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HARMONY GOLD MINING COMPANY – MOAB KHOTSONG OPERATIONS: WASTE WATER TREATMENT PLANTS & VAAL RIVER LANDFILL SITE

BASELINE AIR QUALITY & PLAN OF STUDY REPORT

August 2022

Rayten Project Number: SCI-HARM-222630

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REVISION AND APPROVAL PAGE

Revision Number	**1.0**		
Marang Project Number	**SCI-HARM-222630**		
Report Title	**HARMONY GOLD MINING COMPANY – MOAB KHOTSONG OPERATIONS: WASTE WATER TREATMENT PLANTS & VAAL RIVER LANDFILL SITE BASELINE AIR QUALITY & PLAN OF STUDY REPORT**		
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Report Submission Summary		
Report Revision Number	1.0	Date Submitted: 05 August 2022
Report Revision Number		

DISCLAIMER

Information contained in this report was based on the last information received from Moab Khotsong Operations, between June and August 2022. Where data supplied by the client or other external sources, including previous site investigation data, have been used, it has been assumed that the information is correct unless otherwise stated. No responsibility is accepted by Rayten Engineering Solutions (Pty) Ltd for incomplete or inaccurate data supplied by others. We are aware of the fact that there might have been changes since this report was submitted, however this report and its findings is based on the last information received from the client between June and August 2022. To the best of our knowledge the assumptions and findings are correct at the time of submission of the specialist report. Should any of the assumptions or findings prove to be incorrect subsequent to submission of the report, we as the specialist cannot be held accountable. Note that although every effort has been made by Rayten Engineering Solutions (Pty) Ltd to obtain the correct information and to carry out an appropriate, independent, impartial and competent study, Rayten Engineering Solutions (Pty) Ltd cannot be held liable for any incident which directly or indirectly relates to the work in this document, and which may have an effect on the client or on any other third party.

CONFIDENTIALITY

EXECUTIVE SUMMARY

Rayten Engineering Solutions (Pty) Ltd was appointed by Harmony Gold Mining Company – Moab Khotsong Operations (referred to as Moab Khotsong herein) to compile an Air Quality Impact Assessment report (AQIAr) for their existing waste water treatment plants (WWTPs) and a landfill site located in the North-West and Free State Provinces.

Moab Khotsong operations comprise of gold and uranium processing plants, a tailings storage complex, a waste rock dump and two mine shafts, and they specialise in producing gold bullion and ammonium di-urinate (ADU). Operations at Moab Khotsong trigger sub-category 4.1 (drying and calcining) and sub-category 4.17 (precious and base metal production & refining) in terms of Section 21 of the National Environmental Management Air Quality Act (NEM:AQA) (No. 39 of 2004). Moab Khotsong have an Atmospheric Emission Licence (AEL) (AEL No: AEL/FS/MKO-HGM/14/10/2019F), which expires 30 January 2026. In addition to the above-mentioned operations, there are off-mine services near Orkney, i.e. at the Orkney surface operations.

Three existing WWTPs and one landfill site are associated with the Moab Khotsong operations. The WWTPs are used for treatment of effluent from processing operations and ablution facilities at the mine and include the 3#, 8# and 11# WWTPs, which serve the off-mine services Orkney surface operations, Great Noligwa operations, and Moab Khotsong shaft operations, respectively. The landfill site is known as the Vaal River landfill site and accepts non-hazardous general waste comprising of builders' rubble, domestic waste, municipal waste, commercial waste, industrial waste and general waste from nearby properties, a village, offices, Moab Khotsong and Great Noligwa shafts, HD residences (hostels), workshops, as well as the South Uranium and Noligwa gold plants. As such the landfill site is classified as a Class B waste disposal facility (specifically, G:S:B-).

Due to operation of the three WWTPs and the landfill site, Moab Khotsong are required to conduct an odour assessment in terms of their Environmental Management Plan (EMP) and the Draft Odour Management Guidelines, which were drafted for internal circulation by the DFFE on 31 March 2020. This AQIAr has been compiled for the gold mine to meet these requirements.

The main objective of the AQIAr is to determine the potential impact of emissions associated with the operational activities at the WWTPs and the landfill site on ambient air quality in terms of dustfall, hazardous air pollutants (HAPs), volatile organic compounds (VOCs) and odorous gases.

As part of the AQIA, a Baseline Air Quality Assessment was undertaken to determine the following:

- the prevailing meteorological conditions at the site;
- establish baseline concentrations of key air pollutants of concern;
- identify existing sources of emissions; and
- identify key sensitive receptors surrounding the project site.

MM5 modelled meteorological data (obtained from Lakes Environmental) for the project area for the period January 2017 to December 2019 was used. The existing air quality situation is usually evaluated using available monitoring data from permanent ambient air quality monitoring stations (AQMS) operated near the project site (i.e. within a 10km radius). The existing AQMS is at the Jouberton AQMS (-26.89605°S; 26.6056°E), which is located too far from the mine – approximately 21.5km to the north-west and would not provide an accurate representation of baseline air quality at the mine. Furthermore, air quality monitoring of these pollutants in not undertaken at the mine. As such, background concentrations for the criteria air pollutants (PM_{10}, $PM_{2.5}$, SO_2, NO_2 and CO) could not be presented in this report. However, there was background dustfall data obtained from Moab Khotsong's dustfall monitoring network, which consists of 13 dustfall monitoring sites located in and around the mine. Dustfall rates at the mine for the period January 2021 – December 2021 were used.

Summary of conclusions for baseline assessment

The main conclusions based on information obtained during the Baseline Assessment are as follows:

Moab Khotsong, including associated Tailings Storage Facilities (TSFs), processing plants, WWTPs and the landfill site are located 7 – 15km south-east of Klerksdorp, within the North-West and Free State Provinces. The land use immediately surrounding the Moab Khotsong operations consists predominantly of grassland and agricultural/cultivated land use types. Mining areas, which include the existing Harmony Moab Kopanang and Mine Waste Solutions mines & processing plants, as well as SGS Vaal River Assay Lab, and TSFs; and urban residential, informal and smallholding areas are in near proximity north, north-west, west and south-east of the mine. The larger area surrounding Moab Khotsong is characterised as rural in nature. Existing key sources of air pollution surrounding the project site mostly include:

- Mining activity and TSFs (onsite, at nearby Harmony Moab Kopanang and Mine Waste Solutions mines and processing plants, as well as SGS Vaal River Assay Lab);
- Vehicle dust entrainment on surrounding unpaved roads;
- Wind erosion from open exposed areas (e.g. natural eroded areas, exposed farmland, TSFs, stockpiles, open storage piles, etc); and
- Commercial agricultural activity.

Other sources may also include the Vaal River landfill site (north-west of the mine), domestic fuel burning in urban informal areas located north and north-west of Moab Khotsong, industrial activity, sewage works, and vehicle exhaust emissions from vehicle activity on national and arterial roads located north, north-west, west and south of Moab Khotsong. The sewage works include the three WWTPs owned and operated by Moab Khotsong.

Based on the prevailing wind fields for the period January 2017 to December 2019, emissions from operations at the Vaal River landfill site and the three WWTPs, which are the focus of this study, will likely be transported towards the southerly direction as well as the south-westerly quadrant. In terms of the baseline air quality monitoring and data, the 13 dustfall monitoring sites at the mine consist of 12 single-unit buckets and one multi-directional Gateway dust-watch station with four buckets. Three of the single unit buckets are classified as residential, while the other nine single unit buckets are classified as non-residential. The Gateway dust-watch buckets are classified as residential. For the period January 2021 – December 2021, dustfall rates range from 6.0 – 4560 mg/m^2/day, with four exceedances of the non-residential limit of 1200 mg/m^2/day recorded at the site identified as East of Kopanang TSF, and no exceedances of the residential limit of 600 mg/m^2/day recorded. The four exceedances were recorded in September, October, November and December 2021. The dustfall rates recorded at the mine mostly comply with the South African National Dust Control Regulations at all monitoring sites except at the bucket located east of the Kopanang TSF.

Landfill gas (including HAPs), dust and odour are identified as the key pollutants of concern associated with operational activities at the Vaal River landfill site, while ammonia, volatile organic compounds (VOCs), which include acetone, chloroform, phenol, benzene, toluene and methanol, hydrogen sulphide (H_2S) and odour are identified as the key pollutants of concern associated with operational activities at the WWTPs and are emitted from the following key sources:

Landfill Site Emission Sources:

- Landfill gas emissions (consisting of a mixture of pollutants) due to:
    - anaerobic decomposition of solid matter mainly generated from the biodegradation of the organic matter contained within the waste,
    - general landfill activities such as active tipping of fresh waste and exposed areas of waste.
- Emissions of Hydrogen Sulphide (H_2S) from leachate dams, if leachate dam is available.
- Odour emissions associated with overall landfilling activities.
- Dust emissions from:
    - Vehicle dust entrainment from the movement of trucks on unpaved roads onsite (in and around active Cells),
    - wind erosion of exposed surfaces (exposed waste at active Cell's workface and stockpiling of daily cover material),
    - compacting of waste at the active Cell's workface,
    - material handling (loading and offloading material from trucks).

Waste Water Treatment Plants Emission Sources:

- Odour emissions associated with overall waste water treatment activities;
- Aeration during primary treatment;
- Aerobic digestion;
- Anaerobic digestion; and
- Sludge drying.

The anticipated impact of activities at the WWTPs and the landfill site will be quantitatively assessed through dispersion modelling and presented in the final Level 2 AQIAr. This will include an assessment of landfill gas emissions passively vented to the atmosphere over the Cell surface area, odour emissions associated with overall landfilling activities (i.e. passive emissions over landfill, the compacting of waste at the cell workface, tipping of waste, exposed fresh waste at truck waiting areas and potentially emissions from the leachate dam), odour emissions associated with overall waste water treatment activities (primary and secondary clarification, anaerobic digestion, sludge drying beds, etc), and waste water treatment gas emissions (consisting of several pollutants).

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LIST OF ABBREVIATIONS

AEL	Atmospheric Emissions License
AQIAr	Air Quality Impact Assessment Report
AQMS	Air Quality Monitoring Station
AQMP	Air Quality Management Plan
CH_4	Methane
CL_2	Chlorine
CO	Carbon Monoxide
CO_2	Carbon Dioxide
$CO_{2\text{-eq}}$	Carbon dioxide equivalent
DEA	Department of Environmental Affairs
DFFE	Department of Forestry, Fisheries and the Environment
EA	Environmental Authorisation
EMP	Environmental Management Programme/Plan
H_2S	Hydrogen Sulphide
HF	Hydrogen Fluoride
GHG	Greenhouse gas
GMT	Greenwich Meridian Time
MES	Minimum Emission Standard
N_2O	Nitrous Oxide
NAAQS	National Ambient Air Quality Standards
NAEIS	National Atmospheric Emissions Inventory System
NEM:AQA	National Environmental Management Air Quality Act
NEMA	National Environmental Management Act
NH_3	Ammonia
NO_2	Nitrogen Dioxide
NO_x	Nitrogen Oxides
O_3	Ozone
PBL	Planetary Boundary Layer
PFC	Perfluorocarbons
PM_{10}	Particulate Matter, aerodynamic diameter equal to or size less than 10µm
$PM_{2.5}$	Particulate Matter, aerodynamic diameter size equal to or less than 2.5µm
PRIME	Plume Rise Model Enhancements
SAAQIS	South African Air Quality Information System
SAAELIP	South African Atmospheric Emission Licensing & Inventory Portal
SAGERS	South African Greenhouse Gas Emissions Reporting System
SF_6	Sulphur hexafluoride
SO_2	Sulphur Dioxide
SUP	South Uranium Plant
USEPA	United States Environmental Protection Agency

VOCs	Volatile Organic Compounds
WWTPs	Waste Water Treatment Plants
WRD	Waste Rock Dump

1. INTRODUCTION

Rayten Engineering Solutions (Pty) Ltd was appointed by Harmony Gold Mining Company – Moab Khotsong Operations (referred to as Moab Khotsong herein) to compile an Air Quality Impact Assessment report (AQIAr) for their existing waste water treatment plants (WWTPs) and a landfill site located in the North-West and Free State Provinces.

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Three existing WWTPs and one landfill site are associated with the Moab Khotsong operations. The WWTPs are used for treatment of effluent from processing operations and ablution facilities at the mine and include the 3#, 8# and 11# WWTPs, which serve the off-mine services Orkney surface operations, Great Noligwa operations, and Moab Khotsong shaft operations, respectively. The landfill site is known as the Vaal River landfill site and accepts non-hazardous general waste comprising of builders' rubble, domestic waste, municipal waste, commercial waste, industrial waste and general waste from nearby properties, a village, offices, Moab Khotsong and Great Noligwa shafts, HD residences (hostels), workshops, as well as the South Uranium and Noligwa gold plants. As such the landfill site is classified as a Class B waste disposal facility (specifically, G:S:B-)

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The main objective of the AQIAr is to determine the potential impact of emissions associated with the operational activities at the WWTPs and the landfill site on ambient air quality in terms of dustfall, hazardous air pollutants (HAPs), VOCs, and odorous gases.

As part of the AQIA for Moab Khotsong Operations, a baseline air quality assessment was undertaken through a review of meteorological monitoring data, available air quality monitoring data, air quality legislation and the identification of nearby sensitive receptors and existing emissions sources surrounding the project site. The potential impact of emissions from the operational activities associated with the WWTPs and the landfill on air quality is evaluated through the compilation of an emissions inventory and subsequent dispersion modelling simulations using AERMOD. Comparison of predicted concentrations for benzene and dustfall is made with the South African National Ambient Air Quality Standards (NAAQS) (DEA, 2009 and 2012) and the South African National Dust Control Regulations (DEA, 2013) where applicable. There are no South African NAAQS for many of the pollutants assessed in this study. Therefore, comparisons were also made with various international air quality guidelines to determine compliance.

1.1. Project Details

Client	Moab Khotsong Operations (Harmony Gold Mining Company)
Co-ordinates (centre of landfill)	26.97778°S 26.76667°E
Municipality and Province	Fezile Dabi District Municipality, Free State Province.
AEL number	AEL/FS/MKO-HGM/14/10/2019F
Designated Air Quality Priority Area	N/A – the facility does not fall within a Nationally Declared Air Quality Priority Area
Modelling contractor	Rayten Engineering Solutions (Pty) Ltd *Gertrude Mafusire (MPhil.)* *Snr Air Quality Specialist* *5.3 years working experience* *0117920880* *info@rayten.co.za*

1.2. Brief Project Description

Moab Khotsong operations comprise of gold and uranium processing plants, a TSF complex, a waste rock dump (WRD) and two mine shafts as follows:

- Noligwa and Mispah Gold Plant;
- South Uranium Plant;
- Great Noligwa Shaft;
- Moab Shaft and WRD;
- Mispah 1 & 2 TSFs and Kopanang TSF.

In addition to the above-mentioned operations, there are off-mine services near Orkney, i.e. at the Orkney surface operations. Furthermore, three existing WWTPs and one landfill site are associated with the Moab Khotsong operations. The WWTPs are used for treatment of effluent from processing operations and ablution facilities at the mine and include the 3#, 8# and 11# WWTPs, which serve the off-mine services Orkney surface operations, Great Noligwa operations, and Moab Khotsong shaft operations, respectively. The landfill site is known as the Vaal River landfill site and accepts non-hazardous general waste comprising of builders' rubble, domestic waste, municipal waste, commercial waste, industrial waste and general waste from nearby properties, a village, offices, Moab Khotsong and Great Noligwa shafts, HD residences (hostels), workshops, as well as the South Uranium and Noligwa gold plants. As such the landfill site is classified as a Class B waste disposal facility.

<u>Landfill Site Process Description</u>

At the landfill site, waste is received daily during weekdays and on Saturdays by means of several types of trucks. The access road used by the trucks is unpaved but covered with gravel and treated for dust suppression regularly using a dedicated water truck. Once waste has been offloaded near the workface within the Daily Cell of the Active Cell, the waste is sorted and spread against the workface to a pre-set and specific maximum thickness. A mechanised 30T waste compactor then moves up and down of the working face while spreading the waste to ensure compaction to a specified target density. Once the waste has been compacted, daily cover material is deposited above the working face using a tipper truck, for it to be pushed across the compacted waste to cover the waste as soon as possible. The daily cover material is stockpiled on site prior to being used to cover waste. Methane gas extracted from the landfill is released into the atmosphere via five methane gas ventilation pipes. The gas released at each ventilation pipe outlet is measured using a methane monitor to evaluate the levels and migration of methane generated in the landfill body.

The landfill site is designed to accept an average of 57.53 tonnes of waste per day (estimated based on May 2022 landfill data provided by the mine), with an expected total operational life similar to the operational life of the mine, i.e. 44 years maximum, if the Zaaiplaats extension is considered for the mining operations. Thus, this study is based on an operational throughput of 57.53 tonnes/day for 44 years.

Waste Water Treatment Plants Process Description

At the WWTPs, once the raw sewage has been received, it undergoes three main stages of treatment, which include primary, secondary and tertiary treatment. Primary treatment involves the removal of material that will either float or readily settle out by gravity and includes removal of screenings, comminution, grit removal and sedimentation. Secondary treatment involves the removal of biodegradable organic matter in solution or suspension from sewage or waste water, with the aim of achieving a good effluent quality suitable for re-use or disposal. Tertiary treatment is an advanced treatment process after the secondary treatment of waste water and it produces high quality water. It includes the removal of harmful substances such as inorganic compounds, bacteria, viruses, and parasites, thus, making the water safe to re-use, recycle or release into environment. The waste water treatment stages can be summarised as follows:

- Daily recording of flow figures and on-site tests;
- Removal of screenings and grit from inlet work;
- Withdrawal of raw sludge from primary sedimentation tank and transfer to digestors;
- Removal of scum from water surface in primary sedimentation tank;
- Withdrawal of humus sludge from humus tank and removal of scum from water surface;
- Brushing of primary sedimentation tanks, humus tank, clarifier and bio-filter channels;
- Unblocking of water holes on bio-filtration arms;
- Disconnecting and connecting of chlorine gas cylinders;
- Testing of free chlorine in final effluent;
- Withdrawal of sludge from digestors/clarifier to drying beds; and
- Removal of dry sludge from drying beds.

The 3#, 8# and 11# WWTPs are designed to treat of 4600m^3, 12240m^3 and 2400m^3 of waste water per day but do not operate at maximum capacity. Thus, this study is based on actual operational throughputs of 1000 m^3, 3500m^3 and 600 m^3 for the 3#, 8# and 11# WWTPs, respectively.

The focus of this study is on operational activities associated with the landfill site and WWTPs only. The mining operations and processing plant activities fall outside of the scope of this study but were assessed in the 2020 AQIAr compiled for the mine by Rayten. Thus, the key sources of emissions at the Vaal River landfill site and at the three WWTPs, which have been taken into consideration in this study, include:

Landfill Site Emission Sources:

- Landfill gas emissions (consisting of a mixture of pollutants) due to:
  - anaerobic decomposition of solid matter mainly generated from the biodegradation of the organic matter contained within the waste,
  - general landfill activities such as active tipping of fresh waste and exposed areas of waste.
- Emissions of Hydrogen Sulphide (H_2S) from leachate dams, if leachate dam is available.
- Odour emissions associated with overall landfilling activities.
- Dust emissions from:
  - Vehicle dust entrainment from the movement of trucks on unpaved roads onsite (in and around active Cells),
  - wind erosion of exposed surfaces (exposed waste at active Cell's workface and stockpiling of daily cover material),
  - compacting of waste at the active Cell's workface,
  - material handling (loading and offloading material from trucks).

Waste Water Treatment Plants Emission Sources:

- Odour emissions associated with overall waste water treatment activities;
- Aeration during primary treatment;
- Aerobic digestion;
- Anaerobic digestion; and
- Sludge drying.

A site layout diagram for the mine, which shows the location of the landfill site and the WWTPs, is given in Figure 1-1, and basic process flow diagrams for the three WWTPs are given in Figure 1-2 below.

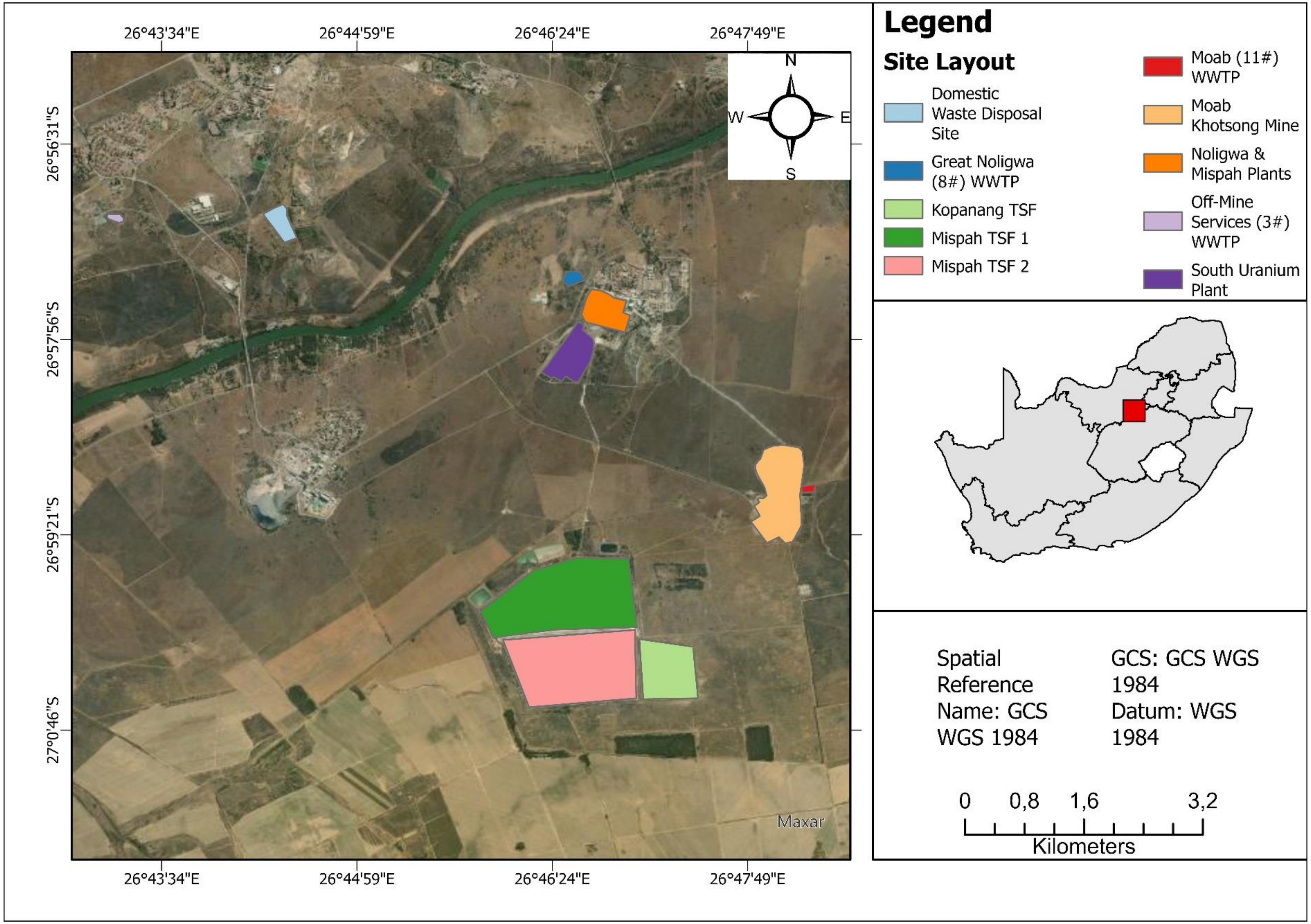


Figure 1-1: Moab Khotsong Operations site layout diagram.

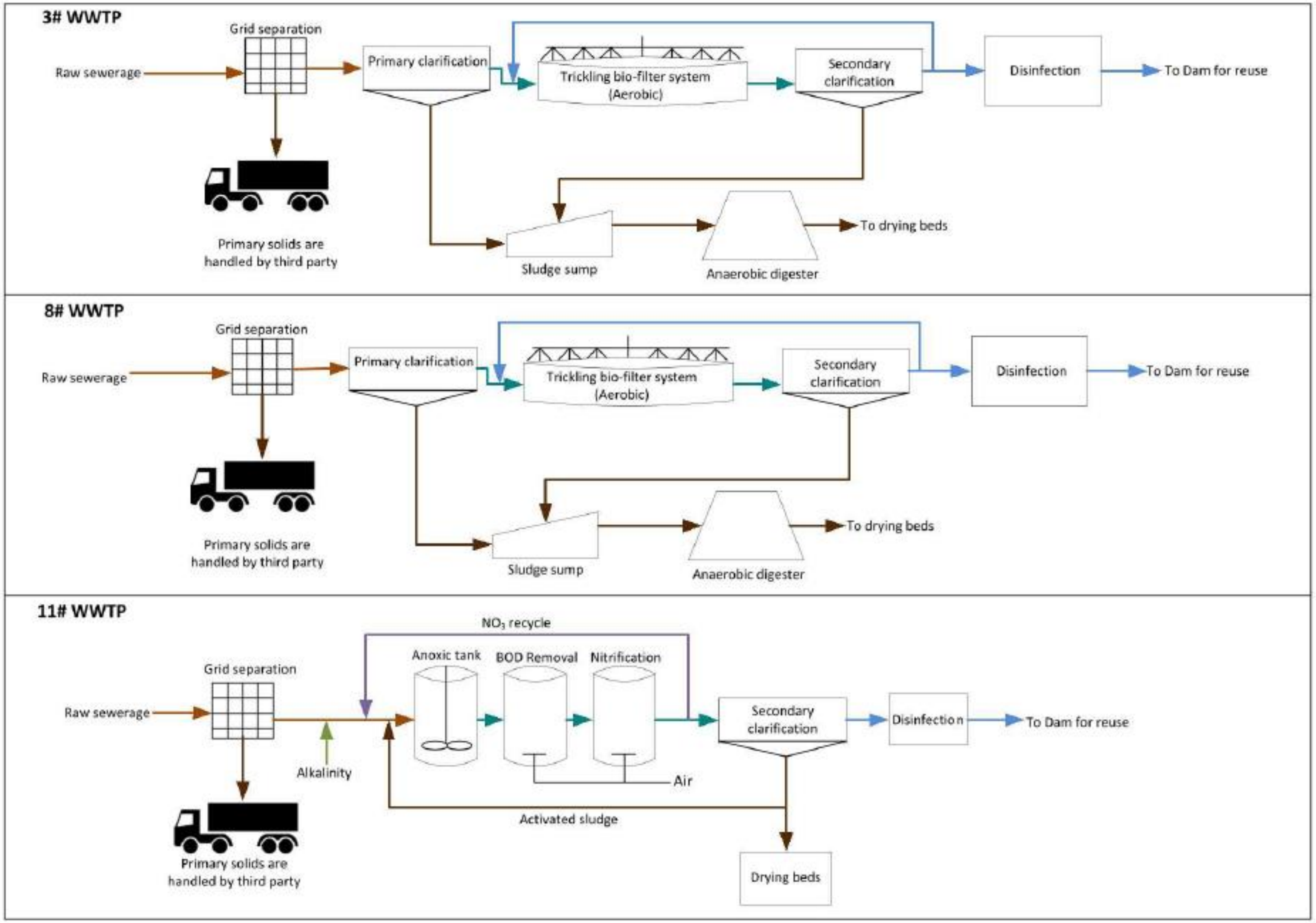


Figure 1-2: Process flow diagrams for the three Waste Water Treatment Plants.

1.3. Terms of Reference

The scope of work for the Baseline Air Quality Assessment is as follows:

- A review of the study site and existing activities;
- An overview of the prevailing meteorological conditions in the area which influence the dilution and dispersion of pollutants in the atmosphere;
- The identification of existing sources of emissions;
- The identification of key air pollutants of concern that may be emitted from WWTPs and landfill activities;
- Characterisation of the ambient air quality within the area using available air quality monitoring data;
- A review of the current South African legislative and regulatory requirements for air quality; and
- The identification of sensitive receptors, such as local communities, surrounding the study area.

1.4. Outline of Report

An overview of the facility, site location including surrounding receptors is given in **Section 1**. National Ambient Air Quality Standards, dust control regulations and associated health impacts for the relevant criteria pollutants are discussed in **Section 3**. An overview of landfill gas and WWTPs emissions, including associated health and odour impacts are provided in **Section 4**. The local meteorological conditions and baseline air pollutants concentrations are provided in **Section 5**. Potential emissions associated with proposed operations are outlined in **Section 6**, with the report summary presented in **Section 7**.

2. SITE CHARACTERISTICS

2.1. Site Location

Moab Khotsong, including associated Tailings Storage Facilities (TSFs), processing plants, WWTPs and the landfill site are located 7 – 15km south-east of Klerksdorp, within the North-West and Free State Provinces (Figure 2-1). The site is located within a predominantly agricultural area. The Vaal River runs north of the site. A number of accommodation facilities are located within 20km of the site. The towns of Orkney, Stilfontein, Klerksdorp and Vierfontein are situated 8km west, 12km north, 10km north-west and 12km south of the mine and processing plants, respectively.

2.2. Surrounding Land Use

The land use immediately surrounding the project site, which comprises of Moab Khotsong mine, the landfill and WWTPs, consists predominantly of grassland and agricultural/cultivated land use types (Figure 2-2). Localised mining areas, which include existing mines and TSFs; and urban residential, informal and smallholding areas are in near proximity north and north-west of the plant. The larger area surrounding the project site is characterised as rural in nature.

2.3. Topography

The topography surrounding the project site is shown in Figure 2-3 below. Moab Khotsong are situated 1315m above sea level and surrounding elevations range from approximately 1222 - 1648m above sea level. Higher topographical features are observed in near proximity south, south-east and north-north-west of the project site.

2.4. Sensitive Receptors

A sensitive receptor is defined as a person or place where involuntary exposure to air pollutants released by the site's activities could occur. Identified sensitive receptors, which are located within 20km from the project site are given in Figure 2-4 below.

The discrete receptors detailed in Table 2-1 below, will be used for modelling purposes. Maximum predicted incremental concentrations will be provided for the identified discrete receptors. These points are located at the centre of residential areas, or near schools, hospitals, old age homes, small-holdings and farms, etc in order to determine the maximum concentrations that could be expected near sensitive receptors. Discrete points are not plotted for each individual sensitive receptor but are used to represent a group of sensitive receptors located near to each other (e.g. several schools).

Table 2-1: Discrete receptors within 20 km of Moab Khotsong Operations. Receptors were identified through a desktop study.

Discrete Receptor ID	Discrete Receptor Name	Co-ordinates		Elevation (m)
		X (m)	Y (m)	
DR1	Educational Facility/Dwellings	472287.00	7019319.00	1311.32
DR2	Orkney/Dwellings	466143.00	7016172.00	1303.47
DR3	Klerksdorp	466383.00	7025997.00	1314.13
DR4	Stilfontein	477480.00	7030808.00	1349.04
DR5	Rietfontein/Educational Facility	477759.00	7003185.00	1345.23
DR6	Klerksdorp/ Educational Facility/Farmhouses	467412.00	7028873.00	1313.17
DR7	Dwellings/Educational Facility	480136.00	7028204.00	1327.81
DR8	Khuma/Educational Facility	485966.00	7030237.00	1331.40
DR9	Orkney Golf Club	467948.00	7014095.00	1296.95
DR10	Dwellings/Educational Facility	473863.00	7020706.00	1325.35
DR11	Dwellings	492020.00	7008833.00	1311.80
DR12	Dwellings	492749.00	7017968.00	1301.75
DR13	Dwellings	471732.00	7004513.00	1327.76
DR14	Dwellings	485607.00	7003739.00	1336.58
DR15	Educational Facility/Dwellings	474526.00	6998337.00	1367.58
DR16	Dwellings	497666.00	7009191.00	1316.19
DR17	Educational Facility	473095.00	7005110.00	1313.74
DR18	Educational Facility	469901.00	7005579.00	1336.32
DR19	Educational Facility	475690.00	7010193.00	1327.05
DR20	Educational Facility	475106.00	6997619.00	1365.50
DR21	Educational Facility	475443.00	6997405.00	1363.42
DR22	Educational Facility	470598.00	6998714.00	1357.52
DR23	Educational Facility	496896.00	7007635.00	1326.53
DR24	Educational Facility	490461.00	7017336.00	1310.34
DR25	Educational Facility	492189.00	7020589.00	1305.13

Discrete Receptor ID	Discrete Receptor Name	Co-ordinates		Elevation (m)
		X (m)	Y (m)	
DR26	Dwellings	492609.00	7020866.00	1303.62
DR27	Educational Facility	495017.00	7017729.00	1312.35
DR28	Educational Facility	496556.00	7025819.00	1310.42
DR29	Educational Facility	477403.00	7029772.00	1357.85
DR30	Educational Facility	462547.00	7017087.00	1305.66
DR31	Health Facility	467615.00	7017525.00	1317.91
DR32	Health Facility	464312.00	7017436.00	1298.25
DR33	Klerksdorp Hospital	466497.00	7027142.00	1313.67
DR34	Health Facility	466378.00	7028251.00	1305.90
DR35	Educational Facility	468487.00	7015367.00	1313.95
DR36	Educational Facility	475470.00	7032141.00	1367.76
DR37	Jouberton/Educational Facility	459805.81	7026214.71	1355.44
DR38	Muzimuhle Village	472235.14	7019553.80	1290.00
DR39	8# Hostel	478216.59	7018290.61	1301.00

Notes:
* Educational facility = schools, nursery, creches, training centres, educational centres, colleges, universities, etc.
* Healthcare facility = doctors' rooms, hospital, clinics, etc.
* Dwellings = houses, infrastructure, buildings, warehouses, informal houses, farmhouses, etc.

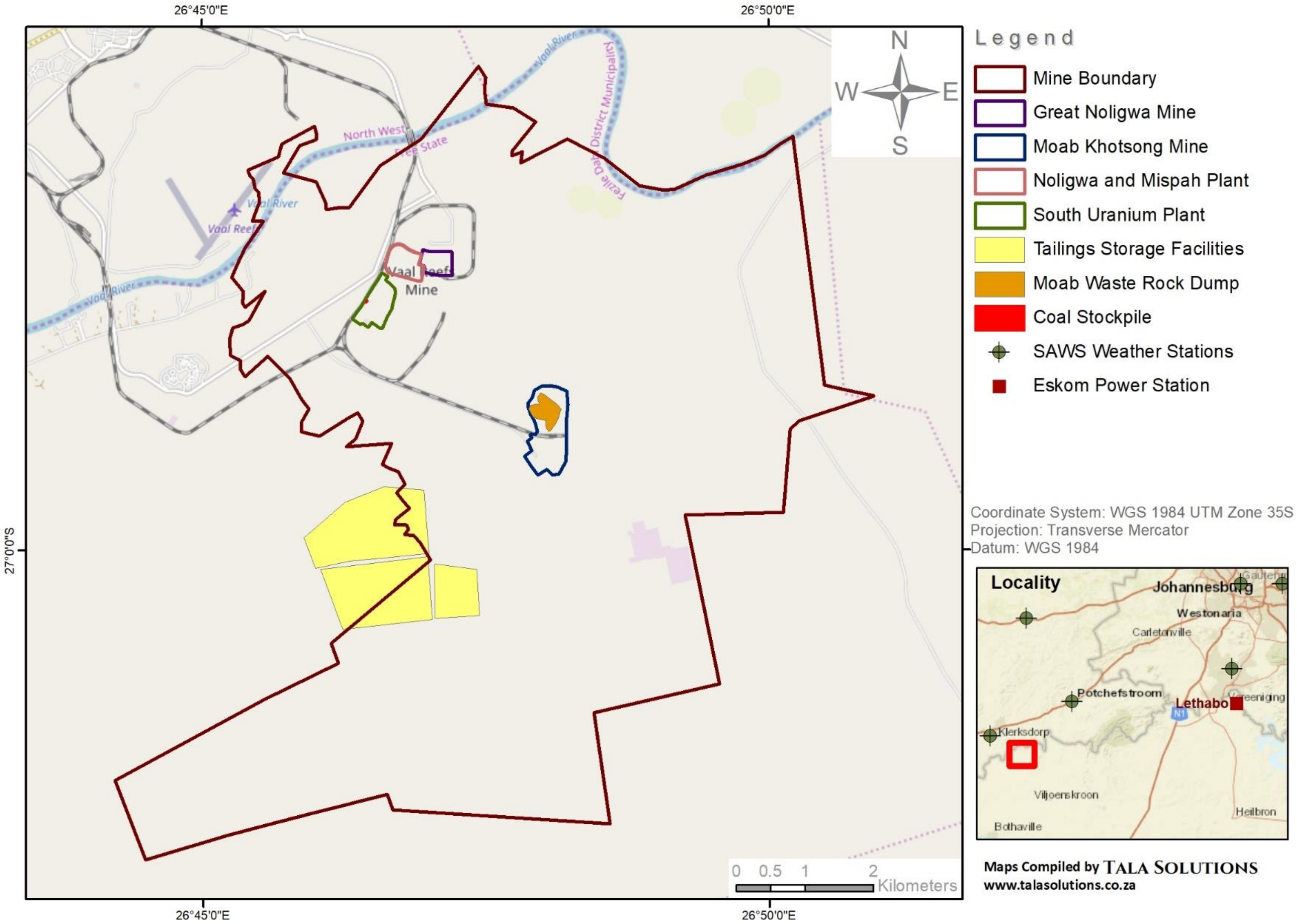


Figure 2-1: Site locality for Moab Khotsong Operations.

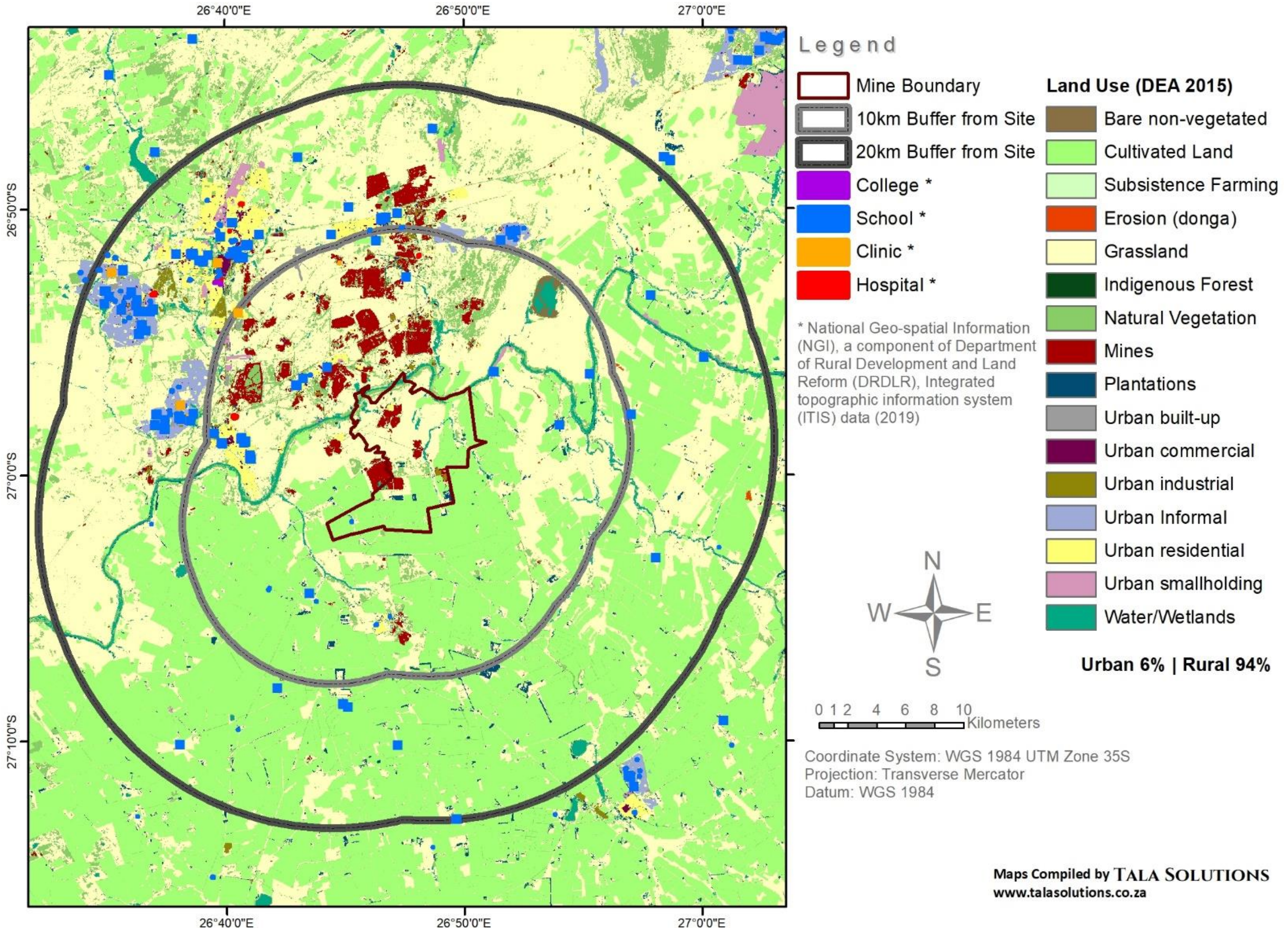


Figure 2-2: Land use surrounding Moab Khotsong Operations.

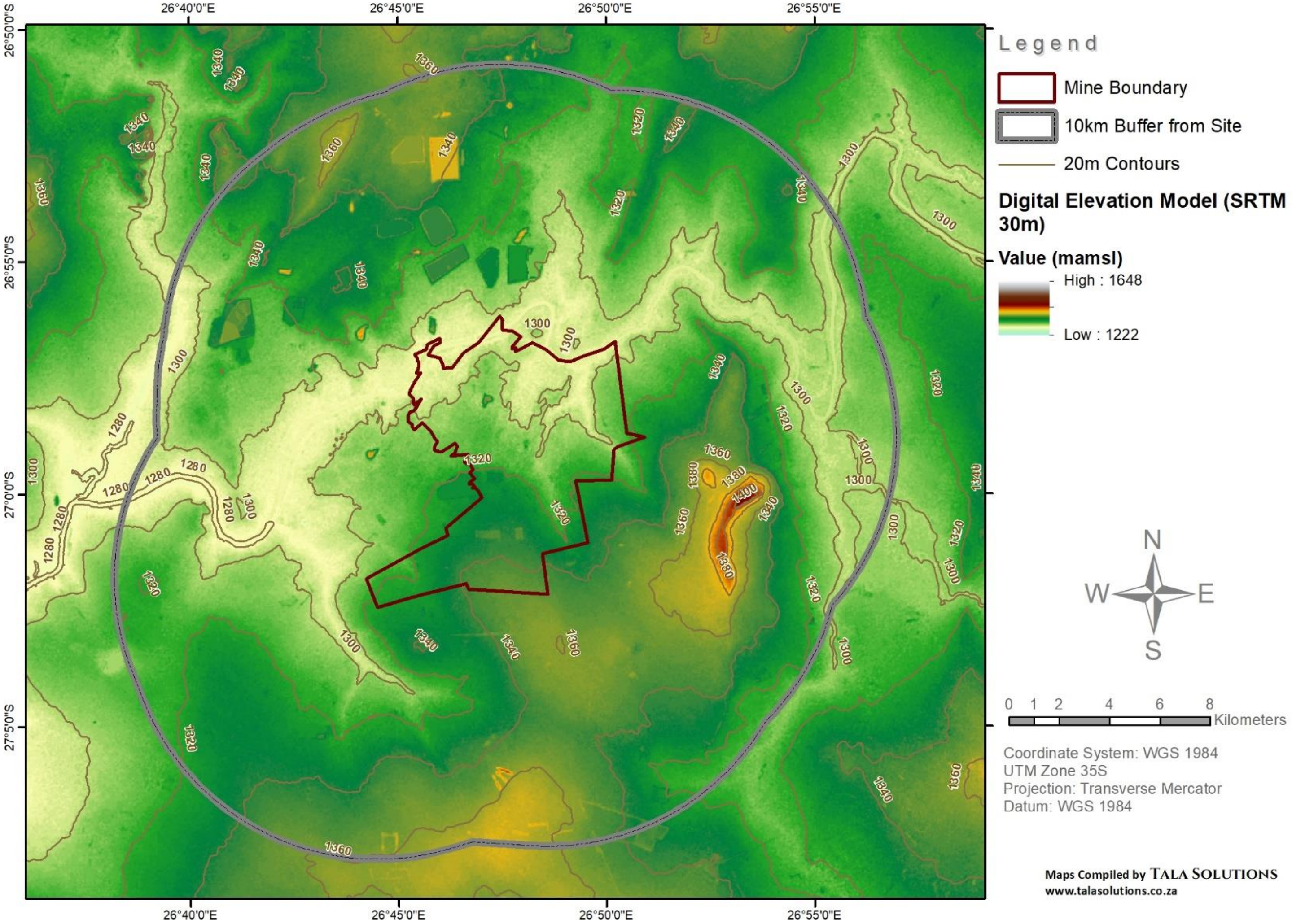


Figure 2-3: Digital elevation surrounding Moab Khotsong Operations.

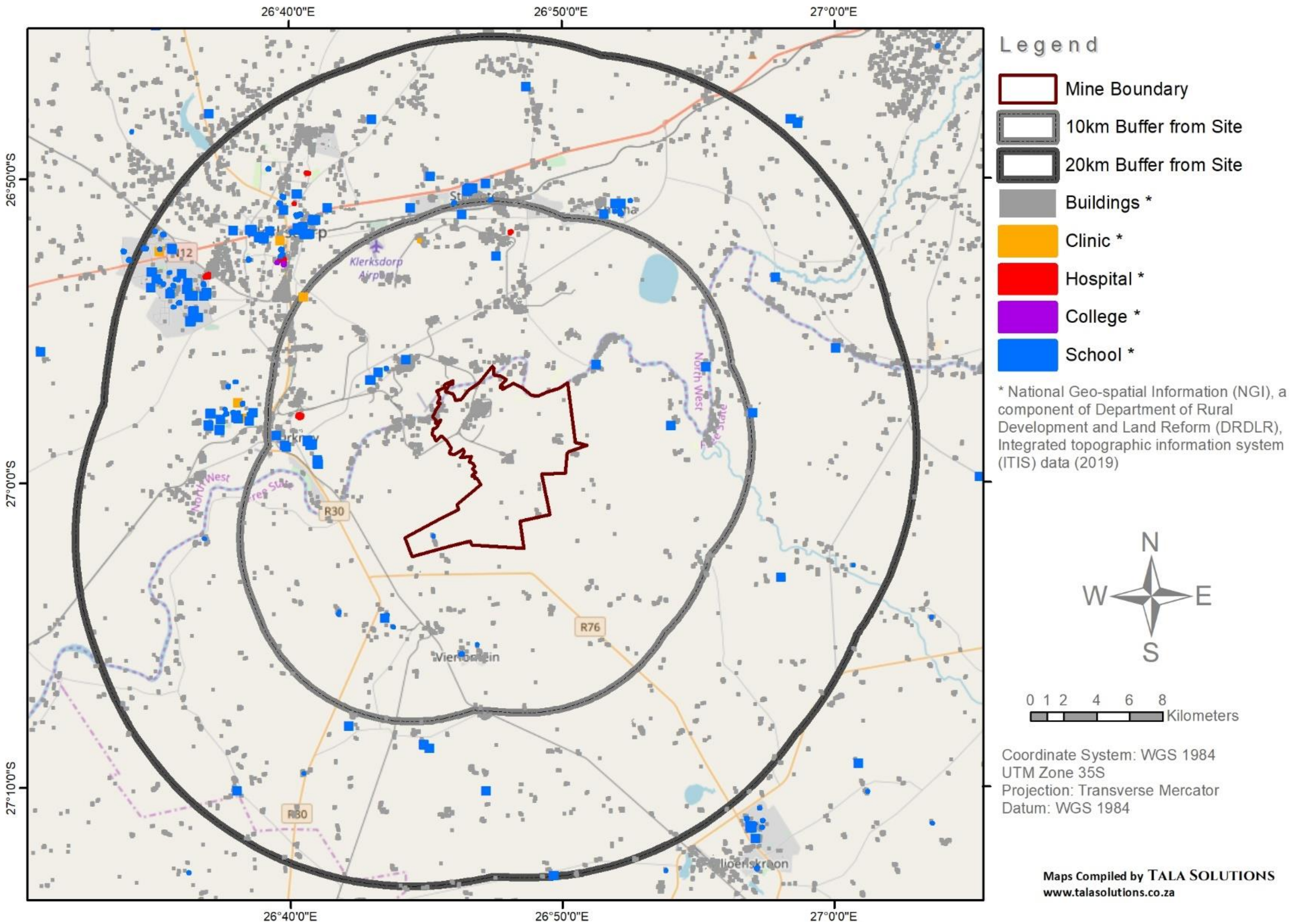


Figure 2-4: Sensitive receptors surrounding Moab Khotsong Operations.

3. LEGISLATION

3.1. National Environmental Management: Air Quality Act (NEM:AQA)

The NEM:AQA, has shifted the approach of air quality management from source-based control to receptor-based control. The main objectives of the Act are to;

- to protect the environment by providing reasonable measures for—
  i. the protection and enhancement of the quality of air in the Republic;
  ii. the prevention of air pollution and ecological degradation; and
  iii. securing ecologically sustainable development while promoting justifiable economic and social development; and
- generally to give effect to section 24(b) of the Constitution in order to enhance the quality of ambient air for the sake of securing an environment that is not harmful to the health and wellbeing of people.

The Act makes provisions for the setting and formulation of NAAQS for “substances or mixtures of substances which present a threat to health, well-being or the environment”. More stringent standards can be established at the provincial and local levels.

The control and management of emissions in the NEM:AQA relates to the listing of activities that are sources of emissions and the issuing of AELs. Listed activities are defined as activities which “result in atmospheric emissions and are regarded as having a significant detrimental effect on the environment, including human health”. Listed activities were identified by the Department of Environmental Affairs (DEA), now known as the Department of Forestry, Fisheries and the Environment (DFFE)), and atmospheric emission standards have been established for each of these activities. These listed activities require an AEL to operate. The issuing of AELs for listed activities will be the responsibility of the Metropolitan and District Municipalities, except for those associated with mining operations. The Department of Fisheries, Forestry and the Environment (DFFE) is responsible for the issuing of AELs for listed activities associated with mining operations or government owned facilities.

In addition, the Minister may declare any substance contributing to air pollution as a priority pollutant. Any industries or industrial sectors that emit these priority pollutants will be required to implement a Pollution Prevention Plan. Municipalities are required to “designate an air quality officer to be responsible for co-ordinating matters pertaining to air quality management in the Municipality”. The appointed Air Quality Officer is responsible for the issuing of AELs.

3.2. Listed Activities and Minimum Emission Standards

The NEM: AQA requires all persons undertaking listed activities in terms of Section 21 of the Act to obtain an AEL. The listed activities and associated minimum emission standards were issued by the DEA on 31 March 2010 (Government Gazette No. 33064 of 31 March 2010) and were amended in:

- 2013 (Government Gazette No. 37054 of 22 November 2013)
- 2015 (Government Gazette No. 38863 of 12 June 2015)
- 2018 (Government Gazette No.41650 of 25 May 2018; Government Gazette No.42013 of 31 October 2018)
- 2019 (Government Gazette No.42472 of 22 May 2019)

- 2020 (Government Gazette No 43174 of 27 March 2020)

Moab Khotsong have an AEL (No. AEL/FS/MKO-HGM/14/10/2019F), which expires on 30 January 2026. The AEL authorises them to conduct the following two listed activities: Category 4 (Metallurgical Industries):

- Sub-category 4.1 Drying and calcining)
- Sub-category 4.17 (Precious and base metal production and refining)

Please refer to Table 3-1 and Table 3-2 for the emission limits associated with the applicable listed activities. Moab Khotsong are required to comply with emission limits for new plants from 01 April 2020.

Table 3-1: Sub-category 4.1 (drying and calcining).

Category 4: Metallurgical Industry

(1) *Subcategory 4.1: Drying and Calcining*

Description:	Drying and calcining of mineral solids including ore.		
Application:	Facilities with capacity of more than 100 tons/month product.		
Substance or mixture of substances		**Plant status**	**mg/Nm^3 under normal conditions of 273 Kelvin and 101.3 kPa.**
Common name	**Chemical symbol**		
Particulate matter	N/A	New	50
		Existing	100
Sulphur dioxide	SO_2	New	1000
		Existing	1000
Oxides of nitrogen	NO_X expressed as NO_2	New	500
		Existing	1200

Table 3-2: Sub-category 4.17 (precious and base metal production and refining).

Description:	The production or processing of precious and associated base metals through chemical treatment (Excluding Inorganic Chemicals-related activities regulated under Category 7).		
Application:	All installations		
Substance or mixture of substances		Plant status	mg/Nm^3 under normal conditions of 273 Kelvin and 101.3 kPa.
Common name	Chemical symbol		
Particulate matter	N/A	New	50
		Existing	100
Chlorine	Cl_2	New	50
		Existing	50
Sulphur dioxide	SO_2	New	400
		Existing	400
Hydrogen chloride	HCl	New	30
		Existing	30
Hydrogen fluoride	HF	New	30
		Existing	30
Ammonia	NH_3	New	100
		Existing	100
Oxides of nitrogen	NO_X expressed as NO_2	New	300
		Existing	500

There is no incineration of any of the waste received at the Vaal River landfill site. Furthermore, there are no combustion sources or material processing activities (needing heat or chemical reactions) associated with the landfill site. Only landfilling activities are currently being undertaken at the landfill site, with the landfill only accepting general waste material considered to be non-hazardous. At the WWTPs, there are no combustion sources and the treatment of waste water utilises biological processes only, with no processing activities needing heat or chemical reactions occurring during waste treatment. Additionally, the WWTPs and landfill site do not store large quantities of chemicals or fuel products. Based on the current information as well as the WWTPs and landfill site designs, the Vaal River general waste disposal facility and WWTPs do not trigger any of the listed activities in terms Section 21 of the NEM:AQA and are therefore not required to obtain an AEL. However, Moab Khotsong have a Waste Management Licence, which authorises operational activities associated with the landfill site and the WWTPs.

South Africa launched an online national reporting system, referred to as the National Atmospheric Emissions Inventory System (NAEIS). The NEM:AQA requires all emission source groups identified in terms of the National Atmospheric Reporting Regulations (Government Gazette No. 38633 of 02 April 2015), to register and report emissions on the NAEIS. Moab Khotsong are classified as Group C emitters and also trigger Group A (i.e. Section 21 listed activities) and Group B (S23 controlled emitters) and are thus required to report annually (by 31 March each year) on the NAEIS and comply with the National Atmospheric Reporting Regulations. It should be noted that Moab Khotsong have already registered on NAEIS.

The landfill site and WWTPs do not fall within any of the groups (Group A - D) listed under Annexure 1 of the regulations. Group D under Annexure 1 states that emitting facilities identified in terms of municipal air quality by-laws are required to report on the NAEIS but at present, landfills and WWTPs are not listed as a controlled activity in the applicable air quality by-laws. However, landfills and

WWTPs may be required to report their Greenhouse Gas (GHG) emissions on the South African Greenhouse Gas Reporting System (SAGERS) in terms of the National GHG Reporting Regulations (refer to Section 3.3 for more details).

3.3. Greenhouse Gas (GHG) Emissions

On 14 March 2014, the DEA (now known as the DFFE) (Government Gazette No. 37421 of 14 March 2014), declared the following six GHGs as priority air pollutants in South Africa:

- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous Oxide (N_2O)
- Hydrofluorocarbons (HFCs)
- Perfluorocarbons (PFCs)
- Sulphur hexafluoride (SF_6)

National GHG Emission Reporting Regulations (Government Gazette No. 40762 of 3 April 2017), as amended (General Notice 994 in Government Notice 43712 of 11 September 2020), were published by the DEA (now known as the DFFE). A person identified as a Category A data provider in terms Annexure 1 of these regulations, must register their facilities using the online South African GHG Reporting System (SAGERS) and must submit a GHG emissions inventory, activity data and report in the required format given under Annexure 3 of these regulations on an annual basis. All data must be provided annually, by the 31 March of the following year. The NEM:AQA and the National GHG Emission Reporting Regulations, establish the legislative framework for the national GHG reporting system in South Africa.

Moab Khotsong operations fall under categories 1A2b (Non-Ferrous Metals), 1A2i (i.e. Mining and Quarrying), 4A1 (Managed Waste Disposal Sites) and 4D1 (Domestic Wastewater Treatment and Discharge) in terms of Annexure 1 of the National GHG emission reporting regulations (Government Gazette No. 40762 of 3 April 2017), as amended (General Notice 994 in Government Notice 43712 of 11 September 2020). The mine has registered on the SAGERS and reports on their GHG emissions by the 31 March of every year.

National Pollution Prevention Plans

National Pollution Prevention Plan Regulations (Gazette No. 40996) were published on 21 July 2017 by the DEA (now known as DFFE). A pollution prevention plan will be required should the development do the following:

a) Undertake any of the following activities identified in Annexure A of the National GHG Emission Reporting Regulations (Government Gazette No. 40762 of 3 April 2017), which involves the direct emission of GHG in excess of **0.1 Megatonnes (Mt)** annually measured as carbon dioxide equivalents ($CO_{2\text{-eq}}$); or
b) Undertake any of the following activities identified in Annexure A of the National Pollution Prevention Plan Regulations (Gazette No. 40996 of 21 July 2017) as a primary activity, which involves the direct emission of GHG in excess of **0.1 Megatonnes (Mt)** annually measured as carbon dioxide equivalents ($CO_{2\text{-eq}}$);

Annexure A activities in terms of the National Pollution Prevention Plan Regulations include:

- Coal mining
- Production and /or refining of crude oil
- Production and/or processing of natural gas
- Production of liquid fuels from coal or gas
- Cement production
- Glass production
- Ammonia production
- Nitric acid production
- Carbon black production
- Iron & steel production
- Ferro-alloys production
- Aluminium production
- Polymers production
- Pulp and paper production
- Electricity production

Moab Khotsong may need to compile a Pollution Prevention Plan for the landfill site and WWTPs, should their total GHG emissions (in CO2-eq) exceed the 0.1 Mt threshold.

3.4. Carbon Tax

The Carbon Tax Act No. 15 of 2019 was promulgated on the 23 May 2019 and is implemented using a phased approach, allowing emitters time to transition to cleaner and more efficient technologies resulting in lower GHG emissions. In summary, the following key points are made:

- The initial carbon tax rate is set at R120/ tonne $CO_{2\text{-eq}}$, however different percentage-based tax-free thresholds will apply, which can make the effective tax rate lower, ranging between R6 – R48 per tonne of $CO_{2\text{-eq}}$. To allow for business to transition to a low carbon economy within the first phase (June 2019 to Dec 2022), a basic percentage-based threshold of 60% will apply which is not taxable. The following additional percentage-based tax-free thresholds will also apply:
    - 10% for process emissions;
    - Up to a maximum of 10% for trade exposed sectors;
    - Up to a maximum of 5% for performance-based emissions against intensity benchmarks (benchmarks have not been developed yet);
    - Up to 5% or 10% for carbon offsets (depending on sector);
    - 5% for companies participating in phase one of the carbon budgeting system;
    - The combination of the above-mentioned threshold will be capped at 95%.
- Liable entities will include those who are listed in Schedule 2 of the Carbon Tax Act. Agriculture and waste land use sectors are excluded from the tax base in phase one (June 2019 to Dec 2022), due to the complexity in measuring emissions.

Carbon offsets can be used to reduce tax liability up to 5% or 10% depending on the sector. On 29 November 2019, the South African National Treasury published the regulations for carbon offsets. The regulation outlines the suitability of offset projects and the procedure which is required to be followed in claiming the offset allowance.

Agriculture and waste land use sectors are excluded from the tax base in phase one, due to the complexity in quantifying emissions. As such it is unlikely that Moab Khotsong will be liable to pay any carbon tax for the Vaal River landfill site and WWTPs up until the end of December 2022. However, this assumption is made solely based on the information known about the landfill site and the WWTPs and excludes any other GHG emitting activities that could potentially fall under the umbrella of the reporting company, Harmony Gold Mining (Pty) Ltd (i.e. other activities not related to the landfill site).

3.5. Ambient Air Quality Standards

National Ambient Air Quality Standards, including permitted frequencies of exceedance and compliance timeframes, were issued by the Minister of Water and Environmental Affairs on 24 December 2009 (Table 3-3). National standards for $PM_{2.5}$ were established by the Minister of Water and Environmental Affairs on 29 June 2012.

Criteria air pollutants are air pollutants that are commonly found in the atmosphere and are known to have a negative impact on human health and environmental quality. Ambient air quality standards have been developed for these common pollutants based on a form of criterion (like a standard), thus they are commonly referred to as criteria air pollutants. In South Africa we have ambient air quality standards for eight (8) criteria air pollutants as shown below.

Table 3-3: National Ambient Air Quality Standards for Criteria Pollutants.

POLLUTANT	AVERAGING PERIOD	CONCENTRATION (µg/m³)	FREQUENCY OF EXCEEDANCE(3)
Sulphur dioxide (SO_2)	10 minutes	500 (191)	526
	1 hour	350 (134)	88
	24 hours	125 (48)	4
	1 year	50 (19)	0
Nitrogen dioxide (NO_2)	1 hour	200 (106)	88
	1 year	40 (21)	0
Particulate Matter (PM_{10})	24 hours	75	4
	1 year	40	0
Particulate Matter ($PM_{2.5}$)	24 hours	40(1) 25(2)	0
	1 year	20(1) 15(2)	0
Ozone (O_3)	8 hours (running)	120 (61)	11
Benzene (C_6H_6)	1 year	5 (1.6)	0
Lead (Pb)	1 year	0.5	0
Carbon monoxide (CO)	1 hour	30 000 (26 000)	88
	8 hours (calculated on 1 hourly averages)	10 000 (8 700)	11

Notes:
*Values indicated in blue are expressed in PPB.
(1) Compliance required by 1 January 2016 – 31 December 2029.
(2) Compliance required by 1 January 2030.
(3) Refers to the number of times exceedances are permitted in a calendar year.

The only South African criteria air pollutants of concern associated with landfill site and WWTPs operations at Moab Khotsong include benzene, PM_{10} and $PM_{2.5}$. However, there are several other air pollutants which are not classified as criteria air pollutants in South Africa that will likely be emitted as part of the landfill and WWTPs gas emissions. These pollutants are considered hazardous air pollutants, commonly referred to as ''HAPs'', and are also known for their malodorous impacts. International guidelines and odour thresholds are available for these pollutants. More detailed information about these pollutants and their guidelines are given in Section 4.6.

3.6. Dust Deposition Standards

The DEA issued National Dust Control Regulations promulgated in Government Notice R517 of 2018, which came into effect on 1 November 2019 (Table 3-4). The purpose of the regulations is to prescribe general measures for the control of dust in all areas. The regulations prohibit activities which give rise to dust in such quantities and concentrations that the dust fall at the boundary or beyond the boundary of the premises where it originates exceeds:

a) 600 mg/m^2/day averaged over 30 days in residential areas measured using reference method ASTM D1739.
b) 1 200 mg/m^2/day averaged over 30 days in non-residential areas measured using reference method ASTM D1739.

Table 3-4: South African National Dust Control Regulations.

RESTRICTION AREAS	DUST FALLOUT RATE (D) (1)	REQUENCY OF EXCEEDANCE
Residential Areas	D < 600	Two within a year, no two sequential months (2)
Non-residential areas	600 < D < 1200	Two within a year, no two sequential months (2)
Notes: (1) Averaged over 1 month (30±2-day average) (mg/m^2/day) (2) Per dust fallout monitoring site.		

Any person who has exceeded the dust control standard must, within three months after submission of a dust fallout monitoring report, develop and submit a dust management plan to the air quality officer for approval. The dust management plan must:

a) Identify all possible sources of dust within the affected site;
b) Detail the best practicable measures to be undertaken to mitigate dust emissions;
c) Develop an implementation schedule;
d) Identify the line management responsible for implementation;
e) Incorporate the dust fallout monitoring plan;
f) Establish a register for recording all complaints received by the person regarding dust fall, and for recording follow up actions and responses to the complainants.

The dust management plan must be implemented within a month of the date of approval. An implementation progress report must be submitted to the air quality officer at agreed time intervals.

Activities at the WWTPs do not result in any dust emissions. In contrast, activities at the landfill site could result in significant dust emissions if mitigation measures are not implemented. Thus, it is recommended that Moab Khotsong continue to implement existing dust control measures at the landfill site to manage and mitigate dust emissions associated with the landfill operations. It must be noted that mitigation measures used for dust control are effective at reducing dust emissions to some extent, depending on control efficiencies associated with each dust control method (e.g. dust suppression using water sprays on haul roads, which is already practiced by Moab Khotsong, has a control efficiency of 50%). Identified fugitive dust sources associated with the Vaal River landfill site include vehicle dust entrainment on unpaved roads onsite, wind erosion from exposed surfaces (uncovered waste at active workface) and material handling operations, and can be easily managed through the implementation of dust mitigation measures, thereby significantly reducing associated fugitive dust emissions.

3.7. Controlled Emitters and Emission Standards

Small boilers were declared as controlled emitters in terms of Section 23 of the NEM:AQA, by the Minister of Water and Environmental Affairs on 01 November 2013 (Government Gazette No. 36973 of 01 November 2013). Further, associated emission standards were issued by the DEA (now known as DFFE) on 01 November 2013 (Government Gazette No. 36973 of 01 November 2013).

Any person that uses an appliance or conducts an activity which has been declared a controlled emitter in terms of S23 (1) of the Act must:

- register the controlled emitters with the relevant authority;
- submit at least one emissions report per annum to the relevant air quality officer in the format set out in Annexure C of the Declaration Notice. The first emission report was to be submitted within 12 months from the date of the Declaration Notice;
- provide any additional emission reports as requested by an air quality officer, for the implementation of the Notice;
- record all measurement results and keep a copy of this record for at least five years after obtaining the results; or
- produce the record of the measurement results for inspection if requested to do so by an air quality officer.

Moab Khotsong have four coal fired boilers at the South Uranium Plant, each with an installed design capacity of 10. 03MW. Therefore, the mine triggers the S23 controlled emitter regulations and must comply with emission standards specified for existing solid fuel-fired small boilers, should the boilers start operating. The emission limits associated with solid fuel-fired small boilers are given below in Table 3-5.

Table 3-5: Emission limits for solid fuel-fired small boiler.

(1) **Solid fuel-fired small boiler**

Description	Small boilers fueled with solid fuels.		
Application	All small boilers fueled with hydrocarbon based solid fuel, excluding biomass.		

Substance or mixture of substances		**Small boiler status**	**Limit value (dry mg/ Nm^3 at 273K; 101.3kPa and 10% O_2)**
Common name	**Chemical/ Commonly-used symbol**		
Particulate matter	PM	New	120
		Existing	250
Sulphur dioxide	SO_2	New	2800
		Existing	2800

4. OVERVIEW OF LANDFILL AND WASTE WATER TREATMENT PLANT GAS EMISSIONS AND ASSOCIATED HEALTH AND ODOUR IMPACTS

4.1. General Solid Waste Landfill Sites

In South Africa, waste is grouped into two classes a) general waste and b) hazardous waste. General waste includes waste types that do not pose a significant risk to public health or the environment if managed and disposed of properly (DWAF, 1998). These types of waste include general domestic and commercial waste (e.g. paper, glass, plastics, food), specific types of industrial waste (mainly dry waste) and demolition or building rubble waste streams. There may be some hazardous components (e.g. batteries, medical waste, insecticides, contaminated cloths) mixed within the incoming general waste, but these generally exist in small quantities (DWAF, 1998).

There are three common types of general waste landfill designs known as area, trench and ramp designs. Similar landfilling techniques are practiced regardless of the type of landfill design. These include the spreading, compacting of waste and then the placement of cover material over the waste (USEPA, 1998). Modern landfills will often make provision for containment barriers, which are liners constructed of either compacted soil, synthetic materials (e.g. high-density polyethylene) or a combination of both to create a barrier which is impermeable to leachate and gas migration (USEPA, 1998). In South Africa, general waste landfills are classified in terms of their potential to generate leachate (liquid or water that has passed through the landfill) (DWAF, 1998). Landfills that have potential to generate significant amounts of leachate are required to incorporate a sophisticated leachate management system and a liner/barrier that can contain the leachate.

Climate parameters (particularly rainfall and evaporation) have a significant impact on leachate generation potential. As such, a climate water balance (represented as B) is normally calculated to provide an indication as to whether the ambient climate in the area will contribute to significant leachate formation at the landfill (DWAF, 1998). A landfill site classified as B- suggests that there will not be significant leachate generation due to the ambient climate of the area (generally drier areas).

The Vaal River landfill site has a climate water balance of B-, thus there is no significant leachate generation from the landfill due to the relatively dry ambient climate in the area, with little to no rainfall observed during the late-autumn, winter and early spring seasons from May to September (see Section 5.1.3. Nevertheless, it is recommended that Moab Khostong incorporate a leachate management system (i.e. a leachate collection system and leachate ponds to prevent surface and groundwater contamination; and a leachate treatment facility to treat leachate and contaminated stormwater runoff in accordance with the landfill's particular needs) into the design of the landfill, if not already done so.

4.2. Waste Water Treatment Plants (WWTPs)

The regulation of WWTPs in South Africa is the responsibility of the Department of Water and Sanitation. WWTPs treat domestic effluent, industrial effluent, and stormwater run-off, depending on the design capacity and the areas they serve. For example, municipal WWTPs treat all three types of effluent, while the three WWTPs associated with Moab Khotsong operations are only used for treatment of effluent from processing operations and ablution facilities at the mine. In general, WWTPs are classified into the following size categories:

- micro size plants: <0.5 Mega litres (ML)/day.
- small size plants: 0.5 - 2 ML/day;
- medium size plants: 2 - 10 ML/day;
- large size plants: 10 - 25 ML/day;
- macro size plants >25 ML/day.

The 3# and 11# WWTPs have design capacities of 4.6ML and 2.4ml and are thus considered as medium size treatment plants, while the 8# WWTP has a design capacity of 12.24ML and is considered a large size treatment plant. However, all three WWTPs no not operate at or exceed the maximum/ design capacities, with average daily inflows of of 1000 m^3 (1ML), 3500m^3 (3.5ML) and 600 m^3 (0.6ML) for the 3#, 8# and 11# WWTPs, respectively, and percentage daily average flows of 21%, 31% and 25%, respectively. Daily inflows determine the scale of a WWTP's chemical usage and potential health or environmental impact ((Environment Australia, 1999).

4.3. Waste Water Treatment Plant Air Emissions

Emissions from WWTPs are released from waste water treatment, collection and storage systems and include VOCs, GHGs, ammonia and hydrogen sulphide. The methane produced from anaerobic digestors may be combusted for power generation or extracted and destroyed through flaring. At Moab Khotsong's three WWTPs, there is no flaring or combusting of the methane gas produced.

The list of air pollutants released from WWTPs and corresponding initial concentrations (in milligram per litre) are presented below (Table 4-1). The pollutants and concentrations are based on Australian literature (Environment Australia, 1999). The ammonia concentrations were taken from effluent testing reports at a WWTP similar to the WWTPs at Moab Khotsong.

Most of the compounds contained in waste water have a very distinct and 'offensive' odour, with the most common odorants being hydrogen sulphide (H_2S) and ammonia (NH_3). Hydrogen sulphide is the main odour pollutant due to its very low odour threshold. Hydrogen sulphide emitted from the waste water treatment processes will be utilised for the odour assessment.

Table 4-1: Initial Concentrations in Waste Water (Environment Australia, 1999).

Pollutant	Initial Concentration in Waste Water (mg/l)
Ammonia	25.5[(1)] 146 [(2)]
Hydrogen Sulphide	2.86
Benzene	0.0026
Chloroform	0.004
2-Chlorophenol	0.189
3-Chlorophenol	0.189
4-Chlorophenol	0.189
Ethylbenzene	0.0019
Phenol	0.024
Ethenylbenzene (styrene)	0.0026
Toluene	0.007
Xylene	0.014
Carbon Disulphide	0.0574
Chloroethane (ethyl chloride)	0.005
Methyl Isobutyl Ketone (MIBK)	0.009
Dichloroethane(1,1) ethylidenedichloride	0.026
Dichloroethane (1,2)	0.0005
1,1-Dichloroethene vinylidene chloride	0.005
Formaldehyde	0.0002
Tetrachloroethane (1,1,2,2)	0.0005
Tetrachloroethene	0.03
1,1,2 Trichloroethane	0.0005
Trichloroethylene	0.0075
Propanone (acetone)	0.025
Acrylonitrile	0.0025
Methylene chloride, dichloromethane	0.006
Notes: 1. Actual measured concentration in domestic effluent at a WWTP similar to the WWTPs at Moab Khotsong. 2. Actual measured concentration in process effluent at a WWTP similar to the WWTPs at Moab Khotsong.	

4.4. Landfill Gas Emissions

Landfill gas consists of a mixture of pollutants, but methane and carbon dioxide collectively make up most of the volume of landfill gas emitted (~90% of total landfill gas). Typically, landfill gas will contain approximately 45 – 60% of methane and 40 – 60% of carbon dioxide, which are both GHG pollutants, thus making landfills a significant source of GHG emissions globally (ATSDR, 2001). The balance of landfill gas contains a variety of other gases such as nitrogen (2 – 5% of total landfill gas), oxygen (0.1 – 1% of total landfill gas), hydrogen (0 – 0.2% of total landfill gas), ammonia (0.1 – 1% of total landfill gas), sulphides (0 – 1% of total landfill gas) and Non-Methane Organic Compounds (NMOCs) (0.01-0.6% of total landfill gas) (ATSDR, 2001) (Figure 4-1). NMOCs are also known as Volatile Organic Compounds (VOCs), but without the methane component. Many of the NMOCs are quite volatile and can easily evaporate at ambient room temperature (20 – 25ºC) and enter the atmosphere.

Landfill gas is mostly produced by anaerobic biodegradation of the organic matter contained in the disposed waste. This occurs when the organic matter in the waste is broken down by bacteria that is present in the actual waste, as well as the material used to cover the waste (e.g. soil, sand) and the surrounding landfill environment (ATSDR, 2001). Typical types of general waste that contain high organic matter include food, paper, garden and landscape waste, textiles and wood products.

Biodegradation of waste at a landfill occurs over four phases which are summarised in Table 4-2. It is important to note that all four phases of the decomposition process can occur at a single landfill site at the same time. Old waste will be in a later phase of decomposition compared to new fresh waste that has recently been deposited. Different gases are released during the different phases of decomposition (Figure 4-1).

Table 4-2: The four phases of biodegradation of waste in landfills (ATSDR, 2001; USEPA, 1998).

Phase	Description	Key Gases Produced
Phase 1	• Aerobic decomposition occurs, where bacteria that lives in the presence of oxygen, breaks down the organic matter contained in the waste. • Oxygen is consumed by the bacteria during this process and carbon dioxide is released as a by-product. • Phase 1 of the aerobic decomposition can last for several days to a few months, depending on the presence of oxygen. As the oxygen becomes depleted and there is little to no oxygen available for the aerobic bacteria anymore, the decomposition will progress to phase 2. Factors such as how well compacted the waste is during landfilling and how much cover material was used, including the frequency of compacting and covering, can influence the availability of oxygen. • Nitrogen content of the waste is high during phase 1 but rapidly declines as decomposition progresses over the next four phases. High amounts of nitrogen gas are released during phase 1.	Carbon dioxide (CO_2) Nitrogen (N_2)
Phase 2	• Phase 2 is characteristic of an anaerobic environment (lack of available oxygen) that is highly acidic. • The anaerobic bacteria convert compounds into acids (i.e. acetic, lactic and formic acids) and alcohols (methanol and ethanol). Nutrients begin to dissolve as the acids and alcohols mix with moisture, generating nitrogen and phosphorous compounds. • The nitrogen and phosphorous feed the acid producing anaerobic bacteria, allowing for further decomposition of waste.	Carbon dioxide (CO_2) Hydrogen (H_2)
Phase 3	• Phase 3 of the anaerobic decomposition begins as some of the bacteria start consuming organic acids produced during phase 2. This results in a more neutral environment in which methanogenic bacteria (capable of producing methane) can establish themselves. • Methanogenic bacteria consume carbon dioxide, resulting in a reduction of carbon dioxide emissions and an increase in methane gas production.	Methane (CH_4)
Phase 4	• In phase 4 of the anaerobic decomposition, the production of carbon dioxide, methane and nitrogen in the landfill gas becomes more stable and constant. • The composition of landfill gas (the mixture of pollutants, gases and their respective volumes) also becomes more stable. • The landfill gas emission rates will be relatively stable for several years throughout the operational life of the landfill and even years after the closure of the landfill.	Landfill gas (CH_4, CO_2, N_2 and other gases/pollutants)

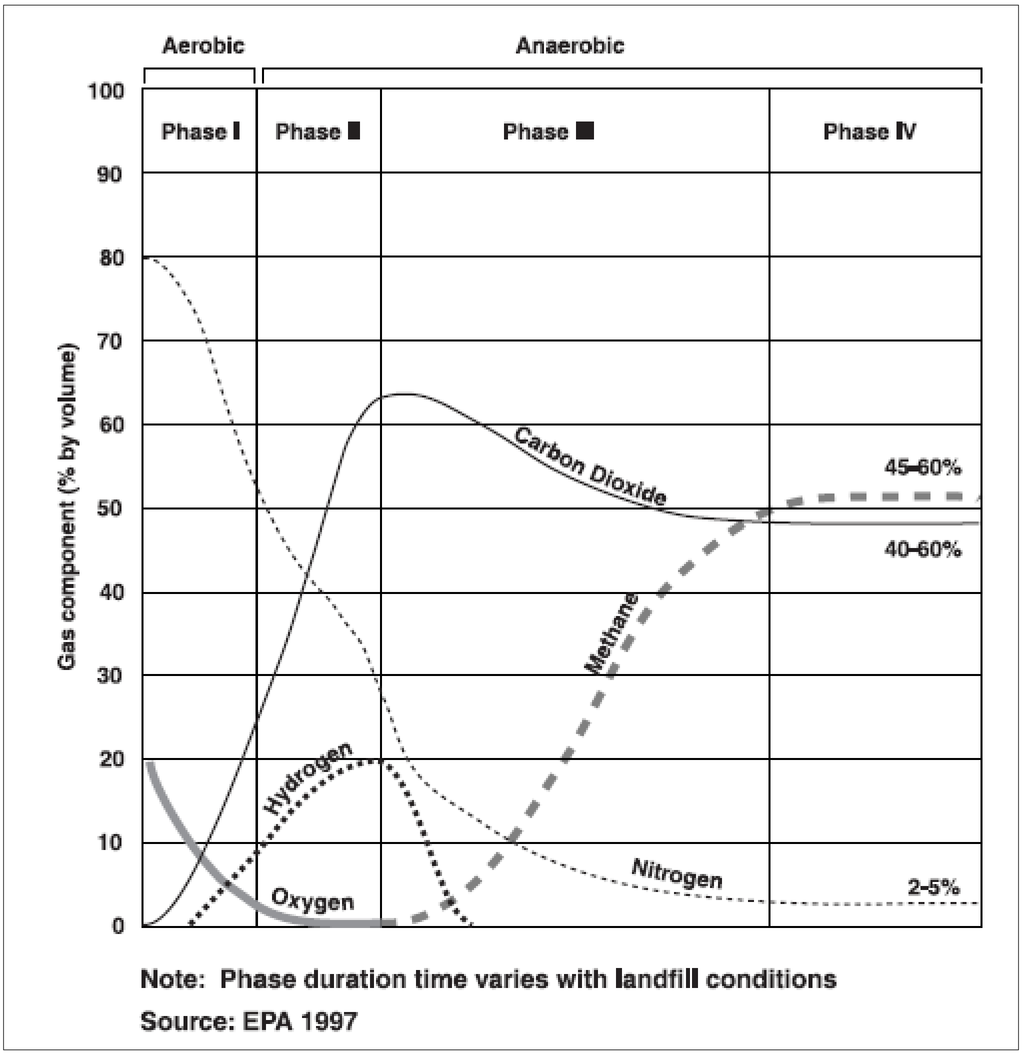


Figure 4-1: Production of landfill gases over the four decomposition phases (taken from ATSDR, 2001, pg. 6).

Landfill gases are also produced through volatilisation processes, where some waste types (such as those containing organic compounds e.g. chemicals) change from a liquid or solid state into a vapour. Emissions of NMOCs can often occur due to volatilisation processes in landfill sites (ATSDR, 2001). Chemical reactions also happen when certain waste products come into contact with each other, such as chlorine and ammonia (often found in house cleaning products). Emissions of NMOCs and other pollutants can occur due to chemical reactions within landfills (ATSDR, 2001).

Factors affecting landfill gas production include waste composition and age, availability of oxygen in the landfill, moisture content (high moisture environment will promote biological and chemical processes) and temperature (higher temperature environment accelerates biological, chemical and volatilisation processes) (ATSDR, 2001).

The mixture of gases that are produced within the landfill will move or migrate through available spaces such as pores or cracks inside the landfill or in the cover material (ATSDR, 2001). The gases, depending on their properties, will generally move in the direction that offers least resistance, resulting in vertical or horizontal movement of gases. The gases diffuse out of the landfill (point of high concentration of landfill gases) into the atmosphere (point of low concentration of landfill gases). It is extremely difficult to monitor emission fluxes over these passive area sources (i.e. landfill surface) due to the large area size. Thus, often it is assumed that the landfill gas emissions are homogenous over certain areas of a landfill that share similar characteristics and are likely to be within the same phase of decomposition. However, landfill gas composition and emission rates will differ over the surface area of a landfill.

4.5. Health and Odour Impacts

Some of the air pollutants, such as NMOCs/VOCs emitted from landfill sites and WWTPs, can have a negative impact on human health and environmental quality. Even though these pollutants only make up a very small percentage (~≤1%) of the total volume of landfill/WWTP gas emitted, they are of importance because of the hazardous and malodorous effects associated with these pollutants, even at very low ambient concentrations.

Air pollutants that are commonly found in landfill gas are listed below in Table 4-3 (ATSDR, 2001; Brattoli *et al.*, 2011). Some of the gases are similar to those produced from waste water treatment processes. A summary of the health impacts associated with exposure (via inhalation) to these pollutants is given in Table 4-3. Acute exposure (i.e. short term) to very high concentrations of these pollutants or long-term exposure to low-medium concentrations of these pollutants can have a negative impact on human health.

Table 4-3: Health impacts associated with exposure to HAPs commonly found in landfill gas.

Air Pollutant		Health Impacts	Reference Link
Name	Chemical formula		
BTEX Group (form part of NMOCs)			
Benzene	C_6H_6	Acute exposure can result in headaches, dizziness, confusion and fatigue. Benzene can also be classified as a moderate eye and skin irritant. Chronic exposure to Benzene may result in cancer due to its carcinogenic properties.	https://www.who.int/ipcs/features/benzene.pdf
Toluene	C_7H_8	Acute exposure to Toluene may cause harmful effects to the central nervous system, irritation to the skin and respiratory track in the human body. Most common side effects are nausea, vomiting, headaches and dizziness. Chronic exposure to Toluene may cause memory loss, loss of coordination, fatigue and headaches.	https://www.atsdr.cdc.gov/mmg/mmg.asp?id=157&tid=29
Ethylbenzene	$C_6H_5C_2H_5$	Exposure of high concentrations in air can cause irritation to the throat and eyes. Increased levels of Ethylbenzene can cause vertigo as well as dizziness. Long term exposure to Ethylbenzene can cause hearing impairments, kidney damage and cancer.	https://www.atsdr.cdc.gov/phs/phs.asp?id=381&tid=66
Xylene	C_8H_{10}	Acute exposure to Xylene may cause harmful effects to the central nervous system, irritation to the skin and respiratory track in the human body. Most common side effects are nausea, vomiting, headaches, dizziness and difficulties in breathing. Chronic exposure to Xylene may cause damage to the brain.	https://www.atsdr.cdc.gov/mmg/mmg.asp?id=291&tid=53

Reduced Sulphur Compounds (RSC) (form part of NMOCs)			
Carbon Disulphide*	CS_2	Carbon Disulphide may cause severe irritation to the eyes, throat and mucus membranes. Acute exposure to very high levels may result in respiratory failure and death. Chronic exposure can cause neurological effects and is harmful to the central nervous system and the peripheral nervous system which may result in permanent damage.	https://www.atsdr.cdc.gov/mmg/mmg.asp?id=470&tid=84#:~:text=Carbon%20disulfide%20is%20severely%20irritating,in%20respiratory%20failure%20and%20death.
Dimethyl Sulphide*	C_2H_6S	Dimethyl Sulphide can cause irritation to the eyes and skin. It can also irritate the respiratory system, causing inflammation and a chronic cough.	http://www.gcesystems.com/dimethyl-sulfide/
Hydrogen Sulphide*	H_2S	Hydrogen Sulphide can cause harmful effects to the central nervous system, the eyes and the respiratory system. Hydrogen Sulphide is not considered carcinogenic to humans.	https://www.atsdr.cdc.gov/substances/toxsubstance.asp?toxid=67
Ethyl Mercaptan (Ethanethiol)*	CH_3CH_2SH	Ethyl Mercaptan can cause harmful effects to the central nervous system, the eyes and the respiratory system. Ethyl Mercaptan is not considered carcinogenic to humans.	https://www.ncbi.nlm.nih.gov/books/NBK201325/#:~:text=Ethyl%20mercaptan%20depresses%20the%20central,gait%2C%20nausea%2C%20and%20vomiting.
Methyl Mercaptan (Methanethiol)*	CH_3SH	Methyl Mercaptan can cause harmful effects to the haematological system impacting on blood formation as well as the neurological system. Methyl Mercaptan is not considered carcinogenic to humans.	https://www.atsdr.cdc.gov/substances/toxsubstance.asp?toxid=40
Chlorinated Compounds			
Vinyl Chloride	C_2H_3CL	Vinyl Chloride can cause harmful effects to the cardiovascular system and the liver. Vinyl Chloride can also have harmful effects in child development as well as harmful effects to the reproductive and immune system. Vinyl Chloride is considered carcinogenic to humans.	https://www.atsdr.cdc.gov/substances/toxsubstance.asp?toxid=51
Dichloromethane (Methylene Chloride)	CH_2CL_2	Dichloromethane can cause harmful effects to the central nervous system and the liver. Dichloromethane is considered carcinogenic to humans.	https://www.atsdr.cdc.gov/substances/toxsubstance.asp?toxid=42
Dichloroethylene (1,2 Dichloroethene)	$C_2H_2CL_2$	Dichloroethylene can cause harmful effects to the haematological system impacting on blood formation as well as the liver. Dichloroethylene is not considered carcinogenic to humans.	https://www.atsdr.cdc.gov/substances/toxsubstance.asp?toxid=82
Trichloroethylene	C_2HCL_3	Exposure of high concentrations in air can cause damaging effects on the central nervous system relating to hearing, seeing and balance. Exposure can also impact the liver, respiratory system, kidneys, blood, immune system, heart, and body weight.	https://www.atsdr.cdc.gov/phs/phs.asp?id=171&tid=30
Tetrachloroethylene (perchloroethylene)	C_2CL_4	Tetrachloroethylene can cause harmful effects to the central nervous system, liver, urinary tracts and kidneys as well as harmful effects to the reproductive system. Tetrachloroethylene is considered carcinogenic to humans.	https://www.atsdr.cdc.gov/substances/toxsubstance.asp?toxid=48

Other Gases			
Ammonia	NH_3	Ammonia can cause irritation to the respiratory system from the nose to the lungs. Not considered as carcinogenic to humans.	https://www.atsdr.cdc.gov/substances/toxsubstance.asp?toxid=2
Notes: * RSC = Reduced sulphur compounds, which are a group of organic and inorganic chemicals that contain sulphur atoms in their low oxidation state. There are many species of RSC, however, only a few are found in the atmosphere. Common RSC pollutants that are emitted into the air include hydrogen sulphide, methyl mercaptan, ethyl mercaptan, dimethyl sulphide, carbon disulphide and dimethyl disulphide.			

All of the pollutants listed in Table 4-3 (above) also have odour impacts. Odours are often the main concern of people living near landfill sites and WWTPs. Odour impacts are not only caused by exposure to one specific pollutant but can occur due to exposure to a mixture or cocktail of various odorous gases (which is common in the case of landfill sites and WWTPs). The human nose is extremely sensitive to odours and can detect malodorous compounds at incredibly low concentrations. Odour perception also varies from person to person and is thus subjective. Some people may identify an odour that is quite irritating, while others don't. Odours are not known to be toxic to human health, however, continuous exposure to objectionable odours can cause physiological symptoms, such as respiratory problems, headaches, nausea, as well as psychological stress (Brattoli *et al.*, 2011).

4.6. Air Quality Guidelines and Odour Thresholds

The pollutants listed in Table 4-3 will all be assessed in the final AQIAr for the landfill site, while only some of the pollutants listed in Table 4-1 will be assessed for the WWTPs due to there being limited emission factors. Comparison of the modelled concentrations of these pollutants will be made with various international air quality guidelines (mainly Canadian guidelines) given in Table 4-4.

Dynamic olfactometry is a commonly used method for determining odour concentrations. The method involves collecting odour samples in specific containers (e.g. Tedlar bags) and taking them to a laboratory where a sensory measurement using a panel of judges takes place. The odour sample is diluted with odour-free air in specific ratios to a point where just barely 50% of the panel of judges can detect the odour (via their nose). The point where 50% of the panel can detect the odour is referred to as the 'threshold of detection' (Nicolas *et al.,* 2006; Brattoli *et al.*, 2011). Typically, the amount of dilution required to achieve the 'threshold of detection' is equal to 1D/T. Odour Units (OU) is the amount of odorous material needed to be added to one m^3 of air to bring the odour level to a point where the 'threshold of detection' (i.e. 50% of panel of judges detect the odour) is achieved. Therefore, 1 D/T = 1 OU per m^3. The concentration of odours can be expressed as OU/m^3 (Nicolas *et al.,* 2006; Brattoli *et al.*, 2011).

Odour thresholds are defined in different ways such as odour detection threshold and odour recognition threshold. The *odour detection threshold* is defined based on the laboratory field tests described above and represents the point at which 50% of the population will just barely detect the odour. However, this does not necessarily mean that the average person will notice the odour in their natural environment. Nor does it mean that the odour will be a nuisance or have a negative impact. As such, an *odour recognition threshold* exists (normally higher than the detection threshold), which represents a level of odour that most people (the average person) will likely recognise or notice in their natural environment. This level of odour may be annoying if someone is repeatedly exposed to it. Odour thresholds for the pollutants that will be assessed in this AQIAr are given in Table 4-4 and were obtained from the AQIAr compiled by Airshed for the proposed Enviroserv Chloorkop landfill expansion in the City of Ekurhuleni (Airshed, 2018). It should be noted that there are many different odour thresholds for a single pollutant, and these can vary significantly. Differences in a person's perception of odour and odour sampling techniques can account for the high variability in published odour thresholds.

Table 4-4: Air quality guidelines and odour thresholds for air pollutants commonly found in landfill gas and WWTP gas.

Air Pollutant		Air Quality Guideline			Odour Thresholds***		
Name	Chemical formula	Air Quality Guideline (µg/m³)	Averaging period	Guideline Source	Detection Threshold (µg/m³)	Recognition Threshold (µg/m³)	Odour Characteristics
BTEX Group (form part of NMOCs)							
Benzene	C_6H_6	30	1-hour	Alberta Ambient Air Quality Guideline	1500	16000	sweet-like odour
		5	Annual	SA Ambient Air Quality Standard			
Toluene	C_7H_8	1880	1-hour	Alberta Ambient Air Quality Guideline	1300	20000	sweet-like odour
Ethylbenzene	$C_6H_5C_2H_5$	2000	1-hour	Alberta Ambient Air Quality Guideline	730	1900	sweet-like odour
Xylene	C_8H_{10}	2300	1-hour	Alberta Ambient Air Quality Guideline	180	2000	sweet-like odour
Reduced Sulphur Compounds (RSC) (form part of NMOCs)							
Carbon Disulphide**	CS_2	30	1-hour	Alberta Ambient Air Quality Guideline	100	1000	strong sweet rotting odour
Dimethyl Sulphide**	C_2H_6S	30	1-hour	Ontario Ambient Air Quality Criteria	1	49	strong rotten cabbage-like odour
Hydrogen Sulphide**	H_2S	14	1-hour	Alberta Ambient Air Quality Guideline	0.57	7	foul rotten egg odour
		4	24-hour				
Ethyl Mercaptan (Ethanethiol)**	CH_3CH_2SH	28	1-hour		1	2.5	strong rotting odour

Methyl Mercaptan (Methanethiol)**	CH_3SH			British Columbia Ambient Air Standard for RSC mercaptan compounds (not defined)**	0.14	2	strong rotting odour
Chlorinated Compounds							
Vinyl Chloride	C_2H_3CL	130	1-hour	Alberta Ambient Air Quality Guideline	520000	910000	sweet-like odour
Dichloromethane (Methylene Chloride)	CH_2CL_2	694000	1-hour*	AIHA ERPG1*	560000	730000	chloroform-like sweet odour
Dichloroethylene (1,2 Dichloroethene)	$C_2H_2CL_2$	unknown	1-hour	could not find an hourly guideline	23000	unknown	sharp harsh odour
		105	24-hour	Ontario Ambient Air Quality Criteria			
Trichloroethylene	C_2HCL_3	unknown	1-hour	could not find an hourly guideline	1500	20000	sweet-like odour
		12	24-hour	Ontario Ambient Air Quality Criteria			
Tetrachloroethylene (perchloroethylene)	C_2CL_4	unknown	1-hour	could not find an hourly guideline	unknown	8000	sharp sweet-like odour
		360	24-hour	Ontario Ambient Air Quality Criteria			
Other Gases							
Ammonia	NH_3	1400	1-hour	Alberta Ambient Air Quality Guideline	1100	35000	strong pungent odour

Notes:
* AIHA ERPG = American industrial Hygiene Association Emergency Response Planning Guidelines.
* ERPG 1 = defined by AIHA as the maximum hourly concentration that individuals can be exposed to without experiencing serious health effects other than mild transient adverse health effects (short term, non-repetitive) or perceiving a clearly defined objectionable odour.
** RSC = Reduced sulphur compounds, which are a group of organic and inorganic chemicals that contain sulphur atoms in their low oxidation state. There are many species of RSC, however, only a few are found in the atmosphere. Common RSC pollutants that are emitted into the air include hydrogen sulphide, methyl mercaptan, ethyl mercaptan, dimethyl sulphide, carbon disulphide and dimethyl disulphide.
*** Odour Thresholds taken from Table 2-6 of the Airshed AQIA Report for proposed expansion of Chloorkop Landfill (2018).

4.7. Dust Emissions and Other Pollutants

4.7.1. Dustfall

Dust-fall are particles with an aerodynamic diameter greater than 20 µm that have been entrained into the air by a physical process such as wind, movement of vehicles, stack emissions or from fugitive dust. These particles are generally too heavy to remain in suspension in the air for any period and fall out of the air over a relatively short distance depending on a combination of various factors such as particle size, density, temperature (of the air and particle), emission velocity or method, ambient wind speed and humidity. These particles are therefore commonly known as "dust-fall". Particulates in this range are generally classified as a nuisance dust and can cause physical damage to property and physical irritation to plants, animals and humans.

4.7.2. Particulates (PM_{10} & $PM_{2.5}$)

Particles can be classified by their aerodynamic properties into coarse particles, PM_{10} (particulate matter with an aerodynamic diameter equal to or less than 10 µm) and fine particles, $PM_{2.5}$ (particulate matter with an aerodynamic diameter equal to or less than 2.5 µm). The fine particles mostly contain secondary formed aerosols such as sulphates and nitrates, combustion particles and re-condensed organic and metal vapours. The coarse particles mostly contain earth crust materials and fugitive dust from roads and industries (Harrison and van Grieken, 1998) (Fenger, 2002).

In terms of health impacts, particulate air pollution is associated with effects on the respiratory system (WHO, 2000). When looking at human health particle size is an important factor to consider because it controls where in the respiratory system a given particle will be deposited. Fine particles are thought to be more damaging to human health than coarse particles as larger particles do not penetrate deep into the lungs compared to smaller particles. Larger particles are deposited into the extra thoracic part of the respiratory tract while smaller particles are deposited into smaller airways that lead to the respiratory bronchioles (WHO, 2000).

Recent studies suggest that short-term exposure to particulate matter leads to adverse health effects, even at low concentrations of exposure (below 100 $\mu g/m^3$). Morbidity effects associated with short-term exposure to particulates include increases in lower respiratory symptoms, medication use and small reductions in lung function. Long-term exposure to low concentrations (~10 $\mu g/m^3$) of particulates is associated with mortality and other chronic effects such as increased rates of bronchitis and reduced lung function (WHO, 2000). Those most at risk include the elderly, individuals with pre-existing heart or lung disease, asthmatics and children.

4.7.3. Ammonia (NH_3)

NH_3 can be produced from industrial processes, but also exists naturally in humans and in the environment. Biologically, NH_3 is a precursor for amino acid and nucleotide production; environmentally, the gas is an essential part of the nitrogen cycle and is produced from soil bacterial processes and the decomposition of organic matter. NH_3 is a colourless, irritating gas with a pungent and suffocating odour. The gas is hygroscopic, soluble in water, corrosive and has alkaline properties (https://www.health.ny.gov, Accessed 17 April 2020).

Human exposure to NH_3 occurs through accidental household or industrial inhalation of the gas or vapours or accidental releases. Exposure to high concentrations of NH_3 may cause immediate burning of the nose, throat and respiratory tract, leading to bronchiolar and alveolar oedema as well as respiratory failure. At low concentrations, exposure to the gas may result in olfactory fatigue, coughing and nose and throat irritations. Skin and eye irritations may also occur from exposure to NH_3, with exposure to elevated concentrations of the gas causing skin burns and eye damage or blindness. Ingestion of NH_3 in solution causes corrosive damage to the mouth, throat and stomach, while contact with liquid NH_3 may result in frostbite injuries (https://www.health.ny.gov, Accessed 17 April 2020).

4.7.1. Volatile Organic Compounds (VOCs)

VOCs are organic compounds with a true vapour pressure higher than 0.13 kPa at 20^{o}C. Even though they exist in trace amounts they are significant in that they play an important role in atmospheric oxidation reactions in the troposphere and can act as a catalyst to produce other hazardous air pollutants. VOCs are often released during the production, use and disposal of household and commercial products including, cleaning agents, paints, varnishes, preservatives, pesticides, wood products, chemicals, adhesives and glues as well as flooring and carpeting products. Similarly, the storage and handling as well as the burning of fuels and products such as petrol, diesel and paraffin are common sources of VOCs. Higher levels of VOCs are generally found in urban environments compared to non-urban areas. However, some VOCs have a relatively long atmospheric life span and can be detected in areas further downwind from the source. Also, trees are a natural source of biogenic VOCs, thus higher VOC concentrations are also found over forested areas.

There are a variety of different types of VOCs (~ > 300) that are released from anthropogenic sources. Of which monoaromatic hydrocarbons are often the most abundant. Monoaromatic hydrocarbon pollutants include the BTEX group: benzene, toluene, ethylbenzene and xylene. BTEX is often measured and used as an indicator to represent other VOCs in air quality studies (Ware et al., 1993; Zabiegala *et al*., 2010).

Exposure to VOCs via inhalation can cause a variety of health effects depending on the concentration and type of VOC a person is exposed to and the duration of exposure. In general exposure to elevated levels of VOCs over a short duration can potentially cause skin, eyes, nose and throat irritations, headaches, drowsiness, nausea and vomiting. Exposure to low levels of VOCs over a longer duration period may potentially cause cancer, kidney and liver damage, chromosomal aberrations and blood disease (Duarte-Davidson et al., 2001). It is necessary to determine the presence of VOCs, in areas where elevated levels of VOCs may be of concern, to appropriately manage air quality issues and implement mitigation measures.

Benzene is the only VOC that is legislated in terms of the South African National Environmental Management: Air Quality Act (No. 34 of 2004) and is a well-known carcinogen. Studies have shown that exposure to low-high concentrations of benzene can cause leukaemia (Cointreau, 2006; Duarte-Davidson *et al*., 2001; Vrijheid, 2000; www.WHO.org, 2012). Bridges *et al*., (2000) and Vrijheid (2000) argue that there should be no standard threshold limit for gases with carcinogenic properties. This suggests that people who are exposed to carcinogenic agents over a long period, irrespective of the concentration, are said to be at some level of risk to adverse health effects.

5. BASELINE ASSESSMENT

5.1. Meteorological Overview

Meteorological processes determine the dispersion and dilution potential of pollutants emitted into the atmosphere. The vertical dispersion of pollution is governed by the stability of the atmosphere as well as the depth of the surface mixing layer. Horizontal dispersion of pollution is influenced by dominant wind fields. Therefore, meteorological parameters including temperature, precipitation, wind speed and wind direction are of significance when looking at pollution dispersion as they will influence the degree to which pollution will accumulate or disperse in the atmosphere.

As per the Code of Practice for Air Dispersion Modelling in Air Quality Management in South Africa (DEA, 2014), representativeness of the meteorological data is influenced by the following four factors:

- Proximity of the meteorological site to the area being modelled;
- Complexity of the terrain;
- Exposure of the meteorological measurement site; and
- Period of data collection.

MM5 modelled meteorological data was used for the project area. MM5 meteorological data was obtained from Lakes Environmental for the period January 2017 to December 2019. MM5 is a PSU/NCAR meso-scale model used to predict meso-scale and regional-scale atmospheric circulation. The model provides integrated model meteorological data, which can be used in a wide range of applications. This model is often used to create weather forecasts and climate projections. Details of the meteorological data obtained is summarised in Table 5-1 below.

The South African dispersion modelling regulations requires a minimum of 3-years of meteorological data for input into the dispersion model. The meteorological overview given below is with reference to the data used for input into the model. The meteorological data is representative of recent prevailing weather conditions that will likely be experienced at the project site.

Table 5-1: Meteorological Data Details.

Meteorological Data Details	
Met Data Information	**Description**
Met data type	MM5 AERMET-Ready (Surface & Upper Air Data)
Datum	WGS 84
Closest Town	Klerksdorp - South Africa
Time zone	UTC +2 hours
Period of record	January 2017 - December 2019
Met Station Parameters	**Description**
Anemometer height	13 m
Station base elevation	1317 m
Upper air adjustment	-2 hours
Grid Cell Information	
Co-ordinates of centre met grid	26.964425º S, 26.777867º E
UTM zone	-35
Cell dimension	12km x 12km

Surface Met Data	Description
File format	SAMSON file
Output interval	Hourly
Upper Air Data	**Description**
Format	TD-6201- Fixed Length
Reported in	GMT
Output interval	00Z and 12Z
Models used to process met data	
Model used to process data for wind roses	WR Plot
Model used to process data for AERMOD	AERMET

5.1.1. Local Wind Field

Figure 5-1 below provides the period wind rose plot for the project site for the period January 2017 to December 2019. The predominant wind directions for the period are observed from the north, north-north-east and north-east/north-north-west. Wind speeds for the three-year period are generally moderate to fast with calm conditions, defined as wind speeds less than 1 m/s, observed for 16.1% of the time (Figure 5-1).

The morning (AM) and evening (PM) period wind rose plots for the period January 2017 to December 2019 are given in Figure 5-2 and show slight diurnal variation in the wind field data. During the morning (AM) period, high frequency winds are observed from the northern and north-eastern quadrants; as opposed to the evening (PM) period, where stronger northerly, north-north-westerly and north-north-easterly winds are observed (Figure 5-2).

Seasonal variation in winds at Moab Khotsong mine for the period January 2017 – December 2019 is shown in Figure 5-3. During all four seasons, northerly and north-north-easterly winds are prevalent. Additional high frequency winds are observed from the north-east and/or north-north-west during summer, autumn and winter.

Based on the prevailing wind fields for the period January 2017 to December 2019, emissions from operations at the Vaal River landfill site and the three WWTPs, which are the focus of this study, will likely be transported towards the southerly direction as well as the south-westerly quadrant.

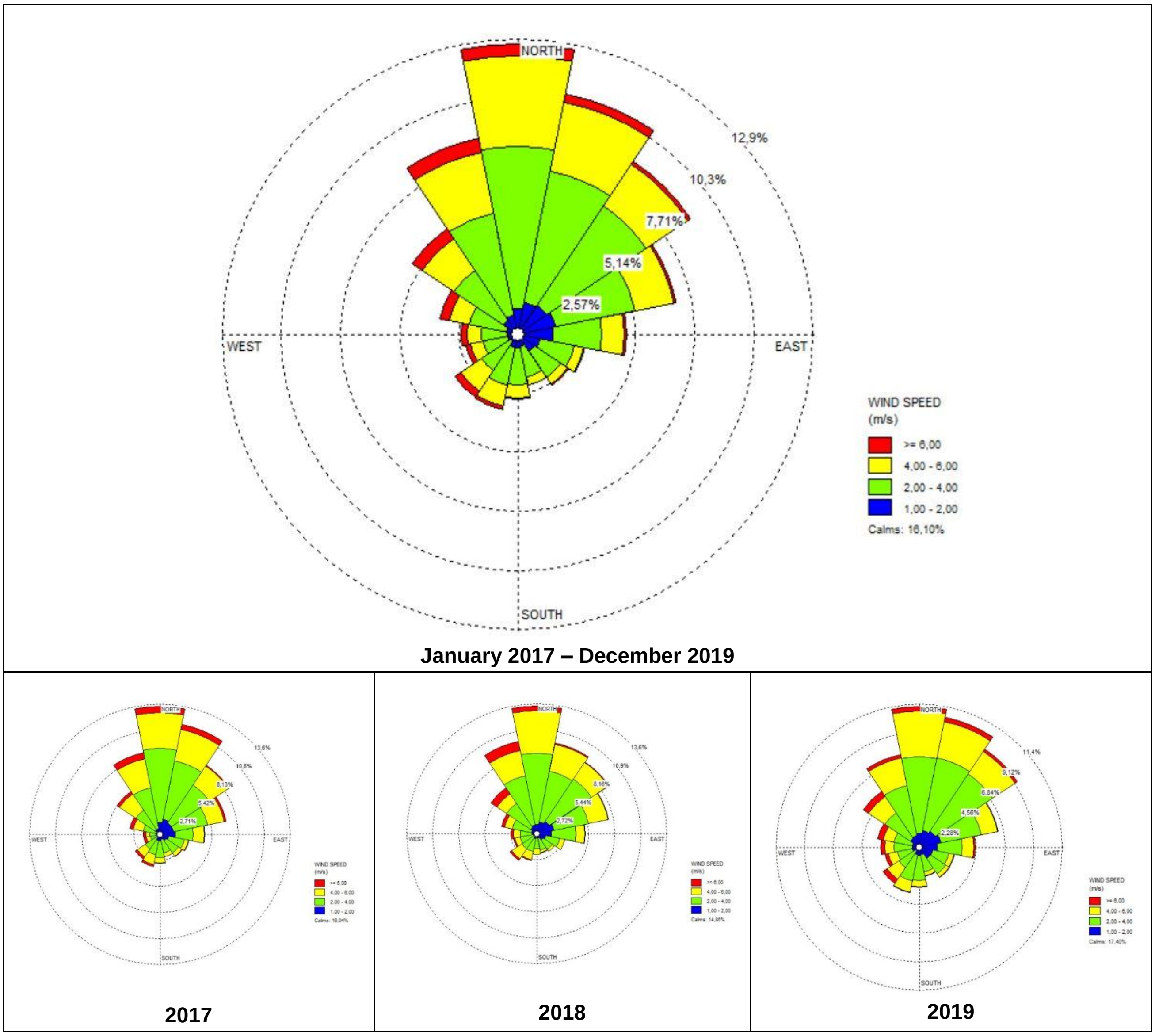
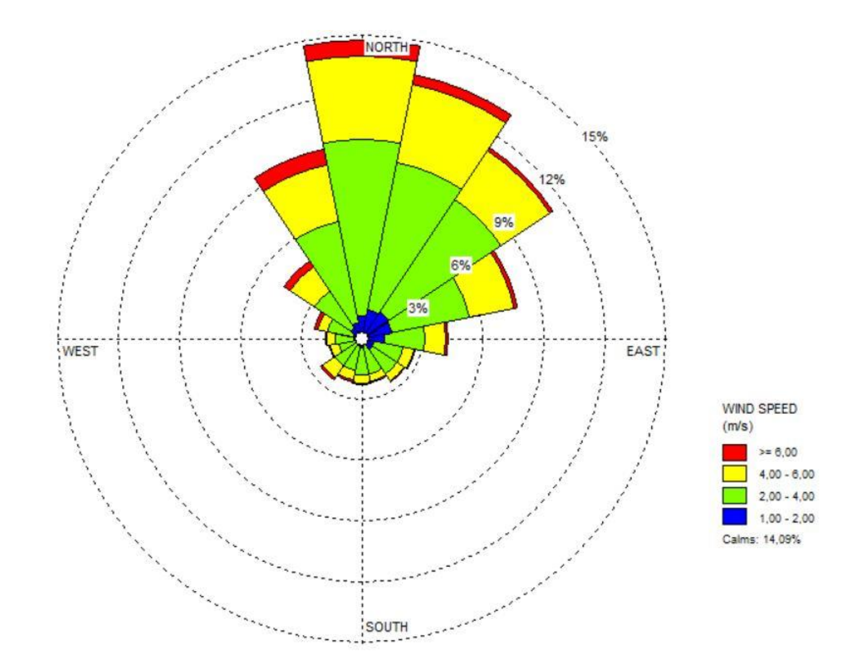
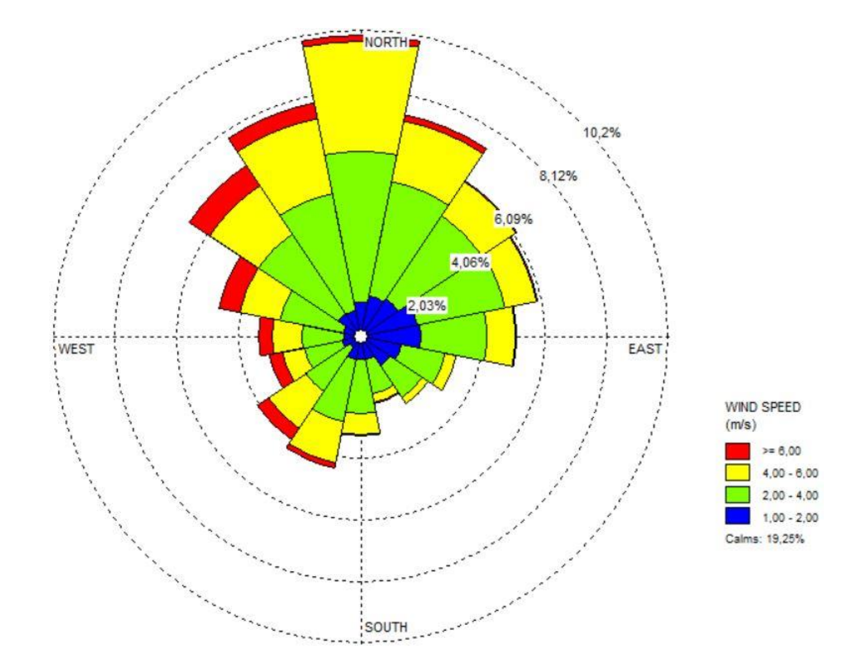


Figure 5-1: Period wind rose plots for Moab Khotsong Mine for the period January 2017 - December 2019.



Morning (AM) (00:00 – 12:00)



Evening (PM) (12:00 – 23:00)

Figure 5-2: Morning (AM) (00:00 - 12:00) and evening (PM) (12:00 - 23:00) period wind rose plots for Moab Khotsong Mine for the period January 2017 - December 2019

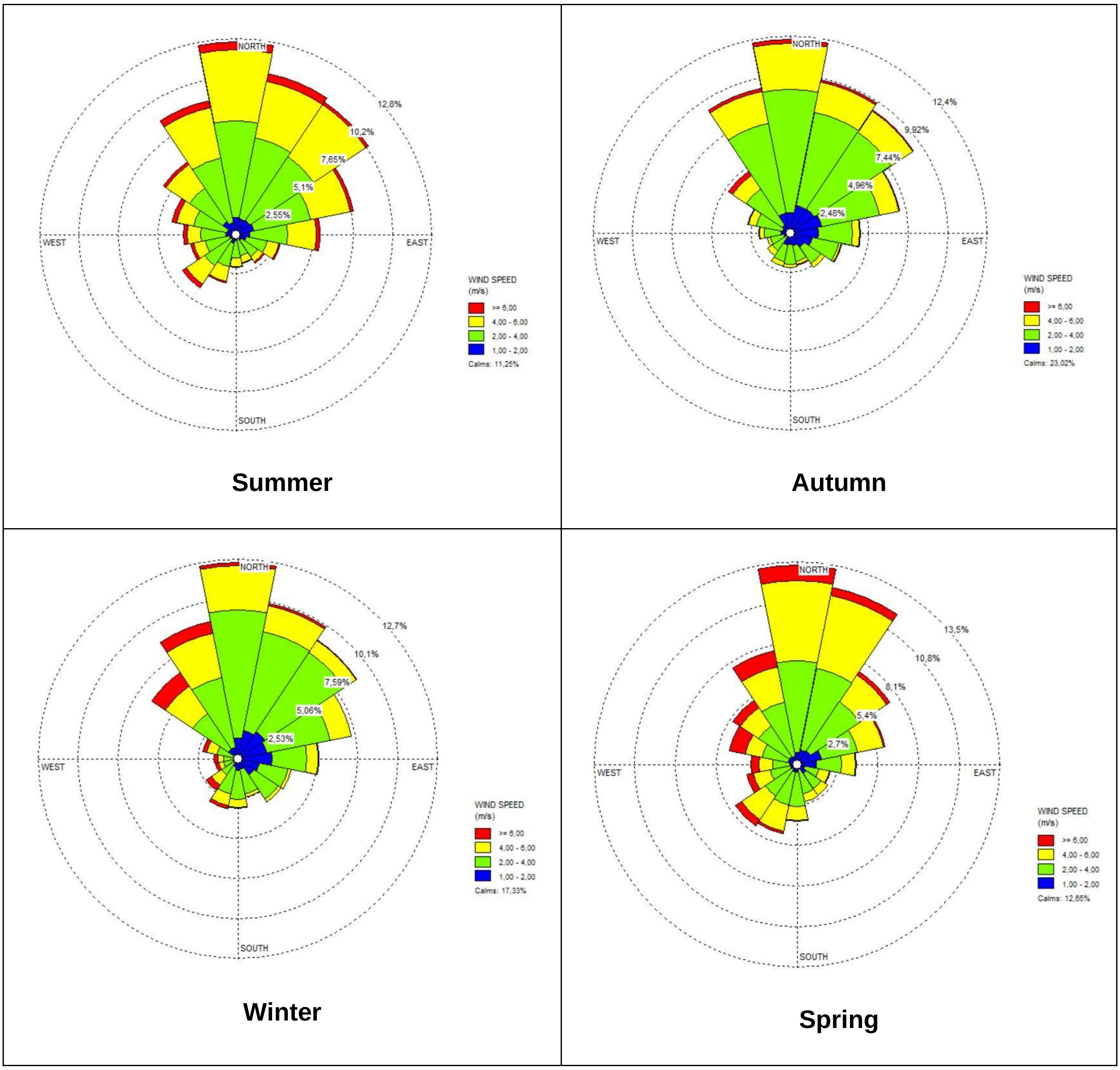


Figure 5-3: Seasonal variation of winds for Moab Khotsong Mine for the period January 2017 - December 2019.

5.1.2. Temperature

Temperature affects the formation, action and interactions of pollutants in various ways. Temperature provides an indication of the rate of development and dissipation of the mixing layer, which is largely controlled by surface inversions. Surface temperature inversions play a major role in air quality, especially during the winter months when these inversions are the strongest. Higher ambient temperatures will facilitate the dispersion of air pollutants which can result in lower ambient concentrations.

Chemical reaction rates also tend to increase with temperature and the warmer the air, the more water it can hold and therefore the higher the humidity. When relative humidity exceeds 70%, light scattering by suspended particles begins to increase, as a function of increased water uptake by the particles. This results in decreased visibility due to the resultant haze. Many pollutants may also dissolve in water to form acids.

Monthly average, maximum and minimum temperature and humidity for the period January 2017 to December 2019 at the project site are presented in Figure 5-4 and Table 5-2. Average monthly temperature and relative humidity range from 10.6 – 23.9 ºC and 45.1 – 67.7% respectively (Table 5-2).

Table 5-2: Monthly average, maximum and minimum temperature and relative humidity for January 2017 - December 2019.

Monthly average, maximum and minimum temperatures (Deg C)												
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Average	23.9	23.1	22.3	18.4	13.7	10.7	10.6	13.8	17.5	19.8	22.4	23.8
Maximum	34.1	32.2	32.1	29.5	24.1	20.6	21.8	24.6	29.1	32.2	32.8	34.1
Minimum	11.2	12.9	11.1	7.4	3.1	1.4	-0.4	1.6	2.1	7.1	4.8	12.6
Monthly average, maximum and minimum relative humidity (%)												
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Average	52.9	59.6	54.2	59.7	64.4	67.7	65.6	62.3	57.8	50.7	45.1	51.3
Maximum	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.0	98.0	100.0
Minimum	15.0	16.0	15.0	22.0	26.0	26.0	22.0	23.0	20.0	13.0	11.0	13.0

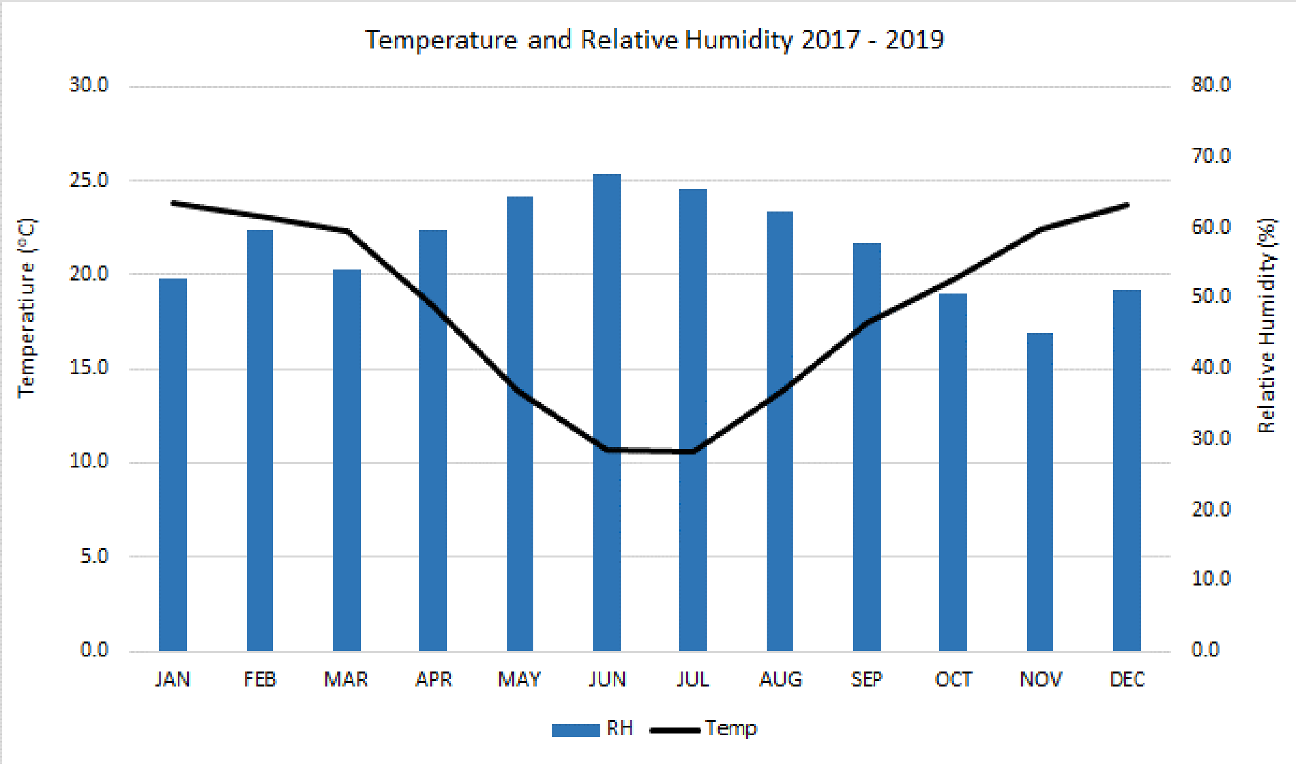


Figure 5-4: Monthly average temperature and relative humidity profiles for the project site for the period January 2017 - December 2019.

5.1.3. Precipitation

Precipitation has an overall dilution effect and cleanses the air by washing out particles and pollutants suspended in the atmosphere. Monthly total rainfall at the project site for the period January 2017 to December 2019 is presented in Table 5-3 and Figure 5-5.

The area receives most of its rainfall during the spring, summer and early autumn seasons during the months October to March. Little to no rainfall is observed during the other seasons (particularly May to August). Removal of pollutants via wet depositional processes would be evident during the late spring, summer and early autumn seasons thus lower ambient concentrations of some pollutants could be expected during this season. Over the remainder of the year higher ambient concentrations of pollutants could be expected.

Table 5-3: Total monthly rainfall for January 2017 - December 2019.

Total Monthly Rainfall (mm)													
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
2017	202.2	255.8	26.9	8.1	1.3	0.0	0.0	11.9	21.1	109.5	82.0	183.9	902.7
2018	135.6	78.5	200.2	6.9	0.5	0.0	0.3	15.7	23.4	48.5	62.5	97.3	669.3
2019	56.1	231.1	56.9	101.9	3.0	0.0	0.0	0.0	3.6	40.4	78.5	484.1	1055.6

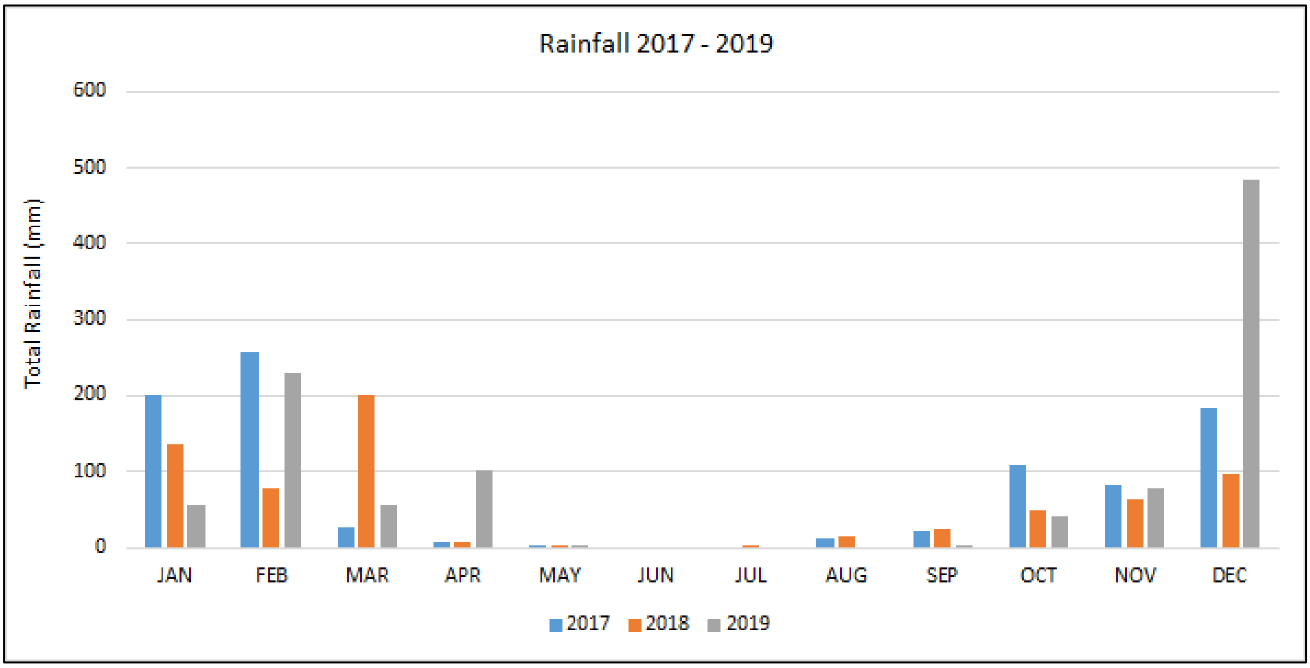


Figure 5-5: Total monthly rainfall (mm) for the project site for the period January 2017 - December 2019.

5.2. Baseline Air Quality Concentrations

The existing air quality situation is usually evaluated using available monitoring data from permanent ambient air quality monitoring stations (AQMS) operated near the project site (i.e. within a 10km radius). The existing AQMS is at the Jouberton AQMS (-26.89605°S; 26.6056°E), which is located too far from the mine – approximately 21.5km to the north-west and would not provide an accurate representation of baseline air quality at the mine. Furthermore, air quality monitoring of these pollutants in not undertaken at the mine. As such, background concentrations for the criteria air pollutants (PM_{10}, $PM_{2.5}$, SO_2, NO_2 and CO) could not be presented in this report. However, there was background dustfall data obtained from Moab Khotsong's dustfall monitoring network, which consists of 13 dustfall monitoring sites located in and around the mine. Dustfall rates at the mine for the period January 2021 – December 2021 were used.

The 13 dustfall monitoring sites at the mine consist of 12 single-unit buckets and one multi-directional Gateway dust-watch station with four buckets. Three of the single unit buckets are classified as residential, while the other nine single unit buckets are classified as non-residential. The Gateway dust-watch buckets are classified as residential. A moveable lid is positioned over the dust-watch containers. The lid alternates between the containers depending on the wind direction recorded by an attached wind sensor.

5.2.1. Baseline Dustfall Rates

Dustfall rates for the period January 2021 to December 2021 are presented in Figure 5-6 and Figure 5-7, and the locality of the dust buckets are shown in Figure 5-8.

For the period January 2021 – December 2021, 178 dustfall rates were recorded, and dustfall rates range from 6.0 – 4560 mg/m^2/day, with four exceedances of the non-residential limit of 1200 mg/m^2/day recorded at the site identified as East of Kopanang TSF, and no exceedances of the residential limit of 600 mg/m^2/day recorded (Table 5-4). The four exceedances were recorded in September, October, November and December 2021 and are likely due to increased wind erosion activity at the TSF as it is dormant and has very little vegetation.

A total of 2 exceedances of the dustfall limits are permissible in a year (no 2 sequential months) (see section 3.6). Moab Khotsong is a gold mine thus dustfall rates recorded at the mine are compared to the non-residential limit of 1 200 mg/m^2/day (depending on the location of the dust bucket). The dustfall rates recorded at the mine mostly comply with the South African National Dust Control Regulations at all monitoring sites, except at the bucket located east of the Kopanang TSF.

Please refer to Table 5-4 to see which dust buckets are classified as residential and non-residential.

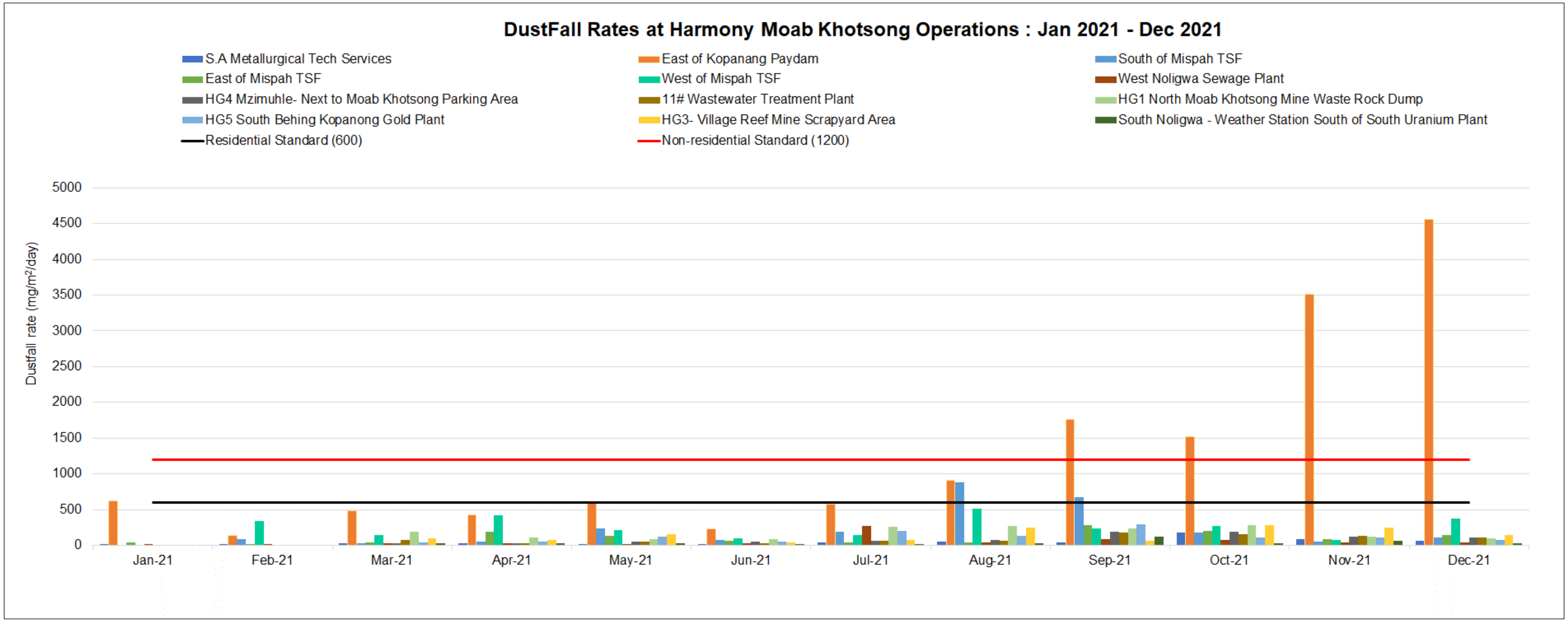


Figure 5-6: Dustfall rates at Moab Khotsong Mine - Single Buckets - for the period January 2021 to December 2021.

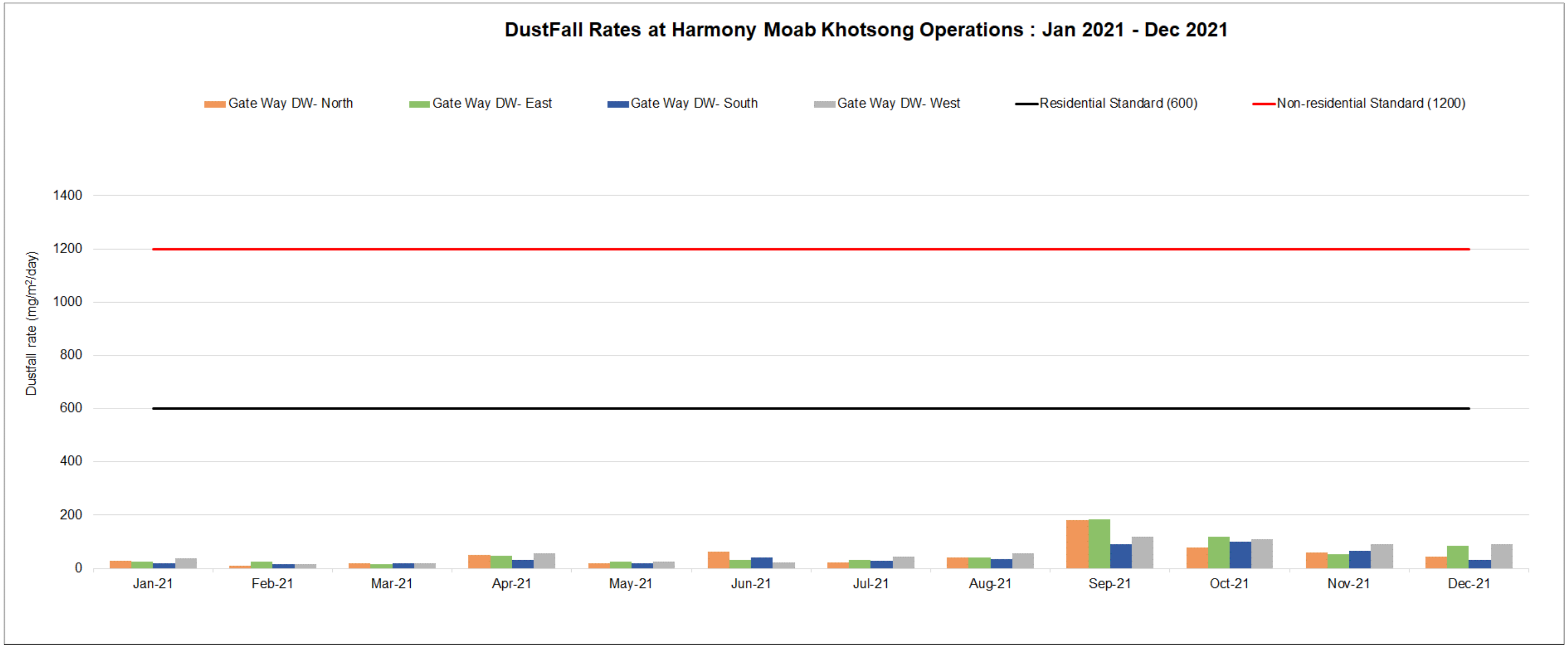


Figure 5-7: Dustfall rates at Moab Khotsong Mine – Multi-directional Station- for the period January 2021 to December 2021.

Table 5-4: Frequency of exceedances of dust control standards at dust bucket sites at Moab Khotsong Mine for the period January 2021 – December 2021.

Harmony Moab Khotsong Operations						Frequency of Exceedance of Applicable National Standard	Applicable National Standard (Residential)	Applicable National Standard (Non-residential)
Number	Description	Unit Type	Classification	Coordinates		2021		
Harmony Moab Khotsong Operations							mg/m²/day	mg/m²/day
Single Units								
1	S.A Metallurgical Tech Services	Single	Residential	26°57'06,9"S	26° 47'07,0"E	0	600	
2	East of Kopanong Paydam	Single	Non-residential	26°00'31,9"S	26° 47'28,3"E	4		1200
3	South of Mispah TSF	Single	Non-residential	26°00'41,7"S	26° 46'31,1"E	0		1200
4	East of Mispan TSF	Single	Non-residential	25°59'41,1"S	26° 47'08,2"E	0		1200
5	West of Mispan TSF	Single	Non-residential	26°59'51,8"S	26° 45'38,3"E	0		1200
6	West Noligwa Sewage Plant	Single	Residential	26°57'28,6"S	26° 46'36,8"E	0	600	
7	HG4 Mzimuhle- Next to Moab Khotsong Parking Area	Single	Residential	26°59'22,27"S	26° 48'3,31"E	0	600	
8	11# Wastewater Treatment Plant	Single	Non-residential	26°59'1,82"S	26° 48'13,33"E	0		1200
9	HG1 North Moab Khotsong Mine Waste Rock Dump	Single	Non-residential	26°58'42,98"S	26° 48'0,23"E	0		1200
10	HG5 South Behind Kopanong Gold Plant	Single	Non-residential	26°59'12,13"S	26° 44'33,99"E	0		1200
11	HG3- Village Reef Mine Scrapyyard Area	Single	Non-residential	26°58'43,18"S	26° 56'28,82"E	0		1200
12	South Noligwa - Weather Station South of South Uranium Plant	Single	Non-residential	26°58'14,66"S	26° 46'35,76"E	0		1200
Gateway Dust-watch buckets								
13	Gate Way DW	Multidirectional (N, E, W, S)	Residential	26°57'33,5"S	26° 46'45,4"E	0	600	

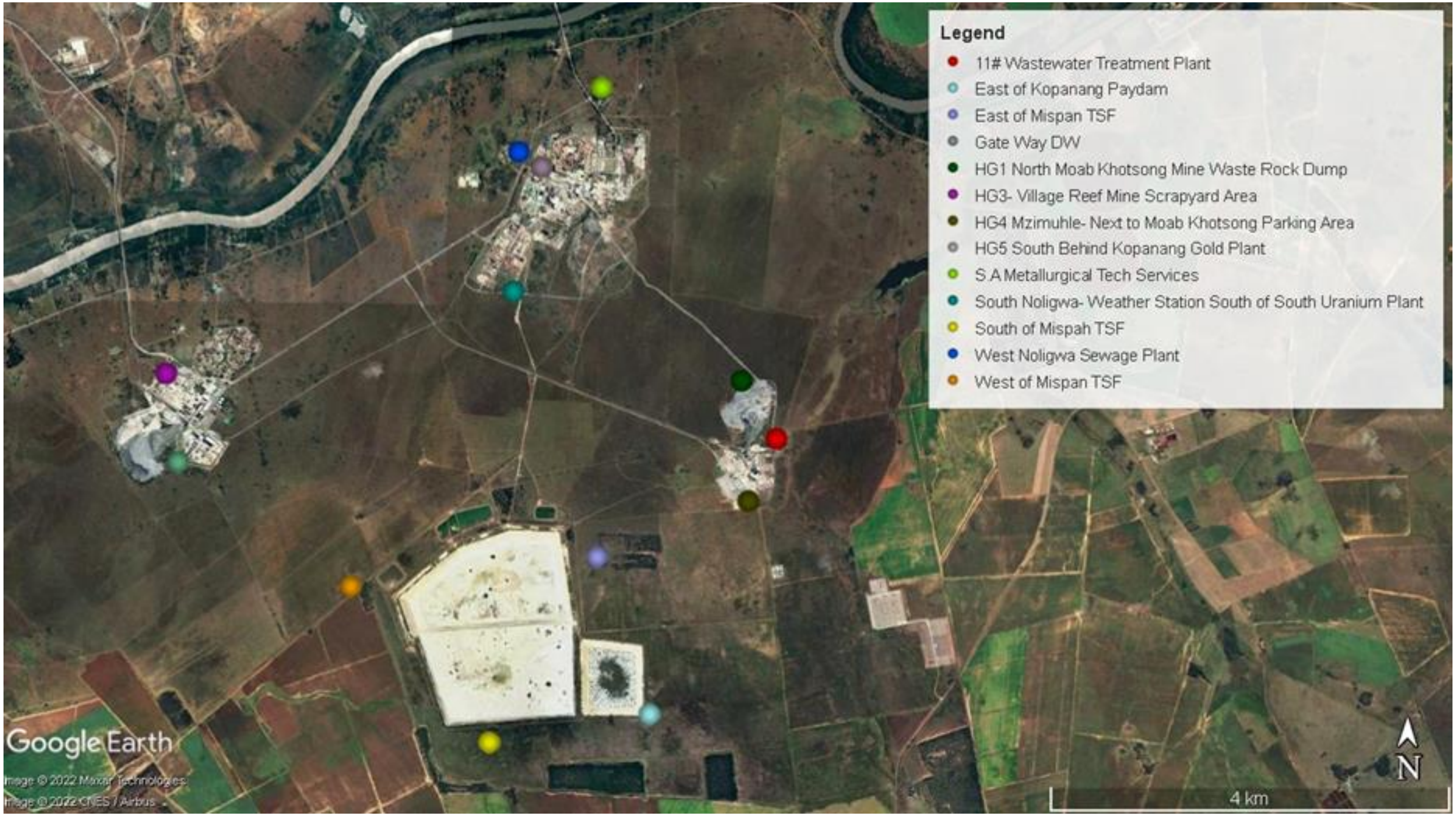


Figure 5-8: Locality of dustfall monitoring sites at Moab Khotsong Mine.

5.3. Surrounding Sources of Air Pollution

The land use immediately surrounding the Moab Khotsong operations consists predominantly of grassland and agricultural/cultivated land use types. Emission sources are mostly associated with mining activity (existing mines), commercial agricultural activities, vehicle dust entrainment on unpaved roads and wind erosion from open exposed areas (e.g. natural eroded areas, TSFs, stockpile areas, exposed farmland, etc). Other sources may include the Vaal River landfill site (north-west of the mine), domestic fuel burning in urban informal areas located north and north-west of Moab Khotsong, industrial activity, sewage works, and vehicle exhaust emissions from vehicle activity on national and arterial roads located north, north-west, west and south of Moab Khotsong. The sewage works include the three WWTPs owned and operated by Moab Khotsong (Figure 5-9 and Figure 5-10).

5.3.1. Mining Activity

There are existing mining operations on site and at areas surrounding the site, particularly north, north-west and south-east of Moab Khotsong operations. Mining activities taking place near to the project site include Mine Waste Solutions operations (~13km north of Moab Khotsong mine), Harmony Moab Kopanang operations (~2.5 km south-east of project site) and Vaal River Assay Laboratory (~10km west of Moab Khotsong Mine). The following activities are generic key sources of emissions associated with mines:

- Material handling, storage and processing;
- Crushing and screening;
- Combustion processes (e.g. gas, diesel & oil combustion);
- Processing plant operations and associated combustion processes;
- Blasting and drilling;
- Excavation, bull dozing, grading;
- Removal of material (e.g. topsoil, overburden, ore);
- Wind erosion from exposed areas (e.g. open pits, stockpile, TSFs and storage piles);
- Conveying of material (material transfer);
- Vehicle dust entrainment due to truck hauling activities on unpaved roads;
- Truck and mining equipment exhaust emissions.

Mining activity taking place near to the project site is a key source of dust in the area.

5.3.2. Vehicle Dust Entrainment on Unpaved Roads

Vehicle-entrained dust emissions from the surrounding unpaved roads in the area potentially represent a source of fugitive dust. When a vehicle or truck travels on an unpaved road, the force of the wheels on the road surface causes the pulverisation of surface material. Particles are lifted and dropped from the rolling 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.

5.3.3. Wind Erosion from Exposed Areas

There are open exposed areas such as bare soil, eroded natural land, etc. and TSFs surrounding the site which represent a source of dust in the area. Two active TSFs (i.e. Mispah 1 & Mispah 2) and one dormant TSF (Kopanang) are associated with mining operations at Moab Khotsong. Further, a WRD (Moab WRD), a coal stockpile area at the SUP, and storage piles exist at the mine. Dust emissions due to the erosion of open storage piles and exposed areas occur when the threshold wind speed is exceeded. The threshold wind speed is dependent on the erosion potential of the exposed surface, which is expressed in terms of the availability of erodible material per unit area (mass/area). Any factor which binds the erodible material or otherwise reduces the availability of erodible material on the surface thus decreases the erosion potential of the surface. Studies have shown that when the threshold wind speeds are exceeded, particulate emission rates tend to decay rapidly due to the reduced availability of erodible material.

5.3.4. Agricultural activity and potential biomass burning

There are several agricultural areas surrounding the project site. Emissions from agricultural activities are difficult to control due to the seasonality of emissions and the large surface area producing emissions. Expected emissions resulting from agricultural activities include particulates associated with wind erosion and burning of crop residue, chemicals associated with crop spraying and odiferous emissions resulting from manure, fertilizer and crop residue. Dust associated with agricultural practices may contain seeds, pollen and plant tissue, as well as agrochemicals, such as pesticides. The application of pesticides during temperature inversions increases the drift of the spray and the area of impact.

Dust entrainment from farming vehicles travelling on gravel roads may also cause increased particulates in an area. Dust from traffic on gravel roads increases with higher vehicle speeds, more vehicles and lower moisture conditions. The seasonal burning of the veld from July to September for field clearing in preparation for planting is also a source of smoke. The nature of the activity has a potential impact on air quality in the area.

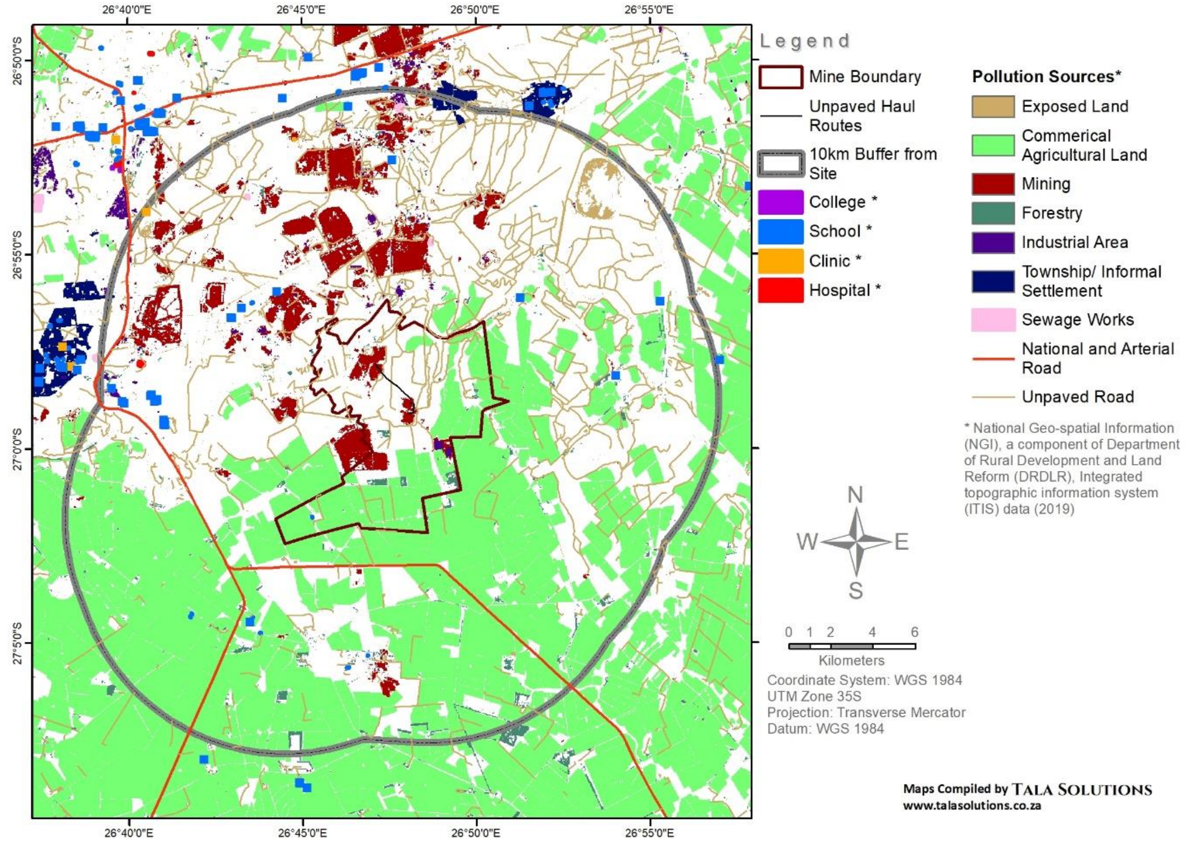


Figure 5-9: Identified surrounding emission sources within 10km of Moab Khotsong Mine.

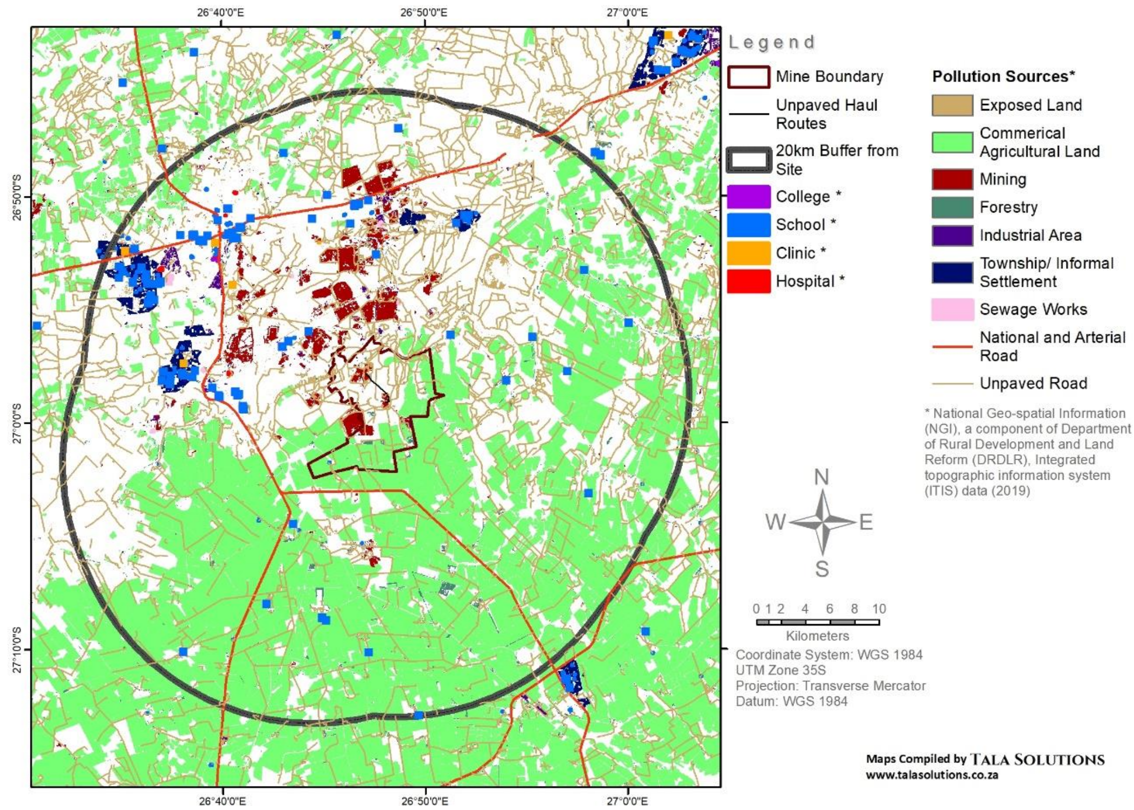


Figure 5-10: Identified surrounding emission sources within 20km of Moab Khotsong Mine.

6. AIR QUALITY IMPACT ASSESSMENT – IMPACT OF ENTERPRISE ON THE RECEIVING ENVIRONMENT.

The focus of this study is on operational activities associated with the landfill site and WWTPs only. The mining operations and processing plant activities fall outside of the scope of this study but were assessed in the 2020 AQIAr compiled for the mine by Rayten.

Landfill gas (including HAPs), dust and odour are identified as the key pollutants of concern associated with operational activities at the Vaal River landfill site, while ammonia, volatile organic compounds (VOCs), which include acetone, chloroform, phenol, benzene, toluene and methanol, hydrogen sulphide (H_2S) and odour are identified as the key pollutants of concern associated with operational activities at the WWTPs and are emitted from the following key sources:

Landfill Site Emission Sources:

- Landfill gas emissions (consisting of a mixture of pollutants) due to:
    - anaerobic decomposition of solid matter mainly generated from the biodegradation of the organic matter contained within the waste,
    - general landfill activities such as active tipping of fresh waste and exposed areas of waste.
- Emissions of Hydrogen Sulphide (H_2S) from leachate dams, if leachate dam is available.
- Odour emissions associated with overall landfilling activities.
- Dust emissions from:
    - Vehicle dust entrainment from the movement of trucks on unpaved roads onsite (in and around active Cells),
    - wind erosion of exposed surfaces (exposed waste at active Cell's workface and stockpiling of daily cover material),
    - compacting of waste at the active Cell's workface,
    - material handling (loading and offloading material from trucks).

Waste Water Treatment Plants Emission Sources:

- Odour emissions associated with overall waste water treatment activities;
- Aeration during primary treatment;
- Aerobic digestion;
- Anaerobic digestion; and
- Sludge drying.

The above-mentioned sources were identified for the landfill and WWTPs based on the information provided by the client. A detailed questionnaire was given to the client prior to modelling to obtain specific details needed for input into the model and for calculation of emission rates. The conservative scenario will be assumed where information is not known for input into the model. To investigate the potential impact of operations associated with the landfill site and WWTPs on local ambient air quality, the following air pollutants were chosen in the quantification of emissions for the operational phase of the landfill and/or WWTPs:

Dust:

- Dustfall;

- Particulate matter (PM_{10} and $PM_{2.5}$);

BTEX:
- Benzene (C_6H_6);
- Toluene (C_7H_8)
- Ethylbenzene ($C_6H_5C_2H_5$)
- Xylene (C_8H_{10})

Reduced Sulphur Compounds:
- Carbon Disulphide (CS_2)
- Dimethyl Sulphide (C_2H_6S)
- Hydrogen Sulphide (H_2S)
- Ethyl Mercaptan (Ethanethiol) (CH_3CH_2SH)
- Methyl Mercaptan (Methanethiol) (CH_3SH)

Chlorinated Compounds:
- Vinyl Chloride (C_2H_3CL)
- Dichloromethane (Methylene Chloride) (CH_2CL_2)
- Dichloroethylene (1,2 Dichloroethene) ($C_2H_2CL_2$)
- Trichloroethylene (C_2HCL_3)
- Tetrachloroethylene (perchloroethylene) (C_2CL_4)

Other:
- Ammonia (NH_3)
- Odour (OU)

A detailed emissions inventory will be compiled for the landfill and WWTPs and the impact of these on air quality will be assessed through dispersion modelling using AERMOD. The results of the assessment will include dispersion isopleth plots and will be presented in the final Level 2 AQIAr. A summary of the AERMOD model used is given in Section 6.1 below.

6.1. Model Overview

6.1.1. AERMOD View

AERMOD, a state-of-the-art Planetary Boundary Layer (PBL) air dispersion model, was developed by the American Meteorological Society and USEPA Regulatory Model Improvement Committee (AERMIC). AERMOD utilizes a similar input and output structure to ISCST3 and shares many of the same features, as well as offering additional features. AERMOD fully incorporates the PRIME building downwash algorithms, advanced depositional parameters, local terrain effects, and advanced meteorological turbulence calculations.

The AERMOD atmospheric dispersion modelling system is an integrated system that includes three modules:

- A steady-state dispersion model designed for short-range (up to 50 km) dispersion of air pollutant emissions from stationary industrial sources.
- A meteorological data pre-processor (AERMET) for surface meteorological data, upper air soundings, and optionally, data from on-site instrument towers. It then calculates atmospheric parameters needed by the dispersion model, such as atmospheric turbulence characteristics, mixing heights, friction velocity, Monin-Obukov length and surface heat flux.
- A terrain pre-processor (AERMAP) which provides a physical relationship between terrain features and the behaviour of air pollution plumes. It generates location and height data for each receptor location. It also provides information that allows the dispersion model to simulate the effects of air flowing over hills or splitting to flow around hills.

AERMOD includes Plume Rise Model Enhancements (PRIME) building downwash algorithms which provide a more realistic handling of building downwash effects. PRIME algorithms were designed to address two fundamental features associated with building downwash; enhanced plume dispersion coefficients due to the turbulent wake and to reduce plume rise caused by a combination of the descending streamlines in the lee of the building and the increased entrainment in the wake. AERMOD is suitable for a wide range of near field applications in both simple and complex terrain. The evaluation results for AERMOD, particularly for complex terrain applications, indicate that the model represents significant improvements compared to previously recommended models (USEPA, 2005).

AERMOD has been used in various dispersion modelling studies in the United States and around the world (Perry *et al*., 2004).

6.1.2. Model Requirements

The approach to this dispersion modelling study is based on the Code *of Practice for Air Dispersion Modelling in Air Quality Management in South Africa* (DEA, 2014). As per the *Code of Practice*, this assessment is a Level 2 assessment. Level 2 assessments should be used for air quality impact assessment in standard/generic licence or amendment processes where:

- The distribution of pollutant concentrations and depositions are required in time and space;
- Pollutant dispersion can be reasonably treated by a straight-line, steady-state, Gaussian plume model with first order chemical transformation. Although more complicated processes may be occurring, a more complicated model that explicitly treats these processes may not be necessary depending on the purposes of the modelling and the zone of interest.
- Emissions are from sources where the greatest impacts are in the order of a few kilometres (less than 50 km) downwind.

A summary of the key variables input into the AERMOD model is given in Table 6-1 below. Data input into the model includes MM5 meteorological data (surface and upper air) for 01 January 2017 – 31 December 2019. Terrain data at a resolution of 90 m (SRTM90) is used for input into the model, as generated by the terrain pre-processor, AERMAP. A modelling domain of 20 km × 20 km is used. A multi-tier grid with a grid receptor spacing of 250 m (5 km from facility), 500 m (10 km from facility) and 1000 m (20km from the facility) (3 tiers) is used.

Table 6-1: Key Variables to be used in the modelling study.

Parameter	Model Input
Model	**Input**
Assessment level	Level 2
Dispersion model	AERMOD Version 10.0.1
Supporting models	AERMET Version 10.0.1 AERMAP Version 10.0.1
Emissions	**Input**
Pollutants to be modelled	Various, see Section 6
Scenarios	Operational
Chemical transformations	n/a
Exponential decay	n/a
Settings	**Input**
Terrain setting	Elevated
Terrain data	SRTM90
Terrain data resolution (m)	90
Land use characteristics	Cultivated land and Grassland
Grid receptors	**Input**
Plant boundary (m)	50
Modelling domain (km)	10 x 10
Fine grid resolution (m)	250 (5 km from facility)
Medium grid resolution (m)	500 (10 km from facility)
Large grid resolution (m)	1000 ((beyond 10 km from facility)

7. SUMMARY AND CONCLUSIONS

Rayten Engineering Solutions (Pty) Ltd was appointed by Harmony Gold Mining Company – Moab Khotsong Operations (referred to as Moab Khotsong herein) to compile an Air Quality Impact Assessment report (AQIAr) for their existing waste water treatment plants (WWTPs) and a landfill site located in the North-West and Free State Provinces.

Moab Khotsong operations comprise of gold and uranium processing plants, a tailings storage complex, a waste rock dump and two mine shafts, and they specialise in producing gold bullion and ammonium di-urinate (ADU). Operations at Moab Khotsong trigger sub-category 4.1 (drying and calcining) and sub-category 4.17 (precious and base metal production & refining) in terms of Section 21 of the National Environmental Management Air Quality Act (NEM:AQA) (No. 39 of 2004). Moab Khotsong have an Atmospheric Emission Licence (AEL) (AEL No: AEL/FS/MKO-HGM/14/10/2019F), which expires 30 January 2026. In addition to the above-mentioned operations, there are off-mine services near Orkney, i.e. at the Orkney surface operations.

Three existing WWTPs and one landfill site are associated with the Moab Khotsong operations. The WWTPs are used for treatment of effluent from processing operations and ablution facilities at the mine and include the 3#, 8# and 11# WWTPs, which serve the off-mine services Orkney surface operations, Great Noligwa operations, and Moab Khotsong shaft operations, respectively. The landfill site is known as the Vaal River landfill site and accepts non-hazardous general waste comprising of builders' rubble, domestic waste, municipal waste, commercial waste, industrial waste and general waste from nearby properties, a village, offices, Moab Khotsong and Great Noligwa shafts, HD residences (hostels), workshops, as well as the South Uranium and Noligwa gold plants. As such the landfill site is classified as a Class B waste disposal facility (specifically, G:S:B-).

Due to operation of the three WWTPs and the landfill site, Moab Khotsong are required to conduct an odour assessment in terms of their Environmental Management Plan (EMP) and the Draft Odour Management Guidelines, which were drafted for internal circulation by the DFFE on 31 March 2020. This AQIAr has been compiled for the gold mine to meet these requirements.

The main objective of the AQIAr is to determine the potential impact of emissions associated with the operational activities at the WWTPs and the landfill site on ambient air quality in terms of dustfall, hazardous air pollutants (HAPs), volatile organic compounds (VOCs) and odorous gases.

As part of the AQIA, a Baseline Air Quality Assessment was undertaken to determine the following:

- the prevailing meteorological conditions at the site;
- establish baseline concentrations of key air pollutants of concern;
- identify existing sources of emissions; and
- identify key sensitive receptors surrounding the project site.

MM5 modelled meteorological data (obtained from Lakes Environmental) for the project area for the period January 2017 to December 2019 was used. The existing air quality situation is usually evaluated using available monitoring data from permanent ambient air quality monitoring stations (AQMS) operated near the project site (i.e. within a 10km radius). The existing AQMS is at the Jouberton AQMS (-26.89605°S; 26.6056°E), which is located too far from the mine – approximately 21.5km to the north-west and would not provide an accurate representation of baseline air quality at the mine. Furthermore, air quality monitoring of these pollutants in not undertaken at the mine. As such, background concentrations for the criteria air pollutants (PM_{10}, $PM_{2.5}$, SO_2, NO_2 and CO) could not be presented in this report. However, there was background dustfall data obtained from Moab Khotsong's dustfall monitoring network, which consists of 13 dustfall monitoring sites located in and around the mine. Dustfall rates at the mine for the period January 2021 – December 2021 were used.

Summary of conclusions for baseline assessment

The main conclusions based on information obtained during the Baseline Assessment are as follows:

Moab Khotsong, including associated Tailings Storage Facilities (TSFs), processing plants, WWTPs and the landfill site are located 7 – 15km south-east of Klerksdorp, within the North-West and Free State Provinces. The land use immediately surrounding the Moab Khotsong operations consists predominantly of grassland and agricultural/cultivated land use types. Mining areas, which include the existing Harmony Moab Kopanang and Mine Waste Solutions mines & processing plants, as well as SGS Vaal River Assay Lab, and TSFs; and urban residential, informal and smallholding areas are in near proximity north, north-west, west and south-east of the mine. The larger area surrounding Moab Khotsong is characterised as rural in nature. Existing key sources of air pollution surrounding the project site mostly include:

- Mining activity and TSFs (onsite, at nearby Harmony Moab Kopanang and Mine Waste Solutions mines and processing plants, as well as SGS Vaal River Assay Lab);
- Vehicle dust entrainment on surrounding unpaved roads;
- Wind erosion from open exposed areas (e.g. natural eroded areas, exposed farmland, TSFs, stockpiles, open storage piles, etc); and
- Commercial agricultural activity.

Other sources may also include the Vaal River landfill site (north-west of the mine), domestic fuel burning in urban informal areas located north and north-west of Moab Khotsong, industrial activity, sewage works, and vehicle exhaust emissions from vehicle activity on national and arterial roads located north, north-west, west and south of Moab Khotsong. The sewage works include the three WWTPs owned and operated by Moab Khotsong.

Based on the prevailing wind fields for the period January 2017 to December 2019, emissions from operations at the Vaal River landfill site and the three WWTPs, which are the focus of this study, will likely be transported towards the southerly direction as well as the south-westerly quadrant. In terms of the baseline air quality monitoring and data, the 13 dustfall monitoring sites at the mine consist of 12 single-unit buckets and one multi-directional Gateway dust-watch station with four buckets. Three of the single unit buckets are classified as residential, while the other nine single unit buckets are classified as non-residential. The Gateway dust-watch buckets are classified as residential. For the period January 2021 – December 2021, dustfall rates range from 6.0 – 4560 $mg/m^2/day$, with four exceedances of the non-residential limit of 1200 $mg/m^2/day$ recorded at the site identified as East of Kopanang TSF, and no exceedances of the residential limit of 600 $mg/m^2/day$ recorded. The four exceedances were recorded in September, October, November and December 2021. The dustfall rates recorded at the mine mostly comply with the South African National Dust Control Regulations at all monitoring sites except at the bucket located east of the Kopanang TSF.

Landfill gas (including HAPs), dust and odour are identified as the key pollutants of concern associated with operational activities at the Vaal River landfill site, while ammonia, volatile organic compounds (VOCs), which include acetone, chloroform, phenol, benzene, toluene and methanol, hydrogen sulphide (H_2S) and odour are identified as the key pollutants of concern associated with operational activities at the WWTPs and are emitted from the following key sources:

Landfill Site Emission Sources:

- Landfill gas emissions (consisting of a mixture of pollutants) due to:
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  - general landfill activities such as active tipping of fresh waste and exposed areas of waste.
- Emissions of Hydrogen Sulphide (H_2S) from leachate dams, if leachate dam is available.
- Odour emissions associated with overall landfilling activities.
- Dust emissions from:
  - Vehicle dust entrainment from the movement of trucks on unpaved roads onsite (in and around active Cells),
  - wind erosion of exposed surfaces (exposed waste at active Cell's workface and stockpiling of daily cover material),
  - compacting of waste at the active Cell's workface,
  - material handling (loading and offloading material from trucks).

Waste Water Treatment Plants Emission Sources:

- Odour emissions associated with overall waste water treatment activities;
- Aeration during primary treatment;
- Aerobic digestion;
- Anaerobic digestion; and
- Sludge drying.

The anticipated impact of activities at the WWTPs and the landfill site will be quantitatively assessed through dispersion modelling and presented in the final Level 2 AQIAr. This will include an assessment of landfill gas emissions passively vented to the atmosphere over the Cell surface area, odour emissions associated with overall landfilling activities (i.e. passive emissions over landfill, the compacting of waste at the cell workface, tipping of waste, exposed fresh waste at truck waiting areas and potentially emissions from the leachate dam), odour emissions associated with overall waste water treatment activities (primary and secondary clarification, anaerobic digestion, sludge drying beds, etc), and waste water treatment gas emissions (consisting of several pollutants).

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9. DECLARATIONS

DECLARATION OF ACCURACY OF INFORMATION - APPLICANT

Name of Enterprise: Harmony Gold Mining Operations – Moab Khotsong Operations

Project Consultant:	Harmony Gold Mining Operations – Moab Khotsong Operations		
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E-mail:	CGeel@Harmony.co.za		

Declaration of accuracy of information provided:

Atmospheric Impact Report in terms of Section 30 of the Act:

I Carlo Geel, declare that – General declaration

The information provided in this atmospheric impact report is, to the best of my knowledge, in all respects factually true and correct.

I am aware that the supply of false or misleading information to an air quality officer is a criminal offence in terms of section 51(1)(g) of this Act.

Signed at Randfontein on this___day of **August 2022**______________

____

SIGNATURE

____

CAPACITY OF SIGNATORY

DECLARATION OF INDEPENDENCE - PRACTITIONER

Specialist:	Rayten Engineering Solutions (Pty) Ltd		
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Professional affiliation(s) (if any)	SACNASP (400171/15)		

Name of Practitioner: Rayten Engineering Solutions (Pty) Ltd

Name of Registration Body: South African Council for Natural Scientific Professions

Professional Registration No: (400171/15)

Declaration of accuracy of information provided:

Atmospheric Impact Report in terms of Section 30 of the Act:

I Sophia Rosslee, declare that – General declaration

I am independent of the applicant;
I have the necessary expertise to conduct the assessments required for the report; and
I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant;
I will disclose to the applicant and the air quality officer all material information in my possession that reasonably has or may have the potential of influencing any decision to be taken with respect to the application by the air quality officer.
The information provided in this atmospheric impact report is, to the best of my knowledge, in all respects factually true and correct. I am aware that the supply of false or misleading information to an air quality officer is a criminal offence in terms of section 51(1)(g) of this Act.

Signed at **Randburg** on the **5th** day of **August 2022**

SIGNATURE

Senior Air Quality Specialist
CAPACITY OF SIGNATORY