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Air Quality Specialist Report for the Proposed Medupi Flue Gas Desulphurisation (FGD) Retrofit Project

Project done on behalf of **Zitholele Consulting**

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Revision Record

Revision Number	Date	Reason for Revision
Draft	27 February 2015	Client review
Draft	2 March 2015	Minor grammatical changes
Rev 0.2	27 March 2015	Inclusion of additional information
Rev 0.3	16 April 2015	Incorporation of comments received by the client
Rev 0.4	7 May 2015	Incorporation of second round of comments received by the client
Rev 0.5	11 May 2015	Incorporation of third round of comments received by the client
Rev 0.6	11 May 2015	Incorporation of minor comments received by the client
Rev 0.7	24 November 2016	Inclusion of additional information regarding the waste disposal of the gypsum, salts and sludge
Rev 0.8	5 December 2016	Minor grammatical changes
Rev 0.9	18 January 2018	Incorporation of changes to authorisation and licencing approach in 2017
Rev 1.0	7 February 2018	Incorporation of comments received by the client

List of Abbreviations

AQA	Air quality act
APCS	Air pollution control systems
ARM	Ambient Ratio Method
As	Arsenic
Cd	Cadmium
Co	Cobalt
CO	Carbon monoxide
CO_2	Carbon dioxide
Cr	Chromium
Cu	Copper
DEA	Department of Environmental Affairs
ESP	Electro static precipitator
g	Gram
g/s	Gram per second
HCl	Hydrogen chloride
Hg	Mercury
HNO_3	Nitric acid
HF	Hydrogen fluoride
LMo	Monin-Obukhov length
m	Meter
m^2	Meter squared
m^3	Meter cubed
m/s	Meters per second
Mn	Manganese
NAAQS	National ambient air quality standards
NH_3	Ammonia
Ni	Nickel
NO	Nitrogen oxide
NO_2	Nitrogen dioxide
NO_x	Oxides of nitrogen
O_3	Ozone
OLM	Ozone Limiting Method
PBL	Planetary boundary layer
Pb	Lead
PM	Particulate matter
PM_{10}	Particulate matter with diameter of less than 10 µm
$PM_{2.5}$	Particulate matter with diameter of less than 2.5 µm
Sb	Antimony
ppb	Parts per billion
SO_2	Sulfur dioxide
SO_3	Sulfur trioxide
Tl	Thalium
US EPA	United States Environmental Protection Agency

V	Vanadium
VOC	Volatile organic concentrations
µ	micro
°C	Degrees Celsius

Glossary

Airshed	An area, bounded by topographical features, within which airborne contaminants can be retained for an extended period
Algorithm	A mathematical process or set of rules used for calculation or problem-solving, which is usually undertaken by a computer
Assessment of environmental effects	A piece of expert advice submitted to regulators to support a claim that adverse effects will or will not occur as a result of an action, and usually developed in accordance with section 88 of the Resource Management Act 1991
Atmospheric chemistry	The chemical changes that gases and particulates undergo after they are discharged from a source
Atmospheric dispersion model	A mathematical representation of the physics governing the dispersion of pollutants in the atmosphere
Atmospheric stability	A measure of the propensity for vertical motion in the atmosphere
Calm / stagnation	A period when wind speeds of less than 0.5 m/s persist
Cartesian grid	A co-ordinate system whose axes are straight lines intersecting at right angles
Causality	The relationship between cause and effect
Complex terrain	Terrain that contains features that cause deviations in direction and turbulence from larger-scale wind flows
Configuring a model	Setting the parameters within a model to perform the desired task
Convection	Vertical movement of air generated by surface heating
Convective boundary layer	The layer of the atmosphere containing convective air movements
Diffusion	Clean air mixing with contaminated air through the process of molecular motion. Diffusion is a very slow process compared to turbulent mixing.
Dispersion	The lowering of the concentration of pollutants by the combined processes of advection and diffusion
Dispersion coefficients	Variables that describe the lateral and vertical spread of a plume or a puff

Executive Summary

Airshed Planning Professionals (Pty) Limited was appointed by Zitholele Consulting to undertake an air quality impact assessment for a proposed Medupi Flue Gas Desulphurisation (FGD) retrofit project (hereafter referred to as the Project). The FGD retrofit project will reduce the sulphur dioxide (SO_2) emissions from the power station by 84% on average, to ensure compliance with an SO_2 emission limit of 500 mg/Nm^3 (at 10% O_2).

The aim of the investigation is to quantify the possible impacts resulting from the proposed activities on the surrounding environment and human health. To achieve this, a good understanding of the local dispersion potential of the site is necessary and subsequently an understanding of existing sources of air pollution in the region and the resulting air quality.

Scope of Work

Confirmed scope of work includes assessment of the following activities and infrastructure:

1. Construction and operation of a rail yard/siding to transport Limestone from a source defined point via the existing rail network to the Medupi Power Station and proposed rail yard / siding. The rail yard infrastructure will include storage of fuel (diesel) in above ground tanks and 15m deep excavation for tippler building infrastructure;
2. Construction and operation of limestone storage area, preparation area, handling and transport via truck and conveyor to the FGD system located near the generation units of the Medupi Power Station;
3. The construction and operation of the wet FGD system that will reduce the SO_2 content in the flue gas emitted;
4. Construction and operation of associated infrastructure required for operation of the FGD system and required services to ensure optimal functioning of the wet FGD system. The associated FGD infrastructure include a facility for storage of fuel (diesel), installation of storm water infrastructure and conservancy tanks for sewage;
5. The handling, treatment and conveyance of gypsum and effluent from the gypsum dewatering plant.
6. Pipeline for the transportation of waste water from the gypsum dewatering plant and its treatment at the waste water treatment plant (WWTP) that will be located close to the FGD infrastructure within the Medupi Power Station;
7. Construction and operation of the WWTP;
8. Management, handling, transport and storage of salts and sludge generated through the waste water treatment process at a temporary waste storage facility.
9. The transportation of salts and sludge via trucks from the temporary waste storage facility to a final Waste Disposal Facility to be contracted by Eskom for the first 5 years of operation of the FGD system.
10. Disposal of gypsum together with ash on the existing licenced ash disposal facility (ADF), with resulting increase in height of the ADF from 60m to 72m.

Study Approach and Methodology

The investigation followed the methodology required for a specialist report as prescribed in the Environmental Impact Assessment (EIA) Regulations (Government Notice R.543 in Government Gazette 33306 of 18 June 2010).

Potential Air Emissions from the Proposed Project

For the Air Quality Assessment initiated in 2014 the approach focussed on the impacts from the operation of the FGD ("the Project"). The main pollutant that will be affected through the operations of the Project is SO2, as the FGD control aims at the reduction of this pollutant. The emission concentrations of nitrogen dioxide (NO2) and particulate matter from the stack releases was provided by Eskom personnel to remain the same with and without the control of FGD but the buoyancy of the plume and its ability to disperse from the point of release will be altered due to changes in exit temperatures effecting the ambient concentrations of the pollutant at ground level. The gypsum by-product will alter the potential wind-blown dust from the ash storage facility (assuming the disposal of ash and gypsum together in an appropriate Class C facility) or may generate additional dust from an independent disposal facility. For the current assessment, the assumption was made that the ash and gypsum would be disposed of in a single facility.

Towards the middle of 2017 changes to the authorisation and licencing approach for the Medupi FGD Retrofit Project applications were proposed in order to streamline the application processes to ensure compliance with the NEMAQA compliance requirements by the year 2021. The changes that influence potential air emissions include the application for activities associated with the construction and operation of the FGD system within the Medupi PS footprint and the railway yard and siding, including limestone and gypsum handling facilities and diesel storage facilities new access roads. The impacts from the construction activities were not assessed further as their impacts would be localised and of a temporary nature. The impacts from the railway siding and handling operations as well as vehicle entrainment from the new access road would contribute to the particulate matter. The diesel storage facility would contribute to volatile organic compounds. Impacts from these activities, however, will be localised and will not exceed National Ambient Air Quality Standards offsite. These changes were therefore not deemed significant and were thus not assessed further.

Baseline Assessment

The baseline study encompassed the analysis of meteorological data. Local meteorological data (including wind speed, wind direction and temperature) was obtained from MM5[1] data for the period 2011 to 2013. The identification of sources of emissions in the study area also formed part of the baseline assessment.

Two scenarios were assessed which consisted of (i) 2014 baseline (including operations of the Matimba Power Station) and (ii) 2020 baseline (including the operations of the Matimba Power Station and the Medupi Power Station with all six units excluding FGD).

Emissions Inventory

Emissions inventories provide the source input required for the simulation of ambient air concentrations. Windblown fugitive source emissions from the ash disposal facilities were quantified. Point source emissions and parameters for the proposed operations were provided by Eskom personnel.

[1] The MM5 (short for Fifth-Generation Penn State/NCAR Mesoscale Model) is a regional mesoscale model used for creating weather forecasts and climate projections. It is a community model maintained by Penn State University and the National Centre for Atmospheric Research.

Impact Prediction Study

SO_2, NO_2 and particulate concentrations due to the baseline and proposed operations were simulated using the CALMET/CALPUFF dispersion modelling suite. Ambient concentrations were simulated to ascertain highest hourly, daily and annual averaging levels occurring as a result of the baseline and proposed Project operations.

Three scenarios were assessed: (i) 2014 baseline: the potential impacts due to the Matimba Power Station operations, (ii) 2020 baseline: the potential impacts due to the Matimba Power Station operations and the Medupi Power Station operations including all six units without FGD, and (iii) proposed Project operations: the potential impacts due to the Matimba Power Station operations and the Medupi Power Station operations including all six units with FGD. The fugitive emissions due to windblown dust from the disposal of ash and gypsum at the ash disposal facility was also quantified at the existing Ash Disposal Facility (ADF) as an unmitigated operation (no controls in place) and as a mitigated operation (80% control efficiency in place through active re-vegetation and wetting). Stack emissions and parameters were provided by Eskom personnel for the study.

Assessment Criteria

For the current study, the impacts were assessed against published National Ambient Air Quality Standards (NAAQS).

Assumptions, Exclusions and Limitations

- Emissions emanating from all existing sources in the area were not quantified nor were resultant ambient air pollutant concentrations due to such sources simulated, with the exception of the existing Matimba Power Station and its associated ashing operations. Given that Matimba Power Station is the most significant source of ambient SO_2 concentrations in the region, this study limitation is not significant for assessing compliance and health risk potentials due to SO_2. Matimba Power Station is, however, not the major contributor to ambient fine particulate concentrations. In order to project cumulative particulate concentrations other significant sources, particularly local mining operation emissions, would need to be quantified.

- Routine emissions from power station operations were estimated and modelled. Atmospheric releases occurring as a result of accidents were not accounted for.

- For the current assessment, the assumption was made that the ash and gypsum would be disposed together in the same facility, until there is an opportunity in the market for alternative use of gypsum. The gypsum material on the disposal facility is expected to provide a crust when mixed with water. To what extent this material will crust will depend on how the material is disposed (i.e. mixed with the ash or deposited as layers of gypsum material in between the ash material) and how much water is added to the disposal facility. The crust may also be disturbed from time to time with activity on the disposal facility. For the current assessment, the effectiveness of this crust in lowering windblown emissions could not be quantified.

- MM5 was used as the "initial guess" field for the CALMET model. Although two monitoring stations are located within the study area, MM5 could not be used together with the surface measurements as the Eskom-operated Marapong station is sited incorrectly providing questionable wind direction and, with one representative station (South African Weather Service Station located at Lephalale), CALMET requires 100% data availability which was not present.

The most important *assumptions* made during the air quality impact assessment are as follows:

- Source parameters and emission rates for these emission scenarios required for input to the dispersion modelling study were provided by Eskom personnel. The assumption was made that this information was accurate and correct.

- A constant NH_3 background concentration of 20 ppb was used in Calpuff (Scorgie et al, 2006). Measured ozone data from the Marapong station was included for the background data required for the chemical transformation module in Calpuff.

Main Findings

The main findings from the baseline air quality characterisation study (prior to the operation of the Medupi Power Station), which was based on information from both monitoring and modelling studies, are as follows:

- SO_2 concentrations have been measured to infrequently exceed short-term NAAQ limits at the monitoring stations located at Marapong and Lephalale. Modelled SO_2 concentrations also indicate infrequent short-term exceedances of the NAAQ limits at these sensitive receptors. There is however compliance with the NAAQS.

- Currently, the Matimba Power Station is likely to be the main contributing source to the ambient SO_2 ground level concentrations in the study area due to the magnitude of its emissions. Other sources which may contribute significantly due to their low release level include: spontaneous combustion of coal discards associated with mining operations, clamp firing emissions during brickmaking at Hanglip and potentially household fuel burning within Marapong. The highest ground level SO_2 concentrations due to the Matimba Power Station stack emissions are expected to occur during unstable conditions, usually occurring during the day, when the plume is brought to ground in relatively close proximity to the power station.

- NO_2 concentrations have been measured to infrequently exceed short-term NAAQ limits (but are in compliance with NAAQS) at the monitoring stations located at Marapong and Lephalale, which is reiterated in the modelled results. Low level sources of NO_x in the region include combustion within coal discard dumps, brick firing operations and possibly also household fuel burning and infrequent veld burning.

- Measured PM_{10} concentrations exceed the daily NAAQS at Marapong for the period 2014 but are lower at Lephalale (where levels comply with daily NAAQS). The measured $PM_{2.5}$ concentrations are within the daily NAAQS applicable till 2030 at Marapong and Lephalale, but exceed the more stringent daily NAAQS applicable in 2030. The annual average PM_{10} and $PM_{2.5}$ concentrations measured at Lephalale are within NAAQS. Measured annual PM_{10} concentrations at Marapong during the period 2013 exceed annual NAAQS.

- 2014 Baseline simulations:
    - The contribution of Matimba Power Station to primary and secondary particulates was simulated, with no exceedances of the SO_2, NO_2, PM_{10} and $PM_{2.5}$ NAAQS at Marapong and Lephalale. Secondary particulates form in the atmosphere through the conversion of SO_x and NO_x emissions to sulfate and nitrate.

- 2020 Baseline simulations:
    - The area of non-compliance with the hourly and daily SO_2 NAAQS extended ~30km southwest of the Medupi Power Station due to the cumulative operations of Matimba Power Station and Medupi Power

Station without FGD control. Non-compliance with the hourly and daily SO_2 NAAQS was simulated at the residential settlement to the northwest of the Matimba Power Station under these conditions.

- Various local (informed through observation from site visits) and far-field (informed by literature) sources are expected to contribute to the suspended fine particulate concentrations in the region. Local dust sources include wind erosion from exposed areas, fugitive dust from mining and brickmaking operations, vehicle entrainment from roadways and veld burning. Household fuel burning may also constitute a local source of low-level emissions. Long-range transport of particulates emitted from remote tall stacks and from biomass burning in countries to the north of Republic of South Africa (RSA) and the accumulation and recirculation of such regional air masses over the interior is well documented (Andreae et al., 1996; Garstang et al., 1996; Piketh, 1996) (detail pertaining to the recirculation of air masses is provided in Section 3.3.1.9).

The main findings of the impact assessment for the proposed Project are provided as follows:

- The area of exceedance of the hourly and daily SO_2 NAAQS was significantly reduced when FGD controls on the Medupi Power Station are considered, bringing the simulated ground level concentrations within compliance of the hourly and daily SO_2 NAAQS at all sensitive receptors in the study area.

- Simulated impacts from the Matimba Power Station and the Medupi Power Station without FGD (2020 baseline) was in non-compliance with SO_2 NAAQS on a regional scale resulting in a MODERATE significance. The area of non-compliance of SO_2 concentrations reduces significantly for proposed Project operations (i.e. Matimba Power Station operations and Medupi Power Station operations with FGD) and reduces the significance to LOW as no exceedances of the NAAQS are simulated at the closest sensitive receptors in the study area. No exceedances of the NAAQS for NO_2, PM_{10} and $PM_{2.5}$ were simulated at sensitive receptors due to proposed Project operations resulting in LOW significance. The available monitoring data shows that the PM_{10} concentrations are in non-compliance with the daily NAAQS at Marapong. Simulated impacts due to proposed Project operations, however, do not contribute significantly to current ambient particulate concentrations.

Recommendation

As the proposed Project operations will significantly reduce SO_2 impacts from the Medupi Power Station, it is recommended that the FGD Retrofit Project (including the increase in height of 12 m at the ADF) be implemented.

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1 INTRODUCTION

Airshed Planning Professionals (Pty) Limited was appointed by Zitholele Consulting to undertake an air quality impact assessment for a proposed Medupi Flue Gas Desulphurisation (FGD) retrofit project (hereafter referred to as the Project). The FGD retrofit project will reduce the sulphur dioxide (SO_2) emissions from the power station by 84%.

The aim of the investigation is to quantify the possible impacts resulting from the proposed activities on the surrounding environment and human health. To achieve this, a good understanding of the regional climate and local dispersion potential of the site is necessary and subsequently an understanding of existing sources of air pollution in the region and the resulting air quality is required.

Typical of specialist investigations conducted, the air quality investigation comprises both a baseline study and an impact assessment. The baseline study includes the review of site-specific atmospheric dispersion potentials, and existing ambient air quality in the region, in addition to the identification of potentially sensitive receptors. The ambient air quality impact assessment comprised the establishment of an emissions inventory for the proposed activities, the simulation of ambient air pollutant concentrations occurring due to Project operations, and the evaluation of the resultant potential for impacts and non-compliance.

1.1 Description of Project Activities from an Air Quality Perspective

Confirmed scope of work includes assessment of the following activities and infrastructure:

11. Construction and operation of a rail yard/siding to transport Limestone from a source defined point via the existing rail network to the Medupi Power Station and proposed rail yard / siding. The rail yard infrastructure will include storage of fuel (diesel) in above ground tanks and 15m deep excavation for tippler building infrastructure;
12. Construction and operation of limestone storage area, preparation area, handling and transport via truck and conveyor to the FGD system located near the generation units of the Medupi Power Station;
13. The construction and operation of the wet FGD system that will reduce the SO_2 content in the flue gas emitted;
14. Construction and operation of associated infrastructure required for operation of the FGD system and required services to ensure optimal functioning of the wet FGD system. The associated FGD infrastructure include a facility for storage of fuel (diesel), installation of storm water infrastructure and conservancy tanks for sewage;
15. The handling, treatment and conveyance of gypsum and effluent from the gypsum dewatering plant.
16. Pipeline for the transportation of waste water from the gypsum dewatering plant and its treatment at the waste water treatment plant (WWTP) that will be located close to the FGD infrastructure within the Medupi Power Station;
17. Construction and operation of the WWTP;
18. Management, handling, transport and storage of salts and sludge generated through the waste water treatment process at a temporary waste storage facility.
19. The transportation of salts and sludge via trucks from the temporary waste storage facility to a final Waste Disposal Facility to be contracted by Eskom for the first 5 years of operation of the FGD system.
20. Disposal of gypsum together with ash on the existing licenced ash disposal facility (ADF), with resulting increase in height of the ADF from 60m to 72m.

1.2 Approach and Methodology

The methodology followed in the assessment to quantify the air quality impacts associated with the proposed Project is discussed below. The general tasks included:

- The establishment of the baseline air quality (based on available information);
- Quantification of air emissions from the proposed Project;
- Discussion of meteorological parameters required to establish the atmospheric dispersion potential;
- Calculation of the air concentrations from the proposed Project using a suitable atmospheric dispersion model;
- Assessment of the significance of the impact through the comparison of simulated air concentrations with local National Ambient Air Quality Standards (for compliance).

1.2.1 Potential Air Emissions from the Proposed Project

For the Air Quality Assessment initiated in 2014 the approach focussed on the impacts from the operation of the FGD ("the Project"). The main pollutant that will be affected through the operations of the Project is SO_2, as the FGD control aims at the reduction of this pollutant. The emission concentrations of nitrogen dioxide (NO_2) and particulate matter from the stack releases was provided by Eskom personnel to remain the same with and without the control of FGD but the buoyancy of the plume and its ability to disperse from the point of release will be altered due to changes in exit temperatures effecting the ambient concentrations of the pollutant at ground level. The gypsum by-product will alter the potential wind-blown dust from the ash storage facility (assuming the disposal of ash and gypsum together in an appropriate Class C facility) or may generate additional dust from an independent disposal facility. For the current assessment, the assumption was made that the ash and gypsum would be disposed of in a single facility.

Towards the middle of 2017 changes to the authorisation and licencing approach for the Medupi FGD Retrofit Project applications were proposed in order to streamline the application processes to ensure compliance with the NEMAQA compliance requirements by the year 2021. The changes that influence potential air emissions include the application for activities associated with the construction and operation of the FGD system within the Medupi PS footprint and the railway yard and siding, including limestone and gypsum handling facilities and diesel storage facilities new access roads. The impacts from the construction activities were not assessed further as their impacts would be localised and of a temporary nature. The impacts from the railway siding and handling operations as well as vehicle entrainment from the new access road would contribute to the particulate matter. The diesel storage facility would contribute to volatile organic compounds. Impacts from these activities, however, will be localised and will not exceed National Ambient Air Quality Standards offsite. These changes were therefore not deemed significant and were thus not assessed further.

1.2.2 Regulatory Requirements and Assessment Criteria

In the evaluation of air emissions and ambient air quality impacts reference is made to National Ambient Air Quality Standards (NAAQS) for compliance. These standards generally apply only to a number of common air pollutants, collectively known as criteria pollutants. Criteria pollutants typically include SO_2, NO_2, carbon monoxide (CO), inhalable particulate matter (including thoracic particulate matter with an aerodynamic diameter of equal to or less than 10 µm or PM_{10} and Inhalable particulate matter with an aerodynamic diameter equal to or less than 2.5 µm or $PM_{2.5}$), benzene, ozone and lead. For the proposed Project, pollutants of concern included SO_2, NO_2, PM_{10} and $PM_{2.5}$ (screened against NAAQS) and metals within the ash deposition facility (screened against international health effect screening levels).

1.2.3 Description of the Baseline Environment

An understanding of the atmospheric dispersion potential of the area is essential to an air quality impact assessment. For this assessment use was made of a numerical weather prediction model (Mesoscale Model version 5 (MM5[2])).

1.2.4 Existing Ambient Air Quality

The Department of Environmental Affairs (DEA) has an ambient air quality monitoring network for the Waterberg-Bojanala Priority area consisting of stations located at Lephalale, Mokopane and Thabazimbi. The closest DEA managed monitoring station to the proposed Project is in Lephalale (~12 km east). Eskom also operates an ambient monitoring station located in Marapong (~8 km northeast of the Project). The monitored information from these two stations was used in the current assessment.

1.2.5 Emissions Inventory

The establishment of a comprehensive emissions inventory formed the basis for the assessment of the air quality impacts from proposed operations. Proposed Project operations will result in point and fugitive gaseous and particulate emissions.

Point sources are well defined with set parameters and emission concentrations. The information on the point sources was provided by Eskom for use in the current assessment.

Fugitive emissions refer to emissions that are spatially distributed over a wide area. In the quantification of fugitive dust, use was made of emission factors which associate the quantity of a pollutant to the activity associated with the release of that pollutant. (Emission factors used are discussed in more detail in Section 3.3.3).

1.2.6 Atmospheric Dispersion Modelling

1.2.6.1 Dispersion Model Selection

Dispersion models compute ambient concentrations as a function of source configurations, emission strengths and meteorological characteristics, thus providing a useful tool to ascertain the spatial and temporal patterns in the ground level concentrations arising from the emissions of various sources. Increasing reliance has been placed on ground level air pollution concentration estimates from models as the primary basis for environmental and health impact assessments, risk assessments and determining emission control requirements. Care was therefore taken in the selection of a suitable dispersion model for the task at hand. For the current study, it was decided to use the US Environmental Protection Agency's CALMET meteorological model and the CALPUFF dispersion model in combination.

Most regulatory dispersion models, such as the widely used AERMOD model, are based on the steady-state plume assumption, with meteorological inputs for these models assuming a horizontally uniform flow field. Usually the winds are derived from a single point measurement, which is often made at a nearby non-complex terrain site. The meteorological processors for the regulatory models do not adjust the winds to reflect terrain effects. The steady-state flow fields either do not or only partially reproduce the terrain-induced spatial variability in the wind field. In addition to which, the straight-line trajectory assumption of the plume models cannot easily handle curved trajectories associated with terrain-induced deflection

[2] The MM5 (short for Fifth-Generation Penn State/NCAR Mesoscale Model) is a regional mesoscale model used for creating weather forecasts and climate projections. It is a community model maintained by Penn State University and the National Centre for Atmospheric Research.

or channelling. These limitations of plume models can significantly affect the models ability to correctly represent the spatial area of impact from sources in complex terrain, in addition to the magnitude of the peak values in certain instances.

CALPUFF is a regional Lagrangian Puff model intended for use on scales from tens of metres to hundreds of kilometres from a source (US EPA 1998). A number of dispersion coefficients options are accommodated, including

- stability-based empirical relationships such as the Pasquill-Gifford or McElroy-Pooler dispersion coefficients;
- turbulence-based dispersion coefficients (based on measured standard deviations of the vertical and crosswind horizontal components of the wind); and
- similarity theory to estimate the turbulent quantities using the micrometeorological variables calculated by CALMET.

The most desirable approach is to use turbulence-based dispersion coefficients using measured turbulent velocity variances or intensity components, if such data are readily available and they are of good quality. However, since reliable turbulent measurements are generally not available, use can be made of the similarity approach.

CALPUFF also has the capability to model the effects of vertical wind shear by explicitly allowing different puffs to be independently advected by their local average wind speed and direction, as well as by optionally allowing well-mixed puffs to split into two or more puffs when across-puff shear becomes important. Another option is to use a probability density function (pdf) model to simulate vertical dispersion during convective conditions.

CALPUFF includes parameterized chemistry modules for the formation of secondary sulfate and nitrate from the oxidation of the emitted primary pollutants, SO_2 and NO_x. The conversion processes are assumed to be linearly dependent (first-order) on the relevant primary species concentrations. Two options are included, namely the MESOPUFF II and RIVAD/ARM3 chemistry options. In both options, a fairly simple stoichiometric thermodynamic model is used to estimate the partitioning of total inorganic nitrate between gas-phase nitric acid and particle-phase ammonium nitrate. Ammonia and ozone concentrations are required as background values to the model.

CALPUFF uses dry deposition velocities to calculate the dry deposition of gaseous and particulate pollutants to the surface. These dry deposition velocities can either be user-specified or calculated internally in CALPUFF. A resistance-based model is used for the latter option. For gaseous pollutants, the resistances that are considered are the atmospheric resistance, the deposition layer resistance, and the canopy resistance. For particles, a gravitational settling term is included and the canopy resistance is assumed to be negligible. CALPUFF uses the scavenging coefficient approach to parameterize wet deposition of gases and particles. The scavenging coefficient depends on pollutant characteristics (e.g., solubility and reactivity), as well as the precipitation rate and type of precipitation. The model provides default values for the scavenging coefficient for various species and two types of precipitation (liquid and frozen). These values may be overridden by the user.

The CALPUFF modelling system consists of a number of components, as summarised in Table 1-1. However only CALMET and CALPUFF contain the simulation engines to calculate the three-dimensional atmospheric boundary layer conditions and the dispersion and removal mechanisms of pollutants released into this boundary layer. The other codes are mainly used to assist with the preparation of input and output data. Table 1-1 also includes the development versions of each of the codes used in the investigation.

Table 1-1: Summary description of CALPUFF/CALMET model suite with versions used in the investigation

Module	Version	Description
CALMET	v6.334	Three-dimensional, diagnostic meteorological model
CALPUFF	v6.42	Non-steady-state Gaussian puff dispersion model with chemical removal, wet and dry deposition, complex terrain algorithms, building downwash, plume fumigation and other effects.
CALPOST	V6.292	A post-processing program for the output fields of meteorological data, concentrations and deposition fluxes.
CALSUM	v1.4 (1)	Sums and scales concentrations or wet/dry fluxes from two or more source groups from different CALPUFF runs
PRTMET	v 4.495(1)	Lists selected meteorological data from CALMET and creates plot files
POSTUTIL	v1.641(1)	Processes CALPUFF concentration and wet/dry flux files. Creates new species as weighted combinations of modelled species; merges species from different runs into a single output file; sums and scales results from different runs; repartitions nitric acid/nitrate based on total available sulfate and ammonia.
TERREL	v3.69(1)	Combines dna grids terrain data
CTGPROC	v3.5(1)	processes and grids land use data
MAKEGEO	v3.2(1)	merges land use and terrain data to produce the geophysical data file for CALMET

Note (1): These modules indicate version number as listed on http://www.src.com/calpuff/download/mod6_codes.htm (for CALPro Plus v6) [version number not given in GUI interface or 'About' information].

1.2.6.2 Atmospheric Dispersion Processes

CALPUFF initiates the simulation of point source plumes with a calculation of buoyant plume rise. Transport winds are extracted from the meteorological data file at the location of the stack and at the effective plume height (stack height plus plume rise). For near-field effects, the height of the plume in transition to the final plume height is taken into account. The puff release rate is calculated internally, based on the transport speed and the distance to the closest receptor.

As the puff is transported downwind, it grows due to dispersion and wind shear, and the trajectory is determined by advection winds at the puff location and height at each time step. The pollutant mass within each puff is initially a function of the emission rate from the original source. The pollutant mass is also subject to chemical transformation, washout by rain and dry deposition, when these options are selected, as is the case in this application. Chemical transformation and removal are calculated based on a one-hour time step.

Both wet and dry deposition fluxes are calculated by CALPUFF, based on a full resistance model for dry deposition and the use of precipitation rate-dependent scavenging coefficients for wet deposition. Pollutant mass is removed from the puff due to deposition at each time step. For the present modelling analyses, most options were set at "default" values, including the MESOPUFF II transformation scheme and the treatment of terrain.

Nitrogen Dioxide Formation

Of the several species of nitrogen oxides, only NO_2 is specified in the NAAQS. Since most sources emit uncertain ratios of these species and these ratios change further in the atmosphere due to chemical reactions, a method for determining the amount of NO_2 in the plume must be selected.

Estimation of this conversion normally follows a tiered approach, as discussed in the Regulations Regarding Air Dispersion Modelling (Gazette No 37804 published 11 July 2014), which presents a scheme for annual averages:

- Tier 1: Total Conversion Method

Use any of the appropriate models recommended to estimate the maximum annual average NO_2 concentrations by assuming a total conversion of NO to NO_2. If the maximum NO_x concentrations are less than the NAAQS for NO_2, then no further refinement of the conversion factor is required. If the maximum NO_x concentrations are greater than the NAAQS for NO_2, or if a more "realistic" estimate of NO_2 is desired, proceed to the second tier level.

- Tier 2: Ambient Ratio Method (ARM) - Multiply NO_x by a national ratio of $NO_2/NO. = 0.80$

Assume a wide area quasi-equilibrium state and multiply the Tier 1 empirical estimate NO_x by a ratio of $NO_2/NO_x = 0.80$. The ratio is recommended for South Africa as the conservative ratio based on a review of ambient air quality monitoring data from the country. If representative ambient NO and NO_2 monitoring data is available (for at least one year of monitoring), and the data is considered to represent a quasi-equilibrium condition[3] where further significant changes of the NO/NO_2 ratio is not expected, then the NO/NO_2 ratio based on the monitoring data can be applied to derive NO_2 as an alternative to the national ratio of 0.80 (as stipulated in the Regulations (Gazette No 37804 published 11 July 2014)).

In the Total Conversion Method, the emission rate of all NO_x species is used in the dispersion model to predict ground-level concentrations of total NO_x. These levels of NO_x are assumed to exist as 100% NO_2, and are directly compared to the NAAQS for NO_2. If the NAAQS are met, the Tier 2 methods are not necessary.

Although not provided in the Regulations (Gazette No 37804 published 11 July 2014), the conversion of NO to NO_2 may also be based on the amount of ozone available within the volume of the plume. The NO_2/NO_x conversion ratio is therefore coupled with the dispersion of the plume. This is known as the Ozone Limiting Method (OLM). Use of onsite ozone data is always preferred for the OLM method.

The MESOPUFF II chemical transformation scheme, used in the current assessment, included in the CALPUFF model accommodates NO_x reactions, these are only considering the formation of nitrates and not the NO/NO_2 reactions.

Given all of the above limitations, it was decided to employ the Ambient Ratio Method (ARM), i.e. the second version of the DEA Tier 2 option. The ARM ambient ratio method is based upon the premise that the NO_2/NO_x ratio in a plume changes as it is transported but attains an equilibrium value some distance away from the source (Scire and Borissova, 2011). In their study, Scire and Borissova analysed hourly monitored NO_2 and NO_x data for 2006 at 325 monitoring sites throughout USA, which amounted to approximately 2.8 million data points for each species. These observations were grouped into a number of concentration ranges (bins), and the binned data were used to compute bin maximums and bin average curves. Short-term (1-hr) NO_2/NO_x ratios were subsequently developed based on bin-maximum data. Similarly, long-term (annual average) NO_2/NO_x ratios were based on bin-averaged data. The method was tested using the NO_2/NO_x ratios applied to the observed NO_x at selected stations to predict NO_2, and then compared to observed NO_2 concentrations at that station. The comparison of NO_2 derived from observed NO_x using these empirical curves was shown to be a conservative estimate of observed NO_2 (as obtained from measurements at Marapong), whilst at the same time arriving at a more realistic approximation than if simply assuming a 100% conversion rate. More details of the adopted conversion factors are given in Appendix A.

[3] A process is called a quasi-equilibrium process if the intermediate steps in the process are all close to equilibrium.

Particulate Formation

CALPUFF includes two chemical transformation schemes for the calculation of sulfate and nitrate formation from SO_2 and NO_x emissions. These are the MESOPUFF II and the RIVAD / ARM3 chemical formulations. The chemical transformation scheme chosen for this analysis was the MESOPUFF II scheme (as recommended via personal communication with Joe Scire[4]). As described in the CALPUFF User Guide it is a "pseudo first-order chemical reaction mechanism" and involves five pollutant species namely SO_2, sulphates (SO_4), NO_x, nitric acid (HNO_3) and particulate nitrate. CALPUFF calculates the rate of transformation of SO_2 to SO_4, and the rate of transformation of NO_x to NO_3, based on environmental conditions including the ozone concentration, atmospheric stability, solar radiation, relative humidity, and the plume NO_x concentration. The daytime reaction formulation depends on solar radiation and the transformation increases non-linearly with the solar radiation (see the SO_2 to SO_4 transformation rate equation (equation 2-253 in the CALPUFF User Guide). At night, the transformation rate defaults to a constant value of 0.2% per hour. Calculations based on these formulas show that the transformation rate can reach about 3 per cent per hour at noon on a cloudless day with 100 ppb of ozone.

With the MESOPUFF-II mechanism, NO_x transformation rates depend on the concentration levels of NO_x and O_3 (equations 2-254 and 2-255 in the CALPUFF User Guide) and both organic nitrates (RNO_3) and HNO_3 are formed. According to the scheme, the formation of RNO_3 is irreversible and is not subject to wet or dry deposition. The formation of HNO_3, however, is reversible and is a function of temperature and relative humidity. The formation of particulate nitrate is further determined through the reaction of HNO_3 and NH_3. Background NH_3 concentrations[5] are therefore required as input to calculate the equilibrium between HNO_3 and particulate nitrate. At night, the NO_x transformation rate defaults to a constant value of 2.0% per hour. Hourly average ozone and ammonia concentrations were included as input in the CALPUFF model to facilitate these sulfate and nitrate formation calculations.

The limitation of the CALPUFF model is that each puff is treated in isolation, i.e. any interaction between puffs from the same or different points of emission is not accounted for in these transformation schemes. CALPUFF first assumes that ammonia reacts preferentially with sulfate, and that there is always sufficient ammonia to react with the entire sulfate present within a single puff. The CALPUFF model performs a calculation to determine how much NH_3 remains after the particulate ammonium sulfate has been formed and the balance would then be available for reaction with NO_3 within the puff to form ammonium nitrate. The formation of particulate nitrate is subsequently limited by the amount of available NH_3. Although this may be regarded as a limitation, in this application the particulate formation is considered as a group and not necessarily per species.

Ozone Formation

Similar to sulphate, nitrate and nitrogen dioxide, ozone (O_3) is also formed through chemical reactions between pollutants released into the atmosphere. As a secondary pollutant, O_3 is formed in the lower part of the atmosphere, from complex photochemical reactions following emissions of precursor gases such as NO_x and VOCs (Seinfeld and Pandis, 1998). O_3 is produced during the oxidation of CO and hydrocarbons by hydroxyls (OH) in the presence of NO_x and sunlight (Seinfeld and Pandis, 1998). The rate of ozone production can therefore be limited by CO, VOCs or NO_x. In densely populated regions with high emissions of NO_x and hydrocarbons, rapid O_3 production can take place and result in a surface air pollution problem. In these urban areas O_3 formation is often VOC-limited. O_3 is generally NO_x-limited in rural areas and downwind suburban areas (Seinfeld and Pandis, 1998).

[4] Joe Scire is the primary developer of the CALMET/CALPUFF modelling suite.
[5] Background NH_3 information was obtained from the previous impacts assessment undertaken for the Medupi Power Station (Scorgie et al., 2006).

O_3 concentration levels have the potential to become particularly high in areas where considerable O_3 precursor emissions combine with stagnant wind conditions during the summer, when high insolation and temperatures occur (Seinfeld and Pandis, 1998). The effects of sunlight on O_3 formation depend on its intensity and its spectral distribution.

In general, the main sectors that emit ozone precursors are road transport, power and heat generation plants, household (heating), industry, and petrol storage and distribution. In many urban areas, O_3 nonattainment is not caused by emissions from the local area alone (Seinfeld and Pandis, 1998). Due to atmospheric transport, contributions of precursors from the surrounding region can also be important. The transport of O_3 is determined by meteorological and chemical processes which typically extend over spatial scales of several hundred kilometres. Thus, in an attempt to study O_3 concentrations in a local area, it is necessary to include regional emissions and transport. This requires a significantly larger study domain with the inclusion of a significantly more comprehensive emissions inventory of NO_x and VOCs sources (e.g. vehicle emissions). Such a study was not within the scope of this report.

For the current assessment, onsite O_3 data from the Marapong monitoring station was used.

1.2.6.3 Model Input

Modelling Domain

A modelling domain of 50 km (east-west) x 50 km (north-south) with a regular Cartesian receptor grid resolution of 200 m by 200 m was selected for the current assessment. The meteorology (based on MM5 data at 4 km resolution) was modelled for the entire area covering 50 km (east-west) x 50 km (north-south) with a resolution of 1000 m by 1000 m.

Meteorological inputs

CALMET was used to simulate the meteorological field within the study area, including the spatial variations – both in the horizontal and in the vertical - and temporal variations in the wind field and atmospheric stability. The initial guess field required by CALMET was informed by MM5-prognostic model data for surface and upper air profiles for the period 2011-2013.

Source Data Requirements

A three dimensional meteorological data set for the region was output by the CALMET model for application in the CALPUFF model. This data set provides spatial (horizontal and vertical) and temporal variations in the parameters required for modelling the dispersion and removal of pollutants, including: vertical wind speed, wind direction, temperature, mixing depths, atmospheric stability, (etc.). Meteorological parameters were projected at various heights above the ground, viz.: 20 m, 40 m, 80 m, 160 m, 300 m, 600 m, 1000 m, 1500 m, 2200 m and 3000 m. In projecting vertical changes in the wind field, temperature, etc. it was possible to accurately parameterize the atmospheric conditions characteristic of within valley layers, transitional layers and atmospheric layers located above the terrain.

1.3 Assumptions, Exclusions and Limitations

In interpreting the study findings it is important to note the limitations and assumptions on which the assessment was based. The most important *limitations* of the air quality impact assessment are as follows:

- Emissions emanating from all existing sources in the area were not quantified nor were resultant ambient air pollutant concentrations due to such sources simulated, with the exception of the existing Matimba Power Station and its

associated ashing operations. Given that Matimba Power Station is currently the most significant source of ambient SO_2 concentrations in the region, this study limitation is not significant for assessing compliance and health risk potentials due to SO_2. Matimba Power Station is, however, not the major contributor to ambient fine particulate concentrations (Scorgie et al, 2006). In order to project cumulative particulate concentrations other significant sources, particularly local mining operation emissions, would need to be quantified.

- Routine emissions from power station operations were estimated and modelled. Atmospheric releases occurring as a result of incidences that would result in shutdown, maintenance or change in routine emissions from the power station was not accounted for.

- For the current assessment, the assumption was made that the ash and gypsum would be disposed together in the same facility, until there is an opportunity in the market for alternative use of gypsum. The gypsum material mixed with the ash for disposal at the existing facility is expected to provide a crust when mixed with water. To what extent this material will crust will depend on how the material is disposed (i.e. mixed with the ash or deposited as layers of gypsum material in between the ash material) and how much water is added to the disposal facility. The crust may also be disturbed from time to time with activity on the disposal facility. For the current assessment, the effectiveness of this crust in lowering windblown emissions could not be quantified.

- MM5 was used as the "initial guess" field for the CALMET model. Although two monitoring stations are located within the study area, MM5 could not be used together with the surface measurements as the Eskom-operated Marapong station is sited incorrectly providing questionable wind direction and, with one representative station (South African Weather Service Station located at Lephalale), CALMET requires 100% data availability which was not present.

- The modelling guidelines stipulate that three years of off-site meteorological data should be used from a period no older than five years to the year of assessment. As the onset of the Air Quality Assessment was in 2014, meteorological data for the period 2011 – 2013 was used. Presently two of the three years falls outside of the last five-year period. This limitation is not found to be significant, however, as the meteorological conditions within the study area have not shown any significant historical changes.

The most important *assumptions* made during the air quality impact assessment are as follows:

- Source parameters and emission rates for these emission scenarios required for input to the dispersion modelling study were provided by Eskom personnel. The assumption was made that this information was accurate and correct.

- A constant NH_3 background concentration of 20 ppb was used in Calpuff (Scorgie et al, 2006). Measured ozone data from the Marapong station was included for the background data required for the chemical transformation module in Calpuff[6].

1.4 Outline of Report

Minimum Emission Standards and National Ambient Air Quality Standards applicable to power station operations and their ancillary infrastructure are presented in Section 2. The synoptic climatology and atmospheric dispersion potential of the area as well as information on existing sources and baseline air quality are discussed in Section 3. Section 4 presents the impact assessment of the proposed Project. Conclusions are presented in Section 5.

[6] Measured NH_3 concentrations within the study area are only available from the Marapong monitoring station.

2 REGULATORY REQUIREMENTS AND ASSESSMENT CRITERIA

2.1 Minimum Emission Standards

Activities associated with the proposed Project will trigger the Listed Activity - Category 1: Combustion Installations, under the NEM Air Quality Act of 2004 (AQA) (Government Gazette No. 37054 published on 22 November 2013).

Table 2-1 provides the requirements as set out in the published Listed Activities and Associated Minimum Emission Standards for Subcategory 1.1: Solid fuel combustion installation. Note that "New plant" relates per definition to all installations applying for authorisation in terms of the National Environmental Management Act 1998, (Act No.107 of 1998), made on or after 1 April 2010. "Existing plant" includes operations legally authorised to commence before 1 April 2010 or any plant where an application for authorisation in terms of the National Environmental Management Act, 1998 (Act No.107 of 1998), was made before 01 April 2010. It is therefore understood that the Medupi Power Station would have to comply with "existing plant" standards until 1 April 2020, where the more stringent "new plant" standards would be applicable.

The minimum emission standards apply to normal operating conditions. Should normal start-up, maintenance, upset and shut-down conditions exceed a period of 48 hours, Section 30 of NEMA (as amended) shall apply unless otherwise stipulated by the Licensing Authority.

Section 30 of NEMA states that; the cause and effect of the incident needs to be reported, within 14 days, to the Director-General, provincial head of department and municipality. Reasonable measures to contain, minimise and remedy the effects of the incident are required and an assessment of the immediate and long-term effects undertaken as soon as reasonably practical.

Table 2-1: Subcategory 1.1: Solid fuel combustion installations

Description:	Solid fuels (excluding biomass) combustion installations used primarily for steam raising or electricity generation.		
Application:	All installations with design capacity equal to or greater than 50 MW heat input per unit, based on the lower calorific value of the fuel used.		
Substance or mixture of substances		**Plant status**	**mg/Nm³ under normal conditions of 10% O_2, 273 K and 101.3 kPa**
Common name	**Chemical symbol**		
Particulate matter	N/A	New	50
		Existing	100
Sulphur dioxide	SO_2	New	500
		Existing	3500
Oxides of nitrogen	NO_x expressed as NO_2	New	750
		Existing	1100

(a) The following special arrangements shall apply –

(i) Continuous emission monitoring of PM, SO_2 and NO_x is required.

Additional Listed Activities that will be undertaken at the Medupi Power Station include Subcategory 2.4: Storage and Handling of Petroleum Products and Subcategory 5.1: Storage and Handling of Coal and Ore.

2.2 National Ambient Air Quality Standards for Criteria Pollutants

The 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 are intended to provide safe hourly, daily and annual exposure levels for the majority of the population, including the very young and the elderly, throughout an individual's lifetime.

The South African Bureau of Standards (SABS) was engaged to assist the Department of Environmental Affairs (DEA) in the facilitation of the development of ambient air quality standards. This included the establishment of a technical committee to oversee the development of standards. National Ambient Air Quality Standards (NAAQS) were determined based on international best practice for $PM_{2.5}$, PM_{10}, SO_2, NO_2, carbon monoxide (CO), ozone (O_3), lead (Pb) and benzene (C_6H_6) (Table 2-2).

Table 2-2: National Ambient Air Quality Standards

Pollutant	Averaging Period	Concentration (µg/m³)	Permitted Frequency of Exceedance	Compliance Date
Benzene (C_6H_6)	1 year	5	0	1 January 2015
Carbon Monoxide (CO)	1 hour	30000	88	Immediate
	8 hour[(a)]	10000	11	Immediate
Lead (Pb)	1 year	0.5	0	Immediate
Nitrogen Dioxide (NO_2)	1 hour	200	88	Immediate
	1 year	40	0	Immediate
Ozone (O_3)	8 hour[(b)]	120	11	Immediate
$PM_{2.5}$	24 hour	65	4	Immediate till 31 December 2015
	24 hour	40	4	1 January 2016 till 31 December 2029
	24 hour	25	4	1 January 2030
	1 year	25	0	Immediate till 31 December 2015
	1 year	20	0	1 January 2016 till 31 December 2029
	1 year	15	0	1 January 2030
PM_{10}	24 hour	75	4	1 January 2015
	1 year	40	0	1 January 2015
Sulfur Dioxide (SO_2)	10 minutes	500	526	Immediate
	1 hour	350	88	Immediate
	24 hour	125	4	Immediate
	1 year	50	0	Immediate

Notes:
(a) Calculated on 1 hour averages.
(b) Running average.

2.3 Code of Practice for Air Dispersion Modelling in Air Quality Management in South Africa, 2014

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. Regulations Regarding Air Dispersion Modelling was published in Government Gazette No. 37804 (11 July 2014), and recommends 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. This code of practice was followed in the current assessment.

2.4 Waterberg-Bojanala Priority Area

The Medupi Power Station falls within the Waterberg-Bojanala Priority Area (Figure 2-1). Under the National Environmental Management: Air Quality Act (Act No. 39 of 2004), airshed priority areas can be declared where there is concern of elevated atmospheric pollutant concentrations within the area. The DEA identified the potential of an airshed priority area in the vicinity of the Waterberg District Municipality (Government Gazette, Number 33600; 8 October 2010). This was later expanded to include the Bojanala Platinum District Municipality, North-West Province (Government Gazette, Number 34631; 30 September 2011) and the Waterberg-Bojanala Priority Area (WBPA) was officially declared on 15th June 2012 (Government Gazette, Number 35435).

Figure 2-1: Location of the Medupi Power Station within the Waterberg-Bojanala Priority Area (Scott, 2012)

The Waterberg-Bojanala Priority Area Air Quality Management Plan: Baseline Characterisation was released for public comment on the 7th August 2014 (SAAQIS, 2014, access date: 2014-08-21). The Baseline Characterisation of the WBPA reported that power generation activities contribute 95% of SO_2, 93% of NO_2 and 68% of the particulate emissions across the Waterberg District Municipality.

3 DESCRIPTION OF THE RECEIVING/BASELINE ENVIRONMENT

3.1 Air Quality Sensitive Receptors

Given that the Project will be associated with low level emissions (e.g. from ashing operations) and elevated emissions (power station stacks), the proposed Project has the potential of impacting on receptors in the near and medium fields[7].

Residential areas in the vicinity of the proposed operations include Marapong northeast of the existing Matimba Power Station, a residential settlement to the northwest of Matimba Power Station and Lephalale situated to the southeast and east of the existing power station respectively. Farm households are scattered through the area, with livestock farming (primarily cattle and game) representing the main agricultural land-use in the area. The closest schools, hospitals and clinics included in the study area are indicated in Figure 3-1.

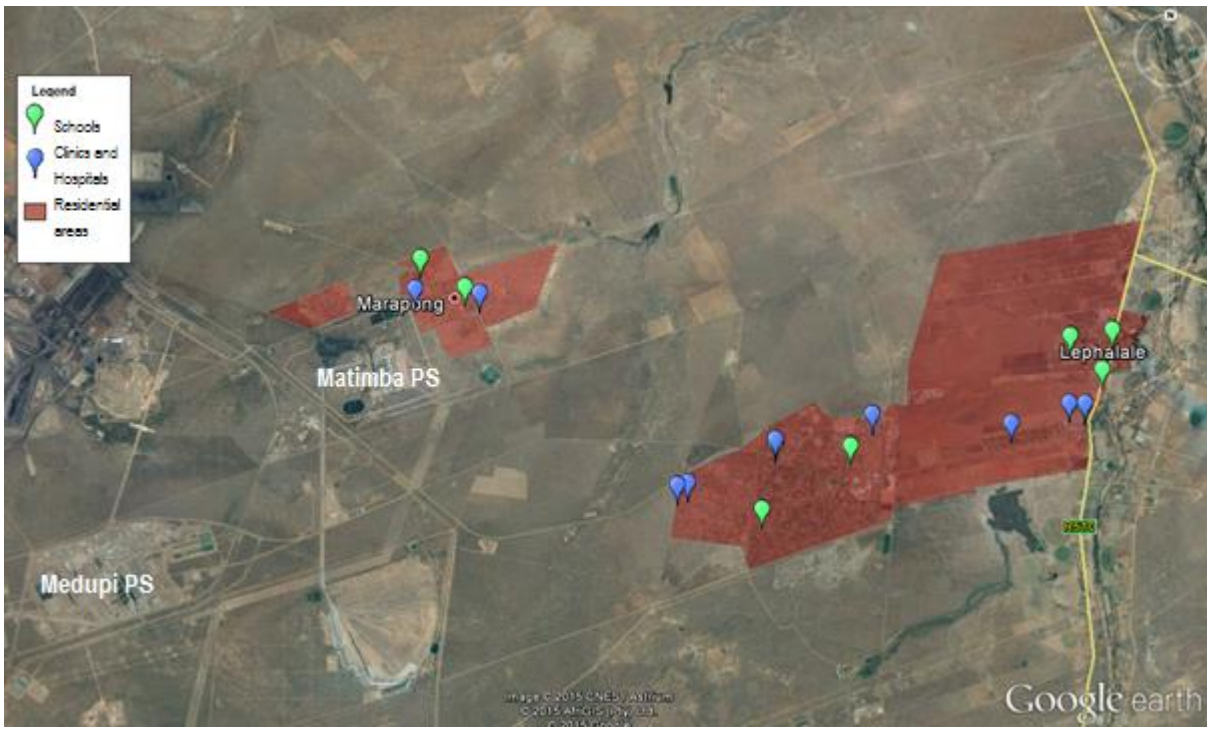

Figure 3-1: Location of sensitive receptors in the vicinity of the Medupi Power Station

3.2 Atmospheric Dispersion Potential

In the assessment of the possible impacts from air pollutants on the surrounding environment and human health, a good understanding of the regional climate and local air dispersion potential of a site is essential. Meteorological characteristics of a site govern the dispersion, transformation and eventual removal of pollutants from the atmosphere (Pasquill and Smith, 1983; Godish, 1990). The extent to which pollution will accumulate or disperse in the atmosphere is dependent on the degree of thermal and mechanical turbulence within the earth's boundary layer as well as advection.

Dispersion comprises vertical and horizontal components of motion. The vertical component is defined by the stability of the atmosphere and the depth of the surface mixing layer. The horizontal dispersion of pollution in the boundary layer is primarily a function of the wind field. The wind speed determines both the distance of downwind transport and the rate of dilution as a

[7] Near field would constitute as a distance of 0 km to 1 km from the operations and medium field as 1 km to 20 km from operations.

result of plume 'stretching'. The generation of mechanical turbulence is similarly a function of the wind speed, in combination with the surface roughness.

The wind direction and its variability, determine the general path pollutants will follow, and the extent of cross-wind spreading (Shaw and Munn, 1971; Pasquill and Smith, 1983; Oke, 1990).

Pollution concentration levels fluctuate in response to changes in atmospheric stability, to concurrent variations in the mixing depth, and to shifts in the wind field. Spatial variations, and diurnal and seasonal changes, in the wind field and stability regime are functions of atmospheric processes operating at various temporal and spatial scales (Goldreich and Tyson, 1988). Atmospheric processes at macro- and meso-scales need therefore be taken into account in order to understand the atmospheric dispersion potential of a particular area.

3.2.1 Surface Wind Field

In characterising the dispersion potential of the site, reference was made to calculated MM5 meteorological data (extracted at the Medupi Power Station site) for the period 2011-2013.

Period, day- and night-time wind roses for the study area are illustrated in Figure 3-2.

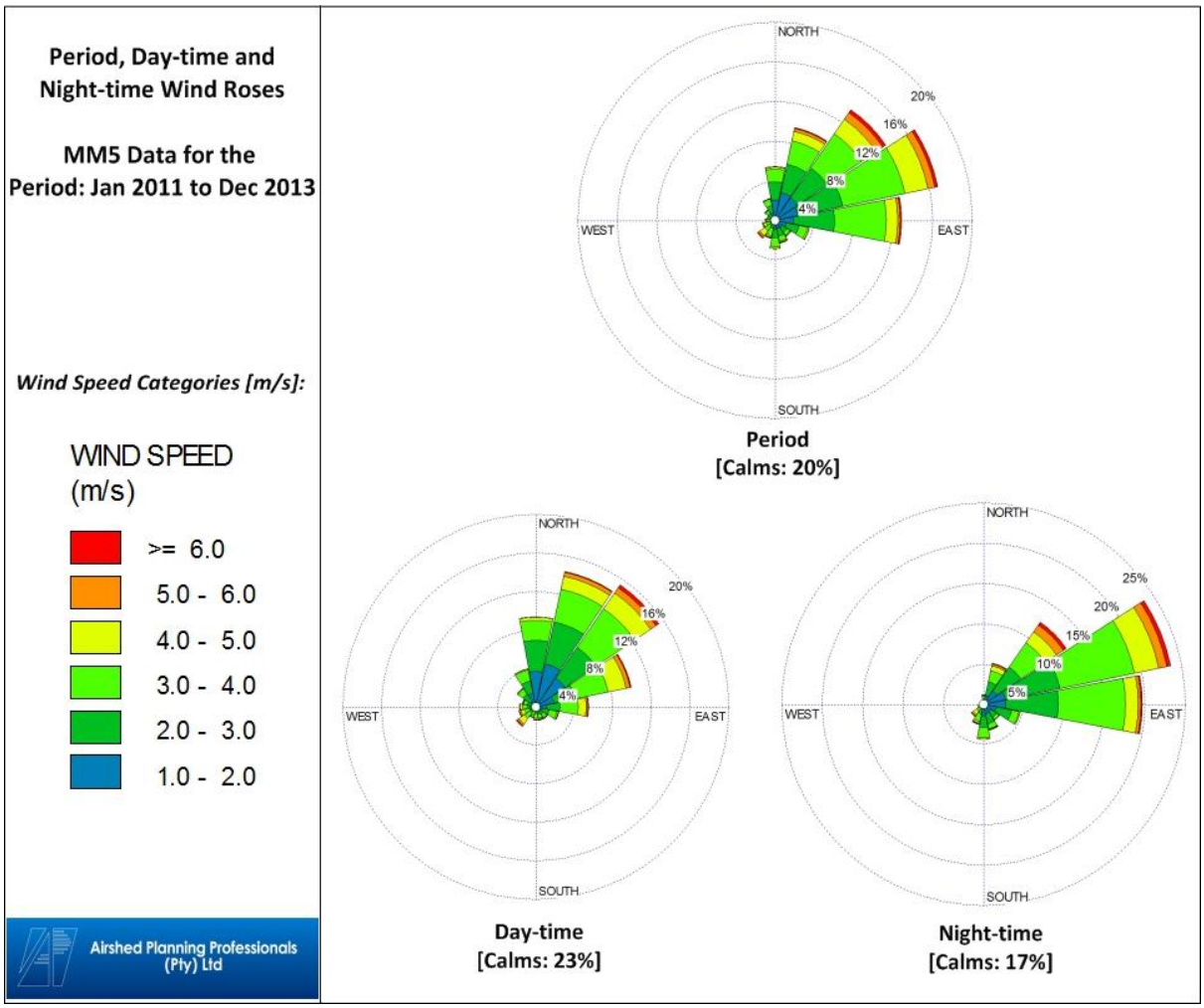

Figure 3-2: Period, day- and night-time wind roses for the period 2011-2013

Wind roses represent wind frequencies for the 16 cardinal wind directions. Wind frequencies are indicated by the length of the shaft when compared to the circles drawn to represent frequency of occurrence. Wind speed classes are assigned to illustrate the frequencies of high and low wind for each wind vector. The frequency of calm periods, defined as periods for which wind speeds are below 1 m/s, are indicated below the wind rose.

The flow field is dominated by north-easterly winds. Winds are infrequently experienced from the westerly and southerly sectors. The wind speeds are generally low (1-3 m/s) to moderate (3-5 m/s) throughout the period.

3.2.2 Temperature

A summary of the monthly diurnal temperature averages of the Medupi Power Station site (as extracted from MM5 data) is provided in Figure 3-3.

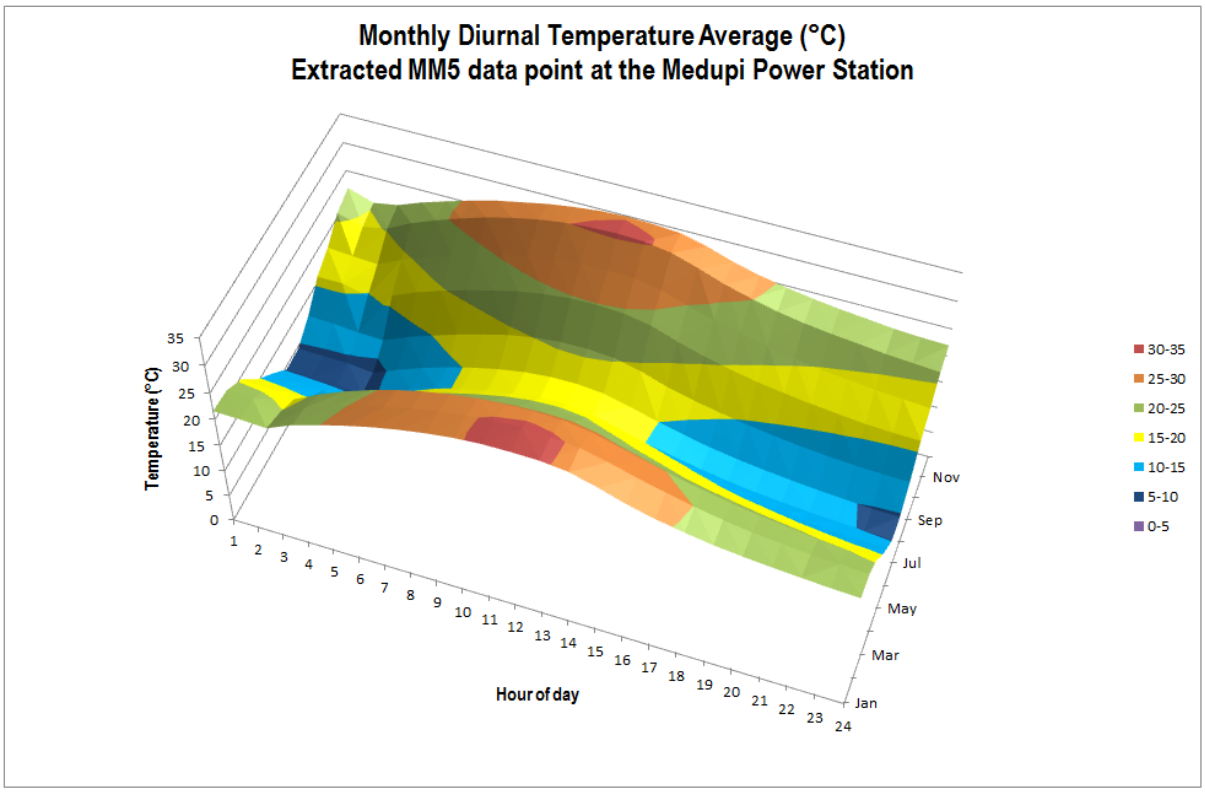

Figure 3-3: Monthly diurnal temperature averages for the Medupi Power Station Site (as extracted from MM5 data)

3.2.3 Atmospheric Stability

The vertical component of dispersion is a function of the extent of thermal turbulence and the depth of the surface mixing layer. Unfortunately, the mixing layer is not easily measured, and must therefore often be estimated using prognostic models that derive the depth from some of the other parameters that are routinely measured, e.g. solar radiation and temperature. During the daytime, the atmospheric boundary layer is characterised by thermal turbulence due to the heating of the earth's surface and the extension of the mixing layer to the lowest elevated inversion. Radiative flux divergence during the night usually results in the establishment of ground based inversions.

Atmospheric stability is frequently categorised into one of six stability classes. These are briefly described in Table 3-1.

Table 3-1: Atmospheric Stability Classes

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

The atmospheric boundary layer is normally unstable during the day as a result of the turbulence due to the sun's heating effect on the earth's surface. The thickness of this mixing layer depends predominantly on the extent of solar radiation, growing gradually from sunrise to reach a maximum at about 5-6 hours after sunrise. This situation is more pronounced during the winter months due to strong night-time inversions and a slower developing mixing layer. During the night a stable layer, with limited vertical mixing, exists. During windy and/or cloudy conditions, the atmosphere is normally neutral.

3.3 Status Quo Ambient Air Quality

3.3.1 Atmospheric Emissions

Source types present in the area and the pollutants associated with such source types are noted with the aim of identifying pollutants that may be of importance in terms of cumulative impact potentials.

Existing sources of atmospheric emissions which occur in the vicinity of the proposed development sites include:

- Matimba Power Station and its associated ash dump;
- Coal mining operations;
- Brickworks operating at Hanglip;
- Household fuel combustion;
- Potential veld fires (infrequent);
- Sewage works (Farm Nelsonskop);
- Windblown dust from open areas and agricultural activities;
- Vehicle exhaust releases and road dust entrainment along paved and unpaved roads in the area.

Emissions from the Matimba Power Station are simulated together with the Medupi Power Station in order to determine resultant cumulative concentrations of key pollutants such as SO_2 and NO_2.

3.3.1.1 Matimba Power Station

The existing Matimba Power Station is a dry-cooled, coal-fired pulverised fuel power station comprising six 665 MW units, representing a total nominal capacity of 3990 MW and a total net maximum capacity of 3690 MW.

Air pollutants released by coal-fired power stations primarily include particulates, SO_2, NO_x, carbon monoxide, carbon dioxide (CO_2), nitrous oxide (N_2O), and trace amounts of mercury. CO_2 and N_2O represent greenhouse gases (i.e. gases associated

with global warming) and are therefore of concern despite not resulting in direct health effects. Air pollutants associated with health effects include SO_2, NO_x (primarily as NO_2) and particulates. South African coals have relatively high ash contents and therefore hold the potential for releasing significant particulate emissions. Eskom however currently implements highly effective particulate abatement technology which reduces its particulate emission concentrations substantially. No SO_2 or NO_2 abatement measures are currently in place at the existing Matimba Power Station.

3.3.1.2 Coal Mining Operations

Open-cast coal mining operations, such as that undertaken at Grootgeluk, are frequently significant sources of fugitive dust emissions, particularly if poorly controlled. Sources of fugitive dust include operations such as drilling, blasting, dragline and/or truck and shovel activities, in addition to vehicle entrainment and materials handling operations. Depending on the type of explosives used, blasting operations are also associated with gaseous emissions, e.g. nitrogen oxides, carbon monoxide and smaller quantities of sulphur dioxide. Gaseous and particulate emissions may also occur as a result of spontaneous combustion of coal discards and dumps.

3.3.1.3 Sewage Works

Volatile organic compounds (VOCs) emissions are associated with wastewater treatment works. Species measured at local works have included: hydrogen sulphide, mercaptans, ammonia, formaldehyde, acetone, toluene, ethyl benzene, xylenes, perchloroethylene (tetrachloroethylene), butyric acid, propionic acid, valeric acid and acetic acid. Species that represent the most important odorants included: hydrogen sulphide, mercaptans, ammonia, and various fatty acids (butyric, propionic, valeric and acetic).

3.3.1.4 Household Fuel Burning

Within the Waterberg District Municipality, 92% and 95% of cooking and space heating respectively in rural areas is undertaken by means of wood and paraffin as an energy source (StatsSA, 2011).

Domestic coal burning emits a large amount of gaseous and particulate pollutants including sulphur dioxide, heavy metals, total and respirable particulates including heavy metals and inorganic ash, carbon monoxide, polycyclic aromatic hydrocarbons, and benzo(a)pyrene. Polyaromatic hydrocarbons are recognised as carcinogens. Pollutants arising due to the combustion of wood include respirable particulates, nitrogen dioxide, carbon monoxide, polycyclic aromatic hydrocarbons, particulate benzo(a)pyrene and formaldehyde. Particulate emissions from wood burning within South Africa have been found to contain about 50% elemental carbon and about 50% condensed hydrocarbons (Terblanche et al., 1992). The main pollutants emitted from the combustion of paraffin are NO_2, particulates, carbon monoxide and polycyclic aromatic hydrocarbons.

3.3.1.5 Veld Burning

Biomass burning is an incomplete combustion process with carbon monoxide, methane and nitrogen dioxide being emitted during the process. About 40% of the nitrogen in biomass is emitted as nitrogen, 10% remains in the ashes and it is assumed that 20% of the nitrogen is emitted as higher molecular weight nitrogen compounds. Unlike N species, only small amount of sulphur dioxide and sulphate aerosols are emitted. The visibility of smoke plumes from vegetation fires is due to their aerosol content (Helas and Pienaar, 1996).

The extent of emissions from veld burning is dependent on the quantity of material (biomass) available for combustion. The quantity of dry, combustible matter per unit area is on average 4.5 ton per hectare for savannah areas.

Crop-residue burning and general wild fires (veld fires) represent significant sources of combustion-related emissions associated with agricultural areas. Given that livestock agriculture prevails in the Lephalale area, it is anticipated that general wild fires are likely to be more important than controlled burning related to agricultural activities. Fires are however reported to occur relatively infrequently in the area (Scorgie et al, 2006).

3.3.1.6 Vehicle Exhaust Emissions

Air pollution from vehicle emissions may be grouped into primary and secondary pollutants. Primary pollutants are those emitted directly into the atmosphere, and secondary, those pollutants formed in the atmosphere as a result of chemical reactions, such as hydrolysis, oxidation, or photochemical reactions. The significant primary pollutants emitted by motor vehicles include CO_2, CO, hydrocarbons (HCs), SO_2, NO_x, particulates and lead. Secondary pollutants include: NO_2, photochemical oxidants (e.g. ozone), HCs, sulphur acid, sulphates, nitric acid, sulphates, nitric acid and nitrate aerosols. Toxic hydrocarbons emitted include benzene, 1.2-butadiene, aldehydes and polycyclic aromatic hydrocarbons (PAH). Benzene represents an aromatic HC present in petrol, with 85% to 90% of benzene emissions emanating from the exhaust and the remainder from evaporative losses.

3.3.1.7 Fugitive Dust Emissions

Fugitive dust emissions may occur as a result of vehicle entrainment of dust from local paved and unpaved roads, wind erosion from open areas and dust generated by agricultural activities (e.g. tilling). The extent, nature and duration of agricultural activities, the moisture and silt content of soils and the extent of open areas is required to be known in order to quantify fugitive emissions from this source. The quantity of windblown dust is similarly a function of the wind speed, the extent of exposed areas and the moisture and silt content of such areas.

3.3.1.8 Brickworks operating at Hanglip

Hendrik Pieterse, the owner of the farm Hanglip, runs the existing brickworks in the vicinity of the Medupi Power Station. The brickworks manufactures approximately 2 million bricks per month, fired by using veld ovens (clamp kilns). Firing by clamp is one of the oldest methods of brickmaking. Despite no longer being used in most parts of the world – having been replaced by coal- and gas-fired kiln operations – firing by clamp is still fairly widely used in South Africa.

The manufacturing of bricks involve quarry operations, crushing, screening, blending of raw materials, and the forming of, cutting or shaping, drying or curing, and firing of the final product. Emissions from brick manufacturing facilities (EPA 1997) include particulate matter (PM_{10} and $PM_{2.5}$), SO_2, sulphur trioxide (SO_3), NO_x, CO, CO_2, total organic compounds (TOC) (including methane, ethane, VOC and some hazardous air pollutants (HAP), hydrochloric acid and fluoride compounds). Other factors that may influence emissions are raw material composition and moisture content as well as firing parameters and fuel type.

The primary sources of particulate matter are material handling (grinding, drying, screening and storing), fuel handling and fugitive dust sources such as paved roads, unpaved roads and storage piles. The combustion products (SO_2, NO_x, CO, CO_2) are emitted from fuel combustion during firing. The main source of SO_2 emissions is the raw materials that sometimes contain sulphur compounds. The organic compounds (methane, ethane, VOC and HAP) are emitted from the firing and drying

processes. Hydrogen fluoride (HF) is emitted as a result of the fluorine compounds contained in the raw materials (where applicable).

3.3.1.9 Trans-Boundary Transportation of Air Masses over Southern Africa

The two main transport modes of air masses consist of direct transport, in which air masses are advected directly from the subcontinent to the oceans beyond, and re-circulated transport, in which air masses re-circulates to the point of origin (Tyson et al., 1996a, Tyson et al., 1996c) (Figure 3-4). Direct transport is made up of the four cardinal compass directions, viz. westerly, easterly, northerly and southerly. Westerly transport (within the Natal Plume) is influenced by the westerly waves (Fishman, 1991; Pickering et al., 1994; Krishnamurti et al., 1993; Benkovitz et al., 1994; Tyson et al., 1996a, Tyson et al., 1996b) moving air from the highveld to the Indian Ocean at north-to-central Kwa-Zulu Natal or southern Mozambique (Tyson et al., 1996a). Air transported in the Natal Plume takes place at high levels of ~525 hPa (Tyson et al., 1996a). Easterly transport takes place by means of easterly waves to move air masses to the Atlantic Ocean. Air masses that move towards the Atlantic Ocean are transported in the Angolan Plume at low levels due to the subsidence over the western subcontinent and South Atlantic Ocean. Northerly and southerly transport moves air masses to equatorial Africa and to the South Indian Ocean respectively (Tyson et al., 1996a).

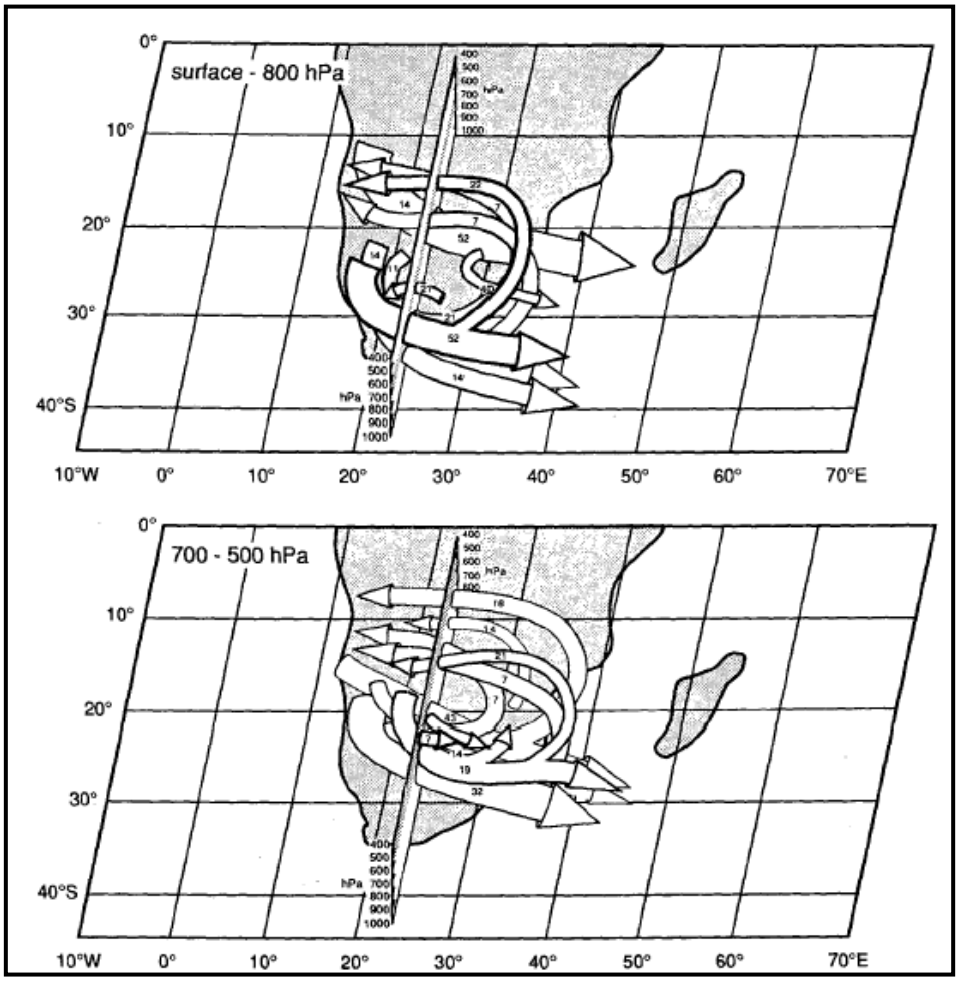

Figure 3-4: Schematic representation of major low-level transport trajectory models likely to result easterly or westerly exiting of material from southern African or in recirculation over the subcontinent (Tyson et al, 1996c)

Re-circulated transport is confined to levels of less than 200 hPa and is mainly anticyclonic (Tyson et al., 1996a). Local and regional recirculation extends over the highveld and surrounding neighbouring countries, such as Mozambique, Zimbabwe and Botswana (Tyson et al., 1996a; Tyson and Gatebe, 2001). Analysis of trajectory fields undertaken by Tyson et al. (1996c) has revealed that air masses emanating from a particular point of origin follow anticyclonic curving streams with radii of 500 – 700 km. The recirculation vortex is evident from the surface to the persistent stable layer of 500 hPa. Above 500 hPa, due to the influence of the circumpolar westerlies, recirculation diminishes rapidly and transport patterns become more zonal. Local and sub-continental re-circulation over the interior makes up for ~44% of total air mass transportation (Tyson et al., 1996c; Tyson and Gatebe, 2001) with a recirculation time frame of 2-9 days (Tyson et al., 1996a). Up to a quarter of re-circulated air masses are observed to re-circulate a second time (Tyson et al., 1996c). Thus, the greatest impact of pollutants on neighbouring countries is under re-circulating air and prolonged residence time (Tyson et al., 1996a).

More than 75% of all air circulating over the southern African continent exits to the Indian Ocean, either by direct or re-circulated transportation (Tyson and Gatebe, 2001).

3.3.2 Measured Ambient Air Pollutant Concentrations

3.3.2.1 Monitoring Stations Operated by the Department of Environmental Affairs

The DEA has ambient monitors to measure the ambient air quality in the Waterberg area. These ambient monitoring stations are located at Lephalale, Mokopane and Thabazimbi. The closest DEA monitoring station, with sufficient data, to the proposed Project is in Lephalale (~12 km east). The measured NO_2, PM_{10}, $PM_{2.5}$ and SO_2 short-term ground level concentrations from the Lephalale monitoring station for the period January 2013 to November 2014 are provided in Figure 3-5 to Figure 3-9 (as obtained from SAAQIS, 2014). A summary of the data availability and compliance with NAAQS is provided in Table 3-2.

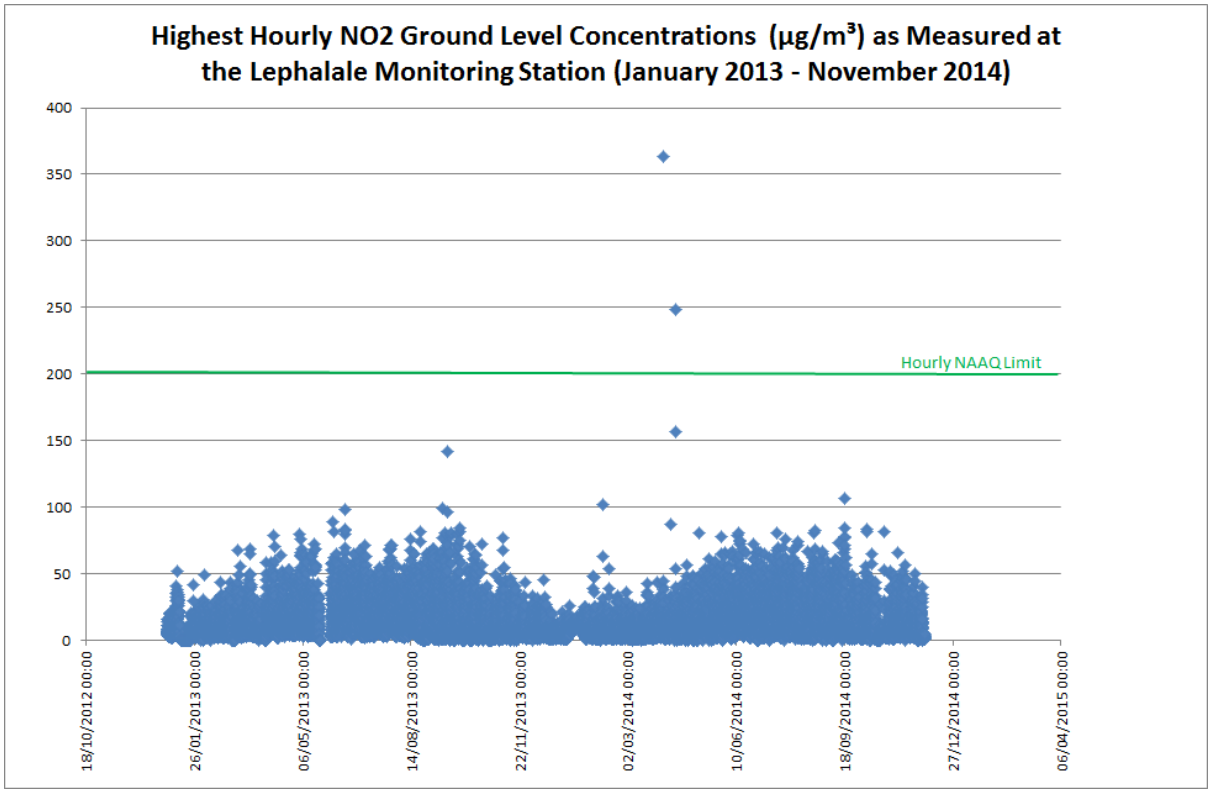

Figure 3-5: Hourly NO_2 measured at the Lephalale monitoring station for the period January 2013 to November 2014

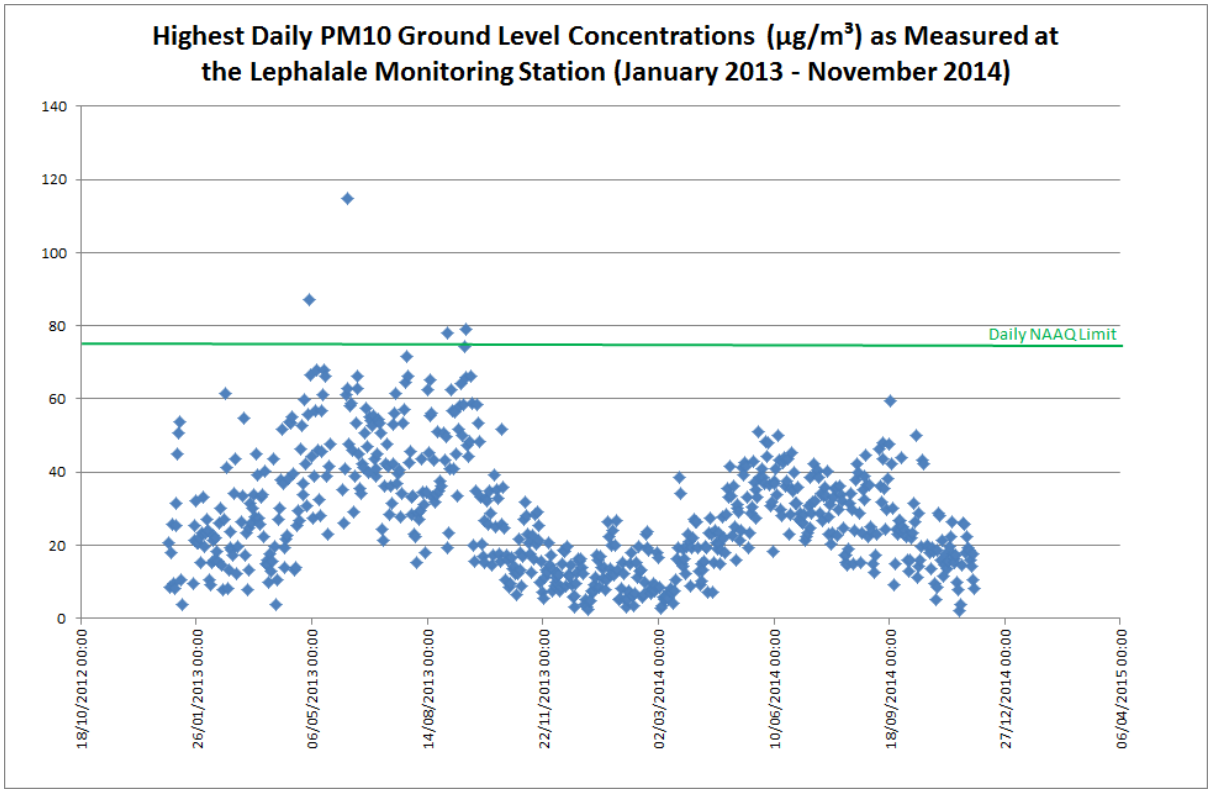

Figure 3-6: Daily PM_{10} measured at the Lephalale monitoring station for the period January 2013 to November 2014

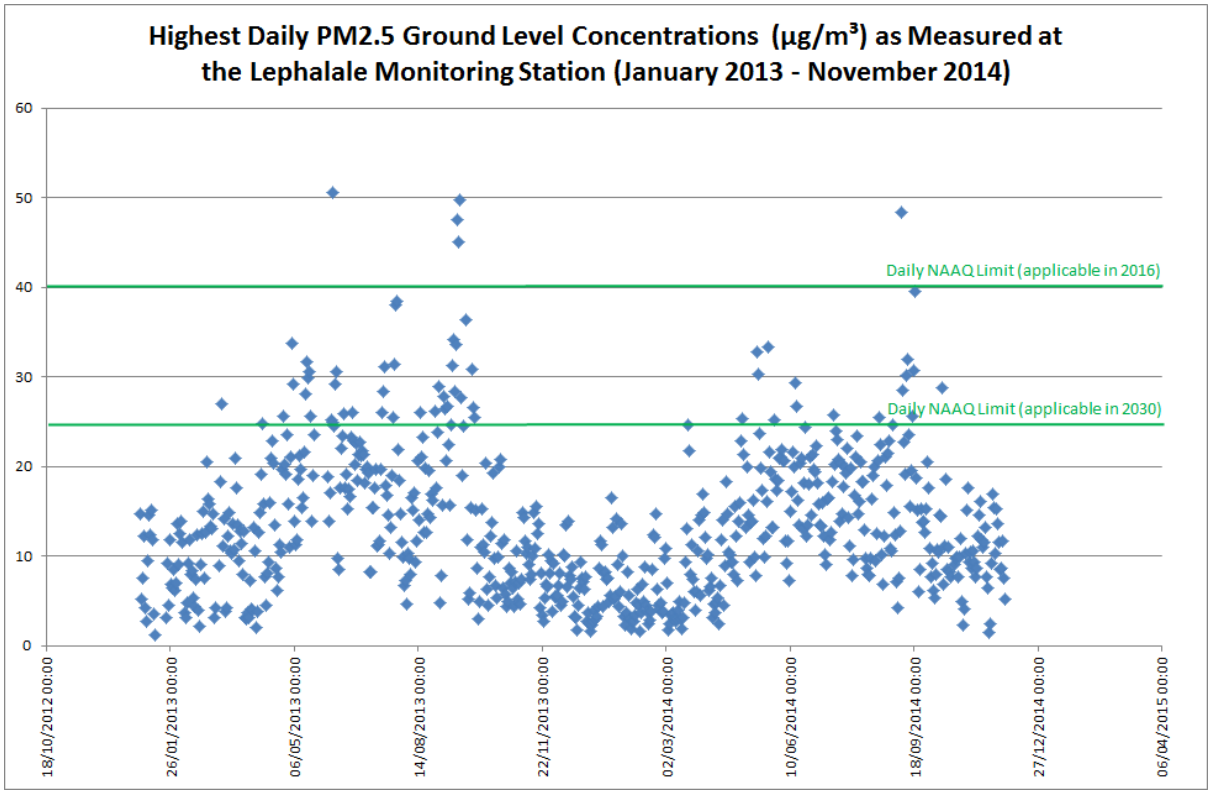

Figure 3-7: Daily $PM_{2.5}$ measured at the Lephalale monitoring station for the period January 2013 to November 2014

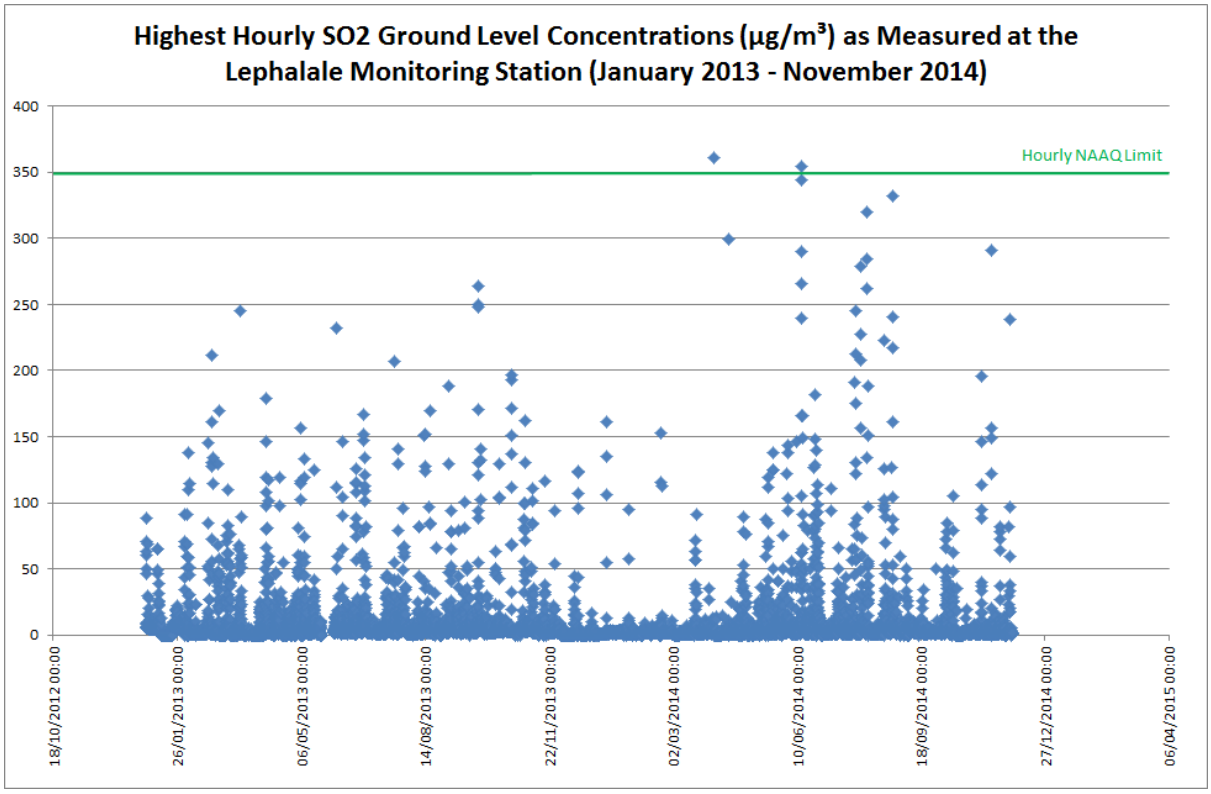

Figure 3-8: Hourly SO_2 measured at the Lephalale monitoring station for the period January 2013 to November 2014

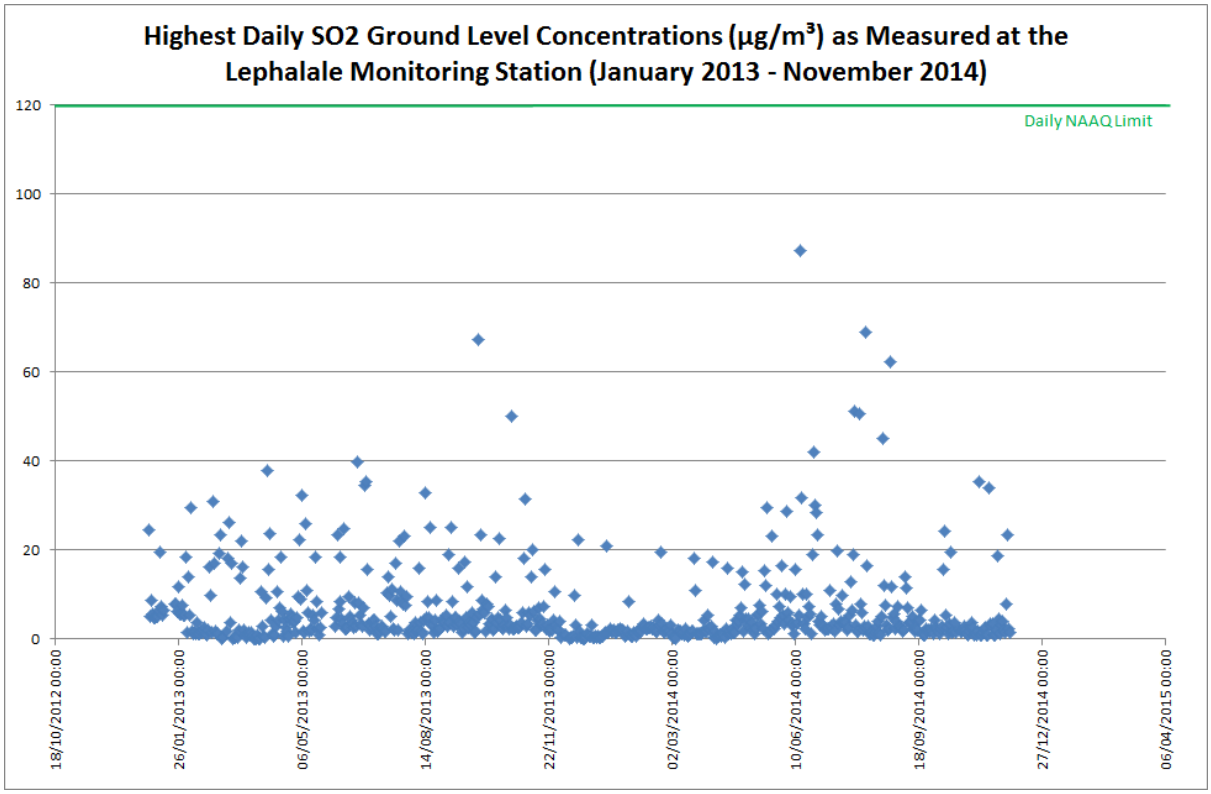

Figure 3-9: Daily SO_2 measured at the Lephalale monitoring station for the period January 2013 to November 2014

Table 3-2: Summary of the data availability and compliance with NAAQS for the ambient data measured at Lephalale

Pollutant	Monitoring Period	Data Availability (%)	Frequency of Exceedance of Hourly NAAQ Limit	Frequency of Exceedence of Daily NAAQ Limit	Annual Average Ground Level Concentrations (µg/m³)	Within Compliance with NAAQS (Y/N)
SO_2	2013	93	0	0	7	Y
	2014	96	2	0	6	Y
NO_2	2013	93	0		14	Y
	2014	98	2		13	Y
PM_{10}	2013	93	NA	4	32	Y
	2014	98	NA	0	23	Y
$PM_{2.5}$	2013	93	NA	0 (a)	14	Y
			NA	4 (b)		Y
			NA	40 (c)		N
	2014	98	NA	0 (a)	12	Y
			NA	1 (b)		Y
			NA	17 (c)		N

NA: Not applicable

(a) Applicable immediately till 31 December 2015

(b) Applicable from 1 January 2016 till 31 December 2029

(c) Applicable from 1 January 2030

The measured SO_2, NO_2 and PM_{10} concentrations are within NAAQS at Lephalale for the period January 2013 to November 2014. The $PM_{2.5}$ concentrations measured at Lephalale are within the NAAQS applicable till 2029 but exceed the more stringent NAAQS applicable in 2030.

3.3.2.2 Monitoring Station Operated by Eskom

Eskom manages an ambient monitoring station located at Marapong. The measured NO_2, PM_{10}, $PM_{2.5}$ and SO_2 short-term ground level concentrations from the Marapong monitoring station for the period January 2013 to November 2014 are provided in Figure 3-10 to Figure 3-14. A summary of the data availability and compliance with NAAQS is provided in Table 3-3.

The data availability (with the exception of $PM_{2.5}$) is poor for the year 2014 and should be kept in mind when assessing the measured data for this period. The measured SO_2 and NO_2 concentrations are within NAAQS at Marapong for the period January 2013 to November 2014. The PM_{10} concentrations exceed the NAAQS at Marapong for the period 2013 and 2014. $PM_{2.5}$ concentrations at Marapong are within the NAAQS applicable till 2029 but exceed the more stringent NAAQS applicable in 2030.

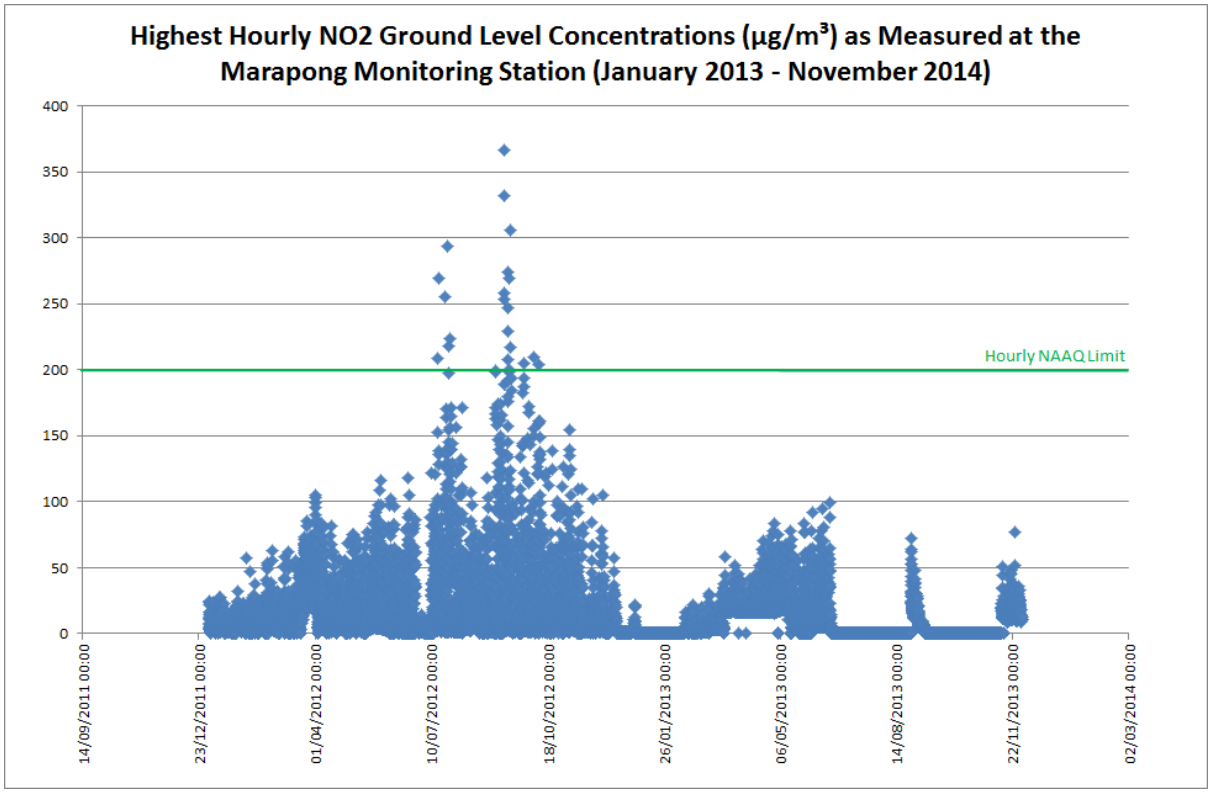

Figure 3-10: Hourly NO_2 measured at the Marapong monitoring station for the period January 2013 to November 2014

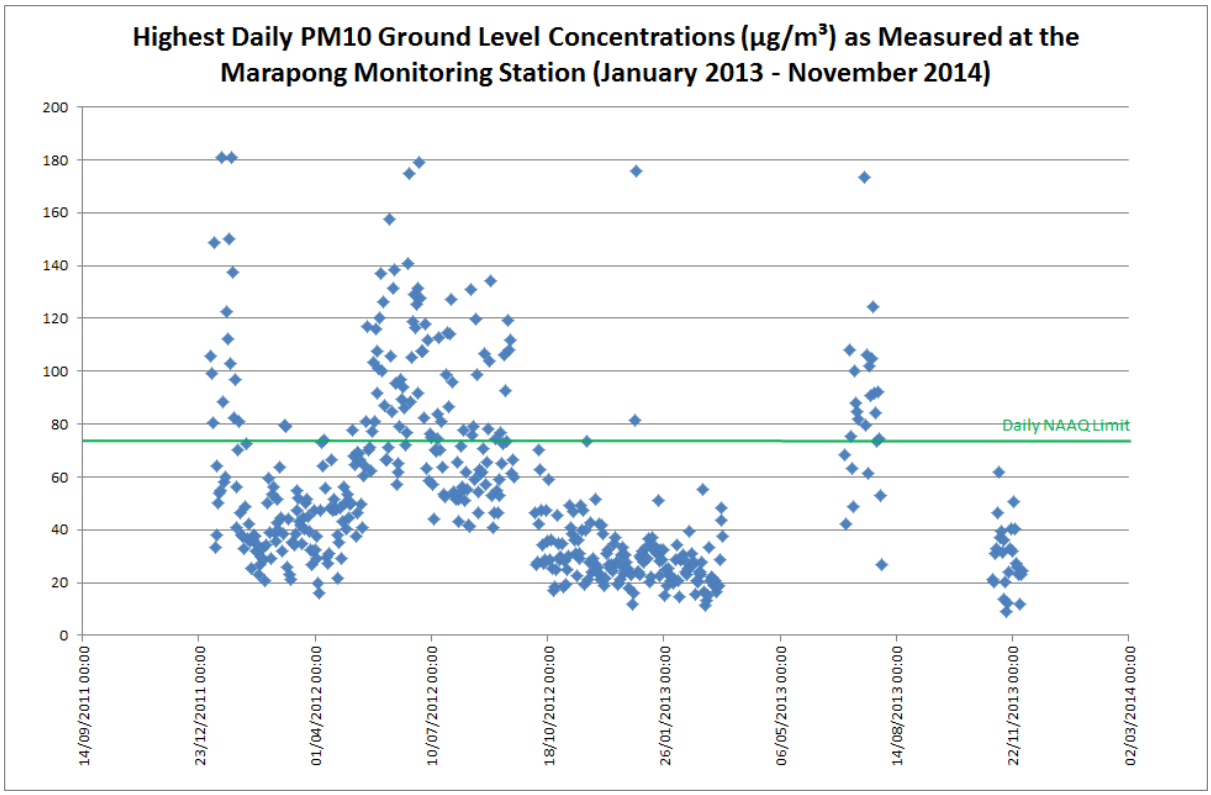

Figure 3-11: Daily PM_{10} measured at the Marapong monitoring station for the period January 2013 to November 2014

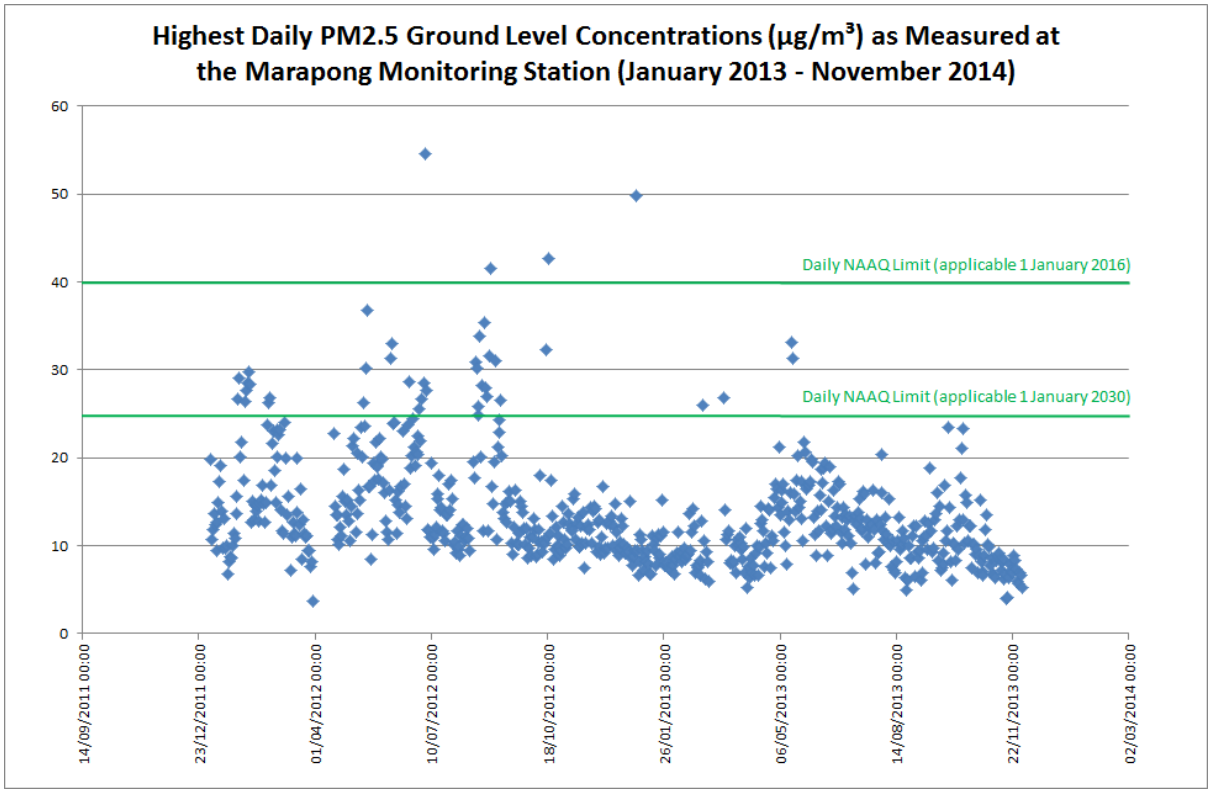

Figure 3-12: Daily $PM_{2.5}$ measured at the Marapong monitoring station for the period January 2013 to November 2014

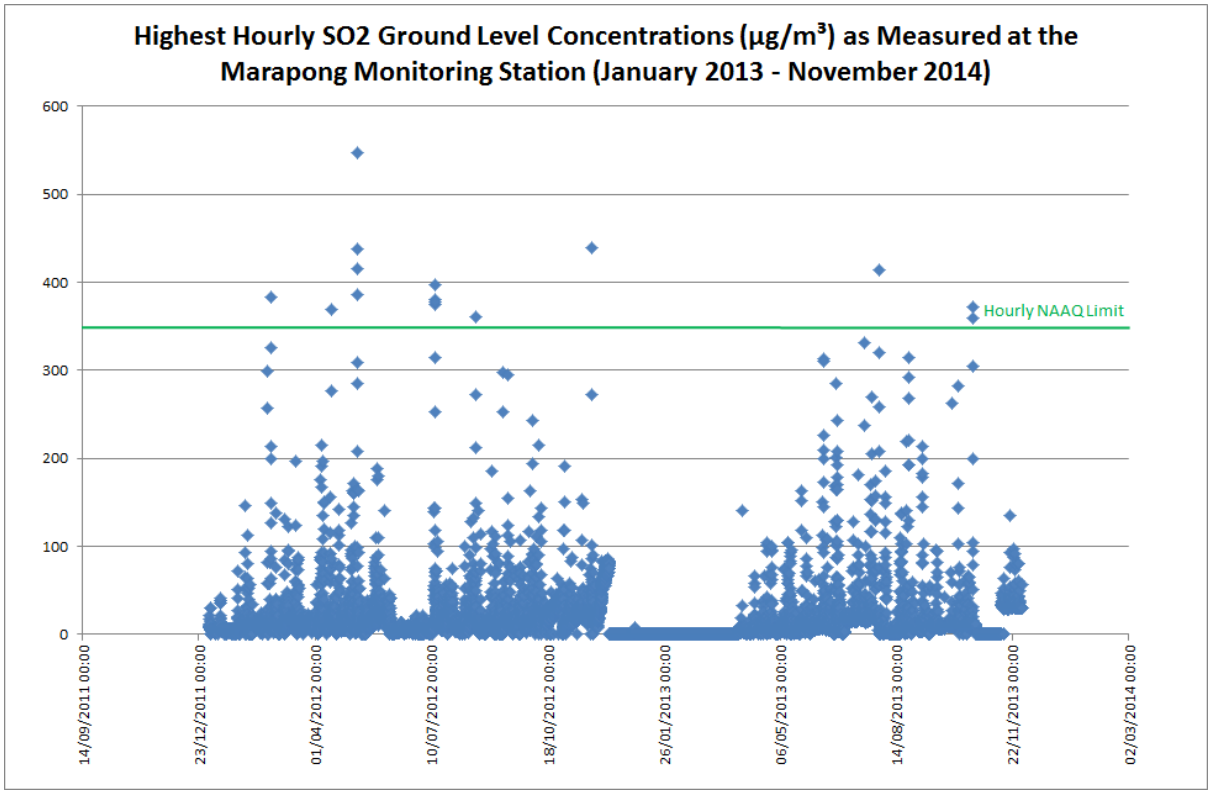

Figure 3-13: Hourly SO_2 measured at the Marapong monitoring station for the period January 2013 to November 2014

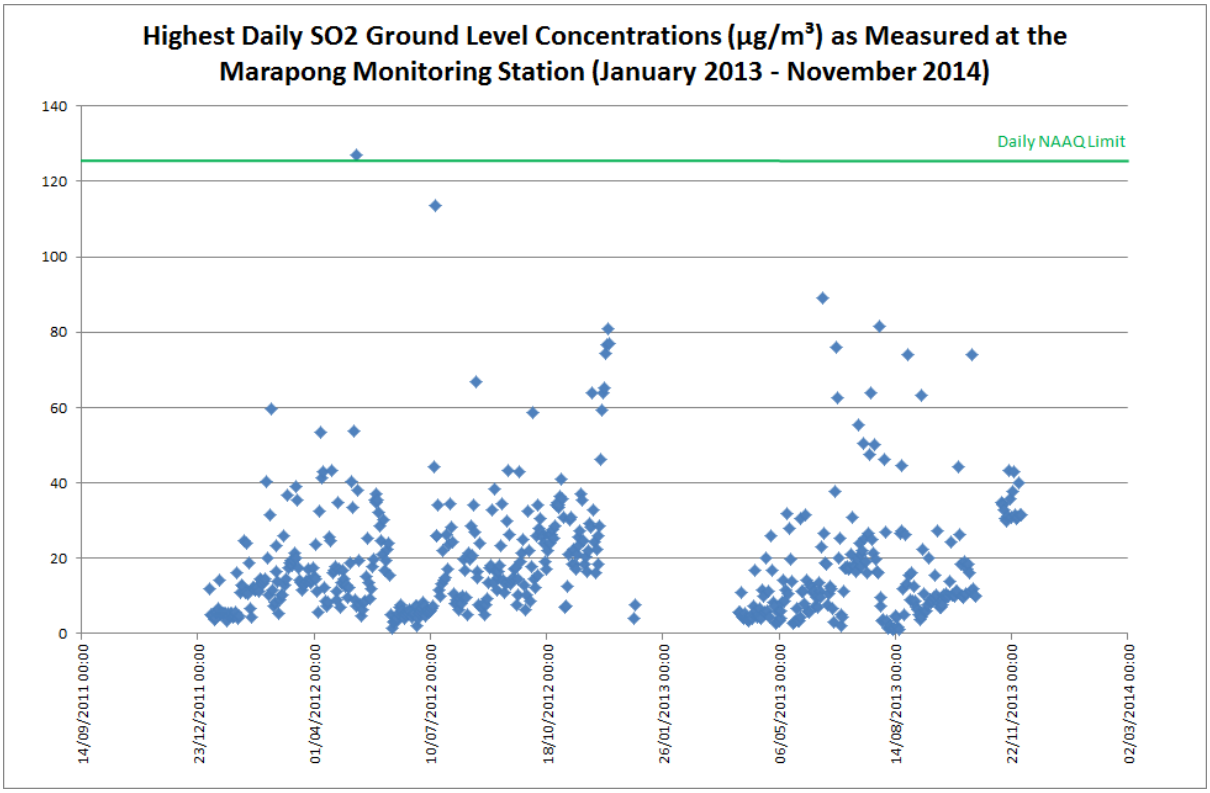

Figure 3-14: Daily SO_2 measured at the Marapong monitoring station for the period January 2013 to November 2014

Table 3-3: Summary of the data availability and compliance with NAAQS for the ambient data measured at Marapong

Pollutant	Monitoring Period	Data Availability (%)	Frequency of Exceedence of Hourly NAAQ Limit	Frequency of Exceedence of Daily NAAQ Limit	Annual Average Ground Level Concentrations (µg/m³)	Within Compliance with NAAQS (Y/N)
SO_2	2013	92	12	1	19	Y
	2014	66	3	0	17	Y
NO_2	2013	98	21		18	Y
	2014	47	0		15	Y
PM_{10}	2013	94	NA	87	59	N
	2014	36		18	40	N
$PM_{2.5}$	2013	90		0 (a)	15	Y
				3 (b)		Y
				34 (c)		N
	2014	94		0 (a)	11	Y
				1 (b)		Y
				5 (c)		N

NA: Not applicable

(a) Applicable immediately till 31 December 2015

(b) Applicable from 1 January 2016 till 31 December 2029

(c) Applicable from 1 January 2030

3.3.3 Simulated Ambient Air Pollutant Concentrations

The baseline air quality impact assessment consisted of two scenarios:

- 2014 Baseline: Matimba Power Station operations, and
- 2020 Baseline: Matimba Power Station operations and Medupi Power Station operations including all six units without FGD.

3.3.3.1 Emissions Inventory

Matimba Power Station and Associated Ash Facility

The main source of emissions from the Matimba Power Station comprises two stacks. Source parameters for these sources, required for input to the dispersion modelling study, include stack height and diameter, gas exit velocity and gas exit temperature. Such information was obtained from the air quality impact assessment study undertaken for the Medupi Power Station and is provided in Table 3-4 (Scorgie et al, 2006).

Table 3-4: Stack parameters for the Matimba Power Station

Number of Stacks	Height (m)	Diameter (m)	Exit Velocity (m/s)	Temperature (°K)
2	250	12.82	24.84	405

Estimated emission rates for SO_2, NO_x, and PM, were obtained from the Matimba Atmospheric Impact Report completed in 2014 and are provided in Table 3-5. Although emissions were provided as total particulates released, such emissions were assumed to comprise primarily of PM_{10} given the abatement measures in place (coarser particles readily removed) and as a conservative approach $PM_{2.5}$ for assessment of this pollutant.

Table 3-5: Annual emissions (in tonnes) for the Matimba Power Station operating conditions (as obtained from the Matimba Atmospheric Impact Report (Zunckel & Raghunandan, 2014))

Compound	Quantity (tpa)
SO_2	309 262
NO_x	67 592
PM	4 904

A fugitive source of particulate emissions (in the form of wind erosion) from the Matimba Power Station operations is the ash disposal facility. Wind erosion is a complex process, including three different phases of particle entrainment, transport and deposition. It is primarily influenced by atmospheric conditions (e.g. wind, precipitation and temperature), soil properties (e.g. soil texture, composition and aggregation), land-surface characteristics (e.g. topography, moisture, aerodynamic roughness length, vegetation and non-erodible elements) and land-use practice (e.g. farming, grazing and mining) (Shao, 2008).

Windblown dust is generated 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, the wind shear at the surface must exceed the gravitational and cohesive forces acting upon them, called the threshold friction velocity (Shao, 2008).

Saltation and suspension are the two modes of airborne particles in the atmosphere. The former relates to larger sand particles that hop and can be deposited as the wind speed reduces or changes. Suspension refers to the finer dust particles that remain suspended in the atmosphere for longer and can disperse and be transported over large distances. It should be noted that wind erosion involves complex physics that is not yet fully understood (Shao, 2008).

Airshed has developed an in-house wind erosion model called ADDAS (Burger & Held, 1997; Burger, 2010). This model, developed for specific use by Eskom in the quantification of fugitive emissions from its ash dumps, is based on the dust emission model proposed by (Marticorena & Bergametti, 1995)[8]. The model attempts to account for the variability in source erodibility through the parameterisation of the erosion threshold (based on the particle size distribution of the source) and the roughness length of the surface. In the quantification of wind erosion emissions, the model incorporates the calculation of two important parameters, viz. the threshold friction velocity of each particle size, and the vertically integrated horizontal dust flux, in the quantification of the vertical dust flux (i.e. the emission rate).

Significant emissions arise due to the mechanical disturbance of granular material from open areas. Parameters which have the potential to impact on the rate of emission of fugitive dust include the extent of surface compaction, moisture content, ground cover, the shape of the storage pile, particle size distribution, wind speed and precipitation. Any factor that binds the erodible material, or otherwise reduces the availability of erodible material on the surface, decreases the erosion potential of the fugitive source. High moisture contents, whether due to precipitation or deliberate wetting, promote the aggregation and cementation of fines to the surfaces of larger particles, thus decreasing the potential for dust emissions. Surface compaction and ground cover similarly reduce the potential for dust generation. The shape of a disposal dump influences the potential for dust emissions through the alteration of the airflow field. The particle size distribution of the material on the disposal site is important since it determines the rate of entrainment of material from the surface, the nature of dispersion of the dust plume, and the rate of deposition, which may be anticipated (Burger, 1994; Burger et al., 1995).

An hourly emissions file was created for each source group, i.e. the topsoil and ash sections of the ash dump. The calculation of an emission rate for every hour of the simulation period was carried out using the ADDAS model.

The particle size distribution used in the simulations as obtained from the previous Medupi air quality impact assessment (Scorgie et al, 2006) is provided in Table 3-6.

Table 3-6: Particle size distribution for the ash dump

Size (µm)	Fraction
600	0.0472
404.21	0.0269
331.77	0.0296
272.31	0.0336
223.51	0.0404
183.44	0.0503
150.57	0.0609
123.59	0.0687
101.44	0.0728
83.26	0.0739
68.33	0.072
56.09	0.0669

[8] The applicability of the Marticorena and Bergametti methodology used in ADDAS for use in impact assessments was demonstrated in a PhD thesis (Liebenberg-Enslin, 2014).

Size (µm)	Fraction
46.03	0.0607
37.79	0.0537
31.01	0.0471
25.46	0.0407
17.15	0.0628
14.08	0.0528
7.78	0.0285
3.53	0.0105

Medupi Power Station and Associated Ash Disposal Facility

Sources associated with the construction phase of the Medupi Power Station are discussed in the air quality study undertaken in 2006 (Scorgie et al, 2006). The focus of this study, therefore, investigates the potential impacts due to Medupi Power Station operations only.

The main source of emissions from the Medupi Power Station comprises two stacks. For the 2020 baseline conditions, the Medupi Power Station without FGD is assessed (emissions provided in Table 3-7), with the Matimba Power Station operations (emissions provided above).

Table 3-7: Stack parameters for the Medupi Power Station[(a)]

Scenario	Number of Stacks	Height (m)	Diameter (m)	Exit Velocity (m/s)	Temperature (°K)
Medupi Power Station without FGD	2	220	15.4	15.81	410

(a) Parameters and emissions provided by Eskom personnel

Emission rates for SO_2, NO_x, and PM, calculated on the basis of information provided by Eskom personnel, are presented in Table 3-8.

Table 3-8: Annual emissions (in tonnes) for Medupi Power Station operating conditions (as calculated based on information provided by Eskom personnel)

Scenario	Compound	Quantity (tpa)
Medupi Power Station without FGD	SO_2	449 396
	NO_x	85 670
	PM	5 711

Fugitive dust from the proposed ash dump was assumed to be similar to 2014 baseline operations with the methodological approach outlined in this Section having been applied. Only the locations at which the emissions occur are different, as will be reflected in the atmospheric dispersion simulation results. This source was assessed as an unmitigated operation (no controls in place) and as a mitigated operation (80% control efficiency in place through active re-vegetation and wetting).

3.3.3.2 Impact Assessment

Isopleth plots illustrating exceedance of the NAAQS are provided in Figure 3-15 to Figure 3-18. A synopsis of compliance with NAAQS for SO_2, NO_2, PM_{10} and $PM_{2.5}$ ground level concentrations occurring due to the 2014 baseline and 2020 baseline conditions is given in Table 3-9.

2014 Baseline Conditions

Simulated SO_2 ground level concentrations exceed NAAQS for hourly and daily averaging periods within the zone of maximum impact (i.e. southwest of the Matimba Power Station) (Figure 3-15 and Figure 3-16). The simulated SO_2 concentrations also exceeded the hourly NAAQ limit infrequently within the residential area of Marapong and the residential settlement to the northwest of the Matimba Power Station but were within the requirements of the NAAQS.

Simulated NO_2, PM_{10} and $PM_{2.5}$ concentrations are well within NAAQS at the closest identified sensitive receptors.

2020 Baseline Conditions

The area of non-compliance of the hourly and daily SO_2 NAAQS extends ~30km southwest of the Medupi Power Station due to the cumulative operations of Matimba Power Station and Medupi Power Station without FGD control (Figure 3-17 and Figure 3-18). Exceedances of the hourly and daily SO_2 NAAQS are simulated at the residential settlement to the northwest of the Matimba Power Station under these conditions.

The simulated NO_2 concentrations at the closest sensitive receptors are within NAAQS due to operations of Matimba Power Station and the Medupi Power Station without FGD (Table 3-9).

Simulated PM_{10} and $PM_{2.5}$ concentrations are similar in magnitude at the closest sensitive receptors (Table 3-9) due to operations of Matimba power Station and the Medupi Power Station with and without controls on the Medupi ash disposal facility and are well within NAAQS.

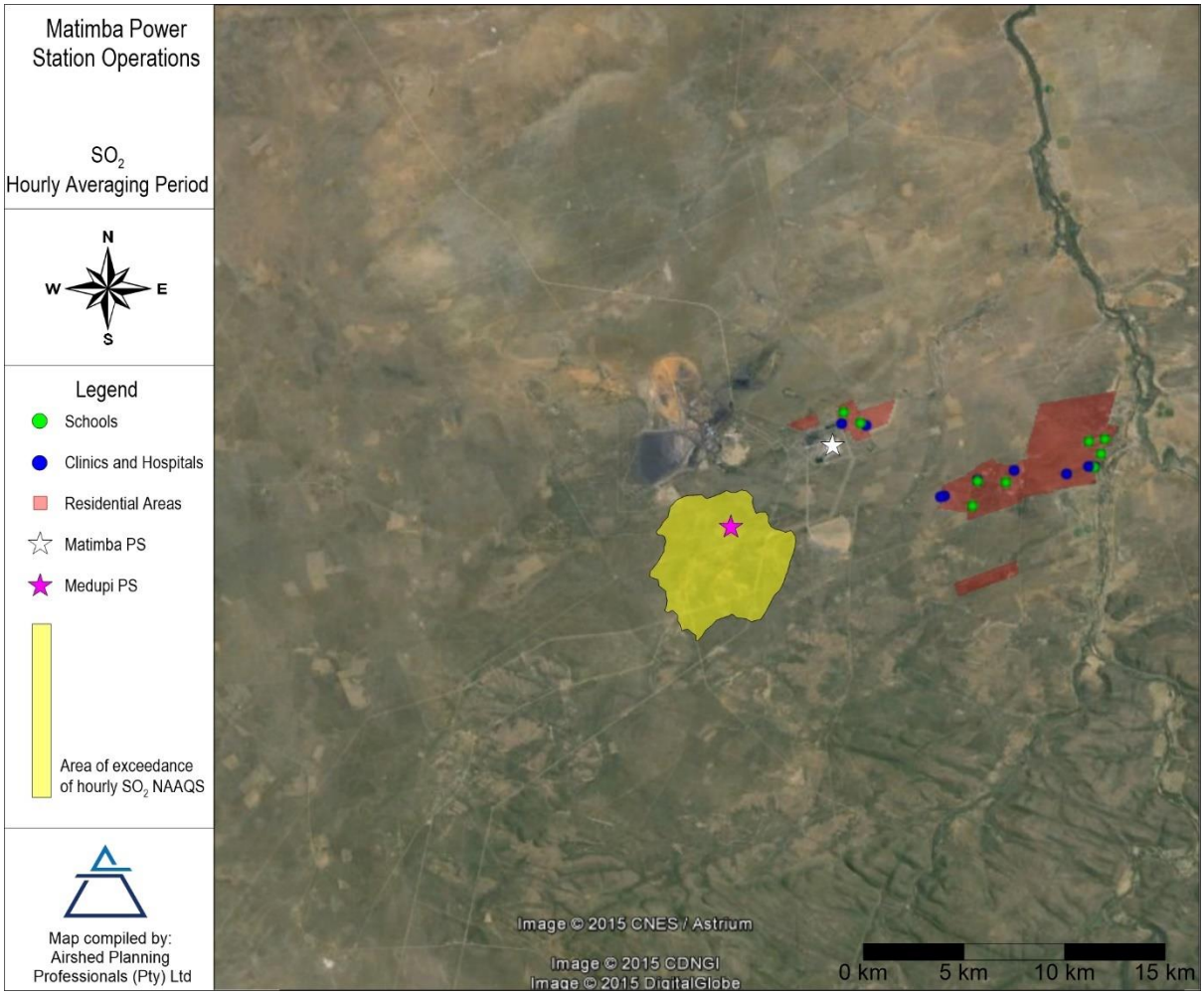

Figure 3-15: Area of exceedance of the hourly SO_2 NAAQS due to the 2014 baseline conditions

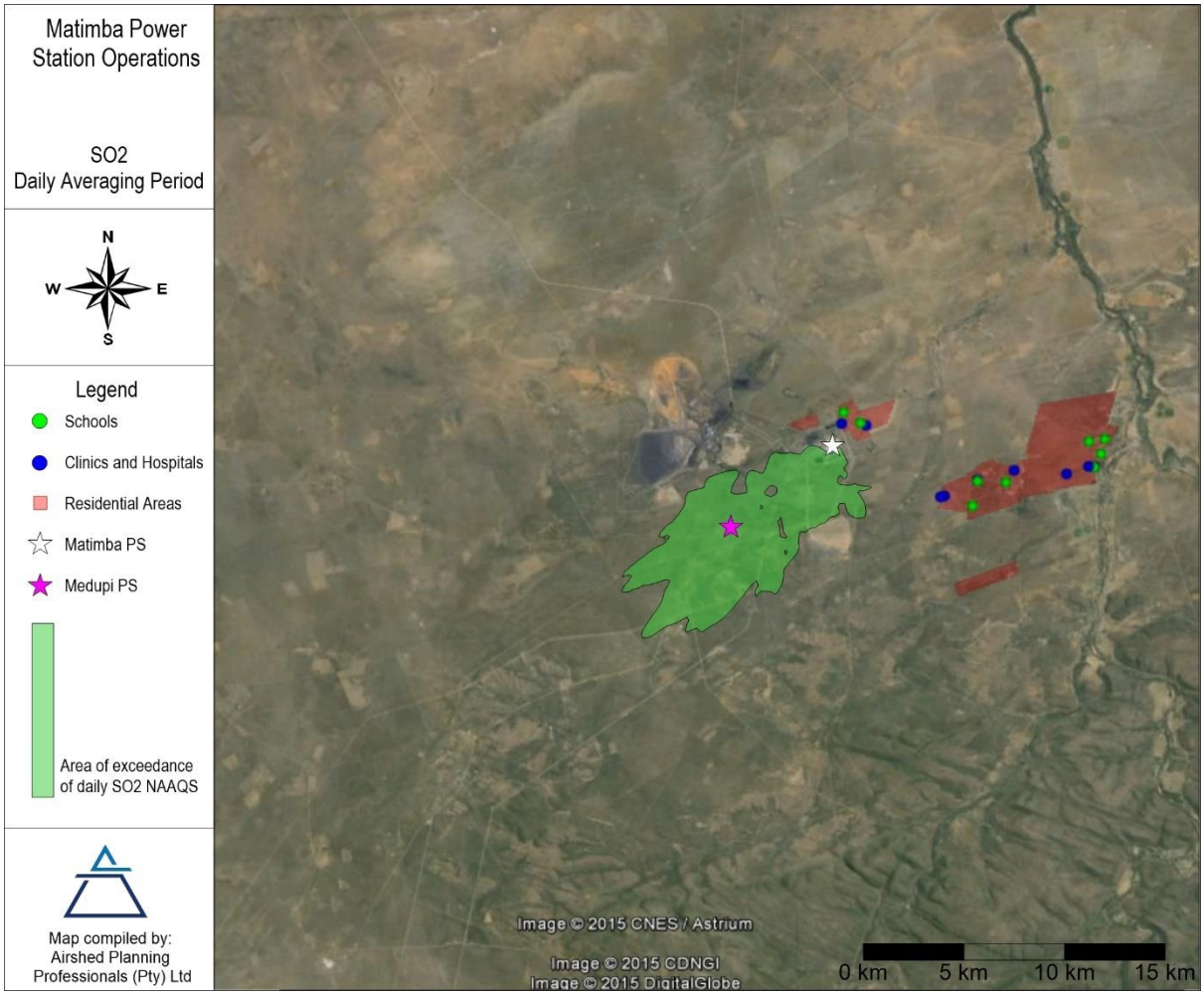

Figure 3-16: Area of exceedance of the daily SO_2 NAAQS due to the 2014 baseline conditions

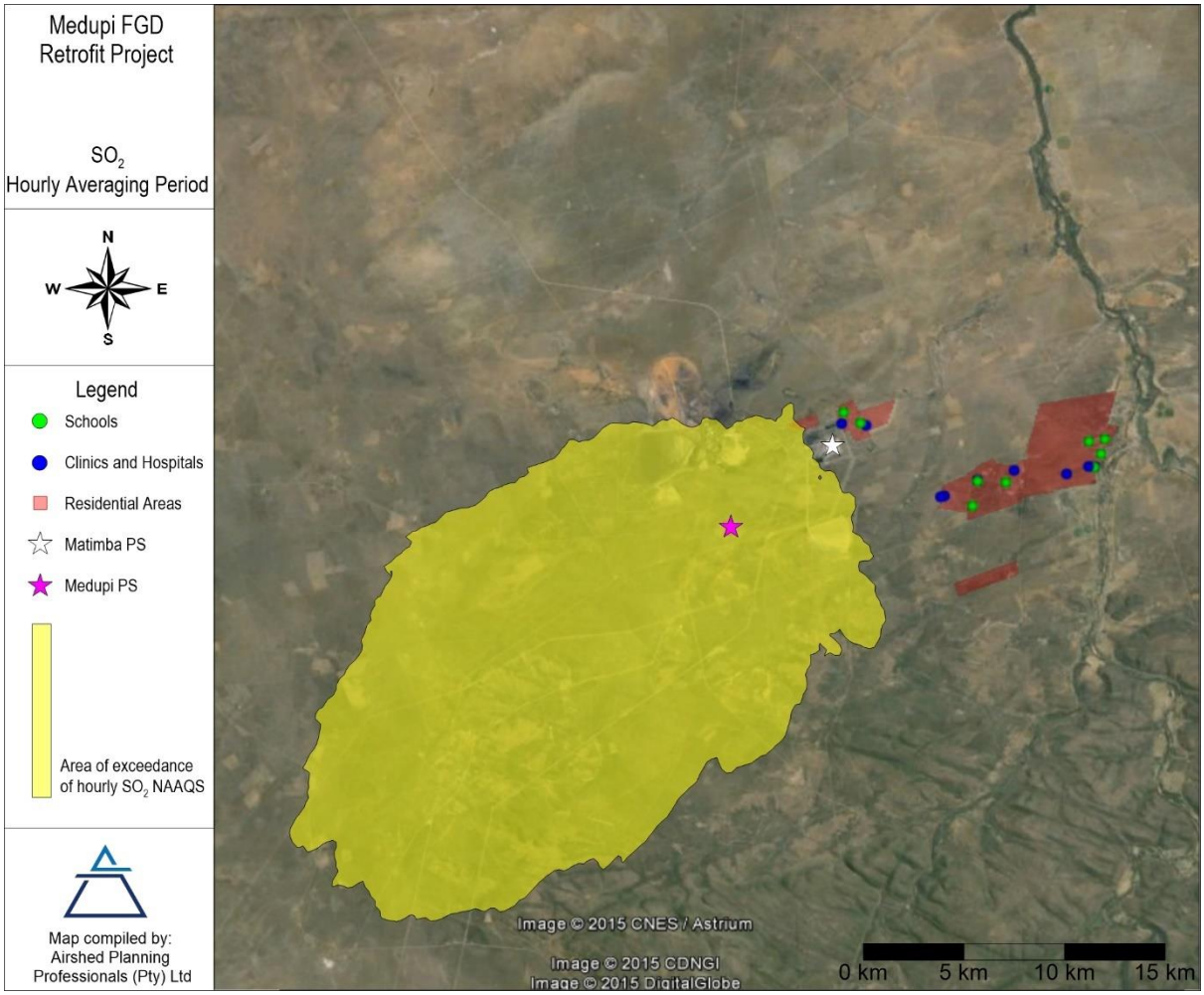

Figure 3-17: Area of exceedance of the hourly SO_2 NAAQS due to the 2020 baseline conditions

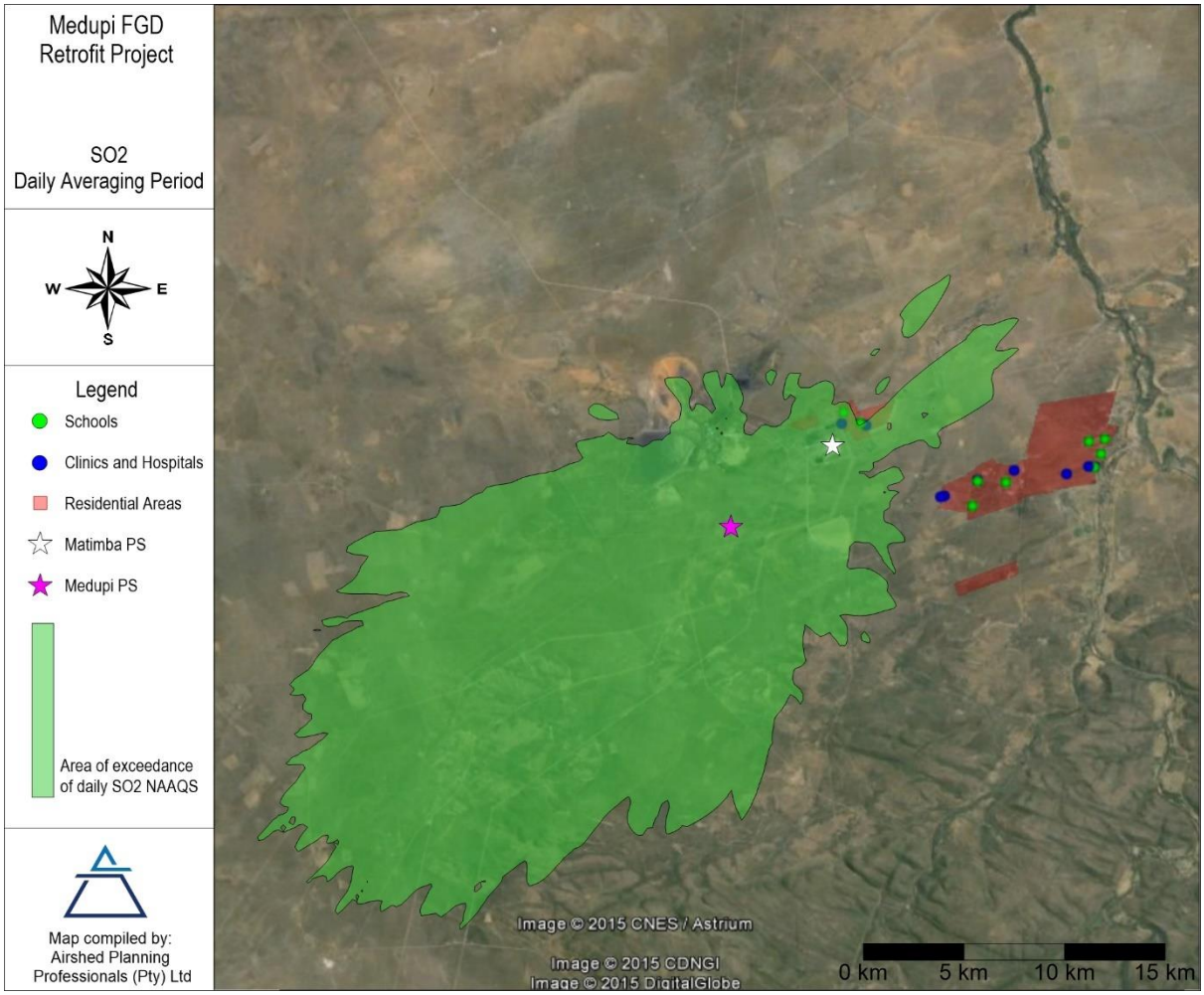

Figure 3-18: Area of exceedance of the daily SO_2 NAAQS due to the 2020 baseline conditions

Table 3-9: Simulated SO_2, NO_2, PM_{10} and $PM_{2.5}$ ground level concentrations at the closest sensitive receptors due to 2014 baseline and 2020 baseline operating conditions

Pollutant	Scenario	Receptor	Frequency of Exceedence of hourly NAAQ limit	Frequency of Exceedence of daily NAAQ limit	Annual Average Concentration (µg/m³)	Within PM_{10} NAAQS (Y/N)
SO_2	**2014 Baseline** (Matimba Power Station operations)	Settlement (NW of Matimba Power Station)	31	1	5.6	Y
		Marapong	22	2	4.3	Y
		Lephalale	24	1	4.2	Y
	2020 Baseline (Matimba Power Station operations and Medupi Power Station operations – all six units without FGD)	Settlement (NW of Matimba Power Station)	89	6	11.8	N
		Marapong	67	4	9.4	Y
		Lephalale	55	1	8.7	Y

Pollutant	Scenario	Receptor	Frequency of Exceedence of hourly NAAQ limit	Frequency of Exceedence of daily NAAQ limit	Annual Average Concentration (µg/m³)	Within PM_{10} NAAQS (Y/N)
NO_2	**2014 Baseline** (Matimba Power Station operations)	Settlement (NW of Matimba Power Station)	3	NA	1.0	Y
		Marapong	4	NA	0.7	Y
		Lephalale	1	NA	0.7	Y
	2020 Baseline (Matimba Power Station operations and Medupi Power Station operations – all six units without FGD)	Settlement (NW of Matimba Power Station)	9	NA	1.9	Y
		Marapong	4	NA	1.5	Y
		Lephalale	1	NA	1.4	Y
PM_{10}	**2014 Baseline** (Matimba Power Station operations)	Settlement (NW of Matimba Power Station)	NA	0	0.4	Y
		Marapong	NA	0	0.3	Y
		Lephalale	NA	0	0.3	Y
	2020 Baseline (Matimba Power Station operations and Medupi Power Station operations – all six units without FGD) - assuming no control on the proposed Medupi ash disposal facility	Settlement (NW of Matimba Power Station)	NA	0	0.7	Y
		Marapong	NA	0	0.6	Y
		Lephalale	NA	0	0.6	Y
	2020 Baseline (Matimba Power Station operations and Medupi Power Station operations – all six units without FGD) - assuming 80% control efficiency on the proposed Medupi ash disposal facility	Settlement (NW of Matimba Power Station)	NA	0	0.7	Y
		Marapong	NA	0	0.6	Y
		Lephalale	NA	0	0.6	Y
$PM_{2.5}$	**2014 Baseline** (Matimba Power Station operations)	Settlement (NW of Matimba Power Station)	NA	0	0.4	Y
		Marapong	NA	0	0.3	Y
		Lephalale	NA	0	0.3	Y

Pollutant	Scenario	Receptor	Frequency of Exceedence of hourly NAAQ limit	Frequency of Exceedence of daily NAAQ limit	Annual Average Concentration (µg/m³)	Within PM_{10} NAAQS (Y/N)
	2020 Baseline (Matimba Power Station operations and Medupi Power Station operations – all six units without FGD) - assuming no control on the proposed Medupi ash disposal facility	Settlement (NW of Matimba Power Station)	NA	0	0.7	Y
		Marapong	NA	0	0.6	Y
		Lephalale	NA	0	0.6	Y
	2020 Baseline (Matimba Power Station operations and Medupi Power Station operations – all six units without FGD) - assuming 80% control efficiency on the proposed Medupi ash disposal facility	Settlement (NW of Matimba Power Station)	NA	0	0.7	Y
		Marapong	NA	0	0.6	Y
		Lephalale	NA	0	0.6	Y

NA: Not applicable

3.3.4 Conclusions Regarding Baseline Air Quality

The following conclusions were drawn based on the monitored and modelled baseline air quality levels in the study region:

- SO_2 concentrations have been measured to infrequently exceed short-term NAAQ limits at the monitoring stations located at Marapong and Lephalale. Modelled SO_2 concentrations also indicate infrequent short-term exceedances of the NAAQ limits at these sensitive receptors. There is however compliance with the NAAQS.

- Currently, the Matimba Power Station is likely to be the main contributing source to the ambient SO_2 ground level concentrations in the study area due to the magnitude of its emissions. Other sources which may contribute significantly due to their low release level include: spontaneous combustion of coal discards associated with mining operations, clamp firing emissions during brickmaking at Hanglip and potentially household fuel burning within Marapong. The highest ground level SO_2 concentrations due to the Matimba Power Station stack emissions are expected to occur during unstable conditions, usually occurring during the day, when the plume is brought to ground in relatively close proximity to the power station.

- NO_2 concentrations have been measured to infrequently exceed short-term NAAQ limits (but are in compliance with NAAQS) at the monitoring stations located at Marapong and Lephalale, which is reiterated in the modelled results.

Low level sources of NO_x in the region include combustion within coal discard dumps, brick firing operations and possibly also household fuel burning and infrequent veld burning.

- Measured PM_{10} concentrations exceed the daily NAAQS at Marapong for the period 2014 but are lower at Lephalale (where levels comply with daily NAAQS). The measured $PM_{2.5}$ concentrations are within the daily NAAQS applicable till 2030 at Marapong and Lephalale, but exceed the more stringent daily NAAQS applicable in 2030. The annual average PM_{10} and $PM_{2.5}$ concentrations measured at Lephalale are within NAAQS. Measured annual PM_{10} concentrations at Marapong during the period 2013 exceed annual NAAQS.

- 2014 Baseline simulations:
    - The contribution of Matimba Power Station to primary and secondary particulates was simulated, with no exceedances of the SO_2, NO_2, PM_{10} and $PM_{2.5}$ NAAQS at Marapong and Lephalale. Secondary particulates form in the atmosphere through the conversion of SO_x and NO_x emissions to sulfate and nitrate.

- 2020 Baseline simulations:
    - The area of non-compliance with the hourly and daily SO_2 NAAQS extended ~30km southwest of the Medupi Power Station due to the cumulative operations of Matimba Power Station and Medupi Power Station without FGD control. Non-compliance with the hourly and daily SO_2 NAAQS was simulated at the residential settlement to the northwest of the Matimba Power Station under these conditions.

- Various local (informed through observation from site visits) and far-field (informed by literature) sources are expected to contribute to the suspended fine particulate concentrations in the region. Local dust sources include wind erosion from exposed areas, fugitive dust from mining and brickmaking operations, vehicle entrainment from roadways and veld burning. Household fuel burning may also constitute a local source of low-level emissions. Long-range transport of particulates emitted from remote tall stacks and from biomass burning in countries to the north of Republic of South Africa (RSA) and the accumulation and recirculation of such regional air masses over the interior is well documented (Andreae et al., 1996; Garstang et al., 1996; Piketh, 1996) (detail pertaining to the recirculation of air masses is provided in Section 3.3.1.9).

4 IMPACT OF PROPOSED PROJECT ON HUMAN HEALTH

The impact assessment for the proposed Project operations includes activities at the Medupi Power station; six units with FGD. To assess this impact with background concentrations in the area, the proposed Project operations have been considered with the Matimba Power Station operations. In order to understand the reduction in ambient SO_2 impacts that the proposed Project provides, the 2020 baseline activities (Matimba Power Station activities provided in Section 3.3.3 and Figure 3-17 and Figure 3-18) should be compared to the assessment provided in this section (Matimba Power Station activities with proposed Project operations) to realise the differential between the two scenarios.

4.1 Atmospheric Emissions

The emissions for the Matimba Power Station operations are provided in Section 3.3.3.1 and of the Medupi Power Station operations with FGD in Table 4-1.

Table 4-1: Stack parameters for the Medupi Power Station[(a)]

Scenario	Number of Stacks	Height (m)	Diameter (m)	Exit Velocity (m/s)	Temperature (°K)
Medupi Power Station with FGD	2	220	15.4	15.96	324

(a) Parameters and emissions provided by Eskom personnel

Emission rates for SO_2, NO_x, and PM, calculated on the basis of information provided by Eskom personnel, are presented in Table 4-2.

Table 4-2: Annual emissions (in tonnes) for Medupi Power Station operating conditions (as calculated based on information provided by Eskom personnel)

Scenario	Compound	Quantity (tpa)
Medupi Power Station with FGD	SO_2	71 605
	NO_x	85 670
	PM	5 711

The gypsum from the FGD activities is proposed to be mixed with the ash on the existing ash disposal facility. The gypsum material is expected to provide a crust when mixed with water. To what extent this material will crust will depend on how the material is disposed (i.e. mixed with the ash or deposited as layers of gypsum material in between the ash material) and how much water is added to the disposal facility. The crust may also be disturbed from time to time with activity on the disposal facility. It is therefore not possible to determine the effectiveness of the gypsum material in mitigating the windblown dust from this source. Fugitive dust from the proposed ash dump were therefore assumed to be similar to 2020 baseline operations with approach outlined in Section 3.3.3.1 having been applied.

Limestone will need to be transported to site for the FGD and the sludge and salts will be temporarily stored on a prepared waste storage facility prior to being transported from site to a licenced facility. The transport of the waste will be undertaken via trucks. The limestone will initially be transported via trucks but will later be transported via rail. The trips per day (as provided by the proponent) were given as 13 and 69 for waste (salts and sludge) and limestone respectively when all six units are operational. The calculated PM_{10} and $PM_{2.5}$ emissions as calculated using the US-EPA emission factor for paved roads was 2.95×10^{-5} g/s/m² and 7.15×10^{-6} g/s/m² respectively. As part of the air quality assessment, a qualitative assessment of the potential impacts from the road was requested and is provided in Section 4.2.

4.2 Impact Assessment

4.2.1 Qualitative Assessment

To provide an indication of the potential distance and significance of impacts from these activities, the US EPA screening model (Screen View version 3.5.0) is used. This model represents a quick method to calculate and "flag" the "worst-case" concentration that might occur. Screening models require very little input and have a built-in set of meteorological conditions based on stability classes. It is a quick screening tool to identify possible sources that might require more detailed modelling. It is important to note that these models do not use actual meteorological data, but rather set stability classes that will produce the highest impacts. The impacts are therefore not related to the actual wind directions or speeds. More sophisticated Gaussian plume and puff models such as the US EPA regulatory AERMOD and CALPUFF models use actual meteorological conditions. For the purpose of providing a professional opinion on the potential impacts from the road (due to vehicle entrainment), a screening model is sufficient as the focus is merely to provide an indication of the potential significance of the operations on the surrounding environment.

The output from the screening model is provided as highest hourly concentrations. In order to obtain the highest daily and annual average concentrations to compare to ambient air quality guidelines, equivalent concentrations were extrapolated. For extrapolating time averaging periods from 1 hour to 24 hours and 1 year, Beychock (2005) recommends the following equation:

$$C_x / C_p = \left(t_p / t_x \right)^{0.2}$$

where:

Cx and Cp are concentrations over any two averaging periods;
tx and tp are corresponding averaging times.

Figure 4-1 and Figure 4-2 provides a graphic representation of the possible PM_{10} and $PM_{2.5}$ concentrations at set distances from the proposed road. The concentrations are irrespective of actual wind speed and direction and reflect the worst-case scenario. The PM_{10} and $PM_{2.5}$ concentrations due to vehicle entrainment as a result of transporting limestone, salts and sludge on a paved road surface (assuming all six units are operational) are well below the NAAQS.

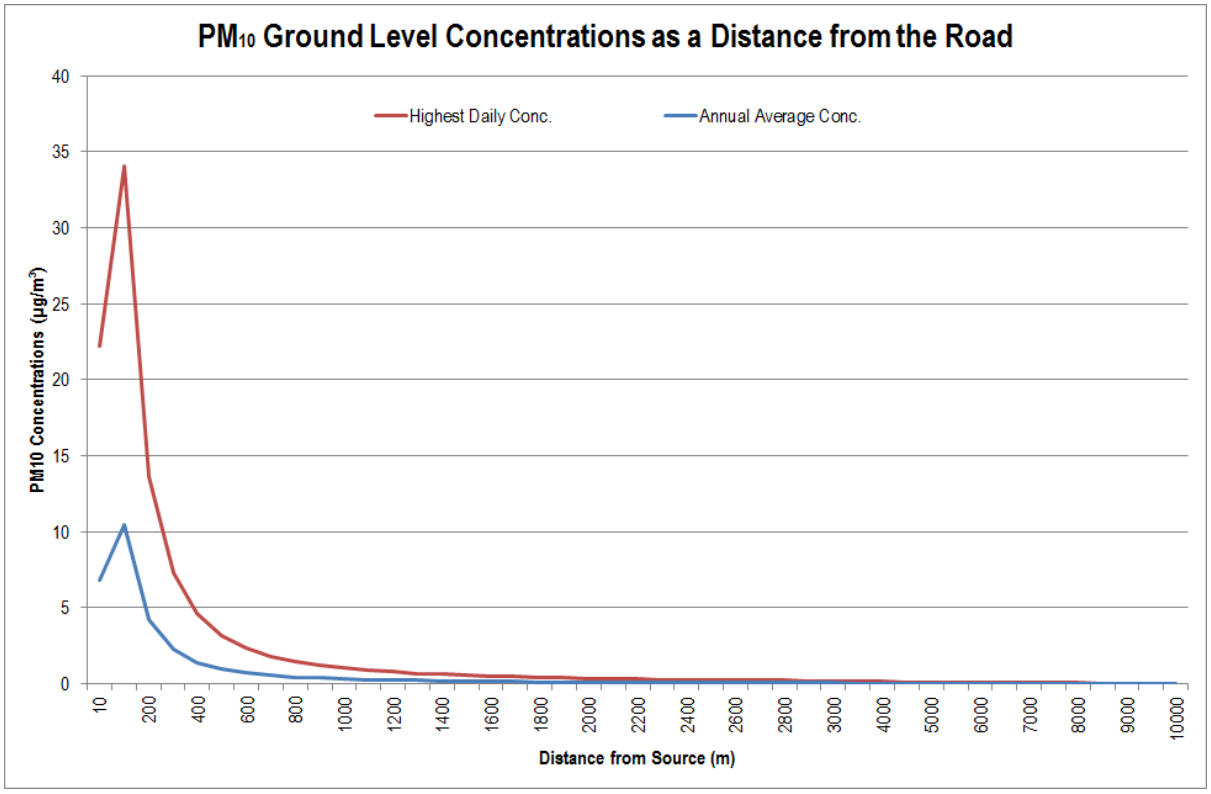

Figure 4-1: Estimated highest daily and annual average PM_{10} ground level concentrations, due to vehicle entrainment, at set distances from the emission source

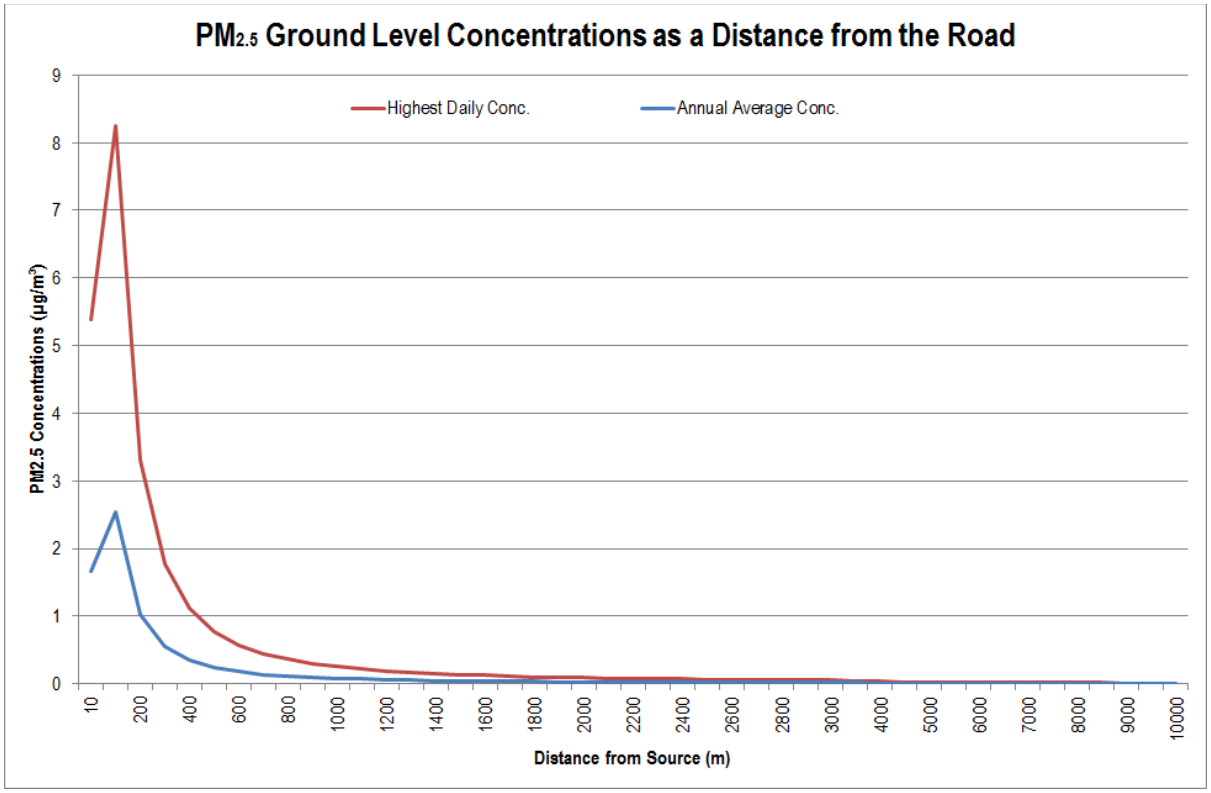

Figure 4-2: Estimated highest daily and annual average $PM_{2.5}$ ground level concentrations, due to vehicle entrainment, at set distances from the emission source

4.2.2 *Quantitative Assessment*

Isopleth plots illustrating exceedance of the NAAQS for the operations of Matimba and Medupi with FGD are provided in Figure 4-3 and Figure 4-4 (to be seen in comparison with 2020 baseline – Figure 3-17 and Figure 3-18). A synopsis of the compliance of SO_2, NO_2, PM_{10} and $PM_{2.5}$ concentrations with the NAAQS due to proposed Project operations is provided in Table 4-3 (to be seen in comparison to Table 3-9 – 2020 baseline).

The area of exceedance of the SO_2 NAAQS due to Matimba Power Station and Medupi with FGD (Figure 4-3 and Figure 4-4) is significantly reduced from the 2020 baseline operations (Figure 3-17 and Figure 3-18) bringing the simulated ground level concentrations into compliance with the hourly and daily NAAQS at all sensitive receptors in the study area.

Simulated NO_2 ground level concentrations due to proposed Project operations (Table 4-3) increase slightly from the 2020 baseline conditions due to the decrease in dispersion potential with the introduction of FGD (i.e. with FGD, the stack exit temperature decreases). The simulated NO_2 concentrations at the closest sensitive receptors are, however, within NAAQS due to Matimba Power Station activities and proposed Project operations.

Simulated PM_{10} and $PM_{2.5}$ concentrations due to Matimba Power Station activities and proposed Project operations (Table 4-3) are similar in magnitude to the 2020 baseline operations (Table 3-9) and are well within NAAQS.

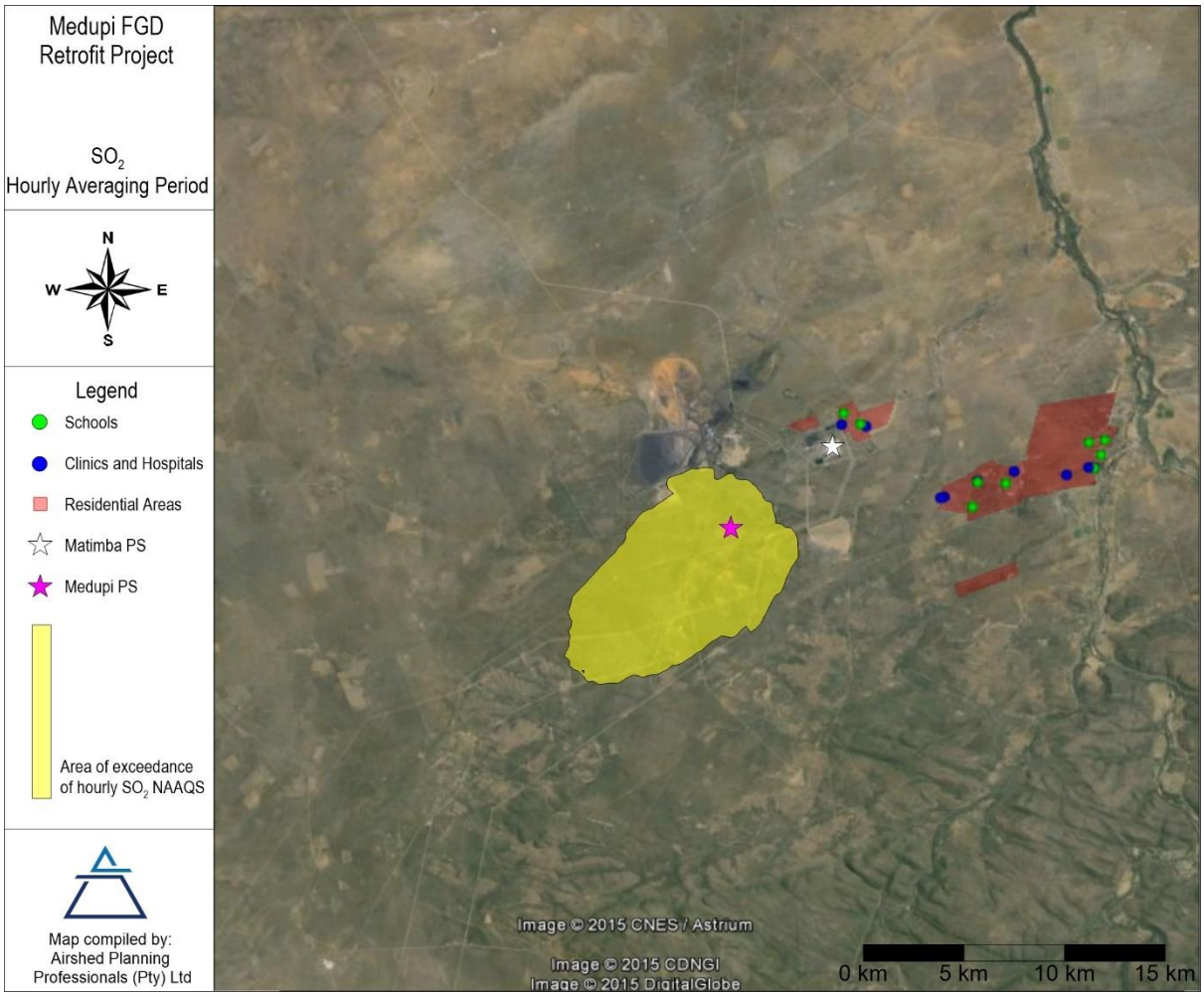

Figure 4-3: Area of exceedance of the hourly SO_2 NAAQS due to Matimba Power Station operations and Medupi with FGD

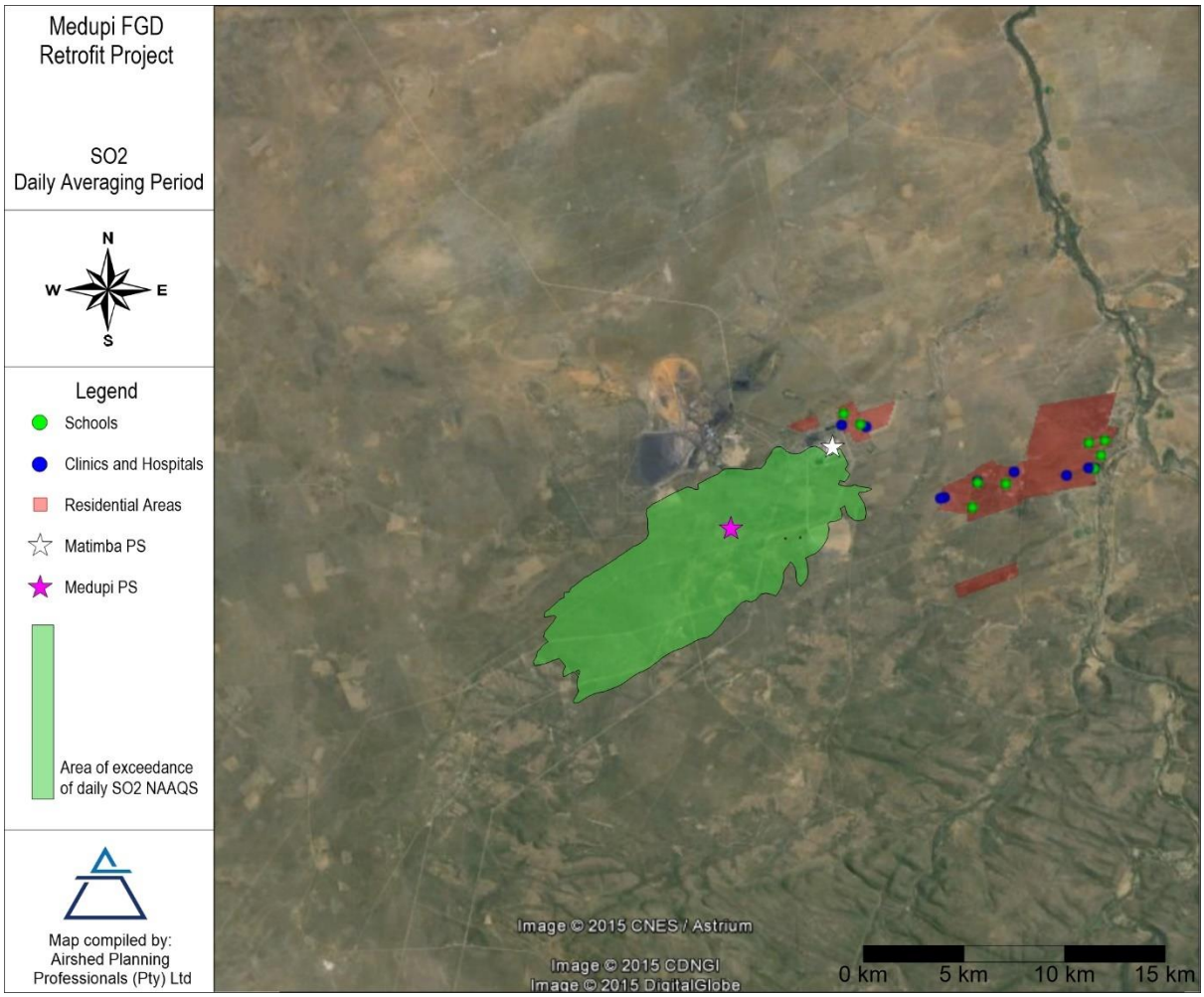

Figure 4-4: Area of exceedance of the daily SO_2 NAAQS due to Matimba Power Station operations and Medupi with FGD

Table 4-3: Simulated SO_2, NO_2, PM_{10} and $PM_{2.5}$ ground level concentrations at the closest sensitive receptors due to Matimba Power Station operations and Medupi with FGD

Pollutant	Scenario	Receptor	Frequency of Exceedence of hourly NAAQ limit	Frequency of Exceedence of daily NAAQ limit	Annual Average Concentration (µg/m³)	Within PM_{10} NAAQS (Y/N)
SO_2	**Proposed Project operations:** Matimba Power Station and Medupi Power Station (with FGD)	Settlement (NW of Matimba Power Station)	34	2	8.0	Y
		Marapong	22	2	5.8	Y
		Lephalale	25	1	5.6	Y
NO_2	**Proposed Project operations:** Matimba Power Station and Medupi Power	Settlement (NW of Matimba Power Station)	27	NA	3.4	Y
		Marapong	14	NA	2.6	Y
		Lephalale	5	NA	2.0	Y

Pollutant	Scenario	Receptor	Frequency of Exceedence of hourly NAAQ limit	Frequency of Exceedence of daily NAAQ limit	Annual Average Concentration (µg/m³)	Within PM_{10} NAAQS (Y/N)
	Station (with FGD)					
PM_{10}	**Proposed Project operations:** Matimba Power Station and Medupi Power Station (with FGD) – assuming no control on the proposed Medupi ash disposal facility	Settlement (NW of Matimba Power Station)	NA	0	0.7	Y
		Marapong	NA	0	0.6	Y
		Lephalale	NA	0	0.6	Y
	Proposed Project operations: Matimba Power Station and Medupi Power Station (with FGD) – assuming 80% control efficiency on the proposed Medupi ash disposal facility	Settlement (NW of Matimba Power Station)	NA	0	0.7	Y
		Marapong	NA	0	0.6	Y
		Lephalale	NA	0	0.6	Y
$PM_{2.5}$	**Proposed Project operations:** Matimba Power Station and Medupi Power Station (with FGD) – assuming no control on the proposed Medupi ash disposal facility	Settlement (NW of Matimba Power Station)	NA	0	0.7	Y
		Marapong	NA	0	0.6	Y
		Lephalale	NA	0	0.6	Y
	Proposed Project operations: Matimba Power Station and Medupi Power Station (with FGD) – assuming 80% control efficiency on the proposed Medupi ash disposal facility	Settlement (NW of Matimba Power Station)	NA	0	0.7	Y
		Marapong	NA	0	0.6	Y
		Lephalale	NA	0	0.6	Y

NA: Not applicable

Although the quantification of trace element emissions from the coal combustion process did not form part of the scope of the assessment, an overview of these emissions and the control thereof are provided in Appendix B.

4.3 Impact Significance Rating

The operational phase is considered to be the phase with the largest impact on ambient air quality. The Construction and Rehabilitation (Closure) phases are not likely to impact the ambient air quality more than the existing (status quo) status. All impacts are based on the dispersion modelling results. The impact significance rating for the operational scenario is presented in Table 4-4.

4.3.1 Existing Status

The 2020 baseline conditions were assessed as the existing status which includes the operations of the Matimba Power Station and the Medupi Power Station including six units without FGD.

Simulated impacts from the Matimba Power Station and the Medupi Power Station without FGD (2020 baseline) was in non-compliance with SO_2 NAAQS on a regional scale resulting in a MODERATE significance.

No exceedances of the NAAQS for NO_2, PM_{10} and $PM_{2.5}$ were simulated at sensitive receptors due to 2020 baseline operations resulting in LOW significance.

4.3.2 Cumulative Impact

The proposed Project operations were assessed as the cumulative impact which includes the operations of the Matimba Power Station and the Medupi Power Station including six units with FGD.

The area of non-compliance of cumulative SO_2 concentrations reduces significantly with FGD with no exceedances of the NAAQS at sensitive receptors, reducing the significance to LOW.

No exceedances of the NAAQS for NO_2, PM_{10} and $PM_{2.5}$ were simulated at sensitive receptors due to proposed Project operations resulting in LOW significance.

4.3.3 Mitigation Measures

Effective mitigation of particulate emissions on the Medupi ash disposal facility will include:

- Regular wetting of exposed areas of disposal facility;
- Stabilization of the exposed areas with a top-soil covering;
- Wetting of exposed top-soil for additional mitigation of dust emissions from the top-soil layer;
- Re-vegetation of the ash disposal facility through application of a deeper top-soil layer and seeding with appropriate grass seeds.

4.3.4 Residual Impact

The residual impact of the ash disposal facility (including the increase in height of 12 m) shows little impact in magnitude at the sensitive receptors (located upwind of the facility) on a daily and annual averaging period providing no change in

significance on PM from cumulative to residual operations. As only mitigation of PM is considered, it is the only pollutant that could be assessed in terms of residual.

Table 4-4: Impact rating matrix for the proposed project operations

OPERATIONAL PHASE									
Activity	**Description of Impact**	**Impact type**	**Spatial Scale**	**Duration**	**Significance**	**Probability**	**Rating**	**Mitigation Measures**	**Interpretation**
Operational phase for the proposed Project	SO_2	Existing[(a)]	4	3	4	4	2.9 - MOD	The FGD control is considered a scenario of the assessment and not a mitigation measure for the significance rating as it is an operational activity that is to take place. The significance of the residual impact for SO_2 and NO_2 therefore remain unchanged.	The significance rating was provided taking into consideration the area of non-compliance with current NAAQS and the location of residential areas. No significant change in PM daily and annual impact in terms of magnitude were simulated at residential areas for mitigated and unmitigated ash facility activities providing little change in significance for cumulative and residual impacts. This is due to high incidental impacts occurring due to ash disposal facility operations, but the incidental impacts average over daily and annual time frames. The measured ambient air quality for PM_{10} is currently in non-compliance with NAAQS at Marapong but no significant change in magnitude and spatial distribution from measured ambient concentrations is simulated due to proposed Project operations.
		Cumulative[(b)]	3	3	3	3	1.8 - LOW		
		Residual	3	3	3	3	1.8 - LOW		
	NO_2	Existing[(a)]	2	3	3	3	1.6 - LOW		
		Cumulative[(b)]	2	3	3	3	1.6 - LOW		
		Residual	2	3	3	3	1.6 - LOW		
	PM_{10}	Existing[(a)]	2	3	3	3	1.6 - LOW	An unmitigated and mitigated (80% control efficiency) scenario on the proposed Medupi ash disposal facility was considered. The mitigation that can be implemented in continual re-vegetation and wetting of the disposal facility.	
		Cumulative[(b)]	2	3	3	3	1.6 - LOW		
		Residual	2	3	3	3	1.6 - LOW		
	$PM_{2.5}$	Existing[(a)]	2	3	3	3	1.6 - LOW		
		Cumulative[(b)]	2	3	3	3	1.6 - LOW		
		Residual	2	3	3	3	1.6 - LOW		

(a) Existing conditions is based on the simulated 2020 baseline operations which includes the activities of the Matimba Power Station and the Medupi Power Station operations with six units excluding FGD

(b) Cumulative conditions are based on the simulated proposed Project operations which includes the activities of the Matimba Power Station and the Medupi Power Station operations with six units including FGD

5 CONCLUSIONS

5.1 Baseline Air Quality Study Findings

The main findings from the baseline air quality characterisation study, which was based on information from both monitoring and modelling studies, are as follows:

- SO_2 concentrations have been measured to infrequently exceed short-term NAAQ limits at the monitoring stations located at Marapong and Lephalale. Modelled SO_2 concentrations also indicate infrequent short-term exceedances of the NAAQ limits at these sensitive receptors. There is however compliance with the NAAQS.

- Currently, the Matimba Power Station is likely to be the main contributing source to the ambient SO_2 ground level concentrations in the study area due to the magnitude of its emissions. Other sources which may contribute significantly due to their low release level include: spontaneous combustion of coal discards associated with mining operations, clamp firing emissions during brickmaking at Hanglip and potentially household fuel burning within Marapong. The highest ground level SO_2 concentrations due to the Matimba Power Station stack emissions are expected to occur during unstable conditions, usually occurring during the day, when the plume is brought to ground in relatively close proximity to the power station.

- NO_2 concentrations have been measured to infrequently exceed short-term NAAQ limits (but are in compliance with NAAQS) at the monitoring stations located at Marapong and Lephalale, which is reiterated in the modelled results. Low level sources of NO_x in the region include combustion within coal discard dumps, brick firing operations and possibly also household fuel burning and infrequent veld burning.

- Measured PM_{10} concentrations exceed the daily NAAQS at Marapong for the period 2014 but are lower at Lephalale (where levels comply with daily NAAQS). The measured $PM_{2.5}$ concentrations are within the daily NAAQS applicable till 2030 at Marapong and Lephalale, but exceed the more stringent daily NAAQS applicable in 2030. The annual average PM_{10} and $PM_{2.5}$ concentrations measured at Lephalale are within NAAQS. Measured annual PM_{10} concentrations at Marapong during the period 2013 exceed annual NAAQS.

- 2014 Baseline simulations:
    - The contribution of current Matimba Power Station operations to primary and secondary particulates was simulated, with no exceedances of the SO_2, NO_2, PM_{10} and $PM_{2.5}$ NAAQS at Marapong and Lephalale. Secondary particulates form in the atmosphere through the conversion of SO_x and NO_x emissions to sulfate and nitrate.

- 2020 Baseline simulations:
    - The area of non-compliance with the hourly and daily SO_2 NAAQS extended ~30km southwest of the Medupi Power Station due to the cumulative operations of the current Matimba Power Station and proposed Medupi Power Station (all 6 units) without FGD control. Non-compliance with the hourly and daily SO_2 NAAQS was simulated at the residential settlement to the northwest of the Matimba Power Station under these conditions.

- Various local (informed through observation from site visits) and far-field (informed by literature) sources are expected to contribute to the suspended fine particulate concentrations in the region. Local dust sources include

wind erosion from exposed areas, fugitive dust from mining and brickmaking operations, vehicle entrainment from roadways and veld burning. Household fuel burning may also constitute a local source of low-level emissions. Long-range transport of particulates emitted from remote tall stacks and from biomass burning in countries to the north of Republic of South Africa (RSA) and the accumulation and recirculation of such regional air masses over the interior is well documented (Andreae et al., 1996; Garstang et al., 1996; Piketh, 1996) (detail pertaining to the recirculation of air masses is provided in Section 3.3.1.9).

5.2 Impact Assessment for Proposed Project

It should be noted that proposed impacts were assessed taking into consideration current Matimba Power Station operations and the proposed Medupi Power Station operations (all 6 units) with FGD. The main findings of the impact assessment for the proposed Project are provided as follows:

- The area of exceedance of the hourly and daily SO_2 NAAQS was significantly reduced when FGD controls on the Medupi Power Station is considered, bringing the simulated ground level concentrations within compliance of the hourly and daily SO_2 NAAQS at all sensitive receptors in the study area.

- Simulated impacts from the Matimba Power Station and the Medupi Power Station without FGD (2020 baseline) was in non-compliance with SO_2 NAAQS on a regional scale resulting in a MODERATE significance. The area of non-compliance of SO_2 concentrations reduces significantly for proposed Project operations (i.e. Matimba Power Station operations and Medupi Power Station operations with FGD) and reduces the significance to LOW as no exceedances of the NAAQS are simulated at the closest sensitive receptors in the study area. No exceedances of the NAAQS for NO_2, PM_{10} and $PM_{2.5}$ were simulated at sensitive receptors due to proposed Project operations resulting in LOW significance. The available monitoring data shows that the PM_{10} concentrations are in non-compliance with the daily NAAQS at Marapong. Simulated impacts due to proposed Project operations, however, do not contribute significantly to current ambient particulate concentrations.

5.3 Recommendation

As the proposed Project operations will significantly reduce SO_2 impacts from the Medupi Power Station, it is recommended that the FGD Retrofit Project (including the increase in height of the ADF with 12 m) be implemented. The movement of sludge and salt off-site to a licenced facility will contribute to fugitive vehicle entrainment emissions. It is recommended that the access road being used is properly maintained to minimise the impacts from this source.

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7 APPENDIX A - THE NO_2/NO_x CONVERSION RATIOS FOR NO_2 FORMATION

As a starting basis, the NO_2/NO_x conversion factors described by Scire and Borissova (2011) as given in Table A-1 will be employed. Observed NO_2/NO_x ratios at the Marapong monitoring station were also analysed and compared to the factors in the table (Figure A-1).

Table A-1: NO_2/NO_x conversation ratios for NO_2 formation

Bin	Concentration (ppb)			NO_2/NO_x Ratios		
				Eskom	Scire and Borissova 2011	
	Min	Max	Ave	Marapong 2012-2014	Bin Average	1-Hour Max
1	0	10	5	0.722	0.798	0.994
2	10	20	15	0.647	0.813	0.992
3	20	40	30	0.629	0.731	0.984
4	40	60	50	0.500	0.554	0.909
5	60	80	70	0.430	0.437	0.748
6	80	100	90	0.360	0.355	0.609
7	100	125	112.5	0.312	0.301	0.498
8	125	150	137.5	0.270	0.256	0.417
9	150	175	162.5	0.248	0.228	0.354
10	175	200	187.5	0.203	0.208	0.306
11	200	225	212.5	0.235	0.185	0.268
12	225	250	237.5	0.187	0.181	0.240
13	250	275	262.5	0.189	0.177	0.219
14	275	300	287.5		0.155	0.204
15	300	325	312.5	0.156	0.152	0.191
16	325	350	337.5		0.148	0.181
17	350	375	362.5		0.140	0.173
18	375	400	387.5		0.136	0.165
19	400	450	425		0.142	0.153
20	450	500	475		0.122	0.151
21	500	600	550		0.109	0.147
22	600	700	650		0.111	0.143
23	700	800	750		0.111	0.139
24	800	950	875		0.117	0.134

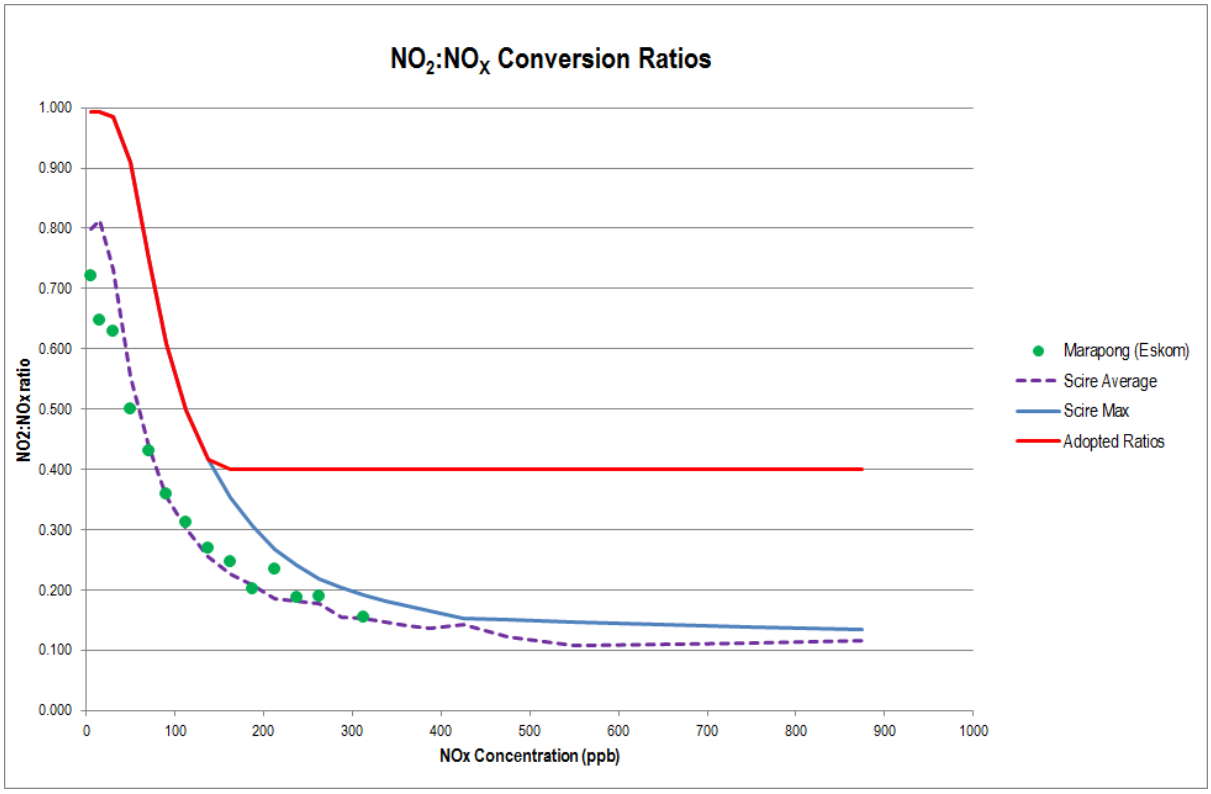

Figure A-1: NO_2/NO_x conversation ratios for the Marapong monitoring station

8 APPENDIX B - SUMMARY OF: STATUS OF TRACE ELEMENT EMISSION IN A COAL COMBUSTION PROCESS: A REVIEW (XUA, ET AL., 2003)

After numerous studies carried out on the occurrence and distribution of trace elements in coal, it is accepted that the trace elements (TEs') combination and contents differ from one coal to another due to the different coalification processes. However, knowledge of TE distribution in coal is very important since it permits the possible prediction of TE release from combustion. Both TE concentration and their chemical affinity vary strongly with the coals from different sources. The comparison between results concerning studies about worldwide coals is useful to find out some general rules. However, it still needs a long time to achieve a general understanding of partitioning in the coal-fired flue gases.

The main proportion of almost all elements is bound with the fly ash and collected in the electrostatic precipitator (ESP). Boron (B) and selenium (Se) are partially discharged in the vapour phase, and mercury (Hg), which exhibits a very high vapour pressure at typical stack outlet temperature, is almost fully released with the flue gas. The elements associated mostly with the organic and sulfide fractions (for example As, Cd, Hg) tend to vaporise firstly and then adsorb onto fine particles during flue gas cooling. In contrast elements combined with the discrete mineral matter (such as Mn) more possibly remain in the ash matrix.

The TE enrichment trends in submicron particles have been reported by many authors. Most TEs, which are partially or fully vaporized during coal combustion, tend to condense and enrich in the submicron particles with a significant surface-to-volume ratio. The submicron particles have more harmful impacts than the super-micron particles since they have long residence time in the atmosphere and a high probability to deposit in human being lungs. Moreover, they can be collected by air pollution control devices (APC) with very low efficiency only.

Based on partition and enrichment behaviour of elements, three basic classes of trace elements can be defined:

- Class I: Elements approximately equally distributed between the bottom ash and fly ash, or show no significant enrichment or depletion in the bottom ash.
- Class II: Elements enriched in the fly ash and depleted in the bottom ash, or show increasing enrichment with decreasing fly ash particle size.
- Class III: Elements totally emitted in the vapor phase.

Mercury is present in coal in trace amounts. During combustion the mercury is released into the exhaust gas as elemental mercury vapour Hg^0. As the combustion gases cool, this elemental mercury is then oxidized to Hg^{2+} via homogeneous mercury chlorination reaction or heterogeneous reaction promoted by fly ash and unburnt carbon. Oxidised mercury is more easily captured in PM control device. Factors affecting the oxidation processes include: coal chlorine content, gas temperature, surface reaction with ash and unburnt carbon and plant operating conditions. There seems to be an important relationship between the chlorine content of coal and the percentage of oxidized mercury. Coals with higher chlorine contents produced greater amounts of oxidized mercury. It has also been reported that other flue gas species especially SO_3 and H_2O tend to suppress the oxidation to Hg^{2+}. This is probably due to competition for active sites on the surface of carbon or other flue gas solids.

The most volatile TEs (Hg, Se, As), to which we have often paid more attention, and halogens, etc., remain mostly in the vapour phase as they pass through heat transfer sections of a boiler. The percentages of the total in-stack concentrations of these elements in the vapour phase have been reported to be: Cl, up to 99% as HCl; F, up to 90% as HF; Br, 25–98% as HBr; Hg, up to 98% as Hg, HgO and CH_3Hg; Se, up to 59% as Se and SeO_2; As, 0.7–52% as As_2O_3; and I, 90–99% as HI. Although

mercury (Hg) concentration in coal is usually extremely low, significant attention is focused on its emission because its capture by APC systems is problematic, and moreover, it is highly toxic to human health and it bioaccumulates.

Emission controls

Donnelly reported a review about metal emission control technologies for waste incineration. The major fraction of toxic metals found in flue gases exists as fine-particle matter; nevertheless, a significant fraction of certain metals (such as B, Hg, Se) exists in the vapour phase at typical incinerator (or boiler) exit flue gas conditions. The control of the particulate fraction is achieved by utilizing traditional particulate control devices. Fabric filter and electrostatic precipitators (ESPs) efficiently trap trace elements in the particulate phase with removal efficiency of the order of 99-99.9% for Class I elements, 95-99% for some Class II elements such as Pb, Cd, Ni & Mn and less for the Class III elements.). As the efficiencies of particulate control devices are generally low in the 0.1–1.5 μm particle size range, there has been concern that trace elements may escape ESPs if they are 'preferentially enriched' on these fine particles.

Control of the vapour phase fraction is achieved through cooling of the flue gas and collection of the fine particulate thus formed. Below, more details about the control methods of toxic metals are given.

Spray dryer absorption systems

Spray dryer absorption (SDA) has been widely applied for waste incinerator emission control, and it has demonstrated high collection efficiencies for most toxic metals present in the flue gas. SDA has been specified as the best available control technology in a number of municipal waste incinerator air permits.

Toxic metal removal in the dust collector is enhanced by cooling the incoming flue gas (from 2000 to 450 jC) as it passes through the spray dryer. Because of the cooling, some vaporized metals condense to form fine particulates, which grow through impaction and agglomeration with the very high number of lime droplets produced by atomization devices. Then these agglomerated particles are easily removed. Generally, the lower the spray dryer outlet temperature, the higher the efficiency of the acid gas absorption and the vaporized toxic metal removal. The minimum reliable operating outlet temperature depends on the spray dryer and dust collector design, and on the composition of the dry fly ash reaction product. The spray dryer outlet temperature must be maintained high enough to ensure complete reagent evaporation and the production of a free-flowing product.

Wet scrubbers

Wet scrubbers control the vapour phase emissions through gas cooling and collection of the resulting condensed fine toxic metal particulates. The most commonly used wet scrubbers for this type of service are the electrostatically (or ionizing) enhanced wet scrubbers and the condensing wet scrubber.

Sorbent injection

It should be noticed that the high volatility and existence in the vapour phase make such trace element control a very difficult task to accomplish. In principle, trace elements in vapour phase can be condensed by lowering the temperature. However, as indicated above, the resulting loss in buoyancy of the flue gas would require reheating the flue gas, which would not be economical. Furthermore, the resultant particles may be in the sub-micrometre sizes, and these particles are not effectively captured in conventional particulate control devices. Capture of these species on sorbents by physical or chemical means is therefore a very attractive alternative.

The sorbent–metal interaction can be physical or chemical in nature, or it can be a combination of these two processes depending on the temperature under consideration. Mineral sorbents such as hydrated lime, limestone and kaolinite were shown to be effective for arsenic, cadmium and lead capture at 1000–1300 °C range. In a fluidized bed combustor, optimum capture of lead and cadmium using mineral sorbents takes place at around 700 °C. Other sorbents such as fly ash and activated carbon have shown to be possible alternatives to these mineral sorbents. Trace elements such as As, Cu, Mo, Pb and Zn have been shown to be concentrated on fly ash in a power station flue gas.

In the past few years, dry sorbent injection for in situ capture of metal from hot flue gas has been studied with the aim of developing a potential control technique. Due to the occurrence of multiple trace elements in flue gas in addition to SO_2, NO_x, etc. recent efforts of the research community have been geared towards developing a multifunctional sorbent which is capable of reducing emission of most of the pollutants below a certain acceptable standard. Activated carbon offers an attractive option for use as a multifunctional sorbent in the low temperature range because of its performance in capturing mercury and SO_2. Direct injection of activated carbon into the flue gas stream in the duct region has been proposed to be an effective technology since it has the potential for high mercury removal efficiencies. Calcium-based sorbents, because of their low cost, have been used extensively for the capture of acidic species such as sulfur dioxide. These sorbents also offer an attractive option to be used as multifunctional sorbents because of their ability to capture sulfur species as well as trace elements such as selenium and arsenic species. When used as a sorbent to capture the toxic species in the flue gas, the sorbent interacts with various components and the extent of interaction kinetics depends on the individual sorbent species.
Emissions levels of toxic metals from incinerators equipped with modern air-pollution control systems are several orders of magnitude lower than levels in 1980. High collection efficiencies are achieved for the 10 toxic metals proposed for regulation (Ag, As, Ba, Be, Cd, Cr, Hg, Pb, Sb and Tl).