure 2 with a brief description of each component in the subsequent sections.

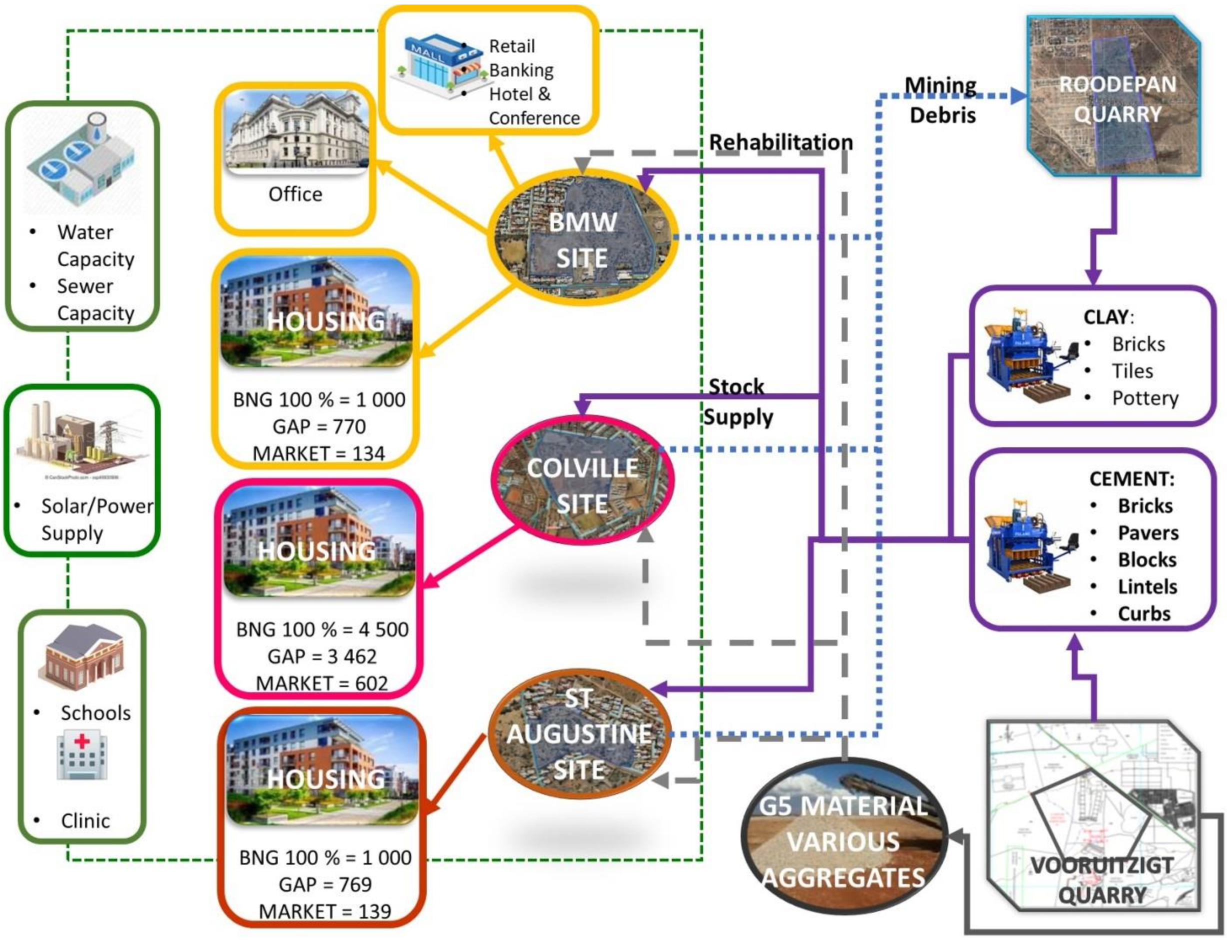

Figure 2: Project component

1.1.1 Mixed-use Sites

The development of commercial and residential areas at the three sites of: BMW, Colville and St Augustine will primarily result in particulate matter emissions from construction activities. Construction will most likely include land clearing activities, including removal of waste rock and surface levelling (grading and scraping), and the off-loading and handling of building materials (bricks, cement, etc.) on-site. Clay material required in the clay brick manufacturing will be sourced from the mixed-use sites and transported to the Roodepan Quarry.

Particulate emissions include Total Suspended Particulates (TSP), thoracic particles (with an aerodynamic diameter of less than 10 µm; PM_{10}) and respirable particles (with an aerodynamic diameter of less than 2.5 µm; $PM_{2.5}$). TSP is a nuisance concern in the form of dust fallout. Whereas PM_{10} and $PM_{2.5}$ pose potential health risks. Vehicle tailpipe emissions can be grouped into primary and secondary pollutants. Primary pollutants are emitted directly into the atmosphere, and mainly include particulate matter (PM_{10} but mainly $PM_{2.5}$), sulphur dioxide (SO_2), oxides of nitrogen (NOx), and carbon monoxide (CO). Secondary pollutants are formed in the atmosphere as a result of chemical reactions, such as hydrolysis, oxidation, or photochemical reactions and include nitrogen dioxide (NO_2), carbon dioxide (CO_2), photochemical oxidants (e.g. ozone), hydrocarbons (HC) compounds, sulfuric acid, nitric acid, sulfate and nitrate aerosols.

1.1.2 Roodepan Quarry Operations

The Roodepan Quarry will primarily be used to process the clay removed from the three mixed-use sites in preparation for the Clay Brick manufacturing. There will be screening, blending of raw materials, materials handling, and vehicle entrainment on unpaved access roads, but no drilling and blasting. All these activities would give rise to particulate emissions (TSP, PM_{10} and $PM_{2.5}$) and to a lesser extent gaseous emission (SO_2, NO_2, CO and HC).

1.1.3 Clay Brick Facility

A Clay Brick facility is proposed to be established at Roodepan Quarry. At the time of the assessment, the preferred technology was Clamp Kilns, but this was later changed to Zig-Zag Kiln technology.

Typical brick making activities that generate significant air emissions include mining of clay, crushing, blending, grinding, firing etc. The main pollutants of concern from an air quality perspective, associated with brickmaking operations, are particulates (TSP, PM_{10} and $PM_{2.5}$). PM_{10} and $PM_{2.5}$ pose a health risk to the surrounding communities whereas dust fallout is of concern due to its nuisance effects. Dust producing activities at the brickmaking facility include the off-loading of raw materials such as clay and coal, mixing and moulding of the raw bricks and finally the firing of bricks. Firing is usually done using fireboxes comprising of coal, gas or oil. Pollutants associated with combustion processes include SO_2, sulfur trioxide (SO_3), NO_x, carbon monoxide (CO), CO_2, metals, total organic compounds (TOC) (including methane, ethane, volatile organic compounds [VOC]), and some hazardous air pollutants (HAP), and fluorides (Akinshipe, 2013; EMEP/EEA, 2009 and US EPA, 1997).

Brick production has been identified as one of the most significant sources of atmospheric pollution, which has recently generated international concern, due to primitive technology application and poor or inadequate combustion processes. The brick manufacturing industry is also one of the significant sources of greenhouse gas emissions in many nations of the world (World Bank, 1997; Le & Oanh, 2010; Ferdausi *et al*. 2008; Akinshipe 2013; CAI-Asia 2008; DEAT 2008; DEA 2013).

1.2 Air Quality Impact Assessment Approach

This report covers the baseline characterisation and air quality impact assessment for the Roodepan Quarry and Clay Brick facility. The study follows a quantitative approach where all sources of pollution are identified, the associated emissions quantified, and the impacts simulated and assessed against the relevant legal guidelines. For the three mixed-use sites, although the emissions were quantified, the potential for impacts were only qualitatively assessed.

The various tasks undertaken as part of the air quality impact assessment include:

1. Baseline characterisation:
    - A brief description of the weather patterns in Kimberley.
    - Identification of existing sources of emission and characterisation of ambient air quality within the region based on observational data recorded to date.
    - The legislative and regulatory context, including ambient air quality standards and dust fall classifications.
    - Identification of all potential sources of atmospheric emissions associated with the proposed development.
    - Identification of air quality sensitive receptors near the Roodepan Quarry.

2. Impact Assessment
    - The compilation of a comprehensive emissions inventory including the identification and quantification of all emissions associated with the Roodepan Quarry and Clay Brick facility.
    - Atmospheric dispersion modelling to simulate ambient air pollutant concentrations and dustfall rates from the project activities.
    - The screening of simulated ambient pollutant concentration levels and dust fallout against ambient air quality guidelines and standards.
    - Assessment of the potential air quality impacts on human health and the environment.
    - The identification and recommendation of suitable mitigation measures and monitoring requirements.
    - The preparation of a comprehensive specialist air quality impact assessment

1.3 Exclusions and Assumptions

The following assumptions and limitations apply:

- The scope of work included a site visit, but due to the tight timeframe and COVID-19 travel restrictions, no site visit was conducted.
- Activities at the Roodepan Quarry, including the Clay Brick facility are quantitatively assessed with the potential for impacts from the mixed-use sites only qualitatively assessed.
- Limited information was available for the air quality impact assessment, and the locations of the various activities at Roodepan Quarry was assumed (see Figure 3).
- It was indicated that the clay material will be crushed at the mixed-use sites before being transported to the Roodepan Quarry for use in the Clay Brick manufacturing. It was assumed that only screening will be required on-site.
- There will be no on-site quarry operations such as drilling and blasting, excavation, etc. at Roodepan Quarry, only Clay Brick manufacturing.
- At the time of the assessment, the preferred brick making technology was Clamp kilns. This was subsequently changed to Zig-Zag kilns. The air quality impact assessment from the Clay Brick facility is regarded representative since the Clamp Kilns, although expected to have higher emission rates than the Zig-Zag kiln technology, were modelled as point sources due to the buoyant nature of the emissions. Once the design for the Zig-Zag kilns are finalized, the dispersion model would need to be rerun to determine the impacts from this technology.
- The location of the Clamp Kilns at Roodepan Quarry was assumed to be on the eastern side of the site, furthest away from the nearest air quality sensitive receptors (AQSRs) located to the west of the quarry boundary (Figure 3).
- Information regarding the AQSRs were obtained from Google maps and Google Earth since no information was provided. Only the AQSRs within a radius of 2.5 km from the Roodepan Quarry were included in the assessment.

2 LEGAL OVERVIEW

The environmental regulations and guidelines governing the emissions and impact of the fugitive dust emissions need to be considered prior to developing a management plan so that National standards and guidelines are met by the actions recommended within the management plan.

The National Environmental Management: Air Quality Act (Act no.39 of 2004) commenced with on 11 September 2005 as published in the Government Gazette on 9 September 2005. Sections omitted from the implementation were Sections 21, 22, 36 to 49, 51(1)(e),51(1)(f), 51(3), 60 and 61. The Act was fully implemented on 1 April 2010, including Section 21 on the Listed Activities and Minimum National Emission Standards. The revised Listed Activities and Minimum Emission Standards were published on 22 November 2013 (Government Gazette 37054, Notice No. 893). Amendments to the Act, primarily pertaining to administrative aspects, were published in 2014 (Government Gazette 37666, Notice No. 390 on 14 May 2014).

The National Framework (first published in Government Gazette Notice No. 30284 of 11 September 2007 and updated in 2013) underpins the Air Quality Act (AQA), providing national norms and standards for air quality management to ensure compliance. The National Framework states that aside from the various spheres of government responsibility towards good air quality, industry too has a responsibility not to impinge on everyone's right to air that is not harmful to health and well-being. Industries therefore should take reasonable measures to prevent such pollution order degradation from occurring, continuing or recurring.

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

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

Section 51 of the Air Quality Act lists possible offences according to the requirements of the Act with Section 52 providing for penalties in the case of offences.

2.1 Listed Activities

The Clay Brick facility will produce 60 million bricks per annum, resulting in five (5) million bricks per month. Clamp Kiln technology, the initial preferred technology, falls under Subcategory 5.3: Clamp Kilns for Brick Production of the Listed Activities. This has changed to Zig-Zag Kiln Technology which falls under Subcategory 5.9: Ceramic Production – the minimum emission standards (MES) are provided in Table 1. When operating a Listed Activity, an application must be submitted to the District Municipality for an Atmospheric Emissions License (AEL). *Existing plant* requirements are applicable to already established facilities whereas *new plant* limits are applicable to new facilities, thus *new plant* limits will apply.

Cement brickmaking is not a Listed Activity and will not require an AEL. This is based on the assumption that the cement will be supplied and not produced on-site.

Table 1: MES for ceramic production

Subcategory 5.9: Ceramic Production			
Description	The production of tiles, bricks, refractory bricks, stoneware or porcelain ware by firing, excluding clamp kilns.		
Application	All installations producing more than 100 ton per annum or more.		
Substance or mixture of substances		**mg/Nm^3 under normal conditions of 273 Kelvin and 101.3 kPa**	
Common Name	**Chemical Symbol**	**New plant**	**Existing plant**
Particulate Matter	PM	50	150
Sulfur dioxide	SO_2	400	1000
Hydrogen Fluoride	HF	50	50

All AEL applications must be accompanied by a processing fee as published in the Government Gazette 38863 (Notice 550 on 12 June 2015).

2.2 National Ambient Air Quality Standards

Air quality guidelines and standards are fundamental to effective air quality management, providing the link between the source of atmospheric emissions and the user of that air at the downstream receptor site. The ambient air quality limits 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. Air quality guidelines and standards are normally given for specific averaging periods.

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

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Table 2: South African National Ambient Air Quality Standards (Government Gazette 32816, 2009)

Substance	Molecular formula / notation	Averaging period	Concentration limit (µg m^{-3})	Frequency of exceedance[a]	Compliance date[b]
Sulfur dioxide	SO_2	10 minutes	500	526	Currently enforceable
		1 hour	350	88	Currently enforceable
		24 hours	125	4	Currently enforceable
		1 year	50	-	Currently enforceable
Nitrogen dioxide	NO_2	1 hour	200	88	Currently enforceable
		1 year	40	-	Currently enforceable
Particulate matter	PM_{10}	24 hours	75	4	Currently enforceable
		1 year	40	-	Currently enforceable
Fine particulate matter	$PM_{2.5}$	24 hours	40	4	1 Jan 2016 – 31 Dec 2029
			25		1 Jan 2030
		1 year	20	-	1 Jan 2016 – 31 Dec 2029
			15		1 Jan 2030
Ozone	O_3	8 hours (running)	120	11	Currently enforceable
Benzene	C_6H_6	1 year	5	-	Currently enforceable
Lead	Pb	1 year	0.5	-	Currently enforceable
Carbon monoxide	CO	1 hour	30 000	88	Currently enforceable
		8 hours (based on 1-hourly averages)	10 000	11	Currently enforceable

Notes: [a] The number of averaging periods where exceedance of limit is acceptable.

[b] Date after which concentration limits become enforceable.

2.3 National Regulations for Dust Deposition

South Africa's Draft National Dust Control Regulations were published on the 27 May 2011 with the dust fallout standards passed and subsequently published on the 1st of November 2013 (Government Gazette No. 36974) with changes in regulations published in 2018 (Notice 517 GG 41650 of 25 May 2018). These are called the National Dust Control Regulations (NDCR). The purpose of the regulations is to prescribe general measures for the control of dust in all areas including residential and light commercial areas. Acceptable dustfall rates according to the regulation are summarised in Table 3.

Table 3: Acceptable Dustfall Rates

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

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

2.4 National Atmospheric Emission Reporting Regulations (NAERR)

The National Atmospheric Emission Reporting Regulations (NAERR) was published on the 2nd of April 2015 by the Minister of Environmental Affairs. The regulation aims to standardize the reporting of data and information from an identified point, non-point and mobile sources of atmospheric emissions to an internet-based National Atmospheric Emissions Inventory System (NAEIS), towards the compilation of atmospheric emission inventories (DEA , 2015). 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. Any person that undertakes a listed activity in terms of section 21(1) of the Act must report emissions in the format required for NAEIS and should be in accordance with the atmospheric emission license or provisional atmospheric emission license. The regulations specify that emission sources and data providers must register on the NAEIS within 30 days from the date upon which these regulations came into effect, i.e. 2 May 2015. Data providers must also 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.

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

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

With regards to registration, the regulation stipulates that:

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

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

(a) A data provider must submit the required information for the preceding calendar year, as specified in Annexure 1 to the Regulations, to the NAEIS by 31 March of each calendar year.
(b) A data provider must keep a record of the information submitted to the NAEIS for five years and such record must, on request, be made available for inspection by the relevant authority.

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

2.5 Greenhouse Gas Emissions

Greenhouse gasses – CO_2, CH_4, N_2O, HFCs, PFCs and SF_6 – have been declared priority pollutants under Section 29(1) of the Air Quality Act (Government Gazette 37421 of 14 March 2014). The declaration provides a list of sources and activities including (i) fuel combustion (both stationary and mobile), (ii) fugitive emission from fuels, (iii) industrial processes and other product use, (iv) agriculture; forestry and other land use and (v) waste management. GHGs in excess of 0.1 Megatons or more, measured as CO_2eq, is required to submit a pollution prevention plan to the Minister for approval.

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

- Scope 1: All direct GHG emissions.
- Scope 2: Indirect GHG emissions from consumption of purchased electricity, heat or steam.
- Scope 3: Other indirect emissions, such as the extraction and production of purchased materials and fuels, transport-related activities in vehicles not owned or controlled by the reporting entity, electricity-related activities not covered in Scope 2, outsourced activities, waste disposal, etc.

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

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.

A draft carbon tax bill was introduced for a further round of public consultation. The Carbon Tax Policy Paper (CTPP) (Department of National Treasury, 2013) stated consideration will be given to sectors where the potential for emissions reduction is limited. GHG in excess of 0.1 Mt, measured as CO_2eq, is required to submit a pollution prevention plan to the Minister for approval.

3 AIR QUALITY BASELINE EVALUATION

The baseline evaluation primarily comprises the assessment of near-site surface meteorology and available ambient concentrations and/ dust fallout rates as reported on previously.

3.1 Receiving Environment

The Roodepan Quarry is located on Portion 32 and 33 of farm Roodepan 70 Kimberley RD, 1.2 km north of Kimberley, next to Roodepan suburb (Figure 1).

Air Quality Sensitive Receptors (AQSR) are where people reside (residential areas) with the most vulnerable regarded to be children, the sick and the elderly. For this reason, schools, hospitals/clinics, and old age homes/frail care were identified from google maps and will be included in the air quality impact assessment as AQSRs. The locations of the residential areas and the AQSRs in relation to the proposed development areas and quarries are shown in Figure 3 and listed in Figure 3.

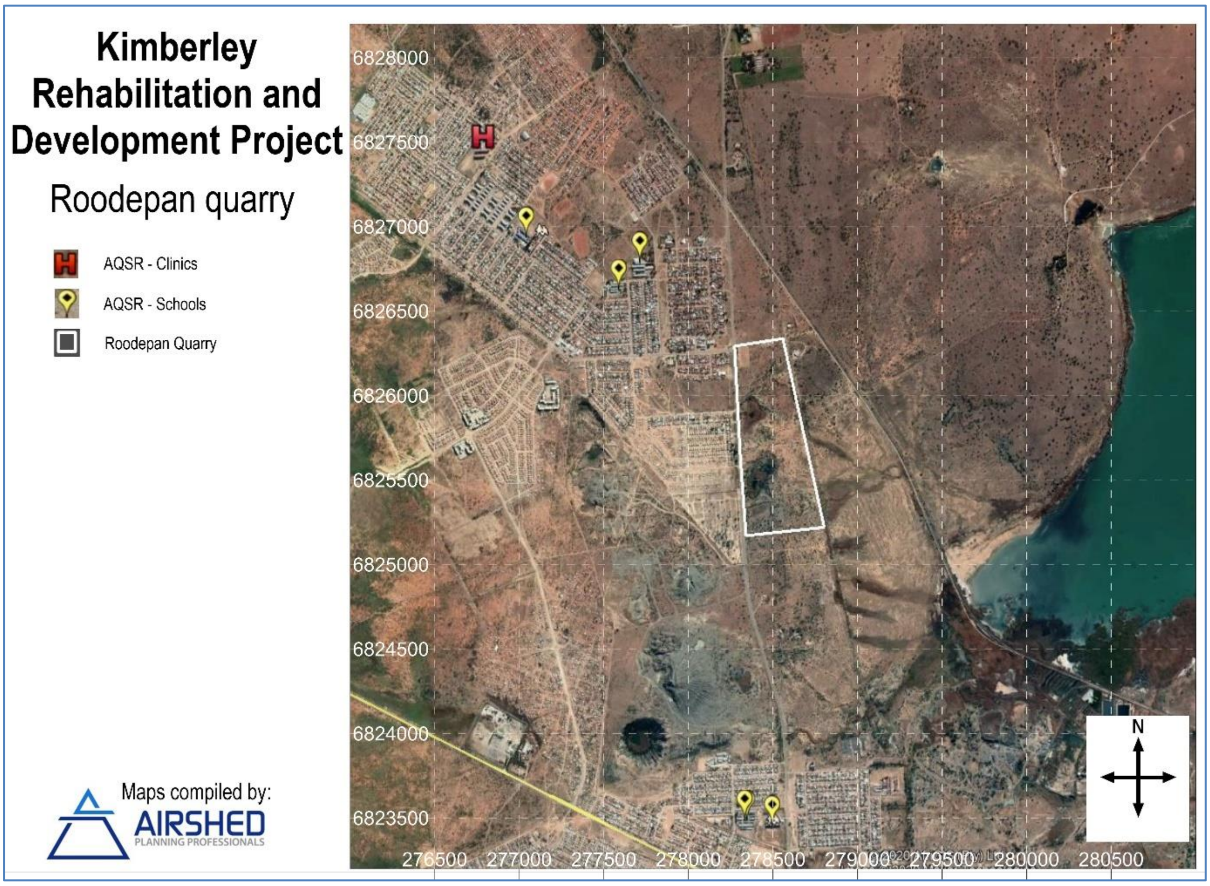


Figure 3: Nearest schools and residential areas

Table 4: Nearest schools and residential areas

AQSR	Distance (km)	Direction
Schools	**From Roodepan Quarry**	
Homevale High School	1 462	S
Homevale Secondary School	1 489	S
Pescodia Primary School	807	NW
Pescodia Secondary School	758	NW
Roodepan Primary School	1 409	NW
Clinics		
Dr Winston Tore Clinic	1856	NW
Boundary & nearest residence		
Site boundary	—	—
Nearest residence (distance from western site boundary)	0.004	W

Kimberley, the largest city in the Northern Cape, has a diverse economy including amongst others mining, construction, tourism, retail, and agriculture.

The topography of the city is flat, ranging between 1 175 mean sea level (mamsl) to 1 242 mamsl.

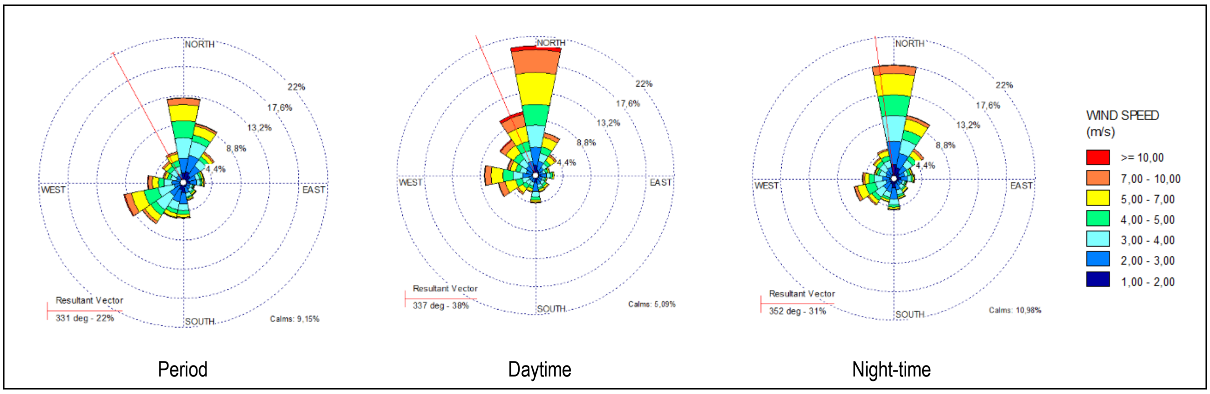
3.2 Influencing Meteorological Conditions

Meteorological mechanisms govern the dispersion, transformation, and eventual removal of pollutants from the atmosphere. The analysis of hourly average meteorological data is necessary to facilitate a comprehensive understanding of the ventilation potential of the site. The vertical dispersion of pollution is largely a function of the wind field. The wind speed determines both the distance of downward transport and the rate of dilution of pollutants. The generation of mechanical turbulence is similarly a function of the wind speed, in combination with the surface roughness.

Meteorological data from the South African Weather Services (SAWS) weather station in Kimberley was supplied for use in this assessment. The dataset provided extended over the period 1 January 2015 to 23 July 2020 and include wind speed, wind direction, temperature, humidity, pressure and rainfall. Data availability is good at 96% for wind speed and wind direction, 97% for temperature and humidity, and 99% for pressure and rainfall.

3.2.1 Surface Wind field

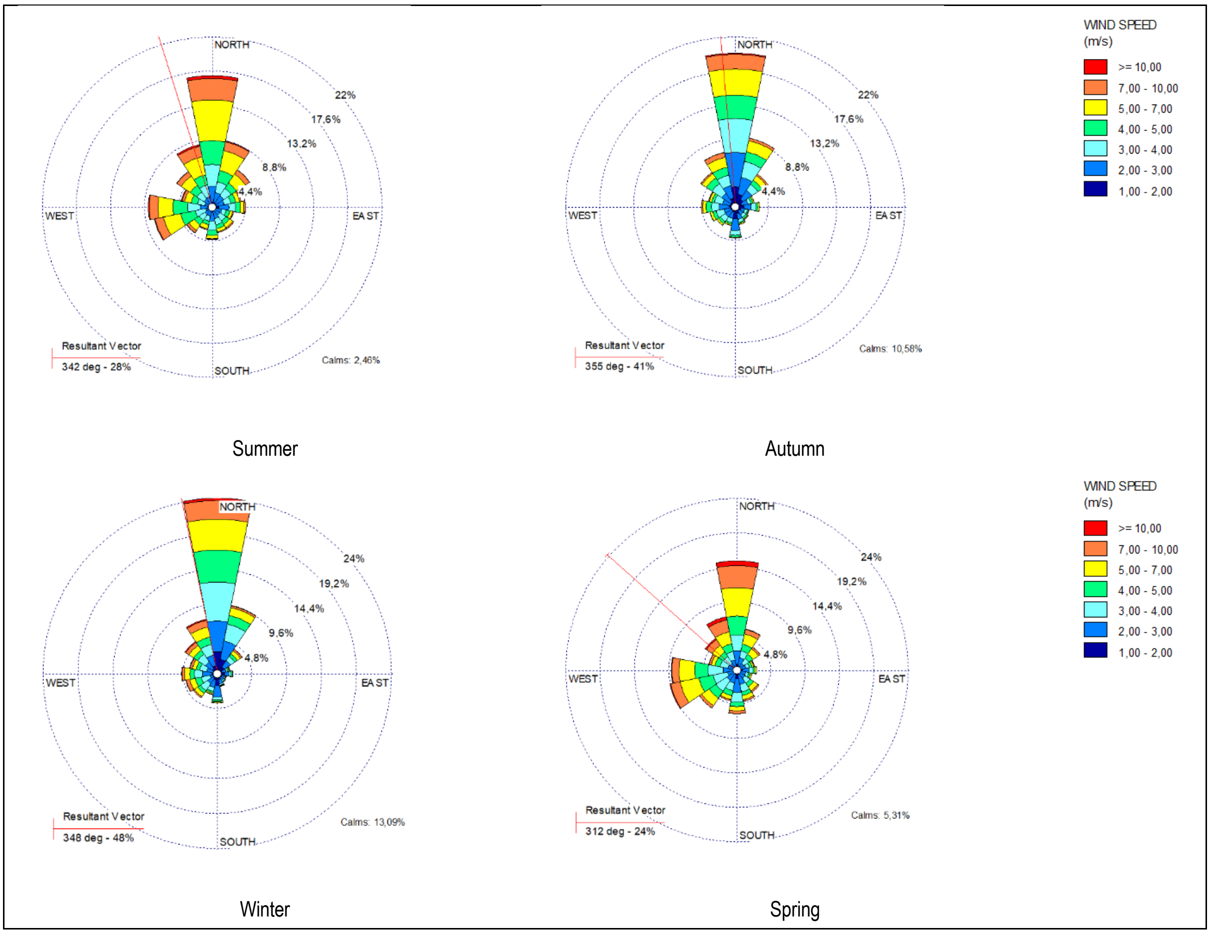
The prevailing wind field in Kimberley is from the north and west-southwest, with stronger winds during the day and calmer conditions during the night (Figure 4). Calm conditions (wind speeds <1 m/s) are more frequent at night (11%) than during the day (5%). Very little wind is recorded from the easterly and south-easterly sectors.



Period Daytime Night-time

Figure 4: Period, day-, and night-time wind roses (SAWS Kimberley, Jan'2015 – Jun'2020)

The wind field does not vary significantly between the seasons (Figure 5**Error! Reference source not found.**). During summer and spring months the dominant wind field is from the north (north-northwest to north-northeast) followed by westerly winds (west and west-southwest). During the autumn and winter months the northerly winds become more dominant with less frequent winds from the other directions. Winds are stronger during spring, followed by the summer months.



Summer Autumn

Winter Spring

Figure 5: Seasonal wind roses (SAWS Kimberley, Jan'2015 – Jun'2020)

According to the Beaufort wind force scale (https://www.metoffice.gov.uk/guide/weather/marine/beaufort-scale), wind speeds between 6-8 m/s equates to a moderate breeze, with wind speeds between 14-17 m/s near gale force winds. Based on the 5½ years of SAWS data, wind speeds fell mostly in the 2 – 4 m/s category with winds exceeding 10 m/s only for 0.6% (Figure 6). Winds exceeding 5 m/s occurred for 18.3% of the time, with a maximum wind speed of 15 m/s. The average wind speed over the period was 3.6 m/s. Calm conditions (wind speeds < 1 m/s) occurred for 9.2% of the time (Figure 4). The US EPA (2006) indicates a friction velocity of 5.4 m/s to initiate erosion from a coal storage piles (Mian & Yanful, 2003). Thus, the likelihood exists for wind erosion to occur from open and exposed surfaces, with loose fine material, when the wind speed exceeds at least 5.4 m/s. Wind speeds exceeding 5.4 m/s occurred for 19% over the 5½ years (2015 – Jun'2020).

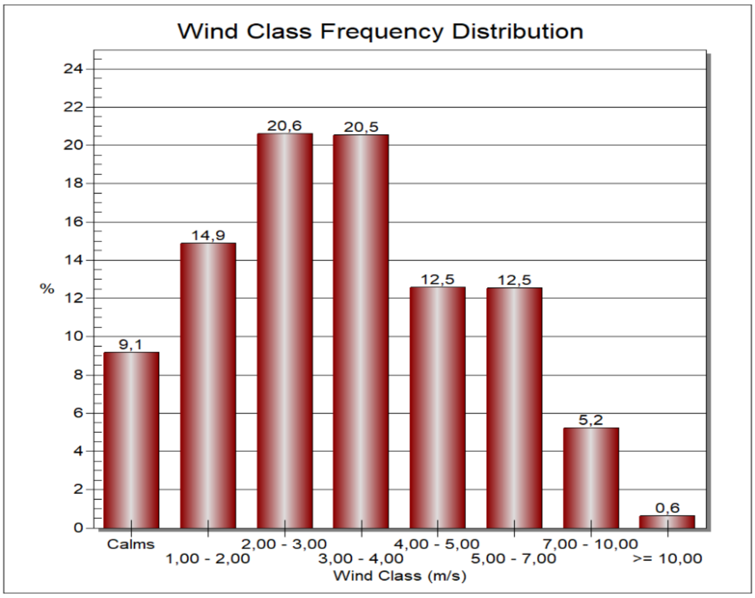


Figure 6: Wind speed categories (SAWS Kimberley, Jan'2015 – Jun'2020)

3.2.2 Temperature

Air temperature is an important parameter for the development of the mixing and inversion layers. It also determines the rate of dissipation of pollutants before it reaches ground level. Incoming solar radiation determines the rate of development and dissipation of the mixing layer. Relative humidity is an inverse function of ambient air temperature, increasing as ambient air temperature decreases. Temperatures during the period Jan'2015 and Jun'2020 ranged between -1°C (June 2018) to 42.5°C (January 2016) as shown in Table 5. The average hourly temperature profile across the year is shown in Figure 7. The highest temperatures are experienced during the summer months, with the lowest temperature during the winter months.

Table 5: Hourly minimum, maximum and average hourly temperatures over the period Jan'2015 – Jun'2020

Hourly Minimum, Hourly Maximum and Monthly Average Temperatures (°C)												
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Minimum	11	8.5	6	0.2	0.1	-1	0	0	0	2.6	2	9.5
Maximum	42.5	39.5	38.1	36.2	29.9	30	28.7	32.2	35.7	38.9	40.5	40.2
Average	25.9	24.6	22.3	18.1	14.3	11.3	11.3	13.7	17.8	21.5	24.0	26.0

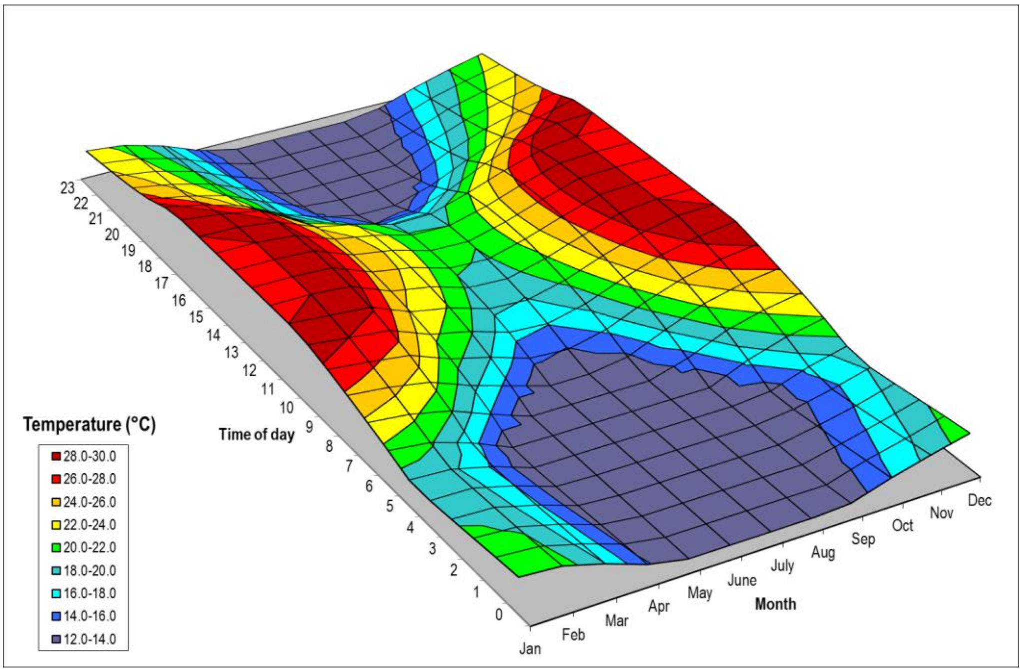
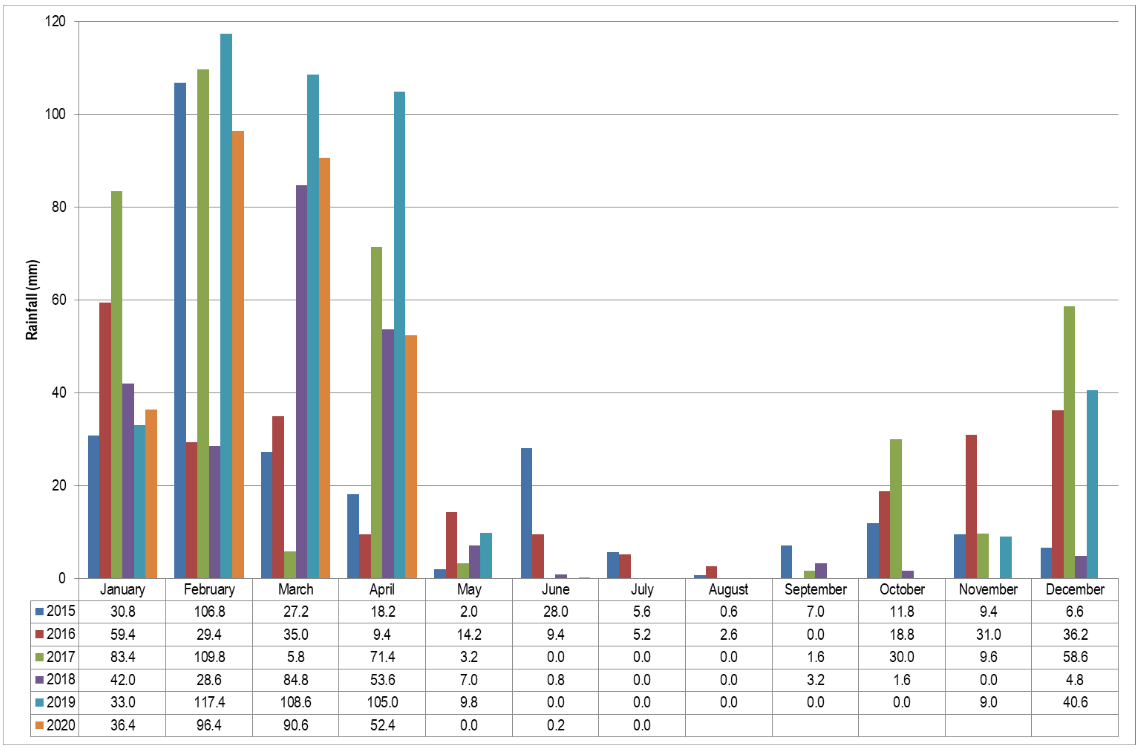


Figure 7:Temperature profile for Kimberley (SAWS Kimberley, Jan'2015 – Jun'2020)

3.2.3 Precipitation

Precipitation represents an effective removal mechanism of atmospheric pollutants and is therefore frequently considered during air pollution studies. Rainfall data was included in the data set provided by SAWS for Kimberley for the period Jan'2015 to Jun'2020. Annual rainfall varied between 226 mm in 2018 to 423 mm in 2019, with average rainfall over the 5½ years of 328 mm. Kimberley falls in the summer rainfall area, with most rainfall recorded between January and April (Figure 8).



	January	February	March	April	May	June	July	August	September	October	November	December
2015	30.8	106.8	27.2	18.2	2.0	28.0	5.6	0.6	7.0	11.8	9.4	6.6
2016	59.4	29.4	35.0	9.4	14.2	9.4	5.2	2.6	0.0	18.8	31.0	36.2
2017	83.4	109.8	5.8	71.4	3.2	0.0	0.0	0.0	1.6	30.0	9.6	58.6
2018	42.0	28.6	84.8	53.6	7.0	0.8	0.0	0.0	3.2	1.6	0.0	4.8
2019	33.0	117.4	108.6	105.0	9.8	0.0	0.0	0.0	0.0	0.0	9.0	40.6
2020	36.4	96.4	90.6	52.4	0.0	0.2	0.0					

Figure 8: Rainfall (mm) recorded at Kimberley (SAWS Kimberley, Jan'2015 – Jun'2020)

3.3 Pollutants of Concern and Associated Health Risk

The health impacts due to NO_2, SO_2, CO and suspended particulates (PM) are discussed below.

3.3.1 *Effects of NO_2 on Human Health*

NO_2 is an irritating gas that is absorbed into the mucous membrane of the respiratory tract. The most adverse health effect occurs at the junction of the conducting airway and the gas exchange region of the lungs. The upper airways are less affected because NO_2 is not very soluble in aqueous surfaces. Exposure to NO_2 is linked with increased susceptibility to respiratory infection, increased airway resistance in asthmatics and decreased pulmonary function. Exposure to high concentrations of NO_2 can lead to pulmonary oedema and pneumonitis (Reprotext, 1999). Subjects reported slight to moderate nasal irritation at 13 ppm (21.7 mg/m³) (Meyers and Hine, 1961).

The Californian Office of Environmental Health Hazard Assessments (OEHHA) has published an inhalation reference concentration (RfC)[1] of 470 µg/m³ for NO_2. Hine *et al*. (1970) found that NO_2 concentrations upward of 40 ppm (72 mg/m³) resulted in signs of toxicity (eye irritation, lacrimation and laboured breathing) in various animals (mice, rats, guinea pigs, rabbits and dogs). Below concentrations of 20 ppm (36 mg/m³) signs of irritation were minimal and no effects on behaviour were noted.

3.3.2 *Effects of SO_2 on Human Health*

Exposure to sulfur dioxide concentrations above certain threshold levels increases the prevalence of chronic respiratory disease and the risk of acute respiratory illness. Due to it being highly soluble, sulfur dioxide is more likely to be adsorbed in the upper airways rather than penetrate to the pulmonary region. Horstman *et al.* (1986) reported increased airway resistance in asthmatics at exposures to concentrations of 0.5 ppm (0.66 mg/m³). Bedi *et al.* (1986) reported no adverse effects on fourteen healthy non-smokers exposed to 2 ppm for 30-minutes and concluded that lack of changes in pulmonary function test indicated that 2 ppm did not adversely affect normal subjects.

Short-period exposures (less than 24 hours): Most information on the acute effects of SO_2 comes from controlled chamber experiments on volunteers exposed to SO_2 for periods ranging from a few minutes up to one hour (WHO, 2000). Acute responses occur within the first few minutes after commencement of inhalation. Further exposure does not increase effects. Effects include reductions in the mean forced expiratory volume over one second (FEV1), increases in specific airway resistance, and symptoms such as wheezing or shortness of breath. These effects are enhanced by exercise that increases the volume of air inspired, as it allows SO_2 to penetrate further into the respiratory tract. A wide range of sensitivity has been demonstrated, both among normal subjects and among those with asthma. People with asthma are the most sensitive group in the community. Continuous exposure-response relationships, without any clearly defined threshold, are evident.

Sub-chronic exposure over a 24-hour period: Information on the effects of exposure averaged over a 24-hour period is derived mainly from epidemiological studies in which the effects of SO_2, suspended particulate matter and other associated pollutants are considered. Exacerbation of symptoms among panels of selected sensitive patients seems to arise in a consistent manner when the concentration of SO_2 exceeds 250 µg/m³ in the presence of suspended particulate matter. Several more subsequent studies in Europe have involved mixed industrial and vehicular emissions now common in ambient air. At low levels of exposure (mean annual levels below 50 µg/m³; daily levels usually not exceeding 125 µg/m³) effects on mortality (total,

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[1] Inhalation reference concentrations (RfCs) are used to estimate non-carcinogenic effects representing a level of environmental exposure at or below which no adverse effect is expected to occur. The RfC is not a direct or absolute estimator of risk, but rather a reference point to gauge potential effects. As the amount and frequency of exposures exceeding the RfC increase, the probability that adverse effects may be observed in the human population also increases.

cardiovascular and respiratory) and on hospital emergency admissions for total respiratory causes and chronic obstructive pulmonary disease (COPD), have been consistently demonstrated. These results have been shown, in some instances, to persist when black smoke and suspended particulate matter levels were controlled for, while in others no attempts have been made to separate the pollutant effects. In these studies, no obvious threshold levels for SO_2 has been identified.

Long-term exposure: Earlier assessments, using data from the coal-burning in Europe judged the lowest-observed-adverse-effect level of SO_2 to be at an annual average of 100 µg/m^3, when present with suspended particulate matter. More recent studies related to industrial sources of SO_2, or to the changed urban mixture of air pollutants, have shown adverse effects below this level. There is, however, some difficulty in finding this value.

Dose-response coefficients for SO_2 used by the United Kingdom (UK) Department of Environment, Transport and the Regions in a recent study were given as follows (Stedman *et al*., 1999):

Health Outcome:	**Dose-Response Coefficient:**
Deaths brought forward (all causes)	+0.6% per 10 µg/m^3 (24-hour mean)
Respiratory hospital admissions	+0.5% per 10 µg/m^3 (24-hour mean)

California has published a 660 µg/m^3 RfC for SO_2, for a one-hour exposure, but states that co-exposure to other irritants such as sulfuric acid, nitrogen dioxide and ozone may potentiate the irritant effect of SO_2 on pulmonary function in asthmatics (OEHHA, 2007).

3.3.3 Effects of CO on Human Health

Carbon monoxide absorbed through the lungs reduces the blood’s capacity to transport available oxygen to the tissues. Approximately 80-90 % of the absorbed CO binds with haemoglobin to form carboxyhaemoglobin (COHb), which lowers the oxygen level in blood. Since more blood is needed to supply the same amount of oxygen, the heart needs to work harder. These are the main causes of tissue hypoxia produced by CO at low exposure levels. At higher concentrations, the rest of the absorbed CO binds with other heme proteins such as myoglobin and with cytochrome oxidase and cytochrome P-450. CO uptake impairs perception and thinking, slows reflexes, and may cause drowsiness, angina, unconsciousness, or death.

3.3.4 Effects of Suspended Particulates on Human Health

The World Health Organization states that the evidence on airborne particulates and public health is consistent in showing adverse health effects at exposures experienced by urban populations throughout the world. The range of effects is broad, affecting the respiratory and cardiovascular systems and extending to children and adults and to a number of large, susceptible groups within a general population. The epidemiological evidence shows adverse effects of particles after both short-term and long-term exposures. However, current scientific evidence indicates that guidelines cannot be proposed that will lead to complete protection against adverse health effects as thresholds have not been identified.

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

The nasal openings permit very large dust particles to enter the nasal region, along with much finer airborne particulates. Larger particles are deposited in the nasal region by impaction on the hairs of the nose or at the bends of the nasal passages.

Smaller particles (PM_{10} and $PM_{2.5}$) pass through the nasal region and are deposited in the tracheobronchial and pulmonary regions. Particles are removed by impacting with the wall of the bronchi when they are unable to follow the gaseous streamline flow through subsequent bifurcations of the bronchial tree. As the airflow decreases near the terminal bronchi, the smallest particles are removed by Brownian motion, which pushes them to the alveolar membrane (CEPA/FPAC Working Group, 1998; Dockery and Pope, 1994).

The Agency for Toxic Substances and Disease Registry state that particulate matter causes a wide variety of health and environmental impacts. Many scientific studies have linked breathing particulate matter to a series of significant health problems, including:

- aggravated asthma
- increases in respiratory symptoms like coughing and difficult or painful breathing
- chronic bronchitis
- decreased lung function
- premature death

3.4 Status Quo of Air Quality

As far as could be established, there is no ambient monitoring station in Kimberley (https://saaqis.environment.gov.za/ - accessed July 2020).

Particulates represent the main pollutant of concern from the current activities in the region – mining operations, vehicles and trucks on gravel roads, agricultural field tilling and windblown dust from exposed surfaces. Airborne particulate matter comes in different sizes and comprises a mixture of organic and inorganic substances, ranging in size, shape and density. As indicated previously, the particle size fraction of concern for air quality assessments include TSP, assessed as dust fallout and PM_{10} and $PM_{2.5}$, assessed for potential health impacts.

Gaseous emissions derive from the haul trucks, mining equipment, public vehicles, biomass burning and domestic fuel burning. These gaseous emissions include primarily SO_2, CO, CO_2, NO_x and hydrocarbons. Vehicles on the roads in Kimberley, and on the national roads (N8, R64 and R357) will also contribute to these gaseous emissions but it is expected that it is not a busy road and therefore the contribution is negligible. It is not known what the frequency and magnitude of veld fires are in the region, but these could be significant contributors to ambient gaseous pollutants. Similarly, domestic fuel burning can be significant contributors to specifically indoor air pollution.

4 AIR QUALITY IMPACT ASSESSMENT

From an air quality assessment perspective, activities at Roodepan Quarry, specifically the Clay Brick facility, are of concern with the activities at the mixed-use sites mainly of concern during the preparation of the sites. Source activities for both the Roodepan Quarry and mixed-use sites are identified and quantified, but only the impacts from the quarry and brickmaking are quantitatively assesses through dispersion modelling. The emissions quantification and dispersion modelling results are provided in the sections below.

4.1 Atmospheric Emissions

4.1.1 Construction Phase

Construction normally comprises a series of different operations including land clearing, topsoil removal, road grading, material loading and hauling, stockpiling, grading, bulldozing, compaction, etc. In the context of this study, the activities at Roodepan Quarry are for the construction of the mixed-use sites – bricks are manufactured as part of the building supply for development of these sites. Thus, all activities assessed fall under construction, but for the purpose of this study construction is seen as the site preparation activities for the brick making facility, with all other activities assessed as operational phase.

The construction of a Clay Brick facility will be undertaken simultaneously with the quarry construction and land clearing at the mixed-use sites. Table 6 provides a list of sources of air pollution associated with these activities.

Table 6: Sources of fugitive particulate emission associated with construction

Source	Activity	Pollutants
Vehicle tailpipe	Transport and general construction activities	Gases (PM, SO_2; NOx; CO; CO_2)
Clay Brick facility infrastructure and other administrative buildings	Clearing of groundcover	Dustfall, PM_{10} and $PM_{2.5}$
	Levelling of area	
	Wind erosion from open areas	
	Materials handling	
On-site road infrastructure	Clearing of vegetation and topsoil	
	Levelling of proposed transportation route areas	
Mixed-use sites preparation	Clearing of groundcover	
	Levelling of area	
	Materials handling	
	Wind erosion from open areas	

The main pollutant of concern from construction operations is particulate matter, including PM_{10}, $PM_{2.5}$ and TSP. PM_{10} and $PM_{2.5}$ concentrations are associated with potential health impacts due to the size of the particulates being small enough to be inhaled. Nuisance effects are caused by the TSP fraction (20 µm to 75 µm in diameter) resulting in soiling of materials and visibility reductions. This could in effect also have financial implications due to the requirement for more cleaning materials.

Each of the operations in Table 6 has their own duration and potential for dust generation. It is therefore often necessary to estimate area wide construction emissions, without regard to the actual plans of any individual construction process. Quantified construction emissions are usually lower than operational phase emissions and since the construction schedule was not available (and due to their temporary nature); and the likelihood that these activities will not occur concurrently at all portions of the site; dispersion simulation was not undertaken for construction emissions. It is therefore often necessary to estimate area wide construction emissions, without regard to the actual plans of any individual construction process. Quantified construction emissions are usually lower than operational phase emissions and since the construction schedule was not available (and due to their temporary nature); and the likelihood that these activities will not occur concurrently at all portions of the site; dispersion simulation was not undertaken for construction emissions.

4.1.2 Operational Phase – Roodepan Quarry and Clay Brick facility

The Roodepan Quarry will primarily include the clay brick manufacturing. Since no detailed design or layout of the site was available at the time of the study, the layout as shown in Figure 9 was assumed and emissions quantified accordingly.

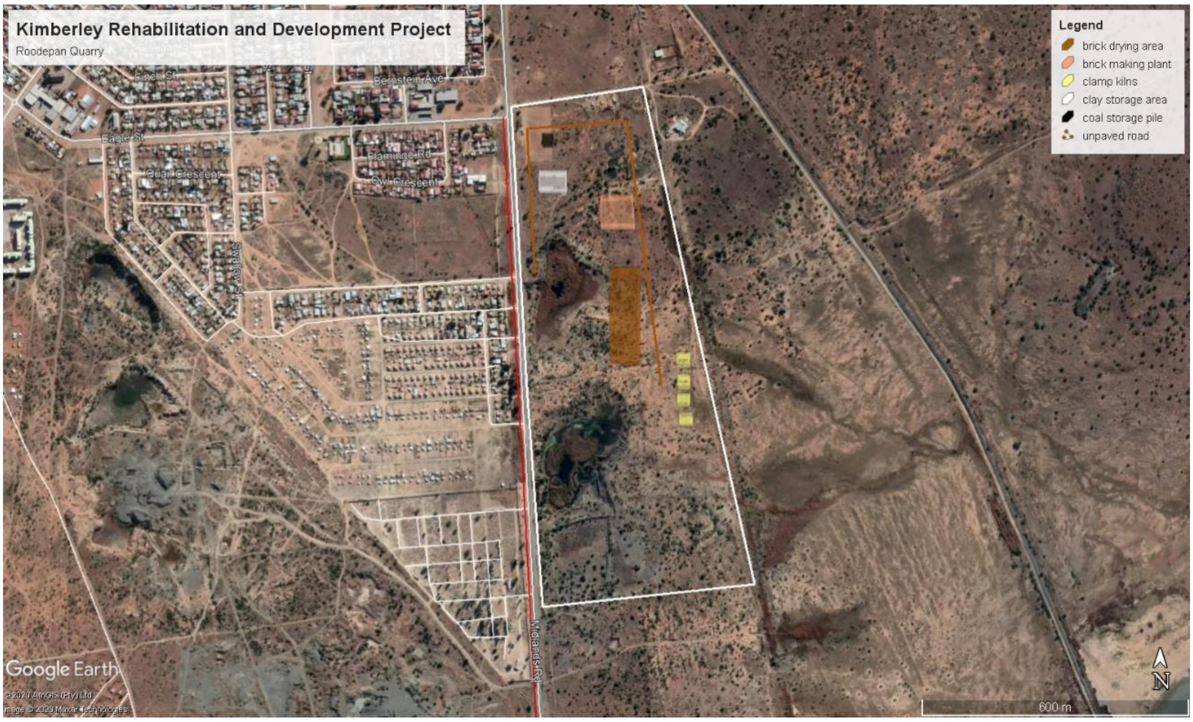

Figure 9: Assumed site layout of activities at Roodepan Quarry and Clay Brick facility

Activities most likely to result in air pollution during the operational phase are listed in Table 7, and described in more detail in the subsequent sections.

Table 7: Operational activities resulting in air pollution

Source	Activity	Pollutants
Roodepan Quarry and Clay Brick facility		
Materials handling	Moving and handling of clay material	Mostly PM from moving material and tipping onto stockpiles, and gaseous emissions from Front-end-loaders and equipment (PM; SO_2; NOx; CO; CO_2)
	Moving and handling of coal	
	Loading and packing of bricks	
Vehicle activity on unpaved on-site access roads	Vehicle activity on the unpaved roads	Mostly PM from road surfaces and windblown dust from trucks, gaseous emissions from truck exhaust (PM; SO_2; NOx; CO; CO_2)
Screening and Mixing	Screening and mixing of clay materials	Mostly PM from screening, gaseous emissions from machinery (PM; SO_2; NOx; CO; CO_2)

Source	Activity	Pollutants
Windblown dust from stockpiles	Clay material will be transported from the mixed used sites and stockpiled on-site	Mostly PM from windblown dust
	Coal will be transported to site and stored on-site	
Clay Brick manufacturing *	Fired tunnel kiln technology – firing using coal as fuel source	Mostly PM from crushing / mixing, gaseous emissions from machinery (PM; SO_2; NOx; CO; CO_2)
Materials handling	Loading and packing of bricks	Mostly PM from crushing / mixing, gaseous emissions from machinery (PM; SO_2; NOx; CO; CO_2)
Mixed-use sites		
Materials handling	Handling and loading of clay material	Mostly PM from moving material and loading into trucks, and gaseous emissions from trucks and equipment (PM; SO_2; NOx; CO; CO_2)
Crushing	Crushing of clay materials	Mostly PM from crushing, gaseous emissions from machinery (PM; SO_2; NOx; CO; CO_2)
Vehicle activity on paved roads	Vehicle activity on the paved roads between mixed-use sites and Roodepan Quarry	Mostly PM from road surfaces and windblown dust from trucks, gaseous emissions from truck exhaust (PM; SO_2; NOx; CO; CO_2)

Notes: * Clam Kiln technology was assumed, but this was changed to Zig-Zag technology as the preferred option.

4.1.2.1 Screening and Blending

The weathered clay materials will be crushed at the mixed-use sites from where it will be loaded onto trucks and transported via the public paved roads to the Roodepan Quarry. At the quarry, the clay material will be off-loaded and stockpiled using front-end-loaders. The clay material will first be screened to get the size fraction down for ease of blending and mixing. Typical plants operate by means of box-feeders, which release a pre-determined quantity of clay and other additives for proper blending (CBA, 2002). Significant emissions from screening and blending of clay materials include TSP, PM_{10} and $PM_{2.5}$ (Akinshipe, 2013; Akinshipe & Kornelius, 2017a).

4.1.2.2 Sun Drying

Bricks are typically stacked on an open hack-line to utilize the free source of energy from the sun, a common method among brick makers in South Africa due to relative abundance of sun light. This cheap method of drying takes about 14 to 21 days to complete, especially during rainy season (Akinshipe, 2013; CBA, 2002).

4.1.2.3 Firing

Clamps are traditional kilns, and the most commonly used kiln type in developing countries (CBA, 2002). The bricks are packed in a pyramid-shaped formation with a layer of combustible material such as coke, cinder or coal at the bottom of the kiln and after each layer of brick. Three layers of fired bricks (skinkles) are arranged to serve as funnel to accommodate the base combustible material (Akinshipe, 2013; Akinshipe & Kornelius, 2017a). When the base layer of coal is ignited, it sets the bricks on fire layer by layer until the whole kiln is ablaze. The kiln temperature rises gradually, igniting the fuel in the clay until the entire kiln is ablaze (Akinshipe, 2013; Akinshipe & Kornelius, 2017a; Akinshipe & Kornelius, 2017b).

In South Africa, "duff" coal or carbon-containing fly ash are added to the clay material before processing to serve as internal or body fuel (the ratio of coal – body fuel – to clay as about 1:10). The internal fuel ensures that the bricks are evenly fired and that the temperature change in the kiln is evenly distributed. "Small nuts" coal is used as external fuel in the skinkles. A large-capacity clamp kiln in its latter period of firing is depicted in **Error! Reference source not found.** (Akinshipe, 2013; Akinshipe & Kornelius, 2017a; Akinshipe & Kornelius, 2017b).

4.1.2.4 Zig-Zag Kilns

Clamp kilns are regarded the most energy inefficient brick kiln technology (CAEM, 2016), not only is the fuel consumption high but also the firing of brick are not uniform. KRD agreed to implement Zig-Zag kilns rather than the traditional Clamp kilns[2]. Zig-Zag kiln technology is a fixed, high draught kiln which is similar to the Fixed Chimney Kiln (FCK) technology. Where the FCK has a chimney proving natural draught, the zig-zag path increases the length of the firing channel thus accelerating the firing through a flue gas fan (Pengoriya, 2016). The Zig-Zag kilns has a rectangular shape with a height of 80 m and a width of 25 m as shown in Figure 10.

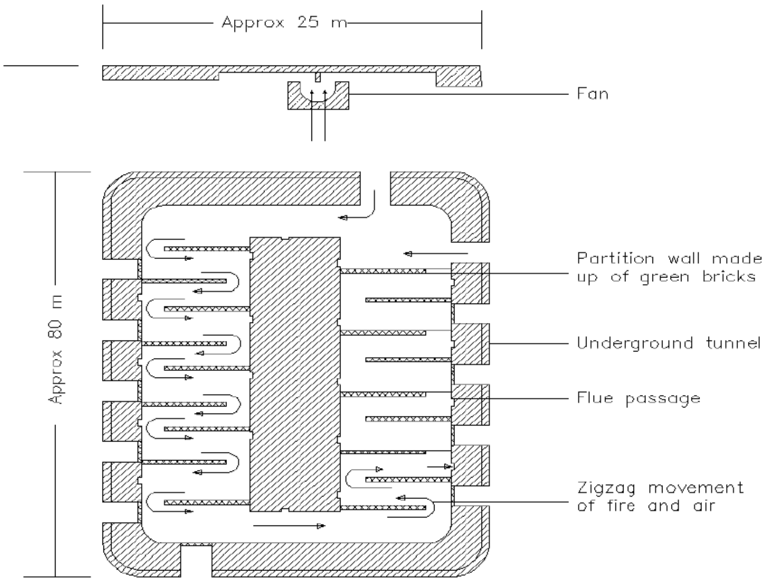

Figure 10: Schematic view of a Habla Zig-Zag kiln (source: Pengoriya, 2016)

The zig-zag design causes continuous change in the flue gas direction which leads to the deposition of significant amounts of particulate matter, resulting in less emissions than the FCK technology, which in turn is a significant improvement on the Clamp kiln technology. Also, the Zig-Zag kiln incorporates a flue gas scrubber which reduced particulate matter emissions even further. Reported PM emissions range between 14-37 mg/Nm³ for a natural draught Zig-Zag kiln and 151 mg/Nm³ for a forced draught Zig-zag kiln (Pengoriya, 2016).

4.1.2.5 Vehicle entrainment

Vehicle-entrained particulate emissions from unpaved roads are significant sources of dust, especially where there are high traffic volumes on a road. The force of the wheels travelling on unpaved roads causes the pulverisation of surface material. Particles are lifted and dropped from the rotating wheels, and the road surface is exposed to strong air currents in turbulent shear with the surface. The turbulent wake behind the vehicle continues to act on the road surface after the vehicle has passed. The quantity of particulate emissions from unpaved roads will vary linearly with the volume of traffic expected on a road.

4.1.2.6 Emission quantification

Emissions from the various activities were quantified based on information provided, and where information was not available, assumptions were made or information from similar processes used. The emission quantification methods and information are listed in Table 8.

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[2] The dispersion modelling was already completed when the decision was made, hence the reason for Clamp Kiln emission rates.

Table 8: Emission equations used to quantify emissions from the Roodepan Quarry and Clay Brick facility

<table>
<tr><th>Activity</th><th>Emission Equation</th><th>Source</th><th>Information assumed/provided</th></tr>
<tr>
<td>**Materials handling**</td>
<td>

$$E = 0.0016\frac{\left(U/_{2.2}\right)^{1.3}}{\left(M/_{2}\right)^{1.4}}$$

Where,
E = Emission factor (kg dust / t transferred)
U = Mean wind speed (m/s)
M = Material moisture content (%)
The $PM_{2.5}$, PM_{10} and TSP fraction of the emission factor is 5.3%, 35% and 74% respectively.</td>
<td>US-EPA AP42 Section 13.2.4
(US EPA, 2006)</td>
<td>The moisture contents of materials were as follows:
Clay: 0.5% (provided)
Coal: 0.5% (provided)
The respective throughput of materials during the operational phase was calculated as:
<table>
<tr><th>Material</th><th>Total (tpa)</th><th>Total (tph)</th></tr>
<tr><td>Clay from mixed-use sites</td><td>540 000</td><td>72.12</td></tr>
<tr><td>Clay after crushing/ screening</td><td>189 000</td><td>25.24</td></tr>
<tr><td>Coal</td><td>21 000</td><td>2.80</td></tr>
</table>
Hours of operation**:** 24 hrs/day; 312 days per year
An average wind speed of 3.64 m/s was used based on the SAWS data for Kimberley for period, Jan'2015 – Jun'2020.
Project design mitigation: water sprays which would result in 50% control efficiency (CE)</td>
</tr>
<tr>
<td>**Vehicle entrainment on-site unpaved roads**</td>
<td>

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

Where,
E = particulate emission factor in grams per vehicle km travelled (g/VKT)
k = basic emission factor for particle size range and units of interest
s = road surface silt content (%)
W = average weight (tonnes) of the vehicles travelling the road
The particle size multiplier (k) is given as 0.15 for $PM_{2.5}$ and 1.5 for PM_{10}, and as 4.9 for TSP
The empirical constant (a) is given as 0.9 for $PM_{2.5}$ and PM_{10}, and 4.9 for TSP
The empirical constant (b) is given as 0.45 for $PM_{2.5}$, PM_{10} and TSP</td>
<td>US-EPA AP42 Section 13.2.2
(US EPA, 2006)</td>
<td>Vehicle kilometre travelled (VKT): VKT were calculated from assumed on-site road lengths, truck capacities and the number of trips required for transporting materials.
Hours of operation**:** 24 hrs/day; 312 days per year
Average truck weight: 25 t
Silt content: 4.8% (US EPA default Table 13.2.2-1 average silt content for Sand and gravel processing – Plant road)
No road layout was provided, and the road lengths were assumed.
Project design mitigation: water sprays which would result in 50% CE</td>
</tr>
</table>

<table>
<tr><th>Activity</th><th>Emission Equation</th><th>Source</th><th>Information assumed/provided</th></tr>
<tr>
<td>Screening (blending and mixing)</td>
<td>Screening:
$$E_{TSP} = 0.08\ kg/t\ material\ processed$$
$$E_{PM10} = \ 0.06\,kg/t\ material\ processed$$
$$E_{PM2.5} = 0.015\ kg/t\ material\ processed$$
Where,
E = Default emission factor for <u>low moisture</u> content ore (moisture < 4%)
Fraction of $PM_{2.5}$ assumed to be 25% of PM_{10}</td>
<td>NPI Mining: Table 3 (NPI, 2012)</td>
<td>Screening/ blending of clay material = 540 000 tpa; 72.1 tph.
<u>Hours of operation</u>: 24 hrs/day; 312 days per year.
<u>Clay moisture</u>: 0.5%
<u>Project design mitigation</u>: water sprays which would result in 50% CE</td>
</tr>
<tr>
<td>Wind Erosion from stockpiles</td>
<td>Wind erosion:
$$E_{TSP} = 0.4\ kg/ha/h$$
$$E_{PM10} = \ 0.2\,kg/ha/h$$
$$E_{PM2.5} = 0.015\ kg/ha/h$$
Where,
E = Default emission factor for <u>low moisture</u> content ore (moisture < 4%) (NPI, 2012)
Fraction of $PM_{2.5}$ assumed to be 25% of PM_{10}</td>
<td>NPI Mining: Table 2 (NPI, 2012)</td>
<td>The respective stockpile areas during the <u>operational phase</u> was calculated as:
<table>
<tr><th>Stockpile</th><th>Area (m²)</th><th>% erodible area</th><th>Erodible area (ha)</th></tr>
<tr><td>Clay</td><td>2 500</td><td>100%</td><td>0.25</td></tr>
<tr><td>Coal</td><td>375</td><td>100%</td><td>0.04</td></tr>
</table>
Threshold friction velocity (u^*) for coal stockpiles is given as 5.4 m/s (US EPA, 2006). Wind speeds exceeding 5.4 m/s occurred for 19% (SAWS Kimberley; 2015 – Jun’2020)
<u>Mitigation measures</u>: None</td>
</tr>
<tr>
<td>Clamp Kilns</td>
<td>Emission factors:
<table>
<tr><th><i>Pollutant</i></th><th><i>Emission factor (kg/ton)</i></th></tr>
<tr><td>PM</td><td>0.34</td></tr>
<tr><td>PM_{10}</td><td>0.34</td></tr>
<tr><td>$PM_{2.5}$</td><td>0.34</td></tr>
<tr><td>SO_2</td><td>0.38</td></tr>
<tr><td>NOx</td><td>0.05</td></tr>
<tr><td>CO</td><td>7.83</td></tr>
<tr><td>CO_2</td><td>132.00</td></tr>
<tr><td>HC/VOC</td><td>0.45</td></tr>
</table></td>
<td>(Akinshipe & Kornelius, 2018)</td>
<td><u>Brick production:</u> 60 000 000 bricks per annum.
<u>Clay consumption rate</u>: 180 000 tpa
The brick facility parameters:
<table>
<tr><th>Area (m²)</th><th>Length (m)</th><th>Breadth (m)</th><th>Height (m)</th></tr>
<tr><td>450</td><td>15</td><td>30</td><td>3.5</td></tr>
</table>
<u>Hours of operation</u>: 24 hrs/day; 312 days per year
<u>Mitigation measures</u>: None</td>
</tr>
</table>

The total emission rates, based on the provided operational hours per year and the mitigation measures KRD committed to, are listed in Table 9.

Table 9: Calculated emission rates due to routine operations from Roodepan Quarry and Clay Brick facility

Source Activity	Unit	TSP	PM_{10}	$PM_{2.5}$	CO	SO_2	NOx as NO_2	VOC
Materials Handling	tpa	17.85	8.44	1.28				
Unpaved roads	tpa	2.36	0.60	0.06				
Crushing	tpa	21.60	16.20	4.05				
Wind Erosion	tpa	1.01	0.50	0.13				
Clamp Kiln	tpa	61.20	61.20	61.20	1 409.00	68.40	9.00	81.00
TOTAL	tpa	**104.02**	**86.95**	**66.71**	**1 409.40**	**68.40**	**9.00**	**81.00**

The main pollutants of concern are particulate matter (TSP, PM_{10} and $PM_{2.5}$) originating from all the identified on-site activities. Of these activities the Clamp Kiln contribute most to TSP (59%), PM_{10} (70%) and $PM_{2.5}$ (92%) and was the only source of gaseous emissions (vehicle emissions were not quantified since these are insignificant in comparison).

4.1.3 Operational Phase – Mixed-use sites

The clay to be used for the clay brick manufacturing will be extracted from the mixed-use sites and transported to Roodepan Quarry via paved public roads. Activities that will result in atmospheric emissions include crushing of the weathered clay materials, loading of the clay material onto haul trucks and transportation to the Roodepan Quarry. Significant emissions from materials handling, crushing and transporting of the clay materials include TSP, PM_{10} and $PM_{2.5}$.

4.1.3.1 Emission quantification

Emissions from the various activities were quantified based on information provided, and where information was not available, assumptions were made or information from similar processes used. The emission quantification methods and information are listed in Table 8, with the total emissions from these activities provide in Table 10.

Table 10: Calculated emission rates due to routine operations from the mixed-use sites

Source Activity	Unit	TSP	PM_{10}	$PM_{2.5}$
Materials Handling	tpa	12.85	6.08	0.92
Paved roads	tpa	219.20	42.07	10.18
Crushing	tpa	0.02	0.00	0.00
TOTAL		**232.07**	**48.16**	**11.10**

The main pollutants of concern from the activities at the mixed-use sites are particulate matter (TSP, PM_{10} and $PM_{2.5}$) with vehicle entrained dust from the paved roads being the main contributor – TSP (95%), PM_{10} (88%) and $PM_{2.5}$ (92%).

Table 11: Emission equations used to quantify emissions from the mixed-use sites

<table>
<tr><th>Activity</th><th>Emission Equation</th><th>Source</th><th>Information assumed/provided</th></tr>
<tr>
<td>Materials handling</td>
<td>$$E = 0.0016\frac{\left(U/_{2.2}\right)^{1.3}}{\left(M/_{2}\right)^{1.4}}$$
Where,
E = Emission factor (kg dust / t transferred)
U = Mean wind speed (m/s)
M = Material moisture content (%)
The $PM_{2.5}$, PM_{10} and TSP fraction of the emission factor is 5.3%, 35% and 74% respectively.</td>
<td>US-EPA AP42 Section 13.2.4
(US EPA, 2006)</td>
<td>The moisture contents of materials were as follows:
Clay: 0.5% (provided)
The respective throughput of materials was calculated as:
<table>
<tr><th>Material</th><th>Total (tpa)</th><th>Total (tph)</th></tr>
<tr><td>Clay from mixed-use sites</td><td>540 000</td><td>72.12</td></tr>
</table>
Hours of operation: 24 hrs/day; 312 days per year
An average wind speed of 3.64 m/s was used based on the SAWS data for Kimberley for period, Jan’2015 – Jun’2020.
Project design mitigation: water sprays which would result in 50% control efficiency (CE)</td>
</tr>
<tr>
<td>Vehicle entrainment paved roads</td>
<td>$$E = k(sL)^{0.91}(W)^{1.02}$$
Where,
E = particulate emission factor in grams per vehicle km travelled (g/VKT)
k = basic emission factor for particle size range and units of interest
<i>sL</i> = road surface silt loading (g/m²)
<i>W</i> = average weight (tonnes) of the vehicles travelling the road
The particle size multiplier (k) is given as 0.15 for $PM_{2.5}$ and 0.62 for PM_{10}, and as 3.23 for TSP</td>
<td>US-EPA AP42 Section 13.2.2
(US EPA, 2006)</td>
<td>Vehicle kilometre travelled (VKT): VKT were calculated from road lengths between the mixed-use sites and Roodepan Quarry, truck capacities and the number of trips required for transporting materials.
Hours of operation: 24 hrs/day; 312 days per year
Average truck weight: 25 t
Silt content: 7.4 g/m² (US EPA default Table 13.2.1-4 average silt content for Municipal)
The shortest distance road lengths between the mixed-use sites and Roodepan Quarry were assumed.
Mitigation measures: None</td>
</tr>
<tr>
<td>Crushing</td>
<td>Primary crushing:
$$E_{TSP} = 0.2\ kg/t\ material\ processed$$
$$E_{PM10} = 0.02\ kg/t\ material\ processed$$
$$E_{PM2.5} = 0.005\ kg/t\ material\ processed$$
Where,
E = Default emission factor for low moisture content ore (moisture < 4%)
Fraction of $PM_{2.5}$ assumed to be 25% of PM_{10}</td>
<td>NPI Mining: Table 3
(NPI, 2012)</td>
<td>Crushing of clay material = 540 000 tpa; 72.1 tph.
Hours of operation: 24 hrs/day; 312 days per year.
Clay moisture: 0.5%
Project design mitigation: water sprays which would result in 50% CE</td>
</tr>
</table>

4.2 Atmospheric Dispersion Modelling

The impact assessment of the project's operations on the environment is discussed in this section. To assess the impact on human health and the environment the following important aspects need to be considered:

- The criteria against which impacts are assessed (Section 2);
- The potential of the atmosphere to disperse and dilute pollutants emitted by the project (Section 3.2);
- The AQSRs in the vicinity of the Roodepan Quarry (Section 3.1); and
- The methodology followed in determining ambient pollutant concentrations and dustfall rates (Section 1.3).

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

4.2.1 Dispersion Model Selection

Gaussian-plume models are best used for near-field applications where the steady-state meteorology assumption is most likely to apply. One of the most widely used Gaussian plume model is the US EPA AERMOD model that was used in this study. AERMOD is a model developed with the support of AERMIC, whose objective has been to include state-of the-art science in regulatory models (Hanna, Egan, Purdum, & Wagler, 1999). AERMOD is a dispersion modelling system with three components, namely: AERMOD (AERMIC Dispersion Model), AERMAP (AERMOD terrain pre-processor), and AERMET (AERMOD meteorological pre-processor).

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

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

4.2.2 Meteorological Requirements

For the current study, use was made of Kimberley SAWS data for the period Jan'2015 – Jun'2020 (Section 3.2).

4.2.3 Source Data Requirements

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

- Clamp kiln – modelled as point sources
- Materials handling – modelled as volume sources;
- Screening – modelled as volume sources;
- Unpaved roads windblown dust – modelled as area sources;
- Windblown dust from stockpiles – modelled as area sources.

4.2.4 Modelling Domain

The dispersion of pollutants expected to arise from proposed activities was modelled for an area covering 5 km (east-west) by 5 km (north-south). The area was divided into a grid matrix with a resolution of 50 m by 50 m, with the project located centrally. AERMOD calculates ground-level (1.5 m above ground level) concentrations and dustfall rates at each grid and discrete receptor points (AQSRs).

4.3 Dispersion Modelling Results for the Roodepan Quarry and Clay Brick facility

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

Pollutants with the potential to result in human health impacts which are assessed in this study include $PM_{2.5}$ and PM_{10}, as well as SO_2, NO_2, CO and VOCs. Dustfall is assessed for its nuisance potential. Results are primarily provided in form of isopleths to present areas of exceedance of assessment criteria. Ground level concentration or dustfall isopleths presented in this section depict interpolated values from the concentrations simulated by AERMOD for each of the receptor grid points specified. The results are shown as the 99th percentile for highest hourly and daily averages, thus where these equal or exceed the NAAQS, it indicates non-compliance with the standards.

Isopleth plots reflect the incremental ground level concentrations (GLCs) for $PM_{2.5}$, PM_{10}, SO_2 and NO_2, where exceedances of the relevant NAAQS were simulated. With no baseline data (Section 3.4), the cumulative pollutant concentrations could not be determined.

It should also be noted that ambient air quality criteria apply to areas where the Occupational Health and Safety regulations do not apply, thus outside the property or lease area. Ambient air quality criteria (NAAQS) are therefore not occupational health indicators but applicable to areas where the general public has access i.e. off-site. In the context of this project, ambient air quality guidelines and dustfall regulations would apply to any area outside the proposed mining right area.

4.3.1 $PM_{2.5}$ Ground Level Concentrations

Isopleth plots of the simulated $PM_{2.5}$ daily concentrations are shown in Figure 11 with the annual averages in Figure 12. The highest concentrations predicted at the AQSRs are provide in Table 12. Design mitigation measures, to which KRD committed to, were assumed which include water sprays to achieve a 50% control efficiency (CE) at all materials handling points, at the screening and on the on-site unpaved roads.

The highest daily and annual GLCs are at the boundary and the nearest AQSR, on the western boundary of the Roodepan Quarry. Neither the daily nor the annual averages exceed the NAAQS at any of these AQSRs.

Table 12: Simulated PM$_{2.5}$ concentrations at the nearest AQSRs

AQSR	Daily GLC (µg/m^3) – 99th Percentile	Within Compliance (Yes/No)	Annual average GLC (µg/m^3)	Within Compliance (Yes/No)
NAAQS	40 µg/m^3		20 µg/m^3	
Pescodia Secondary School	1.67	Y	0.19	Y
Pescodia Primary School	1.79	Y	0.18	Y
Roodepan Primary School	0.82	Y	0.08	Y
Dr Winston Tore Clinic	0.52	Y	0.05	Y
Homevale High School	0.61	Y	0.10	Y
Homevale Secondary School	0.63	Y	0.11	Y
Nearest AQSR (w boundary)	20.30	Y	2.60	Y
Boundary	26.80	Y	4.00	Y

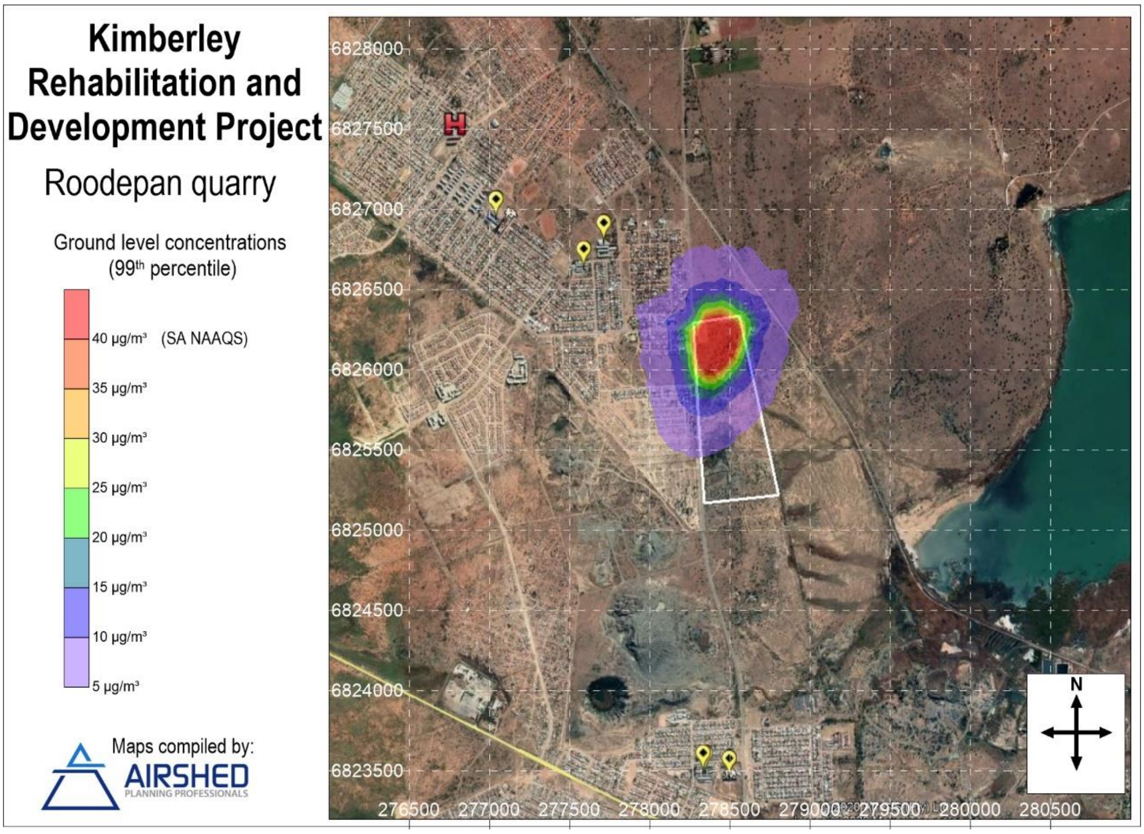

Figure 11: Simulated daily PM$_{2.5}$ GLCs due to design-mitigated emissions

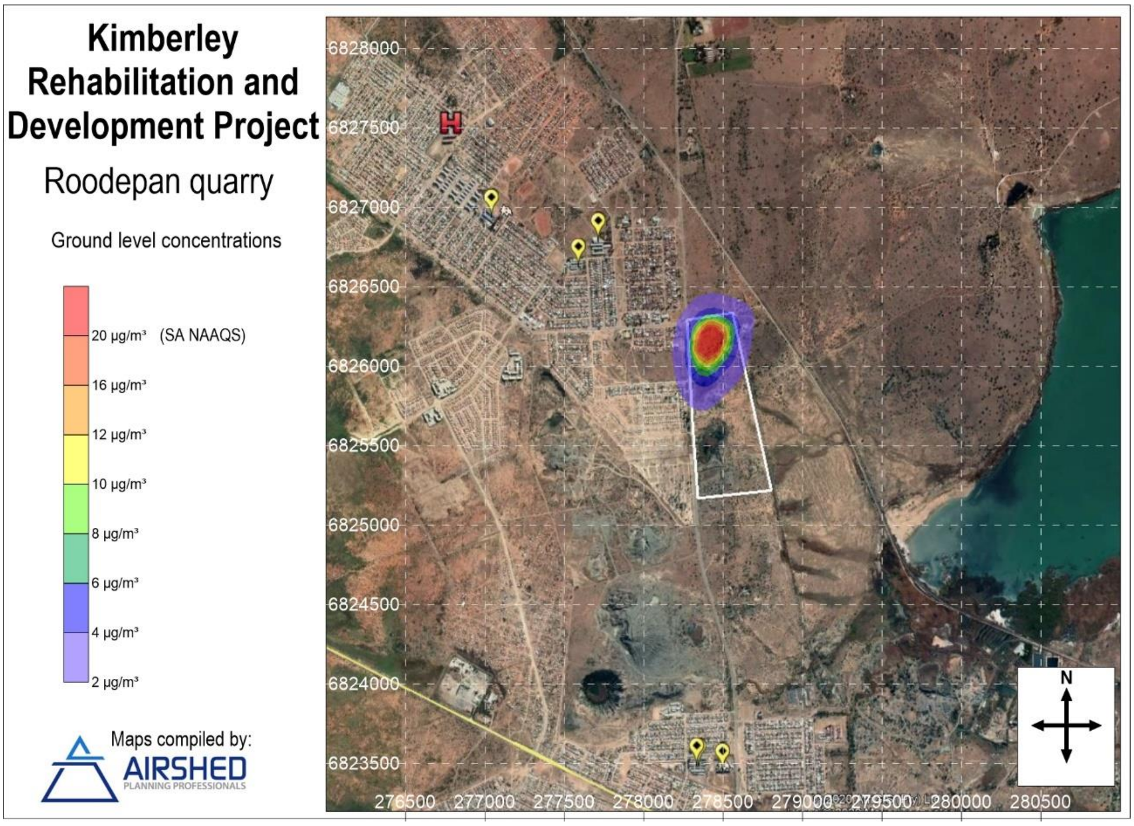

Figure 12: Simulated annual $PM_{2.5}$ GLCs due to design-mitigated emissions

4.3.2 PM_{10} Ground Level Concentrations

Isopleth plots of the simulated PM_{10} daily concentrations are shown in Figure 13 with the annual averages in Figure 14. The highest concentrations predicted at the AQSRs are provide in Table 13. Design mitigation measures include water sprays to achieve a 50% CE at all materials handling points, at the screening and on the on-site unpaved roads.

Highest daily PM_{10} GLCs are in non-compliance at the Roodepan Quarry boundary and at the nearest AQSR on the western side of the quarry, but within compliance at all the other AQSRs. Over an annual average there is no exceedances at any of the receptors.

Table 13: Simulated PM_{10} concentrations at the nearest AQSRs

AQSR	Daily GLC (µg/m³) – 99th Percentile	Within Compliance (Yes/No)	Annual average GLC (µg/m³)	Within Compliance (Yes/No)
NAAQS	75 µg/m³		40 µg/m³	
Pescodia Secondary School	7.9	Y	0.88	Y
Pescodia Primary School	8.4	Y	0.85	Y
Roodepan Primary School	3.9	Y	0.36	Y
Dr Winston Tore Clinic	2.4	Y	0.23	Y
Homevale High School	2.8	Y	0.44	Y
Homevale Secondary School	2.9	Y	0.46	Y
Nearest AQSR (w boundary)	**95.8**	N	12.3	Y
Boundary	**123.7**	N	18.5	Y

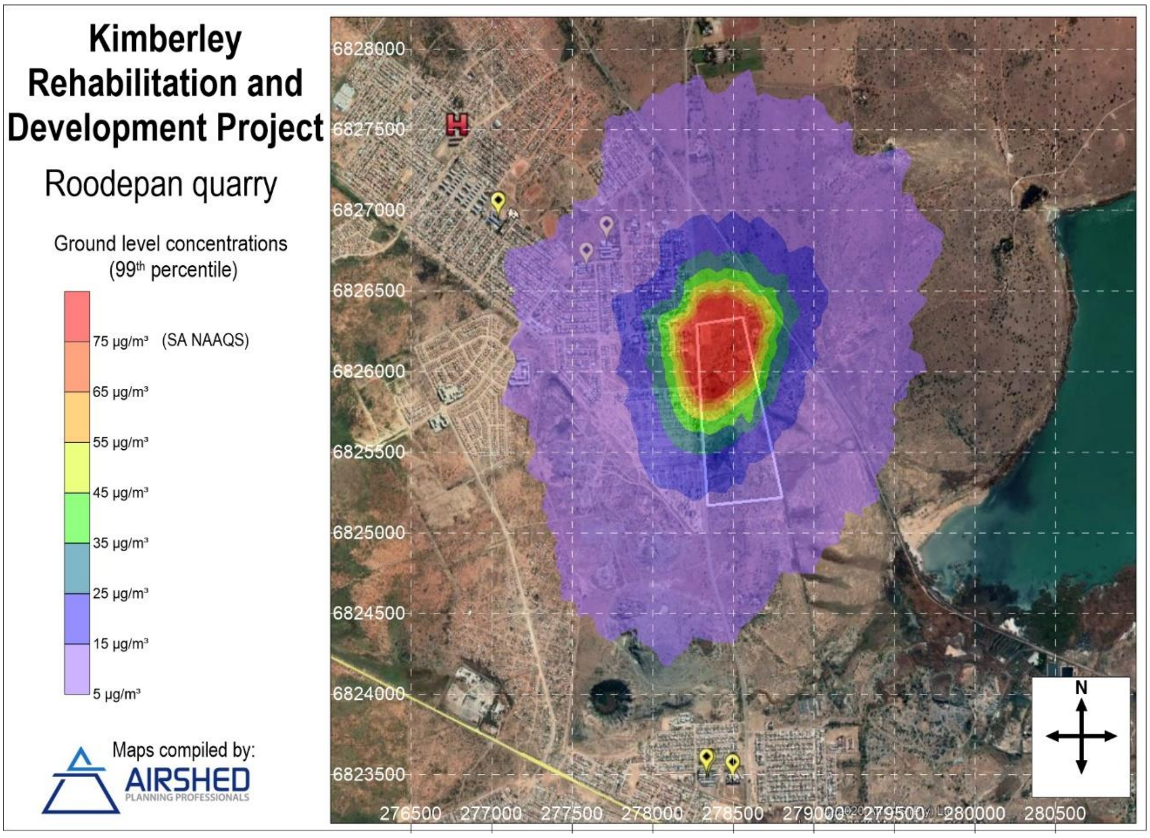

Figure 13: Simulated daily PM_{10} GLCs due to design-mitigated emissions

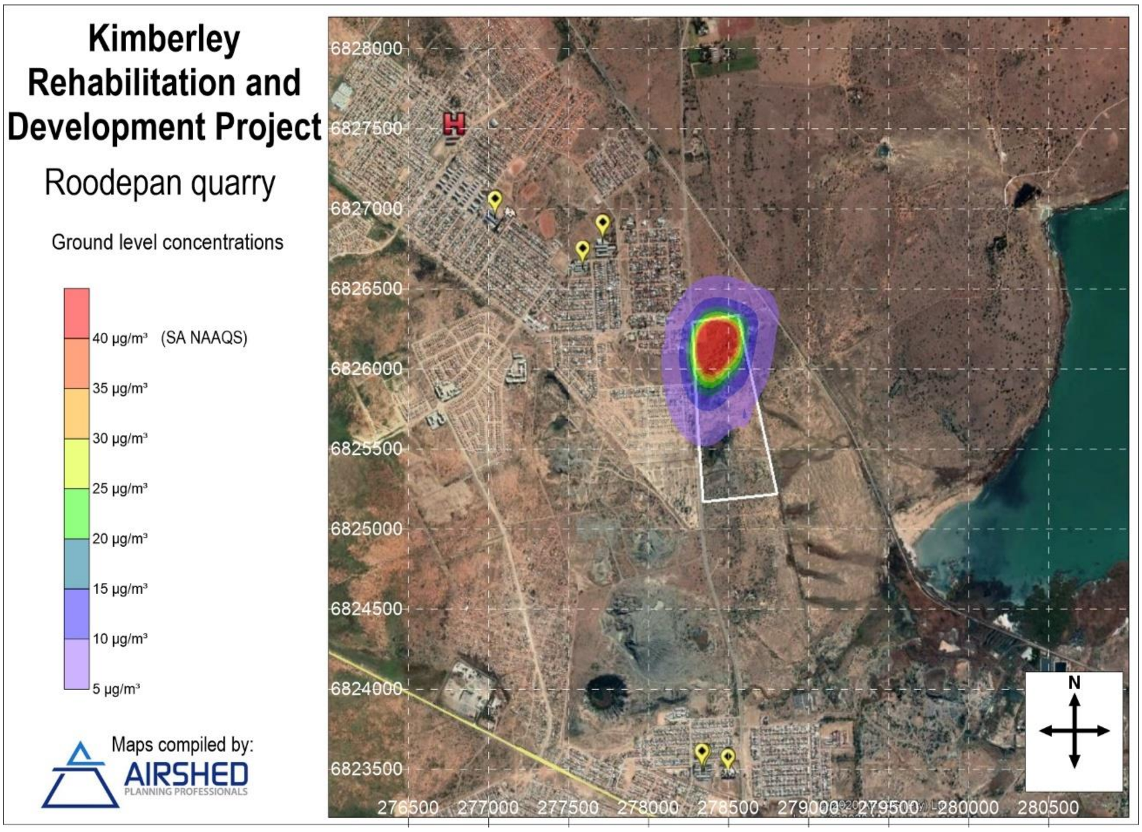

Figure 14: Simulated annual PM_{10} GLCs due to design-mitigated emissions

4.3.3 SO$_2$ Ground Level Concentrations

Isopleth plots of the simulated SO$_2$ hourly, daily and annual GLCs are shown in Figure 15, Figure 16 and Figure 17, respectively with the highest GLCs at the AQSRs provided in Table 14. No control technology was provided for the mitigation of gaseous emissions.

Simulated SO$_2$ hourly, daily and annual GLCs are low and well within the respective NAAQs at all the AQSRs. The main area of impact is to the south and east of the operations.

Table 14: Simulated PM$_{10}$ concentrations at the nearest AQSRs

AQSR	Hourly GLC (µg/m^3) – 99th Percentile	Within Compliance (Yes/No)	Daily GLC (µg/m^3) – 99th Percentile	Within Compliance (Yes/No)	Annual average GLC (µg/m^3)	Within Compliance (Yes/No)
NAAQS	350 µg/m^3		125 µg/m^3		50 µg/m^3	
Pescodia Secondary School	0.09	Y	0.04	Y	0.005	Y
Pescodia Primary School	0.09	Y	0.04	Y	0.005	Y
Roodepan Primary School	0.08	Y	0.04	Y	0.004	Y
Dr Winston Tore Clinic	0.08	Y	0.03	Y	0.004	Y
Homevale High School	0.21	Y	0.09	Y	0.018	Y
Homevale Secondary School	0.20	Y	0.09	Y	0.017	Y
Nearest AQSR (w boundary)	0.14	Y	0.07	Y	0.009	Y
Boundary	0.37	Y	0.12	Y	0.016	Y

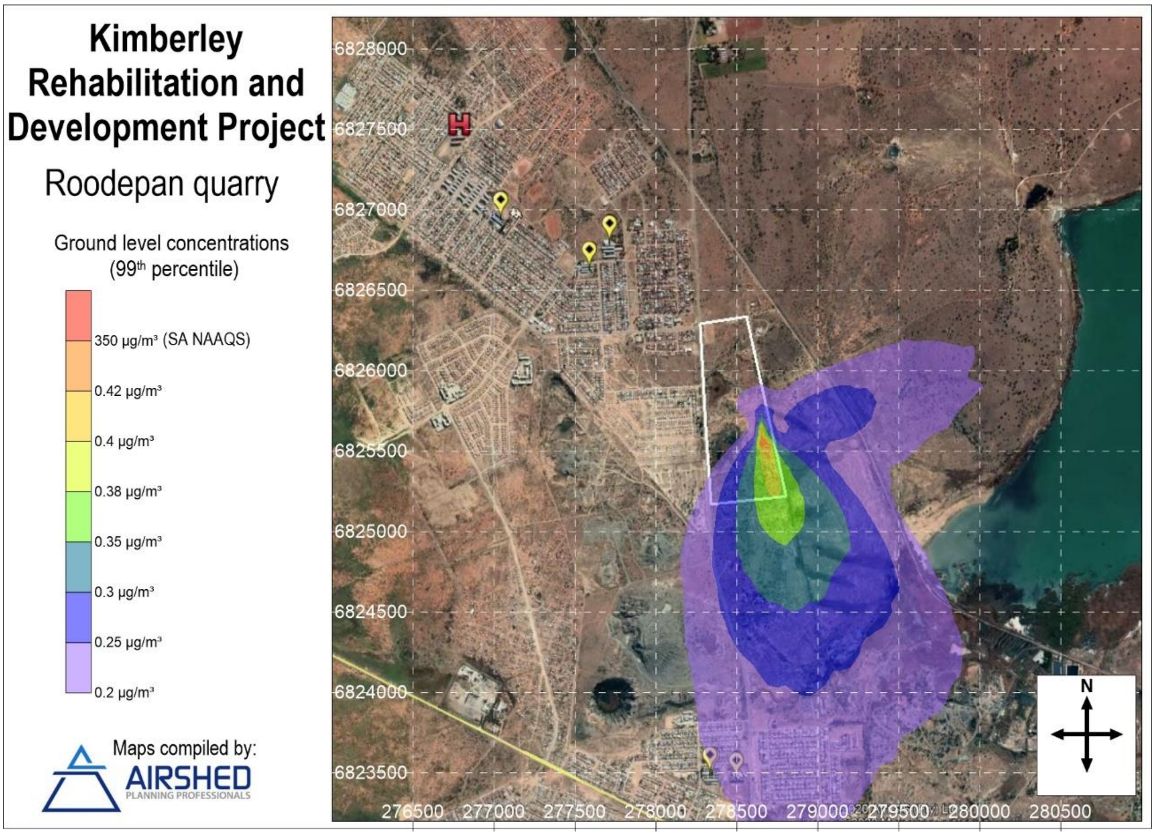

Figure 15: Simulated hourly SO$_2$ GLCs due to unmitigated emissions

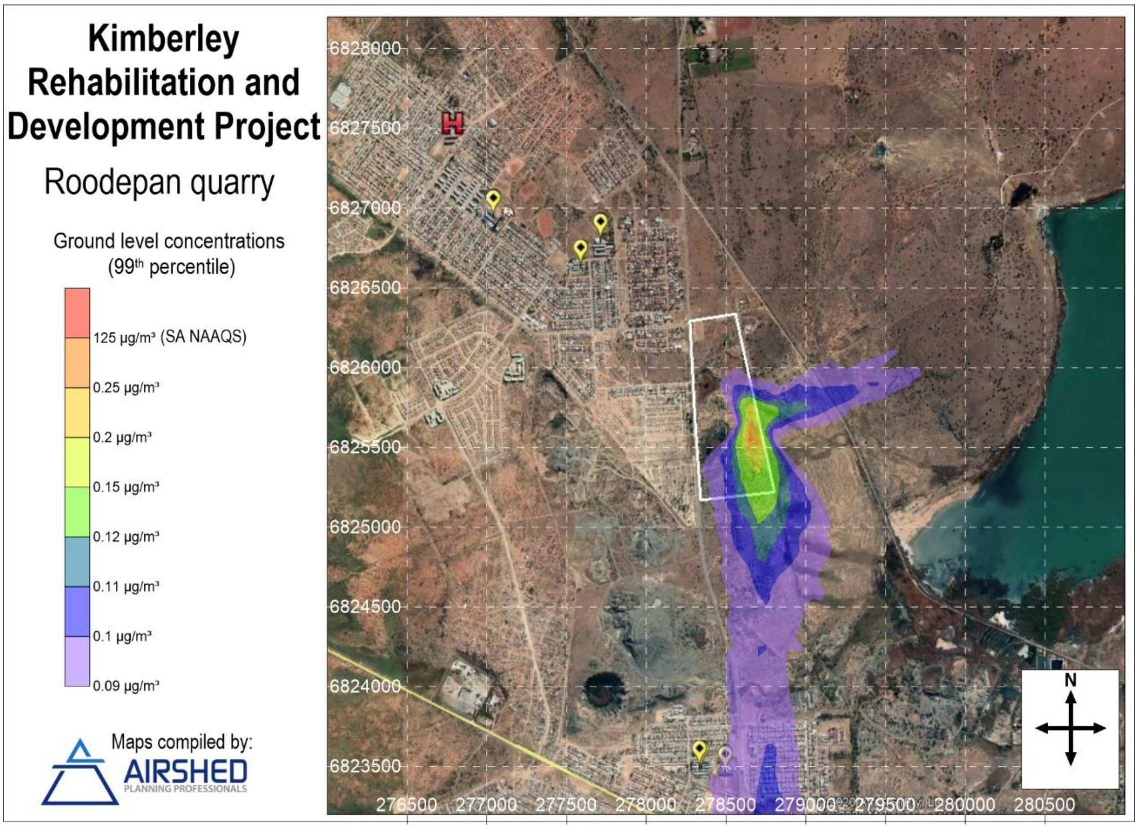

Figure 16: Simulated daily SO_2 GLCs due to unmitigated emissions

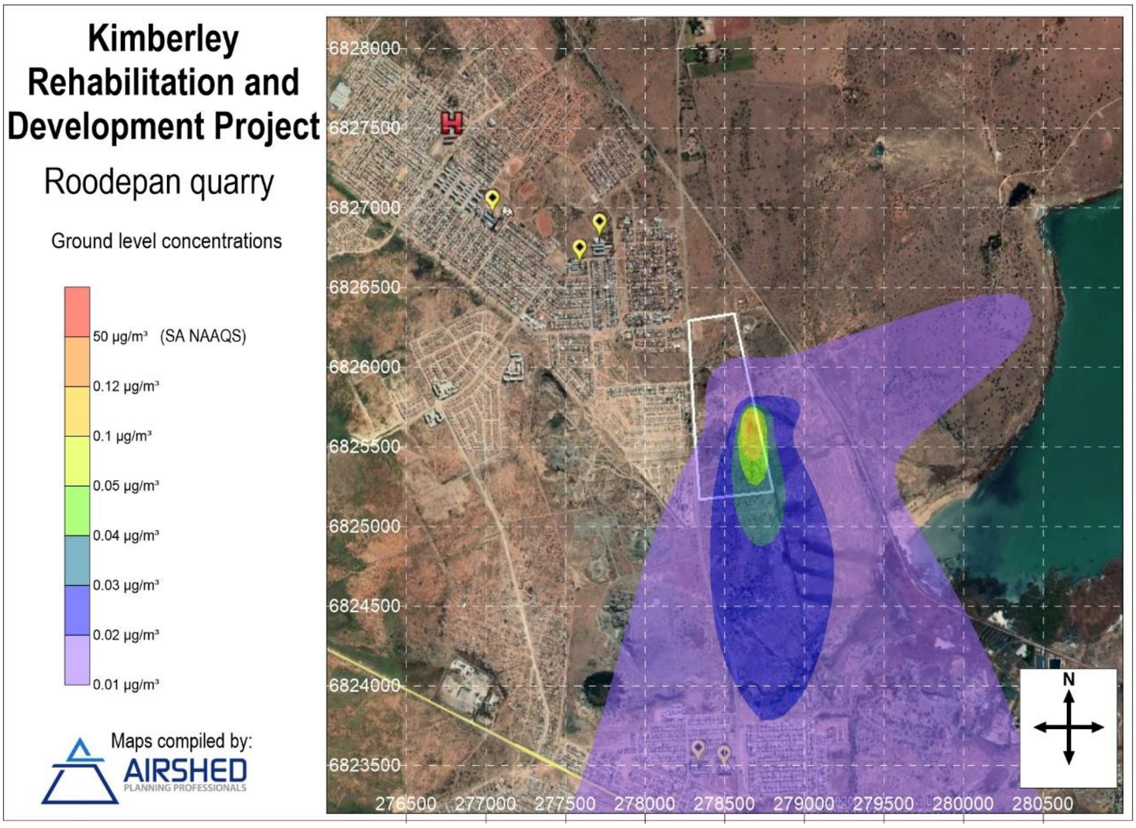

Figure 17: Simulated annual SO_2 GLCs due to unmitigated emissions

4.3.4 NO_2, CO and VOC Ground Level Concentrations

Simulated hourly and annual average NO_2 GLCs are well below the NAAQS of 200 µg/m³ and 50 µg/m³ respectively both at the boundary and at any AQSRs. Similarly, GLCs of CO and VOCs were well below the respective health limits.

4.3.5 Dustfall rates

The isopleth plot showing the area of exceedance of the residential and non-residential limits due to dustfall rates is provided in Figure 18. The simulated maximum daily dustfall rates exceed the NDCR for residential areas (600 mg/m²/day) only on-site and at the boundary, but not at any of the AQSRs.

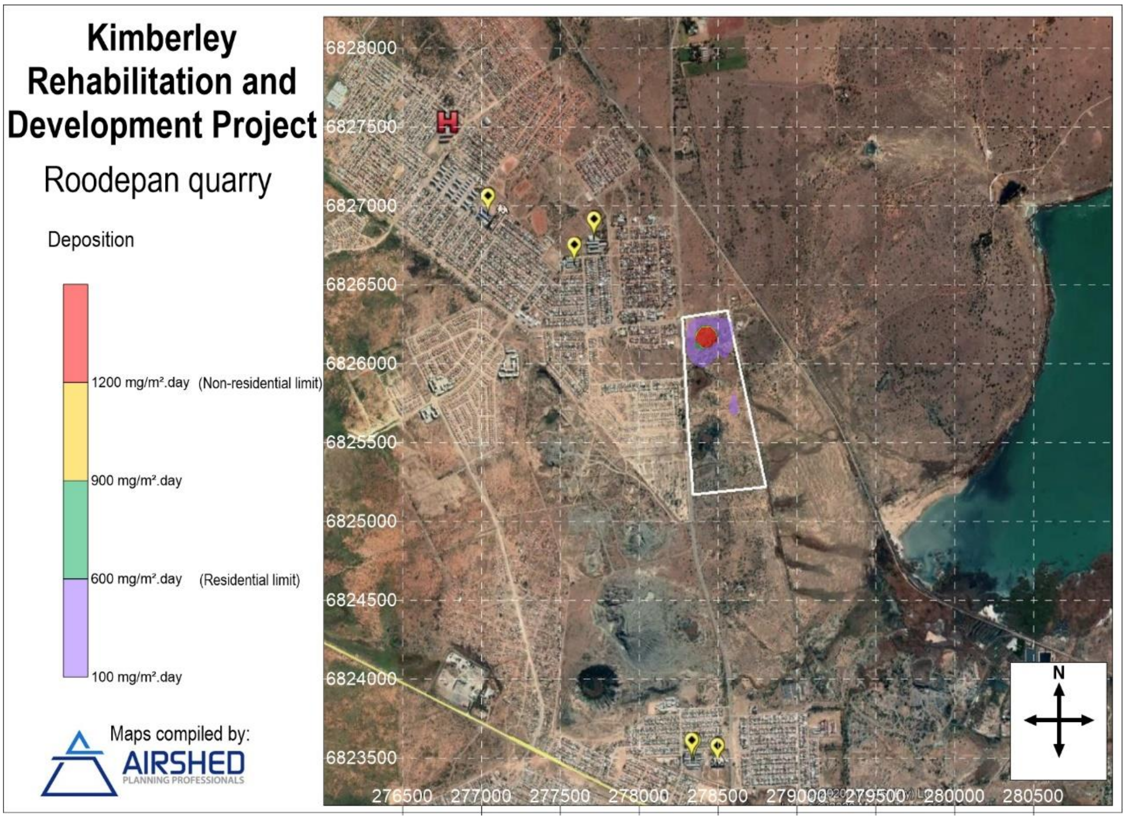

Figure 18: Simulated dustfall deposition rates due to design-mitigated emissions

5 IMPACT EVALUATION

The significance of potential air quality impacts from the KRD – Roodepan Quarry and Clay Brick facility is rated in terms of the consequence (severity of impact, spatial scope of impact and duration of impact) and likelihood (frequency of activity and frequency of impact). The significance rating followed the criteria as provided by NDI (Appendix B).

5.1 Construction Phase

As indicated in Section 4.1.1, the entire project could be regarded as construction operations, where the quarries and brick making facilities will provide the building material for the development of the mixed-use sites. In turn, the clay material sourced during the preparation of the mixed-use sites will be used for the clay brick manufacturing. Construction in this context was thus taken to only include the site preparation at Roodepan Quarry for the Clay Brick facility i.e. construction of site infrastructure.

During construction, the extent of dust emissions would vary substantially from day to day depending on the level of activity, the specific operations, and the prevailing meteorological conditions, and how close these activities are to AQSRs. $PM_{2.5}$ and PM_{10}, as well as dustfall impacts could be harmful (slightly harmful to potentially harmful) but will be limited to the area of construction (site specific). Construction activities are temporary (less than one year) and will cease as soon as the brick making operations start. Thus the significance could range from **Medium-High** (for $PM_{2.5}$ and PM_{10} without mitigation) to **Medium-Low** (with mitigation) as indicated in Table 15.

Table 15: Significance rating for Construction

Project Activity	Consequence			Likelihood		Significance Rating
PM_{10} and $PM_{2.5}$ Concentrations from Roodepan Quarry & Clay Brick Facility	Severity	Spatial Scope	Duration	Frequency of Activity	Frequency of Impact	
	Significance Pre-Mitigation					
	3	2	2	4	3	49
	Significance Post- Mitigation					
	2	2	2	4	2	36
Project Activity	**Consequence**			**Likelihood**		**Significance Rating**
Dust Fallout rates from Roodepan Quarry & Clay Brick Facility	Severity	Spatial Scope	Duration	Frequency of Activity	Frequency of Impact	
	Significance Pre-Mitigation					
	2	2	2	4	3	42
	Significance Post- Mitigation					
	1	2	2	4	2	36

5.2 Operational Phase

In the context of this project, the Clay Brick facility at Roodepan Quarry and the crushing, loading and transport of clay material from the mixed-use sites are included in the operational phase of the project. The significance ratings of impacts from the Roodepan Quarry and Clay Brick facility were based on the simulated results, whereas for the mixed-use sites, the assessment was based on the quantified emissions, and the location of AQSRs within the prevailing wind field.

5.2.1 Roodepan Quarry and Clay Brick facility

During operations, the simulated (design) mitigated PM_{10} and $PM_{2.5}$ impacts are **High** as a result of the severity and spatial scope of the PM_{10} daily concentrations, which exceeded the NAAQSs at the nearest AQSRs. With additional mitigation in place, the impact area footprint would likely reduce to be site specific (within the property boundary) reducing the significance to **Medium-Low**. Simulated unmitigated SO_2 concentrations were limited to the site but regarded as potentially harmful (due to the nature of the pollutant), thus resulting in a significance of **Medium-High** but with mitigation in place the severity, footprint and duration would reduce resulting a **Medium-Low** significance. The significance of impacts from the other gasses (NO_2, CO and VOC) is **Medium-Low**, without and with mitigation. It should be noted that from an air quality perspective, the *Frequency of Impact* is regarded to be for the entire *Life of Operation*, irrespective of the simulated impacts. Also, impacts from the proposed Zig-Zag kiln technology would be significantly lower than the impacts simulated from the Clamp Kiln technology, and are likely to reduce the overall significance rating to **Medium-Low**.

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Dustfall rates from the Clay Brick facility are likely to result in **Medium-High** significance impacts when design-mitigation is applied and would reduce to **Medium-Low** with additional mitigation in place. Dustfall is regarded a nuisance and therefore classified as potentially harmful (design mitigation) due to impacts on visibility, and non-harmful when mitigated due to lower dustfall rates.

5.2.2 Mixed-use sites

For the mixed-use sites, the significance from PM_{10} and $PM_{2.5}$, as well as dustfall impacts is regarded to be **Medium-High** due to the proximity of AQSRs to the roads to be used by the trucks transporting the clay material. With mitigation in place, the significance could reduce to **Medium-Low.**

Table 16: Significance rating for Operations

Project Activity	Consequence			Likelihood		Significance Rating
PM_{10} and $PM_{2.5}$ Concentrations from Roodepan Quarry & Clay Brick Facility	Severity	Spatial Scope	Duration	Frequency of Activity	Frequency of Impact	
	Significance Design-Mitigation					
	4	3	4	4	4	88
	Significance Additional-Mitigation					
	2	2	4	4	3	56
Project Activity	**Consequence**			**Likelihood**		**Significance Rating**
SO_2 Concentrations from Roodepan Quarry & Clay Brick Facility	Severity	Spatial Scope	Duration	Frequency of Activity	Frequency of Impact	
	Significance Design-Mitigation					
	2	2	4	4	2	48
	Significance Additional-Mitigation					
	1	2	3	4	2	36
Project Activity	**Consequence**			**Likelihood**		**Significance Rating**
NO_2, CO and VOC Concentrations from Roodepan Quarry & Clay Brick Facility	Severity	Spatial Scope	Duration	Frequency of Activity	Frequency of Impact	
	Significance Design-Mitigation					
	1	2	3	4	2	36
	Significance Additional-Mitigation					

	1	1	3	4	2	30
Project Activity	**Consequence**			**Likelihood**		**Significance Rating**
Dust Fallout rates as a result of from Roodepan Quarry & Clay Brick Facility	**Severity**	**Spatial Scope**	**Duration**	**Frequency of Activity**	**Frequency of Impact**	
	Significance Design-Mitigation					
	2	2	4	4	3	56
	Significance Additional-Mitigation					
	1	2	3	4	2	36
Project Activity	**Consequence**			**Likelihood**		**Significance Rating**
PM_{10} and $PM_{2.5}$ Concentrations as a result of Mixed-use sites	**Severity**	**Spatial Scope**	**Duration**	**Frequency of Activity**	**Frequency of Impact**	
	Significance Design-Mitigation					
	3	2	4	4	3	63
	Significance Additional-Mitigation					
	2	2	2	4	2	36
Project Activity	**Consequence**			**Likelihood**		**Significance Rating**
Dust Fallout rates as a result of Mixed-use sites	**Severity**	**Spatial Scope**	**Duration**	**Frequency of Activity**	**Frequency of Impact**	
	Significance Design-Mitigation					
	2	2	4	4	3	56
	Significance Additional-Mitigation					
	1	2	3	4	2	36

5.3 Cumulative Impacts

Cumulative PM_{10} and $PM_{2.5}$, as well as dustfall rates are likely to be higher at nearby AQSRs than the significance allocated to the various operations due to expected background concentrations and dustfall in the area (no data is available, and this is based on the types of source activities in the region as discussed under Section 3.4). The significance of cumulative gaseous impacts is less likely to be significantly higher than the project impacts (Section 3.4). With the recommended additional mitigation measures applied, these cumulative impacts could remain at the project specific significance ratings.

Once the mixed-use sites have been developed, and all activities at the Roodepan Quarry and Clay Brick facility cease, the significance should reduce, and the air quality should return to pre-project status. There is a possibility for higher gaseous concentrations due increases in traffic around the mixed-use sites once these are developed.

6 GREENHOUSE GAS EMISSIONS

This section presents the quantified Greenhouse gas (GHG) emissions from the Roodepan Quarry and Clay Brick facility with the resulting carbon footprint. The methodology, approach and assumptions are provided.

6.1 Methodology

Quantification of carbon footprint from the Roodepan Quarry and Clay Brick facility was conducted based guidelines published for use in South Africa (Department Environmental Affairs, 2017a), where mandatory reporting guidelines focus on the reporting of Scope 1 emissions only[3]. "Tier" means a method used for determining greenhouse gas emissions as defined by the "Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories (2006)" and include —

- **Tier 1 method:** Default IPCC emission factors available in the 2006 IPCC Guidelines are used to calculate emissions from activity data;
- **Tier 2 method:** Country specific emission factors published in the Technical Guidelines for Monitoring, Reporting and Verification of Greenhouse Gas Emissions by industry are used to calculate emissions from activity data;
- **Tier 3 method:** Emission models, material carbon balances and continuous emission measurements in the Technical Guidelines for Monitoring, Reporting and Verification of Greenhouse Gas Emissions by Industry available on the DEA website (www.environment.gov.za) are used.

The assessment includes the quantification of greenhouse gasses from all **direct** sources of emission associated with the proposed operations and associated infrastructure. Internationally published emission factors were used in the quantification of carbon dioxide (CO_2), nitrous oxide methane (CH_4) and nitrous oxide (N_2O).

The Carbon Footprint is an indication of the GHGs 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_2eq.

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).

6.2 GHG Emissions

GHG emissions were quantified for the operations using the estimated fuel usage provided by KRDP for both diesel usage and coal. In the quantification of emissions use was made of the 2006 IPCC guidelines and South Africa's CO_2eq emission factors (kg/tonne of fuel consumed, or kg/litre of fuel consumed).

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[3] Direct GHG emissions occur from sources that are owned or controlled by the company, for example, emissions from combustion in owned or controlled boilers, furnaces, vehicles, etc.; emissions from chemical production in owned or controlled process equipment.

Calculated GHG emissions, together with fuel usage rates and emissions factors employed are shown in Table 17. Additional information regarding the calculation of the emissions factor, as well as the sources of information is shown in Table 18.

GHG emission rates are reported as tCO_2eq (this includes CO_2, CH_4 and N_2O emissions expressed as tonne CO_2 equivalent). CO_2eq is a term for describing different GHG in a common unit. For any quantity and type of GHG, CO_2eq signifies the amount of CO_2 which would have the equivalent global warming impact. A quantity of GHG can be expressed as CO_2eq by multiplying the amount of the GHG by its global warming potential (GWP). For example, if 1 kg of CH_4 is emitted, this can be expressed as 23 kg of CO_2eq (1 kg CH_4 * 23 = 23 kg CO_2eq). GWP for CH_4 and N_2O were obtained from the technical guidelines document (Department Environmental Affairs, 2017a).

Table 17: Estimated GHG emissions from the Roodepan Quarry and Clay Brick facility

Fuel	Type of Source	Quantity per annum	Emission Factor	Total GHG Emissions (CO_2eq tpa)
Diesel	Mobile combustion	600 000 litres	0.0031 tonne CO_2eq/litre	1 890
Coal	Stationary combustion	21 000 tonnes	1.9691 tonne CO_2eq/tonne	41 352
			Total	**43 242**

Table 18: GHG emission factors

Fuel Type	Emission Factor Reference	Emission Factor			
		CO_2 (kg/TJ)	CH_4 (kg/TJ)	N_2O (kg/TJ)	CO_2eq Emission Factor
GWP Value	SA Technical Guidelines for Monitoring, Reporting and Verification of GHG Emissions (TG-2016.1, April 2017)-Annexure H		**23**	**296**	
Diesel	SA Technical Guidelines for Monitoring, Reporting and Verification of GHG Emissions (TG-2016.1, April 2017)-Table A.2	74 100	4.15	28.6	0.0031 tonne CO_2eq/litre
Coal	SA Technical Guidelines for Monitoring, Reporting and Verification of GHG Emissions (TG-2016.1, April 2017)-Table A.1	97 500	1	1.5	1.9691 tonne CO_2eq/tonne

The “Declaration of Greenhouse Gases as Priority Air Pollutants” in the Government Gazette of 40996 in July 2017 (Department of Environmental Affairs, 2017b) states processes that emit GHG in excess of 0.1 mega tonnes (10^9 kg) (Mt) or more annually or measured as CO_2eq are required to submit a pollution prevention plan. KRDP does not therefore require the submission of a pollution prevention plan as they emit less than 100 000 tCO_2eq.

7 CONCLUSION AND RECOMMENDATIONS

The potential for air quality impacts from the Roodepan Quarry and Brick Making facility were assessed based on emission quantification and dispersion modelling results, whereas impacts from the planned mixed-use development zones were qualitatively assessed based on emissions and meteorological conditions. All available project and associated data, including meteorological data and technical air quality data were evaluated.

7.1 Main Findings

The findings from the baseline screening assessment can be summarised as follows:

- Meteorological data was obtained from the SAWS station in Kimberley for the period Jan 2015 – Jun 2020. The prevailing wind field in the area is northerly, north-northeasterly and to a lesser extent from the west-southwest and southwest. The average wind speed recorded was 3.6 m/s with a maximum of 15 m/s. The threshold wind speed of 5.4 m/s required for windblown dust to occur, was exceeded for 19% of the time. There was no significant variation in the prevailing wind fields between the seasons, with northerly winds prevailing throughout and a slight change in the frequency of north-northwesterly to north-northeasterly winds which are more prominent in summer and spring and less in winter and autumn. Temperatures ranged between -1°C (June 2018) to 42.5°C (January 2016), with the highest temperatures in summer and the lowest in winter. Kimberley falls within the summer rainfall area with an average annual rainfall of 328 mm recorded.
- No ambient air quality data could be found for Kimberley. Given the activities within the region which include primarily mining operations, vehicles and trucks on gravel roads, agricultural field tilling and windblown dust from exposed surfaces, the main pollutants are expected to be PM_{10} and $PM_{2.5}$. Background concentrations for the Kimberley area are however not known.
- Activities identified that will give rise to air pollutants include:
    - **Mixed-use sites**: air quality related impacts will primarily be from construction activities such as land clearing activities, including removal of waste rock and surface levelling (grading and scraping), crushing and handling of clay material, and the off-loading and handling of building materials (bricks, cement, etc.) on-site. Once the sites are developed, there might be an increase in road traffic contributing to increased vehicle tailpipe emissions.
    - **Roodepan Quarry and Clay Brick facility**: clay brick production will result in the most significant emissions, with particulate emissions deriving from mixing and blending of the raw materials, grinding and firing. The firing will also give rise to SO_2, NO_2, CO and VOCs. Gaseous emissions will result from mobile equipment and vehicle tailpipe emissions on-site. At the time of the assessment, the preferred clay brick making technology was Clamp Kilns, but this was subsequently changed to Zig-Zag Kilns which would result in significantly less particulate emissions due to the zig-zag design causing the deposition of particulates as a result of the continuous change in flue gas, and a flue gas scrubber.
- The main pollutant of concern is particulate matter (TSP, PM_{10} and $PM_{2.5}$). Particulate matter emissions would result from all the planned activities including construction at the mixed-use sites and operations at the Roodepan Quarry (manufacturing of clay bricks). Gaseous emissions (SO_2, NO_2, CO and VOC) would result from vehicle tailpipe emissions – truck activity at the quarry and trucks transporting the clay material from the mixed-use sites to the quarry, as well as from diesel powered equipment at the sites. The Clay Brick facility will emit particulate emissions as well as SO_2, NO_2.

The findings from the impact assessment are as follows:

- **Construction** normally comprises a series of different operations including land clearing, topsoil removal, road grading, etc., with particulate matter the main pollutants of concern from these activities. During construction, the extent of dust emissions would vary substantially from day to day depending on the level of activity, the specific operations, and the prevailing meteorological conditions, and how close these activities are to AQSRs. Construction in this context was thus taken to only include the site preparation at Roodepan Quarry for the Clay Brick facility i.e. construction of site infrastructure. Due to the temporary nature of construction operations, and the localised scale of these activities, the impacts are expected to have a **Medium-High** (for $PM_{2.5}$ and PM_{10} without mitigation) to **Medium-Low** (with mitigation) significance. No baseline data was available, with cumulative impacts expected to increase in proximity of these activities but only for the duration of the activities.
- **Operations** were taken to include the Clay Brick manufacturing at Roodepan Quarry, and the crushing, handling and transport of the clay material at the mixed-use sites. The main pollutants of concern from these sites are particulate matter (TSP, PM_{10} and $PM_{2.5}$), with the main contributing source at Roodepan Quarry the Clamp Kilns (59% of TSP; 70% of PM_{10} and 92% of $PM_{2.5}$) and vehicle entrained dust from the paved roads being the main contributor from the mixed-use sites (95% of TSP; 88% of PM_{10} and 92% of $PM_{2.5}$).
    - Simulated (design) mitigated PM_{10} GLCs resulted in exceedances of the daily NAAQSs at the nearest AQSR and the Roodepan Quarry boundary. Annual average PM_{10} GLCs, as well as the daily and annual $PM_{2.5}$ GLCs were within the NAAQSs. Due to the potential for exceedances, the significance is regarded to be **High** with the design-mitigation in place but would reduce to **Medium-High** with the Zig-Zag kiln technology.
    - Simulated impacts from gaseous emissions (SO_2, NO_2, CO and VOCs) were well within the respective NAAQSs at all AQSRs. With the impacts limited to the site, the significance of the impacts is **Medium-High** for SO_2 and Medium low for NO_2, CO and VOCs. With mitigation in place the severity, footprint and duration would reduce resulting a **Medium-Low** significance for all.
    - Dustfall rates from the Clay Brick facility were limited to the site, and likely to result in **Medium-High** significance impacts when (design) mitigation is applied and would reduce to **Medium-Low** with additional mitigation in place.
    - For the mixed-use sites, the significance from PM_{10} and $PM_{2.5}$, as well as dustfall impacts is regarded to be **Medium-High** due to the proximity of AQSRs to the roads to be used by the trucks transporting the clay material. With mitigation in place, the significance could reduce to **Medium-Low.**
    - No baseline data was available for a **cumulative assessment**. Based on the existing sources of pollution in the region, particulates are expected to be the main pollutant of concern and would likely result in higher impacts at the AQSRs close to the various project activities. With the recommended additional mitigation measures applied, these cumulative impacts could remain at the project specific significance ratings.
    - Once the mixed-use sites have been developed, and all activities at the Roodepan Quarry and Clay Brick facility cease, the significance should reduce, and the air quality should return to pre-project status. There is a possibility for higher gaseous concentrations due increases in traffic around the mixed-use sites once these are developed.
- GHG emissions were quantified for the operations using the estimated diesel and coal usage. In the quantification of emissions use was made of the 2006 IPCC guidelines and South Africa's CO_2eq emission factors (kg/tonne of fuel consumed, or kg/litre of fuel consumed). GHG emission rates are reported as tCO_2eq. The total GHG emissions for the Roodepan Clay Brick Facility and mixed-use sites is 43 242 CO_2eq tpa. This is well below the 100 000 tCO_2eq annually and thus do not require the submission of a pollution prevention plan.

7.2 Conclusion

The air quality impact assessment from the Clay Brick facility is regarded representative since the Clamp Kilns, although resulting in higher emission rates than the Zig-Zag kiln technology, were modelled as point sources due to the buoyancy of the emissions. The Zig-Zag kiln technology could however, if fitted with a flue gas scrubber and designed to meet the Minimum Emission Standards, result in an overall significance rating of **Medium-Low**. Once the design for the Zig-Zag kilns are finalized, the dispersion model would need to be rerun to determine the impacts from this technology. It is further assumed that the brick making operations will only last for the duration of the construction of the mixed-use development sites. It can thus be concluded from the impact assessment that the planned development operations could have a **Medium-Low** significance on the surrounding environment and human health with the required mitigation measures in place.

7.3 Recommendations

7.3.1 Mitigation Measures

- During the operations at the Clay Brick facility, the following should be implemented:
    - Limiting the speed of on-site trucks; limiting unnecessary travelling of vehicles on untreated roads.
    - Access road to be paved.
    - Water sprays on all on-site unpaved roads (at least 50% control efficiency).
    - Water sprays, or other dust control measures, at all material transfer points to ensure at least 50% control efficiency.
    - Screening of clay should be enclosed to ensure at least 50% control efficiency.
    - The Zig-Zag technology should include a flue gas scrubber, and ensure the design comply with the MES as provided in Table 1.
    - Screening of clay material, blending and the brick kilns to be located on the eastern side of the Roodepan Quarry, furthest away from residences, with limited site activity on the western side.
- Operations at the mixed-use sites should be mitigated through water sprays and activities should be visually assessed – where dust is visible, additional water sprays should be applied. The main source on-site would be the crushers, with trucks transporting the clay to the Roodepan Quarry required to be covered to reduce the potential for spills and windblown dust from the trucks.

7.3.2 Monitoring Requirements

- Monitoring requirements for Roodepan Quarry and Clay Brick facility:
    - Continuous sampling of PM_{10} and $PM_{2.5}$ concentrations on the western boundary of the quarry, closest to the AQSRs for the duration of the clay brick manufacturing. It is proposed that the sampling be done using one standalone PM_{10}/$PM_{2.5}$ sampler that can sample continuously with a datalogger, modem, solar power system and local WiFi access for viewing data.
    - Dustfall collection for the duration of the clay brick manufacturing. A network of four (4) single dustfall units are proposed, one in each of the four main wind directions – north, west, east and south. The dustfall monitoring network should follow the American Society for Testing and Materials standard method for collection and analysis of dustfall (ASTM D1739-98). The ASTM method covers the procedure of collection of dustfall and its measurement and employs a simple device consisting of a cylindrical container exposed for one calendar month (30 ±2 days). The method provides for a dry bucket, which is advisable in the dry environment.
    - Bi-annual passive sampling of NOx, SO_2 and VOCs at the four (4) dustfall locations. Limiting the speed of on-site trucks; limiting unnecessary travelling of vehicles on untreated roads. Radiello passive diffusive

samplers consist of a shield, an installation plate, a diffusive body and a cartridge. Cartridges are exposed for a period of 14-days.

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9 APPENDIX A – SPECIALIST CURRICULUM VITAE

Name of Firm	Airshed Planning Professionals (Pty) Ltd
Name of Staff	Hanlie Liebenberg-Enslin
Profession	Managing Director / Air Quality Scientist
Date of Birth	09 January 1971
Years with Firm/ entity	20 years
Nationalities	South African

MEMBERSHIP OF PROFESSIONAL SOCIETIES

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

KEY QUALIFICATIONS

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

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

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

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

RELEVANT EXPERIENCE

Air Quality Management Plans and Strategies

Vaal Triangle Airshed Priority Area Draft Second Generation Air Quality Management Plan (AQMP)(Aug 2017 – Jun 2020); Advanced Air Quality Management for the Strategic Environmental Management Plan for the Uranium and Other Industries in the Erongo Region (May 2016 – Feb 2019); City of Johannesburg AQMP (2016-2019); Air Quality Monitoring and Management for the Al Madinah Al Munawarah Development Authority (MDA) in Saudi Arabia (2016-2017). Provincial Air Quality Management Plan for the Limpopo Province (March 2013); Mauritius Road Development Agency Proposed Road Decongestion Programme (July 2013); Transport Air Quality Management Plan for the Gauteng Province (February 2012); Gauteng Green Strategy (2011); Air Quality and Radiation Assessment for the Erongo Region Namibia as part of a Strategic Environmental Assessment (June, 2010); Vaal Triangle Airshed Priority Area AQMP (March, 2009); Gauteng Provincial AQMP (January 2009); North West Province AQMP (2008); City of Tshwane AQMP (April 2006); North West Environment Outlook 2008 (December 2007); Ambient Monitoring Network for the North West Province (February 2007); Spatial Development Framework Review for the City of uMhlathuze (August 2006); Ambient Particulate Pollution Management System (Anglo Platinum Rustenburg).

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

Mining and Ore Handling

Hanlie has undertaken numerous air quality impact assessments and management plans for coal, platinum, uranium, copper, cobalt, chromium, fluorspar, bauxite and mineral sands mines. These include air quality impact assessments for: Namibia – Husab Uranium Mine, Trekkopje Uranium Mine; Bannerman Uranium Project; Langer Heinrich Uranium Mine, Valencia Uranium Mine, Rössing Uranium Mine; and B2Gold Otjikoto Gold Mine. South Africa – Sishen Iron Ore Mine; Tshipi Borwa Manganese Mine; Mamatwan Manganese Mine; Kolomela Iron Ore Mine; Thabazimbi Iron ore Mine; UKM Manganese Mine; Everest Platinum Mine; Impala Platinum Mine; Anglo Platinum Mines; Abglo Gold Ashanti MWS, Vaal River and West Wits complexes, Harmony Gold, Glencore Coal Mines, South32 and Anglo Coal; Tselentis Coal mine (Breyeton); Lime Quarries (De Hoek, Dwaalboom, Slurry); Beesting Colliery (Ogies); Anglo Coal Opencast Coal Mine (Heidelberg); Klippan Colliery (Belfast); Beesting Colliery (Ogies); Xstrata Coal Tweefontein Mine (Witbank); Xstrata Coal Spitskop Mine (Hendrina); Middelburg Colliery (Middelburg); Klipspruit Project (Ogies); Rustenburg Platinum Mine (Rustenburg); Impala Platinum (Rustenburg); Buffelsfontein Gold Mine (Stilfontein); Kroondal Platinum Mine (Kroondal); Lonmin Platinum Mine (Mooinooi); Rhovan Vanadium (Brits); Macauvlei Colliery (Vereeniging); Voorspoed Gold Mine (Kroonstad); Pilanesberg Platinum Mine (Pilanesberg); Kao Diamond Mine (Lesotho); Modder East Gold Mine (Brakpan); Modderfontein Mines (Brakpan); Zimbiwa Crusher Plant (Brakpan); RBM Zulti South Titanium mining (Richards Bay); Premier Diamond Mine (Cullinan). Botswana – Jwaneng Diamond Mine and Debswana Mining Company. Zimbabwe – Murowa Diamond Mine. Other mining projects include Sadiola Gold Mine (Mali); North Mara Gold Mine (Tanzania); Bulyanhulu North Mara Gold Mine (Tanzania).

Metal Recovery

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

Chemical Industry

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

Petrochemical Industry

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

Pulp and Paper Industry

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

Power Generation

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

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

Waste Disposal

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

Cement Manufacturing

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

Vehicle emissions

Transport Air quality Management Plan for the Gauteng Department of Roads and Transport (Feb 2012); Platinum Highway (N1 to Zeerust); Gauteng Development Zone (Johannesburg); Gauteng Department of Roads and Transport (Transport Air Quality Management Plan); Mauritius Road Development Agency (Proposed Road Decongestion Programme); South African Petroleum Industry Association (Impact Urban Air Quality).

Government and International Strategy Projects

Hanlie was the Terminal Reviewer of the UNEP/UNDA project "Air quality data for health and environment policies in Africa and the Asia-Pacific region" (May 2020). Hanlie was also the project Director on the APPA Registration Certificate Review Project for Department of Environmental Affairs (DEA); Green Strategy for Gauteng (2011).

EDUCATION

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

ADDITIONAL COURSES AND ACADEMIC REVIEWS

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

COUNTRIES OF WORK EXPERIENCE

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

EMPLOYMENT RECORD

March 2003 - Present

Airshed Planning Professionals (Pty) Ltd, Managing Director and Principal Air Quality Scientist, Midrand, South Africa.

January 2000 – February 2003

Environmental Management Services CC, Senior Air Quality Scientist.

May 1998 – December 1999

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

February 1997 – April 1998

GIS Business Solutions (PQ Africa), GIS Analyst

January 1996 – December 1996

Annegarn Environmental Research (AER), Student Researcher

LANGUAGES

	Speak	Read	Write
English	Excellent	Excellent	Excellent
Afrikaans	Excellent	Excellent	Excellent

CONFERENCE AND WORKSHOP PRESENTATIONS AND PAPERS

- Dust and radon levels on the west coast of Namibia – What did we learn? Hanlie Liebenberg-Enslin, Detlof von Oertzen, and Norwel Mwananawa. Atmospheric Pollution Research, 2020. https://doi.org/10.17159/caj/2020/30/1.8467
- Understanding the Atmospheric Circulations that lead to high particulate matter concentrations on the west coast of Namibia. Hanlie Liebenberg-Enslin, Hannes Rauntenbach, Reneé von Gruenewaldt, and Lucian Burger. Clean Air Journal, 27, 2, 2017, 66-74.
- Cooperation on Air Pollution in Southern Africa: Issues and Opportunities. SLCPs: Regional Actions on Climate and Air Pollution. Liebenberg-Enslin, H. 17th IUAPPA World Clean Air Congress and 9th CAA Better Air Quality Conference. Clean Air for Cities - Perspectives and Solutions. 29 August - 2 September 2016, Busan Exhibition and Convention Center, Busan, South Korea.
- A Best Practice prescription for quantifying wind-blown dust emissions from Gold Mine Tailings Storage Facilities. Liebenberg-Enslin, H., Annegarn, H.J., and Burger, L.W. VIII International Conference on Aeolian Research, Lanzhou, China. 21-25 July 2014.

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

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

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

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

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

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

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

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

CERTIFICATION

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

AIRSHED
PLANNING PROFESSIONALS

31 July 2020

Full name of staff member: Hanlie Liebenberg-Enslin

10 APPENDIX B – SIGNIFICANCE RATING CRITERIA

The anticipated impacts associated with the proposed project will be assessed according to a standardised impact assessment methodology, which is presented below. This methodology has been utilised for the assessment of environmental impacts where the consequence (severity of impact, spatial scope of impact and duration of impact) and likelihood (frequency of activity and frequency of impact) have been considered in parallel to provide an impact rating and hence an interpretation in terms of the level of environmental management required for each impact.

The first stage of any impact assessment is the identification of potential environmental activities[4], aspects[5] and impacts, which may occur during the commencement, and implementation of a project. This is supported by the identification of receptors[6] and resources[7], which allows for an understanding of the impact pathway and an assessment of the sensitivity to change. Environmental impacts[8] (social and biophysical) are then identified based on the potential interaction between the aspects and the receptors/resources.

The significance of the impact is then assessed by rating each variable numerically according to defined criteria as outlined in Table 19.

The purpose of the rating is to develop a clear understanding of influences and processes associated with each impact. The severity[9], spatial scope[10] and duration[11] of the impact together comprise the consequence of the impact and when summed can obtain a maximum value of 15. The frequency of the activity[12] and the frequency of the impact[13] together comprise the likelihood of the impact occurring and can obtain a maximum value of 10. The values for likelihood and consequence of the impact are then read off a significance rating matrix table as shown in Table 20.

This matrix thus provides a rating on a scale of 1 to 150 (low, medium low, medium high or high) based on the consequence and likelihood of an environmental impact occurring.

Natural and existing mitigation measures, including built-in engineering designs, are included in the pre-mitigation assessment of significance. Measures such as demolishing of infrastructure, and reinstatement and rehabilitation of land, are considered post-mitigation.

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[4] An ***activity*** is a distinct process or task undertaken by an organisation for which a responsibility can be assigned. Activities also include facilities or pieces of infrastructure that are possessed by an organisation.

[5] An ***environmental aspect*** is an 'element of an organisations activities, products and services which can interact with the environment'. The interaction of an aspect with the environment may result in an impact.

[6] ***Receptors*** comprise, but are not limited to people or man-made structures.

[7] ***Resources*** include components of the biophysical environment.

[8] ***Environmental impacts*** are the consequences of these aspects on environmental resources or receptors of particular value or sensitivity, for example, disturbance due to noise and health effects due to poorer air quality. Receptors can comprise, but are not limited to, people or human-made systems, such as local residents, communities and social infrastructure, as well as components of the biophysical environment such as aquifers, flora and palaeontology. In the case where the impact is on human health or well-being, this should be stated. Similarly, where the receptor is not anthropogenic, then it should, where possible, be stipulated what the receptor is.

[9] ***Severity*** refers to the degree of change to the receptor status in terms of the reversibility of the impact; sensitivity of receptor to stressor; duration of impact (increasing or decreasing with time); controversy potential and precedent setting; threat to environmental and health standards.

[10] ***Spatial scope*** refers to the geographical scale of the impact.

[11] ***Duration*** refers to the length of time over which the stressor will cause a change in the resource or receptor.

[12] ***Frequency of activity*** refers to how often the proposed activity will take place.

[13] ***Frequency of impact*** refers to the frequency with which a stressor (aspect) will impact on the receptor.

Table 19: Criteria for Assessing Significance of Impacts

SEVERITY OF IMPACT	RATING
Insignificant / non-harmful	1
Small / potentially harmful	2
Significant / slightly harmful	3
Great / harmful	4
Disastrous / extremely harmful	5

SPATIAL SCOPE OF IMPACT	RATING
Activity specific	1
Site specific (within the property boundary)	2
Local area (within 5 km of the site boundary)	3
Regional (Greater Sol Plaatje LM area)	4
National	5

DURATION OF IMPACT	RATING
One day to one month	1
One month to one year	2
One year to ten years	3
Life of operation	4
Post closure / permanent	5

CONSEQUENCE

FREQUENCY OF ACTIVITY / DURATION OF ASPECT	RATING
Annually or less / low	1
6 monthly / temporary	2
Monthly / infrequent	3
Weekly / life of operation / regularly / likely	4
Daily / permanent / high	5

FREQUENCY OF IMPACT	RATING
Almost never / almost impossible	1
Very seldom / highly unlikely	2
Infrequent / unlikely / seldom	3
Often / regularly / likely / possible	4
Daily / highly likely / definitely	5

LIKELIHOOD

Table 20: Interpretation of Impact Rating

Consequence

Likelihood

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
3	6	9	12	15	18	21	24	27	30	33	36	39	42	45
4	8	12	16	20	24	28	32	36	40	44	48	52	56	60
5	10	15	20	25	30	35	40	45	50	55	60	65	70	75
6	12	18	24	30	36	42	48	54	60	66	72	78	84	90
7	14	21	28	35	42	49	56	63	70	77	84	91	98	105
8	16	24	32	40	48	56	64	72	80	88	96	104	112	120
9	18	27	36	45	54	63	72	81	90	99	108	117	126	135
10	20	30	40	50	60	70	80	90	100	110	120	1	140	150

🟥	**High**	76 to 150	Improve current management
🟧	**Medium High**	40 to 75	Maintain current management
🟨	**Medium Low**	26 to 39	
🟩	**Low**	1 to 25	No management required

SIGNIFICANCE = CONSEQUENCE x LIKELIHOOD