Air Quality Impact Assessment Report for Cluster 2 of the Gas Gathering Project in Virginia, South Africa

Project done on behalf of **EIMS (Pty) Ltd**

Report Compiled by:
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Report No: 21EIM07 | **Date:** June 2022

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REPORT DETAILS

Project Name	Air Quality Impact Assessment Report for Cluster 2 of the Gas Gathering Project in Virginia, South Africa
Client	Environmental Impact Management Services (EIMS) (Pty) Ltd
Report Number	21EIM07
Report Version	Rev 2
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Reviewed by	Hanlie Liebenberg-Enslin, PhD (University of Johannesburg)
Notice	Airshed Planning Professionals (Pty) Ltd is a consulting company located in Midrand, South Africa, specialising in air quality and environmental noise impact assessments. The company originated in 1990 as Environmental Management Services, which amalgamated with its sister company, Matrix Environmental Consultants, in 2003.
Declaration	I, Hanlie Liebenberg-Enslin, as authorised representative of Airshed Planning Professionals (Pty) Ltd, hereby confirm my independence as a specialist and declare that neither I nor Airshed Planning Professionals (Pty) Ltd have any interest, be it business, financial, personal or other, in any proposed activity, application or appeal in respect of which Airshed Planning Professionals (Pty) Ltd was appointed as air quality specialists in terms of the National Environmental Management Act, 1998 (Act No. 107 of 1998); other than fair remuneration for worked performed, specifically in connection with the assessment summarised in this report. I also declare that I have expertise in undertaking the specialist work as required, possessing working knowledge of the acts, regulations and guidelines relating to the application. I further declare that I am able to perform the work relating to the application in an objective manner, even if this result in views and findings that is not favourable to the application; and that I am confident in the results of the studies undertaken and conclusions drawn as a result of it – as is described in this report.
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REVISION RECORD

Revision Number	Date	Reason for Revision
Rev 0	June 2022	For Client Review
Rev 1	September 2022	Alignment with Cluster1 Management Plan
Rev 2	November 2022	Define Set Back distances in Section 4.3.3

COMPETENCY PROFILES

Report author and Project Manager: H Liebenberg-Enslin, PhD Geography (University of Johannesburg).

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

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

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

Report author: R Bornman (M.Phil in GIS and Remote Sensing, University of Cambridge)

Rochelle Bornman started her professional career in Air Quality in 2008 when she joined Airshed Planning Professionals (Pty) Ltd after having worked in malaria research at the Medical Research Council in Durban. Rochelle has worked on several air quality specialist studies between 2008 and 2022. She has experience on the various components including emissions quantification for a range of source types, simulations using a range of dispersion models, impacts assessment and health risk screening assessments. Her project experience range over various countries in Africa, providing her with an inclusive knowledge base of international legislation and requirements pertaining to air quality. Whilst most of his working experience has been in South Africa, a number of investigations were made in countries elsewhere, including Mozambique, Namibia, Saudi Arabia and Mali.

EXECUTIVE SUMMARY

Tetra4 wishes to expand the natural gas operations within the approved production right area and around the Cluster 1 project. This planned expansion to the existing approved production activities will involve up to 300 new production wells, gas transmission pipelines and associated infrastructure, three (3) compressor stations and an additional new combined Liquid Natural Gas (LNG) and Liquid Helium (LHe) plant ("LNG/LHe Plant") and associated infrastructure.

A quantitative air quality impact assessment was conducted for the planning and design, construction, operation, decommissioning, rehabilitation and closure phase activities of the Tetra4 Cluster 2 Project. The assessment included an estimation of atmospheric emissions, the simulation of pollutant levels and determination of the significance of impacts. This section summarises the main findings of the impact assessment.

The conclusions and recommendations of the assessment are summarised below:

- The receiving environment:
  - The area is dominated by winds from the north-northeast and northeast, followed by northerly and easterly winds with an average wind speed of 3.7 m/s.
  - Ambient air pollutant levels in the project area are currently affected by the following sources of emission: agricultural activities, gold mining and ore processing, fugitive and process emissions, vehicle tailpipe emissions, household fuel combustion, biomass burning and windblown dust from exposed areas.
  - AQSRs such as residences and farm holdings are located within and beyond the project boundary. Nearby towns include Welkom, Virginia, Bronville, Harmony and Theunissen.

- Impact of the Project:
  - Planning, design and construction phase impacts:
    - Construction activities for the roads/pipeline, wells and booster stations (where the location may vary depending on the gas reserves in the area) vehicle and equipment (vehicle entrainment and vehicle exhaust gas), three compressor stations and the plant might include land clearing, topsoil removal, material loading, bulk services construction, hauling, excavation, back-filling, road construction (where necessary) and traffic, rig-move/drilling, pipeline installation, and wind erosion of exposed areas.
    - Resulting potential air quality health and nuisance impacts at the nearest residential receptors resulted in a **medium** significance without mitigation and **low** significance with mitigation. Worst-case simulated construction impacts are not anticipated to occur over long intervals since construction activities will only last a few weeks and peak activities will not be consistent over the specified period.

  - Operational phase impacts:
    - Potential air quality impacts, including health and nuisance impacts, as a result of operational phase activities such as operation of the well pad, roads, pipelines, compression station, booster station and combined LNG/LHe plant, as well as associated emissions from movement of trucks and other vehicles, flaring (if applicable), and gas processing as well as operation of heavy machinery.
    - Vehicles on unpaved roads, and specifically the plant access road, even under mitigated conditions are likely to result in **medium** significance at the nearest receptors but will reduce to **low** significance should the road be paved.
    - Air quality impacts due to booster station (generator) operations of **medium** significance but **low** significance at the nearest receptors with mitigation measures in place.

- Plant (flaring) operations are unlikely to result in exceedances of the respective NAAQS's and are therefore considered to be of **low** significance at the nearest receptors.

- Decommissioning, rehabilitation and closure phase impacts:
  - Potential air quality impacts, including health impacts as a result of decommissioning, rehabilitation and closure phase activities such as decommissioning/ removal of all berms, trenches and other storm water infrastructure, stationary infrastructure, pipeline infrastructure, and wastes.
  - The environmental risk was assigned a score of **low** significance due to localised impacts of the various emissions, their temporary nature, and the likelihood that these activities will not occur concurrently at all portions of the site.

In conclusion, it is the specialist opinion that the project may be authorised provided that the recommended air quality management measures are implemented. These air quality management measures include:

- Source emissions monitoring and reporting;
- Ambient air quality monitoring;
- Mitigation measures aimed at reducing emissions at source;
- Paving of the unpaved road from plant to provincial R30 road; and
- The delineation of impact zones around production wells, pipeline routes, compressor and booster stations and the plant site. As a conservative approached the following setback distances are recommended, where these are seen as management zones where the potential for air quality impacts can be mitigated and managed:

<table>
<tr><th colspan="2">Project phase and associated activities</th><th>Setback distance (m)</th><th>Indicator Pollutant</th><th>Description</th></tr>
<tr><td rowspan="6">Construction</td><td>Well construction site</td><td>750</td><td rowspan="4">NO_2</td><td rowspan="4">Setback distance represents a single exceedance of the NO_2 hourly NAAQS limit, where the distance will be significantly less based on the allowable frequency of exceedance.</td></tr>
<tr><td>Booster station site</td><td>500</td></tr>
<tr><td>Pipeline construction site</td><td>150</td></tr>
<tr><td>Road construction site</td><td>150</td></tr>
<tr><td>Compressor station construction site</td><td>200</td><td rowspan="2">PM_{10}</td><td></td></tr>
<tr><td>Plant construction site</td><td>270</td><td>Based on exceedance of NAAQ daily limit.</td></tr>
<tr><td rowspan="3">Operational</td><td>Booster station</td><td>100</td><td>PM_{10} and NO_2</td><td rowspan="2">Setback distance represents a single exceedance of the NO_2 hourly NAAQS limit and of the daily PM_{10} NAAQS limit, where the distance will be less based on the allowable frequency of exceedance.</td></tr>
<tr><td>Unpaved road</td><td>80</td><td>PM_{10}</td></tr>
<tr><td>Plant</td><td>none</td><td>none</td><td>The flare is an intermittent source with no exceedances</td></tr>
</table>

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ABBREVIATIONS

Airshed	Airshed Planning Professionals (Pty) Ltd
AEL	Atmospheric Emissions Licence
AERMIC	AMS/EPA Regulatory Model Improvement Committee
AERMOD	AERMIC Dispersion Model
AIR	Atmospheric Impact Report
AMS	American Meteorological Society
APPA	Air Pollution and Prevention Act
AQM	Air quality management
AQMS	Air quality monitoring station
AQSRs	Air Quality Sensitive Receptor(s)
AST	Anemometer starting threshold
ASTM	American Society for Testing and Materials
CE	Control Efficiency
DEA	Department of Environmental Affairs (now DEFF)
DEFF	Department of Environment, Forestry, and Fisheries (previously DEA)
DMRE	Department of Mineral Resources and Energy
EA	Environment Australia
EIA	Environmental Impact Assessment
EIMS	Environmental Impact Management Services (Pty) Ltd
EMP	Environmental Management Plan
EMPr	Environmental Management Programme
ER	Environmental Risk
ESL	Effects Screening Level
GLC	Ground level concentration
IRP	Integrated Resource Plan
LHe	Liquid Helium
LNG	Liquid Natural Gas
MES	Minimum Emission Standards
NAAQ Limit	National Ambient Air Quality Limit concentration
NAAQS	National Ambient Air Quality Standards (as a combination of the NAAQ Limit and the allowable frequency of exceedance)
NAEIS	National Atmospheric Emissions Inventory System
NDCR	National Dust Control Regulations
NEMAQA	National Environmental Management Air Quality Act
SAAELIP	South African Atmospheric Emission Licencing and Inventory Portal
SAWS	South African Weather Services
TCEQ	Texas Commission for Environmental Quality
Tetra4	Tetra4 (formerly known as Molopo South Africa Exploration and production (Pty) Ltd)
US EPA	United States Environmental Protection Agency
VKT	Vehicle kilometres travelled

SYMBOLS AND UNITS

°C	Degree Celsius
C_6H_6	Benzene
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
CO_2-eq	Carbon dioxide equivalent
ha	Hectare
H_2S	Hydrogen Sulfide
HC	Hydrocarbons
HFC	Hydrofluorocarbons
kg	Kilograms
1 kilogram	1 000 grams
km	Kilometre
m	Metres
mm	Millimetres
mamsl	Metres above mean sea level
m/s	Metres per second
mm	Millimetres
NO	Nitrogen oxide
N_2O	Nitrous oxide
NO_2	Nitrogen dioxide
NO_x	Oxides of nitrogen
O_3	Ozone
Pb	Lead
PFC	Perfluorocarbons
PM	Particulate Matter
$PM_{2.5}$	Inhalable particulate matter (aerodynamic diameter less than 2.5 µm)
PM_{10}	Thoracic particulate matter (aerodynamic diameter less than 10 µm)
SF6	Sulfur hexafluoride
SO_2	Sulfur dioxide (1)
tpa	Tonnes per annum
VOC	Volatile organic compound(s)
1 ton	1 000 000 grams

Notes:

(1) The spelling of "sulfur" has been standardised to the American spelling throughout the report. The International Union of Pure and Applied Chemistry, the international professional organisation of chemists that operates under the umbrella of UNESCO, published, in 1990, a list of standard names for all chemical elements. It was decided that element 16 should be spelled "sulfur". This compromise was to ensure that in future searchable data bases would not be complicated by spelling variants. (IUPAC. Compendium of Chemical Terminology, 2nd ed. (the "Gold Book"). Compiled by A. D. McNaught and A. Wilkinson. Blackwell Scientific Publications, Oxford (1997). XML on-line corrected version: http://goldbook.iupac.org (2006) created by M. Nic, J. Jirat, B. Kosata; updates compiled by A. Jenkins. ISBN 0-9678550-9-8.doi: 10.1351/goldbook)"

GLOSSARY

Air pollution[a]	The presence of substances in the atmosphere, particularly those that do not occur naturally
Dispersion[a]	The spreading of atmospheric constituents, such as air pollutants
Dust[a]	Solid materials suspended in the atmosphere in the form of small irregular particles, many of which are microscopic in size
Instability[a]	A property of the steady state of a system such that certain disturbances or perturbations introduced into the steady state will increase in magnitude, the maximum perturbation amplitude always remaining larger than the initial amplitude
Mechanical mixing[a]	Any mixing process that utilizes the kinetic energy of relative fluid motion
Oxides of nitrogen (NO_x)	The sum of nitrogen oxide (NO) and nitrogen dioxide (NO_2) expressed as nitrogen dioxide (NO_2)
Particulate matter (PM)	Total particulate matter, that is solid matter contained in the gas stream in the solid state as well as insoluble and soluble solid matter contained in entrained droplets in the gas stream
PM_{10}	Particulate Matter with an aerodynamic diameter of less than 10 µm
$PM_{2.5}$	Particulate Matter with an aerodynamic diameter of less than 2.5 µm
Stability[a]	The characteristic of a system if sufficiently small disturbances have only small effects, either decreasing in amplitude or oscillating periodically; it is asymptotically stable if the effect of small disturbances vanishes for long time periods

Notes:

(a) Definition from American Meteorological Society's glossary of meteorology (AMS, 2014)

1 INTRODUCTION

Tetra4 holds the first and only petroleum production right in South Africa, making Tetra4 the front runner in domestic natural gas distribution. A Production Right (Ref: 12/4/1/07/2/2) was granted in 2012, spanning approximately 187 000 hectares (ha) for the development of natural gas (Helium and Methane) production operations around the town of Virginia in the Free State Province. Within this approval, the 2010 Environmental Management Programme (EMPr) was approved which is applicable to a large portion of the Production Right area (Figure 1). Activities within the Production Right areas include:

- Continued exploration activities;
- Drilling and establishment of further production wells throughout the entire production area (260 production wells);
- Installation of intra-field pipelines throughout the entire production area (~500 km);
- Installation of boosters and main compressors; and
- Central gas processing plant (not approved in the original Environmental Impact Assessment (EIA) and approved EMPr).

An integrated environmental authorisation (EA) for the first phase gas field production referred to as Cluster 1, in terms of the National Environmental Management Act (NEMA), was issued on 21 September 2017 by the Department of Mineral Resources and Energy (DMRE) to Tetra4 ("Cluster 1 EA", reference: 12/04/07) and amended on 26 August 2019 and 1 September 2021. In this EA approval, various new wells and pipelines, booster and compressor stations, a Helium and Liquid Natural Gas (LNG) Facility and associated infrastructure was approved which comprises the first gas field for development within the approved Production Right area. The Cluster 1 EA also authorises certain waste management activities as per the List of Waste Management Activities (Government Notice 921, as amended) published under the National Environmental Management: Waste Act 59 of 2008 (NEMWA).

Tetra4 now plans to expand the natural gas operations (referred to as Cluster 2) to be located within the approved production right area and around the Cluster 1 project (Figure 2). This planned expansion to the existing approved production activities will include:

- Drilling and establishment of further production wells (up to 300 new production wells);
- Installation of gas transmission pipelines and associated infrastructure;
- Installation of three (3) compressor stations;
- An additional new combined LNG and Liquid Helium (LHe) plant ("LNG/LHe Plant") and associated infrastructure, and
- Establishment of powerlines as part of the Cluster 2 expansion of the Project in order to meet the future production requirements.

Airshed Planning Professionals (Pty) Ltd (Airshed) was appointed by Environmental Impact Management Services (EIMS) (Pty) Ltd to conduct an air quality impact assessment (AQIA) for the project. The main objective of the air quality study is to determine air quality related impacts as a result of the proposed project on air quality sensitive receptors (AQSRs).

1.1 Study Objective

The main objective of the air quality impact assessment is to determine the significance of impacts on the surrounding environment and human health as a result of the air pollution generated by activities proposed as part of the project.

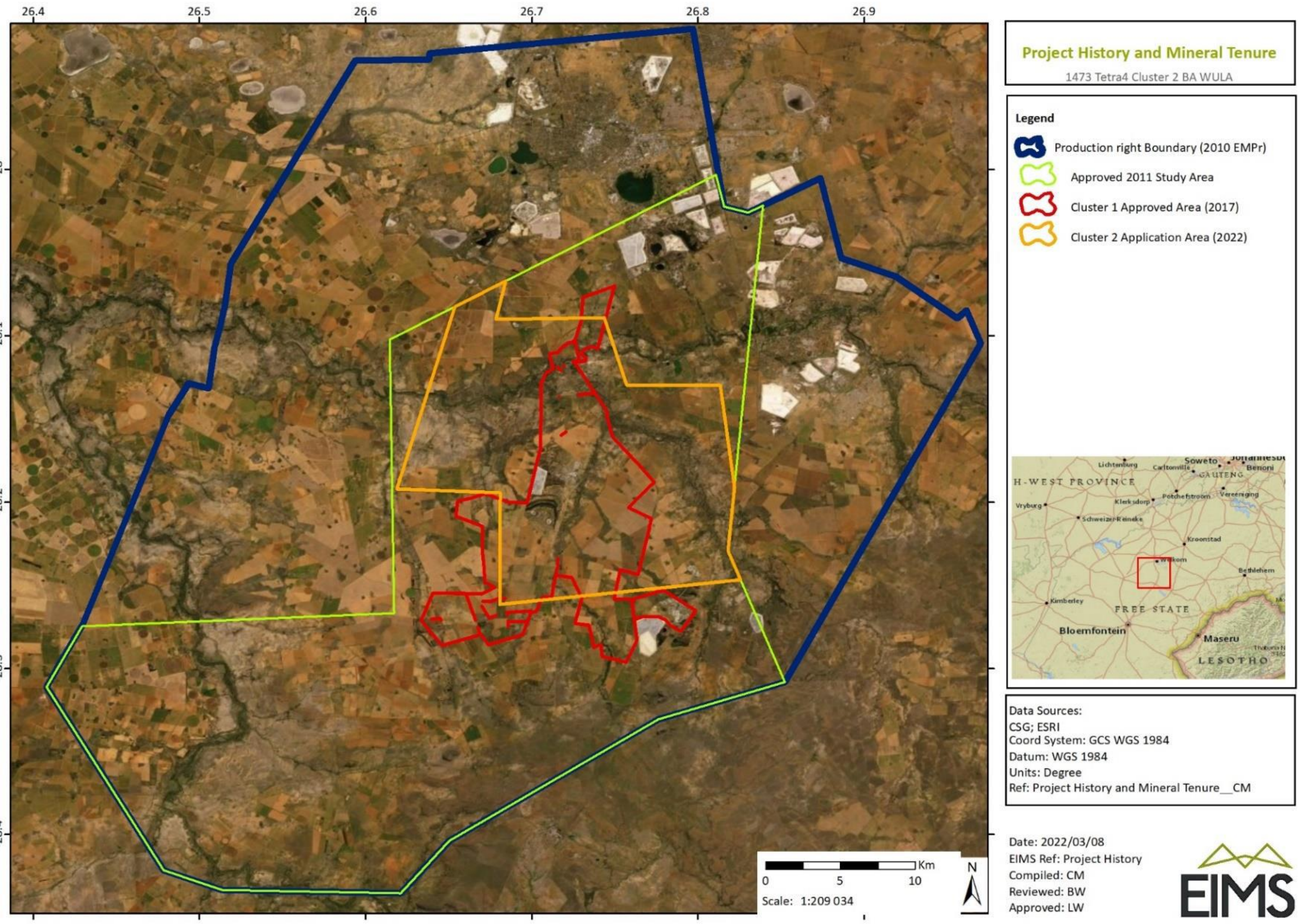

Figure 1: Project history and mineral tenure

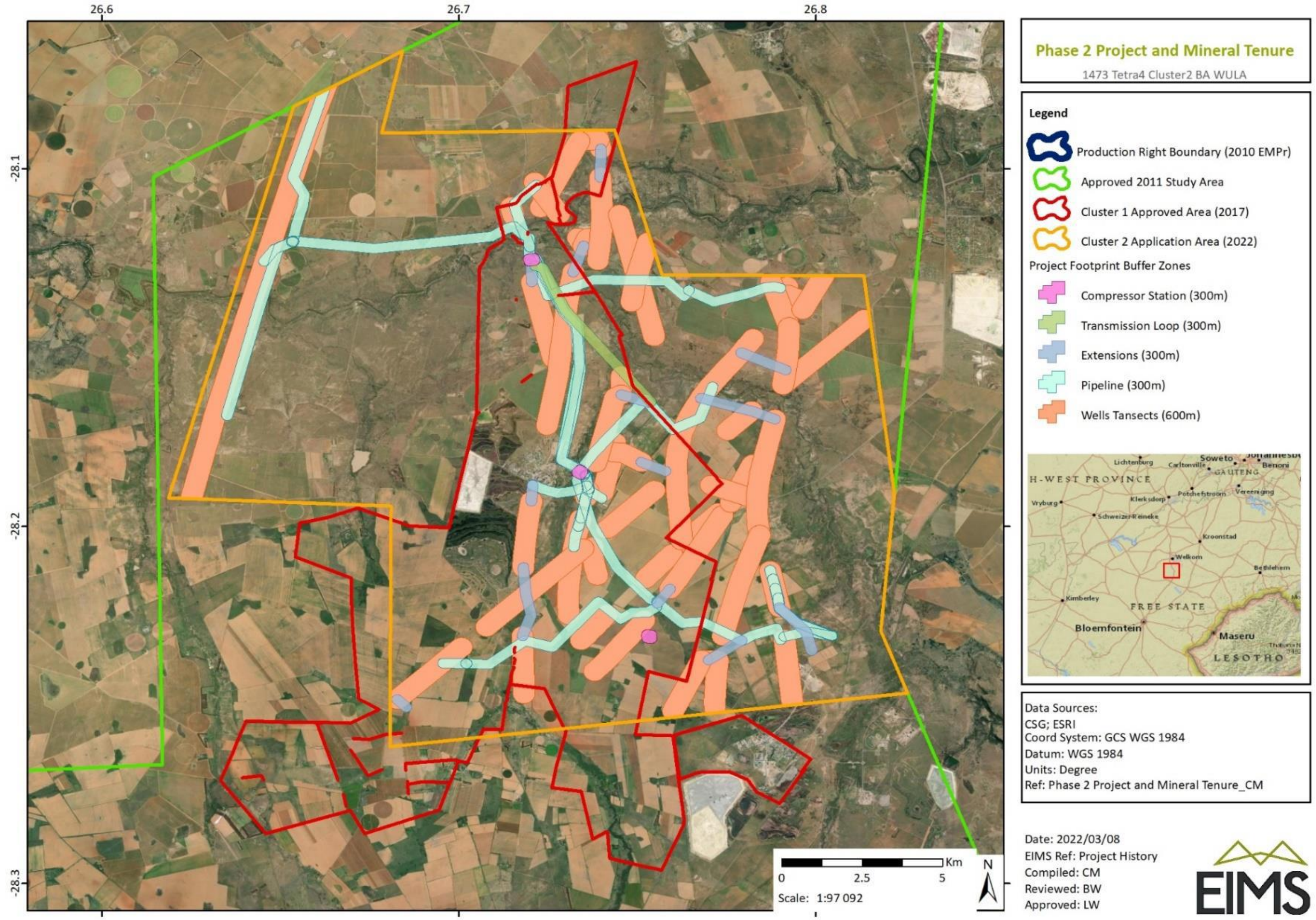

Figure 2: Cluster 2 study area and proposed infrastructure footprint buffer zones

1.2 Scope of Work

The AQIA study encompasses the following tasks:

- A study of legal requirements pertaining to air quality:
  - National Ambient Air Quality Standards,
  - Minimum Emission Limits (if applicable), and
  - National Dustfall Control Regulations.
- A study of the receiving environment by referring to:
  - Desktop review of all available project and associated data, including metrological data, previous air quality assessments, EIAs and technical air quality data and models (specifically the AQIA conducted for Cluster 1 in 2017);
  - Identification of existing air pollution sources;
  - Identification of air quality-sensitive receptors, including any nearby residential dwellings, hospitals, schools and places of worship, etc. including the location of proposed receptors (temporary or permanent workers accommodation site(s)) in the vicinity of the project infrastructure;
  - Collection of local weather conditions from the South African Weather Services (SAWS) station in Welkom for a period of three consecutive years (2019 - 2020) – the data used in the 2017 study falls outside the Department of Forestry, Fisheries and the Environment (DFFE) dispersion modelling guidelines of not older than 5 years;
  - Collect and analyse baseline air pollutant measurements data collection and analysis (if available); and
  - Compilation of an air quality sensitivity map.
- Impact Assessment, including:
  - The compilation of an emissions inventory incl. the identification and quantification of all emissions associated with the construction and operational phases of the project.
  - Atmospheric dispersion simulations of all gaseous pollutants, PM_{10}, $PM_{2.5}$ and dust fallout for the operations reflecting highest hourly, highest daily and annual average concentrations and total daily dust deposition due to routine and upset emissions from the mining operations. The US EPA approved AERMOD model will be used.
  - Compliance and impact assessment by comparing ambient pollutant concentration levels to the relevant air quality requirements.
  - The identification of air quality management and mitigation measures based on the findings of the compliance and impact assessment.
  - A specialist air quality impact assessment report.
  - The development of an air quality monitoring programme to be included in the Environmental Management Plan (EMP).

1.3 Study Approach and Methodology

The baseline description and ranking following the following approach.

1.3.1 Project and Information Review

A review of the project from an air quality perspective in order to identify sources of emission and associated pollutants of concern was conducted. In the review the following documents were referenced:

- Project information supplied by EIMS, including the AQIA conducted in 2017 (Akinshipe, 2017); and

- Section 21 of the National Environmental Management: Air Quality Act (NEMAQA); and,

1.3.2 A Study of the Receiving Environment

The baseline environment was studied by taking into account:

- The local atmospheric dispersion potential;
- The position of air quality sensitive receptors (AQSRs) in relation to the project; and
- Measured ambient air quality in the study area.

An understanding of the atmospheric dispersion potential of the area is essential to an air quality impact assessment. Physical environmental parameters that influence the dispersion of pollutants in the atmosphere include terrain, land cover and meteorology.

Data from the SAWS Welkom meteorological station was used to establish baseline meteorological conditions for the project site. The dataset included a minimum of hourly average wind speed, wind direction and temperature station. For the purposes of establishing the local climatology, it is necessary to analyse at least one year of on-site data; and at least three years of off-site data (DEA, 2014).

Measured air quality data as part of the passive sampling campaign initiated by Environmental Impact Management Services (EIMS) (Pty) Ltd in 2018 around the Tetra 4 (Pty) Ltd in 2018 around the Tetra4 Virginia Compression Plant, was accessed for this study. The dataset includes bi-annual ambient concentrations of sulfur dioxide (SO_2), nitrogen dioxide (NO_2), hydrogen fluoride (HF) and, total volatile organic compounds (TVOCs) for the period 2019 to 2021.

Readily available terrain data was obtained from the United States Geological Survey (USGS) web site (https://earthexplorer.usgs.gov/) in January 2022. A study was made of Shuttle Radar Topography Mission (STRM) 1 arc-sec data.

Potential AQSRs, residential areas, schools and medical facilities, were identified from recent maps of the area using Google Earth™ aerial imagery.

1.4 Project Description

1.4.1 Construction

The construction phase comprises activities, such as drilling and construction of new wells, construction of access roads, installation of pipelines, construction of the helium and LNG plant, as well as site clearing or upgrade activities on existing wells. Each of these operations has its own duration and potential for dust generation with typical activities land clearing, topsoil removal, material loading and hauling, stockpiling, grading, bulldozing, compaction, well drilling etc. It is anticipated therefore that the extent of dust emissions would vary substantially from day to day depending on the level of activity, the specific operations, and the prevailing meteorological conditions. This is in contrast to most other fugitive dust sources where emissions are either relatively steady or follow a discernible annual cycle. It is therefore often necessary to estimate area wide construction emissions, without regard to the actual plans of any individual construction process.

Activities applicable to the Project that would result in air pollution during the construction phase are listed Table 1.

Table 1: Construction activities resulting in air pollution

Activity	Associated pollutants
Handling and storage area for construction materials (paints, solvents, oils, grease) and waste	particulate matter (PM)[(a)] and fumes (Volatile Organic Compounds [VOCs])
Pipeline and power supply infrastructure	sulfur dioxide (SO_2); oxides of nitrogen (NOx); carbon monoxide (CO); carbon dioxide (CO_2)[(b)]; particulate matter (PM)
Drilling of production wells	SO_2; NOx; CO; PM, CO_2
Clearing and other earth moving activities	mostly PM, gaseous emissions from earth moving equipment (SO_2; NOx; CO; CO_2)
Foundation excavations	mostly PM, gaseous emissions from excavators (SO_2; NOx; CO; CO_2)
Opening and backfill of material (specific grade) from borrow pits	mostly PM, gaseous emissions from trucks and equipment (SO_2; NOx; CO; CO_2)
Delivery of materials – storage and handling of material such as sand, rock, cement, chemical additives, etc.	mostly PM, gaseous emissions from trucks (SO_2; NOx; CO; CO_2)
General building/construction activities including, amongst others: mixing of concrete; operation of construction vehicles and machinery; refuelling of machinery; civil, mechanical and electrical works; painting; grinding; welding; etc	mostly PM, gaseous emissions from construction vehicles and machinery (SO_2; NOx; CO; CO_2)

Notes: [(a)] Particulate matter (PM) comprises a mixture of organic and inorganic substances, ranging in size and shape and can be divided into coarse and fine particulate matter. Total Suspended Particulates (TSP) represents the coarse fraction >10µm, with particulate matter with an aerodynamic diameter of less than 10µm (PM_{10}) and particulate matter with an aerodynamic diameter of less than 2.5µm ($PM_{2.5}$) falling into the finer inhalable fraction. TSP is associated with dust fallout (nuisance dust) whereas PM_{10} and $PM_{2.5}$ are considered a health concern.
[(b)] CO_2 is a greenhouse gas (GHG).

1.4.2 Operations

The operational phase of the Project will include mainly the combined Helium/LNG plant (pumps, compressors, motors, cooling towers, trucks and generators) and vehicles on roads.

Activities at Tetra4 Project likely to result in pollutants to air are listed in Table 2.

Table 2: Operational activities resulting in air pollution

Activity	Associated pollutants
Transport of consumables and product	PM from road surfaces and windblown dust from trucks, gaseous emissions from truck exhaust (PM, SO_2; NOx; CO; CO_2)
Management of waste	PM, gaseous emissions from machinery (PM, SO_2; NOx; CO; CO_2) and VOCs
Flaring	PM, SO_2; NOx; CO; CO_2 and VOCs
Helium and LNG plant	PM, SO_2; NOx; CO; CO_2 and VOCs
Diesel generators	PM, metals[(a)(e)], NOx, SO_2, CO, TVOC, PAH, TEQ

1.5 Assumptions and Limitations

The following important limitation applies to the study and should be noted:

- Project information required to calculate emissions for proposed operations were provided by Tetra4 and EIMS. Where necessary, assumptions were made based on common industry practice and experience.
- Only routine emissions for the operational phase were estimated and simulated. Atmospheric releases occurring as a result of non-routine conditions were not accounted for limited to emergency flaring at the plant, with other non-routine releases expected to be minimal.
- Emission factors were used to estimate all fugitive and processing emissions resulting from plant, construction activities and transport. These emission factors generally assume average operating conditions.
- The access road from the R30 road to the plant was assumed to be unpaved.
- The compressor stations were assumed to be electrically powered, whereas the booster stations were assumed to use diesel generators.
- Flaring was simulated at the plant only (no flaring of wells was included). Throughput data were provided for two designs (continuous and emergency design) and modelled accordingly.
- Assumptions on flare stack metrics were made based on similar operation elsewhere (Burger and Akinshipe, 2014).
- It was assumed that no smoke/soot will be emitted by the flare.
- The impact assessment was limited to airborne particulates (including TSP, PM_{10} and $PM_{2.5}$) and gaseous pollutants from combustion and non-combustion machinery, including CO, NOx, VOCs and SO_2.
- Nitrogen monoxide (NO) emissions are rapidly converted in the atmosphere into nitrogen dioxide (NO_2). NO_2 impacts where calculated by using a NO_2/NOx emission ratio of 0.2 (Howard, 1988).
- Planning and design, decommissioning, closure and rehabilitation phase impacts were not quantified. Impacts associated with these phases are highly variable and generally less significant than construction and operational phase impacts. Mitigation and management measures recommended for the construction and operational phases are however also applicable to the planning and design, decommissioning, closure and rehabilitation phases.

2 REGULATORY REQUIREMENTS AND ASSESSMENT CRITERIA

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

Emission standards are generally provided for point sources and specify the amount of the pollutant acceptable in an emission stream and are often based on proven efficiencies of air pollution control equipment.

Air quality guidelines and standards are fundamental to effective air quality management, providing the link between the source of atmospheric emissions and the user of that air at the downstream receptor site. The ambient air quality standards and guideline values indicate safe daily exposure levels for the majority of the population, including the very young and the elderly, throughout an individual's lifetime. Air quality guidelines and standards are normally given for specific averaging or exposure periods.

This section summarises legislation for criteria pollutants relevant to the current study and dustfall. A discussion on inhalation health risk for VOC is also provided.

2.1 National Minimum Emission Standards and AEL Application and Reporting Requirements

2.1.1 National Minimum Emission Standards

The NEMAQA (Act No. 39 of 2004 as amended) mandates the Minister of Environment to publish a list of activities which result in atmospheric emissions and consequently cause significant detrimental effects on the environment, human health and social welfare, economic conditions, ecological conditions or cultural heritage. All scheduled processes as previously stipulated under the Air Pollution Prevention Act are included as listed activities with additional activities added to the list. The updated Listed Activities and Minimum National Emission Standards (MES) were published in 2013 (GN 893, in Government Gazette No. 37054) as amended by GN 551, 12 June 2015; GN 1207, 81 October 2018 and GN 687, 22 May 2019). Based on the information available during the scoping phase of assessment, the proposed project will trigger Minimum Emission Standards (MES) subsection (a) under **Subcategory 2.4: Storage and Handling of Petroleum Products**[1]. The MES of concern for the project is provided in Table 3.

Table 3: Subcategory 2.4 – Storage and Handling of Petroleum Products

Description:	**Storage and handling of petroleum products.**	
Application:	All permanent immobile liquid storage facilities at a single site with a combined storage capacity of greater than 1,000 m³.	
Substance or mixture of substances	**Plant status**	**mg/Nm³ under normal conditions of 273 Kelvin and 101.3 kPa.**
Total Volatile Organic Compounds (TVOC) from vapour recovery/destruction units using thermal treatment	New	150
Total Volatile Organic Compounds (TVOC) from vapour recovery/destruction units using non-thermal treatment	New	40,000

[1] Petroleum Products, according to the NEMAQA, refers to production of gaseous and liquid fuels as well as petrochemicals from crude oil, coal, gas or biomass.

(a) The following transitional arrangement shall apply for the storage and handling of raw materials, intermediate and final products with a vapour pressure greater than 14kPa at operating temperature: -
Leak detection and repair (LDAR) program approved by licensing authority to be instituted, by 01 January 2014.

2.1.2 Reporting of Atmospheric Emissions

The National Atmospheric Emission Reporting Regulations (Government Gazette No. 38633) came into effect on 2 April 2015. The purpose of the regulations is to regulate the reporting of data and information from an identified point, non-point and mobile sources of atmospheric emissions to an internet-based National Atmospheric Emissions Inventory System (NAEIS). The NAEIS is a component of the South African Atmospheric Emission Licencing and Inventory Portal (SAAELIP). Its objective is to provide all stakeholders with relevant, up to date and accurate information on South Africa's emissions profile for informed decision making.

Emission sources and data providers are classified according to groups. The proposed project would be classified under Group A ("Listed activity published in terms of section 21(1) of the NEMAQA"). Emission reports from Group A must be made in the format required for NAEIS and in accordance with the atmospheric emission license or provisional atmospheric emission license.

As per the regulation, Tetra 4 and/or their data provider must register on the NAEIS within 30 days after commencing with proposed activities. Data providers must inform the relevant authority of changes if there are any:

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

A data provider must submit the required information for the preceding calendar year to the NAEIS by 31 March of each year. Records of data submitted must be kept for a period of 5 years and must be made available for inspection by the relevant authority.

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

2.2 Screening Criteria

2.2.1 National Ambient Air Quality Standards (NAAQS)

Criteria pollutants are considered those pollutants most commonly found in the atmosphere, that have proven detrimental health effects when inhaled and are regulated by ambient air quality criteria. South African NAAQS for SO_2, NO_2, PM_{10}, carbon monoxide (CO), ozone (O_3), benzene (C_6H_6), and lead (Pb) were published on 13 March 2009. Standards for $PM_{2.5}$ were published on 24 June 2012. All standards are listed in Table 4 where pollutants of interest to the proposed project are shaded in blue.

Table 4: National Ambient Air Quality Standards for criteria pollutants

Pollutant	Averaging Period	Limit Value ($\mu g/m^3$)	Limit Value (ppb)	Frequency of Exceedance	Compliance Date
SO_2	10-minute	500	191	526	Currently enforceable
	1-hour	350	134	88	Currently enforceable
	24-hour	125	48	4	Currently enforceable
	1-year	50	19	-	Currently enforceable
NO_2	1-hour	200	106	88	Currently enforceable
	1-year	40	21	-	Currently enforceable
PM_{10}	24-hour	75	-	4	Currently enforceable
	1-year	40	-	-	Currently enforceable
$PM_{2.5}$	24-hour	40	-	4	1 Jan 2016 – 31 Dec 2029
		25	-	4	1 Jan 2030
	1-year	20	-	-	1 Jan 2016 – 31 Dec 2029
		15	-	-	1 Jan 2030
CO	1-hour	30 000	26 000	88	Currently enforceable
	8-hour	10 000	8 700	11	Currently enforceable
Benzene (C_6H_6)	1-year	5	1.6	-	Currently enforceable
Ozone (O_3)	8 hours (running)	120	61	11	Currently enforceable
Lead (Pb)	1-year	0.5	-	-	Currently enforceable

2.2.2 *Inhalation Health Criteria for non-criteria Pollutants*

The potential for health impacts associated with non-criteria pollutants (VOCs) emitted from combustion sources are assessed according to guidelines published by the Texas Commission on Environmental Quality (TCEQ) - Effects Screening Levels (ESLs) (TCEQ (2013).

Table 5: Chronic inhalation screening criteria for non-criteria pollutants

Pollutant	Acute/Short term Screening Criteria ($\mu g/m^3$)	Chronic/Long term Screening Criteria ($\mu g/m^3$)	Reference
VOC (*Diesel fuel* used as indicator)	1000	100	TCEQ

2.2.3 *National Dust Control Regulations (NDCR)*

NDCR were published on the 1st of November 2013 (Government Gazette No. 36974 R.827). Acceptable dustfall rates according to the Regulation are summarised in Table 6.

Table 6: Acceptable dustfall rates

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

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

2.2.4 Screening criteria for animals and vegetation

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

2.3 Atmospheric Dispersion Modelling Regulations

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

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

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

- Level 1: where worst-case air quality impacts are assessed using simpler screening models
- Level 2: for assessment of air quality impacts as part of license application or amendment processes, where impacts are the greatest within a few kilometres downwind (less than 50km)
- Level 3: require more sophisticated dispersion models (and corresponding input data, resources and model operator expertise) in situation:
    - where a detailed understanding of air quality impacts, in time and space, is required;
    - where it is important to account for causality effects, calms, non-linear plume trajectories, spatial variations in turbulent mixing, multiple source types & chemical transformations;
    - when conducting permitting and/or environmental assessment process for large industrial developments that have considerable social, economic and environmental consequences;
    - when evaluating air quality management approaches involving multi-source, multi-sector contributions from permitted and non-permitted sources in an air-shed; or,
    - when assessing contaminants resulting from non-linear processes (e.g. deposition, ground-level O_3, particulate formation, visibility).

The first step in the dispersion modelling exercise requires a clear objective of the modelling exercise and thereby gives clear direction to the choice of the dispersion model most suited for the purpose. Accordingly, a Level 2 assessment is considered suitable for proposed project during the Environmental Impact Assessment phase of the study.

3 Description of the Receiving Environment

3.1 Air Quality Sensitive Receptors (AQSRs)

Air quality sensitive receptors (AQSRs) refer to places where humans reside. Ambient air quality guidelines and standards, as discussed under section 2.2, have been developed to protect human health. Ambient air quality, in contrast to occupation exposure, pertains to areas outside of an industrial site or boundary where the public has access to and according to the Air Quality Act, excludes air regulated by the Occupational Health and Safety Act (Act No 85 of 1993).

A map showing locations of AQSRs within the Project boundary is included in Figure 3. These include residences, farmsteads, and Holdings, as well as a mine village. The closest towns in the immediate region of the project include Welkom (located about 6 kilometres (km) north-northeast of the Project boundary), Virginia (located about 2 km east of the Project boundary), Bronville (located about 11 km northeast of the Project boundary), Harmony (located about 11 kilometres south of the Project boundary) and Theunissen (located about 16 km south of the Project boundary).

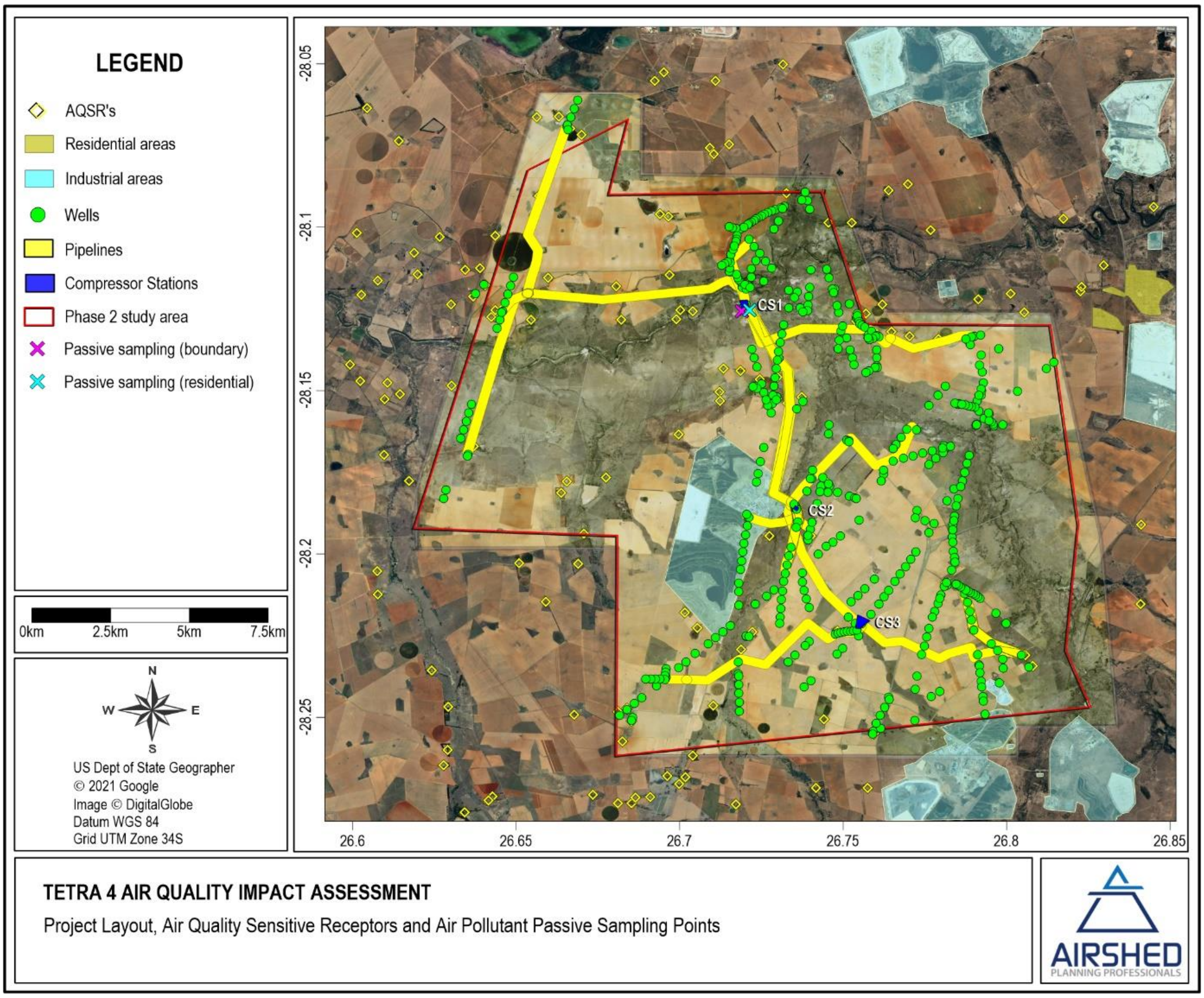

Figure 3: Location map and Air Quality Sensitive Receptors of the proposed project

3.2 Atmospheric Dispersion Potential

Physical and meteorological mechanisms govern the dispersion, transformation, and eventual removal of pollutants from the atmosphere. The analysis of hourly average meteorological data is necessary to facilitate a comprehensive understanding of the dispersion potential of the site. Parameters useful in describing the dispersion and dilution potential of the site i.e. wind speed, wind direction, temperature and atmospheric stability, are subsequently discussed. For the purpose of this study, surface and profile weather data for the period January 2019 to December 2021 was obtained from the South African Weather Service (SAWS) station at Welkom. The Welkom weather station is located 12 km northwest of the Project site.

3.2.1 Topography

The study area is characterised by a flat surface with sparse vegetation. An analysis of topographical data indicated a slope of less than 1:10 from over most of the project area. Dispersion modelling guidance recommends the inclusion of topographical data in dispersion simulations only in areas where the slope exceeds 1:10 (US EPA, 2004). The topography for the study area is provided in Figure 4.

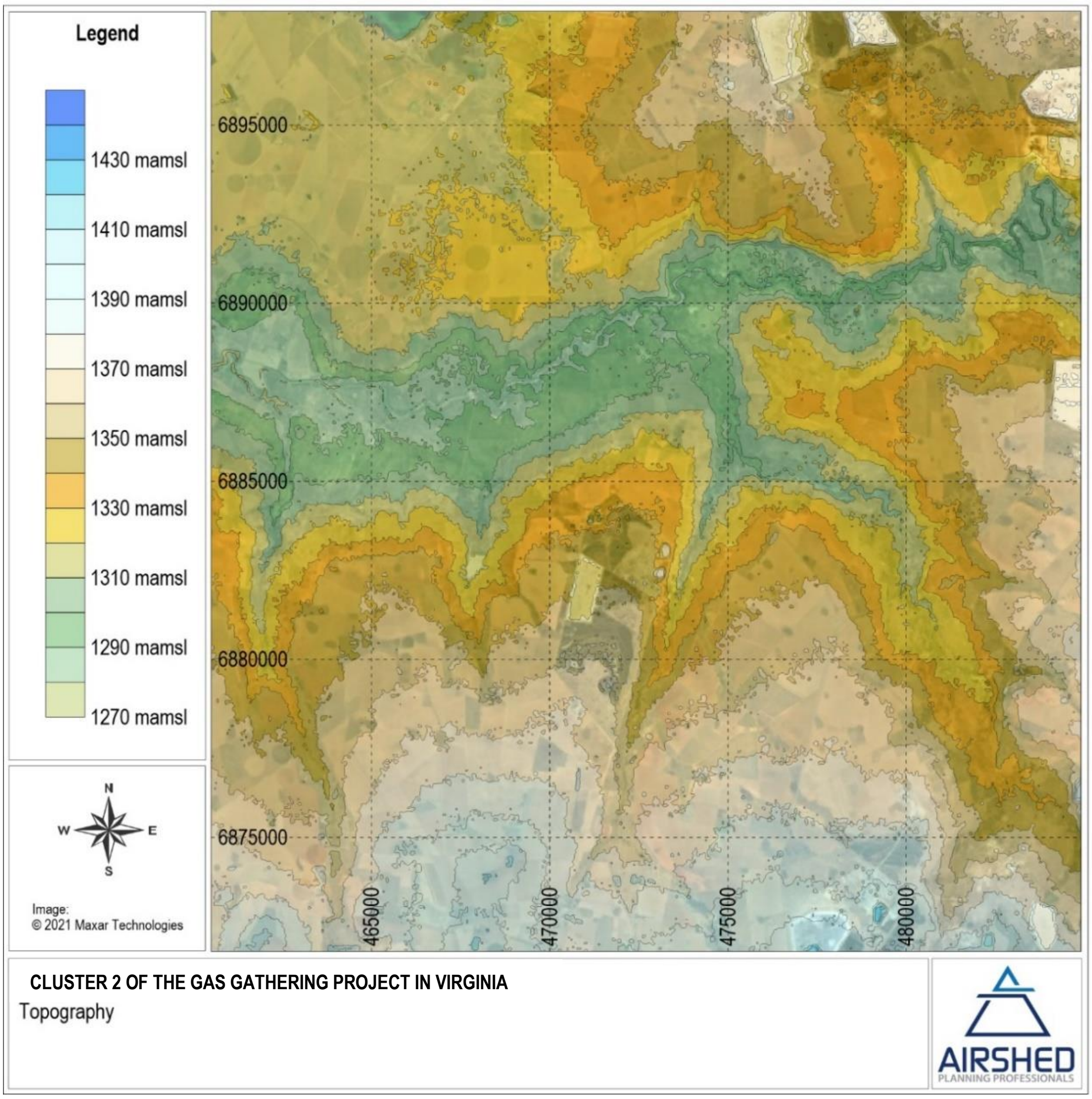

Figure 4: Topography for the study area

3.2.2 Surface Wind Field

The wind roses comprise 16 spokes, which represent the directions from which winds blew during a specific period. The colours used in the wind roses below, reflect the different categories of wind speeds; the yellow area, for example, representing winds in between 4 and 5 m/s. The dotted circles provide information regarding the frequency of occurrence of wind speed and direction categories. The frequency with which calms occurred, i.e. periods during which the wind speed was below 1 m/s are also indicated.

The period wind field and diurnal variability in the wind field are shown in Figure 5, while the seasonal variations are shown in Figure 6.

During the 2019 to 2021 period, the wind field was dominated by winds from the north-northeast and northeast, followed by northerly and easterly winds. During the day (6AM – 6PM), the prevailing wind field is from the north to northeast and the west, with less frequent winds from the north-westerly sector, the easterly sector and the south-west. During the night, the wind field shifts to the easterly sector (north-northeast to east-southeast), with very little flow from the westerly sector. Long-term air quality impacts are therefore expected to be the most significant to the south and southwest of the project area. The strongest winds (more than 6 m/s) were also from the north and northeast and occurred mostly during the day, with 15 m/s the highest wind speed recorded. The average wind speed over the three years is 3.7 m/s, with calm conditions occurring for 3.5% of the time (Figure 5).

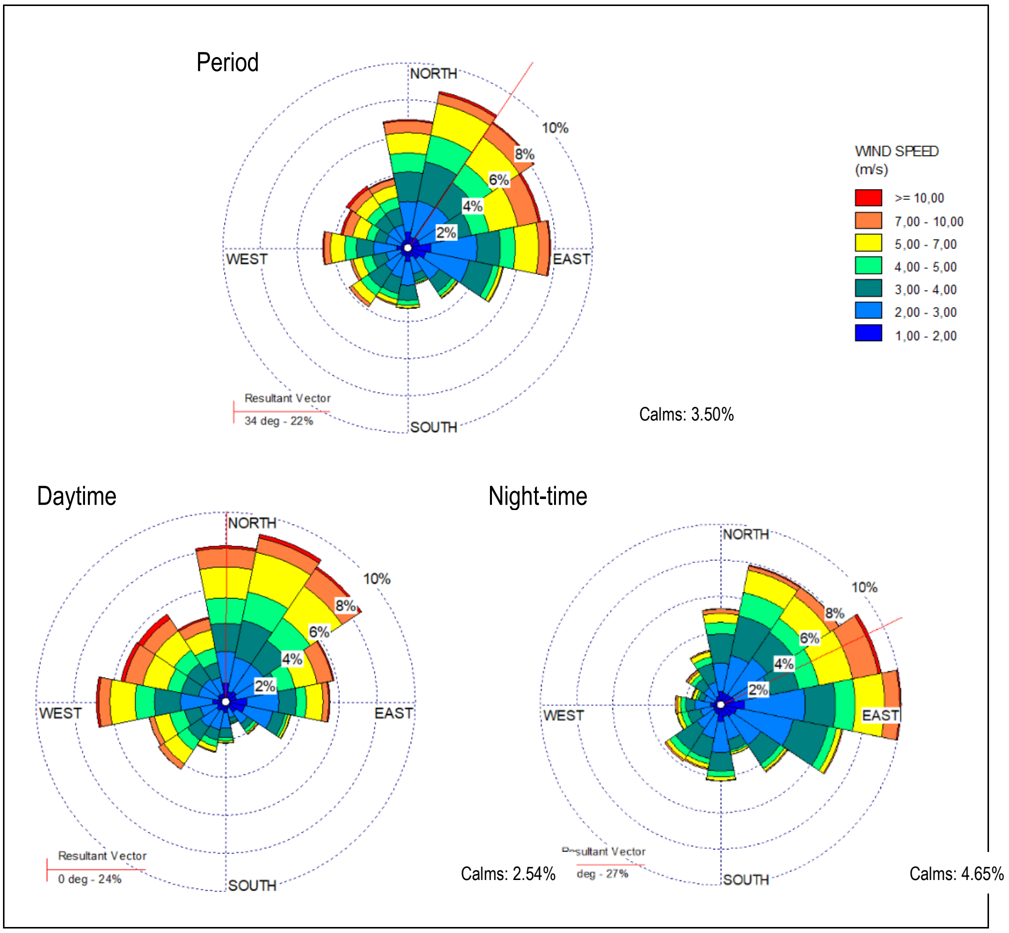

Figure 5: Period, day- and night-time wind roses (SAWS Welkom Data, 2019 to 2021).

Seasonally, the wind flow pattern conforms to the period average wind flow pattern. The seasonal wind field shows little seasonal differences in the wind fields. During summer and spring, the dominant winds are from the north-northeast to east, with more frequent westerly winds during spring. Autumn reflects dominant north-easterly and easterly winds, with a similar wind field during winter, but with more frequent north-northeasterly and east-southeasterly winds (Figure 6).

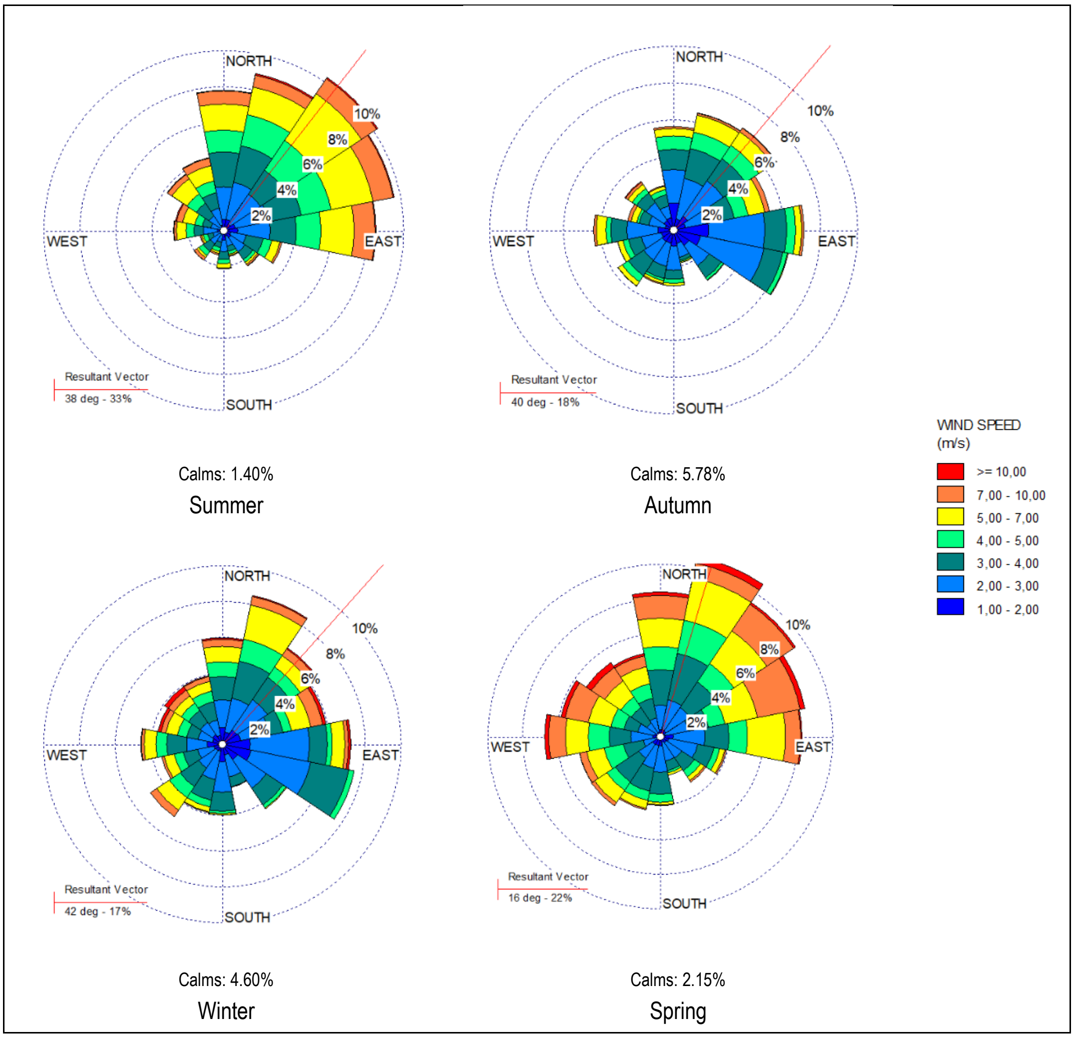

Figure 6: Seasonal wind roses (SAWS Welkom Data, 2019 to 2021)

3.2.3 Temperature and Relative Humidity

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

Monthly mean, maximum and minimum temperatures are given in Table 5. Temperatures ranged between -6.1°C in July and 40.8°C in January. During the day, temperatures increase to reach maximum at around 15:00 in the afternoon. Ambient air temperature decreases to reach a minimum at around 06:00 i.e. just before sunrise.

Table 7: Monthly minimum, average and maximum temperature (°C) (SAWS Welkom Data, 2019 to 2021)

	Temperature (°C)											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Minimum	11.7	10.1	8.1	1.6	-2.8	-4.3	-6.1	-4.8	1.3	3.3	3.0	10.5
Average	23.2	22.4	20.6	17.6	14.2	10.8	10.6	13.6	18.0	20.6	22.1	22.7
Maximum	40.8	36.9	33.3	32.8	28.7	26.9	25.6	31.0	34.0	37.3	36.7	39.0

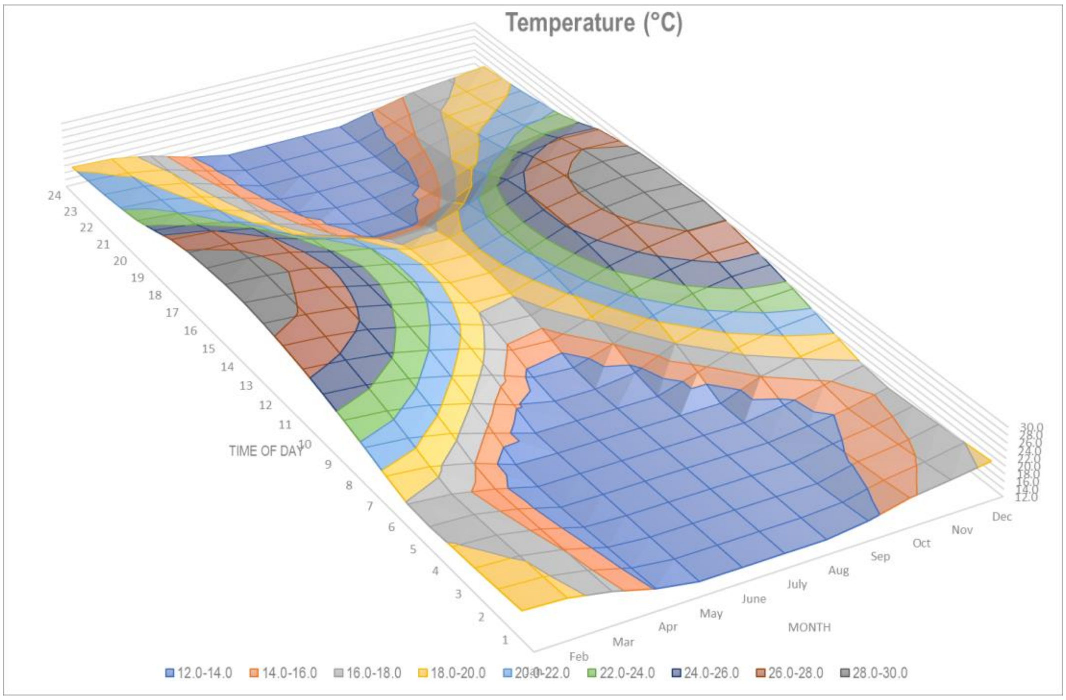

Figure 7: Diurnal temperature profile (SAWS Welkom Data, 2019 to 2021)

3.2.4 Atmospheric Stability and Mixing Depth

The new generation air dispersion models differ from the models traditionally used in a number of aspects, the most important of which are the description of atmospheric stability as a continuum rather than discrete classes. The atmospheric boundary layer properties are therefore described by two parameters; the boundary layer depth and the Monin-Obukhov length, rather than in terms of the single parameter Pasquill Class.

The Monin-Obukhov length (L_{Mo}) provides a measure of the importance of buoyancy generated by the heating of the ground and mechanical mixing generated by the frictional effect of the earth's surface. Physically, it can be thought of as representing the depth of the boundary layer within which mechanical mixing is the dominant form of turbulence generation (CERC, 2004). The atmospheric boundary layer constitutes the first few hundred meters of the atmosphere. During daytime, the atmospheric boundary layer is characterised by thermal turbulence due to the heating of the earth's surface. Night-times are characterised by weak vertical mixing and the predominance of a stable layer. These conditions are normally associated with low wind speeds and lower dilution potential.

The atmospheric stability is frequently categorised into one of six stability classes. These are briefly described in Table 8.

Table 8: Atmospheric stability classes

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

Diurnal variation in atmospheric stability, as calculated from Welkom SAWS data, and described by the inverse Monin-Obukhov length and the boundary layer depth is provided in Figure 8. The highest concentrations for ground level, or near-ground level releases from non-wind dependent sources would occur during weak wind speeds and stable (night-time) atmospheric conditions. For elevated releases, unstable conditions can result in very high concentrations of poorly diluted emissions close to the stack. This is called *looping* (Figure 8(c)) and occurs mostly during daytime hours. Neutral conditions disperse the plume fairly equally in both the vertical and horizontal planes and the plume shape is referred to as *coning* (Figure 8(b)). Stable conditions prevent the plume from mixing vertically, although it can still spread horizontally and is called *fanning* (Figure 8(a)) (Tiwary & Colls, 2010). For ground level releases such as fugitive dust the highest ground level concentrations will occur during stable night-time conditions.

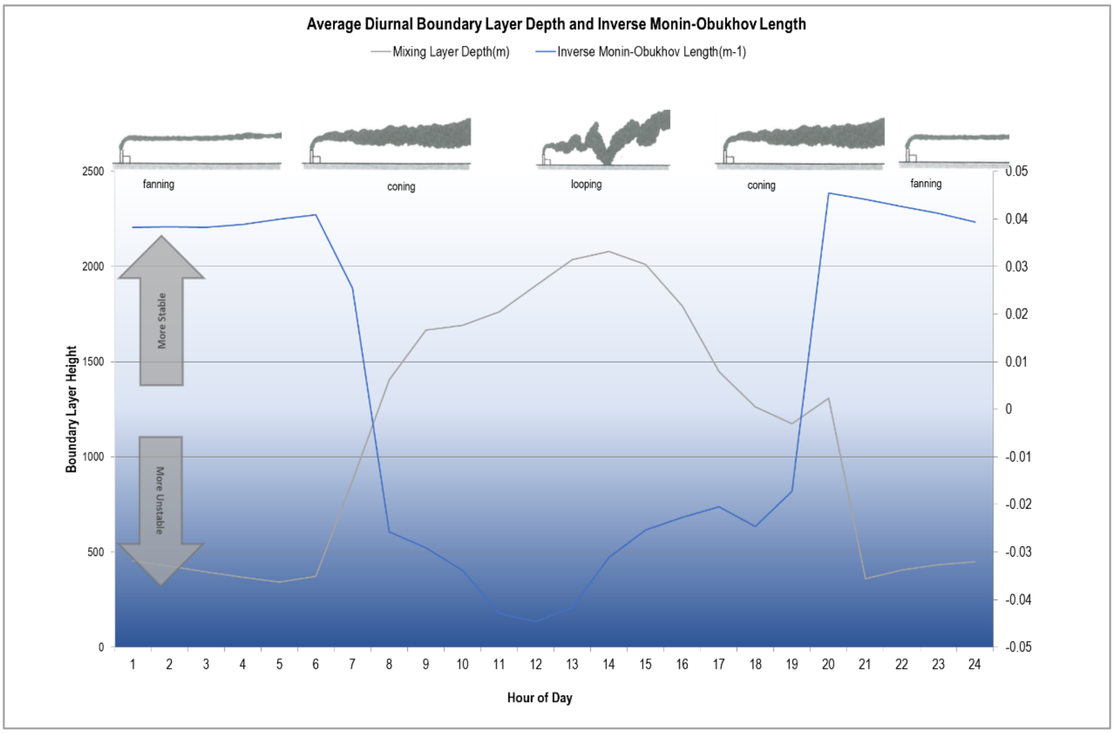

Figure 8: Diurnal atmospheric stability for Welkom (SAWS data, 2019 to 2021)

3.2.5 Precipitation

Precipitation represents an effective removal mechanism of atmospheric pollutants. Precipitation reduces wind erosion potential by increasing the moisture content of materials. Rain-days are defined as days experiencing 0.1 mm or more rainfall.

Rainfall in the region is almost exclusively due to showers and thunderstorms and falls mainly in summer, from October to March. The maximum rainfall occurs during the December-January period. The long term annual average rainfall (1955- 1978) for Welkom is given in Table 9 (Schulze, 1986).

Table 9: Long-term average monthly rainfall at Welkom (Schulze, 1986)

Rainfall	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Average (mm)	99	67	67	49	23	8	7	5	17	49	63	56	526
No. of rain days	10	9	9	7	4	2	2	1	2	7	9	10	72

3.3 Ambient Air Quality within the Region

3.3.1 Sources of Pollution in the Region

Neighbouring land-use in the surrounding of the proposed project comprises predominantly of agriculture activities. These land-uses contribute to baseline pollutant concentrations via fugitive and process emissions, vehicle tailpipe emissions, household fuel combustion, biomass burning and windblown dust from exposed areas.

3.3.1.1 Agriculture

Agriculture is a major land-use activity within and beyond the Project boundary. These activities include crop farming such as maize, and livestock farming. Particulate matter is the main pollutant of concern from agricultural activities as particulate emissions are derived from windblown dust, burning crop residue, and dust entrainment as a result of vehicles travelling along dirt roads. In addition, pollen grains, mould spores and plant and insect parts from agricultural activities all contribute to the particulate load. Should chemicals be used for crop spraying, they would typically result in odiferous emissions. Crop residue burning is also an additional source of particulate emissions and other toxins. Due to the small scale of farming activities these are regarded to have an insignificant cumulative impact.

Livestock farms, especially cattle, are also significant sources of fugitive dust especially when feedlots are used and the cattle trample in confined areas. Pollutants associated with dairy production for instance include ammonia (NH_3), hydrogen sulfide (H_2S), methane (CH_4), carbon dioxide (CO_2), oxides of nitrogen (NOx) and odour related trace gasses. According to the US-EPA, cattle emit methane through a digestive process that is unique to ruminant animals called enteric fermentation. The calf-cow sector of the beef industry was found to be the largest emitter of methane emissions. Where animals are densely confined the main pollutants of concern include dust from the animal movements, their feed and their manure, ammonia (NH_3) from the animal urine and manure, and hydrogen sulfide (H_2S) from manure pits.

Organic dust includes dandruff, dried manure, urine, feed, mould, fungi, bacteria and endotoxins (produced by bacteria, and viruses). Inorganic dust is composed of numerous aerosols from building, materials and the environment. Since the dust is biological it may react with the defence system of the respiratory tract. Odours and VOCs associated with animal manure is also a concern when cattle are kept in feedlots. The main impact from methane is on the dietary energy due to the reduction of carbon from the rumen. Dust and gasses levels are higher in winter or whenever animals are fed, handled or moved.

3.3.1.2 Mining Sources

Particulates represent the main pollutant of concern at mining operations, whether it is underground or opencast. The amount of dust emitted by these activities depends on the physical characteristics of the material, the way in which the

material is handled and the weather conditions (e.g. high wind speeds, rainfall, etc.). Mining of gold, as well as ore extraction and processing plants are all commercial activities situated in the region of the Project.

3.3.1.3 Domestic Fuel Combustion

Domestic households are known to have the potential to be one the most significant sources that contribute to poor air quality within residential areas. Individual households are low volume emitters, but their cumulative impact is significant. It is likely that households within the local communities or settlements utilize coal, paraffin and/or wood for cooking and/or space heating (mainly during winter) purposes. Pollutants arising from the combustion of wood include respirable particulates, CO and SO_2 with trace amounts of polycyclic aromatic hydrocarbons (PAHs), in particular benzo(a)pyrene and formaldehyde. Particulate emissions from wood burning have been found to contain about 50% elemental carbon and about 50% condensed hydrocarbons.

Coal is relatively inexpensive in the region and is easily accessible due to the proximity of the region to coal mines and the well-developed coal merchant industry. Coal burning emits a large amount of gaseous and particulate pollutants including SO_2, heavy metals, PM including heavy metals and inorganic ash, CO, PAHs (recognized carcinogens), NO_2 and various toxins. The main pollutants emitted from the combustion of paraffin are NO_2, particulates, CO and PAHs.

3.3.1.4 Biomass Burning

Biomass burning includes the burning of evergreen and deciduous forests, woodlands, grasslands, and agricultural lands. Within the project vicinity, crop-residue burning and wildfires (locally known as veld fires) may represent significant sources of combustion-related emissions. The frequency of wildfires in the grasslands varies between annual and triennial.

Biomass burning is an incomplete combustion process (Cachier, 1992), with carbon monoxide, methane and nitrogen dioxide gases being emitted. Approximately 40% of the nitrogen in biomass is emitted as nitrogen, 10% is left in the ashes, and it may be assumed that 20% of the nitrogen is emitted as higher molecular weight nitrogen compounds (Held, et al., 1996). The visibility of the smoke plumes is attributed to the aerosol (particulate matter) content. In addition to the impact of biomass burning within the vicinity of the Project activity, long-range transported emissions from this source can be expected to impact on the air quality between the months of August to October. It is impossible to control this source of atmospheric pollution loading; however, it should be noted as part of the background or baseline condition before considering the impacts of other local sources.

3.3.1.5 Fugitive Dust Sources

These sources are termed fugitive because they are not discharged to the atmosphere in a confined flow stream. Sources of fugitive dust identified in the study area include paved and unpaved roads and wind erosion of sparsely vegetated surfaces.

3.3.1.6 Unpaved and paved roads

Emissions from unpaved roads constitute a major source of emissions to the atmosphere in the South African context. When a vehicle travels on an unpaved road the force of the wheels on the road surface causes pulverization of surface material. Particles are lifted and dropped from the rolling wheels, and the road surface is exposed to strong turbulent air shear with the surface. The turbulent wake behind the vehicle continues to act on the road surface after the vehicle has passed. Dust emissions from unpaved roads vary in relation to the vehicle traffic and the silt loading on the roads. Unpaved roads in the region are mainly haul and access roads.

Emissions from paved roads are significantly less than those originating from unpaved roads, however they do contribute to the particulate load of the atmosphere. Particulate emissions occur whenever vehicles travel over a paved surface. The fugitive dust emissions are due to the re-suspension of loose material on the road surface. Paved roads in the region include the R710, M4, R708 and R30.

3.3.1.7 Wind erosion of open areas

Windblown dust generates from natural and anthropogenic sources. For wind erosion to occur, the wind speed needs to exceed a certain threshold, called the threshold velocity. This relates to gravity and the inter-particle cohesion that resists removal. Surface properties such as soil texture, soil moisture and vegetation cover influence the removal potential. Conversely, the friction velocity or wind shear at the surface is related to atmospheric flow conditions and surface aerodynamic properties. Thus, for particles to become airborne, its erosion potential has to be restored; that is, the wind shear at the surface must exceed the gravitational and cohesive forces acting upon them, called the threshold friction velocity. Every time a surface is disturbed, its erosion potential is restored (US EPA, 2004). Erodible surfaces may occur as a result of agriculture and/or grazing activities.

3.3.1.8 Vehicle Tailpipe Emissions

Emissions resulting from motor vehicles can be grouped into primary and secondary pollutants. While primary pollutants are emitted directly into the atmosphere, secondary pollutants form in the atmosphere as a result of chemical reactions. Significant primary pollutants emitted combustion engines include carbon dioxide (CO_2), carbon (C), sulfur dioxide (SO_2), oxides of nitrogen (mainly NO), particulates and lead. Secondary pollutants include NO_2, photochemical oxidants such as ozone, sulfur acid, sulphates, nitric acid, and nitrate aerosols (particulate matter). Vehicle type (i.e. model-year, fuel delivery system), fuel (i.e. oxygen content), operating (i.e. vehicle speed, load) and environmental parameters (i.e. altitude, humidity) influence vehicle emission rates.

Transport in the vicinity of the Project is via trucks and private vehicles along the R710, M4, R708 and R30 roads (which are the main sources of vehicle tailpipe emissions), as well as vehicles and machinery travelling on unpaved and private roads.

3.3.2 Air Quality Sampling Results

Airshed was appointed by Environmental Impact Management Services (EIMS) (Pty) Ltd to sample identified potential pollutants of concern, as stipulated in the Environmental Management Programme (EMPr), around the Tetra4 Virginia Compression Plant. The passive sampling campaign used Radiello® passive diffusive samplers at three (3) sites around the property and at an upwind background site located near a residential receptor. Sampling and assessment of ambient concentrations include sulfur dioxide (SO_2); nitrogen dioxide (NO_2); hydrogen fluoride (HF) and, total volatile organic compounds (TVOCs).

Passive sampling was conducted at two (2) locations near the boundary of the facility and at a background location close to a nearby residential receptor. Sampling site locations are shown in Figure 9, with the coordinates, elevation and site classification detailed in Table 10.

Table 10: Sampling site coordinates, elevation, and classification

Site ID	Site location	Latitude	Longitude	Elevation (m)	Classification
TET1	HDR1 Wellhead	-28.12576	26.718934	1 299	Boundary
TET2	HDR1 Compressor	-28.12701	26.719149	1 299	Boundary
TET3	Background site	-28.12011	26.720198	1 296	Residential

The aim of the passive sampling campaign was to quantify ambient air pollutant concentrations which could present odour and health issues for Tetra4 personnel and the neighbouring communities. Two 14-day campaigns were conducted at the Tetra4 Virginia Compression Plant, one in summer and one in winter since 2019. Pollutants assessed included SO_2, NO_2, and VOCs.

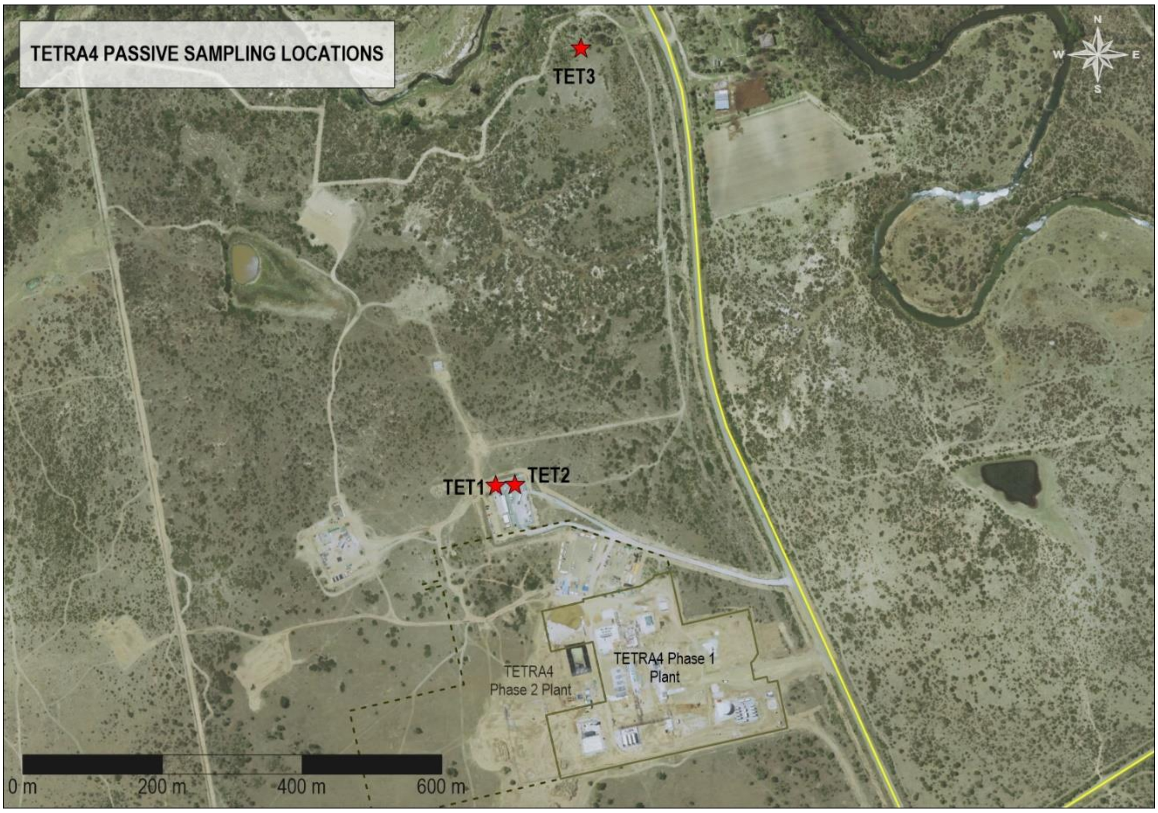

Figure 9: Tetra4 passive sampling locations

Radiello® passive diffusive tubes were used to sample pollutant concentrations at the three sampling locations. Passive diffusive sampling relies on the movement of pollutants through a diffusive surface onto an adsorbent. After sampling, the analytes are chemically desorbed by solvent extraction or thermally desorbed and analysed. Passive sampling does not involve the use of pumping systems and does not require electricity and is therefore an ideal sampling method at rural sampling locations. The concentration of pollutants adsorbed during the exposure period can be calculated to time-frames comparable with the NAAQS for criteria pollutants, international chronic inhalation reference concentrations, and inhalation unit risk factors.

Passive diffusive samplers were placed in a manufacturer approved rain shelter and attached to a post at eye level, ensuring protection against adverse weather conditions while allowing adequate ventilation. Supporting plates were assembled and operated according to manufacturer instructions. The analysis of the adsorbed compounds was conducted by the accredited Biograde Laboratory Services (SANAS Facility T0574) in Pretoria.

To compare the average sampled concentrations to long term (annual average) evaluation criteria (Section 2.2), equivalent annual average concentrations were extrapolated. For extrapolating time averaging periods from 24 hours to 1 year, Beychock (2005)[2], recommends the following equation:

$$\frac{C_x}{C_p} = \left(\frac{t_p}{t_x}\right)^{0.53}$$

where:

C_x *and* C_p are concentrations over any two averaging periods between 24 hours and 1 year,

[2] Beychock, M. R. (2005). *Fundamentals of Stack Gas Dispersion* (4th Edition ed.).

t_x *and* t_p are corresponding averaging times in days.

All pollutant concentrations, including the suite of VOC compounds detected, were screened against NAAQS, chronic inhalation reference concentrations, and inhalation unit risk factors (for increased life-time cancer risk) published by international agencies.

Limitations include:

1. Theoretical hourly peak concentrations were extrapolated from each 14 or 15-day campaign. It is not possible to confirm the date or time of peak concentrations, or if any peaks occurred.
2. Equivalent annual average concentrations of pollutants were calculated based from campaign length averages for each of the sampling campaigns.
3. Where campaign length concentrations were reported as below detection level, the detection level was conservatively used as the campaign length concentration.

All period-length concentrations of SO_2, NO_2, and HF were extrapolated to equivalent hourly, daily, and annual average concentrations are listed in Tables 11, 12 and 13 to allow for comparison against the assessment criteria including, the NAAQS (Table 4). Period-length HF concentrations at all sites for both sampling periods were below detection level and therefore extrapolated concentrations are not presented. Equivalent SO_2 concentrations were compliant with all applicable NAAQS for hourly, daily, and annual averaging periods (Table 4).

Extrapolated results from the seven (7) sampling campaigns indicate low background SO_2 concentrations, falling well within the NAAQSs. Background NO_2 concentrations indicate fairly high short-term (hourly) levels but still below the NAAQ limit and well below the annual limit. Sampled concentrations of HF are very low. Chronic exposure to total VOCs (TVOCs) concentration was less than 6 µg/m^3 at all sites, and therefore lower than the 100 µg/m^3 health-effect screening level (Table 14).

Table 11: Exposure period and extrapolated concentrations of SO_2 for Campaigns 2019 to 2022 (all units: µg/m^3)

Campaign	Sampling period	Annual	Daily	Hourly
	NAAQS	**50**	**125**	**350**
Summer 2019	Mar/Apr 2019	0.2	5.5	32.50
Winter 2019	Aug-19	0.1	2.6	16.00
Summer 2020	Mar-20	5.0	0.2	29.50
Winter 2020	Jul/Aug 2020	0.3	6.3	37.10
Summer 2021	Mar/Apr 2021	0.2	5.1	30.10
Winter 2021	Jul/Aug 2021	0.3	6.2	37.00
Summer 2022	Feb-22	0.3	5.8	34.20
Average		0.9	4.53	30.91

Table 12: Exposure period and extrapolated concentrations of NO_2 for Campaigns 2019 to 2022 (all units: µg/m^3)

Campaign	Sampling period	Annual	Hourly
	NAAQS	**40**	**200**
Summer 2019	Mar/Apr 2019	0.9	115.00
Winter 2019	Aug-19	0.8	107.00
Summer 2020	Mar-20	0.5	67.60
Winter 2020	Jul/Aug 2020	1.0	133.74
Summer 2021	Mar/Apr 2021	0.7	96.00
Winter 2021	Jul/Aug 2021	1.1	150.50

Summer 2022	Feb-22	0.6	86.10
Average		0.8	107.99

Table 13: Exposure period and extrapolated concentrations of HF for Campaigns 2019 to 2022 (all units: µg/m³)

Campaign	Sampling period	Annual	Hourly
	NAAQS	BDL	BDL
Summer 2019	Mar/Apr 2019	BDL	BDL
Winter 2019	Aug-19	BDL	BDL
Summer 2020	Mar-20	BDL	BDL
Winter 2020	Jul/Aug 2020	0.01	1.88
Summer 2021	Mar/Apr 2021	0.01	1.55
Winter 2021	Jul/Aug 2021	0.01	1.87
Summer 2022	Feb-22	0.02	2.68
Average		0.01	2.00

Notes: BDL – below detection limit

Table 14: Exposure period and extrapolated concentrations of VOCs for Campaigns 2019 to 2022 (all units: µg/m³)

Campaign	Sampling period	Annual
	Health-effect screening level	**100** (a)
Summer 2019	Mar/Apr 2019	6.5
Winter 2019	Aug-19	3.1
Summer 2020	Mar-20	5.1
Winter 2020	Jul/Aug 2020	3.10
Summer 2021	Mar/Apr 2021	3.20
Winter 2021	Jul/Aug 2021	3.80
Summer 2022	Feb-22	7.50
Average		4.6

Notes: (a) Texas Commission on Environmental Quality (TCEQ) inhalation reference concentrations (diesel fuel used as indicator)

4 IMPACT ON THE RECEIVING ENVIRONMENT

4.1 Atmospheric Emissions Inventory

The establishment of a comprehensive emission inventory formed the basis for the assessment of the air quality impacts from the project's operations on the receiving environment. The proposed project operations will consist of planning and design, construction, operational, decommissioning and rehabilitation and closure phases. Emissions are quantified for criteria pollutants associated with natural gas production operations and can be divided into two categories, namely; fugitive emissions and process emissions. Fugitive emissions refer to emissions that are spatially distributed over a wide area and not confined to a specific discharge point as would be the case for process related emissions (IFC, 2007).

A discussion on the expected activities typical of natural gas production operations is provided in the sections below with a summary on the typical activities and sources as well as emission inventory for the construction, operational, decommissioning and rehabilitation and closure phases of the Project.

4.1.1 Planning and Design Phase

The planning and design phase of the project is not expected to generate any routine atmospheric emissions. These activities will be intermittent in nature and the extents of the associated emissions are typically minimal. The only impact to be assessed in this study during the planning and design phase is fugitive emissions from exploration drilling.

4.1.2 Construction Phase

Construction activities are a source of primarily criteria pollutants, including CO, SO_2, NO_X and particulate matter (PM, PM_{10} and $PM_{2.5}$). Air emissions (Table 15) would occur from the construction of the Cluster 2 plant, well heads, booster and compressor stations and access roads (where necessary), rig-move/drilling and associated traffic, pipeline installation and associated traffic, and wind erosion of exposed areas during construction activities. Emissions would include fugitive PM_{10} and $PM_{2.5}$ emissions from construction activities and traffic to and from the construction sites. Diesel particulate matter (DPM) and other criteria pollutant emissions would occur from diesel combustion in haul trucks and heavy construction equipment. Malodourous compounds, including H_2S, could be released from the well cuttings, depending on the quantity of hydrocarbon (HC) compounds. It should be noted that venting and flaring (completion and testing) is not planned as part of the Project development.

Table 15: Potential air pollutants emitted during typical construction phase for natural gas production

Location of Emission	CO_2	CO	NO/NO_2	SO_2	VOCs	PM	Odours	Total HC
Road Construction	✓ a	✓	✓	✓	✓	✓		
Pipeline Construction	✓	✓	✓	✓	✓	✓		
Well Construction	✓	✓	✓	✓	✓	✓		
Booster Station Construction	✓	✓	✓	✓	✓	✓		
Compressor Station Construction	✓	✓	✓	✓	✓	✓		
Plant construction	✓	✓	✓	✓	✓	✓		
Road Traffic	✓	✓	✓	✓	✓	✓		
Drilling	✓	✓	✓	✓	✓	✓	✓	✓

Notes: The size of the tick is used to indicate the potential extent of release of emissions; and is not directly related to quantity of emissions

4.1.2.1 General Infrastructure Construction

Fugitive particulate emissions due to the construction of roads, pipelines, wells, booster and compressor stations and the Cluster 2 plant were calculated using an area wide average particulate generation emission factor (US EPA AP-42, Section 13.2.3, "Heavy Construction Operations", US EPA 2004).

The US-EPA documents emissions factors which aim to provide a general rule-of-thumb as to the magnitude of emissions which may be anticipated from construction operations. The quantity of dust emissions is assumed to be proportional to the area of land being worked and the level of construction activity. The approximate emission factors for general construction activity operations are given as:

E = 2.69 Mg/hectare/month of activity (269 g/m²/month)

The PM_{10} fraction is given as ~39% of the US-EPA total suspended particulate factor. These emission factors are most applicable to construction operations with (i) medium activity levels, (ii) moderate silt contents, and (iii) semiarid climates. The emission factor for TSP considers 42 hours of work per week of construction activity. Test data were not sufficient to derive the specific dependence of dust emissions on correction parameters.

The dimensions of sources used in the model, footprint area (in m²), and estimated construction periods (in days) for each construction activity are given in Table 16. Estimated average emissions (in kg/hr) due to general infrastructure construction are presented in Table 19.

Table 16: Estimated fugitive particulate emissions (in kg/hr) due to general infrastructure construction

Location of Emission	Dimensions	Area (m²)	Period (days)
Road construction (per section)	500m x 10m[a]	5 000	15 [f][g]
Pipeline construction (per section)	500m x 5m[b]	2 500	15 [f][g]
Well construction (single)	30m x 30m[c]	900	150 [d]
Booster station construction (single)	30m x 30m[c]	900	150 [d]
Compressor station construction (single)	60m x 60m[d]	3 600	150 [d]
Plant construction	See note [e]	93 979	750 [d]

Notes:

(a) An area measuring 500 m by 10 m was simulated to represent proposed road construction, since the road construction schedule is not yet known and activities will only occur at a section per time.

(b) Similarly, an area measuring 500 m by 5 m was simulated to represent proposed pipeline construction, since pipeline construction activities will only occur at a section per time.

(c) Area assumed for equipment movement and setup

(d) Information provided by engineer

(e) Digitised from project layout

(f) Assumed to be same construction period as that for a single well, viz. 15 days

(g) Construction of all roads, pipelines, wells, booster/compressor stations was given as 150 days (maximum)

4.1.2.2 Engine Exhaust Emissions

Engine exhaust emissions cover a wide variety of industrial applications of both gasoline and diesel internal combustion engines, including mobile (road sources, i.e. buses, trucks, etc. and non-road sources, such as forklifts, backhoes, etc.) and non-mobile sources (such as power generators and pumps). The Australian NPi (2008) manual for combustion engines were used to estimate emission rates for this equipment.

Table 17: Description of equipment per construction activity

Construction Activity	Description of Equipment	Capacity (horsepower) [(a)]	Load Factor [(a)]	Number of Units per Equipment	No of Equipment Hours per Year[(b)]
Drilling	Truck mounted crane (high-up)	325	40%	1	1500
	Concrete mixer truck	325	59%	1	1500
	Forklift	100	20%	1	1500
	Cable percussion drilling rig	425	59%	1	1500
	Water bowser discharging	325	55%	1	1500
Construction of Well/ Booster station/ Compressor station	Dozer	410	55%	1	1500
	Tracked Excavator	268	50%	1	1500
	Grader	297	50%	1	1500
	Water bowser discharging	325	55%	1	1500
	Tractor towing water bowser	530	55%	1	1500
	Truck with trailer	325	50%	1	1500
	Generator [(c)]	188	100%	1	1500
Construction of Pipeline	Back-actor	93	40%	1	1500
	Truck mounted crane (high-up)	325	40%	1	1500
	Compactor	315	50%	1	1500
	Tracked Excavator	268	50%	1	1500
	Grader	297	50%	1	1500
	Ditcher/Digging wheel	150	55%	1	1500
	Backhoe (TLB)	93	40%	2	1500
Construction of Plant	Dozer	410	55%	2	3650
	Tracked Excavator	268	50%	4	3650
	Grader	297	50%	2	3650
	Water bowser discharging	325	55%	2	3650
	Tractor towing water bowser	530	55%	1	3650
	Hauling: Dump truck	351	50%	2	3650
	Backhoe (TLB)	93	40%	4	3650
	Truck mounted crane (high-up)	325	40%	1	3650
	Rough terrain / telescope crane	516	25%	1	3650
	Compactor	315	50%	1	3650
	Forklift	100	20%	2	3650
	Low-bed/flat-bed truck	325	50%	2	3650
	Hydraulic hammer	600	59%	1	3650
	Concrete mixer truck	325	59%	4	3650

Notes:

(a) Capacity of equipment and load factors were obtained from a similar study for the construction of well fields https://www.nrc.gov/docs/ML1306/ML13067A306.pdf

(b) Maximum construction period for wells, booster stations, compressor stations, roads and pipelines, was given as 150 days. Construction working hours were given as 10 hours per day, seven days a week.

(c) Generator only applicable to booster station construction

Table 18: Emission factors (in lb/hp-hr) for diesel industrial engine exhaust emissions

Description of Equipment	Emission factor (lb/hp-hr)					
	NO_x	CO	SO_2	PM_{10}	$PM_{2.5}$	VOC
Back-actor [(b)]	0.02433	0.01013	0.000013	0.00199	0.00182	0.00222
Backhoe (TLB) [(b)]	0.02433	0.01013	0.000013	0.00199	0.00182	0.00222
Cable percussion drilling rig [(b)]	0.02433	0.01013	0.000013	0.00199	0.00182	0.00222
Compactor [(c)]	0.02877	0.01328	0.000014	0.00171	0.00157	0.00214
Concrete mixer truck [(b)]	0.02433	0.01013	0.000013	0.00199	0.00182	0.00222
Ditcher/Digging wheel [(b)]	0.02433	0.01013	0.000013	0.00199	0.00182	0.00222
Dozer [(d)]	0.01792	0.00773	0.000012	0.00091	0.00083	0.00082
Forklift [(b)]	0.02433	0.01013	0.000013	0.00199	0.00182	0.00222
Generator [(a)]	0.031	0.0067	0.000007	0.0022	0.0022	0.0023
Grader [(e)]	0.01573	0.00339	0.000012	0.00138	0.00127	0.00079
Hauling: Dump truck [(f)]	0.01792	0.00773	0.000013	0.00111	0.00102	0.00082
Hydraulic hammer [(b)]	0.02433	0.01013	0.000013	0.00199	0.00182	0.00222
Low-bed/flat-bed truck [(b)]	0.02433	0.01013	0.000013	0.00199	0.00182	0.00222
Rough terrain/ telescope crane [(b)]	0.02433	0.01013	0.000013	0.00199	0.00182	0.00222
Tracked Excavator [(g)]	0.02055	0.00498	0.000012	0.00144	0.00133	0.00245
Tractor towing water bowser [(h)]	0.02630	0.01618	0.000012	0.00279	0.00256	0.00388
Truck mounted crane (high-up) [(b)]	0.02433	0.01013	0.000013	0.00199	0.00182	0.00222
Truck with trailer [(f)]	0.01792	0.00773	0.000013	0.00111	0.00102	0.00082
Water bowser discharging [(h)]	0.02630	0.01618	0.000012	0.00279	0.00256	0.00388

Notes:

(a) Australian NPi Table 49, Emission factors for stationary small (less than 450 kW) diesel engines
(b) Australian NPi Table 35, Emission factors for diesel industrial vehicle (miscellaneous) exhaust emissions
(c) Australian NPi Table 34, Emission factors for diesel industrial vehicle (roller) exhaust emissions
(d) Australian NPi Table 28, Emission factors for diesel industrial vehicle (wheeled dozer) exhaust emissions
(e) Australian NPi Table 30, Emission factors for diesel industrial vehicle (motor grader) exhaust emissions
(f) Australian NPi Table 33, Emission factors for diesel industrial vehicle (off-highway truck) exhaust emissions
(g) Australian NPi Table 32, Emission factors for diesel industrial vehicle (track-type loader) exhaust emissions
(h) Australian NPi Table 27, Emission factors for diesel industrial vehicle (wheeled tractor) exhaust emissions

Engine exhaust emissions were quantified through the application of emission factors (specified in Table 18) as published by the Australian NPI, to the power output and loading factor of each type of equipment during a unit of use (specified in Table 17). Estimated average emissions (in kg/hr) due to engine exhaust emissions are presented in Table 19.

4.1.2.3 Summary of Calculated Emission Rates for Construction

A summary of emissions quantified due to general construction activities and equipment and vehicle exhaust is provided in Table 19.

Table 19: Total estimated average emission rates (in kg/hr) due to the construction of general infrastructure and equipment and vehicle exhaust

Sources	Emissions (kg/hr)						
Construction Emissions - Area wide Construction							
	$PM_{2.5}$	PM_{10}	TSP	VOC	NOx	CO	SO_2
Proposed well construction (single well)	0.03	0.52	0.80				
Proposed booster station construction (single station)	0.03	0.52	0.80				
Proposed compressor station construction (single station)	0.14	2.09	3.19				
Pipeline construction (500 m)	0.09	1.45	2.21				
Road construction (500 m)	0.19	2.90	4.42				
Plant construction	1.72	26.49	40.45				
Construction Emissions - Equipment and Vehicle Exhaust							
Sources	**Emissions (kg/hr)**						
	$PM_{2.5}$	PM_{10}	TSP	VOC	NOx	CO	SO_2
Proposed well construction (single well)	1.57	1.71		2.09	19.74	9.37	0.01
Proposed booster station construction (single station) [a]	1.06	1.14		1.37	13.71	5.91	0.00
Proposed compressor station construction (single station)	0.87	0.95		1.17	11.07	5.34	0.01
Pipeline construction (500 m)	0.55	0.60		0.68	7.94	2.97	0.00
Road construction (500 m)	0.55	0.60		0.86	7.94	2.97	0.00
Plant construction	3.26	3.55		4.20	44.33	18.89	0.02

Notes:

(a) Including emissions from a 140 kW diesel generator at booster station

4.1.3 Operational Phase

Operational activities were assumed to take place 24 hour per day, 7 days per week. Sources of emission and associated pollutants considered in the emissions inventory for the operational phase include:

- Combined LNG/LHe plant flaring emissions – CO, NO_X and VOC
- Generator emissions at booster stations – $PM_{2.5}$, PM_{10}, CO, SO_2, NO_X and VOCs
- Entrained PM from unpaved roads – $PM_{2.5}$, PM_{10}, and TSP.

In the quantification of these releases use was made of the predictive emission factors published by

- the US EPA AP-42, Section 13.2.2 "Unpaved Roads" to estimate particulate emissions from unpaved road surfaces;
- the Australian NPi Manual for Combustion Engines (2008) Table 49 to estimate $PM_{2.5}$, PM_{10}, CO, SO_2, NO_X and VOC emissions from generators with a power rating less than 450 kW; and
- the Australian NPi Manual for Oil and Gas Extraction and Production (2013) Table 8 to estimate CO, NO_X and VOC emissions from industrial flares.

4.1.3.1 Vehicle Entrained Dust from Unpaved Roads

Vehicle-entrained dust emissions have been found to account for a great portion of fugitive dust emissions from industrial operations. The force of the wheels of vehicles travelling on unpaved roads causes the pulverisation of surface material. Particles are lifted and dropped from the rotating wheels, and the road surface is exposed to strong air currents in turbulent shear with the surface. The turbulent wake behind the vehicle continues to act on the road surface after the vehicle has passed. The quantity of dust emissions from unpaved roads varies linearly with the volume of traffic.

Nitrogen (N_2) will be trucked to the plant, and the LNG and LHe products will be exported by truck from the plant via unpaved road. The number of truck trips per day was given as 20 trips per day (information provided by the client).

4.1.3.2 Emissions from Stationary Engines

Stationary engines are those that do not power vehicles but are used for some other operation (e.g., generators). The three primary fuels for combustion engines are petrol, diesel and natural gas. It was assumed that the three proposed compressor stations would be powered by electricity (due to their locations near existing power lines), but the booster stations may require generators in order to operate in the field. Emissions due to diesel generators located at the respective booster stations were calculated based on engine power and operating hours.

4.1.3.3 Flaring

Gas is flared on oil and gas production installations for safety reasons. For example, a lack of process or transport capacity for gas, a continuous surplus gas flow, start-ups, maintenance and emergency (need for pressure relief) could all lead to flaring actions (NPi, 2013). The emissions of pollutants from flaring are either unburnt fuel or by-products of the combustion process. Emission factors from the US EPA AP42, the California Air Resources Board (CARB) and the European Pollutant Release and Transfer Register (E-PRTR) Guidelines indicate that emissions of *metals* from flaring are negligible.

The plant layout includes a wet flare system to collect natural gas vents containing humidity, and a cold flare system to collect natural gas dropouts. Warm or cold flare header blanket gas and pilot gas will be emitted either continuously (as part of normal operations) or under emergency conditions (as part of an intermittent design case).

A summary of emission sources quantified, estimation techniques applied, and source input parameters are included in Table 20. Estimated average emissions, per source group or activity, are presented in Table 21.

Table 20: Emission estimation techniques and metrics (operational phase)

Product Transport (Vehicle Entrained Dust on Unpaved Roads)	US EPA emission factor equation (US EPA, 2006) $$E = k \cdot \left(\frac{s}{12}\right)^{a} \cdot \left(\frac{W}{3}\right)^{0.45} \cdot 281.9$$ Where EF is the emission factor in g/vehicle kilometre travelled (VKT) k is the particle size multiplier (k_{TSP} – 4.9, k_{PM10} – 1.5, $k_{PM2.5}$ – 0.15) a is an empirical constant (a_{TSP} – 0.7, a_{PM10} – 0.9, $a_{PM2.5}$ – 0.9) s is the road surface material silt content in % W is the average vehicle weight in tonnes	Transport activities include the transport of LNG and Helium product and N_2 import on unpaved roads from the plant site towards the paved provincial road R30. VKT were calculated from road lengths, truck capacities and the number of trips required for transporting ore, waste and product. Average capacity of trucks = 24 tonnes (given) Average vehicle weight in tonnes = 25.68 (calculated) A default road surface silt content of 15% (US EPA, 2006) was applied in calculations Hours of operation: 24 hours per day, 365 days per annum **Metrics:** • LNG and Helium production rates = 470 tons/day (given) • Unpaved road length to paved road R30 = 500 m • Road width = 10m (assumed) • Number of trips per day for product delivery =20 (calculated)
Booster Station Emissions	NPI single valued emission factors for diesel internal combustion engines (generators) (NPI, 2008) CO – 4.06 x10^{-03} kg/kWh $PM_{2.5}$ – 1.31 x10^{-030} kg/kWh PM_{10} – 1.34 x10^{-03} kg/kWh SO_2 – 4.28 x10^{-06} kg/kWh VOC – 1.37 x10^{-03} kg/kWh NOx – 1.88 x10^{-02} kg/kWh	Emission rate was estimated for diesel generators at each booster station using their individual power rating and load factor. The emissions for plant operation) utilizing various equipment were quantified based on: • Hours/day and days/annum: 24 hours/ day, 365 days maximum **Equipment list:** Operation generator – 140 kW <u>Specifications for Caterpillar D150 GC</u> • Flow rate = 15.3 m^3/min • Stack temperature = 441 ^oC <u>Assumption based on similar engine type</u> • Stack diameter = 0.2 m • Stack height = 3.0 m
Flaring at Plant (Normal and/or Upset conditions)	NPI single valued emission factors for flaring (NPI, 2013) <u>**Emission Factor**</u> VOC **–** 15 kg/t of gas NOx **–**1.5 kg/t of gas CO **–** 8.7 kg/t of gas PM_{10}, $PM_{2.5}$ **–** 0 kg/t of gas (non-smoking flares)	**Flaring Metrics on the Basis of Continuous or Intermittent design** Flare emissions based on two types of design were given as: <u>Continuous design</u> • Flue gas emissions (constant) = 18 kg/hr <u>Intermittent design (Emergency/Upset conditions)</u> • Flue gas emissions (warm flare) = 37 048 kg/hr • Flue gas emissions (cold flare) = 10 539 kg/hr

	PM_{10}, $PM_{2.5}$ – 0.056 kg/t of gas (lightly smoking flares) PM_{10}, $PM_{2.5}$ – 0.25 kg/t of gas (average smoking flares) PM_{10}, $PM_{2.5}$ – 0.38 kg/t of gas (heavily smoking flares) **NOTE:** The EF of PM from flaring is based on soot, assumed to apply to PM_{10}, $PM_{2.5}$	It was assumed that the flare stack would not give off any soot (hence no PM emissions) Assumptions on flare stack metrics were made based on similar operation elsewhere (Burger & Akinshipe, 2014). • Exit velocity = 20 m/s • Exit temperature = 1400 °C • Calculated heat release = 178 562.83 MJ/s • Release height = 4.0 m (not confirmed yet, conservative assumption) • Radiation loss = 30% Venting is not planned as part of the routine operation for the Project (consequently, odour impacts will be typically minimal).

Table 21: Estimated average emission rates per source (operational phase)

Operational Phase Emissions – Routine Conditions							
Sources	Emissions (tpa)						
	$PM_{2.5}$	PM_{10}	TSP	VOC	NOx	CO	SO_2
Road (from plant to public road)	0.99	9.88	30.88				
Plant emissions (continuous flare)				2.39	0.24	1.39	
Booster station emissions (generator)	1.61	1.64		1.68	23.12	4.98	0.01
Operational Phase Emissions – Upset Conditions							
Sources	Emissions (tpa)						
	$PM_{2.5}$	PM_{10}	TSP	VOC	NOx	CO	SO_2
Emergency flaring at plant (warm flare)				202.8	20.28	117.7	
Emergency flaring at plant (cold flare)				57.50	5.77	33.47	

4.1.4 Decommissioning, Rehabilitation and Closure Phase

All operational activities will have ceased by the rehabilitation and closure phase of the project. This will obviously result in a positive impact on the surrounding environment and human health. The potential for impacts during the closure phase will therefore depend on the extent of rehabilitation efforts to be undertaken at the plant, production wells, pipeline and roads. While impacts associated with rehabilitation and closure phase have been qualitatively assessed and finalized during the scoping phase, the following impacts will be assessed for the decommissioning phase of the Project:

Pollutants of concern during the decommissioning, rehabilitation and closure phase include:

- Fugitive emissions (dust) – This pertains to the potential entrainment of dust by machinery, the potential release of particulates from combustion engines used during decommissioning/ removal of all berms, trenches and other stormwater infrastructure and decommissioning/removal of pipeline infrastructure, and the potential entrainment of dust and particulates during removal of waste and recycling of recyclable / reclaimable waste.

4.2 Atmospheric Dispersion Modelling

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

- The criteria against which impacts are assessed (Section 2.2);
- The potential of the atmosphere to disperse and dilute pollutants emitted by the project (Section 3.2); and
- The methodology followed in determining ambient pollutant concentrations and dustfall rates (Section 4.2)

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

4.2.1 Dispersion Model Selection

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

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

A disadvantage of the model is that spatial varying wind fields, due to topography or other factors cannot be included. Input data types required for the AERMOD model include: Source data, meteorological data (pre-processed by the AERMET model), terrain data, information on the nature of the receptor grid and pre-development or background pollutant concentrations or dustfall rates. Version 10.0 of AERMOD and its pre-processors were used in the study.

4.2.1.1 Meteorological Requirements

For the purpose of this study, surface and profile weather data for the period January 2019 to December 2021 was obtained from the South African Weather Service station at Welkom (Section 3.2).

4.2.1.2 Source and Emission Data Requirements

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

- Plant flare emissions – modelled as flare sources;
- Generator emissions at booster stations – modelled as point sources; and
- Area wide construction, unpaved roads and vehicle exhaust – modelled as area sources.

The sources and AQSRs that were included in the AERMOD model are shown in Figure 10.

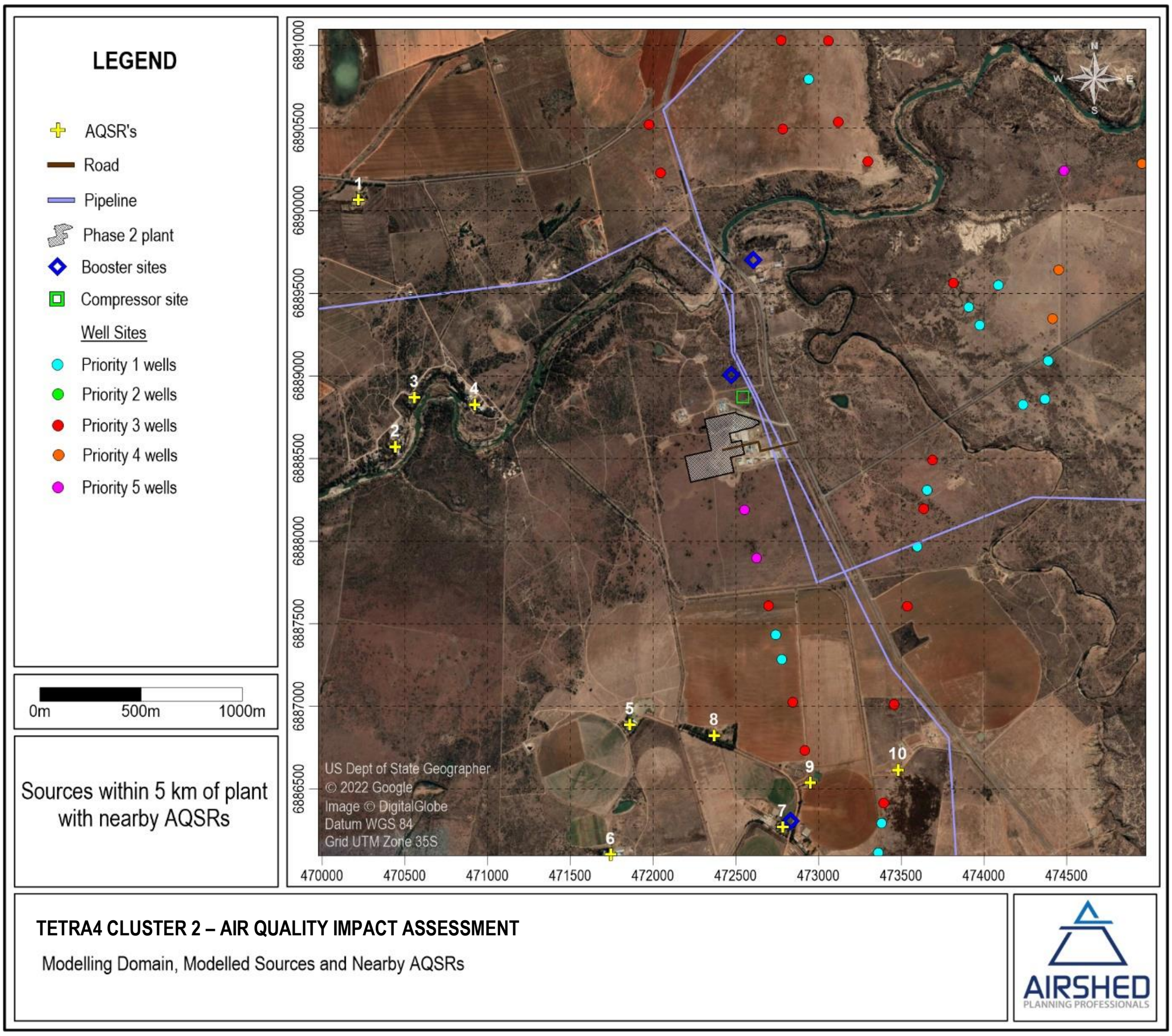

Figure 10: Sources and AQSRs included in the AERMOD model

4.2.1.3 Simulation of NO/NO_2 Transformation

Nitrogen monoxide (NO) emissions are rapidly converted in the atmosphere into the much more poisonous nitrogen dioxide (NO_2) which is regulated by SA NAAQS. The rate of this conversion process is determined by the rate of the physical processes of dispersion and mixing of the plume and the chemical reaction rates as well as the local atmospheric ozone concentration. In the absence of accurate ozone (O_3) data required to estimate the conversion ratio, 20% of all NOx was assumed to be NO_2 as per literature (Howard, 1988).

4.2.1.4 Modelling Domain

The dispersion of pollutants expected to arise from the project was modelled for the following aspects or activities:

- Proposed plant, compressor station, wells, booster stations, road and pipelines – an area covering 5 km (east-west) by 5 km (north-south)

A grid matrix resolution of 100 m was used, with the various project aspects or activities located centrally. AERMOD calculates ground-level (1.5 m above ground level) concentrations and dustfall rates at each grid and discrete receptor point.

4.2.1.5 Presentation of Results

Dispersion modelling was undertaken to determine highest hourly, highest daily and annual average ground level concentrations as well as dustfall rates for each of the pollutants considered in the study. Averaging periods were selected to facilitate the comparison of predicted pollutant concentrations to relevant ambient air quality and inhalation health criteria as well as dustfall regulations. Results are primarily provided in form of isopleths to present areas of exceedance of assessment criteria. Ground level concentration or dustfall isopleths presented in this section depict interpolated values from the concentrations simulated by AERMOD for each of the receptor grid points specified. The reader should take note that isopleths showing 1-hour or 24-hour concentrations reflect the 2nd highest 1-hour or 24-hour concentration simulated at grid receptor locations and not the frequency at which the specific concentration occurred over the simulation period. Separate isopleth plots are given to indicate the frequencies of exceedance where applicable.

Isopleth plots reflect the incremental ground level concentrations (GLCs) for $PM_{2.5}$, PM_{10}, NO_2 and SO_2 and VOCs. While there is a case for assessing the impacts of the proposed project individually, i.e. the incremental effect, potentially affected receptors are more interested in the overall end result, i.e. the cumulative effect. The National Environmental Management Act (NEMA), 107 of 1998 Act 1991 also requires this. This means that modelling results should be added to current background air pollution discharged by other sources. However, due to the unavailability of ambient baseline concentrations, the total cumulative pollutant concentrations could not be quantitatively determined; but qualitative assessment and commentary is provided in the discussion of impact significance in Section 5.

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

4.3 Dispersion Simulation Results, Health Risk and Nuisance Screening

Pollutants with the potential to result in human health impacts which are assessed in this study include CO, NO_2, $PM_{2.5}$, PM_{10}, SO_2 and VOC. Dustfall is assessed for its nuisance potential.

The impact assessment methodology as discussed under section 4.2 was followed. Isopleth plots are provided for all pollutants where exceedances of the relevant NAAQSs were simulated. Isopleth plots reflect the incremental GLCs and deposition rates for all pollutants assessed.

4.3.1 Construction Phase Results

4.3.1.1 Proposed Wells/Booster Stations

Simulated maximum GLCs and deposition rates depicting worst-case air quality impacts during the construction of wells and booster stations are discussed in the below sections for PM_{10}, $PM_{2.5}$, NO_2, SO_2, CO, VOCs and dustfall.

4.3.1.1.1 PM_{10} GLC's

Simulated maximum daily GLCs depicting worst-case air quality impacts during construction as a function of perpendicular distance from wells and booster stations are shown in Figure 11. Maximum daily PM_{10} GLCs due to well and booster station construction are illustrated in Figure 12 and Figure 13 respectively. From Figure 11 simulated PM_{10} GLCs exceed the NAAQS daily limit up to 180 m beyond the well site and up to 150 m beyond the booster station (BL1-10), but not at any AQSRs. Isopleths for other proposed wells and booster stations are not shown since they are all similar in terms of extent, concentration and spatial distribution.

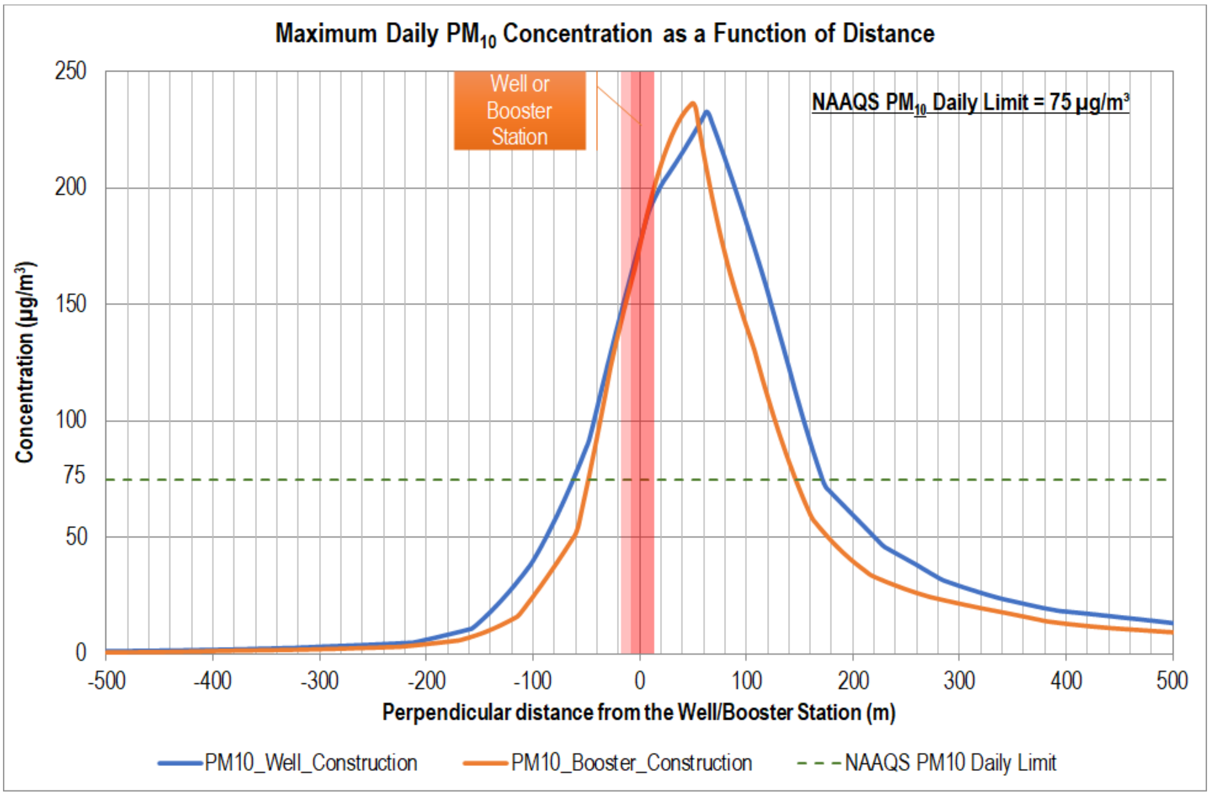

Figure 11: Simulated maximum daily PM_{10} GLCs due to well/booster station construction emissions (exceedances of NAAQS limit up to 150 m perpendicular distance from booster station and 180 m from well were simulated)

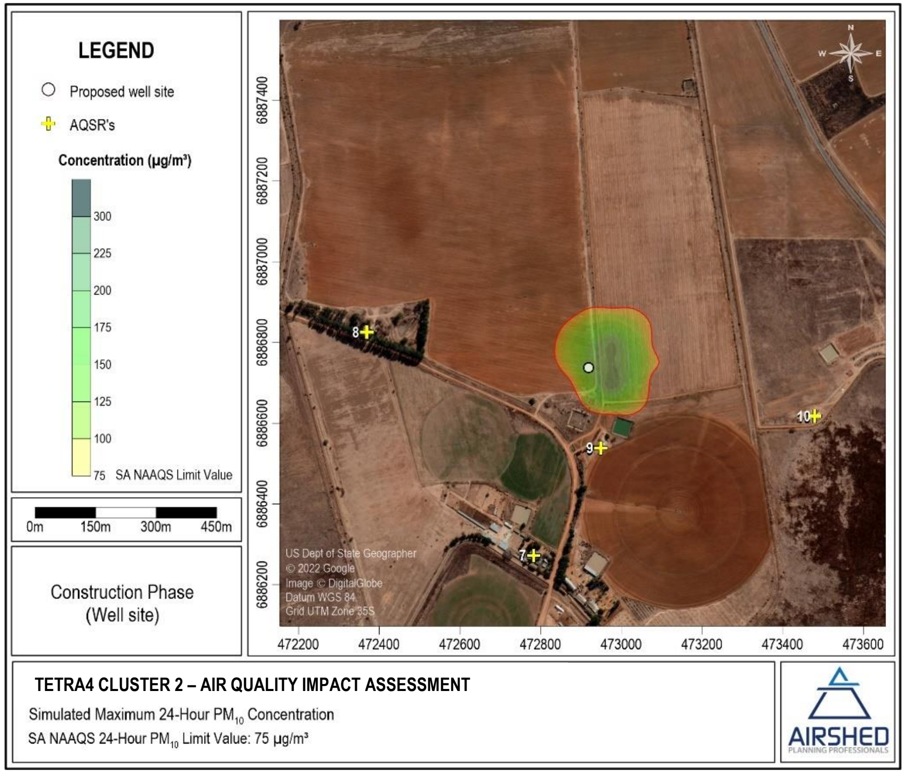

Figure 12: Simulated maximum 24-hour PM_{10} GLCs due to proposed well construction emissions (single exceedance of NAAQS limit up to 180 m beyond well site indicated as red line)

Figure 13: Simulated maximum 24-hour PM_{10} GLCs due to proposed booster station construction emissions (single exceedance of NAAQS limit up to 150 m beyond booster site indicated as red line)

4.3.1.1.2 $PM_{2.5}$ GLC's

Maximum daily GLCs depicting worst-case $PM_{2.5}$ impacts during the construction of proposed wells and booster stations are shown in Figure 15 and Figure 16 respectively. Simulated daily $PM_{2.5}$ GLCs depicting worst-case air quality impacts as a function of perpendicular distance from wells and booster stations are shown in Figure 14. From Figure 14 simulated $PM_{2.5}$ GLCs exceed the NAAQS daily limit up to 290 m beyond the well site and up to 200 m beyond the booster station. Simulated $PM_{2.5}$ GLCs did not exceed the NAAQS limit at any AQSRs for the well site (Figure 15) but did exceed at AQSR 7 for the proposed BL1-10 booster station (Figure 16). However, worst case impacts are not anticipated to occur over long intervals since construction occurs over the short-term and peak activities will not be consistent over the specified period.

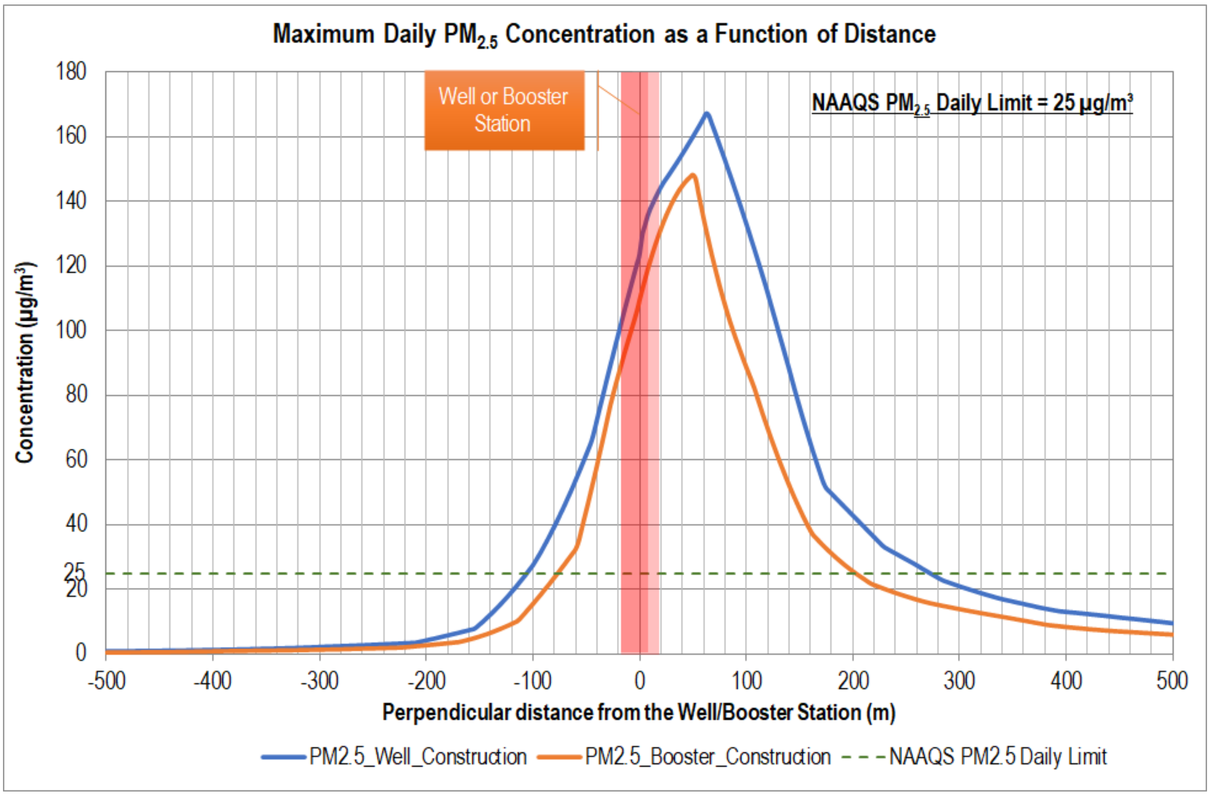

Figure 14: Simulated maximum daily $PM_{2.5}$ GLCs due to well/booster station construction emissions (exceedances of NAAQS limit up to 200 m perpendicular distance from booster station and 290 m from well were simulated)

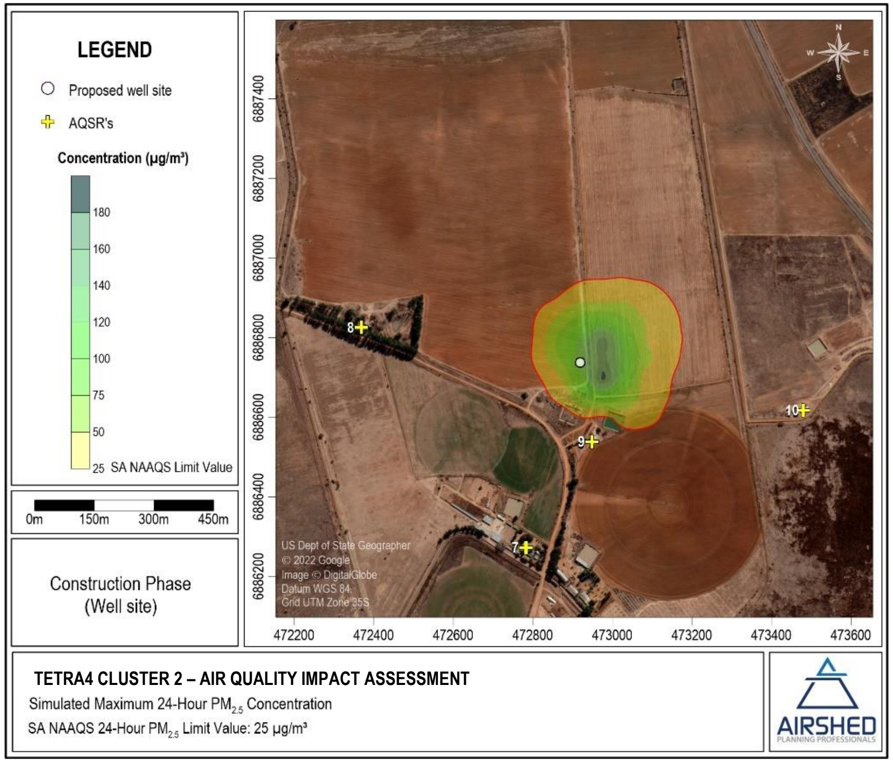

Figure 15: Simulated maximum 24-hour $PM_{2.5}$ GLCs due to proposed well construction emissions (single exceedance of NAAQS limit up to 300 m beyond well site indicated as red line)

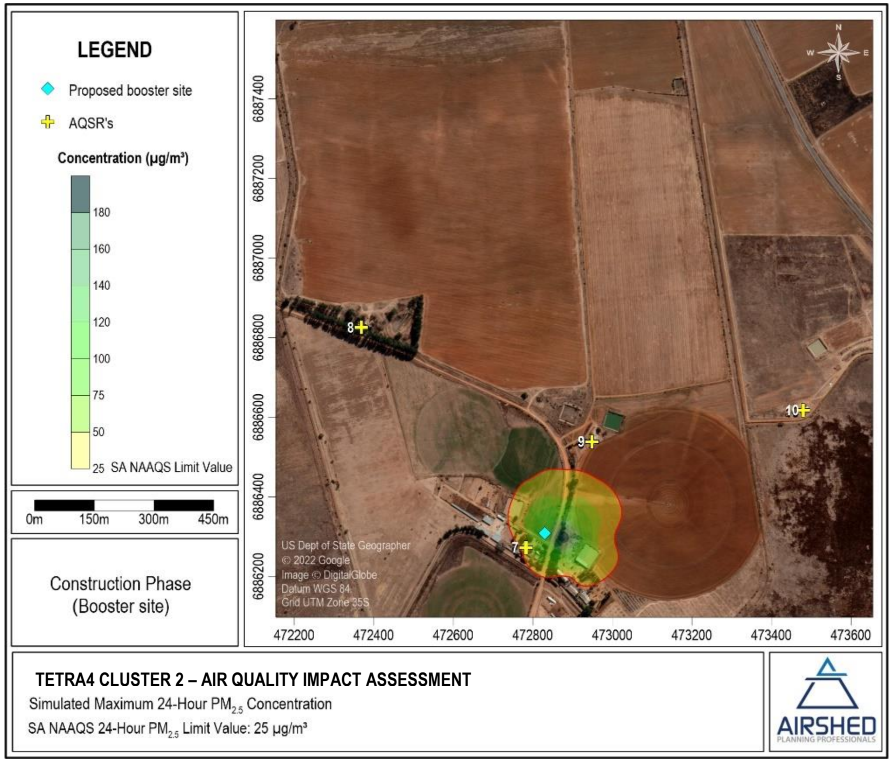

Figure 16: Simulated maximum 24-hour $PM_{2.5}$ GLCs due to proposed booster station construction emissions (single exceedance of NAAQS limit up to 180 m beyond booster site indicated as red line)

4.3.1.1.3 NO_2 GLC's

Maximum hourly GLCs depicting worst-case NO_2 impacts during the construction of proposed wells and booster stations are shown in Figure 18 and Figure 19 respectively. From Figure 17 simulated NO_2 GLCs exceed the NAAQS hourly limit up to 750 m beyond the well site and up to 500 m beyond the booster station. Simulated NO_2 GLCs did not exceed the NAAQS limit at any AQSRs for the well site (Figure 18) but did exceed at AQSR 7 and AQSR 9 for the booster station (Figure 19). However, it must be kept in mind that worst case impacts are not anticipated to occur over long intervals since peak activities will not be consistent over the construction period and will only last short-term.

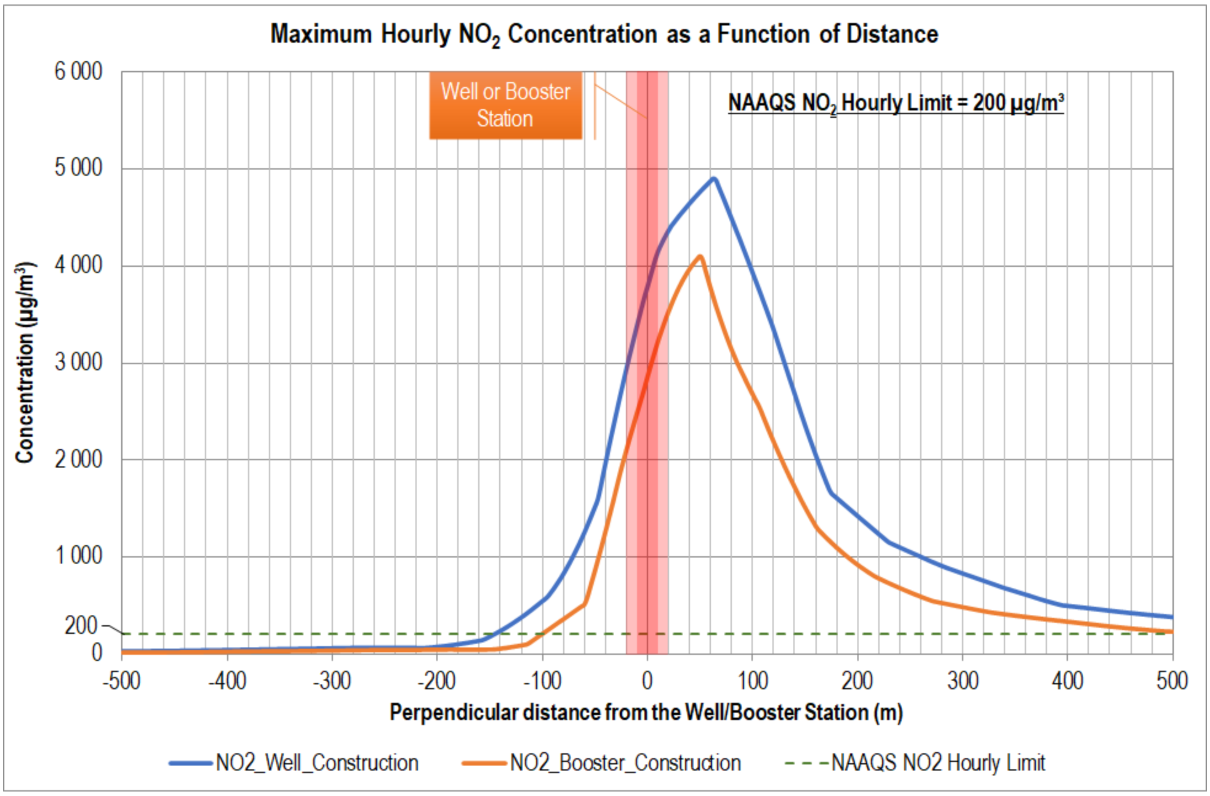

Figure 17: Simulated maximum hourly NO_2 GLCs due to well/booster station construction emissions (exceedances of NAAQS limit up to 500 m perpendicular distance from booster station and 750 m from well were simulated)

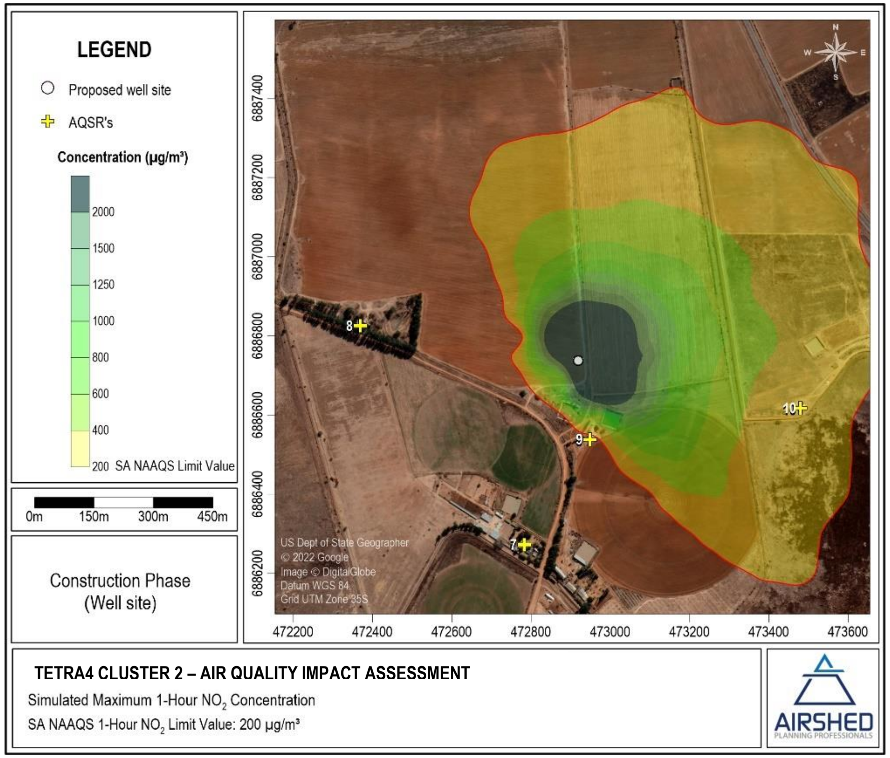

Figure 18: Simulated maximum 1-hour NO_2 GLCs due to proposed well construction emissions (single exceedance of NAAQS limit up to 750 m beyond well site indicated as red line)

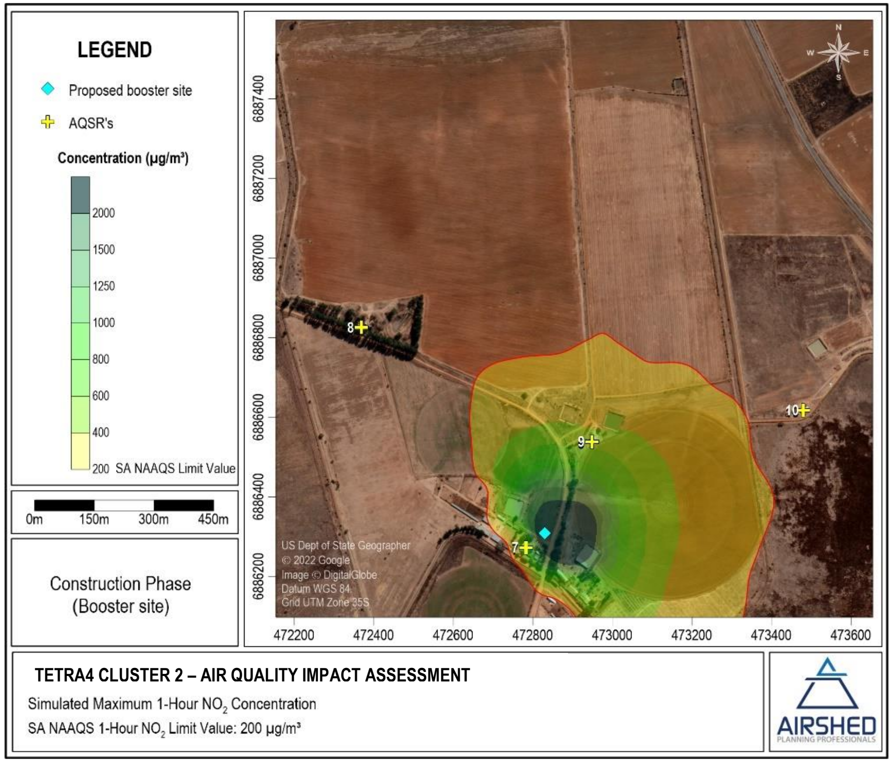

Figure 19: Simulated maximum 1-hour NO_2 GLCs due to proposed booster station construction emissions (single exceedance of NAAQS limit up to 500 m beyond booster site indicated as red line)

4.3.1.1.4 SO_2 GLC's

Simulated hourly GLCs depicting worst-case SO_2 construction impacts as a function of perpendicular distance from the proposed wells and booster stations are shown in Figure 20. Figure 20 illustrates that simulated SO_2 GLCs are very low and are not expected to exceed the NAAQS hourly limit (350 µg/m³) during well/booster station construction.

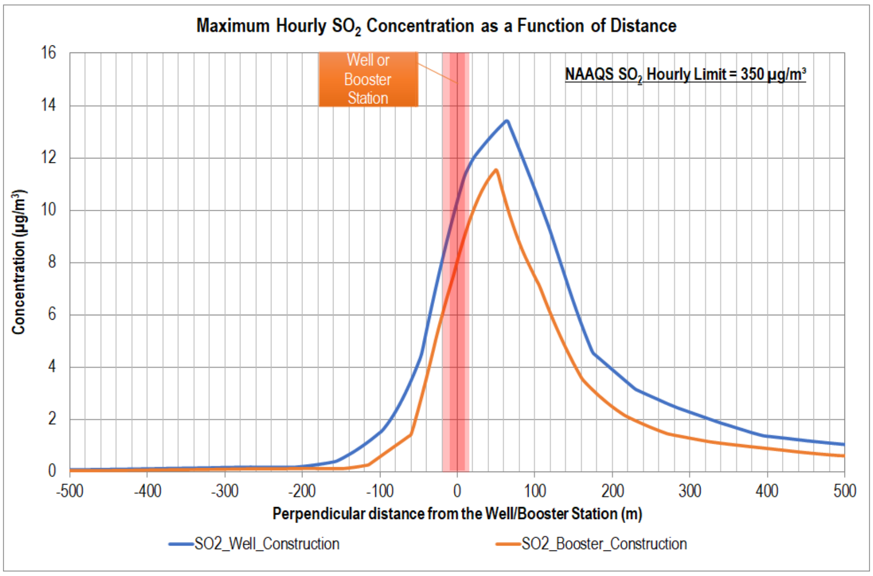

Figure 20: Simulated maximum hourly SO_2 GLCs due to well/booster station construction emissions (the NAAQS limit is not exceeded)

4.3.1.1.5 CO GLC's

Simulated hourly GLCs depicting worst-case CO construction impacts as a function of perpendicular distance from the proposed wells and booster stations are shown in Figure 21. Figure 21 illustrates that simulated CO GLCs are not expected to exceed the NAAQS hourly limit (30 000 µg/m³) during the construction of wells and booster stations.

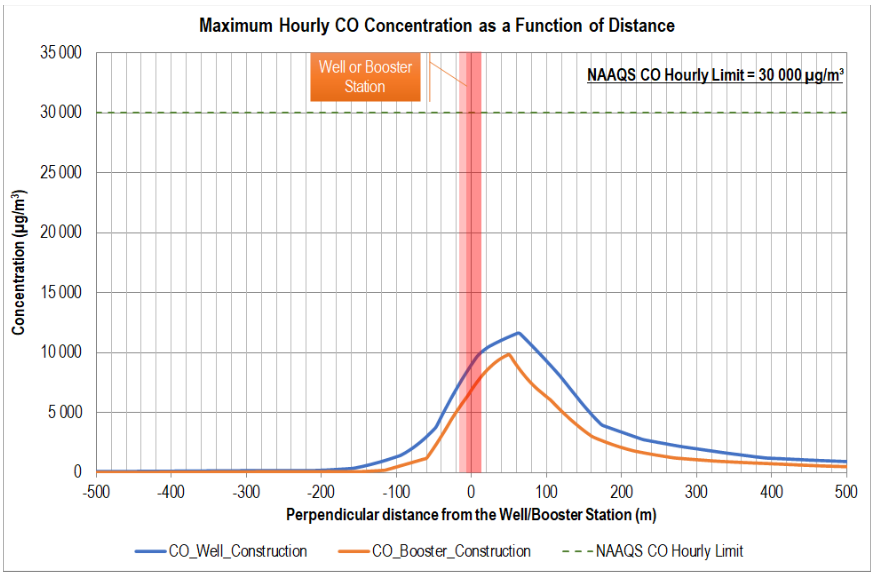

Figure 21: Simulated maximum hourly CO GLCs due to well/booster station construction emissions (the NAAQS limit is not exceeded)

4.3.1.1.6 VOC GLC's

Maximum simulated hourly VOC GLCs due to construction activities as a function of perpendicular distance from the well and booster station are illustrated in Figure 22. From Figure 22 hourly VOC GLCs exceed the TCEQ Effects Screening Level (ESL) of 1 000 µg/m³ up to 170 m beyond the well site and up to 130 m beyond the booster station, but not at any AQSRs (see Figure 23 and Figure 24).

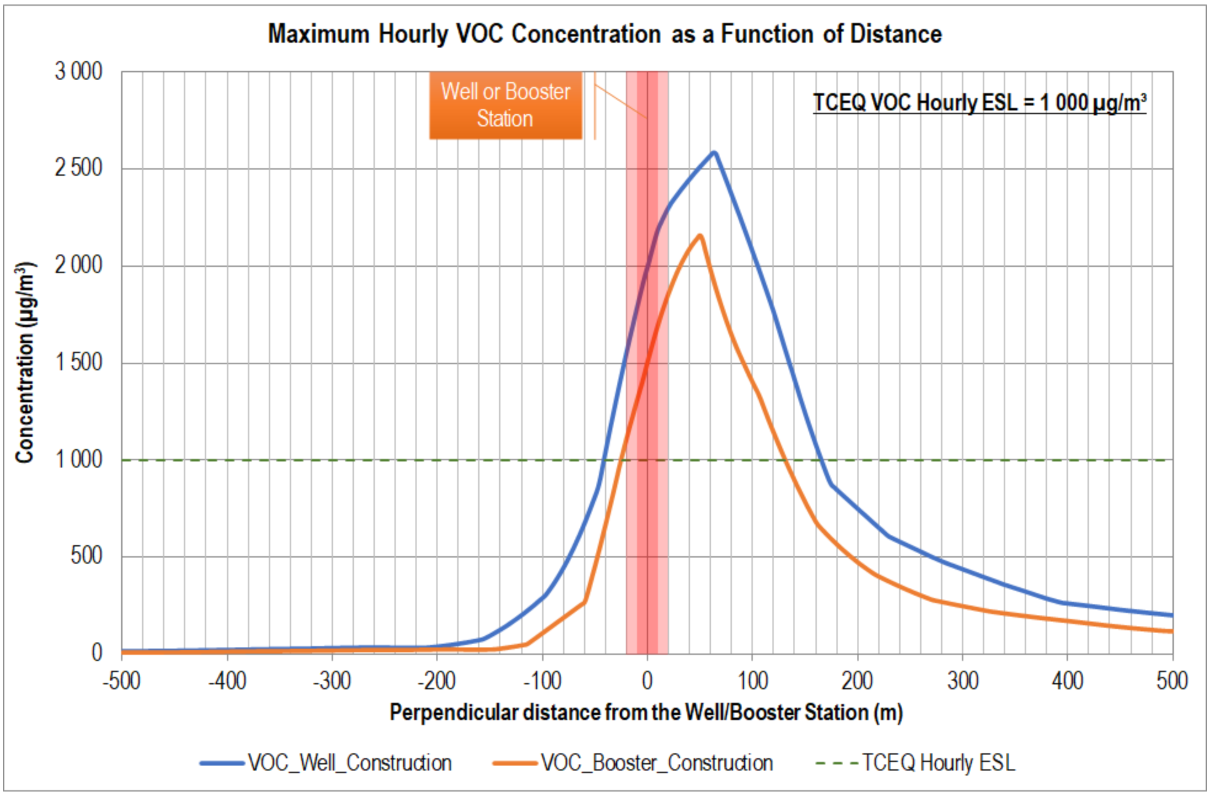

Figure 22: Simulated maximum hourly VOC GLCs due to well/booster station construction emissions (exceedances of TCEQ ESL up to 130 m perpendicular distance from booster station and 170 m from well were simulated)

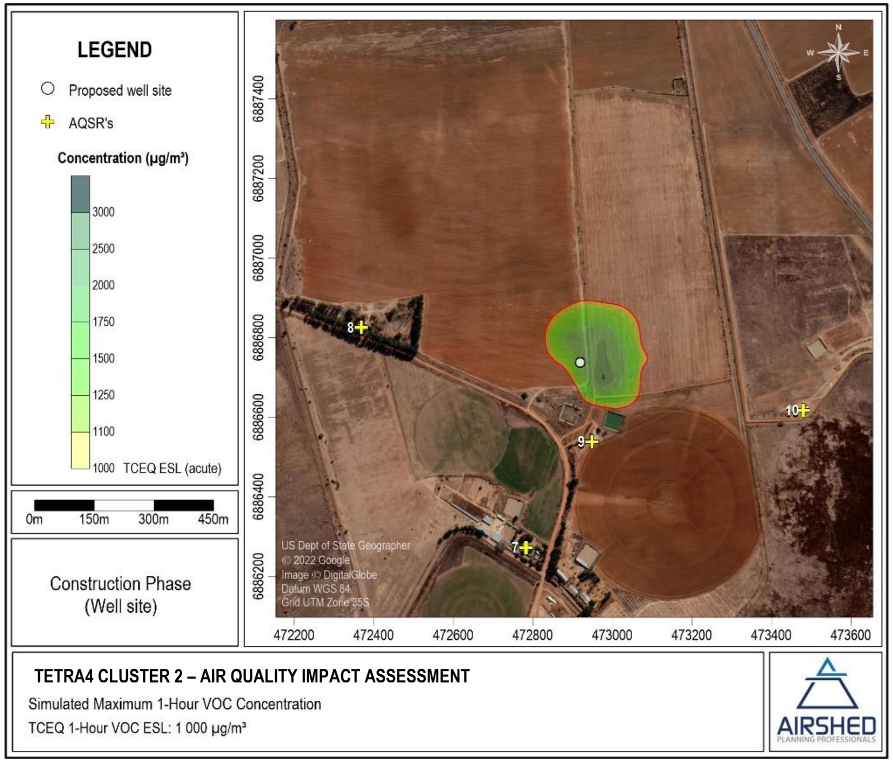

Figure 23: Simulated maximum 1-hour VOC GLCs due to proposed well construction emissions (single exceedance of TCEQ ESL up to 170 m beyond well site indicated as red line)

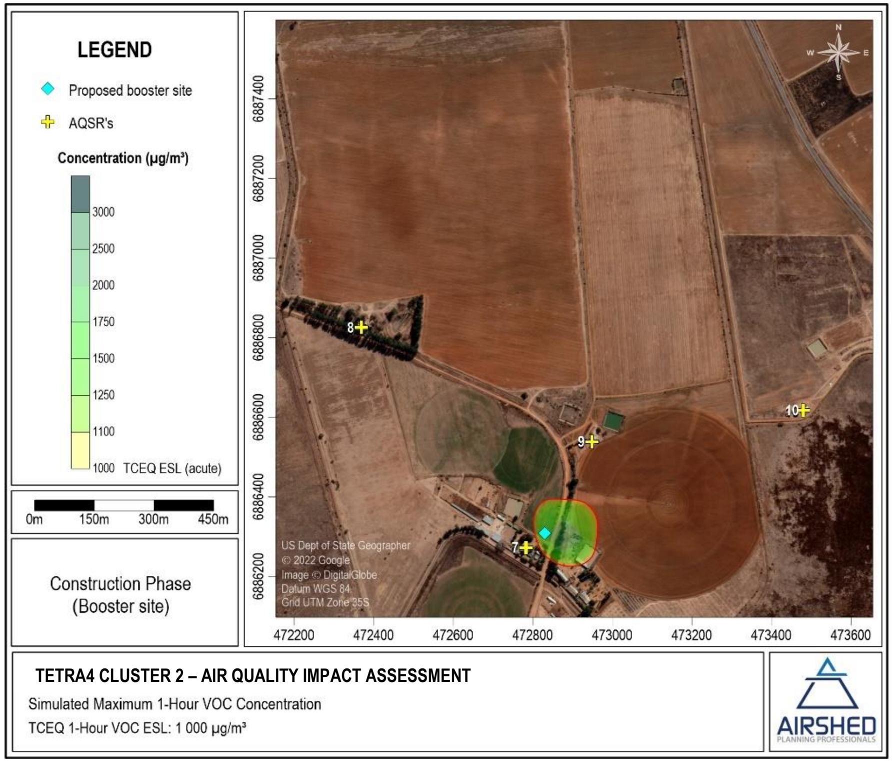

Figure 24: Simulated maximum 1-hour VOC GLCs due to proposed booster station construction emissions (single exceedance of TCEQ ESL up to 130 m beyond booster site indicated as red line)

4.3.1.1.7 Dustfall Deposition Rates

Maximum simulated daily dustfall deposition rates as a result of well and booster station construction emissions are shown in Figure 25 as a function of perpendicular distance from the well and booster station. From Figure 25 simulated daily dustfall deposition rates do not exceed the NDCR residential limit of 600 mg/m²/day.

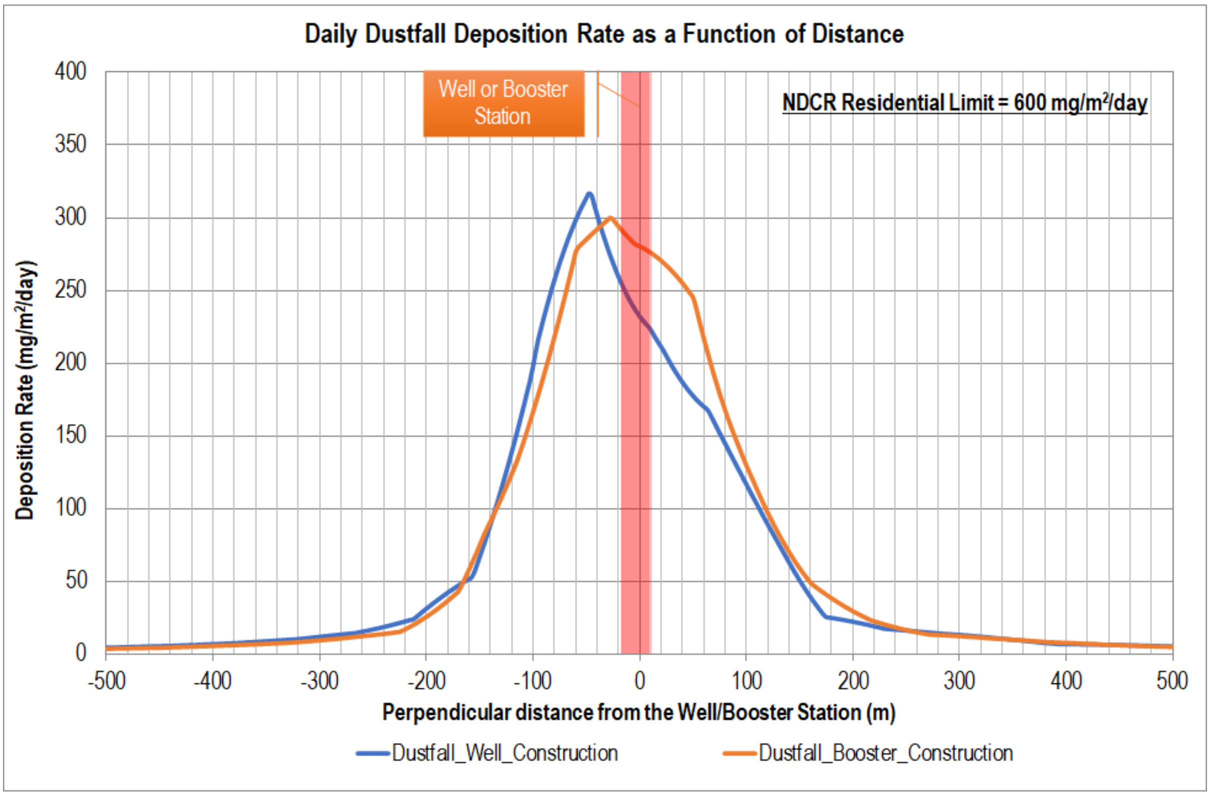

Figure 25: Simulated daily dustfall deposition rates due to well/booster station construction emissions (the NDCR residential limit is not exceeded)

4.3.1.2 *Roads/Pipeline Construction*

Simulated maximum GLCs and deposition rates depicting worst-case air quality impacts during the construction of roads[3] and pipeline are discussed in the below sections for PM_{10}, $PM_{2.5}$, NO_2, SO_2, CO, VOCs and dustfall.

4.3.1.2.1 PM_{10} GLC's

Simulated maximum daily PM_{10} GLCs due to road and pipeline construction emissions are shown in Figure 27 and Figure 28 respectively. Simulated maximum daily PM_{10} GLCs due to road construction emissions exceed the PM_{10} NAAQS limit up to 95 m perpendicular distance from the centre of the road, while maximum daily PM_{10} GLCs due to pipeline construction emissions exceed the PM_{10} NAAQS limit up to 100 m perpendicular distance from the pipeline (Figure 26). Worst case impacts are not anticipated to occur over long intervals since road construction will only last a few days per 500 m stretch and peak activities will not be consistent over that specified period.

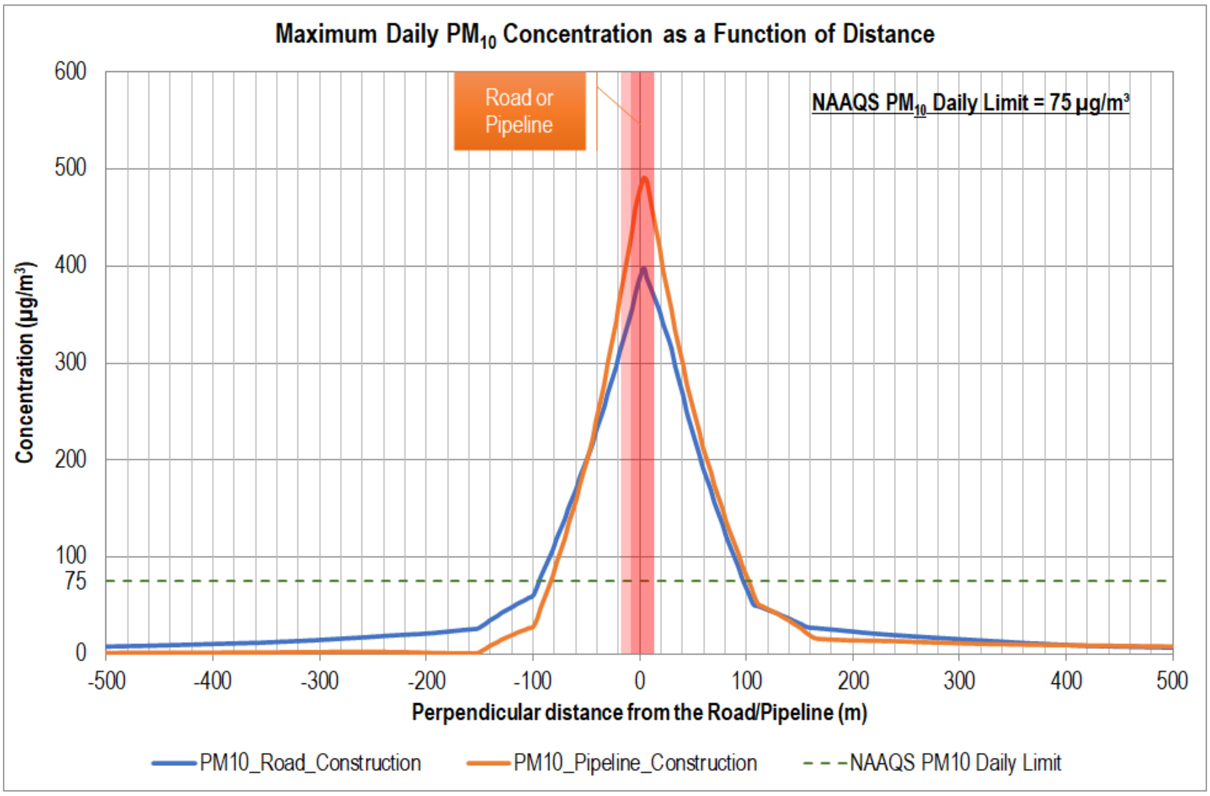

Figure 26: Simulated maximum daily PM_{10} GLCs due to road/pipeline construction emissions (exceedances of NAAQS limit up to 95 m perpendicular distance from the road and 100 m from the pipeline were simulated)

[3] The access road to the plant was modelled as an unpaved road. The results are representative of any new unpaved roads that may be constructed as part of the Project.

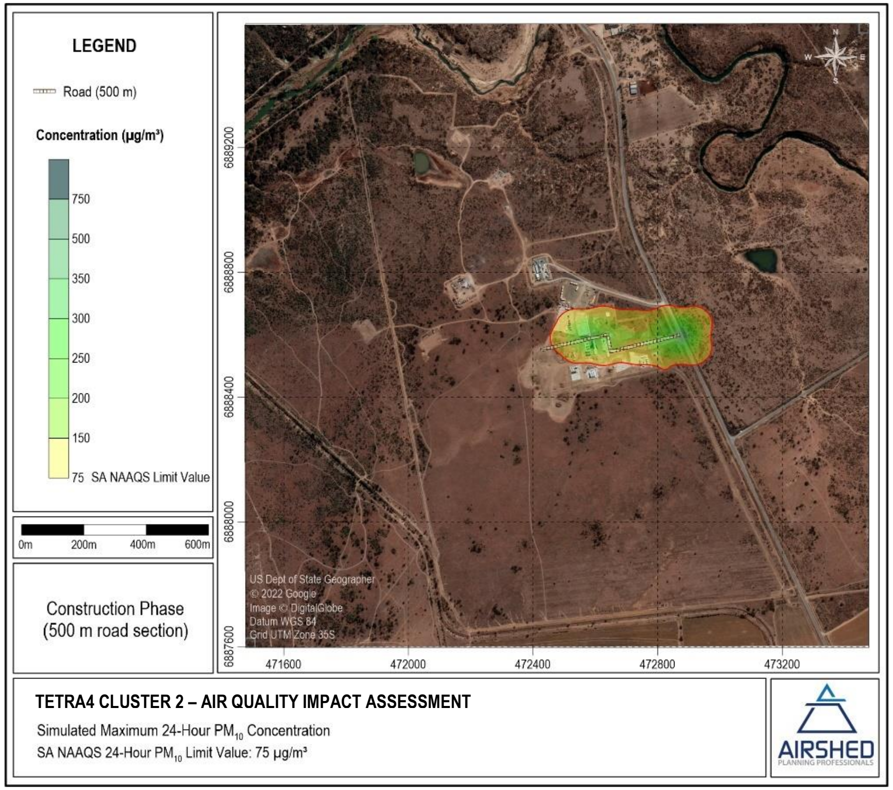

Figure 27: Simulated maximum 24-hour PM_{10} GLCs due to proposed road construction emissions (single exceedance of NAAQS limit up to 95 m beyond road indicated as red line)

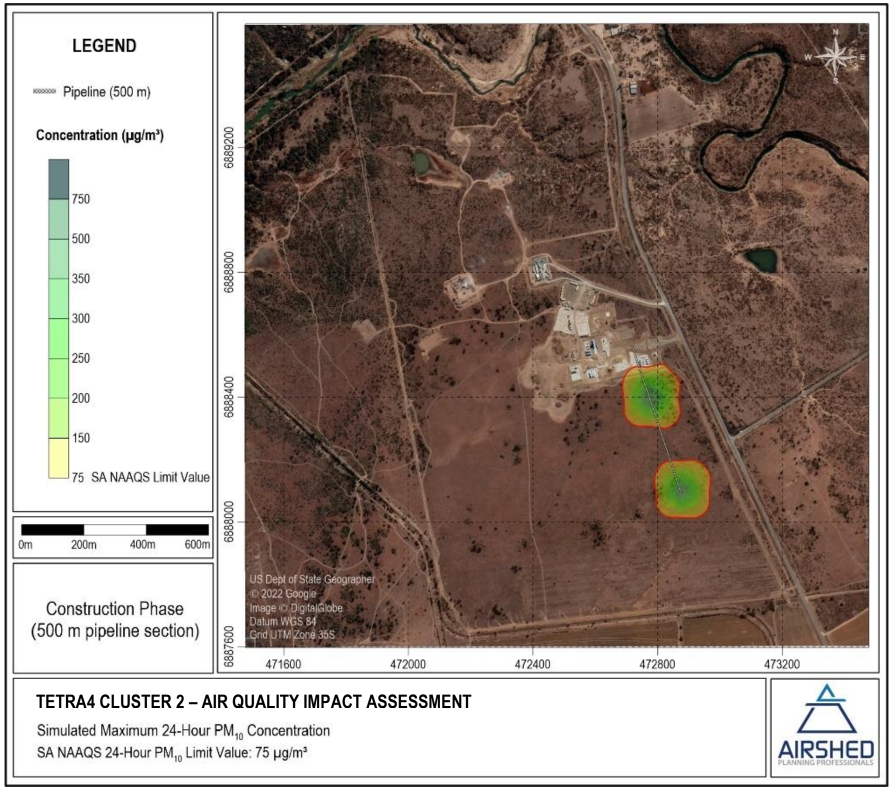

Figure 28: Simulated maximum 24-hour PM_{10} GLCs due to proposed pipeline construction emissions (single exceedance of NAAQS limit up to 100 m beyond pipeline indicated as red line)

4.3.1.2.2 $PM_{2.5}$ GLC's

Simulated maximum daily $PM_{2.5}$ GLCs due to road and pipeline construction emissions are shown in Figure 30 and Figure 31 respectively. Simulated maximum daily $PM_{2.5}$ GLCs due to road construction emissions exceed the $PM_{2.5}$ NAAQS limit up to 80 m perpendicular distance from the centre of the road, while maximum daily $PM_{2.5}$ GLCs due to pipeline construction emissions exceed the $PM_{2.5}$ NAAQS limit up to 100 m perpendicular distance from the pipeline (Figure 29).

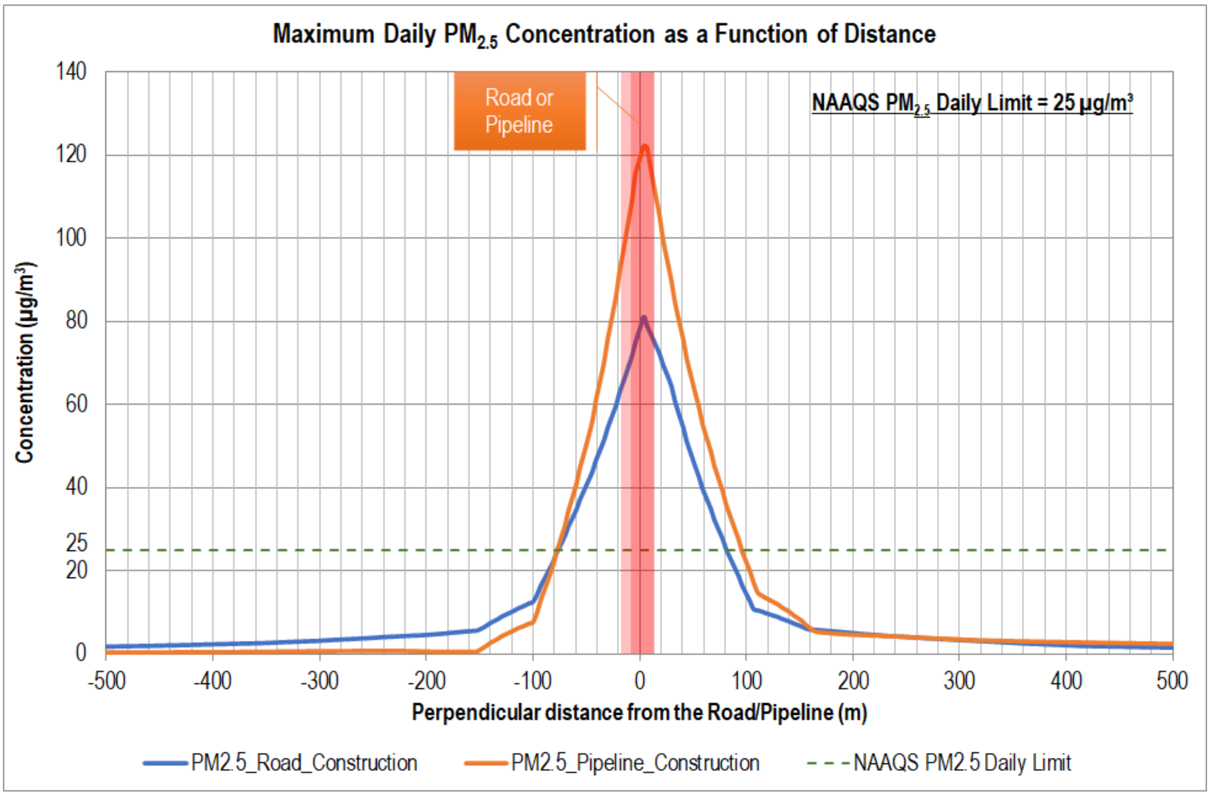

Figure 29: Simulated maximum daily $PM_{2.5}$ GLCs due to road/pipeline construction emissions (exceedances of NAAQS limit up to 80 m perpendicular distance from the road and 100 m from the pipeline were simulated)

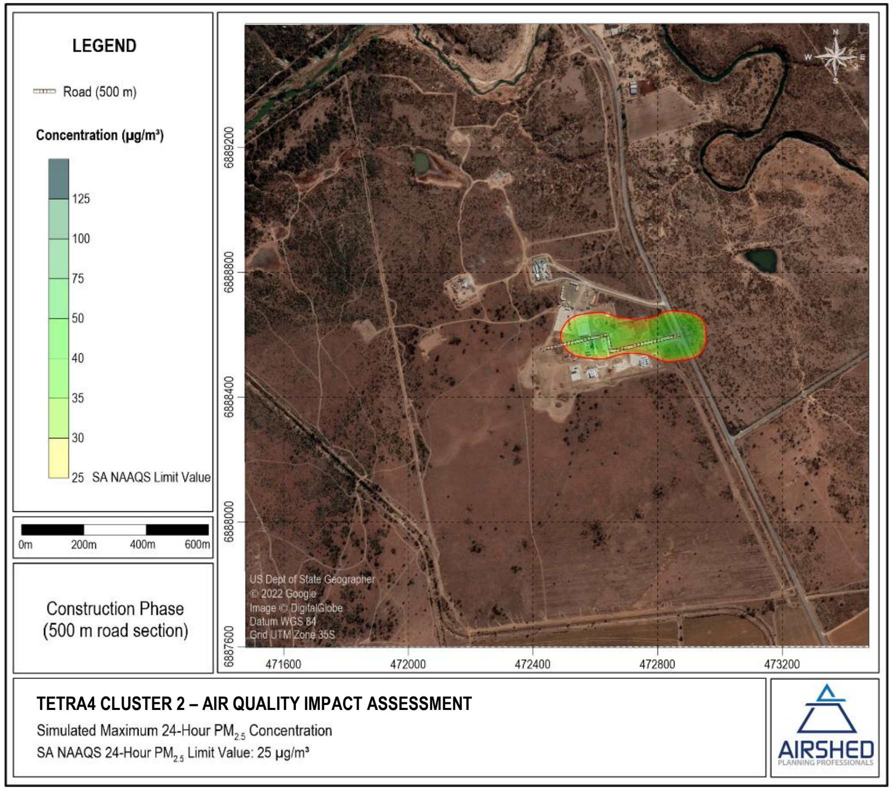

Figure 30: Simulated maximum 24-hour $PM_{2.5}$ GLCs due to proposed road construction emissions (single exceedance of NAAQS limit up to 80 m beyond road indicated as red line)

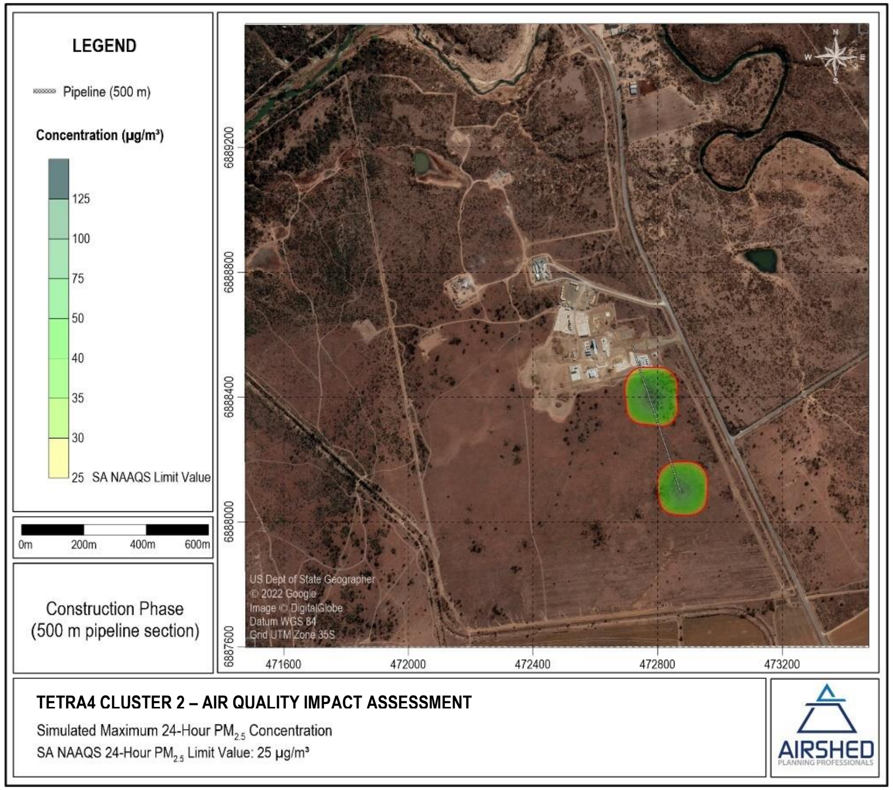

Figure 31: Simulated maximum 24-hour $PM_{2.5}$ GLCs due to proposed pipeline construction emissions (single exceedance of NAAQS limit up to 100 m beyond pipeline indicated as red line)

4.3.1.2.3 NO_2 GLC's

Simulated maximum hourly NO_2 GLCs due to road and pipeline construction emissions are shown in Figure 33 and Figure 34 respectively. Simulated maximum hourly NO_2 GLCs due to road/pipeline construction emissions exceed the NO_2 NAAQS limit up to 150 m perpendicular distance from both the centre of the road and the pipeline (Figure 32).

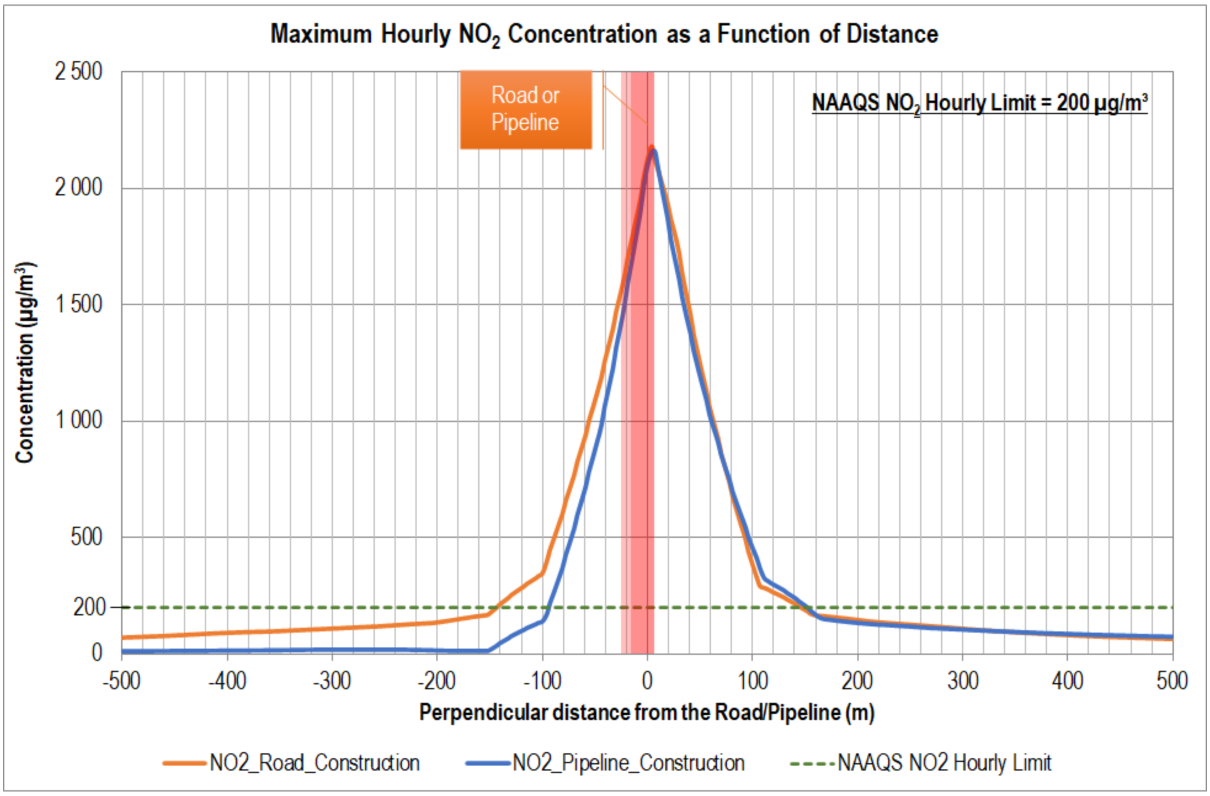

Figure 32: Simulated maximum hourly NO_2 GLCs due to road/pipeline construction emissions (exceedances of NAAQS limit up to 150 m perpendicular distance from the road and pipeline were simulated)

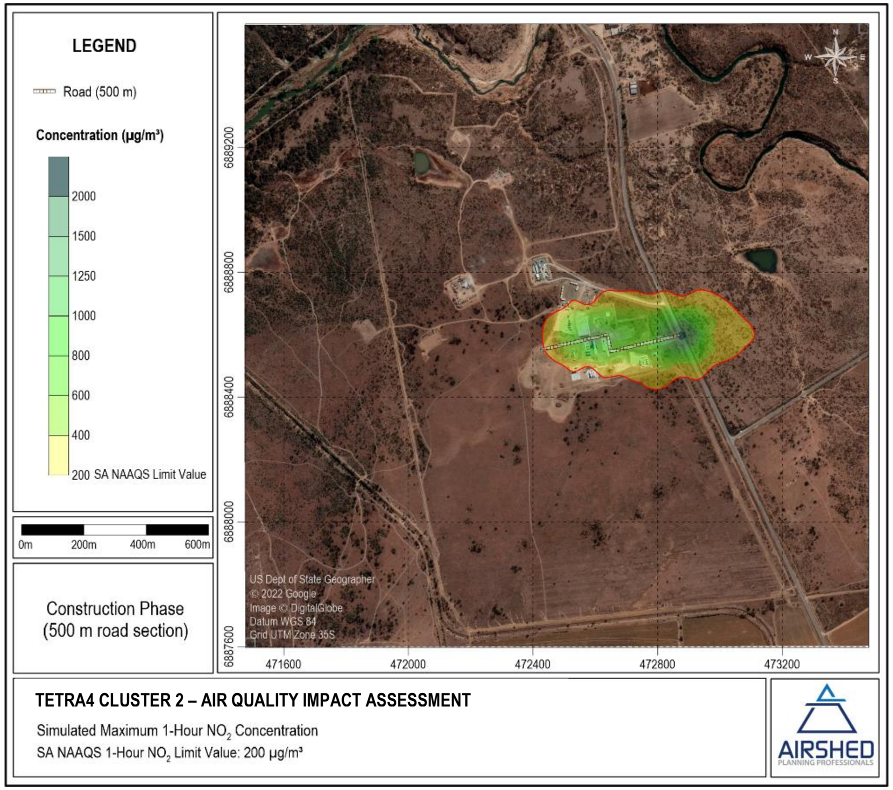

Figure 33: Simulated maximum 1-hour NO_2 GLCs due to proposed road construction emissions (single exceedance of NAAQS limit up to 150 m beyond road indicated as red line)

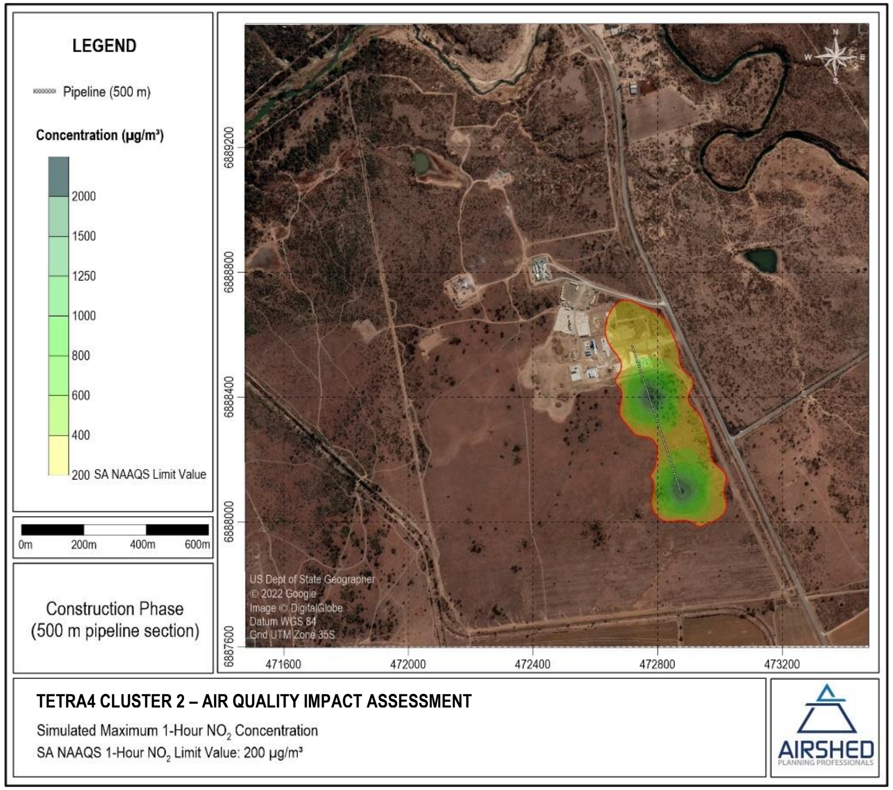

Figure 34: Simulated maximum 1-hour NO_2 GLCs due to proposed pipeline construction emissions (single exceedance of NAAQS limit up to 150 m beyond pipeline indicated as red line)

4.3.1.2.4 SO_2 GLC's

Simulated hourly GLCs depicting worst-case SO_2 construction impacts as a function of perpendicular distance from the proposed road and pipeline are shown in Figure 35. Figure 35 illustrates that simulated SO_2 GLCs are very low and are not expected to exceed the NAAQS hourly limit (350 µg/m³) during road/pipeline construction.

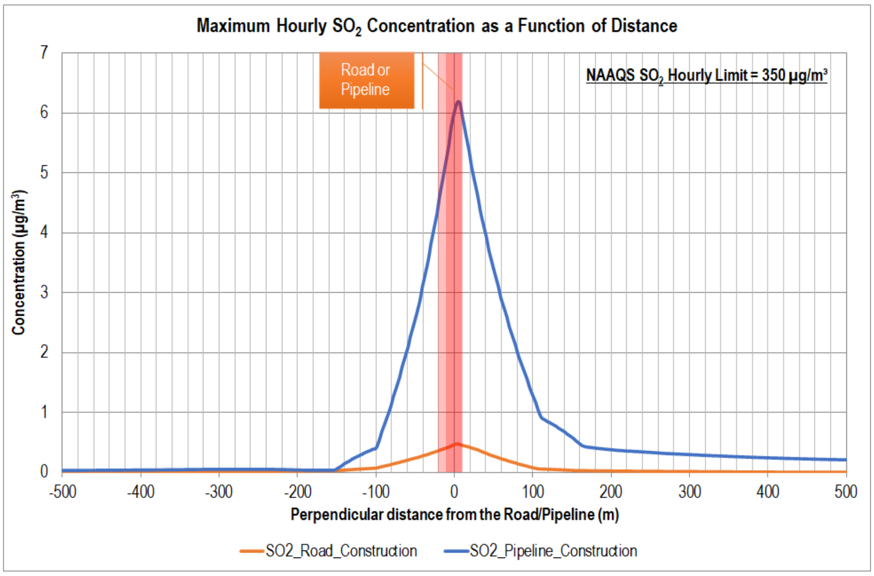

Figure 35: Simulated maximum hourly SO_2 GLCs due to road/pipeline construction emissions (the NAAQS limit is not exceeded)

4.3.1.2.5 CO GLC's

Simulated hourly GLCs depicting worst-case CO construction impacts as a function of perpendicular distance from the proposed road and pipeline are shown in Figure 36. Figure 36 illustrates that simulated CO GLCs are not expected to exceed the NAAQS hourly limit (30 000 µg/m³) during road/pipeline construction.

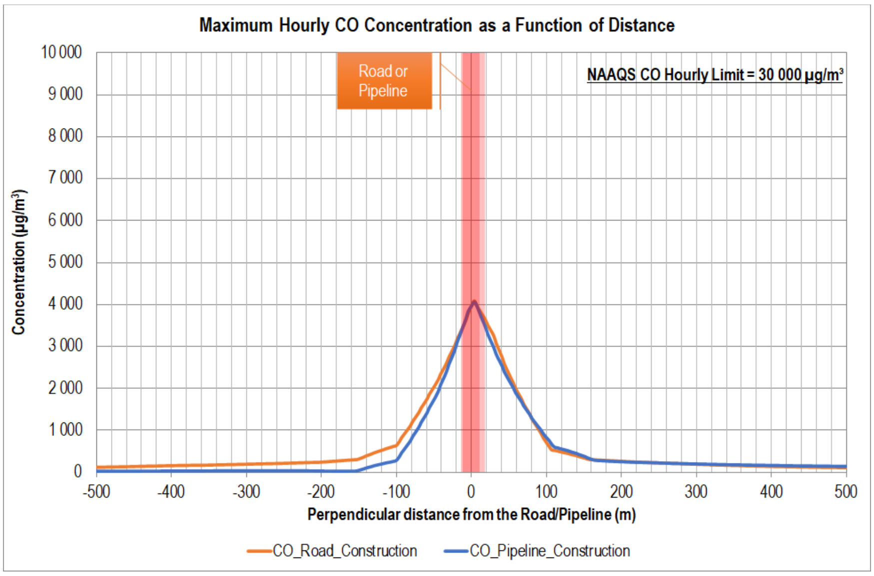

Figure 36: Simulated maximum hourly CO GLCs due to road/pipeline construction emissions (the NAAQS limit is not exceeded)

4.3.1.2.6 VOC GLC's

Maximum simulated hourly VOC GLCs due to construction activities as a function of perpendicular distance from the road and pipeline are illustrated in Figure 37. From Figure 37 hourly VOC GLCs do not exceed the TCEQ ESL of 1 000 µg/m³.

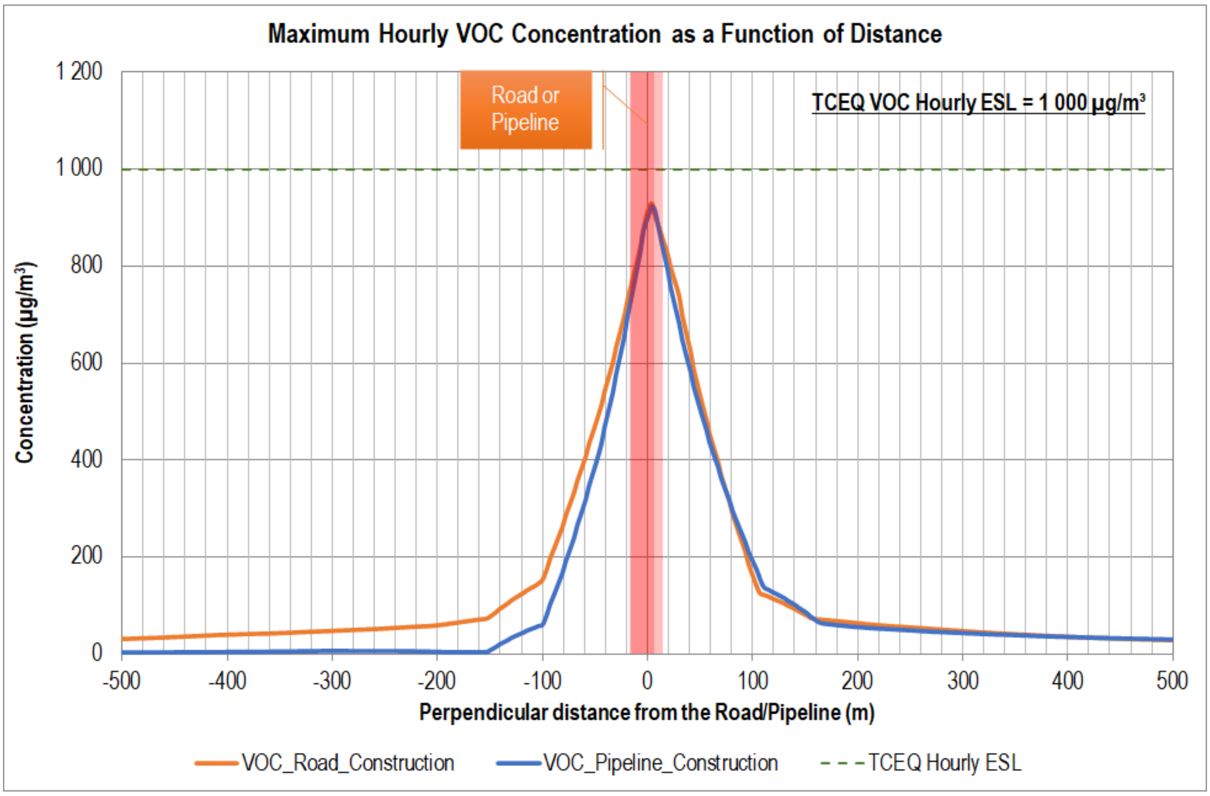

Figure 37: Simulated maximum hourly VOC GLCs due to road/pipeline construction emissions (the TCEQ ESL is not exceeded)

4.3.1.2.7 Dustfall Deposition Rates

Maximum simulated daily dustfall deposition rates as a result of road and pipeline construction emissions are shown in Figure 38 as a function of perpendicular distance from each type of infrastructure. From Figure 38 simulated daily dustfall deposition rates exceed the NDCR residential limit of 600 mg/m²/day up to 50 m and 40 m beyond the road and pipeline respectively (see Figure 39 and Figure 40).

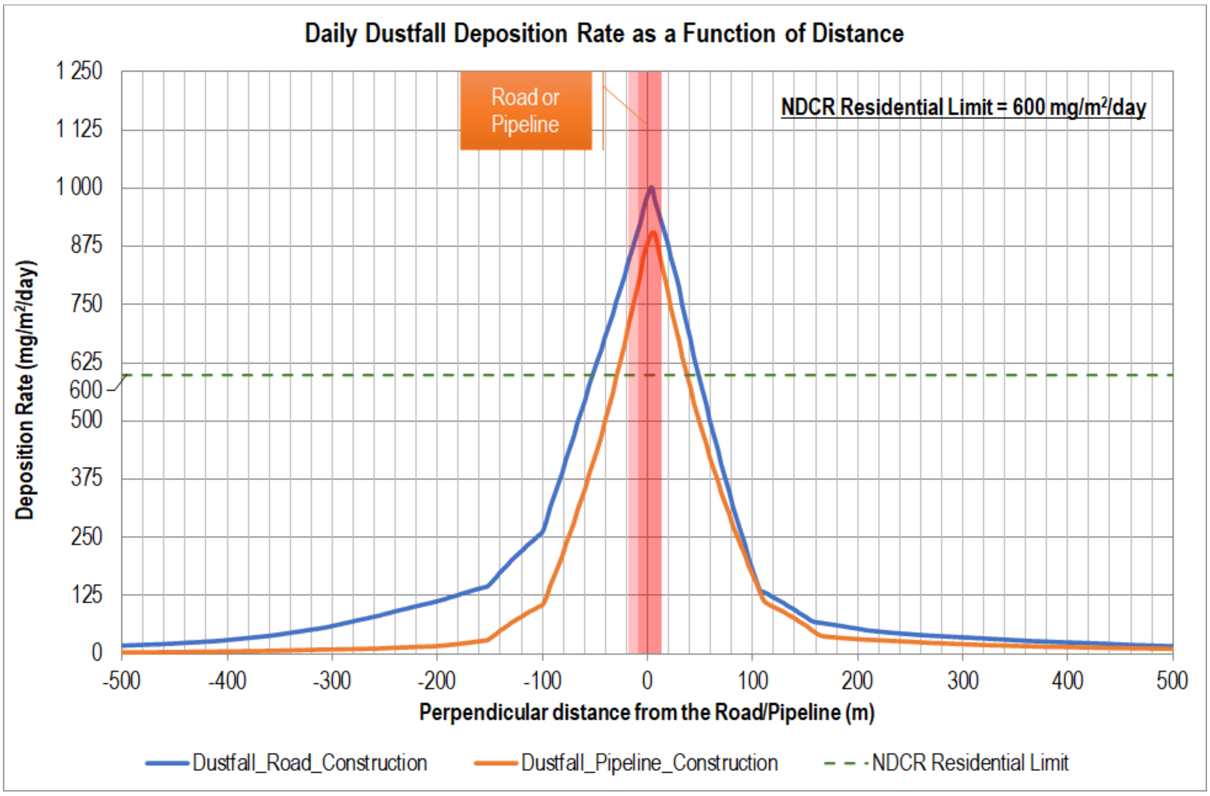

Figure 38: Simulated daily dustfall deposition rates due to road/pipeline construction emissions (exceedances of the NDCR residential limit up to 50 m perpendicular distance from road and 40 m from pipeline were simulated)

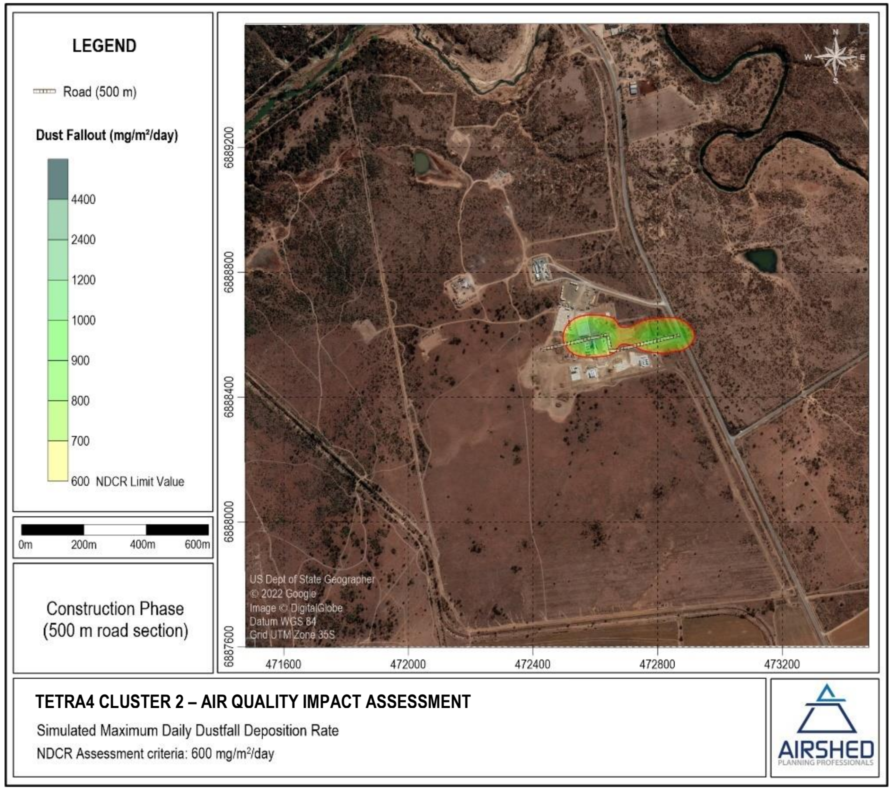

Figure 39: Simulated maximum daily dustfall deposition rates due to proposed road construction emissions (single exceedance of the NDCR residential limit up to 50 m beyond road indicated as red line)

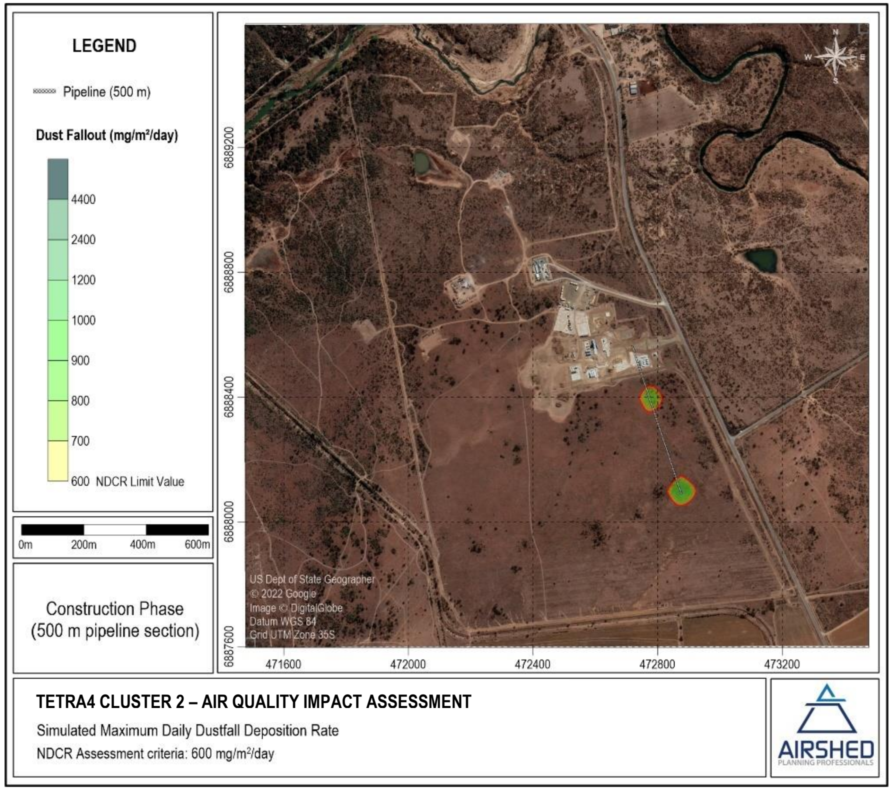

Figure 40: Simulated maximum daily dustfall deposition rates due to proposed pipeline construction emissions (single exceedance of the NDCR residential limit up to 40 m beyond pipeline indicated as red line)

4.3.1.3 *Plant/Compressor Site Construction*

Simulated maximum GLCs and deposition rates depicting worst-case air quality impacts during the construction of compressor stations and plant are discussed in the below sections for PM_{10}, $PM_{2.5}$, NO_2, SO_2, CO, VOCs and dustfall.[4]

4.3.1.3.1 PM_{10} GLC's

Simulated maximum daily GLCs depicting worst-case air quality impacts during construction as a function of perpendicular distance from plant and compressor stations are shown in Figure 41. From Figure 41 simulated PM_{10} GLCs exceed the NAAQS daily limit up to 500 m beyond the plant boundary and up to 200 m beyond the compressor station (also see Figure 42). Isopleth contours representing maximum daily PM_{10} GLCs and frequency of exceedance of the daily NAAQS limit due to plant construction emissions are shown in Figure 43. Figure 43 shows that although PM_{10} GLCs exceed the NAAQS daily limit up to 500 m from the plant boundary, the footprint of exceedance of more than the allowable 4 days per year extends only 270 m beyond the plant boundary.

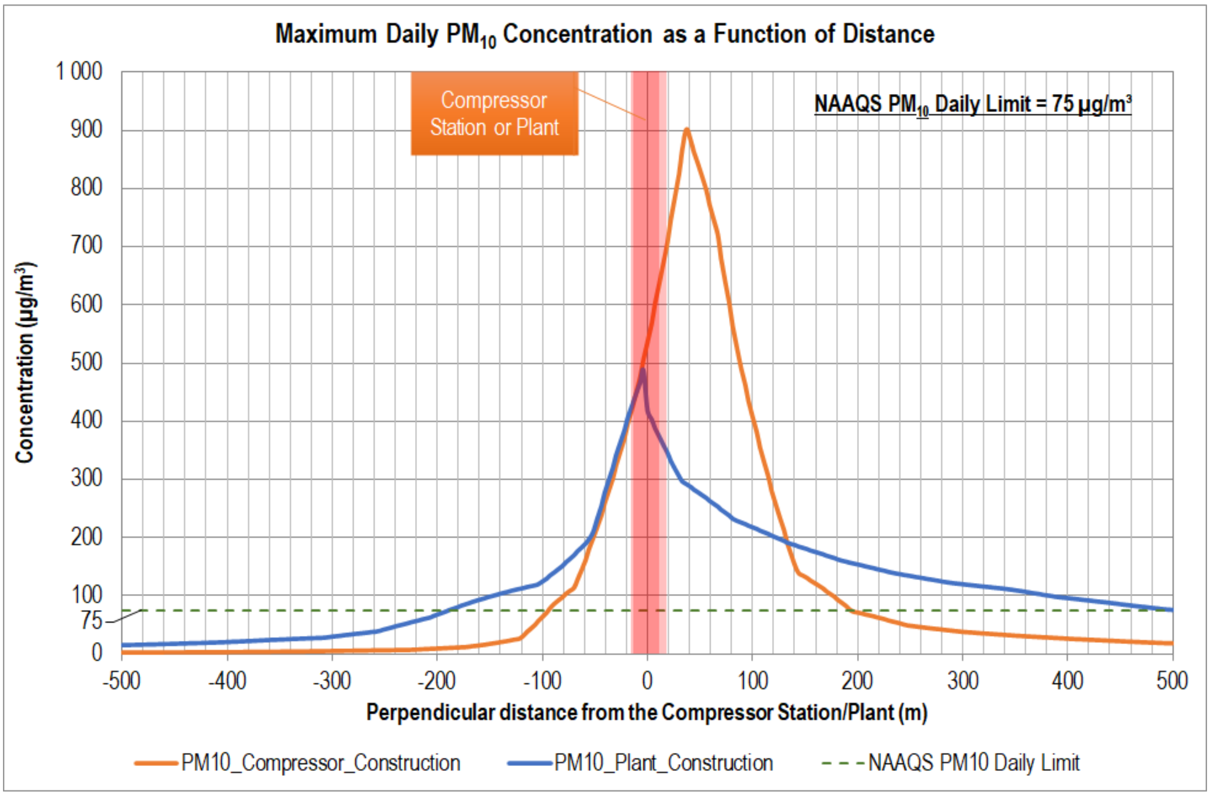

Figure 41: Simulated maximum daily PM_{10} GLCs due to compressor station/plant construction emissions (exceedances of NAAQS limit up to 200 m perpendicular distance from compressor station and 500 m from plant site were simulated)

[4] Three compressor stations are proposed: Compressor Station 1 (CS1), Compressor Station 2 (CS2) and Compressor Station 3 (CS3). There are two potential sites for CS3: the preferred site ~500 m south of CS2 and an alternative site ~4500 m south of CS2. Potential air quality impacts due to construction activities were assessed at CS1 location. The impact at CS1 will be representative of the impacts expected at CS2, CS3 and the other alternative location to CS3.

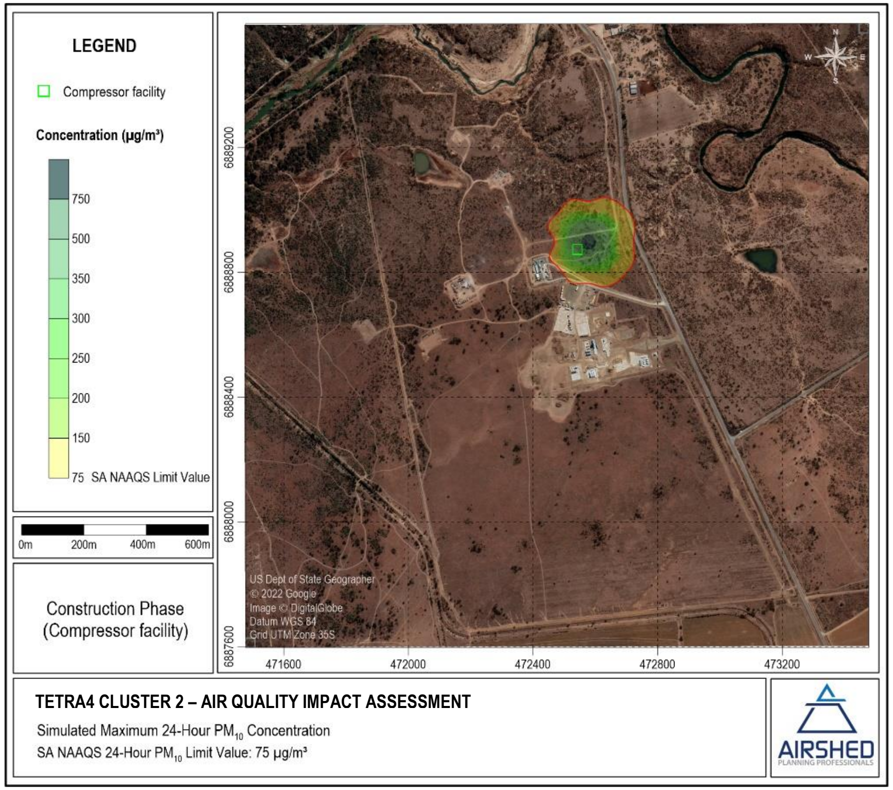

Figure 42: Simulated maximum 24-hour PM_{10} GLCs due to proposed compressor station construction emissions (single exceedance of the NAAQS limit up to 200 m beyond compressor station site indicated as red line)

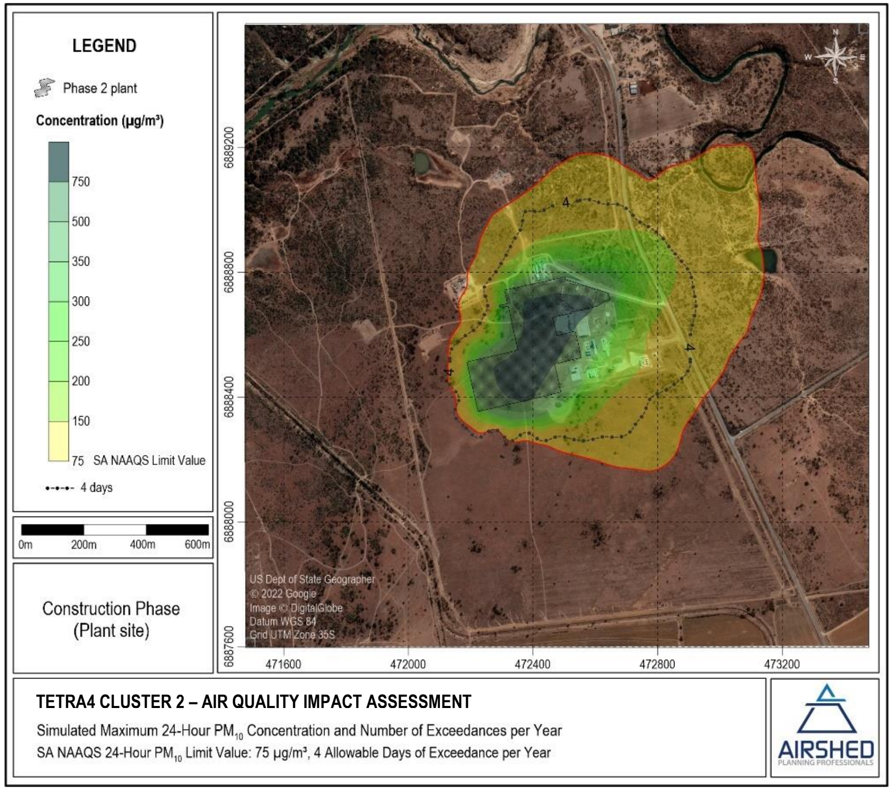

Figure 43: Simulated maximum 24-hour PM_{10} GLCs and frequency of exceedance due to proposed plant construction emissions (single exceedance of NAAQS limit and allowable frequency of exceedance up to 500 m and 270 m respectively beyond plant site)

4.3.1.3.2 $PM_{2.5}$ GLC's

Simulated maximum daily GLCs depicting worst-case $PM_{2.5}$ impacts during construction as a function of perpendicular distance from plant and compressor stations are shown in Figure 44. Isopleth contours representing maximum daily $PM_{2.5}$ GLCs due to construction of the compressor station and plant are shown in Figure 45 and Figure 46 respectively. From Figure 44 simulated $PM_{2.5}$ GLCs exceed the NAAQS daily limit up to 180 m beyond the plant boundary and up to 150 m beyond the compressor station. From Figure 46 the footprint of exceedance of more than the allowable 4 days per year extends 85 m beyond the plant boundary.

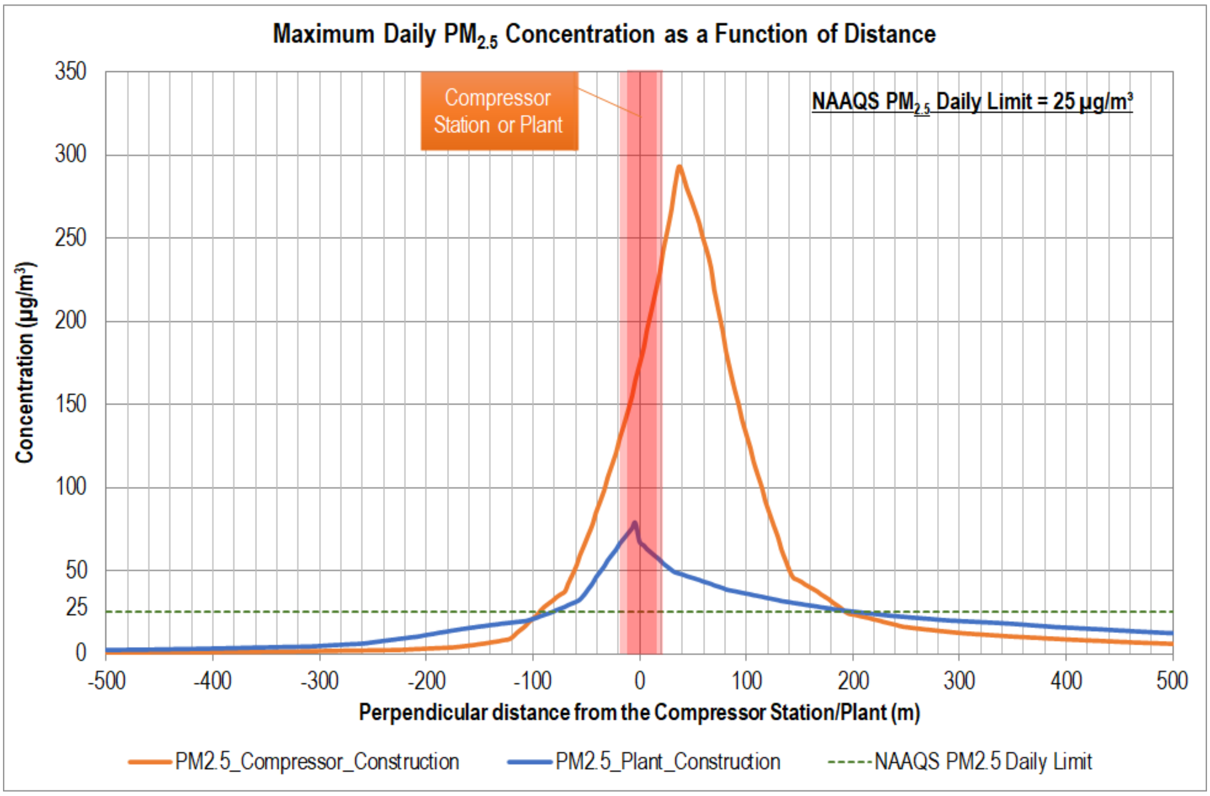

Figure 44: Simulated maximum daily $PM_{2.5}$ GLCs due to compressor station/plant construction emissions (exceedances of NAAQS limit up to 150 m perpendicular distance from compressor station and 180 m from plant site were simulated)

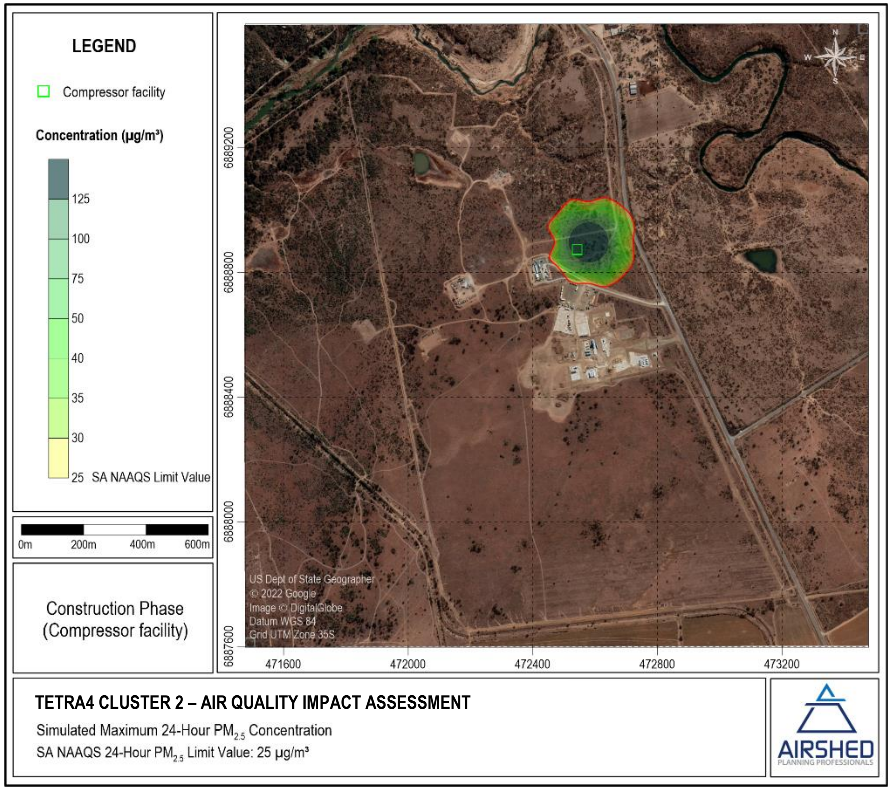

Figure 45: Simulated maximum 24-hour $PM_{2.5}$ GLCs due to proposed compressor station construction emissions (single exceedance of NAAQS limit up to 150 m beyond compressor station site indicated as red line)

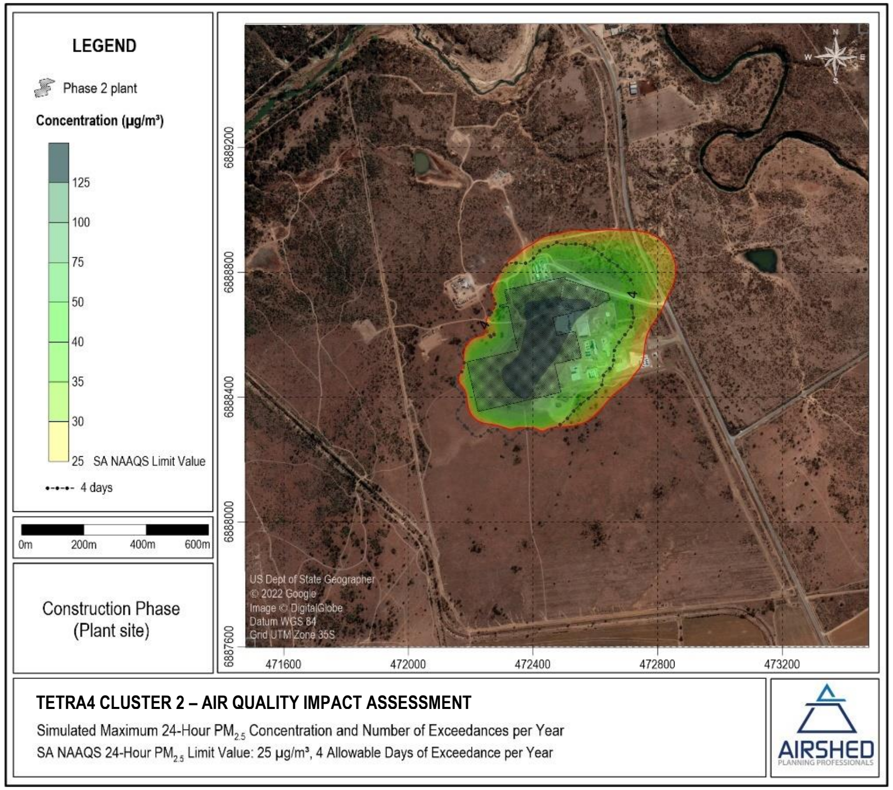

Figure 46: Simulated maximum 24-hour $PM_{2.5}$ GLCs due to proposed plant construction emissions (single exceedance of NAAQS limit and allowable frequency of exceedance up to 180 m and 85 m respectively beyond plant site)

4.3.1.3.3 NO_2 GLC's

Simulated maximum hourly GLCs depicting worst-case NO_2 impacts during construction as a function of perpendicular distance from plant and compressor stations are shown in Figure 47. Isopleth contours representing maximum hourly NO_2 GLCs and frequency of exceedance of the NAAQS hourly limit are shown in Figure 48 and Figure 49 for compressor and plant construction respectively. From Figure 47 and Figure 48 simulated NO_2 GLCs exceed the NAAQS hourly limit up to 500 m beyond the compressor station. From Figure 49 simulated maximum hourly NO_2 GLCs exceed the NAAQS hourly limit up to 700 m beyond the plant boundary. The footprint of exceedance on more than the allowable 88 hours per year extends 140 m beyond the compressor station (Figure 48) and 60 m beyond the plant boundary (Figure 49) respectively.

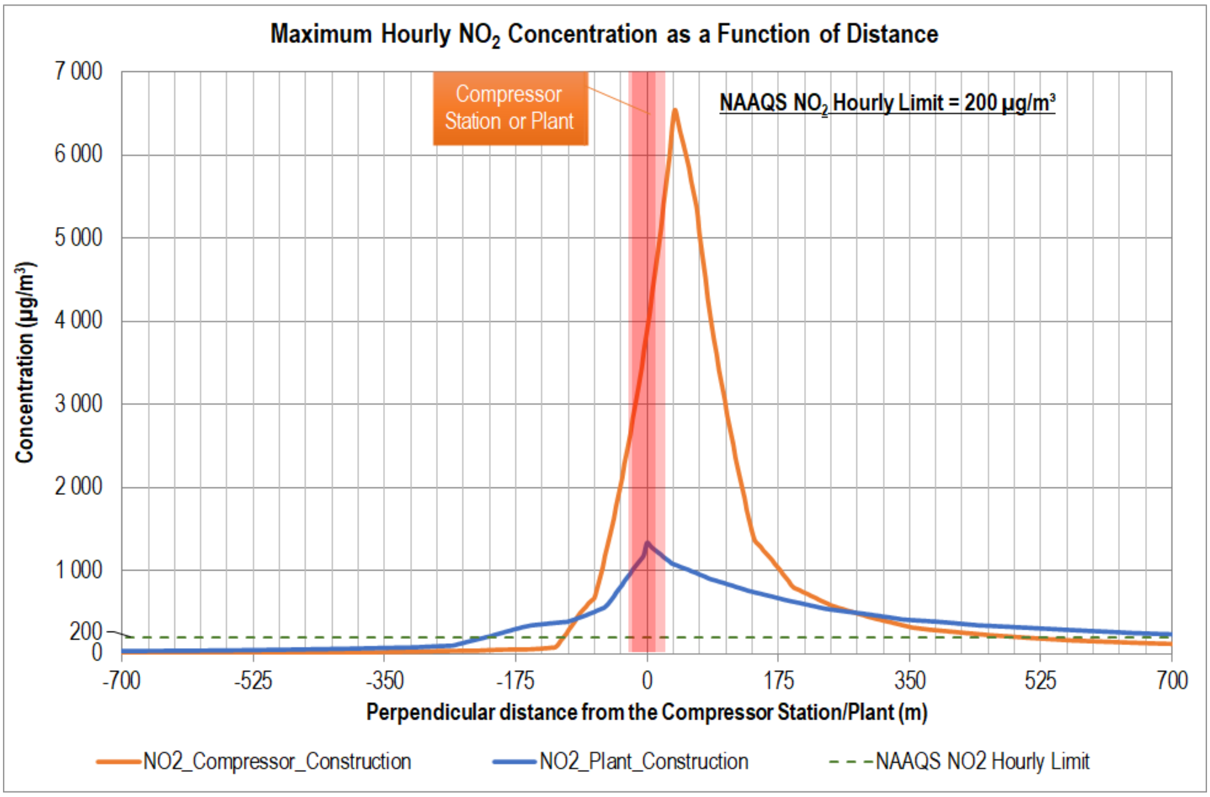

Figure 47: Simulated maximum hourly NO_2 GLCs due to compressor station/plant construction emissions (exceedances of NAAQS limit up to 500 m perpendicular distance from compressor station and 800 m from plant site were simulated)

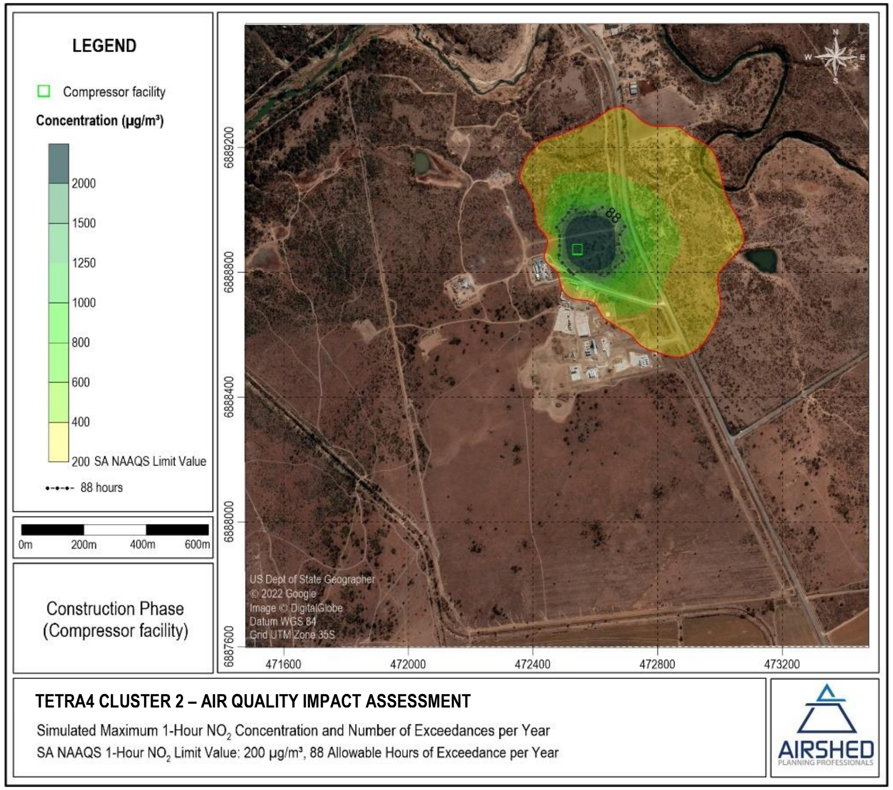

Figure 48: Simulated maximum 1-hour NO_2 GLCs due to proposed compressor station construction emissions (single exceedance of NAAQS limit and allowable frequency of exceedance up to 500 m and 140 m respectively beyond compressor site)

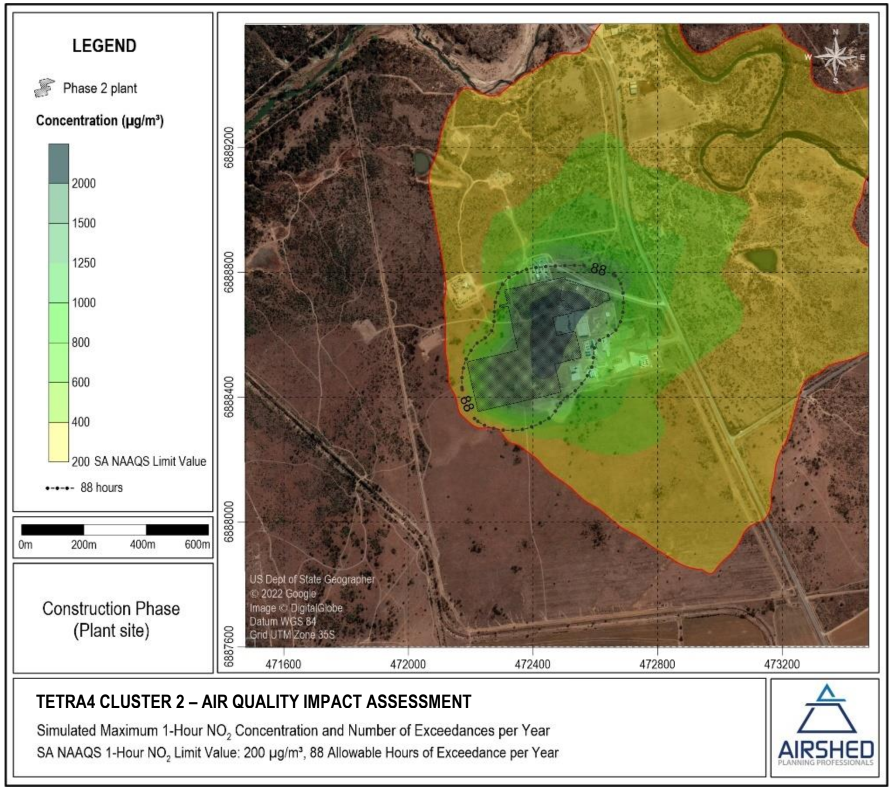

Figure 49: Simulated maximum 1-hour NO_2 GLCs due to proposed plant construction emissions (single exceedance of NAAQS limit and allowable frequency of exceedance up to 800 m and 60 m respectively beyond plant site)

4.3.1.3.4 SO_2 GLC's

Simulated hourly GLCs depicting worst-case SO_2 construction impacts as a function of perpendicular distance from the proposed compressor station and plant are shown in Figure 50. Figure 50 illustrates that simulated SO_2 GLCs are very low and are not expected to exceed the NAAQS hourly limit (350 µg/m³) during compressor station/plant construction.

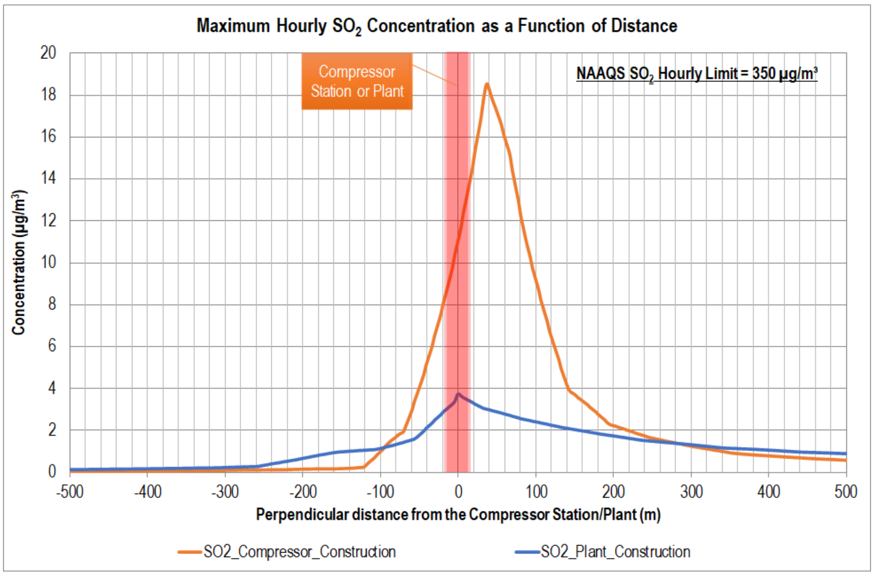

Figure 50: Simulated maximum hourly SO_2 GLCs due to compressor station/plant construction emissions (the NAAQS limit is not exceeded)

4.3.1.3.5 CO GLC's

Simulated hourly GLCs depicting worst-case CO construction impacts as a function of perpendicular distance from the proposed compressor station and plant are shown in Figure 51. Figure 51 illustrates that simulated CO GLCs are not expected to exceed the NAAQS hourly limit (30 000 µg/m³) during the construction of compressor stations or plant.

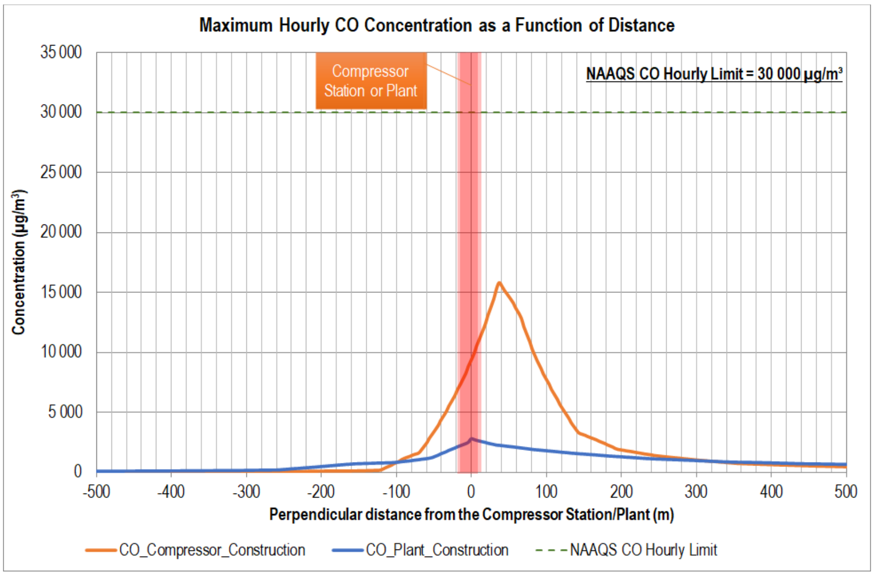

Figure 51: Simulated maximum hourly CO GLCs due to compressor station/plant construction emissions (the NAAQS limit is not exceeded)

4.3.1.3.6 VOC GLC's

Maximum simulated hourly VOC GLCs due to construction activities as a function of perpendicular distance from the compressor station and plant are illustrated in Figure 52. From Figure 52 and Figure 53 hourly VOC GLCs exceed the TCEQ Effects Screening Level (ESL) of 1 000 µg/m³ up to 130 m beyond the compressor station site. From Figure 54 the area of exceedance due to plant construction activities is confined to the plant site and no exceedances are expected beyond the plant boundary.

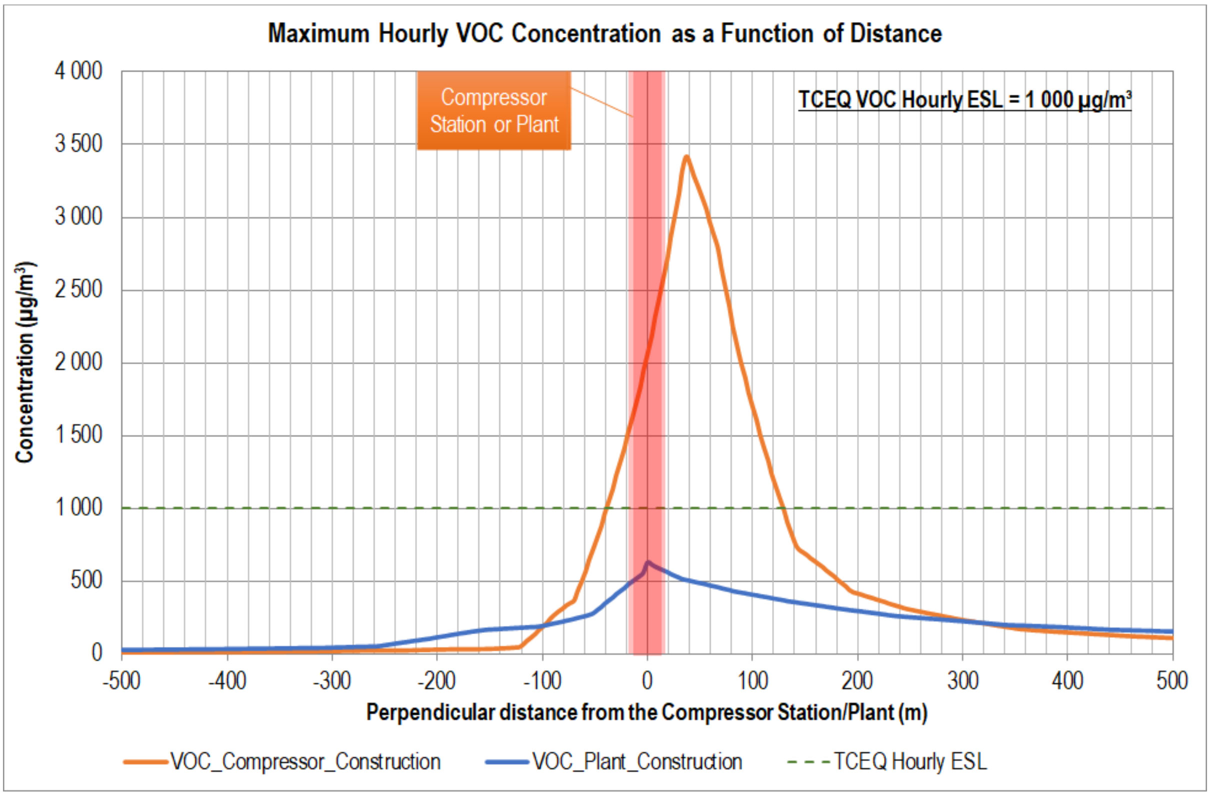

Figure 52: Simulated maximum hourly VOC GLCs due to compressor station/plant construction emissions (exceedance of TCEQ ESL up to 130 m perpendicular distance from compressor station was simulated; no exceedances of TCEQ ESL beyond plant boundary)

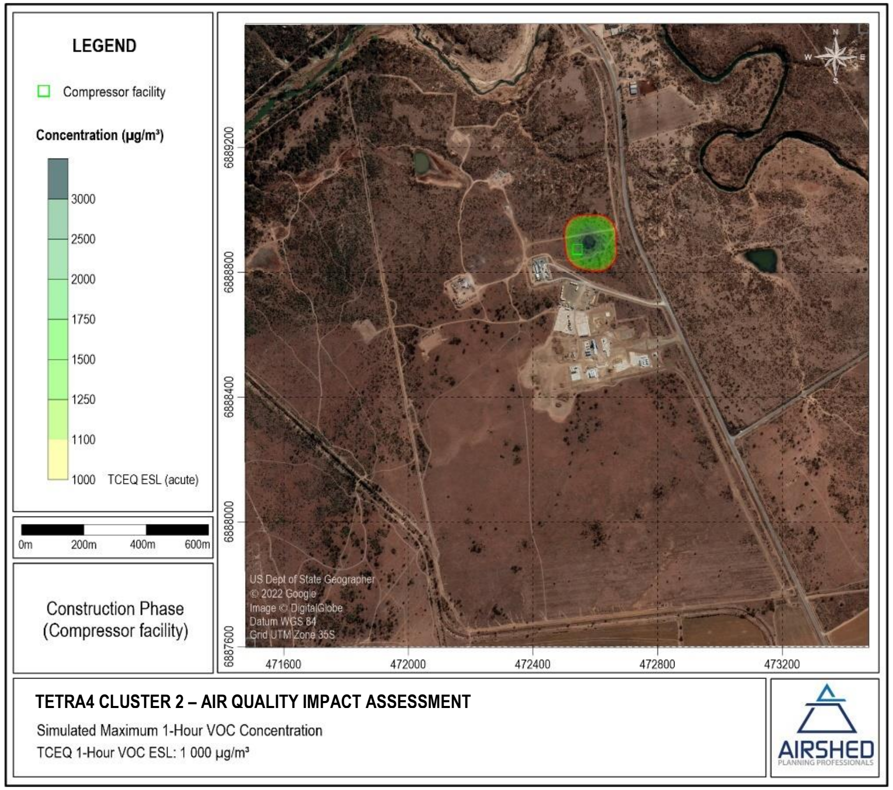

Figure 53: Simulated maximum 1-hour VOC GLCs due to proposed compressor station construction emissions (single exceedance of TCEQ ESL up to 130 m beyond compressor station site indicated as red line)

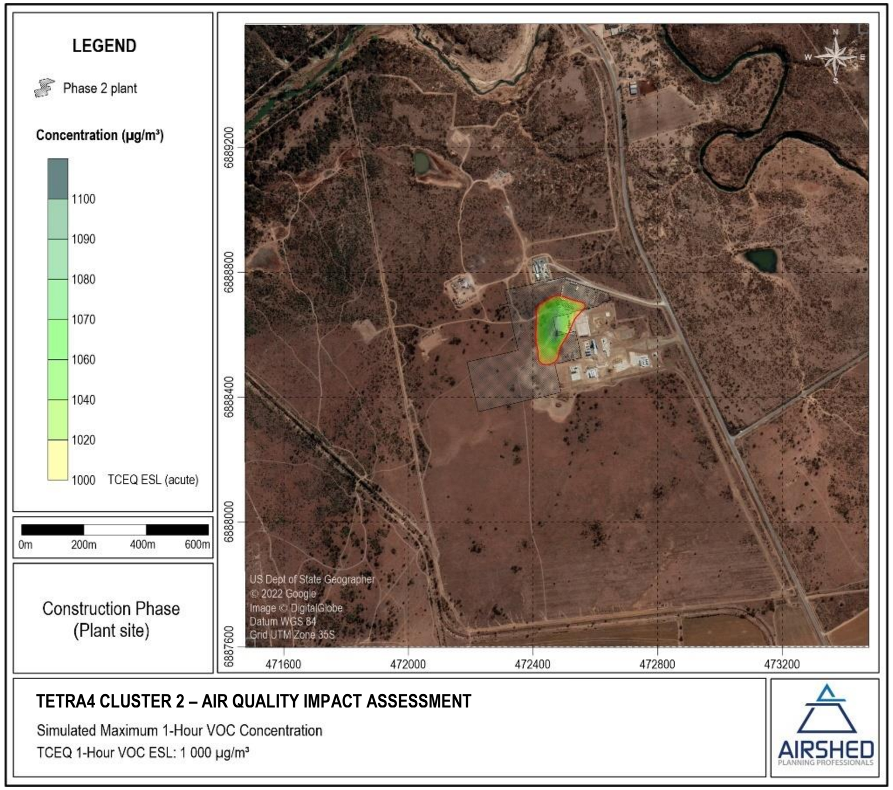

Figure 54: Simulated maximum 1-hour VOC GLCs due to proposed plant construction emissions (no exceedance of TCEQ ESL beyond plant boundary)

4.3.1.3.7 Dustfall Deposition Rates

Maximum simulated daily dustfall deposition rates as a result of compressor station and plant construction emissions are shown in Figure 55 as a function of perpendicular distance from each type of infrastructure. From Figure 55 simulated daily dustfall deposition rates exceed the NDCR residential limit of 600 mg/m²/day up to 60 m and 90 m beyond the compressor station and plant respectively (see Figure 56 and Figure 57).

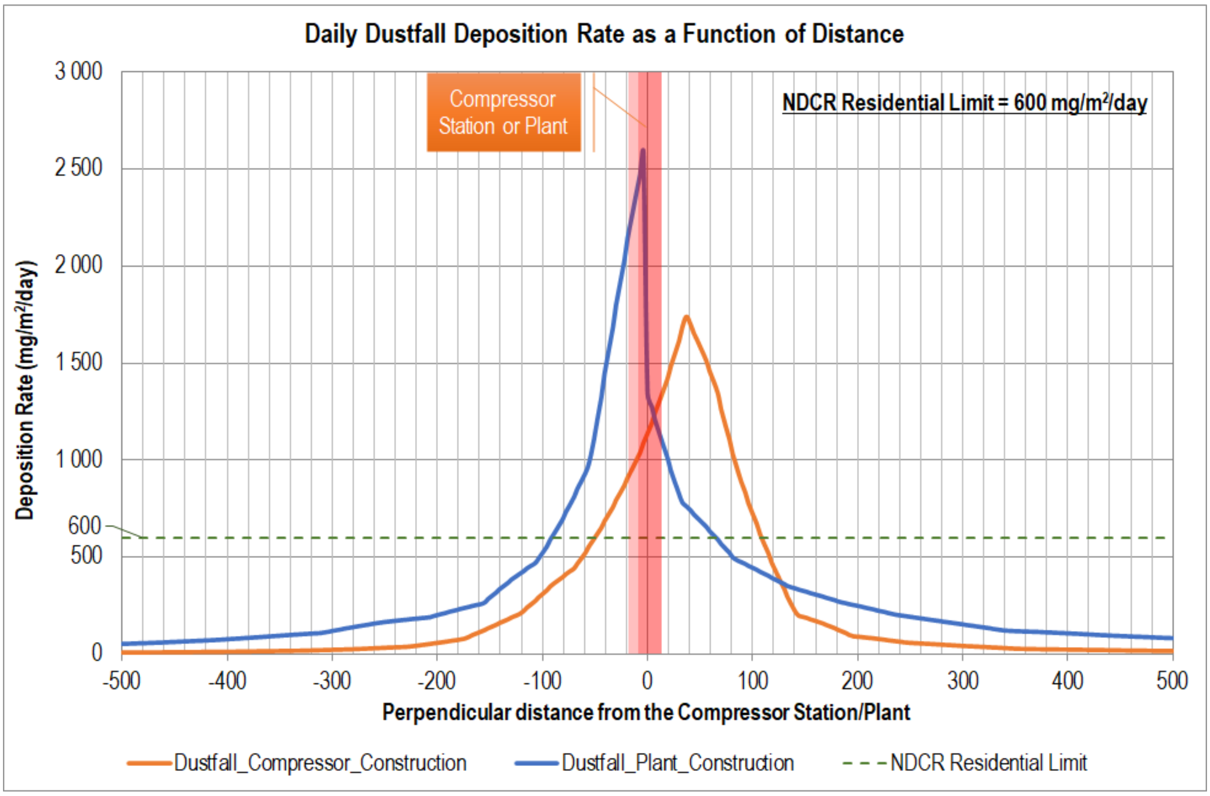

Figure 55: Simulated daily dustfall deposition rates due to compressor station/plant construction emissions (exceedances of the NDCR residential limit up to 60 m perpendicular distance from compressor station and 90 m from plant were simulated)

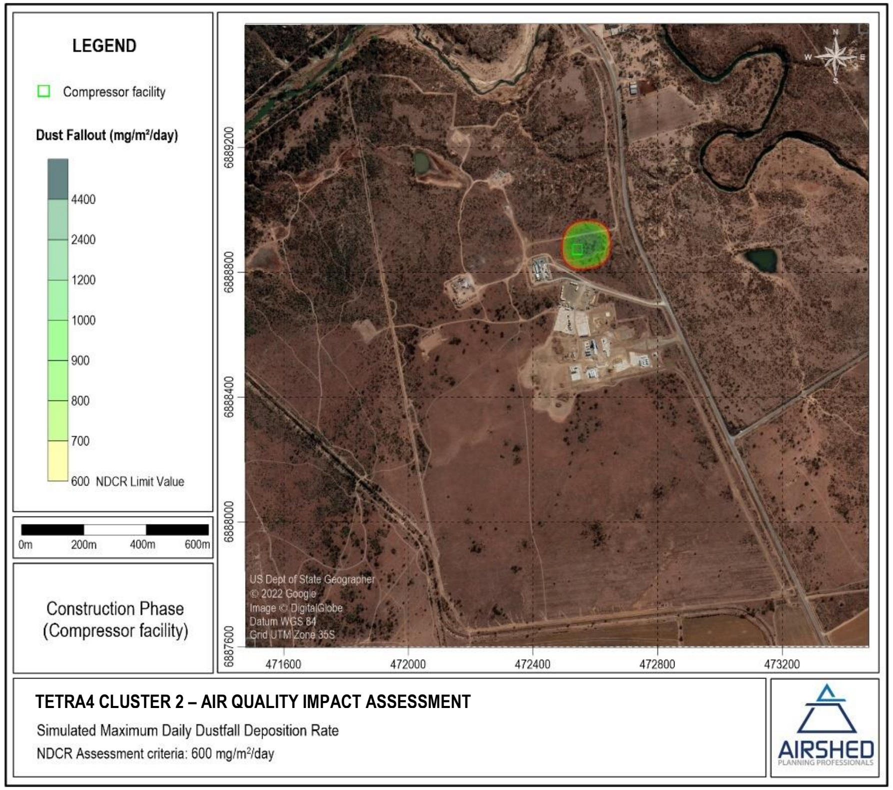

Figure 56: Simulated maximum daily dustfall deposition rates due to proposed compressor station construction emissions (single exceedance of the NDCR residential limit up to 60 m beyond compressor station indicated as red line)

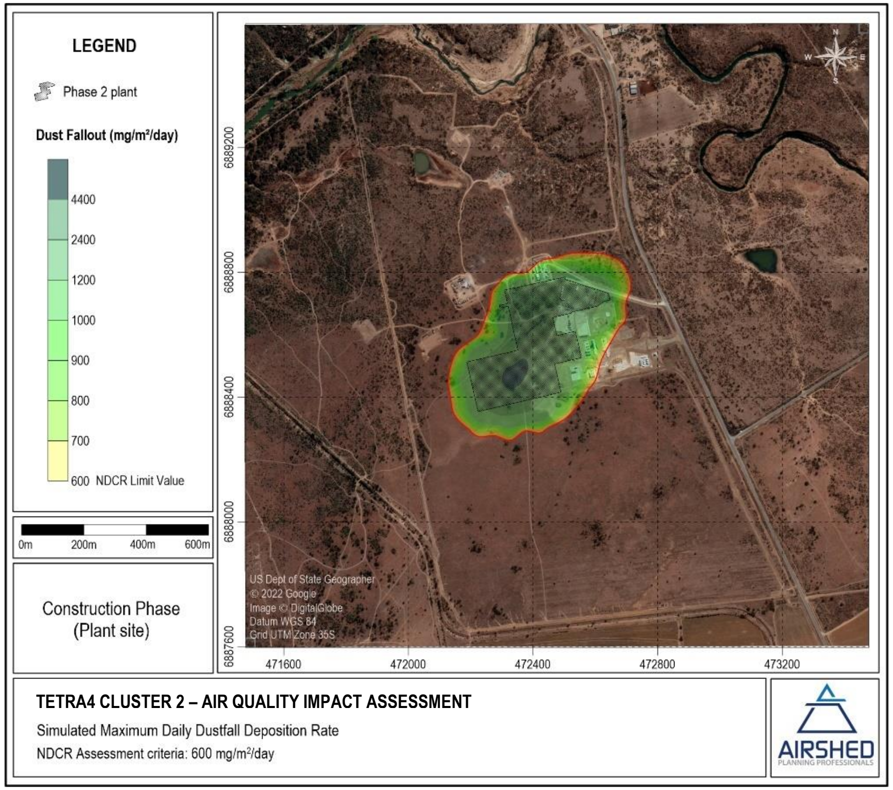

Figure 57: Simulated maximum daily dustfall deposition rates due to plant construction emissions (single exceedance of the NDCR residential limit up to 90 m beyond plant boundary indicated as red line)

4.3.2 Operational Phase Results

4.3.2.1 Routine or Normal operations

Sources of emission and associated pollutants for the operational phase and included in the dispersion model are:

- Combined LNG/LHe plant flaring emissions – CO, NO_X and VOCs
- Generator emissions at booster stations – $PM_{2.5}$, PM_{10}, CO, SO_2, NO_X and VOCs
- Entrained PM from unpaved roads – $PM_{2.5}$, PM_{10}, and TSP.

Isopleth plots are provided for all pollutants where exceedances of the relevant NAAQSs were simulated. Isopleth plots reflect the incremental GLCs and deposition rates over the 5 km by 5 km modelling domain for all pollutants assessed. The modelling domain was selected such that all sources of project emissions are contained in it, to give a good representation of air quality related impacts because of the proposed project on air quality sensitive receptors.

4.3.2.1.1 PM_{10} GLC's

Isopleth plots showing simulated maximum daily and annual average PM_{10} GLCs due to operational phase emissions are presented in Figure 58 and Figure 59 respectively. Maximum daily GLCs representing worst-case PM_{10} impacts at AQSRs during the operational phase are provided in Table 22. From Table 22 simulated PM_{10} concentrations were low and well below the NAAQS for both 24-hour averages and annual averages, at all AQSRs.

Table 22: Simulated PM_{10} GLCs at AQSRs due to operational phase emissions (all sources)

AQSR	Annual average (µg/m³)		24-hr (µg/m³)		Frequency of exceedance	
	GLCs	NAAQS Limit	GLCs	NAAQS Limit	Number of days	NAAQS Limit
1	0.03	40	0.35	75	0	4
2	0.04	40	0.31	75	0	4
3	0.04	40	0.42	75	0	4
4	0.06	40	0.48	75	0	4
5	0.05	40	0.28	75	0	4
6	0.03	40	0.32	75	0	4
7	2.77	40	5.85	75	0	4
8	0.08	40	0.48	75	0	4
9	0.54	40	4.07	75	0	4
10	0.11	40	0.82	75	0	4
Max (grid)	88.40	–	310.99	–	226	–

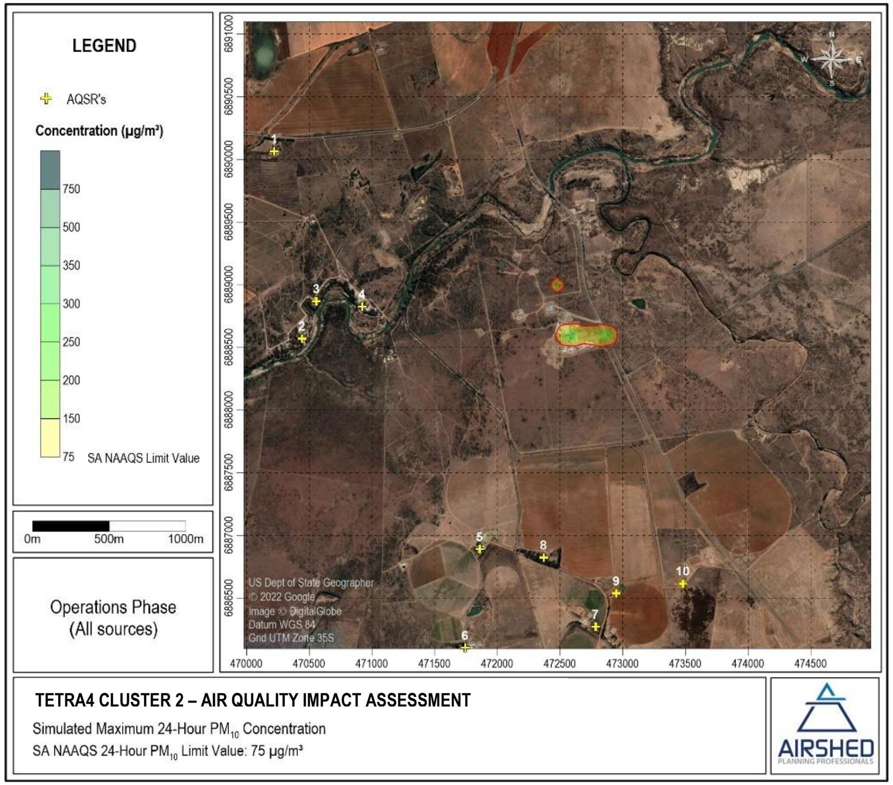

Figure 58: Simulated maximum 24-hour PM_{10} GLCs due to operational phase emissions (single exceedance of NAAQS limit up to 80 m beyond public road and 60 m beyond booster station, indicated as red line)

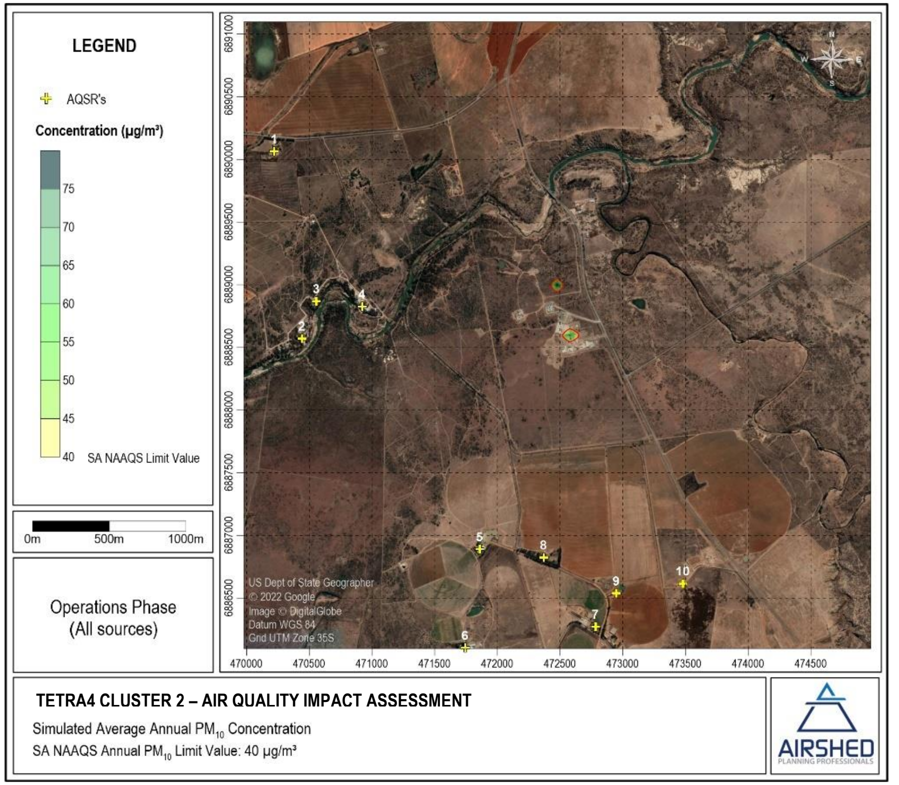

Figure 59: Simulated annual average PM_{10} GLCs due to operational phase emissions (single exceedance of NAAQS limit up to 55 m beyond booster station indicated as red line)

4.3.2.1.2 $PM_{2.5}$ GLC's

Isopleth plots showing simulated maximum daily and annual average $PM_{2.5}$ GLCs due to operational phase emissions are presented in Figure 60 and Figure 61 respectively. Maximum daily GLCs representing worst-case $PM_{2.5}$ impacts at AQSRs during the operational phase are provided in Table 23. From Table 23 simulated $PM_{2.5}$ concentrations were low and well below the NAAQS for both 24-hour averages and annual averages, at all AQSRs.

Table 23: Simulated $PM_{2.5}$ GLCs at AQSRs due to operational phase emissions

AQSR	Annual average (µg/m³)		24-hr (µg/m³)		Frequency of exceedance	
	GLCs	NAAQS Limit	GLCs	NAAQS Limit	Number of days	NAAQS Limit
1	0.01	15	0.08	25	0	4
2	0.01	15	0.05	25	0	4
3	0.01	15	0.06	25	0	4
4	0.02	15	0.09	25	0	4
5	0.02	15	0.07	25	0	4
6	0.02	15	0.08	25	0	4
7	2.70	15	5.72	25	0	4
8	0.05	15	0.42	25	0	4
9	0.52	15	3.99	25	0	4
10	0.10	15	0.81	25	0	4
Max (grid)	85.69	–	164.09	–	333	–

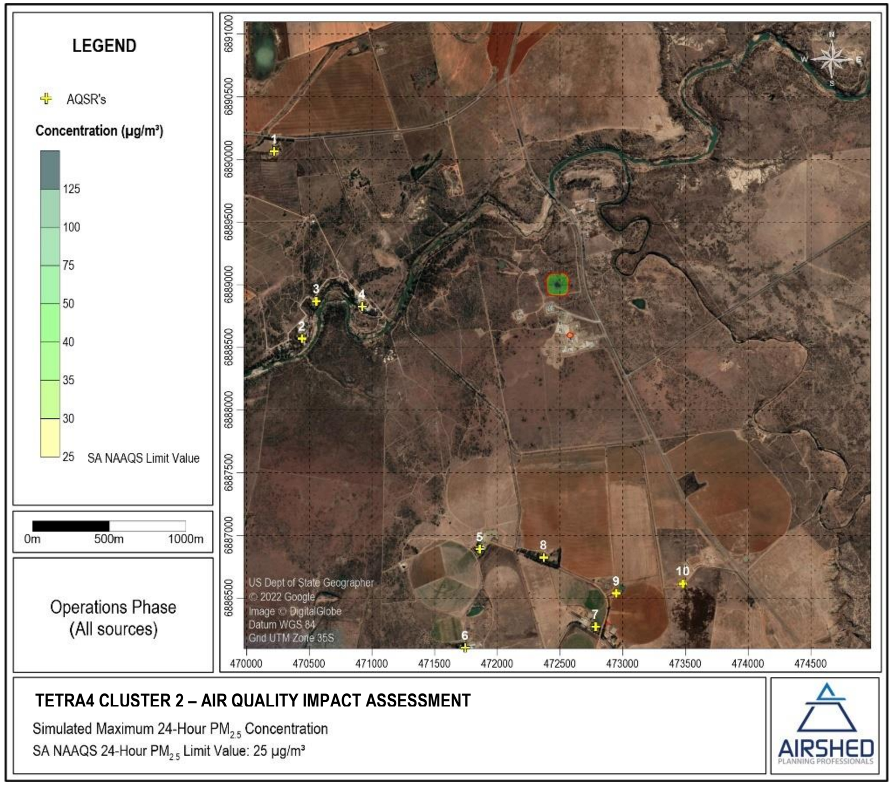

Figure 60: Simulated maximum 24-hour $PM_{2.5}$ GLCs due to operational phase emissions (single exceedance of NAAQS limit up to 100 m beyond booster station indicated as red line)

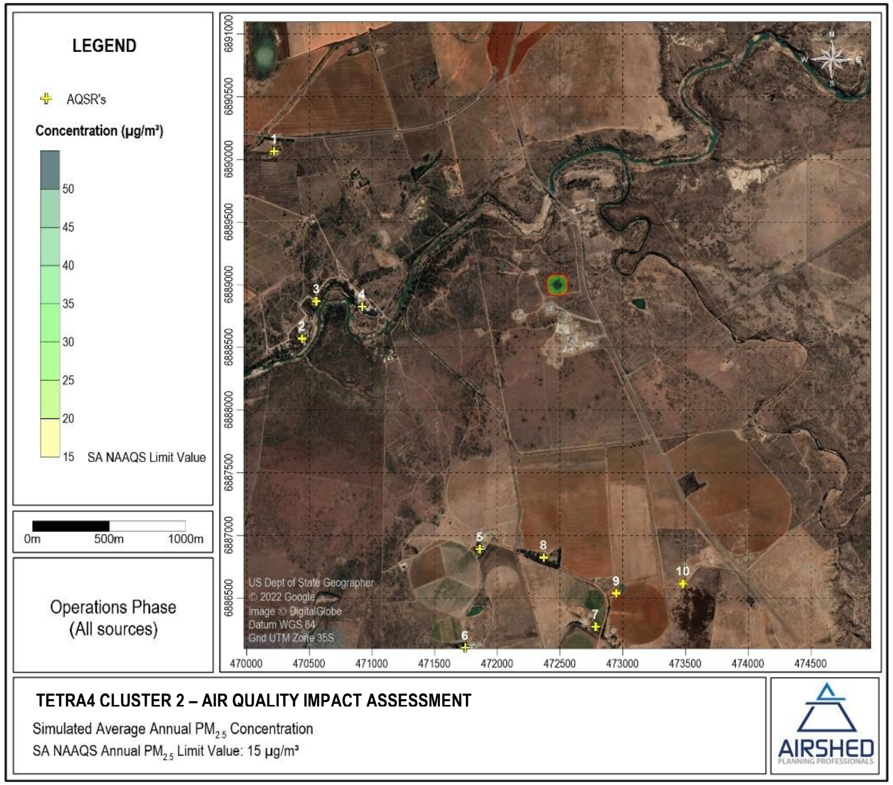

Figure 61: Simulated annual average $PM_{2.5}$ GLCs due to operational phase emissions (single exceedance of NAAQS limit up to 90 m beyond booster station indicated as red line)

4.3.2.1.3 NO_2 GLC's

Isopleth plots showing simulated maximum hourly and annual average NO_2 GLCs due to operational phase emissions are presented in Figure 62 and Figure 63 respectively. Maximum hourly GLCs representing worst-case NO_2 impacts at AQSRs during the operational phase are provided in Table 24. From Table 24 simulated NO_2 concentrations were well below the NAAQS for both 24-hour averages and annual averages, at all AQSRs. The highest hourly concentrations were simulated at AQSRs 7 and 9 due to their close proximity to the booster station (where a diesel generator is operated).

Table 24: Simulated NO_2 GLCs at AQSRs due to operational phase emissions

AQSR	Annual average (µg/m³)		1-hr (µg/m³)		Frequency of exceedance	
	GLCs	NAAQS Limit	GLCs	NAAQS Limit	Number of hours	NAAQS Limit
1	0.02	40	1.73	200	0	88
2	0.03	40	1.37	200	0	88
3	0.03	40	1.30	200	0	88
4	0.04	40	2.98	200	0	88
5	0.04	40	2.36	200	0	88
6	0.04	40	2.00	200	0	88
7	7.78	40	36.90	200	0	88
8	0.14	40	17.49	200	0	88
9	1.49	40	79.15	200	0	88
10	0.28	40	28.86	200	0	88
Max (grid)	247.19	–	724.86	–	4 449	–

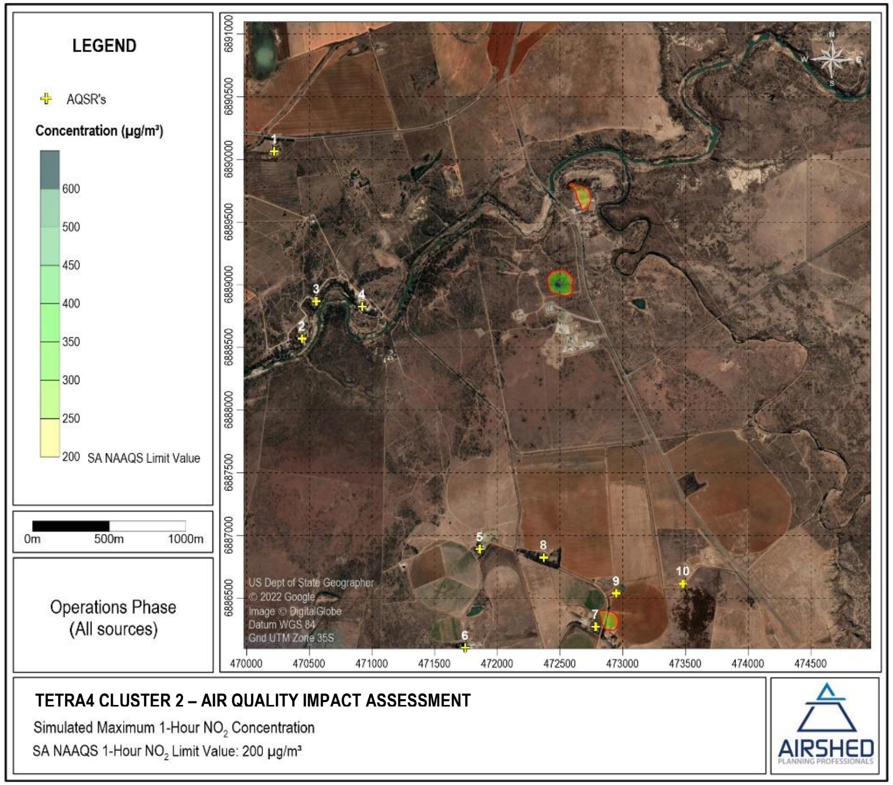

Figure 62: Simulated maximum 1-hour NO_2 GLCs due to operational phase emissions (single exceedance of NAAQS limit up to 100 m beyond booster station indicated as red line)

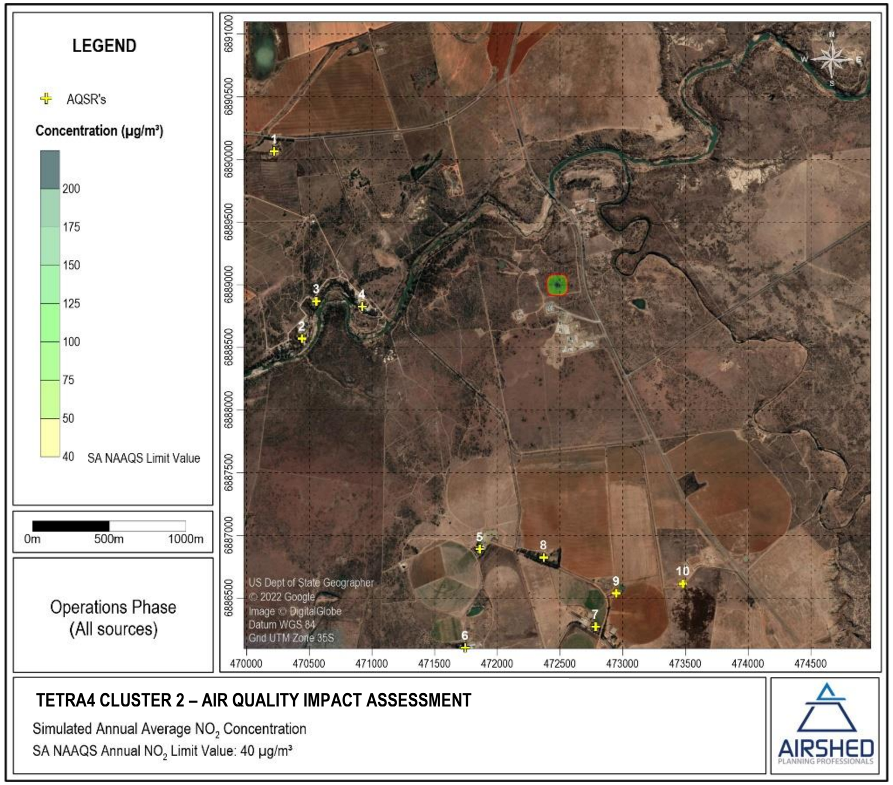

Figure 63: Simulated annual average NO_2 GLCs due to operational phase emissions (single exceedance of NAAQS limit up to 90 m beyond booster station indicated as red line)

4.3.2.1.4 SO_2 GLC's

Maximum hourly GLCs representing worst-case SO_2 impacts at AQSRs during the operational phase are provided in Table 25. The concentrations were well below the NAAQS for both 1-hour averages and annual averages, at all AQSRs.

Table 25: Simulated SO_2 GLCs at AQSRs due to operational phase emissions

AQSR	Annual average (µg/m³)		1-hr (µg/m³)		Frequency of exceedance	
	GLCs	NAAQS Limit	GLCs	NAAQS Limit	Number of hours	NAAQS Limit
1	0.000	50	0.002	350	0	88
2	0.000	50	0.001	350	0	88
3	0.000	50	0.001	350	0	88
4	0.000	50	0.003	350	0	88
5	0.000	50	0.002	350	0	88
6	0.000	50	0.002	350	0	88
7	0.009	50	0.042	350	0	88
8	0.000	50	0.020	350	0	88
9	0.002	50	0.089	350	0	88
10	0.000	50	0.033	350	0	88
Max (grid)	0.022	–	0.374	–	0	–

4.3.2.1.5 CO GLC's

Maximum hourly GLCs representing worst-case CO impacts at AQSRs during the operational phase are provided in Table 26. The concentrations were well below the NAAQS for 1-hour averages, at all AQSRs.

Table 26: Simulated CO GLCs at AQSRs due to operational phase emissions

AQSR	1-hr (µg/m³)		Frequency of exceedance	
	GLCs	NAAQS Limit	Number of hours	NAAQS Limit
1	1.86	30 000	0	88
2	1.48	30 000	0	88
3	1.39	30 000	0	88
4	3.20	30 000	0	88
5	2.54	30 000	0	88
6	2.16	30 000	0	88
7	39.66	30 000	0	88
8	18.80	30 000	0	88
9	85.07	30 000	0	88
10	31.02	30 000	0	88
Max (grid)	779.10	–	0	–

4.3.2.1.6 VOC GLC's

Maximum hourly GLCs representing worst-case VOC impacts at AQSRs during the operational phase are provided in Table 27. The concentrations were well below the TCEQ ESL for both 1-hour averages and annual averages, at all AQSRs.

Table 27: Simulated VOC GLCs at AQSRs due to operational phase emissions

AQSR	Annual (µg/m³)		1-hr (µg/m³)	
	GLCs	TCEQ ESL (chronic)	GLCs	TCEQ ESL (acute)
1	0.01	100	0.63	1 000
2	0.01	100	0.50	1 000
3	0.02	100	0.47	1 000
4	0.02	100	1.08	1 000
5	0.02	100	0.86	1 000
6	0.02	100	0.73	1 000
7	2.82	100	13.38	1 000
8	0.05	100	6.34	1 000
9	0.54	100	28.70	1 000
10	0.10	100	10.46	1 000
Max (grid)	89.63	–	262.83	–

4.3.2.1.7 Dustfall Deposition Rates

An isopleth plot showing simulated maximum 30-day average dustfall deposition rates due to operational phase emissions are presented in Figure 64. Maximum dustfall rates at AQSRs during the operational phase are provided in Table 28. From Table 28 the deposition rates were well below the NDCR residential limit at all AQSRs and higher dustfall rates were limited to the plant site (Figure 64).

Table 28: Simulated daily dustfall deposition rates at AQSRs due to operational phase emissions

AQSR	Maximum daily (mg/m²/day)	
	Deposition Rates	NDCR Residential Limit
1	5.45	600
2	4.56	600
3	5.67	600
4	7.88	600
5	4.91	600
6	2.94	600
7	19.71	600
8	3.89	600
9	2.72	600
10	1.85	600
Max (grid)	6 783.57	–

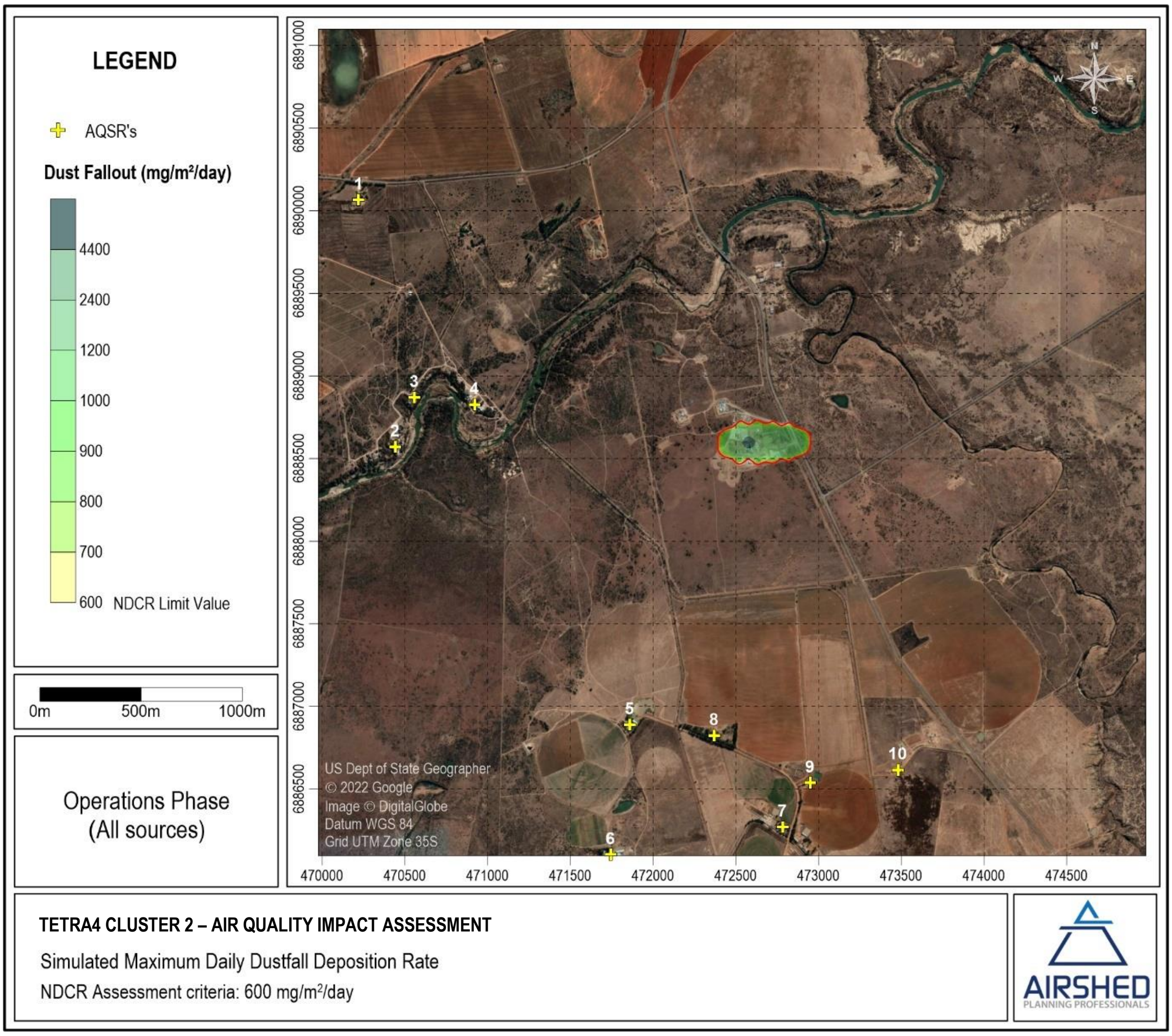

Figure 64: Simulated maximum daily dustfall deposition rates due to operational phase emissions (single exceedance of the NDCR residential limit up to 75 m beyond public road indicated as red line)

4.3.2.2 Emergency or Upset conditions

The impacts of flaring due to short-term emergency or upset conditions during operational phase were assessed based on description and assumptions published in Section 4.1.2.2. Maximum GLCs for each pollutant assessed are shown in Table 29 and are extremely low for flaring under routine conditions. Simulated NO_2 and CO GLCs due to upset conditions (warm or cold flares) fall below the respective NAAQS limits, but simulated VOC GLCs due to upset conditions exceed the TCEQ hourly screening criteria.

Table 29: Simulated maximum GLCs due to flaring during routine versus upset conditions

Pollutant	Routine Conditions (Flare)		Upset Conditions (Warm Flare)		Upset Conditions (Cold Flare)	
	GLCs (µg/m³)	NAAQS Limit	GLCs (µg/m³)	NAAQS Limit	GLCs (µg/m³)	NAAQS Limit
NO_2	0.06	200	119.33	200	33.91	200
CO	1.70	30 000	3 456.27	30 000	984.75	30 000
VOC	2.93	1 000[(a)]	5 947.12	1 000[(a)]	1 695.33	1 000[(a)]

Notes:

(a) TCEQ hourly ESL for VOCs

4.3.3 Proposed Setback Distances

Set back distances represent separations between a construction or project site and any adjacent residential areas or sensitive developments. The width of the setback distances is informed by the results from the dispersion modelling results presented in Sections 4.3.1 and 4.3.2. Since construction will only be for short durations, and operations are only likely to result in single exceedances of the NAAQSs, the setback distances are seen not as exclusion zones, but as management zones where the potential for air quality impacts can be mitigated and managed.

Table 30: Simulated setback distances (approximate)

Construction Phase							
Sources	**Setback distance (m)**						
	$PM_{2.5}$	**PM_{10}**	**TSP**	**VOC**	**NO_2**	**CO**	**SO_2**
Well construction site	290	180	–	170	750[(a)]	–	–
Booster station site	200	150	–	130	500[(a)]	–	–
Pipeline construction site	100	100	40	–	150[(a)]	–	–
Road construction site	80	95	50	–	150[(a)]	–	–
Compressor station construction site	150	200	60	130	140[(b)]	–	–
Plant construction site	85 [(c)]	270 [(c)]	90	–	60[(b)]	–	–
Operations Phase							
Sources	**Setback distance (m)**						
	$PM_{2.5}$	**PM_{10}**	**TSP**	**VOC**	**NO_2**	**CO**	**SO_2**
Booster station	100	60	–	–	100	–	–
Unpaved road	–	80	75	–	–	–	–
Plant[(d)]	–	–	–	–	–	–	–

Notes:

(a) This setback distance represents a single exceedance of the NO_2 hourly NAAQS limit of 200 µg/m³. The distance at which more than the allowable 88 hours of exceedance is expected to occur will be much smaller (see (b))

(b) This setback distance represents the distance at which the simulated frequency of exceedance is in non-compliance with the hourly NO_2 NAAQS.

(c) This setback distance represents the distance at which the simulated frequency of exceedance is in non-compliance with the daily PM_{10} and $PM_{2.5}$ NAAQS

(d) No PM impacts, assuming no smoking flares that give off soot

5 IMPACT SIGNIFICANCE RATING

The significance of environmental noise impacts was assessed according to the methodology adopted by EIMS (Appendix A).

5.1 Construction

The assumption is that construction activities would be during day-time hours only.

Given the nature of construction activities for the roads/pipeline, wells and booster stations (where the location may vary depending on the gas reserves in the area) the air quality impacts (due to dust and vehicle exhaust gas) at the nearest residential receptors to the construction areas may exceed the respective short-term NAAQS's for residential areas. If there are exceedances of the standards, however, it would be of short duration. The negative air quality impacts are therefore considered to be of **medium** significance without mitigation and **low** significance with mitigation at the nearest receptors due to construction activities for roads/pipeline sections (Table 31) and construction of wells/booster stations (Table 32).

Table 31: Significance rating for potential noise impacts due to the construction of the road/pipeline

Impact Name	Increase in air quality impacts due to construction of the road/pipeline				
Alternative	NA				
Phase	Construction				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	3	3
Extent of Impact	3	3	Reversibility of Impact	2	2
Duration of Impact	1	1	Probability	4	3
Environmental Risk (Pre-mitigation)					-9.00
Mitigation Measures					
As construction will only take place during day-time hours and will be of limited duration, AQSRs within 150 m of the road/pipeline construction site should be notified of the activities and potential disturbance durations prior to construction taking place. Additional mitigation measures are detailed in Section 5.					
Environmental Risk (Post-mitigation)					-6.75
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					2
Issue has received a meaningful and justifiable public response					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.13
Final Significance					-7.59

Table 32: Significance rating for potential noise impacts due to the construction of the wells and booster stations

Impact Name	**Increase in air quality impacts due to construction of the wells and booster stations**				
Alternative	NA				
Phase	Construction				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	4	3
Extent of Impact	3	3	Reversibility of Impact	2	2
Duration of Impact	1	1	Probability	4	3
Environmental Risk (Pre-mitigation)					-10.00
Mitigation Measures					
As construction will only take place during day-time hours and will be of limited duration, AQSRs within 300 m radius of all well construction sites and 200 m from booster station construction sites should be notified of the activities and potential disturbance durations prior to construction taking place. Additional mitigation measures are detailed in Section 5.					
Environmental Risk (Post-mitigation)					-6.75
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					2
Issue has received a meaningful and justifiable public response					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.13
Final Significance					-7.59

Unlike the roads/pipeline, wells or booster stations (where the location may vary depending on the gas reserves in the area) the locations of the three compressor stations and plant have been fixed. The construction period for the plant is also longer (i.e. more than 1 year). The air quality impacts (due to dust and vehicle tailpipe emissions) at the nearest residential receptors to the construction areas may exceed the respective short-term NAAQS's for residential areas. These exceedances, should they occur, would be of short duration as the construction activities will be intermittent in nature and not part of routine operations. The negative air quality impacts are therefore considered to be of **medium** significance without mitigation and **low** significance with mitigation at the nearest receptors (Table 33).

Table 33: Significance rating for potential noise impacts due to the construction of the plant and compressor stations (assuming the preferred location for CS3)

Impact Name	**Increase in air quality impacts due to construction of the plant and compressor stations**				
Alternative	Assuming preferred location for CS3				
Phase	Construction				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	3	3
Extent of Impact	3	3	Reversibility of Impact	2	2
Duration of Impact	2	2	Probability	4	3
Environmental Risk (Pre-mitigation)					-11.00
Mitigation Measures					
Mitigation measures are detailed in Section 5.					
Environmental Risk (Post-mitigation)					-7.50
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					2
Issue has received a meaningful and justifiable public response					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.13
Final Significance					-8.44

Table 34: Significance rating for potential noise impacts due to the construction of the plant and compressor stations (assuming the alternative location for CS3)

Impact Name	Increase in air quality impacts due to construction of the plant and compressor stations				
Alternative	Assuming the alternative location for CS3				
Phase	Construction				
Environmental Risk					
Attribute	Pre-mitigation	Post-mitigation	Attribute	Pre-mitigation	Post-mitigation
Nature of Impact	-1	-1	Magnitude of Impact	3	3
Extent of Impact	3	3	Reversibility of Impact	2	2
Duration of Impact	2	2	Probability	4	3
Environmental Risk (Pre-mitigation)					-11.00
Mitigation Measures					
Mitigation measures are detailed in Section 5.					
Environmental Risk (Post-mitigation)					-7.50
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					2
Issue has received a meaningful and justifiable public response					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.13
Final Significance					-8.44

5.2 Operation

The operational activities would take place during day- and night-time conditions.

Given the location of the plant and the compressor stations and their potential air quality impacts, it is unlikely that the respective NAAQS's and NDCR limits for residential areas will be exceeded at AQSRs due to plant or compressor operations.

The operation of vehicles on unpaved roads, and specifically the plant access road, even under mitigated conditions, could result in single exceedances of the respective NAAQS's and NDCR limits for residential areas at AQSRs. The negative air quality impacts are therefore considered to be of **medium** significance at the nearest receptors but will reduce to **low** significance should the roads be paved (Table 35).

The air quality impacts due to booster station (generator) operations are likely to exceed the long-term NAAQS's for residential areas up to 90 m from the operations. Care should be taken to site the booster stations at least 100 m from all AQSRs. With careful siting, NAAQSs for residential areas should not be exceeded at AQSRs. The negative air quality impacts are therefore considered to be of **medium** significance (given the possible impact zone of 90 m) but will reduce to **low** significance at the nearest receptors with mitigation measures in place (Table 36).

The air quality impacts due to plant (flaring) operations are not likely to exceed the long-term NAAQS's. The negative air quality impacts are therefore considered to be of **low** significance at the nearest receptors (Table 37).

Table 35: Significance rating for potential air quality impacts due to the operation of vehicles on unpaved roads

Impact Name	Increase in air quality impacts due to the operation of vehicles on unpaved roads				
Alternative	NA				
Phase	Operations				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	3	2
Extent of Impact	3	2	Reversibility of Impact	2	2
Duration of Impact	4	4	Probability	4	3
Environmental Risk (Pre-mitigation)					-12.00
Mitigation Measures					
Ground level concentrations and dust fallout due to vehicle operations on unpaved roads are likely to exceed the PM_{10} NAAQS limit and NDCR limit for residential areas up to 80 m from the operations. Care should be taken to apply mitigation measures to unpaved roads located near AQSRs. Mitigation measures are detailed in Section 5.					
Environmental Risk (Post-mitigation)					-7.50
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					2
Issue has received a meaningful and justifiable public response					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.13
Final Significance					-8.44

Table 36: Significance rating for potential air quality impacts due to the operation of the booster stations

Impact Name	**Increase in air quality impacts due to operation of the booster stations**				
Alternative	NA				
Phase	Operations				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	3	2
Extent of Impact	3	3	Reversibility of Impact	2	2
Duration of Impact	4	4	Probability	4	3
Environmental Risk (Pre-mitigation)					-12.00
Mitigation Measures					
Air quality impacts due to booster station operations are likely to exceed the $PM_{2.5}$ and NO_2 NAAQS for residential areas up to 100 m from the operations. Care should be taken to site the booster stations at least 100 m from all AQSRs. Mitigation measures are detailed in Section 5.					
Environmental Risk (Post-mitigation)					-8.25
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					2
Issue has received a meaningful and justifiable public response					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.00
Final Significance					-8.25

Table 37: Significance rating for potential air quality impacts due to the operation of the plant

Impact Name	Increase in air quality impacts due to operation of the plant				
Alternative	NA				
Phase	Operations				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	2	2
Extent of Impact	2	2	Reversibility of Impact	2	2
Duration of Impact	4	4	Probability	3	3
Environmental Risk (Pre-mitigation)					-7.50
Mitigation Measures					
Air quality impacts due to routine plant operations are not likely to exceed the limits for criteria pollutants, dustfall or VOCs. Mitigation measures are detailed in Section 5.					
Environmental Risk (Post-mitigation)					-7.50
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					2
Issue has received a meaningful and justifiable public response					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.00
Final Significance					-7.50

5.3 Decommissioning and Closure

The assumption is that decommissioning would be during day-time hours only. Given the nature of decommissioning activities, and the extent of the process, NAAQS limits for residential areas may be exceeded sporadically at AQSRs. Mitigation measures, however, can be implemented to reduce emissions due to fugitive dust. The negative air quality impacts are therefore considered to be of **medium** significance without mitigation and **low** significance with mitigation at the nearest receptors (Table 38).

Table 38: Significance rating for potential noise impacts due to the decommissioning and closure phase of the project

Impact Name	Increase in air quality impacts due to decommissioning and closure				
Alternative	NA				
Phase	Decommissioning				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	4	3
Extent of Impact	3	3	Reversibility of Impact	2	2
Duration of Impact	2	2	Probability	4	3
Environmental Risk (Pre-mitigation)					-11.00
Mitigation Measures					
Mitigation measures are detailed in Section 6.					
Environmental Risk (Post-mitigation)					-7.50
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					1
Low: Issue not raised in public responses					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.00
Final Significance					-7.50

6 Recommended Air Quality Management Measures

In the quantification of air emissions and simulation of impacts as a result of the project, it was found that environmental air quality evaluation criteria for residential, educational, and institutional receptors will be met at all off-site air quality sensitive receptors.

The measures discussed in this section are measures typically applicable to industrial sites and are considered good practice. It should be noted that not all mitigation measures are to be implemented, but should the need arise the mitigation measures as discussed in this section can be considered.

The mitigation measured discussed also takes into account the existing management measures utilised for the existing Cluster 1 Environmental Management Programme (EIMS, 2019). The approach adopted for this section is as follows:

- If the current mitigation measures for a particular impact are considered adequate, reference will be made to the existing mitigation measures (using the mitigation reference numbers provided in the 2019 Environmental Management Programme (EMPr));
- If the current mitigation measures are inadequate, amendments will be provided; and,
- If additional mitigation measures are required, these will be highlighted as additional to the existing approved EMPr.

6.1 Proposed Mitigation Measures and Target Control Efficiencies

The following air quality measures are recommended during construction, operational, decommissioning and rehabilitation and closure phases of the Project:

- The existing EMPr (nr 39) states that in controlling vehicle entrained PM during construction, it is recommended that water (at an application rate of 2 litre/m^2-hour), be applied on all unpaved road sections to ensure a minimum of 50% control efficiency (CE), and that binding agents or chemical suppressants (such as "Dust-A-Side" or "Dustex") should be considered for application on all unpaved road sections (emissions reduction efficiency of more than 80%). This should be amended to also be applicable during the operational phase.
- Additionally, for construction/operation, it is recommended to pave the access road between the plant and the R30 provincial road. This would result in a control efficiency of between 87% and 92% (US EPA, 2006).
- For topsoil management during construction and rehabilitation, the existing EMPr (nr 35) should be amended to include the recommendation that exposed areas must be ensured to remain moist through water spraying during dry, windy periods (CE 50%).
- During all phases, material transfers are to be controlled through the use of water sprays resulting in 50% control efficiency.
- The following good practice should be followed during all phases of the project: In order to ensure lower exhaust emissions from vehicles and machinery, equipment suppliers or contractors should be required to ensure compliance with appropriate emission standards for production fleets. Also, maintenance and repair of diesel engines should be carried out as prescribed by manufacturer in order to maximize combustion and reduce gaseous emissions.
- Fuel efficient driving practices on site, during all phases of the Project, may also help lower exhaust emissions from vehicles and machinery, such as stipulating a maximum speed on all unpaved roads. In addition, other fuel-efficient practices that may lower exhaust emissions include limiting idling of machinery, driving in an upper gear rather than a lower gear as much as possible, ensuring tire pressure are always adequate etc.
- Products, liquid fuels, and chemicals should be stored in areas where there are provisions for containment of spills.

- The project proponent has indicated that all infrastructure and facilities will be designed, installed and maintained according to best industry practices to control fugitive and unintended methane emissions as prescribed in (US EPA, 2015). In addition, the following actions are recommended:
    - If applicable, the implementation of a leak detection and repair (LDAR) program, which include identifying equipment, leak definition, monitoring equipment, repairing equipment, and recordkeeping; and
    - Regular check (monthly or quarterly) and reporting of exploration well, booster and compressor facility installations, as well as pipelines portions close to ground surface or those that have potential to be vandalized.

In addition, the following are suggestions for consideration in the design of the combined Helium and LNG plant:

- If applicable, the use of low–NOx burners in combustion systems should be considered for operation of the combined LNG/LHe plant; and
- The implementation of vapour recovery systems, for storage tanks and/or other applicable units, to control losses of VOCs and achieve over 90% recovery, should be considered.

6.2 Air Quality Monitoring

The existing EMPr subsection 11.4 on Air Quality Monitoring contains references to emissions monitoring (11.4.1) and ambient air quality monitoring (11.4.2). The air quality monitoring programme for Tetra4 is specified in Table 11.

The air quality monitoring programme reference to monthly dustfall sampling during construction (Table 11) can be amended to say that "monthly dustfall sampling should be conducted at the four main wind directions (north; east; south and west) during the construction of the plant to assess cumulative deposition rates".

6.3 Impact Zones

The impact zones in the existing EMPr can be amended to include distances for air quality impacts, due to various activities, as indicated in Table 39. These are conservative buffer zones in consideration of cumulative air quality impacts in the Project region. Therefore, these are seen as management zones where the potential for air quality impacts can be mitigated and managed.

Table 39: Recommended setback distances

Project phase		Setback distance (m)	Indicator Pollutant	Description
Construction	Well construction site	750	NO_2	Setback distance represents a single exceedance of the NO_2 hourly NAAQS limit, where the distance will be significantly less based on the allowable frequency of exceedance.
	Booster station site	500		
	Pipeline construction site	150		
	Road construction site	150		
	Compressor station construction site	200	PM_{10}	
	Plant construction site	270		Based on exceedance of NAAQ daily limit.
Operational	Booster station	100	PM_{10} and NO_2	Setback distance represents a single exceedance of the NO_2 hourly NAAQS limit and of the daily PM_{10} NAAQS limit, where the distance will be less based on the allowable frequency of exceedance.
	Unpaved road	80	PM_{10}	
	Plant	none	none	The flare is an intermittent source with no exceedances

7 CONCLUSIONS AND RECOMMENDATIONS

A quantitative air quality impact assessment was conducted for the planning and design, construction, operation, decommissioning, rehabilitation and closure phase activities of the Tetra4 Cluster 2 Project. The assessment included an estimation of atmospheric emissions, the simulation of pollutant levels and determination of the significance of impacts. This section summarises the main findings of the impact assessment.

The conclusions and recommendations of the assessment are summarised below:

- The receiving environment:
  - The area is dominated by winds from the north-northeast and northeast, followed by northerly and easterly winds with an average wind speed of 3.7 m/s.
  - Ambient air pollutant levels in the project area are currently affected by the following sources of emission: agricultural activities, gold mining and ore processing, fugitive and process emissions, vehicle tailpipe emissions, household fuel combustion, biomass burning and windblown dust from exposed areas.
  - AQSRs such as residences and farm holdings are located within and beyond the project boundary. Nearby towns include Welkom, Virginia, Bronville, Harmony and Theunissen.

- Impact of the Project:
  - Planning, design and construction phase impacts:
    - Construction activities for the roads/pipeline, wells and booster stations (where the location may vary depending on the gas reserves in the area) vehicle and equipment (vehicle entrainment and vehicle exhaust gas), three compressor stations and the plant might include land clearing, topsoil removal, material loading, bulk services construction, hauling, excavation, back-filling, road construction (where necessary) and traffic, rig-move/drilling, pipeline installation, and wind erosion of exposed areas.
    - Resulting potential air quality health and nuisance impacts at the nearest residential receptors resulted in a **medium** significance without mitigation and **low** significance with mitigation. Worst-case simulated construction impacts are not anticipated to occur over long intervals since construction activities will only last a few weeks and peak activities will not be consistent over the specified period.

  - Operational phase impacts:
    - Potential air quality impacts, including health and nuisance impacts, as a result of operational phase activities such as operation of the well pad, roads, pipelines, compression station, booster station and combined LNG/LHe plant, as well as associated emissions from movement of trucks and other vehicles, flaring (if applicable), and gas processing as well as operation of heavy machinery.
    - Vehicles on unpaved roads, and specifically the plant access road, even under mitigated conditions are likely to result in **medium** significance at the nearest receptors but will reduce to **low** significance should the road be paved.
    - Air quality impacts due to booster station (generator) operations of **medium** significance but **low** significance at the nearest receptors with mitigation measures in place.
    - Plant (flaring) operations are unlikely to result in exceedances of the respective NAAQS's and are therefore considered to be of **low** significance at the nearest receptors.

- Decommissioning, rehabilitation and closure phase impacts:
    - Potential air quality impacts, including health impacts as a result of decommissioning, rehabilitation and closure phase activities such as decommissioning/ removal of all berms, trenches and other storm water infrastructure, stationary infrastructure, pipeline infrastructure, and wastes.
    - The environmental risk was assigned a score of **low** significance due to localised impacts of the various emissions, their temporary nature, and the likelihood that these activities will not occur concurrently at all portions of the site.

In conclusion, it is the specialist opinion that the project may be authorised provided that the recommended air quality management measures are implemented. These air quality management measures include:

- Source emissions monitoring and reporting;
- Ambient air quality monitoring;
- Mitigation measures aimed at reducing emissions at source;
- Paving of the unpaved road from plant to provincial R30 road; and
- The delineation of management zones around production wells, pipeline routes, compressor and booster stations and the plant site. As a conservative approached the following setback distances are recommended, where these are seen as management zones where the potential for air quality impacts can be mitigated and managed:

<table>
<tr><th colspan="2">Project phase</th><th>Setback distance (m)</th><th>Indicator Pollutant</th><th>Description</th></tr>
<tr><td rowspan="6">Construction</td><td>Well construction site</td><td>750</td><td rowspan="4">NO_2</td><td rowspan="4">Setback distance represents a single exceedance of the NO_2 hourly NAAQS limit, where the distance will be significantly less based on the allowable frequency of exceedance.</td></tr>
<tr><td>Booster station site</td><td>500</td></tr>
<tr><td>Pipeline construction site</td><td>150</td></tr>
<tr><td>Road construction site</td><td>150</td></tr>
<tr><td>Compressor station construction site</td><td>200</td><td rowspan="2">PM_{10}</td><td></td></tr>
<tr><td>Plant construction site</td><td>270</td><td>Based on exceedance of NAAQ daily limit.</td></tr>
<tr><td rowspan="3">Operational</td><td>Booster station</td><td>100</td><td>PM_{10} and NO_2</td><td rowspan="2">Setback distance represents a single exceedance of the NO_2 hourly NAAQS limit and of the daily PM_{10} NAAQS limit, where the distance will be less based on the allowable frequency of exceedance.</td></tr>
<tr><td>Unpaved road</td><td>80</td><td>PM_{10}</td></tr>
<tr><td>Plant</td><td>none</td><td>none</td><td>The flare is an intermittent source with no exceedances</td></tr>
</table>

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9 APPENDIX A – IMPACT SIGNIFICANCE RATING METHODOLOGY

The impact assessment methodology is guided by the requirements of the NEMA EIA Regulations (2010). The broad approach to the significance rating methodology is to determine the environmental risk (ER) by considering the consequence (C) of each impact (comprising Nature, Extent, Duration, Magnitude, and Reversibility) and relate this to the probability/likelihood (P) of the impact occurring. This determines the environmental risk. In addition, other factors, including cumulative impacts, public concern, and potential for irreplaceable loss of resources, are used to determine a prioritisation factor (PF) which is applied to the ER to determine the overall significance (S).

Determination of Environmental Risk:

The significance (S) of an impact is determined by applying a prioritisation factor (PF) to the environmental risk (ER). The environmental risk is dependent on the consequence (C) of the particular impact and the probability (P) of the impact occurring. Consequence is determined through the consideration of the Nature (N), Extent (E), Duration (D), Magnitude (M), and reversibility (R) applicable to the specific impact.

For the purpose of this methodology the consequence of the impact is represented by:

$$C = \frac{(E+D+M+R)}{4} \times N$$

Each individual aspect in the determination of the consequence is represented by a rating scale as defined in Table 40.

Table 40: Criteria for determining impact consequence

Aspect	Score	Definition
Nature	- 1	Likely to result in a negative/ detrimental impact
	+1	Likely to result in a positive/ beneficial impact
Extent	1	Activity (i.e. limited to the area applicable to the specific activity)
	2	Site (i.e. within the development property boundary),
	3	Local (i.e. the area within 5 km of the site),
	4	Regional (i.e. extends between 5 and 50 km from the site
	5	Provincial / National (i.e. extends beyond 50 km from the site)
Duration	1	Immediate (<1 year)
	2	Short term (1-5 years),
	3	Medium term (6-15 years),
	4	Long term (the impact will cease after the operational life span of the project),
	5	Permanent (no mitigation measure of natural process will reduce the impact after construction).
Magnitude/ Intensity	1	Minor (where the impact affects the environment in such a way that natural, cultural and social functions and processes are not affected),
	2	Low (where the impact affects the environment in such a way that natural, cultural and social functions and processes are slightly affected),
	3	Moderate (where the affected environment is altered but natural, cultural and social functions and processes continue albeit in a modified way),
	4	High (where natural, cultural or social functions or processes are altered to the extent that it will temporarily cease), or
	5	Very high / don't know (where natural, cultural or social functions or processes are altered to the extent that it will permanently cease).

Aspect	Score	Definition
Reversibility	1	Impact is reversible without any time and cost.
	2	Impact is reversible without incurring significant time and cost.
	3	Impact is reversible only by incurring significant time and cost.
	4	Impact is reversible only by incurring prohibitively high time and cost.
	5	Irreversible Impact

Once the C has been determined the ER is determined in accordance with the standard risk assessment relationship by multiplying the C and the P (Table 42). Probability is rated/scored as per Table 41.

Table 41: Probability scoring

Probability	1	Improbable (the possibility of the impact materialising is very low as a result of design, historic experience, or implementation of adequate corrective actions; <25%),
	2	Low probability (there is a possibility that the impact will occur; >25% and <50%),
	3	Medium probability (the impact may occur; >50% and <75%),
	4	High probability (it is most likely that the impact will occur- > 75% probability), or
	5	Definite (the impact will occur)

The result is a qualitative representation of relative ER associated with the impact. ER is therefore calculated as follows:

ER= C x P

Table 42: Determination of environmental risk

Consequence	5	5	10	15	20	25
	4	4	8	12	16	20
	3	3	6	9	12	15
	2	2	4	6	8	10
	1	1	2	3	4	5
		1	2	3	4	5
	Probability					

The outcome of the environmental risk assessment will result in a range of scores, ranging from 1 through to 25. These ER scores are then grouped into respective classes as described in Table 43.

Table 43: Significance classes

Environmental Risk Score	
Value	**Description**
< 9	Low (i.e. where this impact is unlikely to be a significant environmental risk),
≥9; <17	Medium (i.e. where the impact could have a significant environmental risk),
≥ 17	High (i.e. where the impact will have a significant environmental risk).

The impact ER will be determined for each impact without relevant management and mitigation measures (pre-mitigation), as well as post implementation of relevant management and mitigation measures (post-mitigation). This allows for a prediction in the degree to which the impact can be managed/mitigated.

Impact Prioritisation:

In accordance with the requirements of Regulation 31 (2)(l) of the EIA Regulations (GNR 543), and further to the assessment criteria presented in the Section above it is necessary to assess each potentially significant impact in terms of:

- Cumulative impacts; and
- The degree to which the impact may cause irreplaceable loss of resources.

In addition, it is important that the public opinion and sentiment regarding a prospective development and consequent potential impacts is considered in the decision-making process.

In an effort to ensure that these factors are considered, an impact prioritisation factor (PF) will be applied to each impact ER (post-mitigation). This prioritisation factor does not aim to detract from the risk ratings but rather to focus the attention of the decision-making authority on the higher priority/significance issues and impacts. The PF will be applied to the ER score based on the assumption that relevant suggested management/mitigation impacts are implemented.

Table 44: Criteria for determining prioritisation

Public response (PR)	Low (1)	Issue not raised in public response.
	Medium (2)	Issue has received a meaningful and justifiable public response.
	High (3)	Issue has received an intense meaningful and justifiable public response.
Cumulative Impact (CI)	Low (1)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.
	Medium (2)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cumulative change.
	High (3)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is highly probable/definite that the impact will result in spatial and temporal cumulative change.
Irreplaceable loss of resources (LR)	Low (1)	Where the impact is unlikely to result in irreplaceable loss of resources.
	Medium (2)	Where the impact may result in the irreplaceable loss (cannot be replaced or substituted) of resources but the value (services and/or functions) of these resources is limited.
	High (3)	Where the impact may result in the irreplaceable loss of resources of high value (services and/or functions).

The value for the final impact priority is represented as a single consolidated priority, determined as the sum of each individual criteria represented in Table 44. The impact priority is therefore determined as follows:

$$\textbf{Priority} = \textbf{PR} + \textbf{CI} + \textbf{LR}$$

The result is a priority score which ranges from 3 to 9 and a consequent PF ranging from 1 to 2 (refer to Table 45).

Table 45: Determination of prioritisation factor

Priority	Ranking	Prioritisation Factor
3	Low	1
4	Medium	1.17
5	Medium	1.33
6	Medium	1.5
7	Medium	1.67
8	Medium	1.83
9	High	2

In order to determine the final impact significance the PF is multiplied by the ER of the post mitigation scoring (Table 46). The ultimate aim of the PF is to be able to increase the post mitigation environmental risk rating by a full ranking class, if all the priority attributes are high (i.e. if an impact comes out with a medium environmental risk after the conventional impact rating, but there is significant cumulative impact potential, significant public response, and significant potential for irreplaceable loss of resources, then the net result would be to upscale the impact to a high significance).

Table 46: Final environmental significance rating

Environmental Significance Rating	
Value	**Description**
< 10	Low (i.e. where this impact would not have a direct influence on the decision to develop in the area),
≥10 <20	Medium (i.e. where the impact could influence the decision to develop in the area),
≥ 20	High (i.e. where the impact must have an influence on the decision process to develop in the area).