9. AIR QUALITY IMPACT ASSESSMENT

9.1. Introduction

Airshed Planning Professionals (Pty) Limited was appointed by Bohlweki Environmental to undertake the air quality impact assessment for a proposed new coal-fired power station in the Lephalale Local Municipality (previously Ellisras) of the Limpopo Province in the vicinity of the existing Matimba Power Station (Figure 9.1).

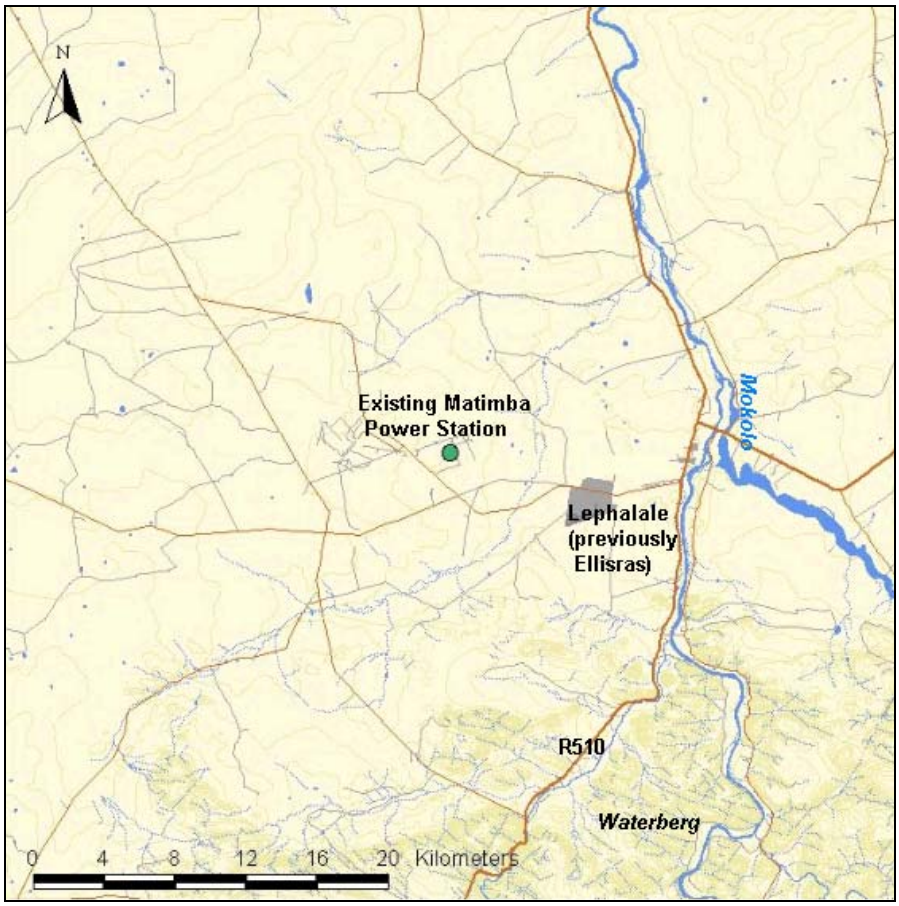

Figure 9.1: Location of the existing Matimba Power Station near Lephalale (previously Ellisras). The new power station is proposed for development in the vicinity of the existing Matimba Power Station.

Specialist investigations conducted as part of an air quality assessment typically comprise two components, viz. a baseline study and an air quality impact and compliance assessment study.

The *baseline study* includes the review of the site-specific atmospheric dispersion potential, relevant air quality guidelines and limits and existing ambient air quality in the region. In this investigation, use was made of readily available meteorological and air quality data recorded in the study area in the

characterisation of the baseline condition. The baseline study was also extended to include the consideration and qualitative evaluation of the candidate sites from an air quality impact assessment perspective. The initial baseline characterisation and evaluation of siting options was documented in a previous report (Scorgie and Thomas, October 2005). Further baseline information was subsequently received and an updated baseline characterisation is presented in this report. A preferred site for the proposed power station was also selected and formed the focus of the air quality impact study.

The *ambient air quality impact assessment* comprised the establishment of an emissions inventory for the proposed development, the simulation of ambient air pollutant concentrations and dustfall rates occurring due to project development and operation, and the evaluation of the resultant potential for impacts and non-compliance.

9.1.1. Terms of Reference

The terms of reference of the *baseline study component* are as follows:

- Description of the synoptic climatology and meso-scale atmospheric dispersion potential based on available literature and meteorological data;
- Review of legislative and regulatory requirements pertaining to air pollution control and air quality management, specifically local and international ' good practice' emission limits and air quality limits;
- Characterisation of the existing air quality including the identification of existing sources and the analysis of existing air quality monitoring data; and
- Identification of sensitive receptors in the vicinity of the proposed development sites.

The terms of reference of the *air quality impact assessment component* include the following:

- Compilation of an emissions inventory for the proposed development including the identification and quantification of all potentially significant source of atmospheric emission including stack and fugitive emissions (e.g. power station stack emissions; fugitive dust from ashing and coal handling operations);

- Application of an atmospheric dispersion model and prediction of incremental air pollutant concentrations and dustfall rates occurring as a result of proposed operations;
- Air quality impact assessment including:
  - compliance evaluation of emissions and air pollutant concentrations based on both local and international 'good practice' limits,

- analysis of the potential for local air quality impacts given sensitive receptor locations, and
- review of the projects in terms of its contribution to national greenhouse gas emissions.

9.1.2. Project Description

- *Proposed Technology*

  The proposed power station is coal-fired and will source coal from local coalfields. The planned power station is given as having a maximum installed capacity of up to 4800 MW, with the capacity being approximately half the installed capacity during the first phase. The project comprises a power plant and associated plant (terrace area) of about 700 h and associated ashing facilities (covering 500 – 1000 ha). It is estimated that approximately 7 million tpa of coal would be needed to supply the power station, and it is proposed that this coal be conveyed in from the Grootgeluk Colliery located to the west of Matimba Power Station.

  The proposed power station would be similar to the existing Matimba Power Station in terms of operation, design and dimensions. The dimensions of the power station structure will be approximately 130 m high and 500 m wide with stacks of approximately 200 m in height. Other infrastructures related to the power station include a coal stockpile, conveyor belts, an ash dump and transmission lines.

  The two technology alternatives, in terms of combustion, being considered for the proposed power station are:

  - Pulverized Fuel Combustion (PF), and
  - Fluidized Bed Combustion (FBC)

  With ***PF technology***, the coal is pulverised and then blown into a furnace to be combusted at high temperatures. The heat is used to generate the steam that drives the steam turbine and generator. ***FBC technology*** is the option under consideration for the second phase of proposed power station. In this process coal is burnt in a furnace comprising of a bed through which gas is fed to keep the fuel in a turbulent state. This technology allows the use of a lower grade coal in greater volumes to achieve the same calorific value. With FBC SO_x emissions are reduced but CO_2 emissions are higher.

  In terms of cooling technology the new power station is proposed to be dry cooled, as opposed to the conventional wet-cooling systems, due to the limited water supply in the area. Dry cooled systems use less than 0.2 l/kWh compared to the 1.5 l/kWh used by wet-cooling systems.

The proposed power station is thus a dry-cooled, pulverised fuel (PF) supercritical station with a thermal efficiency of up to 40%.

- *Preferred Site*
  The sites identified for the construction of the proposed **power station** and the **ashing operations** are the **Farms Naauwontkomen** and **Eenzaamheid** respectively (Figure 9.2).

  Farm Eenzaamheid, 687 LQ, is privately owned currently used for cattle farming, and is bisected by a road (Steenbokpan Road) dividing the property into two smaller portions. The farm is about 930 ha in size. The southern boundary is bordered by a railway line. This farm lies 11 km from the existing Matimba Power Station, 12 km from the Marapong Township and 15km from Lephalale. A total of 9 dwellings were found within 6 km of the site.

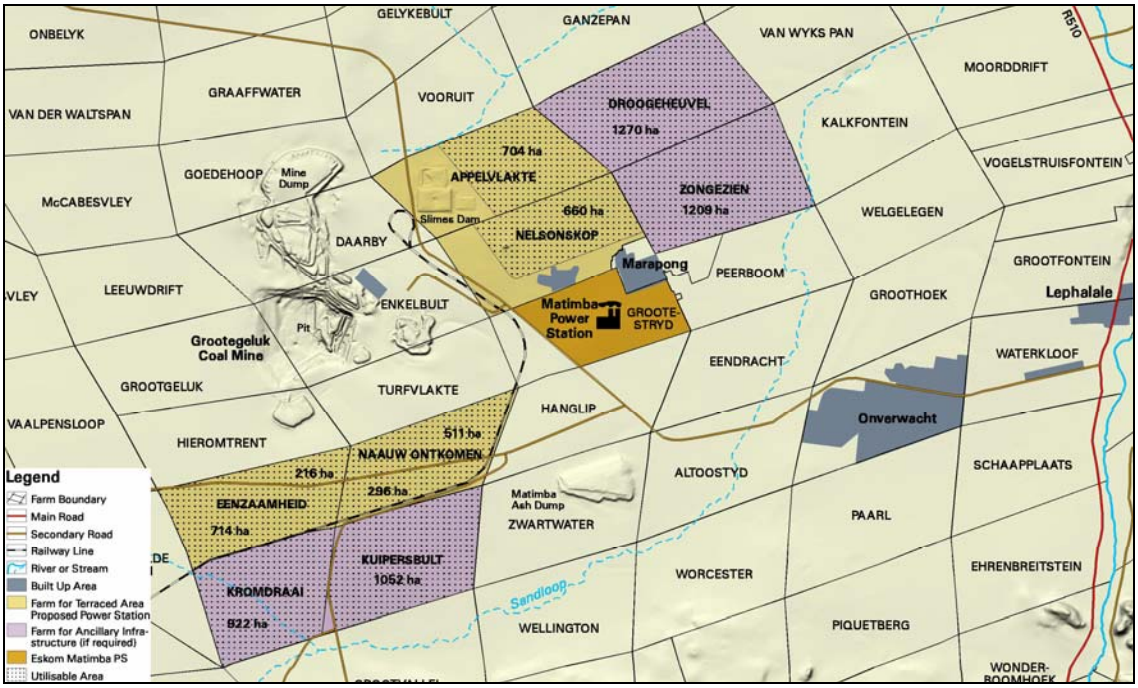

Figure 9.2: Location of the proposed sites for power station and ancillary infrastructure development (as obtained from Bohlweki Environmental).

Farm Naauwontkomen, 509 LQ, owned by Kumba Resources, is currently utilised in a breeding programme but is bisected by a road (Steenbokpan Road) dividing the property in two portions. The site is 807 ha in extent and a railway line runs along the eastern and southern boundaries of the farm. The farm lies 4 km from the existing Matimba Power Station, 5.2 km from the Marapong Township and 8.5 km from Lephalale.

9.1.3. Sensitive Receptors

Given that the project will be associated with low level emissions (e.g. from mining and ashing operations) and elevated emissions (power station stacks), the proposed project has the potential of impacting on receptors in the near and medium fields. Ward numbers 2, 3 and 4 of the Lephalale Local Municipality are the most sensitive to impacts related to atmospheric emissions. Wards 1 and 5 may also be affected depending on the spatial extent of impacts.

Residential areas in the vicinity of the proposed operations include Marapong (Ward 2) located just south of the Farm Zongezien and northeast of the existing Matimba Power Station and Onverwacht (Ward 4) and Lephalale (Ward 5) 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 landuse in the area. The closest schools and clinics include: Ellisras School, Clinic and Hospital (Ward 4), the Lekhureng Primary School (Ward 1) and Weltevrede Montoma School (Ward 5).

9.1.4. Limitations and Assumptions

In interpreting the study findings it is important to note the limitation 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 and materials handling operations.
- Given that Matimba Power Station is the most significant source of ambient SO_2 concentrations in the region and that predicted concentrations due to this source approximated measured levels, 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. An air quality impact study is currently underway to quantify emissions and resultant ambient air pollutant concentrations associated with existing Grootgeluk mining operations and proposed mine expansion. This study will quantify cumulative airborne particulate concentrations occurring due to both current and proposed Grootgeluk Mine and Matimba Power Station operations.
- The health risk screening study was restricted to the quantification of risks due to inhalation exposures. Although inhalation represents the main

pathway for airborne particulates, sulphur dioxide, nitrogen oxides and various of the metals considered, ingestion is important for certain of the metals such as mercury and lead.

- Routine emissions from power station operations were estimated and modelled. Atmospheric releases occurring as a result of accidents were not accounted for.
- The quantification of trace metal releases was restricted to those studied and documented previously. Furthermore, data were unavailable to quantify gaseous trace metal releases from stacks. Although studies have been undertaken in this regard previously, the methods of monitoring are still being scrutinized and reliable data are not yet available (personal communication, Gerhard Gericke, Chief Consultant, Water and Applied Chemistry, Eskom Research & Development, 10 March 2006). Mercury represents the constituent most likely to be emitted in the gas phase. The total emissions of mercury, and hence the associate risk, could not therefore be ascertained. **(subsequent to the compilation of the draft Air Quality Assessment further work has been conducted in order to more accurately assess the potential for mercury emissions and associated impacts with reference being made to the mercury content of the coal and emission factors published internationally for power generation. These findings are summarised and attached as Appendix AF)**
- The trace metal composition of the proposed power station's fly and bottom ash was assumed to be the same as that generated by the current Matimba Power Station. The validity of this assumption depends on the combustion technology, operating conditions and trace metal coal composition to be used in comparison to that used by the existing power station.
- Three years of meteorological data were used in the atmospheric dispersion modelling. A minimum of 1 year, and typically 3 to 5 years of meteorological data are generally recommended for use in atmospheric dispersion modelling for air quality impact assessment purposes.
- It is proposed that a contractor camp, comprising ~2000 residents, be established and occupied during the construction and commissioning phases of the power station. The impact of existing and proposed power station emissions on such residents was not included in the current study due to the location of this camp not having been decided during the period of study.

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

- The Calpuff dispersion model was found to significantly overpredict, by a factor of two, actual monitored near ground level concentrations. It was therefore necessary to use a correction factor of 0.5 for predicted ambient air pollutant concentrations.
- Source parameters and emission rates for these emission scenarios required for input to the dispersion modelling study were provided by Eskom personnel. For the scenarios comprising the control of sulphur dioxide emissions, source parameters and emission rates of other pollutants were

assumed to remain the same as for the zero control scenarios. This is a simplistic assumption given that the implementation of abatement technology able to achieve such reductions is likely to alter the stack parameters (e.g. reduction in gas exit temperatures) and possibly increase the emissions of certain other pollutants should the overall combustion efficiency be reduced. In the event that sulphur dioxide abatement is required, a more detailed review of the implications of such abatement for stack configuration and emissions will need to be undertaken.

- In the assessment of human health risk potentials arising due to sulphur dioxide exposures the assumption is made that no residential settlements will be developed within the main impact areas of the power station(s) during their operational phases. Should this not be the case the exposure potential, and hence the health risk potential, would need to be reassessed. (The health risk potential plots presented could aid decision making regarding the siting of residential settlements.)
- In the calculation of cancer risks persons were assumed to be exposed for 24 hours a day over a 70-year lifetime at all locations. Maximum possible exposures were also assumed in the estimation of cancer risks. These are highly conservative assumptions but were used to undertake a first order assessment of the potential which exists for elevated cancer risks due to existing and proposed power station operations.

9.1.5. Outline of Report

Emission limits and ambient air quality criteria applicable to power station operations and their ancillary infrastructure are presented in Section 2. The synoptic climatology and atmospheric dispersion potential of the area are discussed in Section 3 and information on existing sources and baseline air quality given in Section 4. Section 5 presents the emissions inventory for the proposed Matimba B operations. Dispersion model results are presented and the main findings of the air quality compliance and impact assessments documented in Section 6. Recommendations and conclusions are presented in Section 7.

9.2. Atmospheric Emission Limits And Ambient Air Quality Criteria

Legislative, regulatory and 'good practice' requirements pertaining to power station and related ashing operations are outlined in this section. Such requirements include source and operational requirements including emission limits and permissible ambient air quality limits. Source and operational requirements and permissible emission concentrations for Scheduled Processes are given in the Department of Environmental Affairs and Tourism's *Guidelines for Schedule Processes*, as discussed in Section 9.2.1. Local and international 'good practice' ambient air quality guidelines and standards are presented in Section 9.2.2. Inhalation human health risk evaluation criteria applicable to substances of interest in the current study are discussed in Section 9.2.3.

9.2.1. DEAT Permit Requirements for Scheduled Processes

Power generation processes, including the combustion of fuel for the generation of electricity for distribution to the public, are classified as Scheduled Processes (Process number 29) in the Atmospheric Pollution Prevention Act, Act 45 of 1965 (as amended)[1]. Such processes are required to obtain a registration certificate from the Chief Air Pollution Control Officer (CAPCO), who operates from the Department of Environmental Affairs and Tourism (DEAT), in order to operate.

Terms and conditions related to the operation of Scheduled Processes, the extent of emissions and the control efficiency and availability of abatement technology are typically included in the registration certificates. DEAT requirements pertaining to power generation processes, as extracted from DEAT's *Guidelines for Scheduled Processes*, are given in Appendix A. It is recognised that these requirements represent primarily an indication of the pollutants controlled and the likely extent of emissions limits, with specific registration certificate conditions having historically been the result of discussions on individual operations between the CAPCO and project proponent.

Pollutants which are controlled for include:

- fly-ash (particulates) with an emission concentration limit of 100 mg/Sm³ indicated,
- sulphur dioxide - it being required that at least 70% of the sulphur in the coal be removed or captured, and
- oxides of nitrogen – required that provision be made for the use of low-NOx burners by new plants.

The air quality impact assessment will inform the recommendation of plant-specific emission limits for the proposed power station, with the potential for impacts reflecting the prevailing meteorology, the proximity of sensitive receptors and the extent of existing air pollution.

9.2.2. Local and International Ambient Air Quality Guidelines and Standards

[1] The APPA is scheduled to be replaced by the National Environmental Management: Air Quality Act 39 of 2004. The new Act was signed by the President and gazetted in February 2005 but has not yet come into force. In terms of this Act power generation processes will be classified as a 'listed activity' and as such will require an 'atmospheric emissions license' in order to operate. During the transitional phase an application for a registration certificate under the APPA will be taken as an application for an atmospheric emission license under the Air Quality Act. Holders of registration certificates will be responsible for proving compliance with the requirements of such permits and for applying for atmospheric emissions licenses.

Air quality guidelines and standards are fundamental to effective air quality management, providing the link between the source of atmospheric emissions and the user of that air at the downstream receptor site. The ambient air quality limits are intended to indicate safe daily exposure levels for the majority of the population, including the very young and the elderly, throughout an individual's lifetime. Such limits are given for one or more specific averaging periods, typically 10 minutes, 1-hour average, 24-hour average, 1-month average, and/or annual average.

The ambient air quality guidelines and standards for pollutants relevant to the current study are presented in subsequent subsections. Air quality limits issued nationally by the DEAT and SABS[(2)] are reflected together with limits published by the WHO, EC, World Bank, UK, Australia and US-EPA.

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

  The nasal openings permit very large dust particles to enter the nasal region, along with much finer airborne particulates. Larger particles are deposited in the nasal region by impaction on the hairs of the nose or at the bends of the nasal passages. Smaller particles (PM10) pass through the nasal region and are deposited in the tracheobronchial and pulmonary regions. Particles are removed by impacting with the wall of the bronchi when they are unable to follow the gaseous streamline flow through subsequent bifurcations of the bronchial tree. As the airflow decreases near the terminal bronchi, the smallest particles are removed by Brownian motion, which pushes them to the alveolar membrane (CEPA/FPAC Working Group, 1998; Dockery and Pope, 1994).

[2] The SABS was initially engaged to assist DEAT in the facilitation of the development of ambient air quality standards. This process resulted in the publication of: (a) SANS 69 - South African National Standard - Framework for setting & implementing national ambient air quality standards, and (b) SANS 1929 - South African National Standard - Ambient Air Quality - Limits for common pollutants. The latter document includes air quality limits for particulate matter less than 10 µm in aerodynamic diameter (PM10), dustfall, sulphur dioxide, nitrogen dioxide, ozone, carbon monoxide, lead and benzene. The SANS documents were approved by the technical committee for gazetting for public comment, were made available for public comment during the May/June 2004 period and were finalized and published during the last quarter of 2004. Although the SANS documents have been finalised, it was decided by the DEAT not to adopt these limits but rather to include the previous CAPCO guidelines as standards in the second schedule of the new Air Quality Act with a view of replacing these with alternative thresholds in the future. Although the threshold levels to be selected for future air quality standards are not currently known it is expected that such thresholds will be more stringent than the initial standards included in the Act and more in line with the SANS limits.

Air quality guidelines for particulates are given for various particle size fractions, including total suspended particulates (TSP), inhalable particulates or PM10 (i.e. particulates with an aerodynamic diameter of less than 10 µm), and respirable particulates of PM2.5 (i.e. particulates with an aerodynamic diameter of less than 2.5 µm). Although TSP is defined as all particulates with an aerodynamic diameter of less than 100 µm, and effective upper limit of 30 µm aerodynamic diameter is frequently assigned. PM10 and PM2.5 are of concern due to their health impact potentials. As indicated previously, such fine particles are able to be deposited in, and damaging to, the lower airways and gas-exchanging portions of the lung.

PM10 limits and standards issued nationally and abroad are documented in Table 9.1. In addition to the PM10 standards published in schedule 2 of the Air Quality Act, the Act also includes standards for total suspended particulates (TSP), viz. a 24-hour average maximum concentration of 300 µg/m³ not to be exceeded more than three times in one year and an annual average of 100 µg/m³.

Table 9.1: Air quality standard for inhalable particulates (PM10)

Authority	Maximum 24-hour Concentration (µg/m³)	Annual Average Concentration (µg/m³)
SA standards (Air Quality Act)	180(a)	60
RSA SANS limits (SANS:1929,2004)	75(b) 50(c)	40(d) 30(e)
Australian standards	50(f)	-
European Community (EC)	50(g)	30(h) 20(i)
World Bank (General Environmental Guidelines)	70(j)	50(j)
World Bank (Thermal Power Guidelines)	150(k)	50(k)
United Kingdom	50(l)	40(m)
United States EPA	150(n)	50(o)
World Health Organisation	(p)	(p)

Notes:

(a) Not to be exceeded more than three times in one year.

(b) Limit value. Permissible frequencies of exceedance, margin of tolerance and date by which limit value should be complied with not yet set.

(c) Target value. Permissible frequencies of exceedance and date by which limit value should be complied with not yet set.

(d) Limit value. Margin of tolerance and date by which limit value should be complied with not yet set.

(e) Target value. Date by which limit value should be complied with not yet set.

(f) Australian ambient air quality standards. (http://www.deh.gov.au/atmosphere/airquality/standards.html). Not to be exceeded more than 5 days per year. Compliance by 2008.

(g) EC First Daughter Directive, 1999/30/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Compliance by 1 January 2005. Not to be exceeded more than 25 times per calendar year. (By 1 January 2010, no violations of more than 7 times per year will be permitted.)
(h) EC First Daughter Directive, 1999/30/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Compliance by 1 January 2005
(i) EC First Daughter Directive, 1999/30/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Compliance by 1 January 2010
(j) World Bank, 1998. Pollution Prevention and Abatement Handbook. (www.worldbank.org). Ambient air conditions at property boundary.
(k) World Bank, 1998. Pollution Prevention and Abatement Handbook. (www.worldbank.org). Ambient air quality in Thermal Power Plants.
(l) UK Air Quality Objectives. www.airquality.co.uk/archive/standards/php. Not to be exceeded more than 35 times per year. Compliance by 31 December 2004
(m) UK Air Quality Objectives. www.airquality.co.uk/archive/standards/php. Compliance by 31 December 2004
(n) US National Ambient Air Quality Standards (www.epa.gov/air/criteria.html). Not to be exceeded more than once per year.
(o) US National Ambient Air Quality Standards (www.epa.gov/air/criteria.html). To attain this standard, the 3-year average of the weighted annual mean PM10 concentration at each monitor within an area must not exceed 50 µg/m³.
(p) WHO (2000) issues linear dose-response relationships for PM10 concentrations and various health endpoints. No specific guideline given.

- *Sulphur Dioxide*
  SO_2 is an irritating gas that is absorbed in the nose and aqueous surfaces of the upper respiratory tract, and is associated with reduced lung function and increased risk of mortality and morbidity. Adverse health effects of SO_2 include coughing, phlegm, chest discomfort and bronchitis. Ambient air quality guidelines and standards issued for various countries and organisations for sulphur dioxide are given in Table 9.2.

Table 9.2: Ambient air quality guidelines and standards for sulphur dioxide for various countries and organisations

Authority	Maximum 10-minute Average (µg/m³)	Maximum 1-hourly Average (µg/m³)	Maximum 24-hour Average (µg/m³)	Annual Average Concentration (µg/m³)
SA standards (Air Quality Act)	500(a)	-	125(a)	50
RSA SANS limits (SANS:1929,2004)	500(b)	-	125(b)	50
Australian standards	-	524(c)	209 (c)	52
European Community (EC)	-	350(d)	125(e)	20(f)
World Bank (General Environmental Guidelines)	-	-	125(g)	50(g)
World Bank (Thermal			150(h)	80(h)

Power Guidelines)				
United Kingdom	266(i)	350(j)	125(k)	20(l)
United States EPA	-	-	365(m)	80
World Health Organisation	500(n)	350(n)	125(n)	50(n) 10-30(o)

Notes:

(a) No permissible frequencies of exceedance specified

(b) Limit value. Permissible frequencies of exceedance, margin of tolerance and date by which limit value should be complied with not yet set.

(c) Australian ambient air quality standards. (http://www.deh.gov.au/atmosphere/airquality/standards.html). Not to be exceeded more than 1 day per year. Compliance by 2008.

(d) EC First Daughter Directive, 1999/30/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Limit to protect health, to be complied with by 1 January 2005 (not to be exceeded more than 4 times per calendar year).

(e) EC First Daughter Directive, 1999/30/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Limit to protect health, to be complied with by 1 January 2005 (not to be exceeded more than 3 times per calendar year).

(f) EC First Daughter Directive, 1999/30/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Limited value to protect ecosystems. Applicable two years from entry into force of the Air Quality Framework Directive 96/62/EC.

(g) World Bank, 1998. Pollution Prevention and Abatement Handbook. (www.worldbank.org). Ambient air conditions at property boundary.

(h) World Bank, 1998. Pollution Prevention and Abatement Handbook. (www.worldbank.org). Ambient air quality in Thermal Power Plants.

(i) UK Air Quality Objective for 15-minute averaging period (www.airquality.co.uk/archive/standards/php). Not to be exceeded more than 35 times per year. Compliance by 31 December 2005.

(j) UK Air Quality Objective (www.airquality.co.uk/archive/standards/php). Not to be exceeded more than 24 times per year. Compliance by 31 December 2004.

(k) UK Air Quality Objective (www.airquality.co.uk/archive/standards/php). Not to be exceeded more than 3 times per year. Compliance by 31 December 2004.

(l) UK Air Quality Objective (www.airquality.co.uk/archive/standards/php). Compliance by 31 December 2000.

(m) US National Ambient Air Quality Standards (www.epa.gov/air/criteria.html). Not to be exceeded more than once per year.

(n) WHO Guidelines for the protection of human health (WHO, 2000).

(o) Represents the critical level of ecotoxic effects (issued by WHO for Europe); a range is given to account for different sensitivities of vegetation types (WHO, 2000).

- *Oxides of Nitrogen*

  NO_x, primarily in the form of NO, is one of the primary pollutants emitted during combustion. NO_2 is formed through oxidation of these oxides once released in the air. NO_2 is an irritating gas that is absorbed into the mucous membrane of the respiratory tract. The most adverse health effect occurs at the junction of the conducting airway and the gas exchange region of the lungs. The upper airways are less affected because NO_2 is not very soluble in aqueous surfaces. Exposure to NO_2 is linked with increased susceptibility to respiratory infection, increased airway resistance in asthmatics and decreased pulmonary function.

The standards and guidelines of most countries and organisations are given exclusively for NO_2 concentrations. South Africa's NO_2 standards are compared to various widely referenced foreign standards and guidelines in Table 9.3. In addition, South Africa also publishes standards for oxides of nitrogen (NO_x).

Table 9.3: Ambient air quality guidelines and standards for nitrogen dioxide for various countries and organisations

Authority	Instantaneous Peak (µg/m³)	Maximum 1-hourly Average (µg/m³)	Maximum 24-hour Average (µg/m³)	Maximum 1-month Average (µg/m³)	Annual Average Concentration (µg/m³)
SA standards (Air Quality Act)	940(a)	376(a)	188(a)	150(a)	94
RSA SANS limits (SANS:1929,2004)	-	200(b)	-	-	40(b)
Australian standards		226(c)			56
European Community (EC)	-	200(d)	-	-	40(e)
World Bank (General Environmental Guidelines)	-	-	150 (as NO_x)(f)	-	-
World Bank (Thermal Power Guidelines)			150(g)		100(g)
United Kingdom	-	200(h)	-	-	40(i) 30(j)
United States EPA	-	-	-	-	100(k)
World Health Organisation	-	200(l)	150(l)	-	40(l)

Notes:

(a) No permissible frequencies of exceedance specified

(b) Limit value. Permissible frequencies of exceedance, margin of tolerance and date by which limit value should be complied with not yet set.

(c) Australian ambient air quality standards. (http://www.deh.gov.au/atmosphere/airquality/standards.html). Not to be exceeded more than 1 day per year. Compliance by 2008.

(d) EC First Daughter Directive, 1999/30/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Averaging times represent the 98th percentile of averaging periods; calculated from mean values per hour or per period of less than an hour taken throughout the year; not to be exceeded more than 8 times per year. This limit is to be complied with by 1 January 2010.

(e) EC First Daughter Directive, 1999/30/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Annual limit value for the protection of human health, to be complied with by 1 January 2010.

(f) World Bank, 1998. Pollution Prevention and Abatement Handbook. (www.worldbank.org). Ambient air conditions at property boundary.

(g) World Bank, 1998. Pollution Prevention and Abatement Handbook. (www.worldbank.org). Ambient air quality in Thermal Power Plants.
(h) UK Air Quality Provisional Objective for NO_2 (www.airquality.co.uk/archive/standards/php). Not to be exceeded more than 18 times per year. Compliance by 31 December 2005.
(i) UK Air Quality Provisional Objective for NO_2 (www.airquality.co.uk/archive/standards/php). Compliance by 31 December 2005.
(j) UK Air Quality Objective for NOx for protection of vegetation (www.airquality.co.uk/archive/standards/php). Compliance by 31 December 2000.
(k) US National Ambient Air Quality Standards (www.epa.gov/air/criteria.html).
(l) WHO Guidelines for the protection of human health (WHO, 2000).

- *Carbon Monoxide*

  Carbon monoxide absorbed through the lungs reduces the blood's capacity to transport available oxygen to the tissues. Approximately 80-90 % of the absorbed CO binds with haemoglobin to form carboxyhaemoglobin (COHb), which lowers the oxygen level in blood. Since more blood is needed to supply the same amount of oxygen, the heart needs to work harder. These are the main causes of tissue hypoxia produced by CO at low exposure levels. At higher concentrations, the rest of the absorbed CO binds with other heme proteins such as myoglobin and with cytochrome oxidase and cytochrome P-450. CO uptake impairs perception and thinking, slows reflexes, and may cause drowsiness, angina, unconsciousness, or death. The ambient air quality guidelines and other standards issued for various countries and organisations for carbon monoxide are given in Table 9.4.

Table 9.4: Ambient air quality guidelines and standards for carbon monoxide for various countries and organisations

Authority	Maximum 1-hourly Average (µg/m³)	Maximum 8-hour Average (µg/m³)
SA Guidelines(a)	40 000(a)	10 000(a)
RSA SANS limits (SANS:1929,2004)	30 000(b)	10 000(b)
Australian standards	-	10 000 (c)
European Community (EC)	-	10 000(d)
World Bank	-	-
United Kingdom	-	10 000(e)
United States EPA	40 000(f)	10 000(f)
World Health Organisation	30 000(g)	10 000(g)

Notes:
(a) Issued in 1990s by CAPCO. No air quality standards for CO were included in the National Environmental Management: Air Quality Act.
(b) Limit value. Permissible frequencies of exceedance, margin of tolerance and date by which limit value should be complied with not yet set.
(c) Australian ambient air quality standards. (http://www.deh.gov.au/atmosphere/airquality/standards.html). Not to be exceeded more than 1 day per year. Compliance by 2008.

(d) EC Second Daughter Directive, 2000/69/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Annual limit value to be complied with by 1 January 2005.
(e) UK Air Quality Objective (www.airquality.co.uk/archive/standards/php). Maximum daily running 8-hourly mean. Compliance by 31 December 2003.
(f) US National Ambient Air Quality Standards (www.epa.gov/air/criteria.html). Not to be exceeded more than one per year.
(g) WHO Guidelines for the protection of human health (WHO, 2000).

- *Air Quality Standards for Metals*
  Air quality guidelines and standards are issued by various countries, including South Africa, for lead (Table 9.5). There is also an increasing trend towards the specification of air quality limits for certain other metals. The limits published by the EC for arsenic, nickel and cadmium are summarised in Table 9.6. No air quality limits have been set for such metals in South Africa to date.

Table 9.5 Ambient air quality guidelines and standards for lead

Authority	Maximum 1-month/Quarterly Average (µg/m³)	Annual Average (µg/m³)
SA Standard (Air Quality Act)	2.5 (1-month)	
RSA SANS limits (SANS:1929,2004)	-	0.5(a) 0.25(b)
European Community (EC)	-	0.5(d)
World Bank	-	-
United Kingdom	-	0.5(e) 0.25(f)
United States EPA	1.5 (quarterly)(g)	-
World Health Organisation	-	0.5(h)

Notes:
(a) Limit value. Compliance date not yet set.
(b) Target value. Compliance date not yet set.
(d) EC First Daughter Directive, 1999/30/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Annual limit value to be complied with by 1 January 2010.
(e) UK Air Quality Objective (www.airquality.co.uk/archive/standards/php). Compliance by 31 December 2004.
(f) UK Air Quality Objective (www.airquality.co.uk/archive/standards/php). Compliance by 31 December 2008.
(g) US National Ambient Air Quality Standards (www.epa.gov/air/criteria.html).
(h) WHO Guidelines for the protection of human health (WHO, 2000).

Table 9.6 Ambient air quality target values issued by the EC for metals (EC Fourth Daughter Directive, 2004/107/EC.

Pollutant	Target Value (for the total content in the PM10 fraction averaged over a calendar year) (ng/m^3)
Arsenic	6
Cadmium	5
Nickel	20

- *Dust Deposition*
  Foreign dust deposition standards issued by various countries are given in Table 9.7. It is important to note that the limits given by Argentina, Australia, Canada, Spain and the USA are based on annual average dustfall. The standards given for Germany are given for maximum monthly dustfall and therefore comparable to the dustfall categories issued locally. Based on a comparison of the annual average dustfall standards it is evident that in many cases a threshold of ~200 $mg/m^2/day$ to ~300 $mg/m^2/day$ is given for residential areas.

Table 9.7: Dust deposition standards issued by various countries

Country	Annual Average Dust Deposition Standards (based on monthly monitoring) (mg/m2/day)	Maximum Monthly Dust Deposition Standards (based on 30 day average) (mg/m2/day)
Argentina	133	
Australia	133 (onset of loss of amenity) 333 (unacceptable in New South Wales)	
Canada Alberta: Manitoba:	179 (acceptable) 226 (maximum acceptable) 200 (maximum desirable)	
Germany		350 (maximum permissible in general areas) 650 (maximum permissible in industrial areas)
Spain	200 (acceptable)	
USA: Hawaii Kentucky New York Pennsylvania	 200 175 200 (urban, 50 percentile of monthly value) 300 (urban, 84 percentile of monthly value) 267	

Country	Annual Average Dust Deposition Standards (based on monthly monitoring) (mg/m2/day)	Maximum Monthly Dust Deposition Standards (based on 30 day average) (mg/m2/day)
Washington	183 (residential areas) 366 (industrial areas)	
Wyoming	167 (residential areas) 333 (industrial areas)	

Locally dust deposition is evaluated according to the criteria published by the South African Department of Environmental Affairs and Tourism (DEAT). In terms of these criteria dust deposition is classified as follows:

SLIGHT	-	less than 250 mg/m^2/day
MODERATE	-	250 to 500 mg/m^2/day
HEAVY	-	500 to 1200 mg/m^2/day
VERY HEAVY	-	more than 1200 mg/m^2/day

The Department of Minerals and Energy (DME) uses the uses the 1 200 mg/m^2/day threshold level as an action level. In the event that on-site dustfall exceeds this threshold, the specific causes of high dustfall should be investigated and remedial steps taken.

"Slight" dustfall is barely visible to the naked eye. "Heavy" dustfall indicates a fine layer of dust on a surface, with "very heavy" dustfall being easily visible should a surface not be cleaned for a few days. Dustfall levels of > 2000 mg/m^2/day constitute a layer of dust thick enough to allow a person to "write" words in the dust with their fingers.

A perceived weakness of the current dustfall guidelines is that they are purely descriptive, without giving any guidance for action or remediation (SLIGHT, MEDIUM, HEAVY, VERY HEAVY). It has recently been proposed (as part of the SANS air quality standard setting processes) that dustfall rates be evaluated against a four-band scale, as presented in Table 9.8. Proposed target, action and alert thresholds for ambient dust deposition are given in Table 9.9.

According to the proposed dustfall limits an enterprise may submit a request to the authorities to operate within the Band 3 ACTION band for a limited period, providing that this is essential in terms of the practical operation of the enterprise (for example the final removal of a tailings deposit) and provided that the best available control technology is applied for the duration. No margin of tolerance will be granted for operations that result in dustfall rates in the Band 4 ALERT.

Table 9.8: Bands of dustfall rates proposed for adoption

BAND NUMBER	BAND DESCRIPTION LABEL	DUST-FALL RATE (D) (mg m^{-2} day^{-1}, 30-day average)	COMMENT
1	RESIDENTIAL	D < 600	Permissible for residential and light commercial
2	INDUSTRIAL	600 < D < 1 200	Permissible for heavy commercial and industrial
3	ACTION	1 200 < D < 2 400	Requires investigation and remediation if two sequential months lie in this band, or more than three occur in a year.
4	ALERT	2 400 < D	Immediate action and remediation required following the first exceedance. Incident report to be submitted to relevant authority.

Table 9.9: Target, action and alert thresholds for ambient dustfall

LEVEL	DUST-FALL RATE (D) (mg m^{-2} day^{-1}, 30-day average)	AVERAGING PERIOD	PERMITTED FREQUENCY OF EXCEEDANCES
TARGET	300	Annual	
ACTION RESIDENTIAL	600	30 days	Three within any year, no two sequential months.
ACTION INDUSTRIAL	1 200	30 days	Three within any year, not sequential months.
ALERT THRESHOLD	2 400	30 days	None. First exceedance requires remediation and compulsory report to authorities.

9.2.3. Inhalation Health Risk Evaluation Criteria for Metals (and Sulphur Dioxide)

Air quality criteria for non-criteria pollutants are published by various sources. Such criteria include:

(i) World Health Organization guideline values for non-carcinogens and unit risk factor guidelines for carcinogens,

(ii) Chronic and sub-chronic inhalation reference concentrations and cancer unit risk factors published by the US-EPA in its Integrated Risk Information System (IRIS),

(iii) Acute, sub-acute and chronic effect screening levels published by the Texas Natural Resource Conservation Commission Toxicology and Risk Assessment Division (TARA) and

(iv) Reference exposure levels (RELs) published by the Californian Office of Environmental Health Hazard Assessment (OEHHA).

(v) Minimal risk levels issued by the US Federal Agency for Toxic Substances and Disease Registry (ATSDR).

Various non-carcinogenic exposure thresholds for pollutants of interest in the current study are given in Table 9.10.

TARA ESLs are based on data concerning health effects, odour nuisance potential, vegetation effects, or corrosion effects. *ESLs are not ambient air quality standards!* If predicted or measured airborne levels of a constituent do not exceed the screening level, it is not expected that any adverse health or welfare effects would results. If ambient levels of constituents in air exceed the screening levels it does not, however, necessarily indicate a problem, but should be viewed as a trigger for a more in-depth review.

WHO guideline values are based on the no observed adverse effect level (NOAEL) and the lowest observed adverse effect level (LOAEL). Although most guideline values are based on NOAELs and/or LOAELs related to human health endpoints, certain of the guidelines given for 30 minute averaging periods are related to odour thresholds. The short term ESLs issued by TARA for certain odourous compounds are similarly intended to be used for a screening for potential nuisance impacts related to malodour.

Inhalation reference concentrations (RfCs) *related to inhalation exposures* are published in the US-EPA's Integrated Risk Information System (IRIS) database. RfCs are used to estimate non-carcinogenic effects representing a level of environmental exposure at or below which no adverse effect is expected to occur. The RfC is defined as "an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without appreciable risk of deleterious effects during a lifetime" (IRIS, 1998). Non-carcinogenic effects are evaluated by calculating the ratio, or hazard index, between a dose (in this case the dosage) and the pollutant-specific inhalation RfC. In the current study reference will be made to the chronic inhalation toxicity values published by US-EPA (IRIS, 1998)[(3)].

RfCs are based on an assumption of lifetime exposure and thus provide a very conservative estimate when applied to less-than-lifetime exposure situations. The RfC is also not a direct or absolute estimator of risk, but rather a reference point to gauge potential effects. Doses at or below the RfC are not likely to be

[3] The Integrated Risk Information System (IRIS), prepared and maintained by the U.S. Environmental Protection Agency (U.S. EPA), is an electronic data base containing information on human health effects that may result from exposure to various chemicals in the environment. IRIS was initially developed for EPA staff in response to a growing demand for consistent information on chemical substances for use in risk assessments, decision-making and regulatory activities. The information in IRIS is intended for those without extensive training in toxicology, but with some knowledge of health sciences.

associated with any adverse health effects. However, exceedance of the RfC does not imply that an adverse health effect would necessarily occur. As the amount and frequency of exposures exceeding the RfC increase, the probability that adverse effects may be observed in the human population also increases. *The US-EPA has therefore specified that although doses below the RfC are acceptable, doses above the RfC are not necessarily unsafe.*

The US Federal Agency for Toxic Substances and Disease Registry (ATSDR) uses the no-observed-adverse-effect-level/uncertainty factor (NOAEL/UF) approach to derive maximum risk levels (MRLs) for hazardous substances. They are set below levels that, based on current information, might cause adverse health effects in the people most sensitive to such substance-induced effects. MRLs are derived for acute (1-14 days), intermediate (>14-364 days), and chronic (365 days and longer) exposure durations, and for the oral and inhalation routes of exposure. MRLs are generally based on the most sensitive substance-induced end point considered to be of relevance to humans. ATSDR does not use serious health effects (such as irreparable damage to the liver or kidneys, or birth defects) as a basis for establishing MRLs. Exposure to a level above the MRL does not mean that adverse health effects will occur.

MRLs are intended to serve as a screening tool to help public health professionals decide where to look more closely. They may also be viewed as a mechanism to identify those hazardous waste sites that are not expected to cause adverse health effects. Most MRLs contain some degree of uncertainty because of the lack of precise toxicological information on the people who might be most sensitive (e.g., infants, elderly, and nutritionally or immunologically compromised) to effects of hazardous substances. ATSDR uses a conservative (i.e., protective) approach to address these uncertainties consistent with the public health principle of prevention. Although human data are preferred, MRLs often must be based on animal studies because relevant human studies are lacking. In the absence of evidence to the contrary, ATSDR assumes that humans are more sensitive than animals to the effects of hazardous substances that certain persons may be particularly sensitive. Thus the resulting MRL may be as much as a hundredfold below levels shown to be nontoxic in laboratory animals. When adequate information is available, physiologically based pharmacokinetic (PBPK) modeling and benchmark dose (BMD) modeling have also been used as an adjunct to the NOAEL/UF approach in deriving MRLs.

Proposed MRLs undergo a rigorous review process. They are reviewed by the Health Effects/MRL Workgroup within the Division of Toxicology; and expert panel of external peer reviewers; the agency wide MRL Workgroup, with participation from other federal agencies, including EPA; and are submitted for public comment through the toxicological profile public comment period. Each MRL is subject to change as new information becomes available concomitant with updating the

toxicological profile of the substance. MRLs in the most recent toxicological profiles supersede previously published levels.

In the assessment of the potential for health risks use will generally be made of the lowest threshold published for a particular pollutant and averaging period (as given in Table 9.10), with the exception that TARA ESLs will only be used where other criteria such as WHO guidelines, IRIS RfCs or OEHHA RELs are not available .

Table 9.10 Health risk criteria for non-carcinogenic exposures via the inhalation pathway

	WHO Guidelines (2000)		US-EPA IRIS Inhalation Reference Concentrations		California OEHHA		US ATSDR Maximum Risk Levels (MRLs)			TARA ESLs (2003)	
Constituent	Acute & Sub-acute Guidelines (ave period given)	Chronic Guidelines (year +)	Sub-chronic inhalation RfCs	Chronic inhalation RfCs	Acute RELs (ave period given)	Chronic RELs	Acute (1-14 days)	Intermediate (>14 – 365 days)	Chronic (365+ days)	Short-term ESL (1 hr)	Long-term ESL (year+)
	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
Arsenic					0.19 (4 hrs)	0.03				0.1	0.0
Barium										50	
Bismuth											
Cadmium		0.005 (GV)				0.02				0.1	0.0
chromium (II) and (III) compounds										1	0.
chromium (VI) compounds				0.1		0.2		1.0		0.1	0.0
Cobalt								0.1		0.2	0.0
Copper					100 (1 hr)					10	
Gallium											
Germanium											
Lead		0.5(GV)									
Manganese		0.15 (GV)		0.05		0.2			0.04	2	0.
Mercury		1(GV)		0.3	1.8 (1 hr)	0.09			0.2	0.25	0.02
Nickel & compounds					6 (1 hr)	0.05		0.2	0.09	0.15	0.01
Niobium											
Nitrogen dioxide	See Table 2.11	See Table 2.11			470 (1 hr)(a)						

Constituent	WHO Guidelines (2000)		US-EPA IRIS Inhalation Reference Concentrations		California OEHHA		US ATSDR Maximum Risk Levels (MRLs)			TARA ESLs (2003)	
	Acute & Sub-acute Guidelines (ave period given)	Chronic Guidelines (year +)	Sub-chronic inhalation RfCs	Chronic inhalation RfCs	Acute RELs (ave period given)	Chronic RELs	Acute (1-14 days)	Intermediate (>14 – 365 days)	Chronic (365+ days)	Short-term ESL (1 hr)	Long-term ESL (year+)
	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
Rhiobium											
Selenium						20				2	0.
Strontium										20	
Sulphur dioxide	See Table 2.11	See Table 2.11			660 (1 hr)(a)		26.2				
Thorium											
Tin										20	
Tungsten										50(b) 10(c)	5(b 1(c
Uranium								8(b) 0.4(c)	0.3(c)	2(b) 0.5(c)	0.2(b 0.05(c
Vanadium	1(GV, 24hrs)						0.2				
Yiddium											
Zinc										50	
Zirconium										50	

Abbreviations: WHO – World Health Organisation
IRIS – Integrated Risk Information System
OEHHA – Office of Environmental Health Hazard Assessment
ATSDR – US Federal Agency for Toxic Substances and Disease Registry
TARA - Texas Natural Resource Conservation Commission Toxicology and Risk Assessment Division

GV – guideline value
RfC – inhalation reference concentration
MRL – maximum risk level
ESL – effect screening level
REL – reference exposure level

Notes:
(a) Threshold for mild respiratory irritation
(b) Insoluble compounds
(c) Highly soluble

Table 9.11 WHO guidelines for nitrogen dioxide and sulphur dioxide including health endpoints, observed effect levels and uncertainty factors (WHO, 2000)

Compound	Health Endpoint	Observed Effect Level (µg/m³)	Uncertainty Factor	Guideline Value (µg/m³)	Averaging Period
Nitrogen dioxide	Slight changes in lung function in asthmatics	365-565	0.5	200	1 hour
Sulphur dioxide	Changes in lung functions in asthmatics	1000	2	500	10 minutes
		250	2	125	24 hours
	Exacerbations of respiratory symptoms in sensitive individuals	100	2	50	1 year

- *Cancer Risk Factors*

  Unit risk factors are applied in the calculation of carcinogenic risks. These factors are defined as the estimated probability of a person (60-70 kg) contracting cancer as a result of constant exposure to an ambient concentration of 1 µg/m^3 over a 70-year lifetime. *In the generic health risk assessment undertaken as part of the current study, maximum possible exposures (24-hours a day over a 70-year lifetime) are assumed for all areas beyond the boundary of the proposed development site.* Unit risk factors were obtained from the WHO (2000) and from the US-EPA IRIS database. Unit Risk Factors for compounds of interest in the current study are given in Table 9.12.

Table 9.12 Unit risk factors from the California EPA, US-EPA Integrated Risk Information System (IRIS) (as at February 2006) and WHO risk factors (2000)

Chemical	California EPA Unit Risk Factor (µg/m^3)	WHO Inhalation Unit Risk (µg/m^3)	US-EPA IRIS Unit Risk Factor (µg/m^3)	IARC Cancer Class	US-EPA Cancer Class[a]
Arsenic, Inorganic[a]	3.3×10^{-3}	1.5×10^{-3}	4.3×10^{-3}	1	A
Cadmium	4.2×10^{-3}	-	1.8×10^{-3}	2A	B1
Chromium VI (particulates)	1.5×10^{-1}	1.1×10^{-2} to 13×10^{-2}	1.2×10^{-2}	1	A
Lead	1.2×10^{-5}	-	-	2B	B2
Nickel & nickel compounds	2.6×10^{-4}	3.8×10^{-4}	2.4×10^{-4}[b]	1	A
Nickel sulphide	4.9×10^{-4}	-	4.8×10^{-4}[c]	1	A

[a]EPA cancer classifications:

A--human carcinogen.

B--probable human carcinogen. There are two sub-classifications:

B1--agents for which there is limited human data from epidemiological studies.

B2--agents for which there is sufficient evidence from animal studies and for which there is inadequate or no evidence from human epidemiological studies.

C--possible human carcinogen.

D--not classifiable as to human carcinogenicity.

E--evidence of non-carcinogenicity for humans.

[b]Refinery dust

[c]Nickel subsulfide

- *Evaluation of Cancer Risk Acceptability*

  The definition of what is deemed to be an acceptable risk remains one of the most controversial aspects of risk characterisation studies. An important point to be borne in mind is the crucial distinction between voluntary and involuntary risks. The risk to which a member of the public is exposed from an industrial activity is an involuntary one. In general, people are prepared to tolerate higher levels of risk for hazards to which they exposure themselves voluntarily.

There appears to be a measure of uncertainty as to what level of risk would be acceptable to the public. Pollutants are often excluded from further assessment when they contribute an individual risk of less than 1×10^{-7}. (A carcinogenic risk of 1×10^{-7} corresponds to a one-in-ten-million chance of an individual developing cancer during their lifetime.) The US-EPA adopts a 1 in a million chance for cancer risks (i.e. 1×10^{-6}), applied to a person being in contact with the chemical for 70 years, 24-hours per day. Although a risk of 10^{-7} (1 in 10 million) would be desirable, and a risk of less than 10^{-6} (1 in 1 million) acceptable in terms of US regulations, some authors (Kletz, 1976; Lees, 1980; Travis *et al*., 1987) suggest that a risk level of between 10^{-5} and 10^{-6} per year (i.e. 1:100 000 and 1: 1000 000) could still be acceptable. Further work by Travis *et al.* (1987) indicated that for small populations, risks of less than 10^{-4} (1 in 10 000) may also potentially be acceptable, whereas risks greater than 10^{-4} are likely to prompt action.

Nationally the Department of Environmental Affairs and Tourism (DEAT) has only been noted to give an indication of cancer risk acceptability in the case of dioxin and furan exposures. According to the DEAT, emissions of dioxins and furans from a hazardous waste incinerator may not result in an excess cancer risk of greater than 1: 100 000 on the basis of annual average exposure (DEAT, 1994). Excess cancer risks of less than 1:100 000 appear therefore to be viewed as acceptable to the DEAT.

9.2.4. UK Banding Approach and Dose-response Thresholds for Sulphur Dioxide

- *UK Banding Approach to Classification of Air Pollutants*
  The United Kingdom Department of Environment uses "banding" to make air quality information more meaningful. In banding, a set of criteria are used to classify air pollution levels into bands with a description associated with each band. The UK air quality bands for various pollutants and the definitions of such bands are given in Tables 9.13 and 9.14.

Table 9.13 UK bands for the classification of air pollution concentrations (after http://www.aeat.co.uk/netcen/airqual/).

Band	Index	Ozone		Nitrogen Dioxide		Sulphur Dioxide		Carbon Monoxide		PM10 Particles
		8 hourly or hourly mean*		hourly mean		15 minute mean		8 hour mean		24 hour mean
		µgm-3	ppb	µgm-3	ppb	µgm-3	ppb	mgm-3	ppm	µgm-3
Low										
	1	0-32	0-16	0-95	0-49	0-88	0-32	0-3.8	0.0-3.2	0-16
	2	33-66	17-32	96-190	50-99	89-176	33-66	3.9-7.6	3.3-6.6	17-32
	3	67-99	33-49	191-286	100-149	177-265	67-99	7.7-11.5	6.7-9.9	33-49
Moderate										
	4	100-126	50-62	287-381	150-199	266-354	100-132	11.6-13.4	10.0-11.5	50-57
	5	127-152	63-76	382-476	200-249	355-442	133-166	13.5-15.4	11.6-13.2	58-66
	6	153-179	77-89	478-572	250-299	443-531	167-199	15.5-17.3	13.3-14.9	67-74
High										
	7	180-239	90-119	573-635	300-332	532-708	200-266	17.4-19.2	15.0-16.5	75-82
	8	240-299	120-149	363-700	333-366	709-886	267-332	19.3-21.2	16.6-18.2	83-91
	9	300-359	150-179	701-763	367-399	887-1063	333-399	21.3-23.1	18.3-19.9	92-99
Very High										
	10	360 or more	180 or more	764 or more	400 or more	1064 or more	400 or more	23.2 or more	20 or more	100 or more
* For ozone, the maximum of the 8 hourly and hourly mean is used to calculate the index value.										

Table 9.14 Definition of UK bands for the classification of air pollution concentrations (after http://www.aeat.co.uk/netcen/airqual/).

Banding	Index	Health Descriptor
Low	1	Effects are unlikely to be noticed even by individuals who know they are sensitive to air pollutants
	2	
	3	
Moderate	4	Mild effects, unlikely to require action, may be noticed amongst sensitive individuals.
	5	
	6	
High	7	Significant effects may be noticed by sensitive individuals and action to avoid or reduce these effects may be needed (e.g. reducing exposure by spending less time in polluted areas outdoors). Asthmatics will find that their 'reliever' inhaler is likely to reverse the effects on the lung.
	8	
	9	
Very High	10	The effects on sensitive individuals described for 'High' levels of pollution may worsen.

- *Health-related Dose-Response Thresholds for Sulphur Dioxide*
  Sulphur dioxide is damaging to the human respiratory function, increasing both the prevalence of chronic respiratory disease, and the risk of acute respiratory disease. Being highly soluble, SO_2 is more likely to be absorbed in the upper airways rather than penetrate to pulmonary region. The impact of SO_2 on human health related to various dosages is given in Table 9.15 (Ferris, 1978; Godish, 1990; .Harrison, 1990; Quint *et al*., 1996; WHO, 2000).

  The lowest concentration of sulphur dioxide at which adverse health effects were noted in community exposure was 70 ppb (24-hour exposure). The World Health Organisation selected the 24-hour mean concentration of 180 ppb as the level at which excess mortality might be expected among elderly people or those with pulmonary diseases, and 90 ppb (24-hour exposure) as the level at which the conditions of people with respiratory disease might become worse (WHO, 1979). For long-term exposure at 35 ppm (annual mean), increased respiratory symptoms can be expected in adults and children, and increased frequencies of respiratory illnesses among children (WHO, 1979). Current South African guidelines for sulphur dioxide exposures have been set close to these ambient air pollutant threshold levels. During a more recent publication, the WHO stipulates 95 ppb and 38 ppb as the lowest sulphur dioxide concentration levels at which observed health effects have occurred based on daily and annual exposures, respectively (WHO, 2000).

Table 9.15 Symptoms in humans related to various dosages of sulphur dioxide[(1)]

Symptoms	Concentrations (mg/m^3)	Concentrations (ppm)	Duration of Exposure
Lung edema; bronchial inflammation	1047	400	-
Eye irritation; coughing in healthy adults	52	20	-
Decreased mucociliary activity	37	14	1 hr
Bronchospasm	26	10	10 min
Throat irritation in healthy adults	21	8	-
Increased airway resistance in healthy adults at rest	13	5	10 min
Increased airway resistance in asthmatics at rest and in healthy adults at exercise	2.6	1	10 min
Increased airway resistance in asthmatics at exercise	1.3	0.5	10 min
Odour threshold	1.3	0.5	-
Aggravation of chronic respiratory disease in adults	0.50	0.19	24 hr[(2)]
Excess mortality may be expected among the elderly and people suffering from respiratory illnesses	0.47	0.18	24 hr
Aggravation of chronic respiratory disease in children	0.18	0.07	annual[(2)]
Lowest levels at which adverse health effects noted	0.18	0.07	24 hr

Notes:

[(1)] References: Harrison, 1990; Godish, 1991; Ferris, 1978; Quint*et al*., 1996; WHO, 2000.

[(2)] Occurs in the presence of high concentrations of particulate matter.

9.2.5. Potential for Damage to Metals

Concerns have been raised in the region regarding the potential for elevated atmospheric pollutants concentrations resulting in the accelerated rusting of farm fences. For this reason, the relationship between air pollutant concentrations and damage to metals is explored.

The atmospheric corrosion of metals is a complex process, with both the extent of deterioration and the mechanisms varying considerably depending on the metal. Depending on the way pollutants are transported from the atmosphere to the corroding surface, two types of deposition processes are recognized in atmospheric corrosion – dry deposition and wet deposition. Wet deposition refers to precipitation whereas dry deposition refers to the remaining processes, including gas phase deposition and particle deposition. The most important pollutants acting as corrosive agents are sulphur and nitrogen compounds, including secondary pollutants and particulates. Pollutants can contribute to corrosivity individually; however there may be a synergistic effect when more than one of these pollutants is present in the environment being affected. In the field of atmospheric corrosion, sulphur dioxide is the single most investigated

gaseous pollutant and the quantification of the direct contribution of sulphur dioxide to the corrosion process of metallic materials is comparatively well understood (Tidblad and Kucera, 2003).

It is important to recognise that atmospheric corrosion is a process that occurs even in the absence of pollutants and that the interplay between natural and anthropogenic factors determine the extent to which elevated air pollutant concentrations accelerates the "natural" or background atmospheric corrosion.

This section focuses on the effects of acidifying air pollutants, specifically sulphur dioxide, on metallic materials and provides a methodology for assessing excess rates of corrosion associated with sulphur dioxide concentrations occurring due to power station emissions. In the absence of readily available measurements on the corrosion action of air pollutants on metals (e.g. fences) locally, European studies (Tidblad and Kucera, 2003) were consulted to determine the corrosion potential for the current study.

The natural corrosivity over South Africa without the influence of pollutants is illustrated in Figure 9.3. The natural background corrosivity in the Lephalale area is "low". The corrosion rate (r_{corr}) is specified in the International Standard ISO 9226, given in Table 9.16 with the corrosivity classes given in Table 9.17. Using this data it is evident that the natural "low" corrosivity of the area is between 1.3 µm/yr to 25 µm/yr (average corrosivity is 13.15 µm/yr).

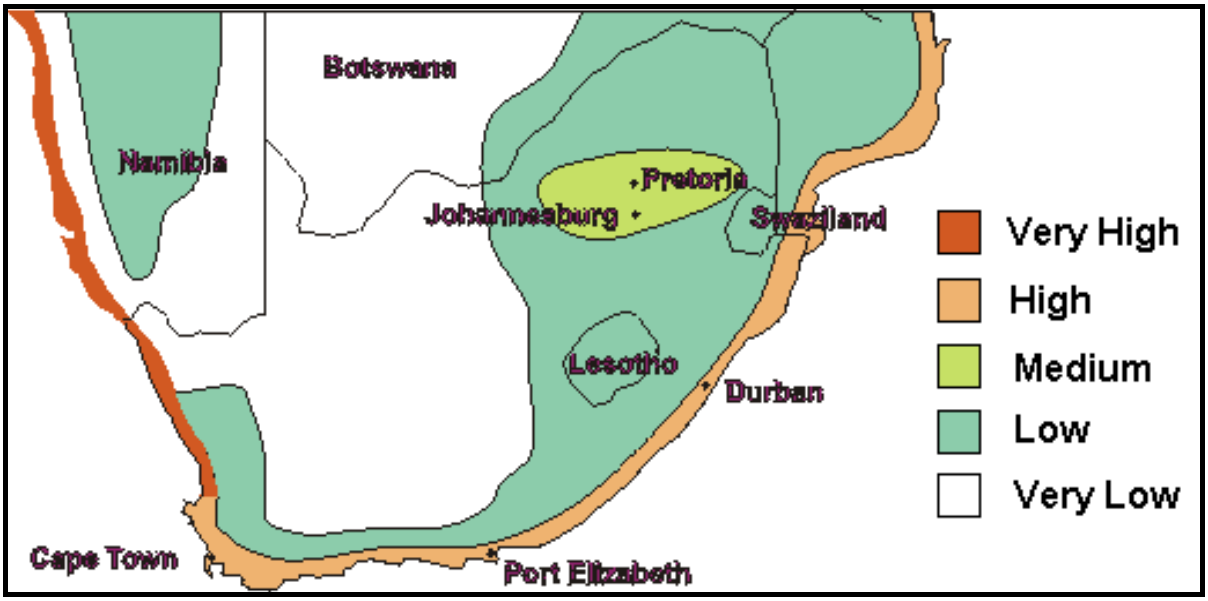

Figure 9.3 Corrosivity map of South Africa.

Table 9.16 Corrosivity categories from first year exposure data (ISO 9226)

Corrosivity Category	Corrosion rate (r_{corr}) of metals				
	Units	**Carbon Steel**	**Zinc**	**Copper**	**Aluminium**
C1	g/(m².yr)	0-10	0-0.7	0-0.9	Negligible
	µm/yr	0-1.3	0-0.1	0-0.1	
C2	g/(m².yr)	10-200	0.7-5	0.9-5	0-0.6
	µm/yr	1.3-25	0.1-0.7	0.1-0.6	
C3	g/(m².yr)	200-400	5-15	5-12	0.6-2
	µm/yr	25-50	0.7-2.1	0.6-1.3	
C4	g/(m².yr)	400-650	15-30	12-25	2-5
	µm/yr	40-80	2.1-4.2	1.3-2.8	
C5	g/(m².yr)	650-1500	30-60	25-50	5-10
	µm/yr	80-200	4.2-8.4	2.8-5.6	

Table 9.17 Categories of corrosivity (ISO 9226)

Category	Corrosivity
C1	Very Low
C2	Low
C3	Medium
C4	High
C5	Very High

The amount of annual corrosion due to dry deposition that can be expected due to various SO_2 concentration levels is illustrated in Figure 2.2 based on information from various European cities. From this information, ground level concentrations for various corrosion categories can be assumed. Table 9.18 provides calculated corrosion rates occurring due to SO_2 exposures without natural corrosivity action and associated ground level concentration levels.

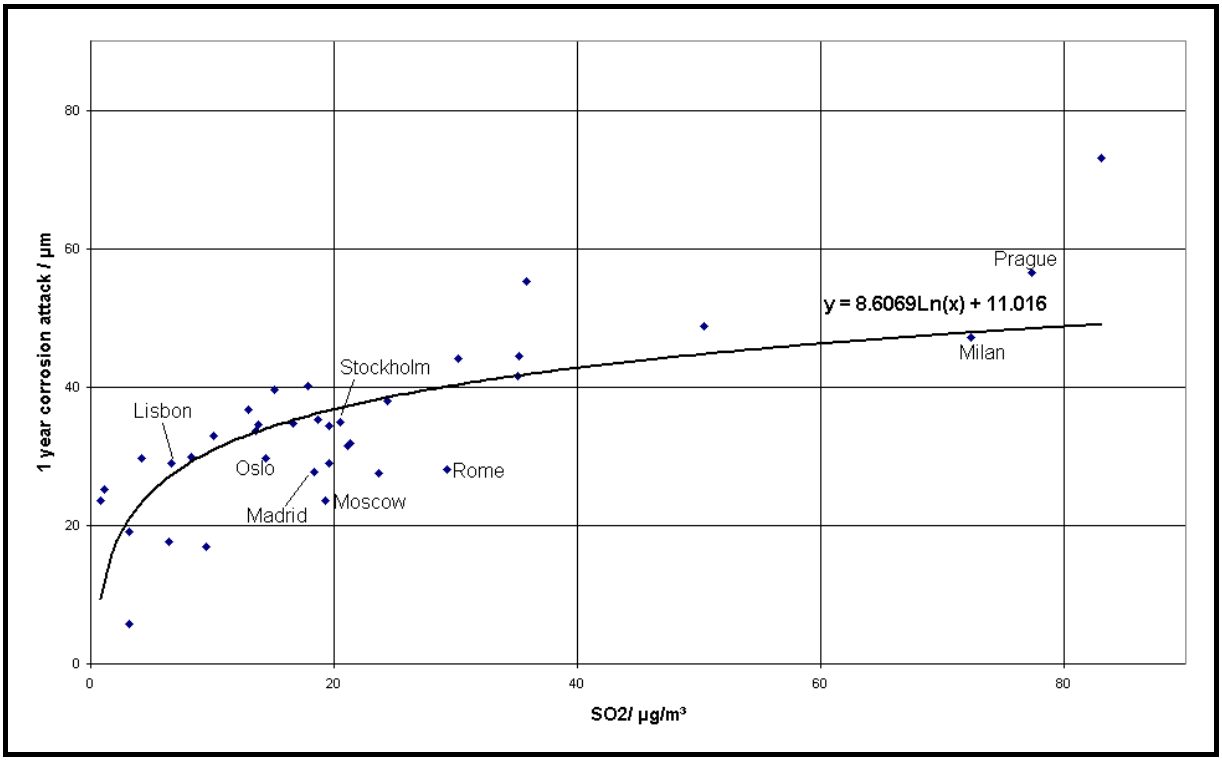

Figure 9.4 Corrosion attack of unsheltered carbon steel exposed in various European cities to SO_2 concentration, as analysed in the UN ECE exposure program during the period September 1987 to August 1988 (Tidblad and Kucera, 2003).

Table 9.18 Corrosion potential of SO_2 at various ground level concentrations.

SO_2	Corrosivity			
	Low	**Medium**	**High**	**Very High**
Corrosion Rate (µm/yr)	11.85	36.85	66.85	186.85
Ground Level Concentration (µg/m³)	1.1	20	657	745,078,396

9.2.6. Vegetation Exposures to Air Pollution

- *Sulphur Dioxide*

  High concentrations of SO_2 over short periods may result in acute visible injury symptoms. Such symptoms are usually observed on broad-leaved plants as relatively large bleached areas between the larger veins which remain green. On grasses acute injury, usually caused by exposures to sub-lethal long-term intermittent episodes of relatively low concentrations, may be observed as general chlorosis of the leaves (Lacasse and Treshow, 1976). This visible injury may decrease the market value of certain crops and lower the productivity of the plants. Sulphur dioxide impairs stomatal functioning resulting in a decline in photosynthetic rates, which in turn causes a decrease in plant growth. Reduction in plant yields can occur, even in the absence of visible foliar symptoms (Mudd, 1975). Relationships between plant injury and SO_2 dosages are given in Table 9.19.

Species that are sensitive to SO_2 include spinach, cucumber and oats. These species may show decreases in growth at concentrations of 0.01 to 0.5 ppm (26 to 1309 µg/m³) (Mudd, 1975). Visible SO_2 injury can occur at dosages ranging from 0.05 to 0.5 ppm (131 to 1309 µg/m³) for 8 hours or more (Manning and Feder, 1976). Maize, celery and citrus show much less damage at these low concentrations (Mudd, 1975).

Table 9.19 Injury to plants due to various doses of sulphur dioxide[(1)]

Symptoms	Concentrations (µg/m³)	Concentrations (ppm)	Duration of Exposure
visible foliar injury to vegetation in arid regions	26179	10	2 hr
Coverage of 5% of leaf area of sensitive species with visible necrosis[(2)]	1309 – 2749	0.5 - 1.05	1 hr
visible injury to sensitive vegetation in humid regions	2618	1	5 min
Coverage of 5% of leaf area of sensitive species with visible necrosis[(2)]	785 – 1571	0.3 - 0.6	3 hr
visible injury to sensitive vegetation in humid regions	1309	0.5	1 hr
visible injury to sensitive vegetation in humid regions	524	0.2	3 hr
Visible injury to sensitive species	131 – 1309	0.05 - 0.5	8 hrs
Decreased growth in sensitive species	26 – 1309	0.01 - 0.5	-
Coverage of 5% of leaf area of sensitive species with visible necrosis[(2)]	524 – 680	0.2 - 0.26	6 - 8 hrs
Yield reductions may occur	524	0.2	monthly mean
Growth of conifers and yield of fruit trees may be reduced	262	0.1	monthly mean
Yield reductions may occur	209	0.08	annual mean
Growth of conifers and yield of fruit trees may be reduced	131	0.05	annual mean
Critical level for agricultural crops, forest trees and natural vegetation[(3)]	79	0.03	24-hrs
Critical level for agricultural crops[(3)]	26	0.01	annual mean
Critical level for forest trees and natural vegetation [(3)]	21	0.008	annual mean

Notes:

[(1)]References: Laccasse and Treshow, 1976; Mudd, 1975; Manning and Feder, 1976; Harrison, 1990; Godish, 1991; Ferris, 1978

[(2)]Resistant species found to have threshold levels at three times these concentrations.

[3]Refer to critical levels used by the United National Economic Commission for Europe to map exceedence areas. These represent levels at which negative responses have been noted for sensitive receptors.

Air quality criteria issued by the EC, UK and WHO for the protection of ecosystems against sulphur dioxide exposures are summarised in Table 9.20.

Table 9.20. Thresholds specified by certain countries and organisations for vegetation and ecosystems

Pollutant	Averaging Period	Threshold (ppb/ppm)	Threshold ($\mu g/m^3$ or mg/m^3)
Sulphur dioxide	annual average	3.7 - 11.1 ppb(a) 7.4 ppb(b)	10 - 30 $\mu g/m^3$(a) 20 $\mu g/m^3$ (b)

(a) Represents the critical level for ecotoxic effects issued by the WHO for Europe; a range is given to account for different sensitivities of vegetation types

(b) EC and UK limit value to protect ecosystems

- *Oxides of Nitrogen*

  Direct exposure to NO_x may cause growth inhibitions in some plants (Table 9.21). Higher concentrations of NO_x are usually needed to cause injury than for other pollutants such as ozone and sulphur dioxide. Chronic injury, such as chlorosis, may be caused by long-term exposures to relatively low concentrations of nitrogen dioxide but are reversible on young leaves. Acute injury is observed as irregularly shaped lesions that become white to tan, similar to those produced by SO_2. Sensitive plants to NO_x include beans and lettuce, whereas citrus and peach trees are rated as having an intermediary sensitivity. NO_x may also impact indirectly on plants since the oxidation of NO_2 to nitric acid contributes to acid rain problems. Acid rain serves to increasing the leaching of base cations from most soils in affected areas, resulting in the change in the acidity of the soils.

Table 9.21 Injury to plants caused by various dosages of NO_2**.**

Symptoms	Concentration ($\mu g/m^3$)	Concentration (ppm)	Duration of Exposure
foliar injury to vegetation	3774	2	4 hr
slight spotting of pinto bean, endive, and cotton	1887	1	48 hr
subtle growth suppression in some plant species without visible foliar markings	943	0.5	10-20 days
decreased growth and yield of tomatoes and oranges	472	0.25	growing season
reduction in growth of Kentucky bluegrass	189	0.1	20 weeks

References: (Ferris, 1978; Godish, 1990; Harrison, 1990; Quint *et al.*, 1996).

Critical levels for **NO_x**, used by the United National Economic Commission for Europe to map exceedence areas, are given as 30 µg/m^3 for annual means and 95 µg/m^3 for a 4-hour mean for agricultural crops, forest trees and natural and semi-natural vegetation.

Air quality criteria issued by the EC and UK for the protection of vegetation against nitrogen oxide exposures are summarised in Table 9.22.

Table 9.22. Thresholds specified by certain countries and organisations for vegetation and ecosystems

Pollutant	Averaging Period	Threshold (ppb/ppm)	Threshold (µg/m^3 or mg/m^3)
nitrogen oxides (NOx)	annual average	20 ppb(a)	30 µg/m^3 (a)

(a) EU limit value specifically designed for the protection of vegetation

9.3. Climatology And Atmospheric Dispersion Potential

Meteorological mechanisms 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. 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 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 the variability in wind direction, 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 therefore 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 accurately parameterise the atmospheric dispersion potential of a particular area.

A qualitative description of the synoptic systems determining the macro-ventilation potential of the proposed development site is provided in Section 3.1

based on the review of pertinent literature and on the analysis of meteorological data observed for the region. The meso-scale wind field and ventilation potential is characterised (Section 3.2) based on the analysis of surface meteorological data from stations located in the area including:

- South African Weather Services (SAWS) station at Ellisras
- Eskom's monitoring sites, viz. Zwartwater, Grootstryd and Waterberg

Upper air meteorological data generated by the SAWS using the ETA model were also purchased for a point in the region to provide the required input data for the atmospheric dispersion modelling to be conducted during the air quality impact assessment component of the project. The data availability for the surface and upper are data used / to be used in the current study is given in Table 9.23.

Windfield data were also obtained for the Waterberg station which was operated by Eskom during the 1984 to 1989 period at a site located ~18 km south of Matimba Power Station. These data were primarily used in the analysis of the air pollutant concentrations recorded at this station and will not be input into the dispersion model. Windfield data availability for this station was in the order of 70%.

Table 9.23: Data availability for surface and upper air meteorological data for the period 2001 to 2003.

Data	Station	Period		
		2001	2002	2003
Surface data	Ellisras	100%	100 %	100 %
	Zwartwater(1)	64%	90 %	69%
	Grootstryd(2)	0 %	0 %	100 %
Upper air data	ETA	100 %	42 %	76%

Notes:

The Zwartwater monitoring station was decommissioned in October 2003.

The Grootstryd monitoring station was started in October 2003.

9.3.1. Synoptic Climatology and Regional Atmospheric Dispersion Potential

- *Synoptic Climatology*
  Situated in the subtropical high pressure belt, southern Africa is influenced by several high pressure cells, in addition to various circulation systems prevailing in the adjacent tropical and temperature latitudes. The mean circulation of the atmosphere over southern Africa is anticyclonic throughout the year (except near the surface) due to the dominance of three high pressure cells, viz. the South Atlantic HP off the west coast, the South Indian HP off the east coast, and the continental HP over the interior.

The five major synoptic circulation types affecting southern Africa are: continental anticyclone, ridging anticyclone, topical easterly disturbances, westerly waves and troughs and cut-off lows (Vowinckel, 1956; Schulze, 1965; Taljaard, 1972; Preston-Whyte and Tyson, 1988). The most important of these is the semi-permanent, subtropical continental anticyclones which are shown by both Vowinckel (1956) and Tyson (1986) to dominate 70 % of the time during winter and 20 % of the time in summer. This leads to the establishment of extremely stable atmospheric conditions which can persist at various levels in the atmosphere for long periods.

Seasonal variations in the position and intensity of the HP cells determine the extent to which the tropical easterlies and the circumpolar westerlies impact on the atmosphere over the subcontinent. The tropical easterlies, and the occurrence of easterly waves and lows, affect most of southern Africa throughout the year. In winter, the high pressure belt intensifies and moves northward, the upper level circumpolar westerlies expand and displace the upper tropical easterlies equatorward. The winter weather of South Africa is, therefore, largely dominated by perturbations in the westerly circulation. Such perturbations take the form of a succession of cyclones or anticyclones moving eastwards around the coast or across the country. During summer months, the anticyclonic belt weakens and shifts southwards, allowing the tropical easterly flow to resume its influence over South Africa. A weak heat low characterises the near surface summer circulation over the interior, replacing the strongly anticyclonic winter-time circulation (Schulze, 1986; Preston-Whyte and Tyson, 1988).

Anticyclones situated over the subcontinent are associated with convergence in the upper levels of the troposphere, strong subsidence throughout the troposphere, and divergence in the near-surface wind field. Subsidence inversions, fine conditions with little or no rainfall, and light variable winds occur as a result of such widespread anticyclonic subsidence. Anticyclones occur most frequently over the interior during winter months, with a maximum frequency of occurrence of 79 percent in June and July. During December such anticyclones only occur 11 percent of the time. Although widespread subsidence dominates the winter months, weather occurs as a result of uplift produced by localized systems.

Tropical easterly waves give rise to surface convergence and upper air (500 hPa) divergence to the east of the wave resulting in strong uplift, instability and the potential for precipitation. To the west of the wave, surface divergence and upper-level convergence produces subsidence, and consequently fine clear conditions with no precipitation. Easterly lows are usually deeper systems than are easterly waves, with upper-level divergence to the east of the low occurring at higher levels resulting in strong uplift

through the 500 hPa level and the occurrence of copious rains. Easterly waves and lows occur almost exclusively during summer months, and are largely responsible for the summer rainfall pattern and the northerly wind component which occurs over the interior.

Westerly waves are characterised by concomitant surface convergence and upper-level divergence which produce sustained uplift, cloud and the potential for precipitation to the rear of the trough. Cold fronts are associated with westerly waves and occur predominantly during winter when the amplitude of such disturbances is greatest. Low-level convergence in the southerly airflow occurs to the rear of the front producing favourable conditions for convection. Airflow ahead of the front has a distinct northerly component, and stable and generally cloud-free conditions prevail as a result of subsidence and low-level divergence. The passage of a cold front is therefore characterised by distinctive cloud bands and pronounced variations in wind direction, wind speeds, temperature, humidity, and surface pressure. Following the passage of the cold front the northerly wind is replaced by winds with a distinct southerly component. Temperature decrease immediately after the passage of the front, with minimum temperatures being experienced on the first morning after the cloud associated with the front clears. Strong radiational cooling due to the absence of cloud cover, and the advection of cold southerly air combining to produce the lowest temperatures.

- *Regional Atmospheric Dispersion Potential*
  The impact of various synoptic systems and weather disturbances on the dispersion potential of the atmosphere largely depends on the effect of such systems on the height and persistence of elevated inversions. Elevated inversions suppress the diffusion and vertical dispersion of pollutants by reducing the height to which such pollutants are able to mix, and consequently result in the concentration of pollutants below their bases. Such inversions therefore play an important role in controlling the long-range transport, and recirculation of pollution.

  Subsidence inversions, which represent the predominant type of elevated inversion occurring over South Africa, result from the large-scale anticyclonic activity which dominates the synoptic circulation of the subcontinent. Subsiding air warms adiabatically to temperatures in excess of those in the mixed boundary layer. The interface between the subsiding air and the mixed boundary layer is thus characterised by a marked elevated inversion. Protracted periods of anticyclonic weather, such as characterize the plateau during winter, result in subsidence inversions which are persistent in time, and continuous over considerable distances. The fairly constant afternoon mixing depths, with little diurnal variation, associated with the persistence of subsidence inversions, are believed to greatly reduce the dispersion potential

of the atmosphere over the plateau, resulting in the accumulation of pollutants over the region.

Multiple elevated inversions occur in the middle to upper troposphere as a result of large-scale anticyclonic subsidence. The mean annual height and depth of such absolutely stable layers are illustrated in Figure 9.5. Three distinct elevated inversions, situated at altitudes of approximately 700 hPa (~3 km), 500 hPa (~5 km) and 300 hPa (~7 km), were identified over southern Africa. The height and persistence of such elevated inversions vary with latitudinal and longitudinal position. During winter months the first elevated inversion is located at an altitude of around 3 km over the plateau. In summer this inversion is known to increase in to 4 to 5 km over the plateau (Diab, 1975; Cosijn, 1996).

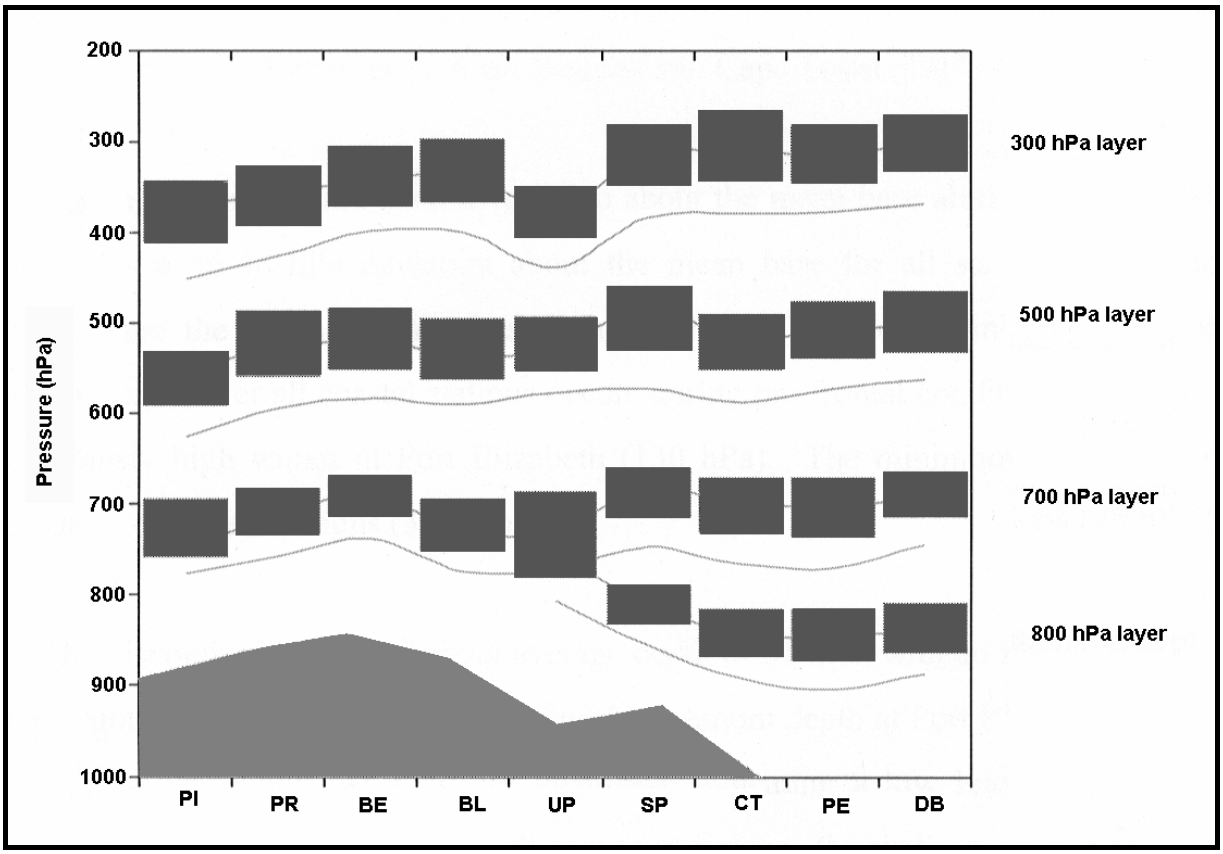

Figure 9.5: Mean annual stable layers (shaded) over Pietersburg (PI), Pretoria (PR), Bethlehem (BE), Bloemfontein (BL), Upington (UP), Springbok (SP), Cape Town (CT), Port Elizabeth (PE) and Durban DB). Upper and lower 95% confidence limits for the base heights of the layers are shown in each case (after Cosijn, 1996).

In contrast to anticyclonic circulation, convective activity associated with westerly and easterly wave disturbances hinders the formation of inversions. Cyclonic disturbances, which are associated with strong winds and upward vertical air motion, either destroy, weaken, or increase the altitude of,

elevated inversions. Although cyclonic disturbances are generally associated with the dissipation of inversions, pre-frontal conditions tend to lower the base of the elevated inversion, so reducing the mixing depth. Pre-frontal conditions are also characterised by relatively calm winds. Over the interior due to the passage of a cold front, there is a tendency for the lowest mixing depths to coincide with the coldest air temperatures and rising pressure. Following the passage of the front, a gradual rise in the mixing depth occurs over the interior (Cosijn, 1996; Preston-Whyte and Tyson, 1988).

9.3.2. Meso-scale Atmospheric Dispersion Potential

- *Meso-Scale Wind Field*
  Annual and seasonal wind roses generated based on measured data from the Ellisras Weather Service Station are illustrated in Figure 9.6 and Figure 9.7 respectively.

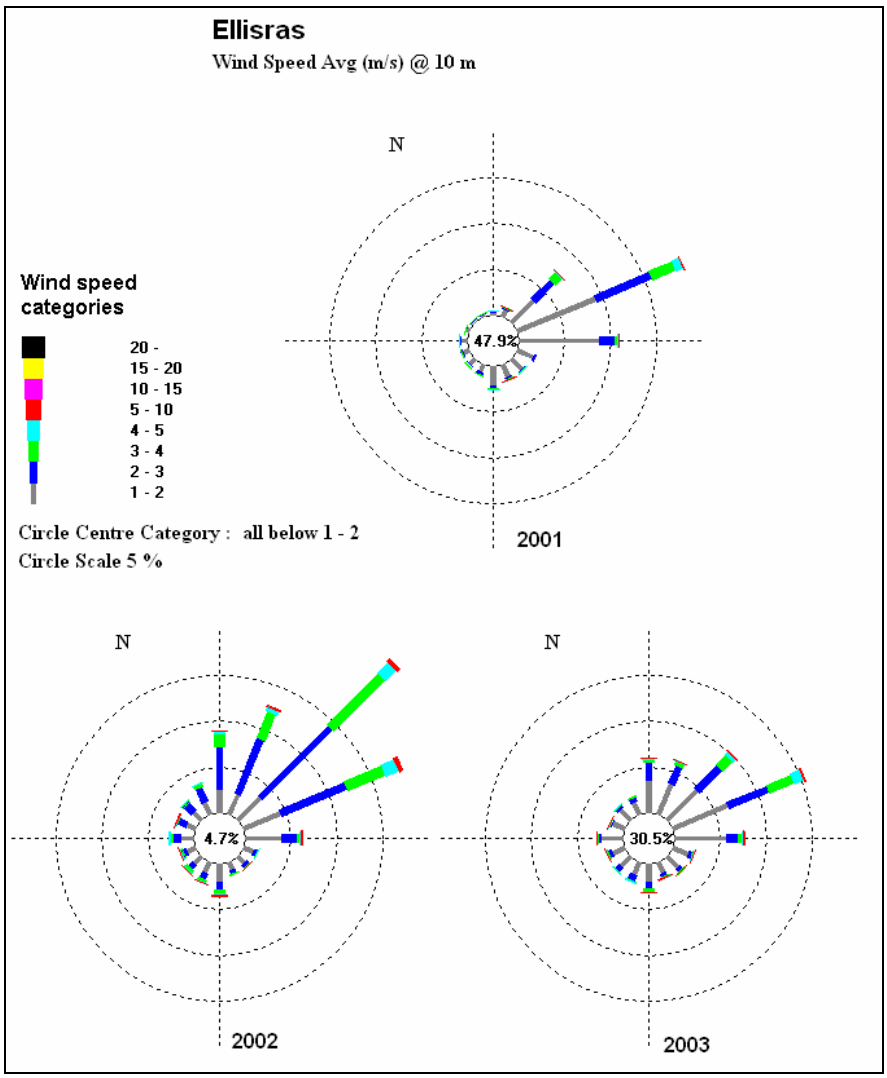

Figure 9.6: Annual average wind roses for the Ellisras Weather Service Station.

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 a 5% 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 in the centre of the wind rose.

The wind regime of the study area largely reflects the synoptic scale circulation. The flow field is dominated by northeasterly winds as may be expected due to the continental high pressure, which persists over the region, in combination with the tropical easterly systems which influence the flow field during much of the year. Winds are infrequently experienced from the westerly and southeasterly sector for all three periods analysed. The wind speeds are generally low throughout the period (1-3 m/s).

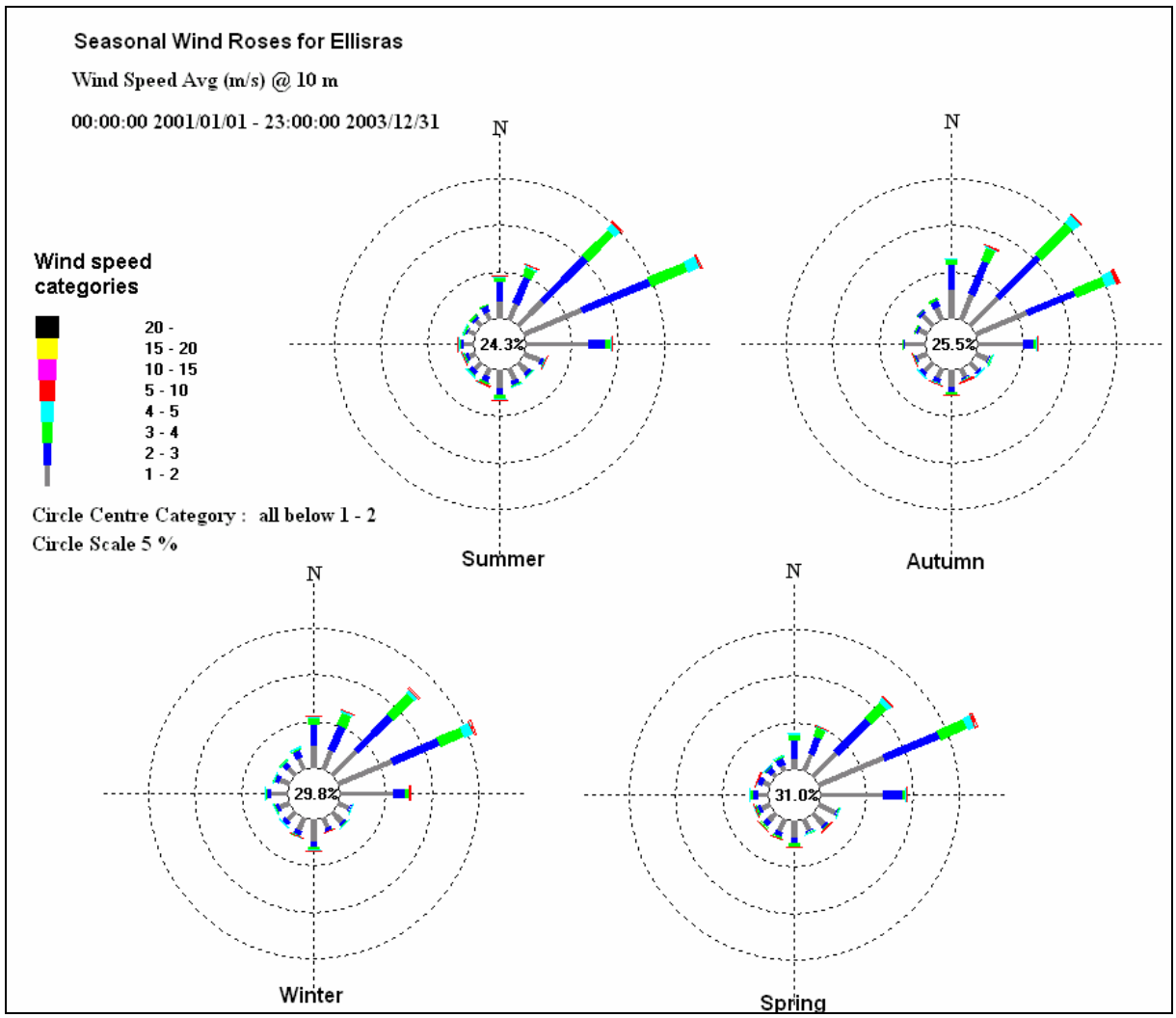

Figure 9.7: Seasonal-average wind roses for the Ellisras Weather Service Station for the period 2001 to 2003.

Although the northeasterly winds dominate for all four seasons the frequency of occurrence of these winds vary. During winter, the percentage of northeasterly winds decreases due to the northward shift of the high-pressure belt. East-northeasterly and northeasterly winds increase in frequency during summer months, with the continental high pressure and tropical easterlies having resumed their influence over the region.

Period average and day- and night-time wind roses for the Waterberg station are illustrated in Figure 9.8. This station is located within a WSW – ENE orientated valley. The influence of slope and valley flows is clearly evident with the easterly component being stronger than is typical of the regional windfield. The west-southwesterly airflow recorded at this site similarly represents a deviation from the regional wind regime. This flow component is predominantly associated with katabatic airflow down the valley during the night-time. A higher incidence of calm conditions was measured to occur at Waterberg when compared to Ellisras.

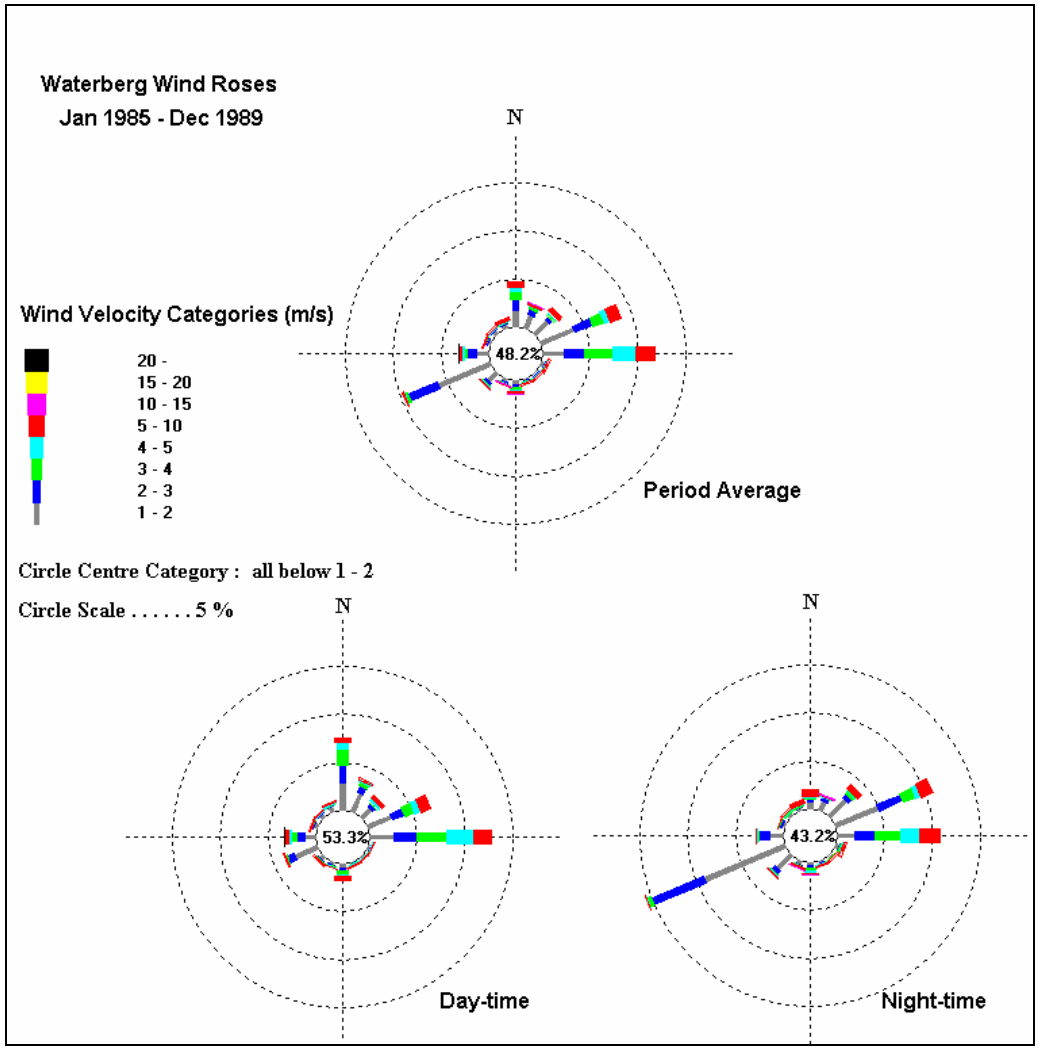

Figure 9.8: Period-average and daytime and night-time wind roses for the Waterberg Station for the period 1985 to 1989.

- *Atmospheric Stability and Mixing Depth*

  The atmospheric boundary layer constitutes the first few hundred metres of the atmosphere. This layer is directly affected by the earth's surface, either through the retardation of flow due to the frictional drag of the earth's surface, or as result of the heat and moisture exchanges that take place at the surface. 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 and the erosion of the mixing layer. Nighttimes are characterised by weak vertical mixing and the predominance of a stable layer. These conditions are normally associated with low wind speeds, hence less dilution potential.

  The mixed layer ranges in depth from a few metres (i.e. stable or neutral layers) during nighttimes to the base of the lowest-level elevated inversion during unstable, daytime conditions. Elevated inversions may occur for a variety of reasons, and on some occasions as many as five may occur in the first 1000 m above the surface. The lowest-level elevated inversion is located at a mean height above ground of 1 550 m during winter months with a 78 % frequency of occurrence. By contrast, the mean summer subsidence inversion occurs at 2 600 m with a 40% frequency.

  Atmospheric stability is frequently categorised into one of six stability classes. These are briefly described in Table 9.24.

Table 9.24: 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.

For elevated releases, the highest ground level concentrations would occur during unstable, daytime conditions. In contrast, the highest concentrations for ground level non-wind dependent releases would occur during weak wind speeds and stable (night-time) atmospheric conditions.

9.4. Existing Sources Of Emission And Baseline Air Quality

The identification of existing sources of emission in the region and the characterisation of existing ambient pollutant concentrations is fundamental to the assessment of the potential for cumulative impacts and synergistic effects. Existing sources of emissions are briefly discussed in Section 9.4.1. Air pollution monitoring measurements undertaken in the region are primarily limited to the measurement of key criteria pollutants by Eskom (Section 9.4.2).

9.4.1. Existing Sources of Atmospheric Emission

A comprehensive emissions inventory has not been completed for the region to date. The establishment of such an inventory is not within the scope of the current study. Instead 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 emission which occur in the vicinity of the proposed development sites include:

- existing Matimba Power Station and its associated ash dump,
- Grootgeluk coal mining operations
- brickworks operating at Hanglip
- household fuel combustion
- potential veld fires (very infrequent)
- sewage works (Farm Nelsonskop)
- wind blown dust from open areas and agricultural activities
- vehicle exhaust releases and road dust entrainment along paved and unpaved roads in the area

During the air quality impact assessment stack emissions from the existing Matimba Power Station are simulated together with the proposed power station in order to determine resultant cumulative concentrations of key pollutants such as sulphur dioxide and nitrogen dioxide.

- *Existing 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, sulphur dioxide (SO_2), nitrogen oxides (NO_x) – primarily as nitric oxide (NO) with smaller quantities of nitrogen dioxide (NO_2), 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 (> 99%). No SO_2 or NO_2 abatement measures are currently in place at the existing Matimba Power Station.

- Current Matimba Power Station Stack Emissions
  The main source of emissions from the Matimba Power Station comprises two stacks (Figure 9.9). 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, provided by Eskom personnel, is given in Table 9.25.

Table 9.25 Parameters for the current pulverised fuel (PF) power station at Matimba

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 PM10, calculated for each source on the basis of the existing data, are presented in Table 9.26. Monthly emission variations were calculated based on the energy outputs per month for Jan 2001 to October 2005 from the current pulverised fuel (PF) power station at Matimba. Eskom personnel provided the energy outputs as well as the total emissions per year. Although emissions were provided as total particulates released such emissions were assumed to comprise primarily of PM10 given the abatement measures in place (coarser particles readily removed).

Table 9.26: Annual emissions (in tonnes) for current Matimba Power Station operating conditions for the years Jan 2001 to October 2005 (as received from John Keir, Eskom Holdings)

Compound	2001	2002	2003	2004	Jan - Sep 2005
CO_2	19,601,372	20,735,661	23,936,050	22,857,852	18,141,074
SO_2	247,475	248,393	294,186	262,980	218,281
NO_x	90,725	94,216	100,514	100,389	49,588
NO(b)	57,985	60,216	64,241	64,161	31,693
NO_2(c)	1,814	1,884	2,010	2,008	992
PM	5,177	4,957	6,194	8,372	5,178

Notes:

(a) NO_x emissions reported as NO_2 (pers com. John Keir, 2 June 05).

(b) NO_x emissions (reported as NO_2) were converted to NO and 98% taken as being emitted from the stacks (pers com. John Keir, 2 June 05).

(c) 2% of the NO_x emissions (reported as NO_2) were taken as representing the NO_2 emissions from the stacks (pers com. John Keir, 2 June 05).

In order to determine seasonal and diurnal variations in emission rates reference was made to data from stack monitoring conducted on one of the six flues during the December 2004 to December 2005 period. No seasonal variations in emission rates were apparent. Diurnal variations in emission rates were however noted to occur (Figure 9.10). Typical diurnal variations for each month were identified and used during the dispersion simulations.

Figure 9.9: Existing Matimba Power Station showing the two 250 m stacks. Due to the particulate abatement measures implemented no visible plumes occur during routine operations.

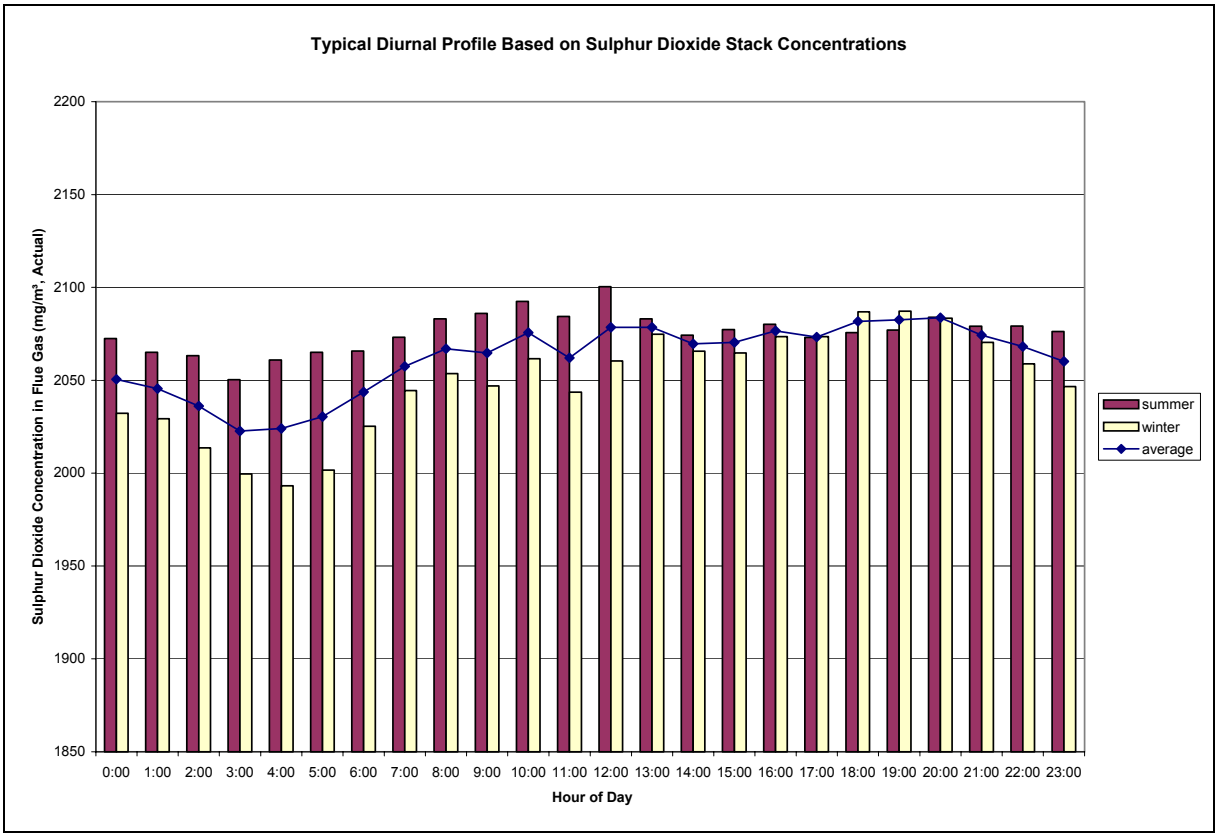

Figure 9.10: Diurnal variations in sulphur dioxide concentrations measured to occur during summer and winter months at Matimba Power Station

- Current Matimba Power Station Fugitive Emissions

  (a) Wind Blown dust from Ash dump (Zwartwater)

  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 reduces 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. This model is based on the dust emission model proposed by Marticorena and Bergametti (1995). 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).

Source specific information regarding the nature of the source, the percentage of exposed surface area and the type of material was provided by Eskom personnel. Where no source specific information was available use was made of information from similar operations. A site layout map provided by Eskom was used to determine the location, dimensions and orientations of the ash dump.

The source parameters used in the simulations for the ash dump can be found in Table 9.27. Table 9.28 show the particle size distribution used in the simulations.

Table 9.27: Source parameters pertaining to the ash dump

Source	Height (m)	X length (m)	Y length (m)	Moisture (%)	Clay (%)	Bulk density (g/cm³)
Ash section 1	40	2000	165	13.45	1	0.771
Ash section 2	52	1800	150	13.45	1	0.771
Topsoil section 1	40	2000	165	3.4	15	1.2
Topsoil section 2	52	2000	900	3.4	15	1.2

Table 9.28: Particle size distribution for the materials found on the ash dump

Ash		**Topsoil**	
µm	fraction	µm	fraction
600	0.0472	75	0.12
404.21	0.0269	45	0.14
331.77	0.0296	30	0.21
272.31	0.0336	15	0.09
223.51	0.0404	10	0.14
183.44	0.0503	5	0.1
150.57	0.0609	2.5	0.13
123.59	0.0687	1	0.07
101.44	0.0728		
83.26	0.0739		
68.33	0.072		
56.09	0.0669		
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		

Figure 9.11: Southern side of the ash dump at Zwartwater, with the topsoil covering of the ash and the use of wet suppression evident.

Figure 9.12: Borrow area located to the south of the existing ash dump at Zwartwater from where soil is removed for placement on the surface of the ash dump. The ash dump will expand into this area.

Figure 9.13: Stacking of ash by stacker at the Zwartwater ash dump. The relatively high moisture content of the ash reduces the potential for fugitive emissions during this process.

(b) Materials handling

Materials handling operations associated with the activities at the power station includes the transfer of coal and topsoil by means of tipping, loading and off-loading of trucks. The quantity of dust that will be generated from such loading and off-loading operations will depend on various climatic parameters, such as wind speed and precipitation, in addition to non-climatic parameters such as the nature (i.e. moisture content) and volume of the material handled. Fine particulates are most readily disaggregated and released to the atmosphere during the material transfer process, as a result of exposure to strong winds. Increases in the moisture content of the material being transferred would decrease the potential for dust emissions, since moisture promotes the aggregation and cementation of fines to the surfaces of larger particles.

The amount of material handled per day will differ for various steps in the process. Significant materials handling operations conditions include:

- Topsoil tipped at ash dump; and
- Coal tipped at power station.

The quantity of dust generated from the operations identified was based on the average amount of material stored and retrieved monthly (24 000 tpa of topsoil was assumed to be removed for the ash dump, and 1 570 tph of coal was assumed to be handled at the power station) and on the

particle size distribution. No particle size breakdown was available and use was made of information obtained from similar operations. Where no site-specific information was available on parameters required by the equations use was made of the US.EPA AP42 documentation on similar processes.

The PM10 fraction of the TSP was assumed to be 35%. Hourly emission rates, varying according to the prevailing wind speed, were used as input in the dispersion simulations. A moisture content of 3.4% was assumed for the topsoil and 2.3% for the coal.

- Heavy Metal Releases from Matimba Power Station – Stacks and Ash Dump Operations

The trace metal composition of fly ash and coarse ash generated at Matimba Power Station was obtained from a study undertaken previously by Eskom Holding's Chemical Technologies Division (Delport, Novemer 2003). These data, given as follows, were used to quantify trace metal emissions within fugitive ash dam dust and within the fly ash emitted by the power station stacks:

Trace Element	Raw Coal	Coarse Ash	Fly Ash
Arsenic (As)	3.72	4.86	19.74
Barium (Ba)	353.69	771.12	862.85
Bismuth (Bi)	1.52	4.32	3.79
Cobalt (Co)	8.19	16.47	17.33
Chromium (Cr)	49.38	379.80	255.07
Copper (Cu)	18.05	21.30	28.06
Gallium (Ga)	16.74	16.21	27.12
Germanium (Ge)	1.82	1.55	6.11
Lead (Pb)	23.19	42.79	71.19
Mercury (Hg)	0.45	0.02	0.17
Nickel (Ni)	25.69	114.71	80.76
Niobium (Nb)	16.97	7.12	7.17
Rhiobium (Rb)	21.06	48.27	48.40
Selenium (Se)	192.04	298.44	451.56
Thorium (Th)	8.75	39.74	49.89
Tin (Sn)	3.63	9.46	4.89
Tungsten (W)	2.76	9.45	12.38
Uranium (U)	4.47	14.35	10.68
Vanadium (V)	57.54	94.36	116.91
Yiddium (Y)	25.98	45.48	45.64
Zinc (Zn)	46.33	236.20	100.09
Zirconium (Zr)	163.69	181.43	191.55

Coarse ash and fly ash are both sent to the ash dam for disposal, with it being estimated that the coarse ash represents approximately 80% of the total ash and fly ash the remaining 20%. These ratios were used in estimating the trace metal composition of the ash dam ash.

The quantification of trace metal releases was restricted to those studied and documented in the November 2003 study. Furthermore, data were unavailable to quantify gaseous trace metal releases from stacks. Although studies have been undertaken in this regard previously, the methods of monitoring are still being scrutinized and reliable data not yet available (*personal communication*, Gerhard Gericke, Chief Consultant, Water and Applied Chemistry, Eskom Research & Development, 10 March 2006). Mercury represents the constituent most likely to be emitted in the gas phase. The total emissions of mercury, and hence the associate risk, could not therefore be ascertained. **(subsequent to the compilation of the draft Air Quality Assessment further work has been conducted in order to more accurately assess the potential for mercury emissions and associated impacts with reference being made to the mercury content of the coal and emission factors published internationally for power generation. These findings are summarised and attached as Appendix AF)**

- *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.

  An air quality study was undertaken for Grootgeluk Mine by ANMAR Environmental Group (February 2004). Fugitive dust emissions from certain mine operations, specifically wind entrainment from dumps and vehicle entrainment from unpaved roads were quantified and resultant total suspended dust concentrations predicted. Sulphur dioxide emissions from the discard dumps were similarly quantified and ambient sulphur dioxide concentrations due to such emissions simulated. Maximum sulphur dioxide concentrations predicted to occur due to the Grootgeluk Mine's operations were as follows:

  Maximum hourly sulphur dioxide concentration – 74 µg/m³

Maximum daily sulphur dioxide concentration – 21 µg/m³
Maximum annual sulphur dioxide concentration – 6.8 µg/m³

An updated air quality study is currently underway by Airshed Planning Professionals for the proposed expansion of the Grootgeluk Mining operation aimed at providing the coal requirements of the proposed new power station. This study will build on the previously conducted study by ANMAR, and will aim to quantify emissions of PM10, sulphur dioxide and other pollutants from the current and proposed future mining operations. This study is due for completion in May 2006 and will quantitatively assess the potential for cumulative impacts arising due to the existing Matimba Power Station and the proposed power station.

- *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).

- *Household Fuel Burning*
  It is likely that certain households within local communities, specifically Marapong residential area are likely to use coal, wood and paraffin for space heating and/or cooking purposes. According to the 2001 census information, Marapong (Ward 2) comprises about 5600 people living in ~1200 households (55% of which are classified as not being "formal" households, despite 80% of households using electricity for lighting purposes). Despite the high percentage of electrification it is feasible that fuel burning may take place within a portion of electrified households at certain times of the year due to it being potentially more cost-effective for space heating purposes.

  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.

- *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 savanna 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.

- *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 carbon dioxide (CO_2), carbon monoxide (CO), hydrocarbons (HCs), sulphur dioxide (SO_2), oxides of nitrogen (NO_x), particulates and lead. Secondary pollutants include: nitrogen dioxide (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.

  Given the low population number living in the region it is anticipated that vehicle exhaust emissions will be relatively limited and its contribution to ambient air pollutant concentrations dispersed and relatively insignificant.

- *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 know in order to quantify fugitive emissions from this source. The quantity of wind blown dust is similarly a function of the wind speed, the extent of exposed areas and the moisture and silt content of such areas.

- *Brickworks operating at Hanglip*
  Hendrik Pieterse, the owner of the farm Hanglip, runs the existing brickworks located approximately 500 m from the Grootgeluk SO_2 monitoring station (Figures 9.14 to 9.16). 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 being replace 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 (PM10 and PM2.5), sulphur dioxide (SO_2), sulphur trioxide (SO_3), nitrogen oxides (NO_x), carbon monoxide (CO), carbon dioxide (CO_2), total organic compounds (TOC) (including methane, ethane, volatile organic compounds (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).

  Emission factors are unavailable for the estimation of atmospheric emissions from clamp firing of bricks. In order to provide an approximation of the combustion related PM10 and SO_2 emissions from the brickmaking operations at Hanglip reference was made to US-EPA AP42 emission factors given for

uncontrolled coal-fired kilns. It was assumed that each brick weighs approximately 3 kg. PM10 emissions were estimated at 50.4 tpa and the sulphur dioxide emissions at 43.1 tpa for this operation. Insufficient information was however available on which to estimate the fugitive dust emissions from materials handling, crushing and screening and blending operations. Due to the low level of the releases and the proximity of the operation to the Grootstryd monitoring station, emissions from the brickmaking operation are anticipated to contribute to the air pollutant concentrations recorded at this station.

Figure 9.14: Operations at the brickworks at Hanglip located in close proximity to the Matimba Power Station (evident in background).

Figure 9.15: Firing by clamp at the brickmaking operations at Hanglip.

Figure 9.16: Fugitive emissions due to materials handling and raw material preparation at the brickmaking operations at Hanglip

9.4.2. Measured Baseline Air Quality

- *Continuous Air Quality Monitoring*
  Eskom has undertaken recent continuous monitoring of ambient SO_2 and PM10 concentrations in the vicinity of the Matimba Power Station. This monitoring was conducted at Zwartwater for the period 2001 to September 2003. In September 2003 the Zwartwater monitoring station was relocated to Grootstryd (Figure 9.17). Various other historical monitoring campaigns were undertaken including:
  - Sampling at five sites (M1-M5) during the August 1991 to January 1992 period; and
  - Sampling at Waterberg station during the 1984 to 1989 period; and
  - Sampling at the Wits caravan from 16 June to 10 July 2005.

  The data availability for the Zwartwater and Grootstryd monitoring stations is given in Table 9.29. Data availability for the monitoring campaigns undertaken is given in Table 9.30. The locations of the various stations are illustrated in Figure 9.18. Maximum hourly, daily and period average air pollutant concentrations recorded at the Zwartwater and Grootstryd stations for the period 2001 to 2004 are given in Table 9.31. Maximum measured concentrations for the five-station monitoring campaign conducted between August 1991 and January 1992 are given in Table 9.32, concentrations recorded at Waterberg station during the 1980s presented in Table 9.33, and the Wits caravan results are given in Table 9.34.

Figure 9.17 Grootstryd ambient air quality monitoring station located downwind of the Matimba Power Station.

Table 9.29: Data availability for the Zwartwater and Grootstryd monitoring stations.

Monitoring Station	Pollutant	Data Availability			
		2001	2002	2003	2004
Zwartwater	PM	16 %	0 %	0 %	-
	SO_2	71 %	37 %	55 %	-
Grootstryd	PM	-	-	61 %	86 %
	SO_2	-	-	83 %(a)	74 %

(a) Data availability from September to December 2003

Table 9.30: Data availability for the monitoring campaigns undertaken at stations M1-M5, Wits caravan and at Waterberg

Monitoring Period	Monitoring Station - Pollutant	Data Availability
Aug 1991 to Jan 1992	Matimba 1 (M1) – SO_2	89 %
	Matimba 2 (M2) – SO_2	93 %
	Matimba 3 (M3) – SO_2	70 %
	Matimba 4 (M4) – SO_2	73 %
	Matimba 5 (M5) – SO_2	64 %
16 June to 10 July 2005	Wits caravan – SO_2	83 %
16 June to 10 July 2005	Wits caravan – PM10	70 %
Jan 1985 – Dec 1989	Waterberg – SO_2	69%
Jan – Dec 1989	Waterberg – NO_x	75%
Jan – Dec 1989	Waterberg – NO	37%
Jan – Dec 1989	Waterberg – NO_2	42%
Jan – Dec 1989	Waterberg – O_3	47%

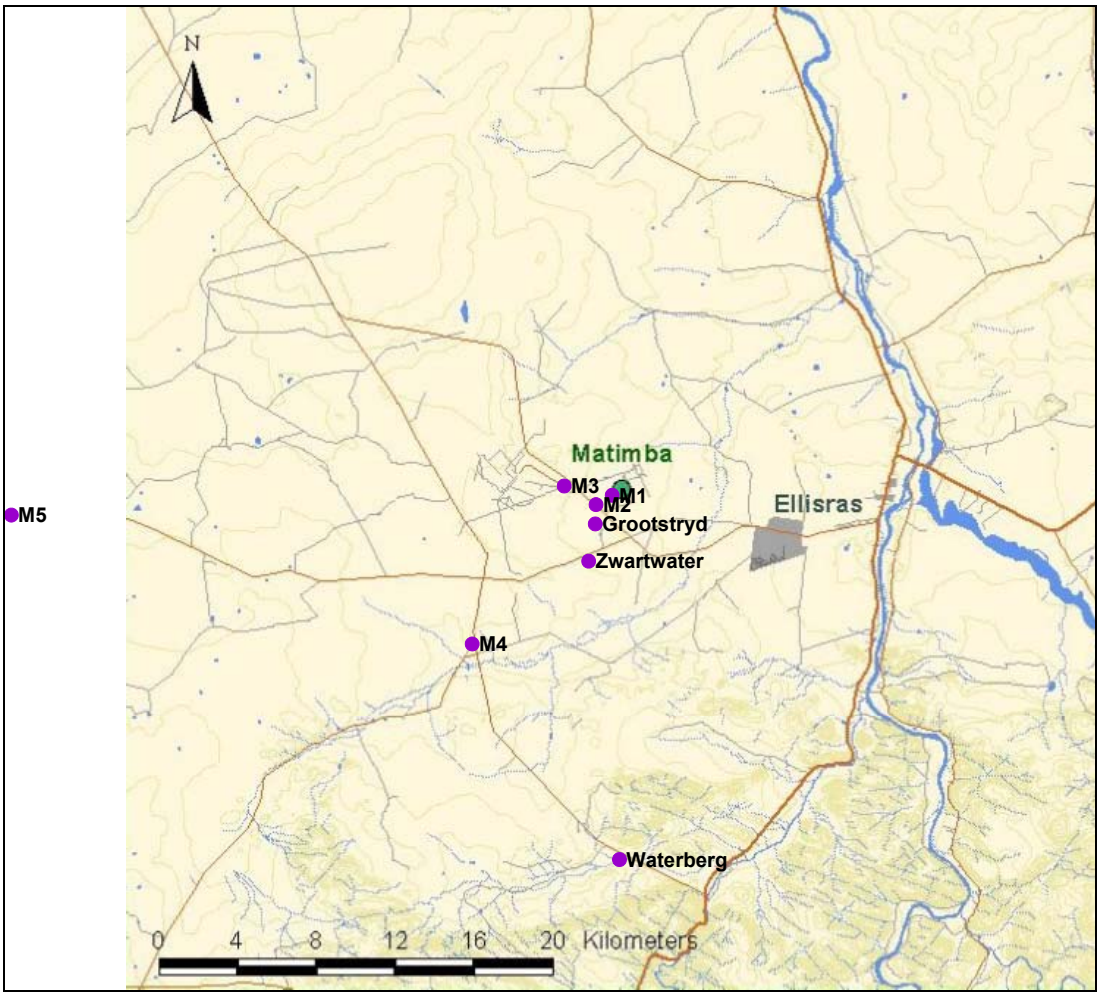

Figure 9.18: Location of the Eskom monitoring stations in the vicinity of the Matimba Power Station.

Table 9.31: Monitored ground level concentrations (µg/m³) at the Eskom monitoring stations of Zwartwater and Grootstryd[(a)].

Monitoring Station	Pollutant	Highest Hourly Averages				Highest Daily Averages				Period Averages			
		2001	2002	2003	2004	2001	2002	2003	2004	2001	2002	2003	2004
Zwartwater (ZW)	PM10	153	-	-	-	73	-	-	-	9 [(b)]	-	-	-
	SO_2	563	825	387	-	68	98	6	-	10 [(b)]	14 [(b)]	-	-
Grootstryd (GS)	PM10	-	-	325	624	-	-	86	130	-	-	-	35
	SO_2	-	-	620	529	-	-	103	100	-	-	-	14

[(a)] Air quality limit value exceedances indicated in bold print, with reference made to the EC hourly SO_2 limit of 350 µg/m³, the DEAT, SANS, EC, WHO daily SO_2 limit of 125 µg/m³ and the SANS and EC daily PM10 limits of 75 µg/m³ and 50 µg/m³ respectively.
[(b)] Period averages do not actually represent annual averages due to poor data availability.

Table 9.32 Monitored SO_2 ground level concentrations (µg/m³) for the monitoring campaign undertaken from August 1991 to January 1992

Monitoring Station	Highest Hourly Averages	Highest Daily Averages	Period Averages
Matimba 1 (M1)	398	72	10.6
Matimba 2 (M2)	560	69	14.8
Matimba 3 (M3)	806	176	19.0
Matimba 4 (M4)	487	87	13.4
Matimba 5 (M5)	662	112	13.5

[(a)] Air quality limit value exceedances indicated in bold print, with reference made to the EC hourly SO_2 limit of 350 µg/m³, the DEAT, SANS, EC, WHO daily SO_2 limit of 125 µg/m³ and the SANS and EC daily PM10 limits of 75 µg/m³ and 50 µg/m³ respectively.

Table 9.33: Monitored ground level concentrations (µg/m³) at the Eskom monitoring stations of Waterberg[(a)].

Year	SO_2			NOx[(b)]			NO			NO_2[(b)]			O_3		
	highest hourly (µg/m³)	highest daily (µg/m³)	Annual/period average (µg/m³)	highest hourly (µg/m³)	highest daily (µg/m³)	period average (µg/m³)	highest hourly (µg/m³)	highest daily (µg/m³)	period average (µg/m³)	highest hourly (µg/m³)	highest daily (µg/m³)	period average (µg/m³)	highest hourly (µg/m³)	highest daily (µg/m³)	period average (µg/m³)
1985	86	31	7	-	-	-	-	-	-	-	-	-	-	-	-
1986	35	22	6	-	-	-	-	-	-	-	-	-	-	-	-
1987	232	27	10	-	-	-	-	-	-	-	-	-	-	-	-
1988	330	56	6	-	-	-	-	-	-	-	-	-	-	-	-
1989	565	99	16	103	40	10	69	18	4	66	31	12	147	99	33

[(a)] Air quality limit value exceedances indicated in bold, with reference made to EC hourly SO_2 limit of 350 µg/m³.

[(b)] The validity of the NO_X data was found to be questionable given that NO_2 concentrations were frequently recorded as being greater than the measured NO_x levels.

Table 9.34: Monitored ground level concentrations (µg/m³) for the monitoring campaign undertaken from 16 June 2005 to 10 July 2005 at the Wits caravan.

Monitoring Station	Sulphur Dioxide		PM10	
	Highest Hourly Averages	Highest Daily Averages	Highest Hourly Averages	Highest Daily Averages
Wits caravan	172	33	1062	202

[(a)] Air quality limit value exceedances indicated in bold print, with reference made to the EC hourly SO_2 limit of 350 µg/m³, the DEAT, SANS, EC, WHO daily SO_2 limit of 125 µg/m³ and the SANS and EC daily PM10 limits of 75 µg/m³ and 50 µg/m³ respectively.

Air quality limit exceedances have been measured to occur for the following pollutants-stations-averaging periods:

- Sulphur dioxide – EC hourly limit – Zwartwater, Grootstryd, M1-M5 and Waterberg;
- Sulphur dioxide – SANS daily limit – M3;
- PM10 – daily limit – Zwartwater, Wits caravan and Grootstryd (no measurements of PM10 at the M1-M5 and Waterberg stations).

In assessing recorded hourly sulphur dioxide concentrations reference was made to the EC hourly limit given that no SANS limit is issued for this averaging period. The EC limit is classified as an equivalent limit, i.e. hourly average sulphur dioxide concentrations of 350 µg/m³ are estimated to be associated with 10 minute peak sulphur dioxide concentrations of 500 µg/m³. An exceedance of the EC hourly limit of 350 µg/m³ is therefore likely to signal and exceedance of the SANS 10-minute limit of 500 µg/m³. The frequencies of exceedance of the EC hourly limit and SANS daily limit is summarised in Table 9.35. It is evident that the exceedances occur relatively infrequently, with the greatest frequency of occurrence having been recorded to occur at the M3 station.

Table 9.35: Frequencies of exceedance of sulphur dioxide limits recorded to occur at the various monitoring stations

Station	No. of Hours Exceeding the EC Hourly Limit Value of 350 µg/m³	No. of Days Exceeding the SANS Daily Limit of 125 µg/m³	Total Hours of Data Available	Total Days of Data Available	Frequencies of Exceedance (%) of the EC Hourly Limit Value of 350 µg/m³	Frequencies of Exceedance (%) of the SANS Daily Limit Value of 125 µg/m³
Grootstryd (Sep – Dec 2003)	4		2365		0.17	
Grootstryd (2004)	3		6494		0.05	
Wits caravan						
Zwartwater	11		14995		0.07	
Waterberg (1989 only)	1		3714		0.03	
M1	1		3936		0.03	
M2	1		4113		0.02	
M3	7	3	3072	137	0.23	2.19
M4	1		3216		0.03	
M5	2		2810		0.07	

NO_x and ozone was only measured at Waterberg during 1989. NO_x concentrations were recorded at Waterberg during this year to represent up to 9% of the SA guideline for NO_x and up to 17% of the guideline for NO_2. The measured NO_2 concentrations constitute ~30% of the more stringent SANS NO_2 annual and hourly limits. It should be noted that the validity of the NO_X data is questionable given that NO_2 concentrations were frequently recorded as being greater than the measured NO_x levels. Measured ozone concentrations were observed to comprise up to 74% of the SANS limit and 63% of the SA standard.

Although no obvious seasonal variations in sulphur dioxide concentrations were apparent, diurnal trends were evident in measured sulphur dioxide levels (Figure 9.19). Generally higher ground level sulphur dioxide concentrations were recorded to occur during the daytime (08h00 to 19h00) at most monitoring stations (with the exception of M5 as may be expected due to the distance of this station). Primary peaks in ground level sulphur dioxide concentrations were observed to occur during the morning (10h00 to 12h00) at Zwartwater and M4, whereas M1 and M2 recorded peaks at 13h00. The lower concentrations at M1 are to be expected given the stack height and the proximity of this station to the power station. It is interesting to note that the M3 station, located to the west of the Matimba Power Station, recorded higher ground level concentrations during the afternoon (14h00 – 15h00).

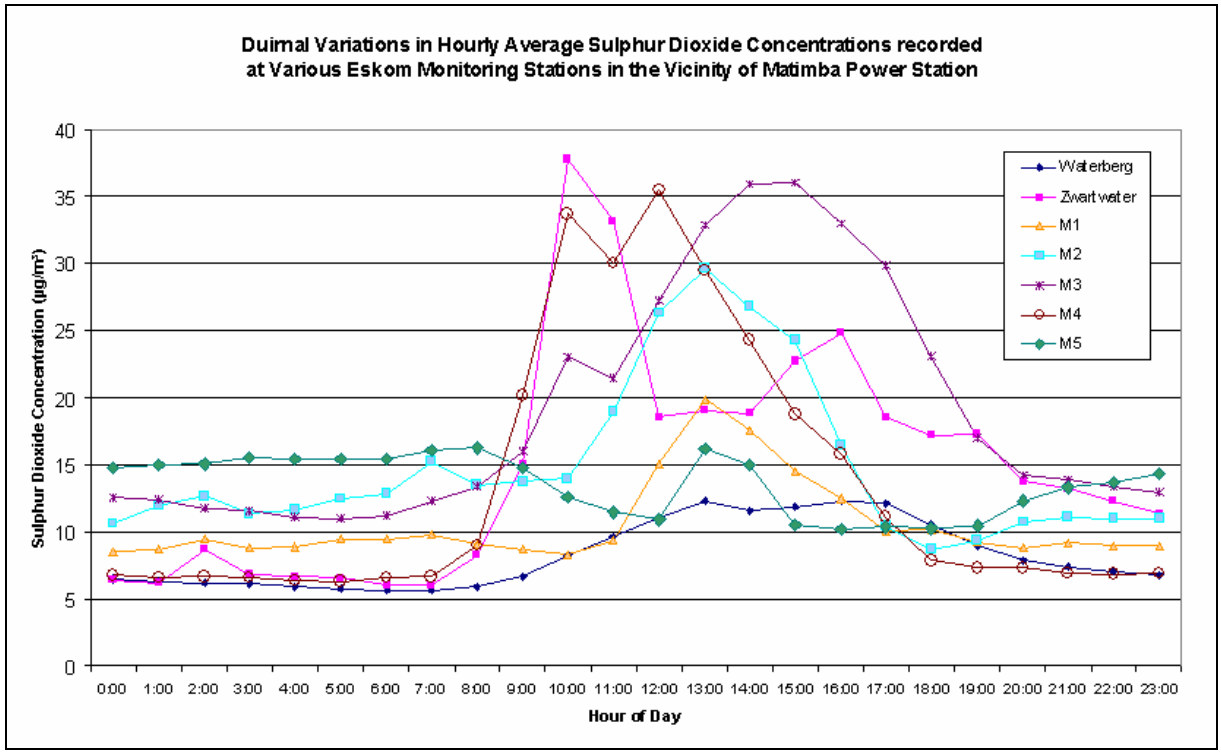

Figure 9.19: Diurnal variations in hourly average sulphur dioxide concentrations recorded at various Eskom monitoring stations located in the vicinity of Matimba Power Station

Ground level concentrations recorded at the distant M5 station were observed to be higher during the night-time hours with lower day-time concentrations coinciding with periods when the power station plume is more likely to be mixed down to ground within the vicinity of the power station.

Despite the Waterberg station also being situated at a more distant site it is notable that the diurnal variations in ground level sulphur dioxide concentrations were distinctly different from that measured at M5. The lower ground level sulphur dioxide concentrations recorded during the night-time at

Waterberg are anticipated to be due to the increased frequency of occurrence of southwestern airflow at this site, associated with the onset of katabatic down-valley airflow. Generally higher ground level SO_2 concentrations were recorded at Waterberg during the daytime when airflow from the east to northeasterly sectors prevailed. Marginally higher concentrations occurred in the afternoon during which time the extent of downmixing in the immediate vicinity of the power station was likely to be reduced.

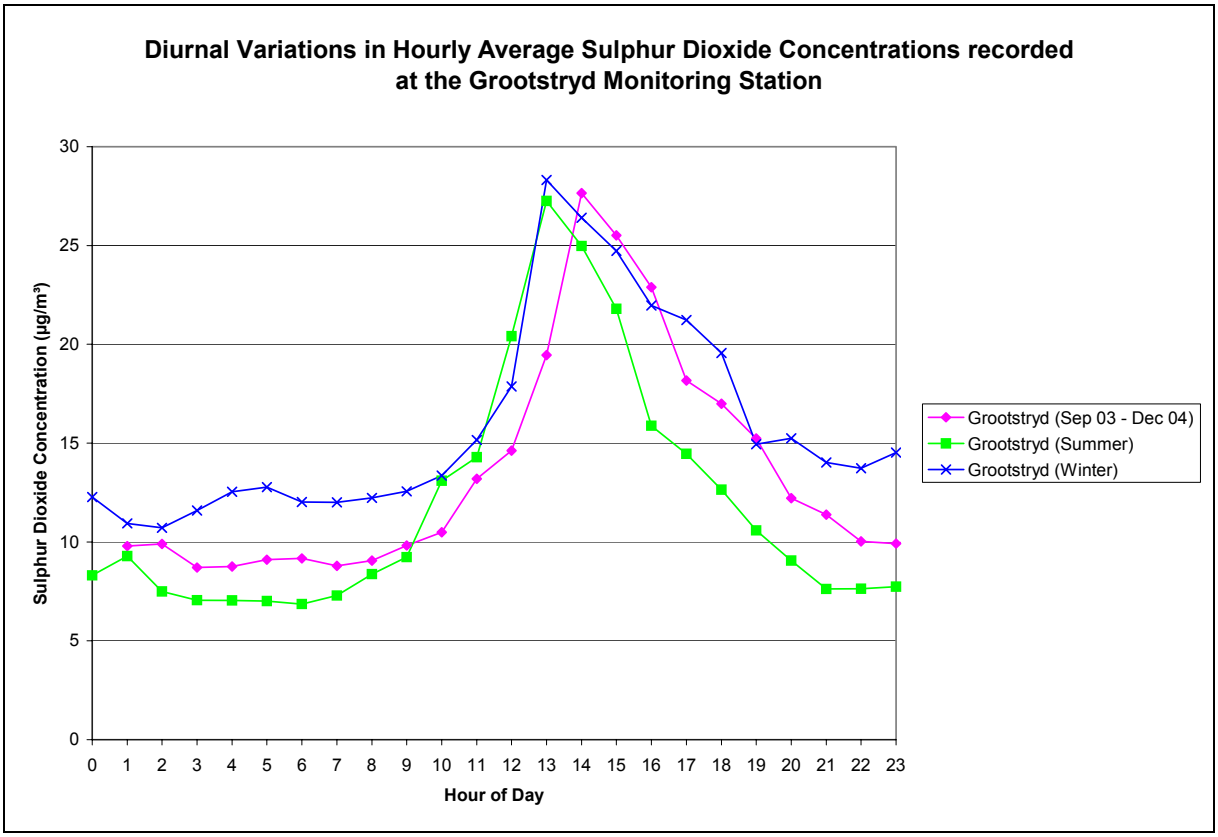

Figure 9.20: Diurnal variations in hourly average sulphur dioxide concentrations recorded at Grootstryd monitoring station

Similarly, for Grootstryd a diurnal trend can be seen, as well as a seasonal trend (Figure 9.20). The winter season has higher sulphur dioxide concentrations than the summer season. This is either due to additional sources of pollution or a change in meteorological conditions. Due to the fact that there are limited variations in sources of pollution, this seasonal variation is most likely due to different meteorological conditions present in the winter months.

Air pollution roses depict the prevailing wind direction coincident with the occurrences of elevated air pollutant concentrations at a particular monitoring station. Such roses are therefore useful in identifying the location of the contribution source in relation to the monitoring station.

Air pollution roses generated for the Grootstryd and Wits caravan stations are illustrated in Figures 9.21 to 9.24. The highest SO_2 concentrations recorded at Grootstryd and the Wits caravan tend to coincide with airflow from the ENE and NE sector. This is to be expected given the location of the monitoring stations in relation to the power station (Figure 9.18). It is however evident that elevated sulphur dioxide concentrations do coincide with wind from other sectors. This may be due either to the recirculation of emissions from the power station or due to the contribution of other sources (e.g. combustion of coal discards or firing at Hanglip brickworks). Elevated PM10 concentrations tended to coincide with westerly, west-northwesterly and southeasterly airflow. Sources which could contribute to PM10 concentrations recorded at Grootstryd monitoring station include fugitive emissions from mining operations, ash dump operations and brickmaking.

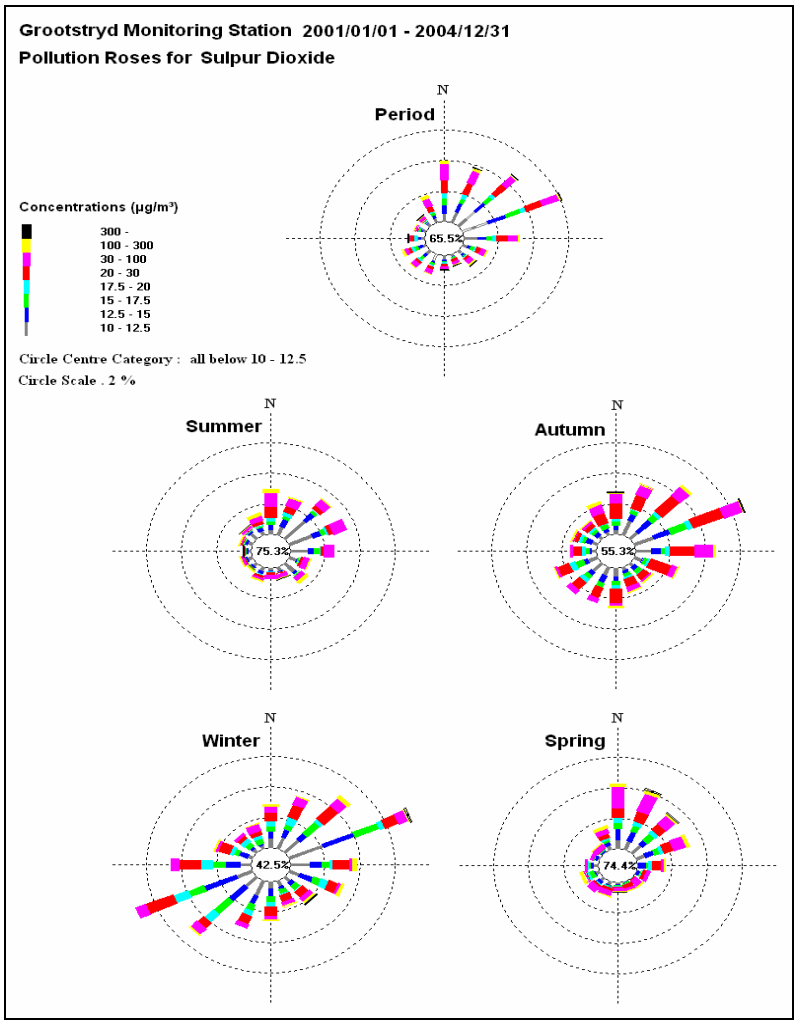

Figure 9.21: Pollution roses for sulphur dioxide measurements at the Grootstryd monitoring station.

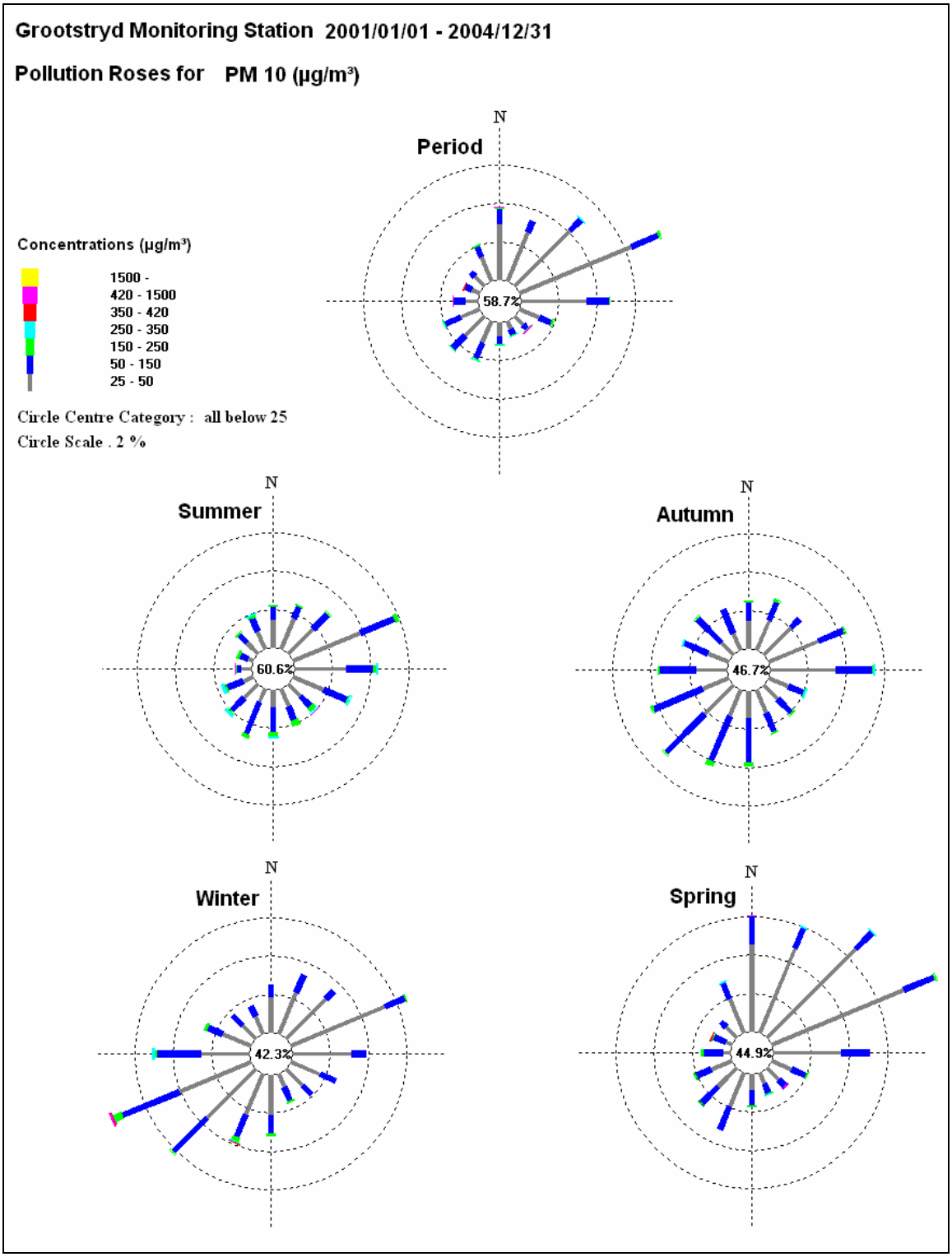

Figure 9.22: Pollution roses for PM10 measurements at the Grootstryd monitoring station.

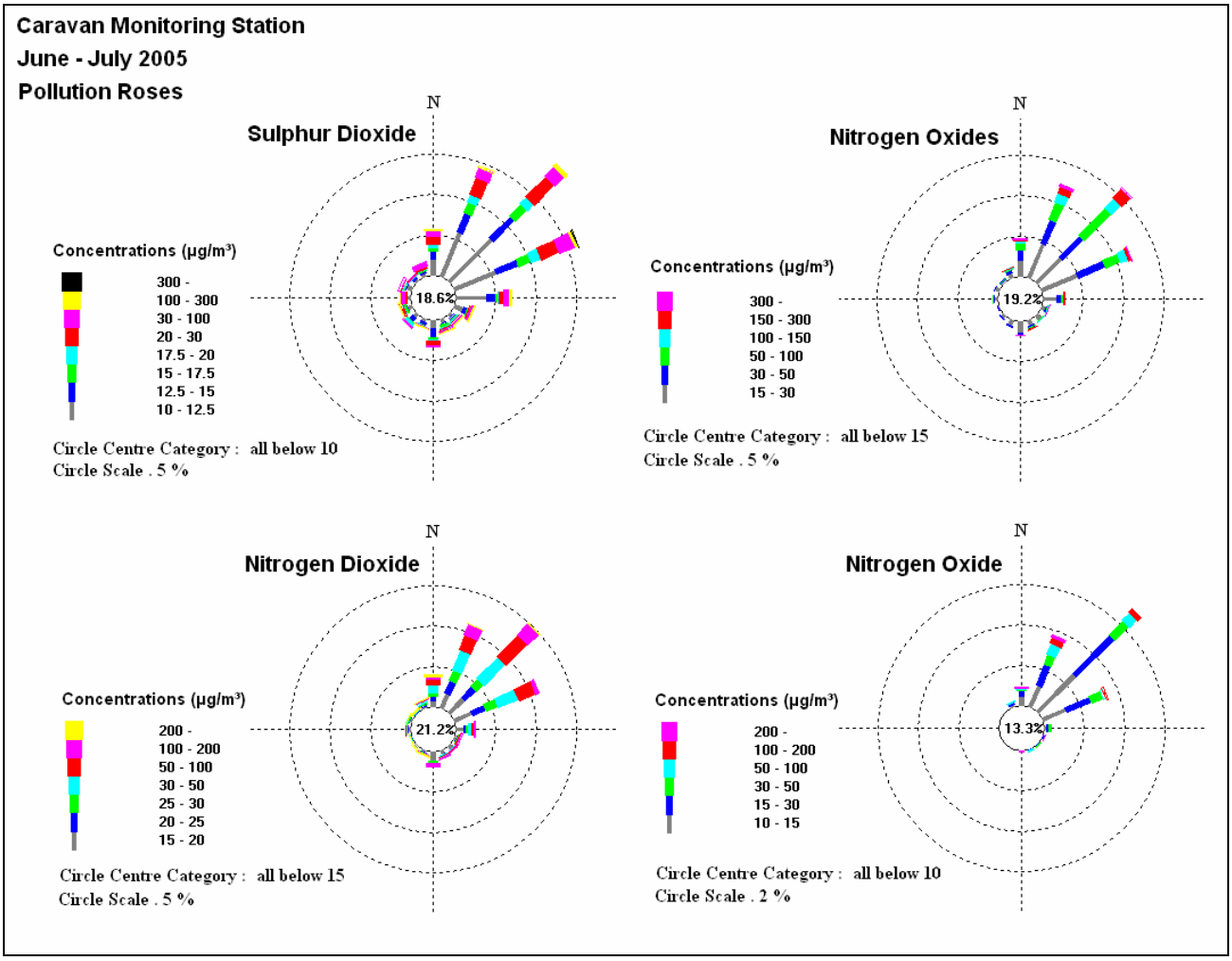

Figure 9.23: Pollution roses for various pollutants at the Wits caravan monitoring station.

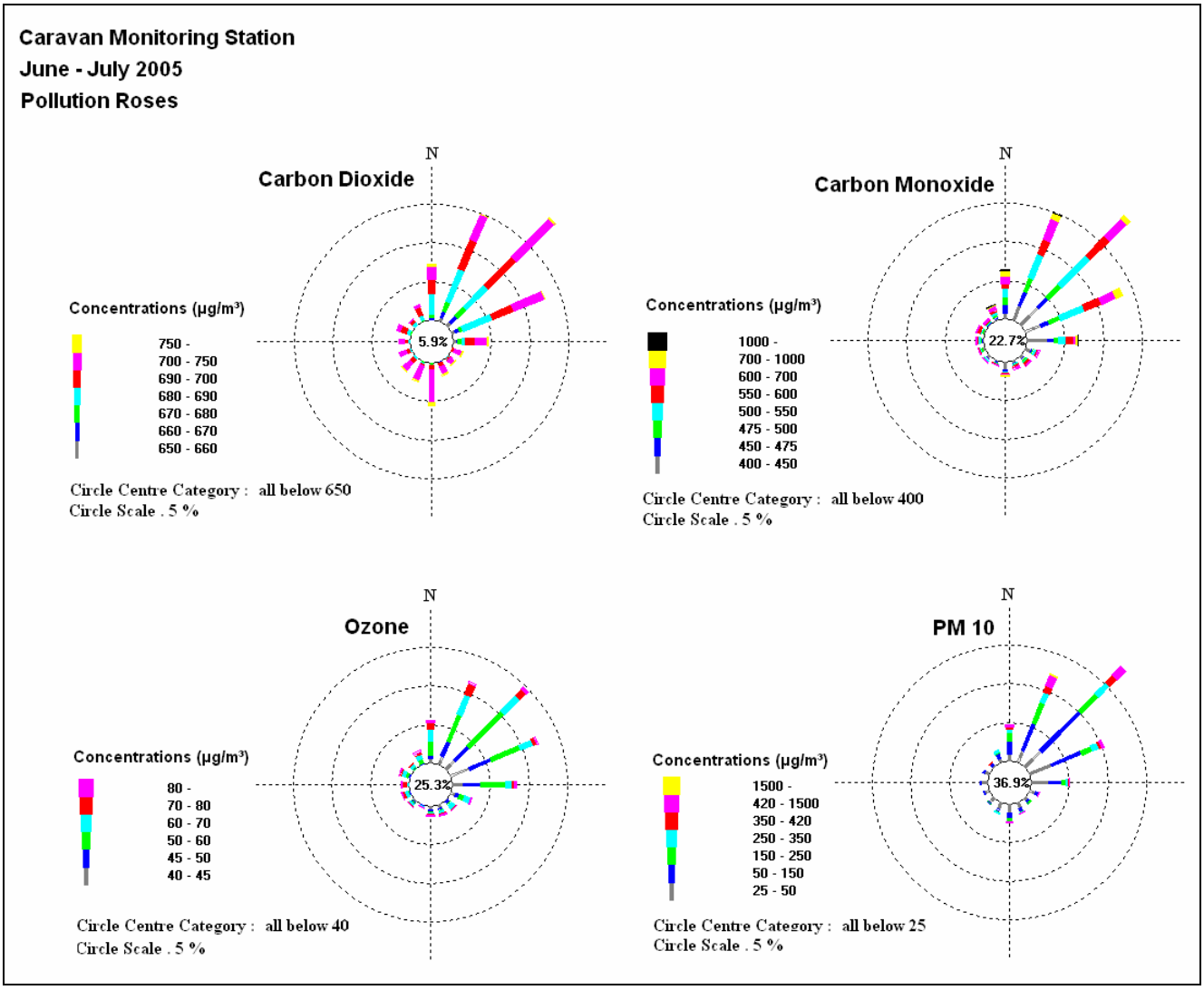

Figure 9.24: Pollution roses for various pollutants at the Wits caravan monitoring station.

- *Passive Diffusive Sampling of Sulphur Dioxide*
  SO_2 passive sampling was undertaken at 10 locations surrounding the power station from December 2004 to Oct 2005. The location of these passive diffusive sampling stations is shown in Figure 9.25. The monthly results from the passive diffusive sampling campaign are depicted in Figure 9.26, with the period average recorded given in Table 9.36. (Values are expressed in µg/m³ - the volume of SO_2 is standardized at a temperature of 25 °C and a pressure of 101.3 kPa).

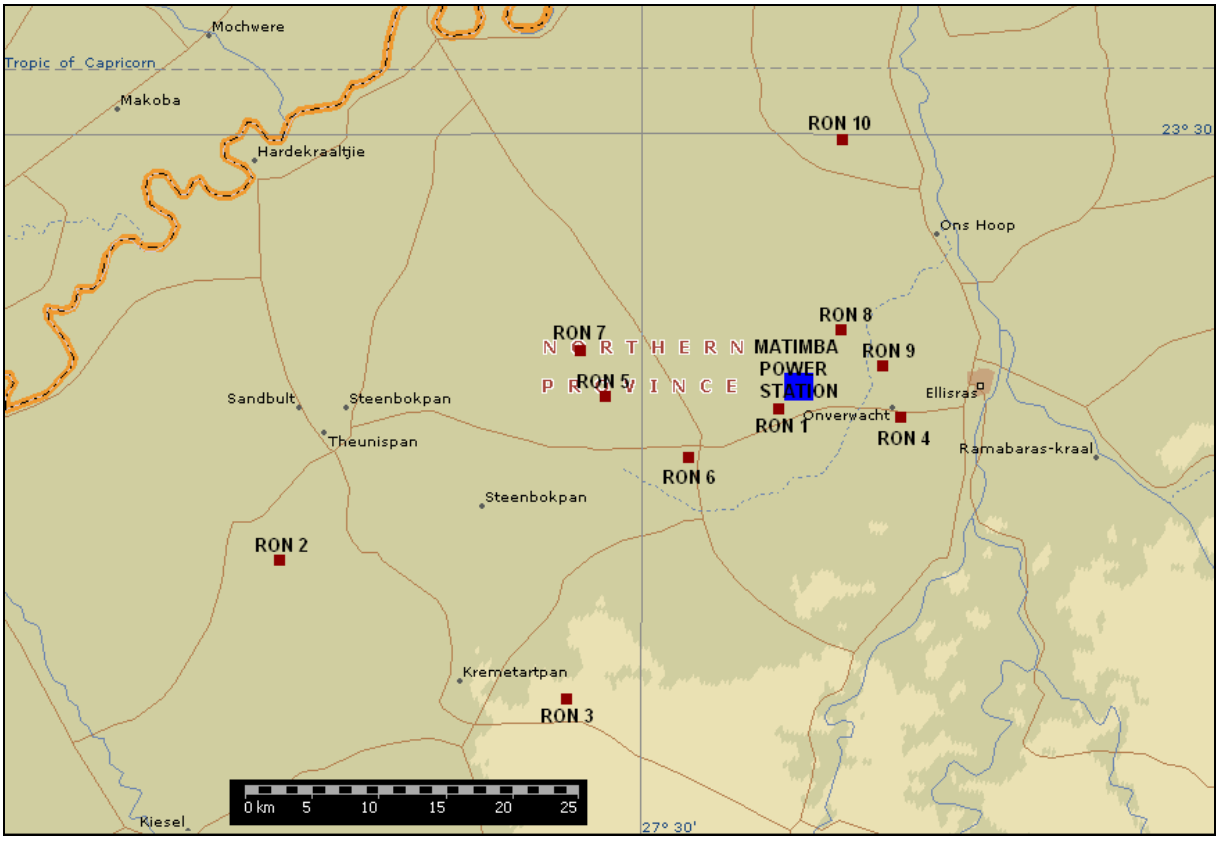

Figure 9.25: Location of SO_2 passive diffusive sampling sites in relation to Matimba Power Station.

Table 9.36: Period (December 2004 – October 2005) average sulphur dioxide concentrations recorded at the passive diffusive sampling stations.

Station	Period Average (µg/m³)
RON 1	7
RON 2	8
RON 3	11
RON 4	2
RON 5	7
RON 6	11
RON 7	6
RON 8	6
RON 9	6
RON 10	3

Period average sulphur dioxide concentrations were recorded to be well within the SA standard for annual averages given as 50 µg/m³. They were also noted to be within the limits stipulated by the EC and the WHO for the protection of ecosystems (20 µg/m³ and 10-30 µg/m³ respectively).

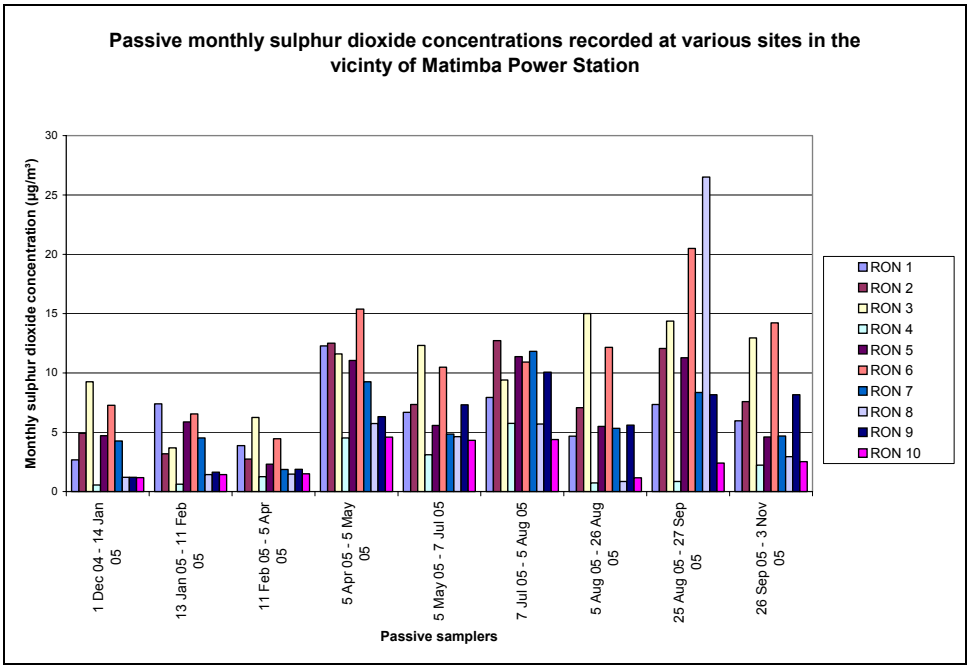

Figure 9.26: Monthly sulphur dioxide concentrations recorded at the passive diffusive sampling sites

Passive sampler RON1 is situated close to the Grootstryd continuous monitoring station. Data for Grootstryd was available for 2004 whereas the passive monitoring campaign only commenced in 2005 making it impossible to compare the concentrations recorded for a coincident period. For illustrative purposes a comparison was made between the passive diffusive results recorded during 2005 and the Grootstryd data for 2004 (Table 9.37). The passive diffusive monitoring undertaken during 2005 recorded significantly lower levels when compared with the continuous monitoring at Grootstryd. It is uncertain whether this is due to the monitoring methods or whether lower concentrations did occur during the 2005 period. This should be ascertained when the 2005 Grootstryd ambient data becomes available (not available as at 10 March 2006).

Table 9.37: Comparison between the continuous monitoring and the passive monitoring

Grootstryd monthly mean SO_2 concentration for 2004 (µg/m³)		RON 1 passive sample SO_2 concentration for 2005 (µg/m³)	
Jan	9.4	13 Jan 05 - 11 Feb 05	7.39
Feb	12.7	11 Feb 05 - 5 Apr 05	3.87
Mar	20.1	11 Feb 05 - 5 Apr 05	3.87
Apr	9.2	5 Apr 05 - 5 May 05	12.28
May	16.3	5 May 05 - 7 Jul 05	6.69
Jun	19.5	5 May 05 - 7 Jul 05	6.69
Jul	16.5	7 Jul 05 - 5 Aug 05	7.93
Aug	13.6	5 Aug 05 - 26 Aug 05	4.67

Sep	16.3	25 Aug 05 - 27 Sep 05	7.33
Oct	12.7	26 Sep 05 - 3 Nov 05	5.97
Nov	4.0		
Dec	11.1		

- *Passive Corrosion Monitoring*
  The Mechanical and Materials Technology Department at the Environmental Department of Technology Services International determined the relative corrosivity indices at 10 different sites around the Matimba Power Station in the Lephalale area from December 2003 to the end of March 2004 (K. Northcott, 2004). This was done to determine the impact of the Power Station and the Grootgeluk Coal Mine emissions on the corrosivity indices and to determine the role of hydrogen sulphide and SO_x in the corrosion of mild steel and galvanizing.

  The ten units shown in Figure 9.27, placed in roughly a triangle, 28 km in length and 24 km in height, detected sulphur based pollutants by the following means:

  - As a measured increase in ICI (industrial corrosivity index)
  - As a visible blackening of the copper bolt of the ICI fixture in the corrosion unit
  - By a semi-quantitative measurement of sulphur present on a copper wire sample, using EDX
  - By increases in the corrosion rates of zinc and of iron wire coils exposed on the units

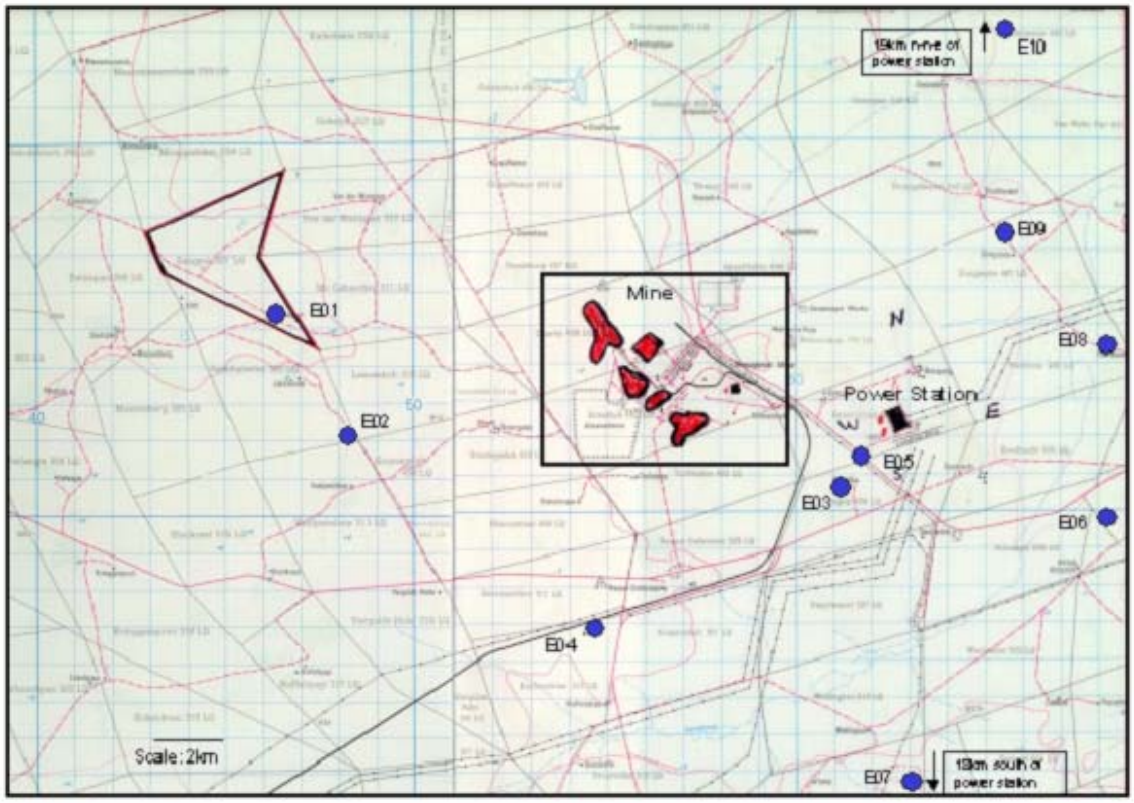

Figure 9.27: Positioning of corrosivity sampling units in relation to the Matimba Power Station and Grootgeluk mine (Northcott, 2004).

Considering the prevailing wind directions (NE, NNE and ENE), it is expected that pollution from the power station be detected at E04, E03 and E05 and that pollution from the mine dump be detected at E01, E02 and 04. A synopsis of the main findings is given in Table 9.38.

Table 9.38: Passive Corrosion monitoring results (reproduced from Northcott, 2004)

No:	EDAX (% S)	EDAX (% Cl)	ICI	Zn rate*	Steel rate*	Comments	Visual evidence of sulphur on copper bolt
E01	2.60	0.20	0.07	6.01	24.4	High S measured on EDAX, could imply high Zn. However no indication from the ICI or steel rate.	Highest
E02	3.04	0.32	0.12	5.76	32.7	Very high S and some Cl, high Zn rate, but little increase in ICI or steel.	Little
E03	0.49	0.14	0.26	4.60	33.7	Some corrosivity on the ICI. Zn and steel rates above normal, but no EDAX evidence.	Medium
E04	0.73	0.21	0.15	3.74	37.7	Little EDAX evidence – S. ICI and Zn fairly low, but steel highest!	Fairly high
E05	0.87	0.15	0.15	4.61	31.7	Some S on EDAX, ICI fairly low but Zn and steel rates above normal.	Medium
E06	No analysis	No analysis	0.10	4.52	10.3	No EDAX data for S. ICI and steel very low, but Zn above normal.	None
E07	0.57	0.12	0.09	7.42	33.2	No S on EDAX, and ICI negligible, but Zn high! And steel fairly high.	Fairly high
E08	0.89	0.87	0.09	2.80	19.8	EDAX detects both Cl and S. However ICI, Zn and steel all low!	None
E09	0.74	0.31	0.43	3.60	24.7	Fairly high S and Cl reflected in substantial ICI. However Zn and steel only moderate!	Medium
E10	No analysis	No analysis	0.28	3.06	17.3	Some corrosivity on the ICI. Zn and steel rates low. No EDAX analysis.	Medium
Note: ICI is indicator of chemical contamination including S and Cl							
Zinc rate in microns per annum with an *estimated correction for the period < 1 year							
Steel rate as for the zinc, * corrected, using low carbon steel							

The main conclusions drawn by Northcott (2004) were as follows:

- The area was measured, according to a modified ISO 9223 methodology, to be "medium" in corrosivity.
- A slight increase in corrosivity was measured to the south to southwest of the coal mine. The reason for this small increase is not proven but may be due to mine and/or power station emissions.

- The specific industrial corrosivity – as measured using the sensitive galvanic couple of an aluminium wire on a copper bolt – is very low at all tend sites and rates "negligible".
- With regard to the E01 sampling site at Zaagput farm, Northcott stated that there was no evidence, at all that the site E01 (Zaagput farm) was subject to SO_2 corrosion, although some of the measured evidence implicates H_2S pollution there, with possible effects on zinc. It was given as being highly unlikely that this pollution originated from the power station, both in terms of its composition and the distance it would have travelled.

9.4.3. Modelled Air Pollutant Concentration and Deposition due to Existing Power Station Operations

- *Dispersion Modelling Methodology*
  Atmospheric dispersion modelling was undertaken for the existing Matimba Power Station using the CALPUFF modelling suite recommended for regulatory use by the US-EPA for complex terrain environments and regional-scale modelling domains (typically 50 to 250 km). A detailed description of the modelling methodology and data inputs is given in Appendix B. Prior to the use of the dispersion model in assessing incremental and cumulative air pollutant concentrations due to the proposed power station, model results were validated. The validation process and rational for implementing a correction factor of 0.5 is also outlined in Appendix B.

- *Calculation of 10-minute Averages*
  The CALPUFF model only facilitates the estimation of hourly or longer period averages. In order to facilitate comparisons with the SA and SANS SO_2 10-minute averages limit, 10-minute SO_2 predicted concentrations were extrapolated from the hourly average predictions using the equation:

$$C_x / C_p = \left(t_p / t_x\right)^n \qquad (1)$$

  where,
  C_x , C_p = concentrations for averaging times t_x and t_p respectively
  t_x , t_p = any two averaging times

  Some have suggested a single-value ***n*** in the range of 0.16 to 0.25:

Stewart, Gale, Crooks (Slade, 1968)	***n*** = 0.2
Hilst (Slade, 1968)	***n*** = 0.25
Wipperman (Slade, 1968)	***n*** = 0.18
Turner (1970)	***n*** = 0.17 – 0.20
Meade (Nonhebel, 1960)	***n*** = 0.16

Beychok (1979) studied this range summarising the values of ***n*** as follows:

- A single-value n of about 0.2
- Values of n ranging from 0.2 to 0.68.

In this study a single-value of 0.2 for ***n*** was assumed in the estimation of 10-minute average SO_2 concentrations occurring due to Matimba Power Station emissions.

- *Dispersion Model Results*
  - Results for Criteria Pollutants

    Isopleth plots illustrating predicted sulphur dioxide, nitrogen dioxide and PM10 concentrations and dust deposition rates occurring due to Matimba Power Station related emissions are presented in Appendix C. A synopsis of the maximum hourly, daily and annual sulphur dioxide, nitrogen dioxide and PM10 concentrations occurring due to Matimba Power Station operations is given in Table 9.39.

    Predicted NO and NO_2 concentrations were predicted to be well within local and international air quality limits. Predicted PM10 concentrations were within the SA daily and annual standards but exceeded the SANS and EC limit values in the immediate vicinity of the ash dump at Zwartwater. Public exposure within this area is not expected to be significant. Maximum monthly dustfall rates were typically "moderate" (i.e. 250 - 500 mg/m²/day) immediately downwind of the Zwartwater ash dump and materials handling section of the power station, with "slight" dustfalls (i.e. < 250 mg/m²/day) occurring beyond these areas.

    Exceedances of local and international air quality limits given for sulphur dioxide were predicted to be exceeded for hourly and daily averaging periods within the zone of maximum impact (i.e. southwest of the Matimba Power Station). The hourly limit value was also predicted to be exceeded infrequently within the residential area of Marapong and along the western boundaries of Onverwacht (with no exceedances predicted for central Onverwacht) (Table 9.39).

    In order to determine the significance of exceedances of air quality limits, health and vegetation thresholds and material damage thresholds, reference is made to:

    - *distance of exceedance of limits and thresholds* – with specific attention paid to the likelihood of public/vegetation/property exposures within the exceedance area; and
    - *frequencies of exceedance of limits and thresholds.* Countries with stringent limit values such as EC member states frequently specifying a

number of exceedances permissible prior to listing an area as being in non-compliance. (It should be noted that the SA standard for SO_2 currently makes no provision for permissible frequencies and is therefore considered more stringent that limits passed by the EC, UK, Australia and the US-EPA amongst other countries. Given that permissible frequencies are likely to be added to the SA standards in coming years, reference is made to the permissible frequencies of other countries for information and decision making purposes.)

The distances of exceedance of various air quality limits and health risk, vegetation damage and corrosion potential thresholds are illustrated in Figure 9.28. A synopsis is given in Table 9.40 of the frequencies of exceedance of air quality limits and thresholds for selected receptor points and therefore the potential which exists for non-compliance and impacts.

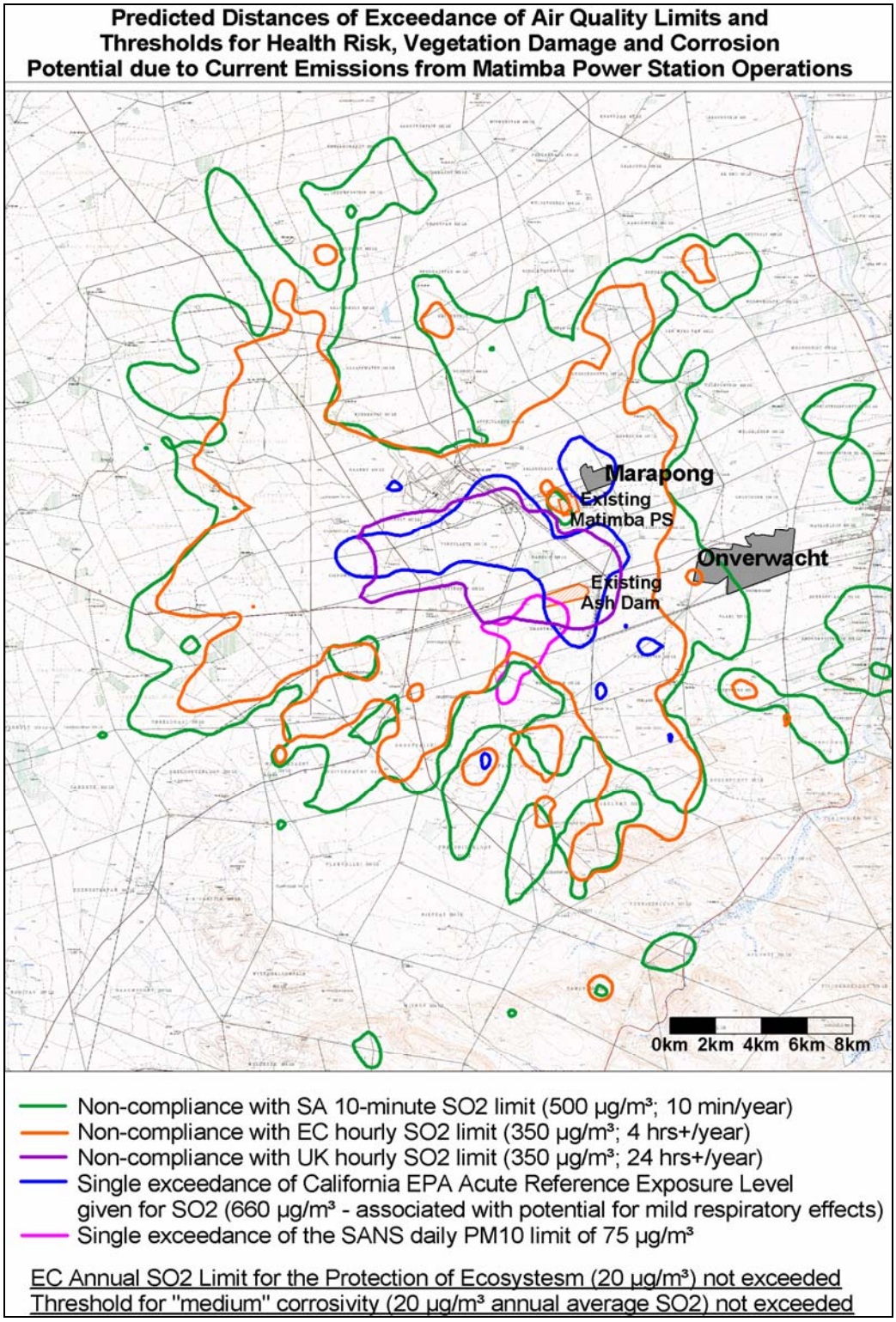

Figure 9.28: Areas over which various air quality limits and health, vegetation injury and material damage thresholds are exceeded due to existing Matimba Power Station emissions.

All local and international air quality limit values for sulphur dioxide considered are exceeded for hourly and daily averaging periods within the maximum impact zone of the power station. This impact zone is however located to the southwest of the power station where residential settlement is currently restricted to scattered farmsteads. Within the residential areas of Marapong and Onverwacht predicted sulphur dioxide concentrations comply with UK and World Bank limits, despite exceeding EC, SA and Australian limits. SA limits are more stringent that UK limits given that no permissible frequencies have been set by DEAT, with the SA standards for SO_2 therefore being more stringent than the UK and EC.

Taking into account the likelihood of exceeding SO_2 thresholds and the potential for exposure given the number of persons residing in the area, it may be concluded that little potential exists for vegetation damage, significant corrosion and health effects due to sulphur dioxide levels. The potential for infrequent mild respiratory effects occurring in the Marapong area was classified as "moderate" given that the threshold associated with the potential for such effects was exceeded four times per year in this area which has a population of ~17000 people.

Table 9.39 Predicted SO_2, NO, NO_2 and PM10 concentrations occurring due to Matimba Power Station emissions – given at the point of maximum ground level concentration (glc) and at nearby sensitive receptor locations. (Exceedance of air quality limit values indicated in bold.)

Location	Sulphur Dioxide Concentrations			Nitric Oxide Concentrations			Nitrogen Dioxide Concentrations			PM10 Concentrations	
	Highest Hourly (µg/m³)	Highest Daily (µg/m³)	Annual Average (µg/m³)	Highest Hourly (µg/m³)	Highest Daily (µg/m³)	Annual Average (µg/m³)	Highest Hourly (µg/m³)	Highest Daily (µg/m³)	Annual Average (µg/m³)	Highest Daily (µg/m³)	Annual Average (µg/m³)
GLC Maximum	1521.1	171.6	19.6	285.4	33.9	3.8	96.1	19.5	1.4	5.5	0.5
Marapong	993.2	90.7	3.3	204.5	19.5	0.6	35.4	3.2	0.2	4.9	0.2
Onverwacht (maximum)	660.5	47.4	3.9	86.7	7.2	0.6	78.8	7.7	0.4	2.8	0.2
Onverwacht (central)	297.7	35.8	2.7	34.9	6.0	0.4	47.5	5.0	0.3	2.5	0.2
Air Quality Limit Value	350	125	50	750	375	188	200	188	40	75	40
Details of Limit Value Used	EC & UK limit, EC permits 4 exceedances; UK 24 exceedances	SA, WHO, EC, UK Limit – EC & UK permit 3 exceedances; no permissible frequencies stipulated by SA & WHO	SA standard for protection of human health (EC limit for ecosystem given as 20 µg/m³)	SA standard	SA standard	SA standard	SA, WHO, EC, UK Limit – EC & UK permit 8 and 18 exceedances respectively; no permissible frequencies stipulated by SA & WHO	SA standard	SA, WHO, EC, UK Limit – EC & UK permit 3 exceedances; no permissible frequencies stipulated by SA & WHO	SANS limit value (no permissible frequencies stipulated to date)	SANS limit (also EC and UK limit)

	Predicted Sulphur Dioxide Concentrations as a Fraction of the Selected Limit			Predicted Nitric Oxice Concentrations as a Fraction of the Selected Limit			Predicted Nitrogen Dioxide Concentrations as a Fraction of the Selected Limit			Predicted PM10 Levels as a Fraction of Selected Limit	
	Highest Hourly	Highest Daily	Annual Average	Highest Hourly	Highest Daily	Annual Average	Highest Hourly	Highest Daily	Annual Average	Highest Daily	Annual Average
GLC Maximum	4.35	1.37	0.39	0.38	0.09	0.02	0.48	0.10	0.03	0.07	0.01
Marapong	2.84	0.73	0.07	0.27	0.05	0.00	0.18	0.02	0.01	0.07	0.00
Onverwacht (maximum)	1.89	0.38	0.08	0.12	0.02	0.00	0.39	0.04	0.01	0.04	0.01
Onverwacht (central)	0.85	0.29	0.05	0.05	0.02	0.00	0.24	0.03	0.01	0.03	0.00

Table 9.40: Potential for non-compliance, health effects, vegetation damage and corrosion occurring due to sulphur dioxide concentrations occurring as a result of existing Matimba Power Station emissions

Receptor Category	Receptor Name	Predicted SO_2 Concentration (µg/m³)			Corrosion Potential		Potential for Vegetation Injury and Ecosystem Damage			Potential for Health Effects		Compliance Potential			
		Highest Hourly (99th Percentile)	Highest Daily	Annual Average	Annual Average as Fraction of Threshold for "Medium" Corrosivity (20 µg/m³)	Potential for Corrosion	Highest Hourly as Fraction of Hourly Threshold of 1300 µg/m³	Annual Average as Fraction of EC Annual Limit for Protection of Ecosystems (20 µg/m³)	Potential for Vegetation Damage	Health Risk Categorisation based on Highest Hourly Average	Freq Exc California EPA Acute REL of 660 µg/m³ - indicative of mild respiratory effects (hours/year)	Freq Exc SA 10-minute Limit of 500 µg/m³ (no permissible frequencies) / Freq Exc EC Hourly Limit of 350 µg/m³ (EC permits 4, UK 24)	Freq Exc SA Daily Limit of 125 µg/m³ (EC & UK permit 3)	Compliance with SA Standards	Compliance with UK Standards
Maximum	GLC Maximum	1323	172	19.6	1.0	low	1.0	1.0	low	low(a)	17	99	7	FALSE	FALSE
Residential areas	Marapong	864	91	3.3	0.2	low	0.7	0.2	low	moderate	4	19	1	FALSE	TRUE
	Onverwacht (maximum)	575	47	3.9	0.2	low	0.4	0.2	low	low	3	5	0	FALSE	TRUE
	Onverwacht (central)	259	36	2.7	0.1	low	0.2	0.1	low	low	0	1	0	FALSE	TRUE
Farms (centre point)	Eendracht	384	48	3.9	0.2	low	0.3	0.2	low	low(a)	0	6	0	FALSE	TRUE
	Altoostyd	505	51	5.4	0.3	low	0.4	0.3	low	low(a)	1	11	0	FALSE	TRUE
	Worcester	482	65	5.8	0.3	low	0.4	0.3	low	low(a)	1	6	0	FALSE	TRUE
	Paarl	391	34	3.6	0.2	low	0.3	0.2	low	low(a)	0	2	0	FALSE	TRUE
	Turfvlakte	628	167	13.6	0.7	low	0.5	0.7	low	low(a)	6	61	5	FALSE	FALSE
	Hieromtrent	398	107	8.8	0.4	low	0.3	0.4	low	low(a)	0	15	0	FALSE	TRUE
	Leeuwdrift	322	50	6.6	0.3	low	0.2	0.3	low	low(a)	0	7	0	FALSE	TRUE
	Hanglip	750	93	13.4	0.7	low	0.6	0.7	low	low(a)	7	73	1	FALSE	FALSE
	Wellington	262	60	7.0	0.3	low	0.2	0.3	low	low(a)	1	2	0	FALSE	TRUE

	Kromdraai	210	48	5.5	0.3	low	0.2	0.3	low	low(a)	0	0	0	TRUE	TRUE
	Kuipersbult	396	76	11.0	0.5	low	0.3	0.5	low	low(a)	1	10	0	FALSE	TRUE
	Grootvallei	575	53	8.3	0.4	low	0.4	0.4	low	low(a)	3	4	0	FALSE	TRUE
	Nooitgedacht	274	42	7.1	0.4	low	0.2	0.4	low	low(a)	1	3	0	FALSE	TRUE
	Peerboom	341	35	3.2	0.2	low	0.3	0.2	low	low(a)	0	7	0	FALSE	TRUE
	Nelsonskop	408	38	3.2	0.2	low	0.3	0.2	low	low(a)	2	8	0	FALSE	TRUE
	Appelvlakte	329	33	2.6	0.1	low	0.3	0.1	low	low(a)	0	2	0	FALSE	TRUE
	Zongezien	482	60	2.6	0.1	low	0.4	0.1	low	low(a)	0	9	0	FALSE	TRUE
	Droogeheuvel	423	41	2.1	0.1	low	0.3	0.1	low	low(a)	1	5	0	FALSE	TRUE
	Vooruit	259	21	2.0	0.1	low	0.2	0.1	low	low(a)	0	1	0	FALSE	TRUE
	Ganzepan	309	28	1.6	0.1	low	0.2	0.1	low	low(a)	0	2	0	FALSE	TRUE
	Goedehoop (mine, dump)	401	52	3.9	0.2	low	0.3	0.2	low	low(a)	0	5	0	FALSE	TRUE
	Enkelbult (mine, pit)	480	95	9.1	0.5	low	0.4	0.5	low	low(a)	0	36	1	FALSE	FALSE
	Grootgeluk (mine, pit)	439	80	8.3	0.4	low	0.3	0.4	low	low(a)	0	14	1	FALSE	TRUE
	Vaalpensloop	439	68	7.5	0.4	low	0.3	0.4	low	low(a)	0	7	1	FALSE	TRUE
	McCabesvley	384	63	5.1	0.3	low	0.3	0.3	low	low(a)	0	9	0	FALSE	TRUE
	Graaffwater	253	28	2.5	0.1	low	0.2	0.1	low	low(a)	1	3	0	FALSE	TRUE
	Verguldehelm	411	72	7.9	0.4	low	0.3	0.4	low	low(a)	1	7	0	FALSE	TRUE
	Daarby (mine, dump)	484	98	5.6	0.3	low	0.4	0.3	low	low(a)	2	14	1	FALSE	TRUE

Notes:

(a) In assessing potential reference is made to the frequencies of exceedance of the threshold for mild respiratory effects in addition to the likelihood of exposure – based on the number of persons residing in the area.

- Results for Heavy Metals

  Cancer risks associated with inhalation exposures to predicted lead, arsenic and nickel were calculated based on predicted maximum annual average concentrations. Given the range of unit risk factors published by the California OEHHA, the WHO and the US-EPA it was decided to calculate cancer risks based on the maximum and minimum unit risk factors available (Table 9.41). Cancer risks were calculated to be very low, with total incremental cancer risks across all carcinogens quantified to be in the range of 1: 20.5 million to 1: 48 million.

Table 9.41: Cancer risks calculated due to inhalation exposures to individual carcinogens predicted to be emitted from existing Matimba Power Station emissions (stack and ash dam)

Carcinogens / Suspected Carcinogens	US-EPA IRIS Classification	Calculated Cancer Risk (expressed as a 1: xxx chance of contracting cancer)	
		Based on Lowest Risk Factor (least conservative)	Based on Highest Unit Risk Factor (most conservative)
Arsenic	A	80,865,724	28,208,974
Nickel	A	123,271,418	77,855,632
Lead	B2	2,800,934,002	2,800,934,002
Total incremental cancer risk across all carcinogens quantified		**47,995,278**	**20,554,553**

Maximum hourly, daily, monthly and annual average heavy metal concentrations occurring due to power station fly ash emissions and fugitive emissions from the ash dump at Zwartwater. These predicted ambient metal concentrations were compared to relevant health thresholds in order to determine the potential for health impacts. Such health thresholds and the predicted concentrations as a fraction of such thresholds are given in Table 9.42. Fractions of greater than 1 indicate an exceedance of the threshold. No inhalation-related, non-carcinogenic health thresholds were predicted to be exceeded.

Table 9.42: Predicted ambient trace metal concentrations (in the PM10 range) due to existing Matimba Power Station emissions, with concentrations given as a fraction of the relevant health thresholds. Fractions of > 1 indicate threshold exceedances.

Compound	Predicted Ambient Air Concentrations (µg/m³)				Relevant Health Thresholds (µg/m³)				Predicted Concentrations as a Fraction of the Relevant Health Threshold			
	Highest Hourly	Highest Daily	Highest Monthly	Annual Average	Acute Health Threshold	Sub-acute Health Threshold	Intermediate (Sub-chronic) Health Threshold	Chronic Health Threshold	Highest Hourly Concentration as a Fraction of the Acute Threshold	Highest Daily Concentration as a Fraction of the Sub-acute Threshold	Highest Monthly Concentration as a Fraction of the Sub-chronic Threshold	Annual Average Concentration as a Fraction of the Chronic Threshold
As	1.38E-03	8.97E-05	1.69E-05	8.24E-06	0.19			0.03	0.73			0.03
Ba	1.23E-01	7.31E-03	7.41E-04	3.61E-04	50			5	0.25			0.01
Bi	6.43E-04	3.78E-05	3.28E-06	1.58E-06								
Co	2.57E-03	1.53E-04	1.49E-05	7.25E-06				0.1				0.01
Cr	5.32E-02	3.08E-03	2.26E-04	1.07E-04			1	0.1			0.02	0.11
Cu	3.57E-03	2.15E-04	2.40E-05	1.17E-05	100			1	0.00			0.00
Ga	2.96E-03	1.81E-04	2.32E-05	1.13E-05								
Ge	4.32E-04	2.80E-05	5.22E-06	2.55E-06								
Pb	7.80E-03	4.77E-04	6.08E-05	2.98E-05				0.5				0.01
Hg	9.20E-06	6.24E-07	1.42E-07	6.96E-08	1.8			0.09	0.00			0.00
Ni	1.62E-02	9.43E-04	7.05E-05	3.38E-05	6		0.2	0.05	0.27		0.04	0.07
Nb	1.10E-03	6.51E-05	6.18E-06	3.00E-06								
Rb	7.44E-03	4.41E-04	4.17E-05	2.02E-05								
Se	5.25E-02	3.19E-03	3.86E-04	1.89E-04				20				0.00
Th	6.55E-03	3.93E-04	4.27E-05	2.09E-05								
Sn	1.26E-03	7.24E-05	4.78E-06	2.05E-06	20			2	0.01			0.00
W	1.58E-03	9.51E-05	1.06E-05	5.18E-06	10			1	0.02			0.00
U	2.06E-03	1.20E-04	9.30E-06	4.47E-06			0.4	0.3			0.00	0.00

Compound	Predicted Ambient Air Concentrations (µg/m³)				Relevant Health Thresholds (µg/m³)				Predicted Concentrations as a Fraction of the Relevant Health Threshold			
	Highest Hourly	Highest Daily	Highest Monthly	Annual Average	Acute Health Threshold	Sub-acute Health Threshold	Intermediate (Sub-chronic) Health Threshold	Chronic Health Threshold	Highest Hourly Concentration as a Fraction of the Acute Threshold	Highest Daily Concentration as a Fraction of the Sub-acute Threshold	Highest Monthly Concentration as a Fraction of the Sub-chronic Threshold	Annual Average Concentration as a Fraction of the Chronic Threshold
V	1.55E-02	9.29E-04	1.00E-04	4.89E-05		0.2				0.46		
Y	7.01E-03	4.15E-04	3.93E-05	1.91E-05								
Zn	3.06E-02	1.74E-03	1.07E-04	4.20E-05	50			5	0.06			0.00
Zr	2.84E-02	1.69E-03	1.65E-04	8.01E-05	50			5	0.06			0.00

9.4.4. Conclusions regarding Baseline Air Quality

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

- **Sulphur dioxide** concentrations have been measured to infrequently exceed short-term air quality limits at several of the monitoring stations (Zwartwater, Grootstryd, Waterberg, M2, M3 and M5) within infrequent exceedance of such limits modelled to occur at the nearby residential areas of Marapong and Onverwacht.

  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. This has being confirmed through atmospheric dispersion modelling of the power station's stack emissions. Other sources which may contribute significantly due to their low release level include: spontaneous combustion of coal discards associated with Grootgeluk mining operations, clamp firing emissions during brickmaking at Hanglip and potentially household fuel burning within Marapong. The highest ground level concentrations due to the Matimba Power Station stack emissions are expected to occur during the day when unstable atmospheric conditions prevail and when the plume is brought to ground in relatively close proximity to the power station.

  The comparison of measured and predicted sulphur dioxide concentrations to thresholds indicative of the potential for health, corrosion and vegetation impacts resulted in the following observations:

  - The health threshold given as being associated with mild respiratory effects (660 µg/m³ as an hourly threshold for SO_2) was measured to be exceeded at Zwartwater and at the M3 and M5 monitoring sites. This threshold was predicted to be exceeded a maximum of 3 to 4 hours at Marapong.

  - Measured and predicted sulphur dioxide concentrations were within limits indicative of low corrosion potentials. This is substantiated by the corrosivity monitoring documented by Northcott (2004).

  - Measured and predicted sulphur dioxide concentrations were within the EC annual sulphur dioxide limit of 20 µg/m³ which aims to protect ecosystems. The WHO guideline to protect ecosystems is given as a range of 10 to 30 µg/m³, depending on ecosystem sensitivity. The lower end of the WHO guideline range (viz. 10

µg/m³ intended for protection of highly sensitive vegetation types) was predicted and measured to be exceeded only on the southwestern side of the Matimba Power Station to a maximum distance of ~10 km (i.e. covering Turfvlakte, Hanglip, Zwartwater, Naauwontkomen and Kuipersbult farms). Given the nature of the vegetation on these farms it is unlikely that injury to the annual averages measured/predicted is likely to occur.

- Although the Matimba Power Station contributes to ambient **nitrogen oxide** and nitrogen dioxide concentrations in the region, local and international air quality limit exceedances are not predicted, nor measured, to occur. Other low level sources of NO_x anticipated to occur in the region include combustion within coal discard dumps, brick firing operations and possibly also household fuel burning and infrequent veld burning and motor vehicles.

- Although ambient **PM10** concentrations were measured to be within the current lenient SA Standards (as given in the second schedule of the Air Quality Act), exceedances of the more stringent SANS and EC limit values were observed to occur. (The highest PM10 concentrations recorded to date were measured on-site within the Grootgeluk Mine. Due however to these being on-site measurements, the should not be evaluated based on ambient air quality limits which are intended for use beyond the fenceline of industrial and mining operations.)

  The contribution of Matimba Power Station to primary and secondary particulates was simulated, with the SANS and EC limits only predicted to be exceeded immediately downwind of Zwartwater ash dump operations. (Secondary particulates form in the atmosphere through the conversion of SO_x and NO_x emissions to sulphate and nitrate.)

  Various local and far-field 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 large-scale biomass burning in countries to the north of 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).

- Based on the screening of the potential for health risks occurring due to inhalation exposures to trace metals released from existing Matimba Power

Station it was concluded that predicted concentrations were within acute and chronic health thresholds and that total incremental cancer risks were very low. This is due to the high control efficiency of fly ash abatement systems in place on stacks and the dust abatement measures being implemented at the ash dam. The study was however restricted to the trace metals included in the fly ash and bottom ash composition studies (e.g. excluded metals like cadmium, beryllium and others which are likely to occur). Furthermore, the gaseous trace metals released could not be quantified. Given the volatility of the various trace elements, and the ratio between the trace metal composition of the coal and the composition of the fly and coarse ash, mercury is expected to occur primarily in the gaseous phase.

Given the elevated levels of sulphur dioxide and fine particulate concentrations measured/predicted to occur within parts of the study region it is imperative that the potential for cumulative concentrations due to any proposed developments be minimized and carefully evaluated.

9.5. EMISSIONS INVENTORY FOR MATIMBA B OPERATIONS

Sources associated with the construction phase of the proposed power station project are discussed and their emissions quantified in Section 9.5.1. Various possible power station configurations were evaluated for the operational phases. These configurations are presented in Section 9.5.2 and the source and emissions data for such scenarios presented.

9.5.1. Construction Phase

The construction phase will comprise land clearing and site development operations at the power station site and the associated infrastructure, specifically the ash dump. In order to determine the significance of the potential for impacts it is necessary to quantify atmospheric emissions and predicted airborne pollutant concentrations and dustfall rates occurring as a result of such emissions.

The construction phase will comprise a series of different operations including land clearing, topsoil removal, material loading and hauling, stockpiling, grading, bulldozing, compaction, (etc.). Each of these operations has its own duration and potential for dust generation. It is anticipated therefore that the extent of dust emissions would vary substantially from day to day depending on the level of activity, the specific operations, and the prevailing meteorological conditions. This is in contrast to most other fugitive dust sources where emissions are either relatively steady or follow a discernible annual cycle. It is therefore often necessary to estimate area wide construction emissions, without regard to the actual plans of any individual construction process. Should detailed information

regarding the construction phase be available, the construction process would have been broken down into component operations for emissions quantification and dispersion simulations. Due to the lack of detailed information (e.g. number of dozers to be used, size and locations of raw materials stockpiles and temporary roads, rate of on-site vehicle activity), emissions were instead estimated on an area wide basis. The quantity of dust emissions is assumed to be proportional to the area of land being worked and the level of construction activity.

The US-EPA documents emissions factors which aim to provide a general rule-of-thumb as to the magnitude of emissions which may be anticipated from construction operations. Based on field measurements of total suspended particulate, the approximate emission factors for construction activity operations are given as:

$$E = 2.69 \text{ Mg/hectare/month of activity } (269 \text{ g/m}^2\text{/month})$$

These emission factors are most applicable to construction operations with (i) medium activity levels, (ii) moderate silt contents, and (iii) semiarid climates. Estimated emissions during the surface infrastructure phase were calculated to be as follows:

Development	TSP Emissions (t/month)	PM10 Emissions (t/month)
Power station	172	60

PM10 was assumed to represent ~35% of the TSP emissions given that this is the approximate PM10 component of vehicle-entrainment releases and such releases are anticipated to represent the most significant source of dust during construction operations.

9.5.2. Operational Phase

As at the existing Matimba Power Station, sources of atmospheric emission associated with the proposed power station will include stack emissions in addition to fugitive dust releases arising as a result of coal and ash handling, wind entrainment from the ash dump, and recovery and use of topsoil material.

- *Power Stack Emissions (Criteria Pollutants)*
  Power station configuration options which were requested for inclusion in the study by Eskom personnel are as follows:

Scenario	No. of Units	Technology	Stack Height (m)	SO_2 Control Efficiency
A.1	3 x 800 MW	PF	220	0%
B.1	3 x 800 MW	PF	250	0%
C.1	6 x 800 MW	PF	220	0%
D.1	6 x 800 MW	PF	250	0%
E.1	3 x 800 MW 3 x 800 MW	PF FBC	220	0%
F.1	3 x 800 MW 3 x 800 MW	PF FBC	250	0%
A.2	3 x 800 MW	PF	220	60%
A.3	3 x 800 MW	PF	220	80%
A.4	3 x 800 MW	PF	220	90%
C.2	6 x 800 MW	PF	220	60%
C.3	6 x 800 MW	PF	220	80%
C.4	6 x 800 MW	PF	220	90%

Source parameters and emission rates for these emission scenarios required for input to the dispersion modelling study were provided by Eskom personnel (see Tables 9.43 and 9.44). For the scenarios comprising the control of sulphur dioxide emissions, source parameters and emission rates of other pollutants were assumed to remain the same as for the zero control scenarios. This is a simplistic assumption given that the implementation of abatement technology able to achieve such reductions is likely to alter the stack parameters (e.g. reduction in gas exit temperatures) and possibly increase the emissions of certain other pollutants should the overall combustion efficiency be reduced. In the event that sulphur dioxide abatement is required, a more detailed review of the implications of such abatement for stack configuration and emissions will need to be undertaken.

Table 9.43: Stack parameters for proposed Matimba B Power Station operations

Power Station Configuration	Number of Stacks	Height (m)	Diameter (m)	Exit Velocity (m/s)	Temperature (°K)
3 x 800 MW (2400 MWe)	1	220 or 250(a)	12.82	26.00	403
6 x 800 MW (4800 MWe)	2	220 or 250(a)	12.82	26.00	403

(a) Stack height dependent on scenario.

Table 9.44: Emission rates for power station configurations, assuming 0% control efficiency for sulphur dioxide (received from Yokesh Singh, Eskom Holdings, 28 February 2006)

Capacity	Technology	Annual Emission Rates					
		SO_2	PM	NO_x (a)	NO (b)	NO_2 (c)	Units
2400 MWe	PF	206 885	2 167	35 603	22 755	712	tpa
4800 MWe	PF	413 769	4 333	71 206	45 510	1 424	tpa
2400 MWe	FBC	190 314	5 117	36 002	23 010	720	tpa
4800 MWe	FBC	496 523	5 200	85 447	54 612	1 709	tpa

(a) NO_x as NO_2.

(b) Provided NO_x (as NO_2) emissions were converted to NO and 98% taken as being emitted from the stacks (pers com. John Keir, 2 June 05).

(c) Provided NO_x (as NO_2) emissions were taken at 2% as NO_2 being emitted from the stacks (pers com. John Keir, 2 June 05).

No seasonal variations in emission rates were assumed for the proposed power station configurations. Use was however made of the diurnal trends characterised on a monthly basis for the existing power station based on stack monitoring data.

In order to quantify greenhouse gas emissions, nitrous oxide (N_2O) and carbon dioxide (CO_2) emissions were calculated based on information sourced from Eskom's annual emission reporting. The emission factors and resultant tonnages estimated was as follows:

Pollutant	Eskom Emission Factors	
	g/KWh	kg/ton
CO_2	850	1 746.48
N_2O	0.011	0.02

Capacity	Coal Consumption (tpa)	Annual Emissions	
		CO_2 kT/ann	N_2O kT/ann
4800 MWe	17,117,436	29,895	0.342
2400 MWe	8,558,718	14,948	0.171

- *Fugitive Dust Emissions*

  Materials handling and fugitive dust from the proposed ash dump were assumed to be similar to current operations with the methodological approach outlined in Section 9.4.1 having been applied. Only the locations at which the emissions occur are different, as will be reflected in the atmospheric dispersion simulation results.

- *Heavy Metal Releases from Proposed Power Station – Stack and Ash Dump Operations*
  The trace metal composition of the proposed power station's fly and bottom ash was assumed to be the same as that generated by the current Matimba Power Station (see subsection 9.4.1). The validity of this assumption depends on the combustion technology, operating conditions and trace metal coal composition to be used in comparison to that used by the existing power station.

9.6. Compliance And Air Quality Impact Assessment

9.6.1. Dispersion Model Results

Atmospheric dispersion modelling was undertaken for the proposed Matimba Power Station using the CALPUFF modelling suite recommended for regulatory use by the US-EPA for complex terrain environments and regional-scale modelling domains. A detailed description of the modelling methodology and data inputs is given in Appendix B. Prior to the use of the dispersion model in assessing incremental and cumulative air pollutant concentrations due to the proposed power station, model results were validated based on the performance of the model in simulating existing Matimba Power Station emissions. The validation process and rational for implementing a correction factor of 0.5 is also outlined in Appendix B.

The CALPUFF model only facilitates the estimation of hourly or longer period averages. In order to facilitate comparisons with the SA and SANS SO_2 10-minute averages limit, 10-minute SO_2 predicted concentrations were extrapolated from the hourly average predictions using the equation documented in Section 9.4.3.

In order to establish the potential for cumulative air quality impacts the proposed power station configurations were simulated together with the existing emissions from the operational Matimba Power Station.

The maximum hourly, daily and annual sulphur dioxide, nitrogen dioxide and PM10 concentrations occurring as a result of proposed power station configurations (taking cumulative concentrations due to existing Matimba Power Station operations into account) are presented in tables in **Appendix D**. The potential for compliance with local and international (UK) limits, and for health risks, vegetation injury and damage to property through corrosion is summarised in tables in **Appendix E** for all scenarios and various selected receptor points.

9.6.2. Compliance with Ambient Air Quality Limits

In assessing "compliance" with air quality limits it is important to note the following:

- Variations in where air quality limits are applicable. The EC (and UK) stipulate that air quality limits are applicable in areas where there is a reasonable expectation that public exposures will occur over the averaging period of the limit. In the US, the approach is frequently adopted of applying air quality limits within all areas to which the public has access (i.e. everywhere not fenced off or otherwise controlled for public access). In South Africa there is still considerable debate regarding the practical implementation of the air quality standards included in the schedule to the Air Quality Act. The Act does however define "ambient air" as excluding air regulated by the Occupational Health and Safety Act of 1993. This implies that air quality limits may be required to be met beyond the fencelines of industries.

- The SA standards included in the schedule to the Air Quality Act are incomplete when compared to legal limits issued by other countries. Air quality standards typically comprise: thresholds, averaging periods, monitoring protocols, timeframes for achieving compliance and typically also permissible frequencies of exceedance. (Thresholds are generally set based on health risk criteria, with permissible frequencies and timeframes taking into account the existing air pollutant concentrations and controls required for reducing air pollution to within the defined thresholds. The practice adopted in Europe is to allow increasingly more limited permissible frequencies of exceedance, thus encouraging the progressive reduction of air pollution levels to meeting limit values.)

NOTE: Given the above uncertainties a conservative approach was adopted in assessing compliance with SA air quality standards, with single exceedances of thresholds beyond the "fenceline" of the power station being taken as constituting "non-compliance". In order however to demonstrate areas of "non-compliance" should permissible frequencies be issued at a latter date reference is made to the UK air quality limits. The UK and SA primarily support similar short-term thresholds for sulphur dioxide. The UK however permits a number of annual exceedances of these short-term thresholds to account for meteorological extremes and to support progressive air quality improvement.

- *Nitrogen Oxides*
  Predicted NO and NO_2 concentrations were within local and international air quality limits for all proposed power station configuration scenarios (including cumulative concentrations due to existing Matimba Power Station emissions) (Appendix D).

- *Airborne Fine Particulates and Dust Deposition*
  Predicted total PM10 concentrations arising due to primary and secondary emissions from current and proposed power station operations (i.e. including stack emissions and fugitive dust from coal and ash handling, borrow pit activity and wind erosion from the ash dams) are illustrated in **Appendix F**. Projected dustfall rates are also depicted in this appendix.

  Predicted PM10 concentrations were within the SA daily and annual standards but exceeded the SANS and EC limit values in the vicinity (within 4 km) of the ash dump at Zwartwater and the proposed ash dump on Eenzamheid. Farms downwind of these dams include Wellington and Grootvallei (existing Zwartwater ash dam) and Kromdraai, Veguldeheim and Nooitgedacht (proposed ash dam). Public exposure within this area is restricted to scattered farmsteads with an average residential density of ~5 persons/km².

  Maximum monthly dustfall rates were typically "moderate" (i.e. 250 - 500 mg/m²/day) immediately downwind of the Zwartwater ash dump and materials handling section of the power station, with "slight" dustfalls (i.e. < 250 mg/m²/day) occurring beyond these areas.

- *Sulphur Dioxide Emissions - Uncontrolled*
  Emissions from the existing Matimba Power Station are predicted to be responsible for exceedances of SA standards particularly downwind of the facility. Given this baseline it is evident that no future development resulting in sulphur dioxide emissions within the same area can be in compliance with the SA standard. It is due to this cumulative impact that all proposed power station configurations are indicated to be in non-compliance with SA standards in Appendix E. The magnitude, frequency of occurrence and area of exceedance of air quality limits varies significantly however between configurations. A synopsis of the maximum sulphur dioxide concentrations and frequencies of exceedance of the short-term air quality limits is given in Table 9.45 for all emission scenarios. The areas of exceedance of the SA 10-minute standard, the SA daily standard and the UK hourly limit are illustrated in Figures 9.29, 9.30 and 9.31 respectively for current operations and emission scenarios A, C and E. Emission scenarios B, D and F gave very similar results to scenarios A, C and E respectively and were therefore not depicted in the spatial plot. Ground level maximum concentrations and

frequencies of exceedance are given in the zone of maximum impact and at Marapong.

Table 9.45: Maximum sulphur dioxide concentrations and frequencies of exceedances or air quality limits predicted to occur due to basecase operations and cumulatively as a result of uncontrolled emissions from various proposed power station configurations

Receptor Point	Emission Scenario (cumulative for proposed PS, includes existing Matimba PS emissions)	Predicted SO_2 Concentration (µg/m³)			Compliance Potential			
		Highest Hourly	Highest Daily	Annual Average	Freq Exc SA 10-minute Limit of 500 µg/m³ (no permissible frequencies) / Freq Exc EC Hourly Limit of 350 µg/m³ (EC permits 4, UK 24)	Freq Exc SA Daily Limit of 125 µg/m³ (EC & UK permit 3)	Compliance with SA Standards	Compliance with UK Standards
Maximum Impact Zone	Existing Matimba PS	1521	172	19.6	99	7	FALSE	FALSE
	Scenario A - uncontrolled	1994	177	26.8	157	10	FALSE	FALSE
	Scenario B - uncontrolled	1994	172	25.3	139	7	FALSE	FALSE
	Scenario C - uncontrolled	3585	303	42.7	419	33	FALSE	FALSE
	Scenario D - uncontrolled	2819	294	37.7	352	21	FALSE	FALSE
	Scenario E - uncontrolled	3442	293	41.2	400	29	FALSE	FALSE
	Scenario F - uncontrolled	2708	276	36.5	330	20	FALSE	FALSE
Marapong	Existing Matimba PS	993	91	3.3	19	1	FALSE	TRUE
	Scenario A - uncontrolled	1232	111	5.1	27	2	FALSE	FALSE
	Scenario B - uncontrolled	1232	115	4.9	27	2	FALSE	FALSE
	Scenario C - uncontrolled	1481	153	6.8	35	4	FALSE	FALSE
	Scenario D - uncontrolled	1361	163	6.3	34	3	FALSE	FALSE
	Scenario E - uncontrolled	1471	150	6.6	35	3	FALSE	FALSE
	Scenario F - uncontrolled	1363	155	6.1	34	3	FALSE	FALSE

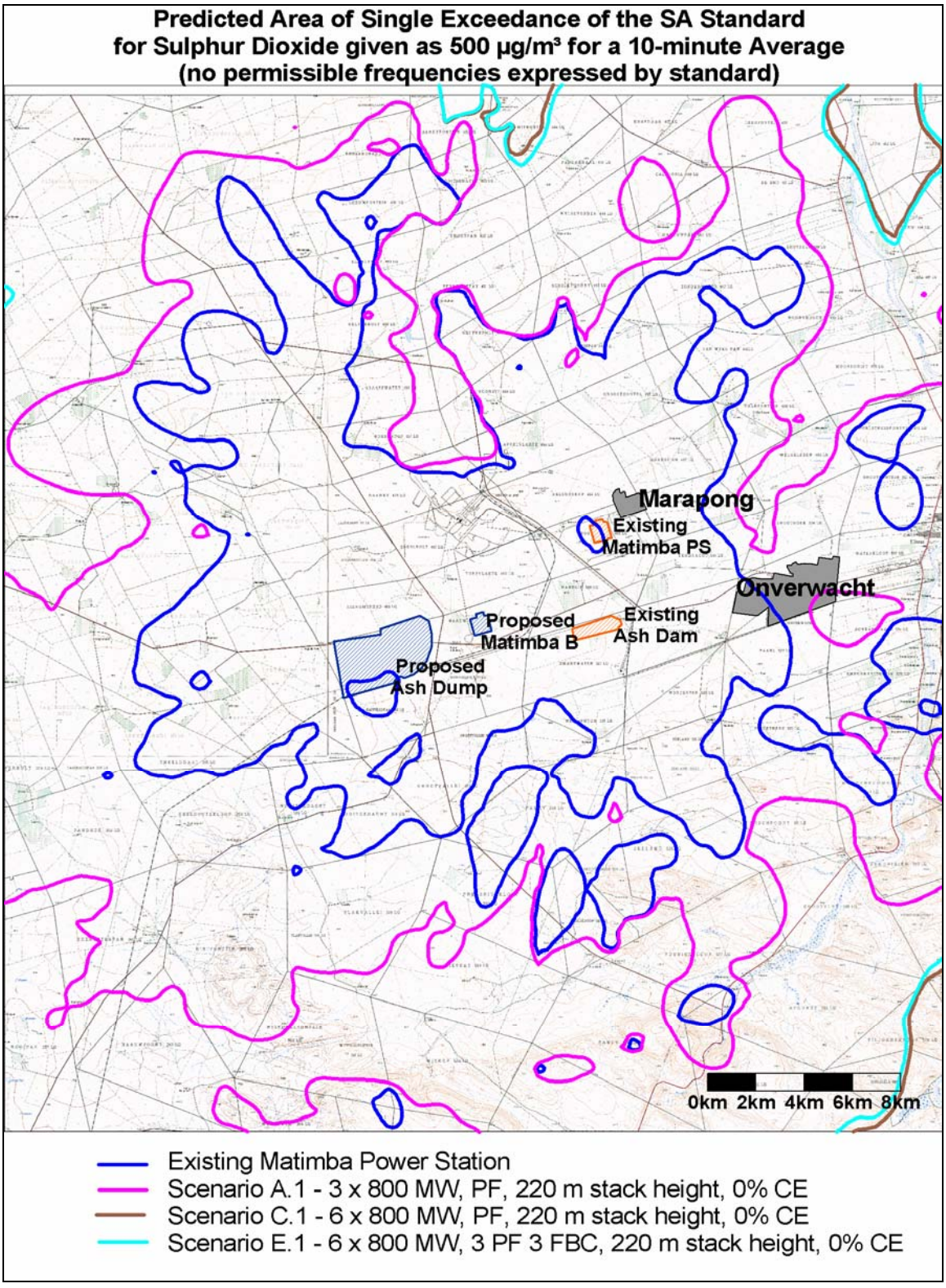

Figure 9.29 Predicted area of a single exceedance of the SA 10-minute SO2 standard due to existing Matimba PS emissions and existing Matimba PS emissions together with uncontrolled emissions from various of the proposed power station configurations. (Scenarios B, D and F produced similar results to A, C and E respectively and were omitted to improve clarity.)

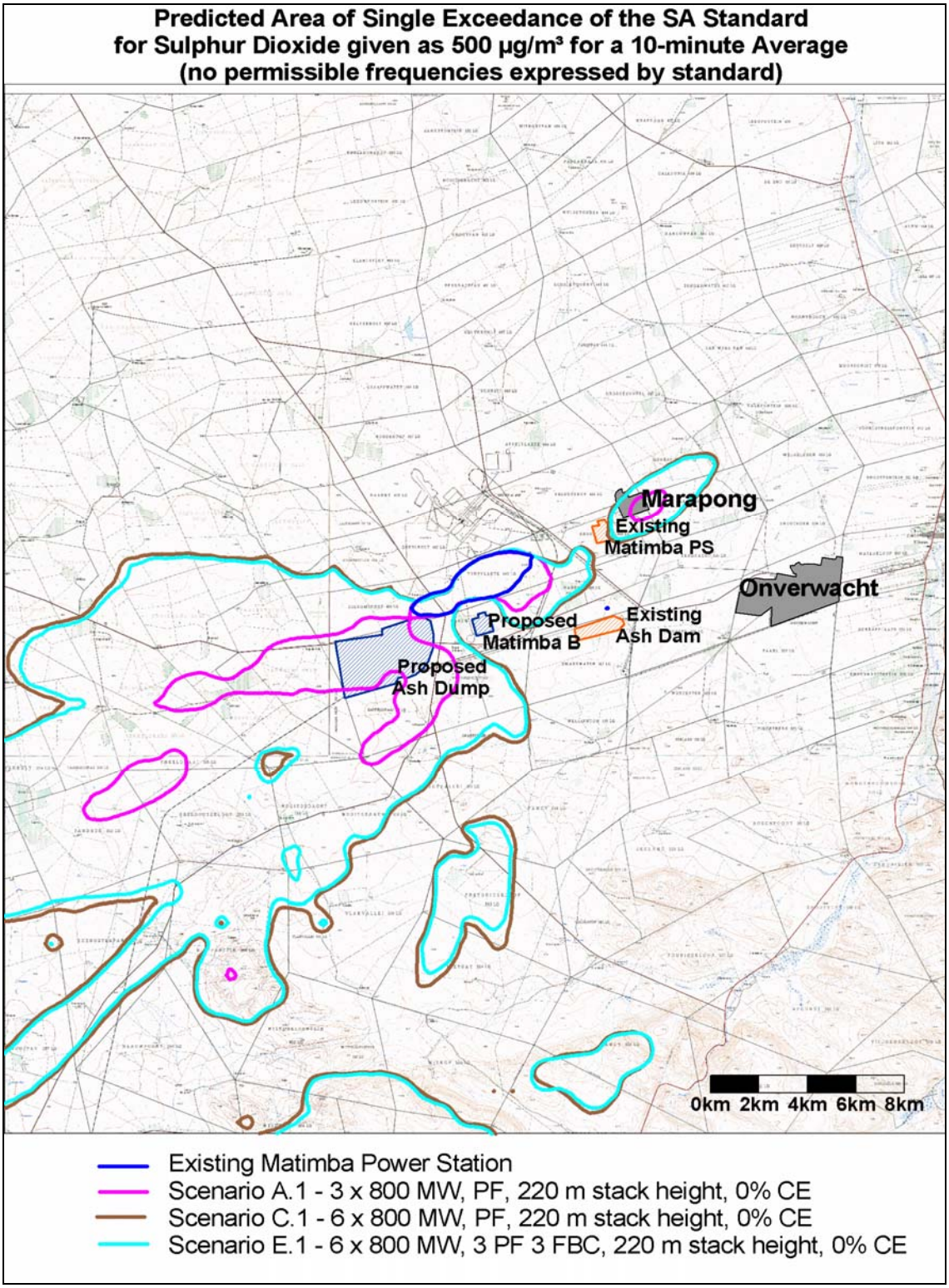

Figure 9.30: Predicted area of a single exceedance of the SA daily SO_2 standard due to existing Matimba PS emissions and existing Matimba PS emissions together with uncontrolled emissions from various of the proposed power station configurations. (Scenarios B, D and F produced similar results to A, C and E respectively and were omitted to improve clarity.)

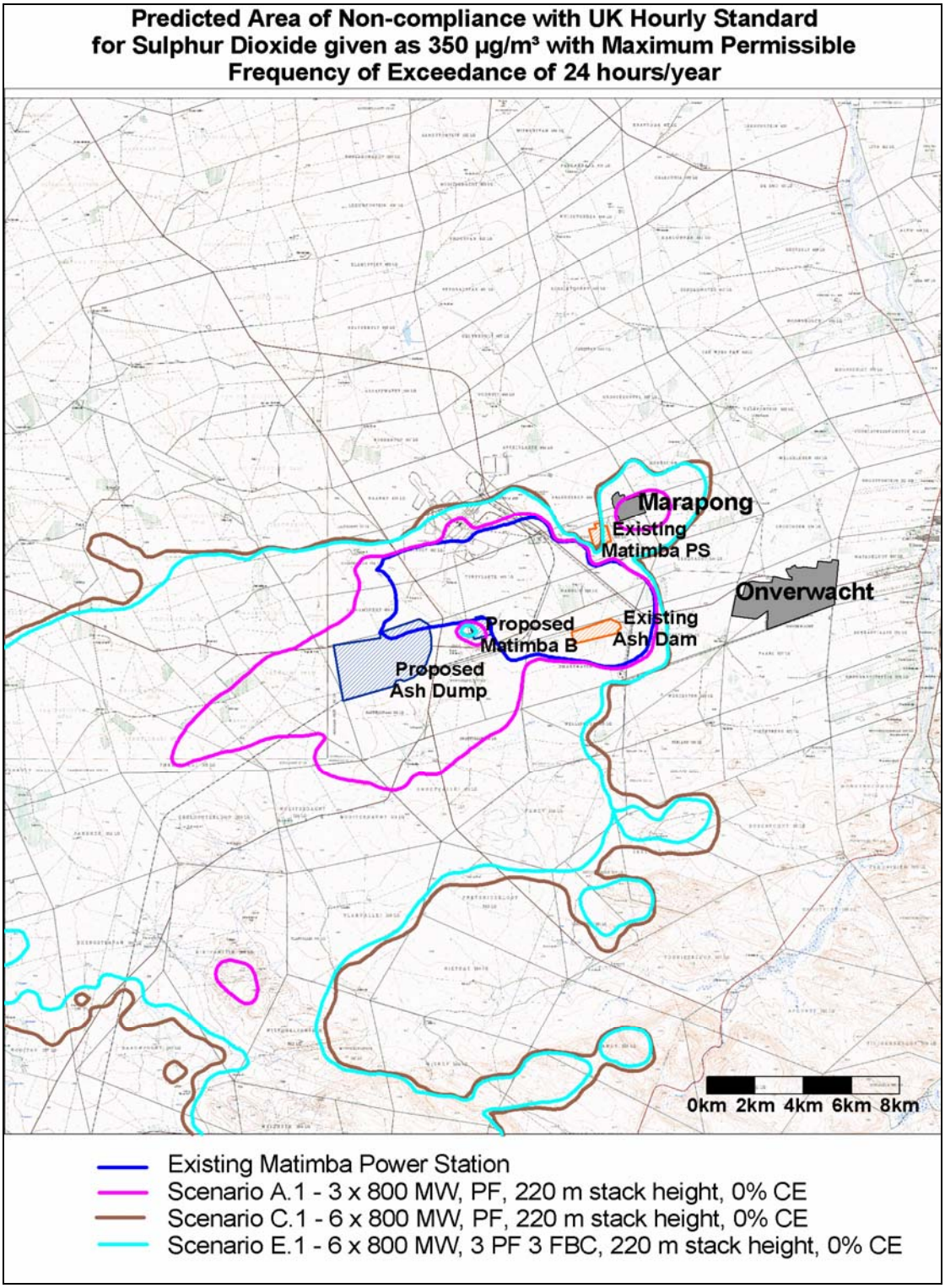

Figure 9.31: Predicted area of exceedance of the UK hourly SO_2 standard (permits a maximum of 24 exceedances per year) due to existing Matimba PS emissions and existing Matimba PS emissions together with uncontrolled emissions from various of the proposed power station configurations. (Scenarios B, D and F produced similar results to A, C and E respectively and were omitted to improve clarity.)

Observations made regarding compliance implications of various power station configurations given uncontrolled emissions:

- SA short-term standards (10-minute and daily) are exceeded within the zone of maximum impact occurring to the SW of the power station(s) due to basecase and all proposed configurations. At Marapong the SA 10-minute standard is exceeded for basecase and all proposed configurations, whereas the SA daily standard is only predicted to be exceeded when an additional six 800 MW units are in operation.
- Under current Matimba PS operations there is predicted to be compliance with the UK hourly sulphur dioxide standard at Marapong. This standard is however exceeded at Marapong with the addition of three or more 800 MW units.
- Under current Matimba PS operations, the exceedance of the SA 10-minute standard is predicted to extend to include western parts of Onverwacht. Given the addition of three new units, this standard will be exceeded over the entire Onverwacht and broader Lephalale area. The exceedance zone is projected to extend beyond the modelling domain with the addition of six new units.
- The increase of the stack height from 220 m to 250 m is predicted to result in relatively small reductions in ground level maximum, with only marginal changes in the areas of non-compliance.

It may be concluded that the addition of 3 new 800 MW PF units with no sulphur dioxide abatement in place would result in significant increases in the magnitude, frequency and spatial extent of non-compliance with SA standards. A further 3 units would more than double the magnitude and spatial extent of non-compliance, whilst resulting in a 3 to 4 fold increase in the frequency of exceedance of air quality limits. The extension of the height of the stack by 30 m, from 220 m to 250 m, is not sufficient to negate the need for considering abatement measures.

- *Sulphur Dioxide Emissions - Controlled*
  Changes in projected ground level sulphur dioxide concentrations and limit value exceedances were simulated for various control efficiencies (60%, 80% and 90%) for two proposed power station configurations, viz. Scenario A (3 x 800 MW PF with 220 m stack) and Scenario C (6 x 800 MW PF with 220 m stack). A synopsis of the maximum sulphur dioxide concentrations and frequencies of exceedance of the short-term air quality limits is given in Table 9.46. The areas of exceedance of the SA 10-minute standard, the SA daily standard and the UK hourly limit are illustrated in Figures 9.32 to 9.37 for Scenarios A and C given control efficiencies in the 60% to 90% range. (Basecase and uncontrolled Scenario A and C results are also depicted in the plots for comparative purposes.)

Table 9.46: Maximum sulphur dioxide concentrations and frequencies of exceedances or air quality limits predicted to occur due to basecase operations and cumulatively as a result of controlled emissions from various proposed power station configurations

Receptor Point	Emission Scenario (cumulative, includes existing Matimba PS emissions)	Predicted SO_2 Concentration (µg/m³)			Compliance Potential			
		Highest Hourly	Highest Daily	Annual Average	Freq Exc SA 10-minute Limit of 500 µg/m³ (no permissible frequencies) / Freq Exc EC Hourly Limit of 350 µg/m³ (EC permits 4, UK 24)	Freq Exc SA Daily Limit of 125 µg/m³ (EC & UK permit 3)	Compliance with SA Standards	Compliance with UK Standards
Maximum Impact Zone	Scenario A - 60% CE	1521	171.6	20.6	99	7	FALSE	FALSE
	Scenario A - 80% CE	1521	171.6	19.9	99	7	FALSE	FALSE
	Scenario A - 90% CE	1521	171.6	19.7	99	7	FALSE	FALSE
	Scenario C - 60% CE	1994	171.6	23.8	117	7	FALSE	FALSE
	Scenario C - 80% CE	1994	171.6	20.1	100	7	FALSE	FALSE
	Scenario C - 90% CE	1994	171.6	20.6	99	7	FALSE	FALSE
Marapong	Scenario A - 60% CE	1083	97.7	4.0	21	1	FALSE	TRUE
	Scenario A - 80% CE	1056	92.5	3.5	20	1	FALSE	TRUE
	Scenario A - 90% CE	1042	91.1	3.4	19	1	FALSE	TRUE
	Scenario C - 60% CE	1282	104.5	4.7	24	2	FALSE	TRUE
	Scenario C - 80% CE	1244	94.2	3.7	21	1	FALSE	TRUE
	Scenario C - 90% CE	1257	97.6	4.0	21	1	FALSE	TRUE

Observations made regarding compliance implications of various power station configurations given controlled emissions:

- Even given a 90% control efficiency for Scenario A (3 x 800 MW units, PF, 220 m stack), cumulative sulphur dioxide concentrations would exceed the SA 10-minute standard at the maximum impact zone and at Marapong and the SA daily standard in the maximum impact zone – primarily due to emissions from the existing Matimba Power Station.
- The implementation of abatement measures with a 60%+ control efficiency for Scenario A (3 x 800 MW units) would be sufficient to reduce the magnitude, frequency and spatial extent of non-compliance to levels comparable to those projected for current operations. With a 90% control efficiency, the magnitude of maximum daily and annual average concentrations, the spatial extent of non-compliance with the daily limit and the frequency of exceedance of both short-term limits closely reflects

the current situation. (The magnitude of the highest hourly concentration and the spatial extent of non-compliance with the 10-minute limit are marginally higher than for current.)

- Given Scenario C (6 x 800 MW units) an 80%+ control efficiency would be required to bring the magnitude, frequency and spatial extent of non-compliance within levels comparable to those projected for current operations. Even given a 90% control efficiency the maximum predicted concentrations and the frequencies of exceedance at Marapong would be higher – albeit relatively marginally higher – than for current operations.

It may be concluded that a 60%+ control efficiency would suffice to ensure that the proposed 3 units could operate coincident with the existing Matimba Power Station without substantial changes in the magnitude, frequency or spatial extent of non-compliance. This is however assuming that no further units are installed at a latter date, or that more stringent air quality limits are not introduced.

With the addition of six new units (whether commissioned together or phased in) operating coincident with the existing Matimba Power Station, at least a 90% control efficiency would be required to ensure that the magnitude, frequency and spatial extent of non-compliance was within levels comparable to those projected for the basecase. Even given 90% control efficiencies on all six units, the maximum predicted hourly concentrations, the spatial extent of non-compliance with the 10-minute limit and the frequencies of exceedance at Marapong would be *marginally* higher than for current operations.

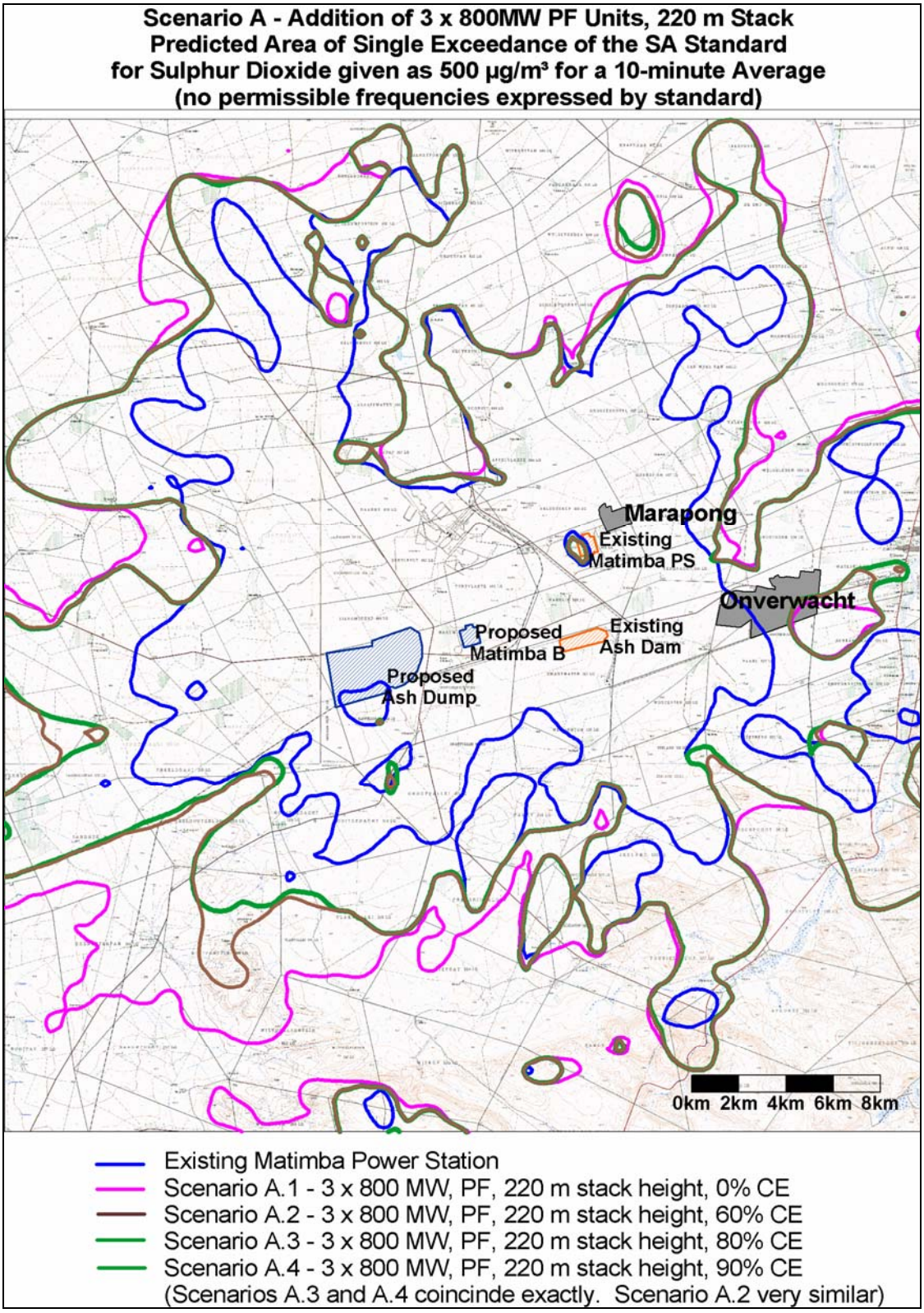

Figure 9.32: Predicted area of a single exceedance of the SA 10-minute SO_2 standard due to Scenario A (3 x 800 MW PF, 220 m stack) emissions and existing Matimba PS emissions, given various sulphur dioxide abatement efficiencies**.**

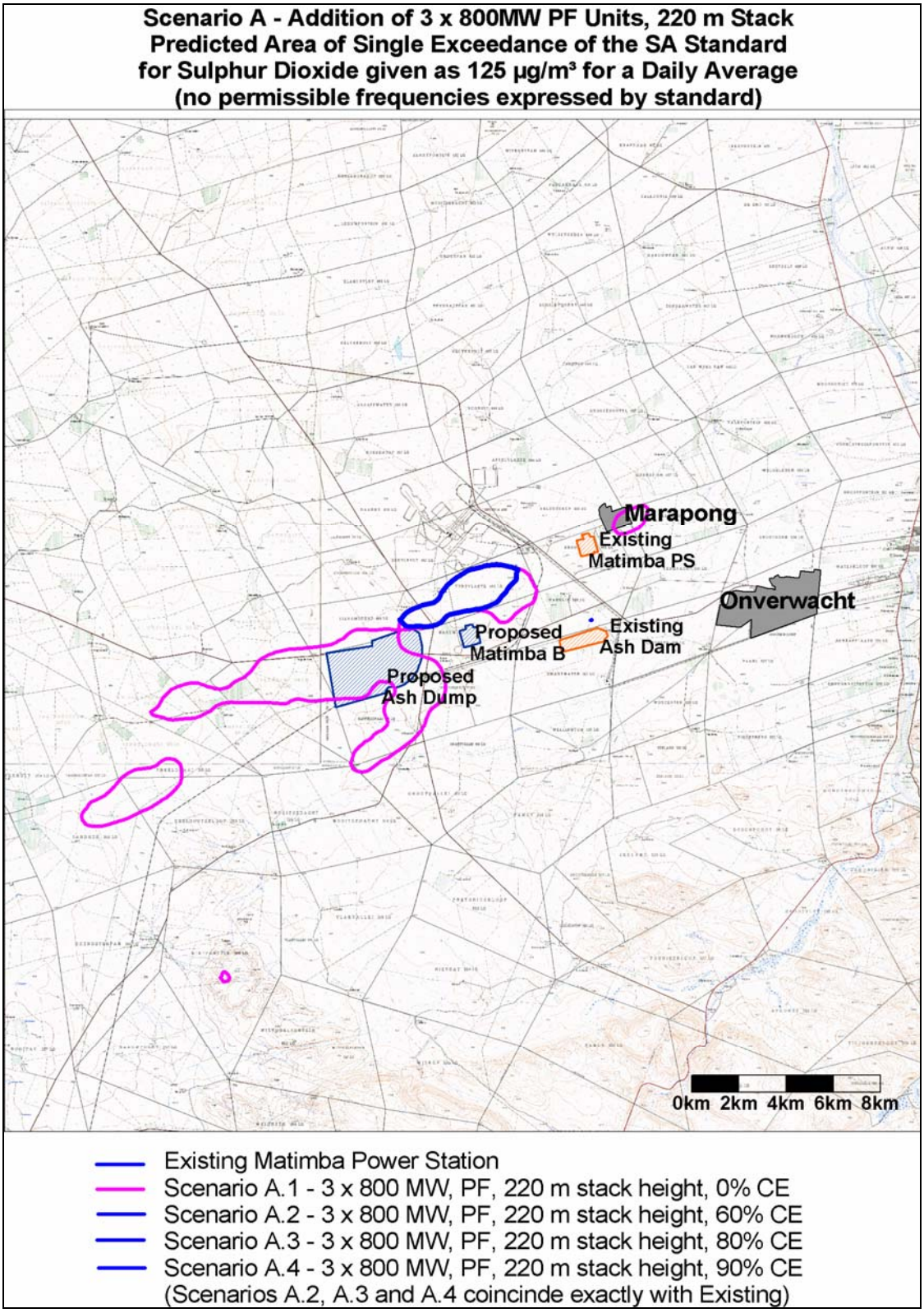

Figure 9.33: Predicted area of a single exceedance of the SA daily SO_2 standard due to Scenario A (3 x 800 MW PF, 220 m stack) emissions and existing Matimba PS emissions, given various sulphur dioxide abatement efficiencies.

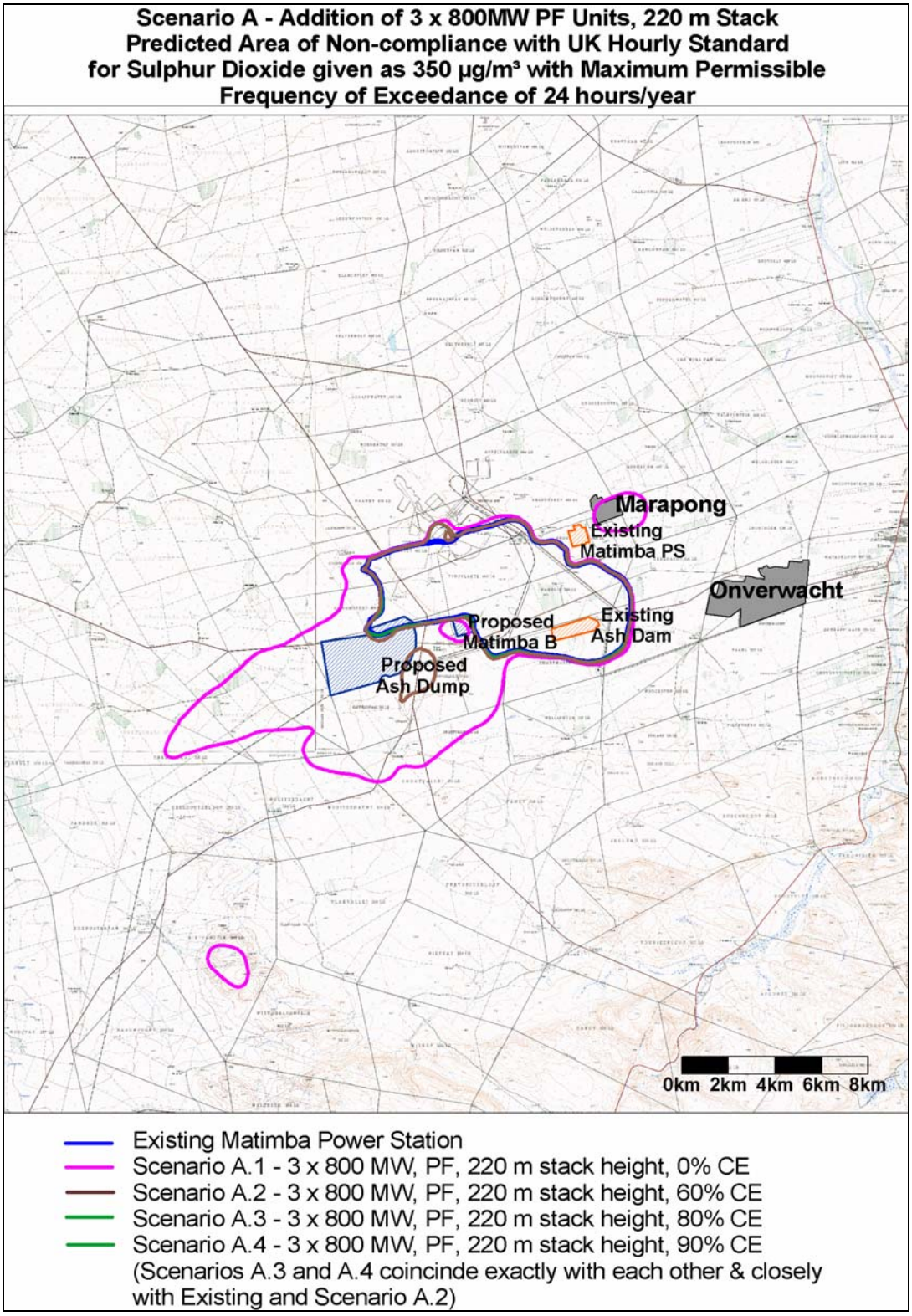

Figure 9.34: Predicted area of exceedance of the UK hourly SO_2 standard (permits a maximum of 24 exceedances per year) due to Scenario A (3 x 800 MW PF, 220 m stack) emissions and existing Matimba PS emissions, given various sulphur dioxide abatement efficiencies.

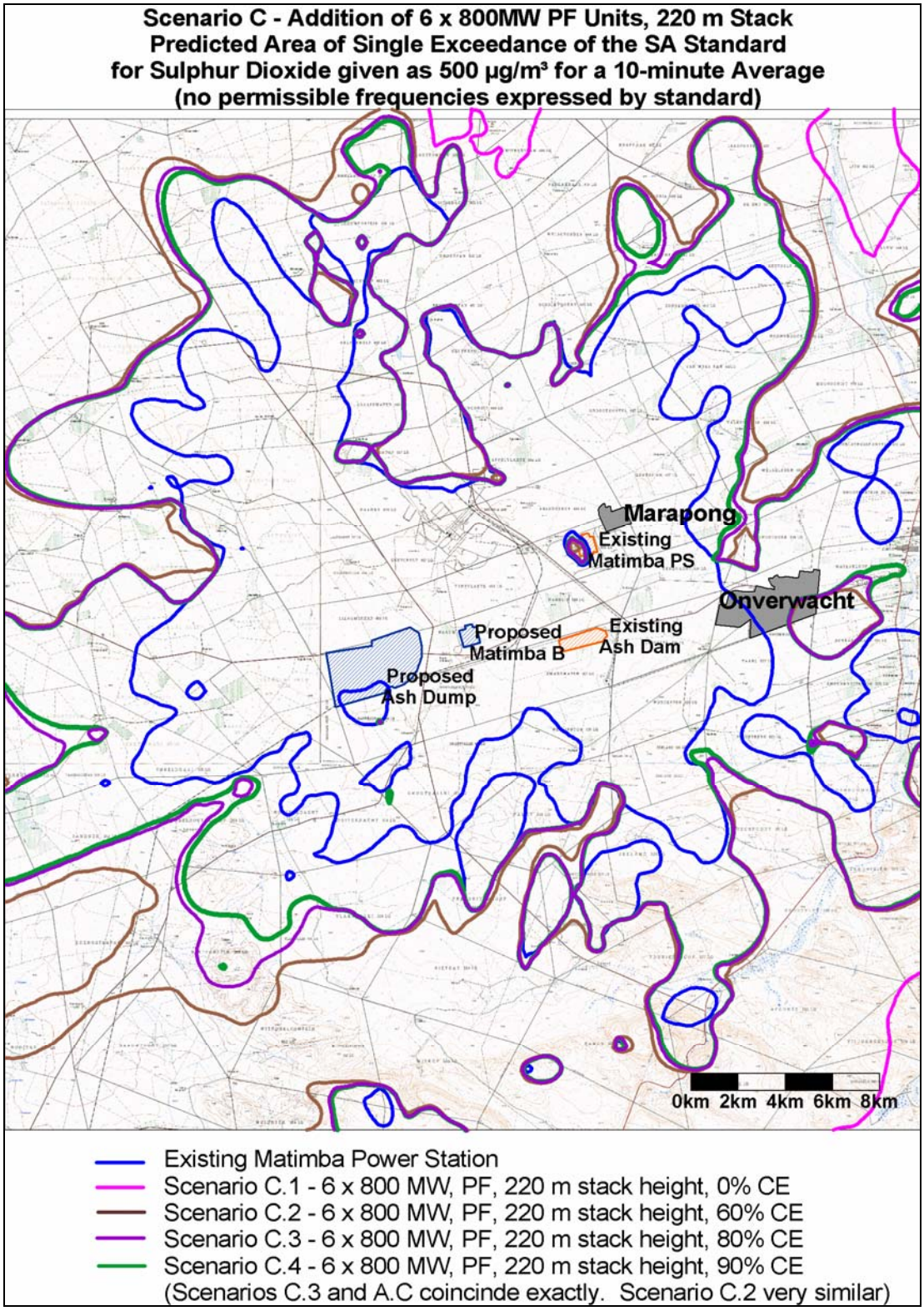

Figure 9.35: Predicted area of a single exceedance of the SA 10-minute SO_2 standard due to Scenario C (6 x 800 MW PF, 220 m stack) emissions and existing Matimba PS emissions, given various sulphur dioxide abatement efficiencies.

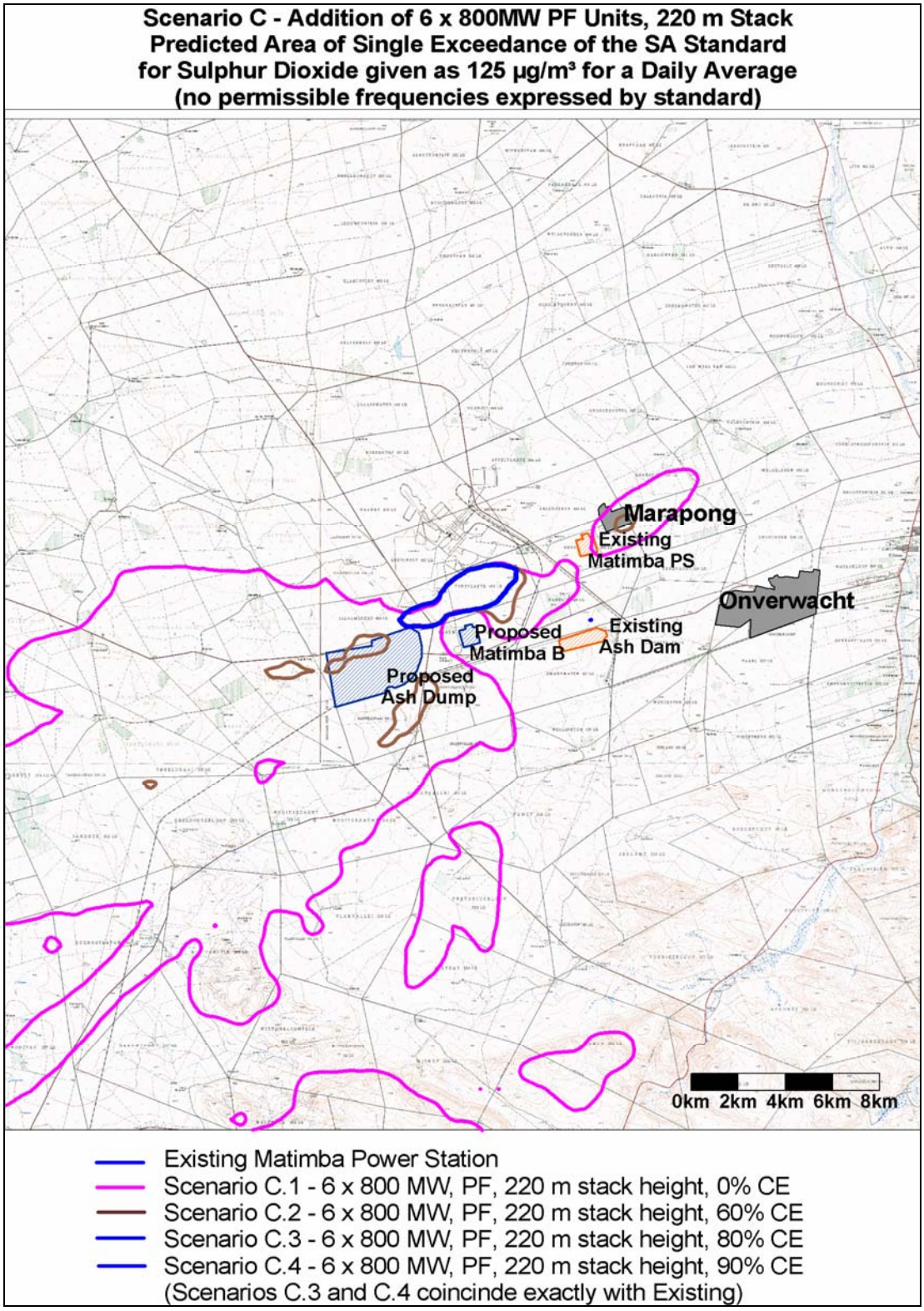

Figure 9.36: Predicted area of a single exceedance of the SA daily SO_2 standard due to Scenario C (6 x 800 MW PF, 220 m stack) emissions and existing Matimba PS emissions, given various sulphur dioxide abatement efficiencies.

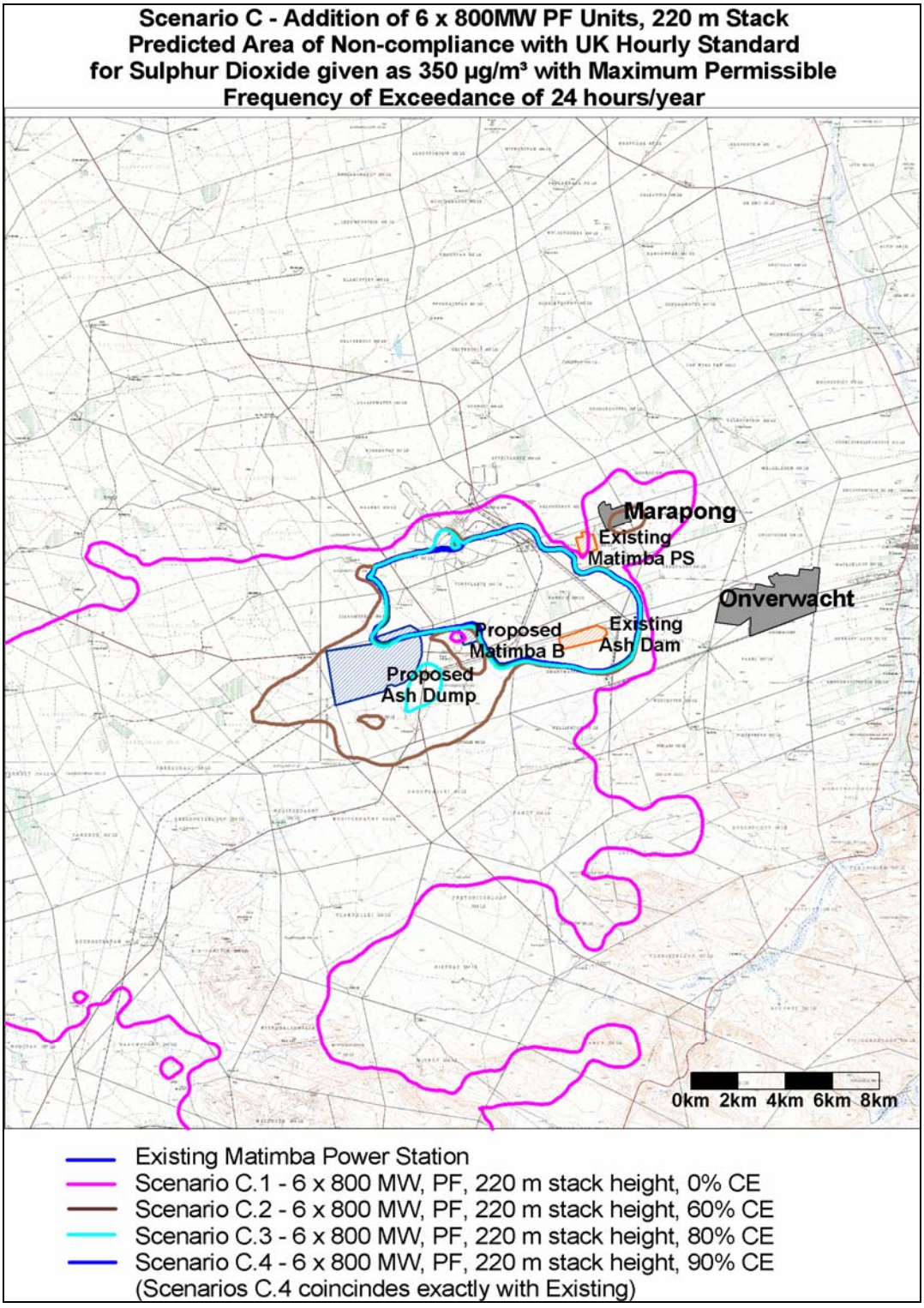

Figure 9.37: Predicted area of exceedance of the UK hourly SO_2 standard (permits a maximum of 24 exceedances per year) due to Scenario C (6 x 800 MW PF, 220 m stack) emissions and existing Matimba PS emissions, given various sulphur dioxide abatement efficiencies.

9.6.3. Potential for Health Effects

- *Exposures to Sulphur Dioxide Concentrations*
  Based on the health-related dose-response thresholds for sulphur dioxide outlined in Section 9.2.4 and the classification of risks due to various sulphur dioxide concentrations by the UK (Section 9.2.4) it was decided to categorize risks to SO_2 exposures in the following manner for the purpose of the current study:

Category of Risk(a)	Maximum Hourly Average SO_2 Concentration (µg/m³) (99th percentile)	Basis
Low	<660	California Acute Reference Level for Mild Respiratory Effects given as 660 µg/m³
Moderate	660 – 930	
High	930 – 1400	Upper range of UK's "high" band (i.e. 708 µg/m³ for 15 minute average – projected as 934 µg/m³ for a 1-hourly averaging period)(b). Coincides closely with the dose-response threshold at 916 µg/m³ given for increased airway resistance in asthmatics at exercise
Very high	>1400	UK's "very high" band (i.e. 1064 µg/m³ for 15 minute average – projected as 1404 µg/m³ for a 1-hourly averaging period)(b)

(a) Low risks were assigned to all areas with very low exposure potentials, e.g. neighbouring farms where the average population density is ~5 persons/km².
(b) "High" band expressed by UK Department for Environment, Food and Rural Affairs (DEFRA) as "significant effects may be noticed by sensitive individuals and action to avoid or reduce these effects may be needed (e.g. reducing exposure by spending less time in polluted areas outdoors). Asthmatics will find that their 'reliever' inhaler is likely to reverse the effects on the lung"
(c) "Very high" band expressed by UK DEFRA as follows: "the effects on sensitive individuals described for 'High' levels of pollution may worsen".

Health risk potentials are depicted in Figures 9.30 to 9.42 for basecase and proposed uncontrolled power station configurations, and in Figures 9.43 to 9.47 for emission scenarios incorporating various control efficiencies. These health risk potential plots do not take into account actual exposure, with the likelihood of risk therefore depended on the actual exposures. The residential areas of Marapong and Onverwacht are indicated in the plots to illustrate areas of concentrated settlement and hence high exposure potentials.

A synopsis of the health risks deemed likely to occur, taking predicted sulphur dioxide concentrations in the vicinity of dense settlement into account, is given in Table 6.3. Risks were categorised as "low" in areas with low exposure potentials, such as on neighbouring farms where the average population density is given based on the Census data as being ~5

persons/km². Significant exposure potentials were assumed to occur within Marapong (population of 17000; 75 persons for km²) and Onverwacht/Lephalale residential area (population of 3000; 180 persons per km²).

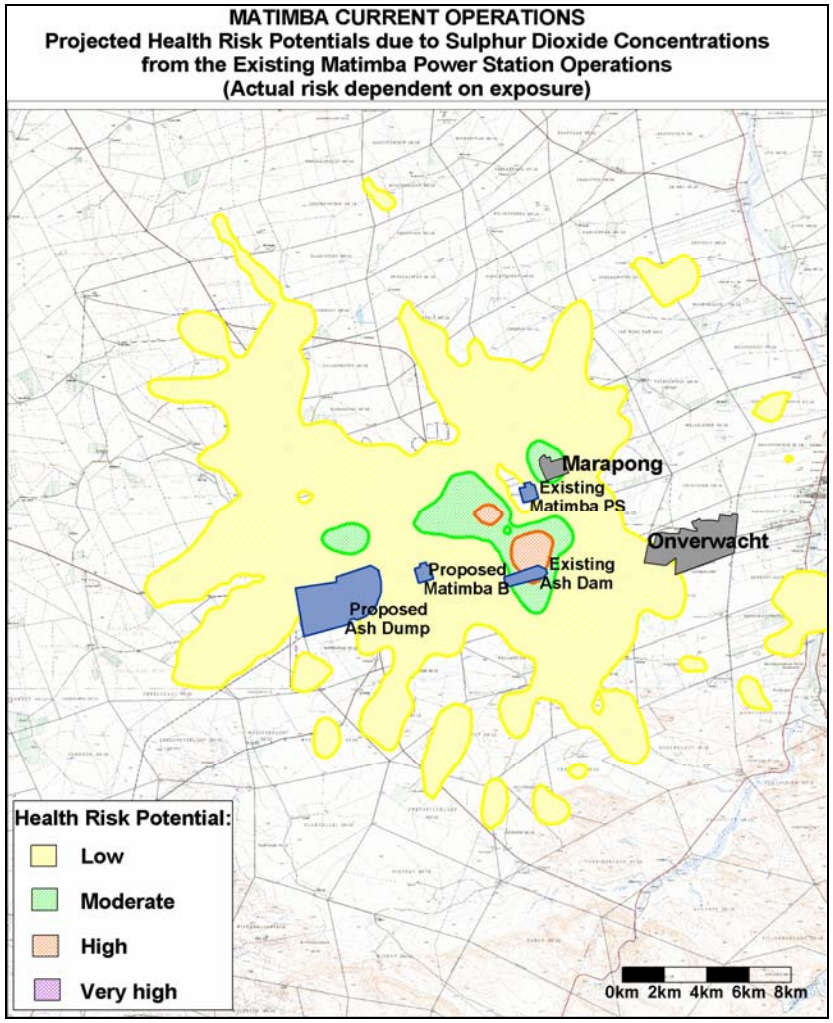

Figure 9.38 Projected health risk potential zones for current Matimba Power Station Operations

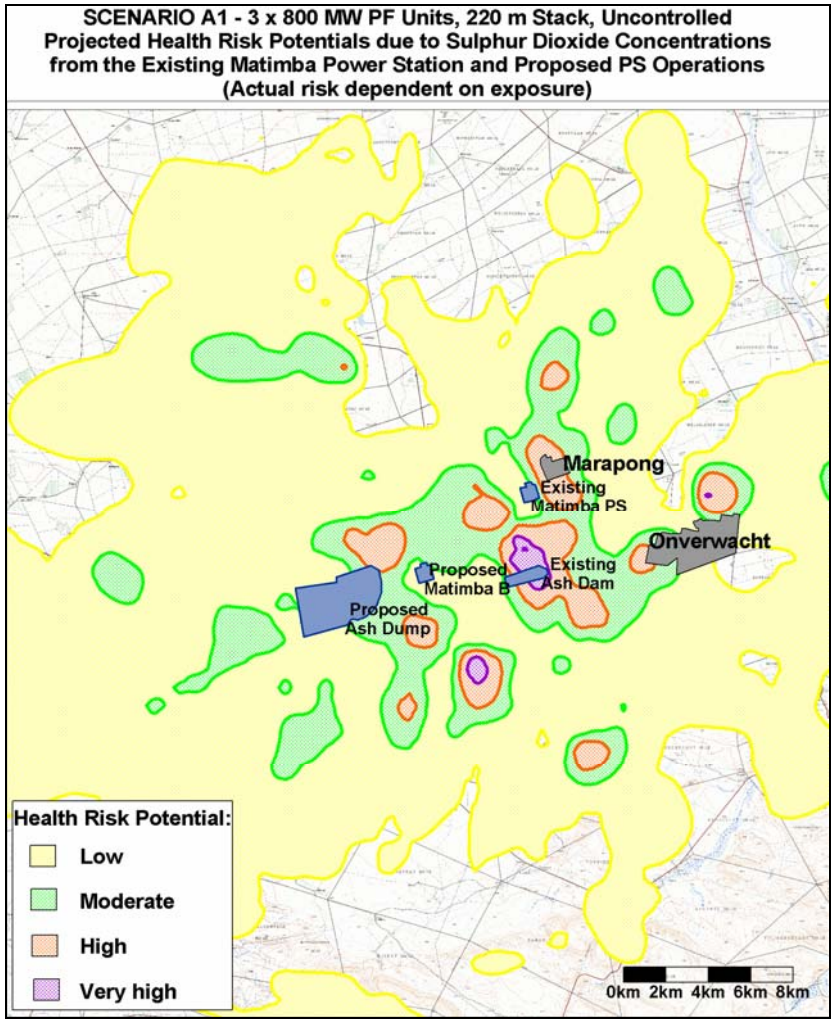

Figure 9.39 Projected health risk potential zones for Scenario A1 Operations(i.e. 3 x 800 MW PF units, 220 m stack, uncontrolled)

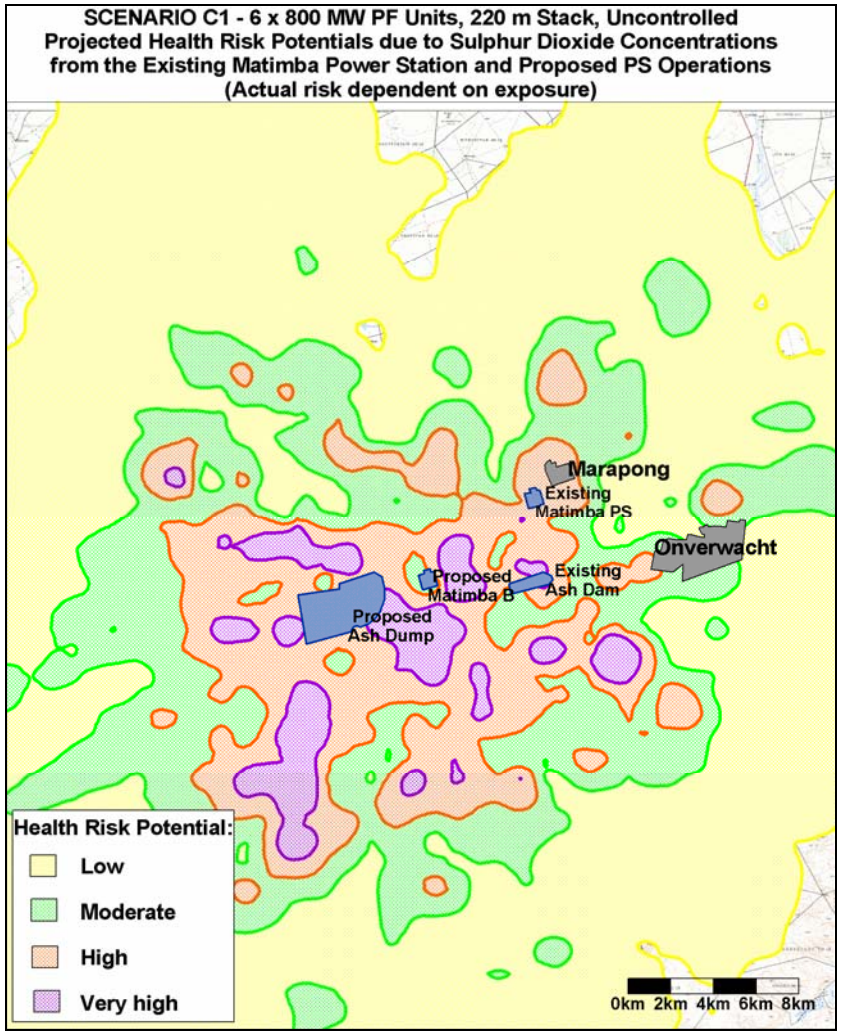

Figure 9.40 Projected health risk potential zones for Scenario C1 Operations (i.e. 6 x 800 MW PF units, 220 m stack, uncontrolled)

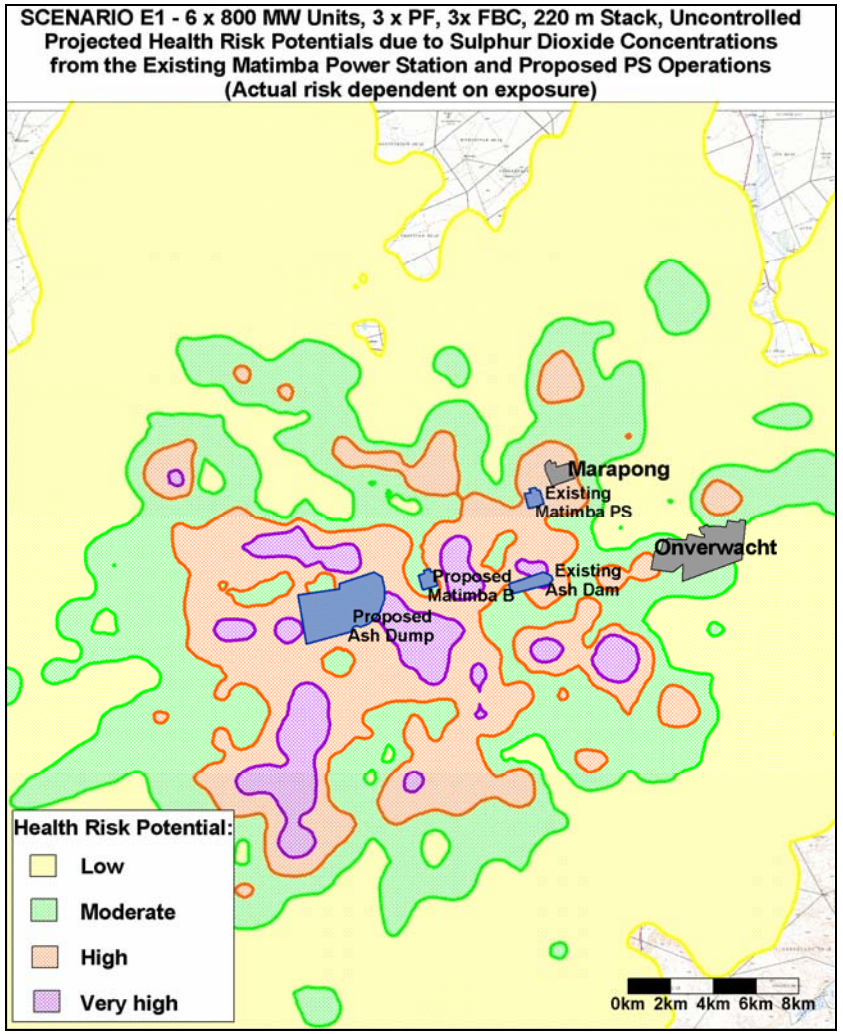

Figure 9.41 Projected health risk potential zones for Scenario E1 Operations (i.e. 6 x 800 MW units – 3 PF, 3 FBC - 220 m stack, uncontrolled)

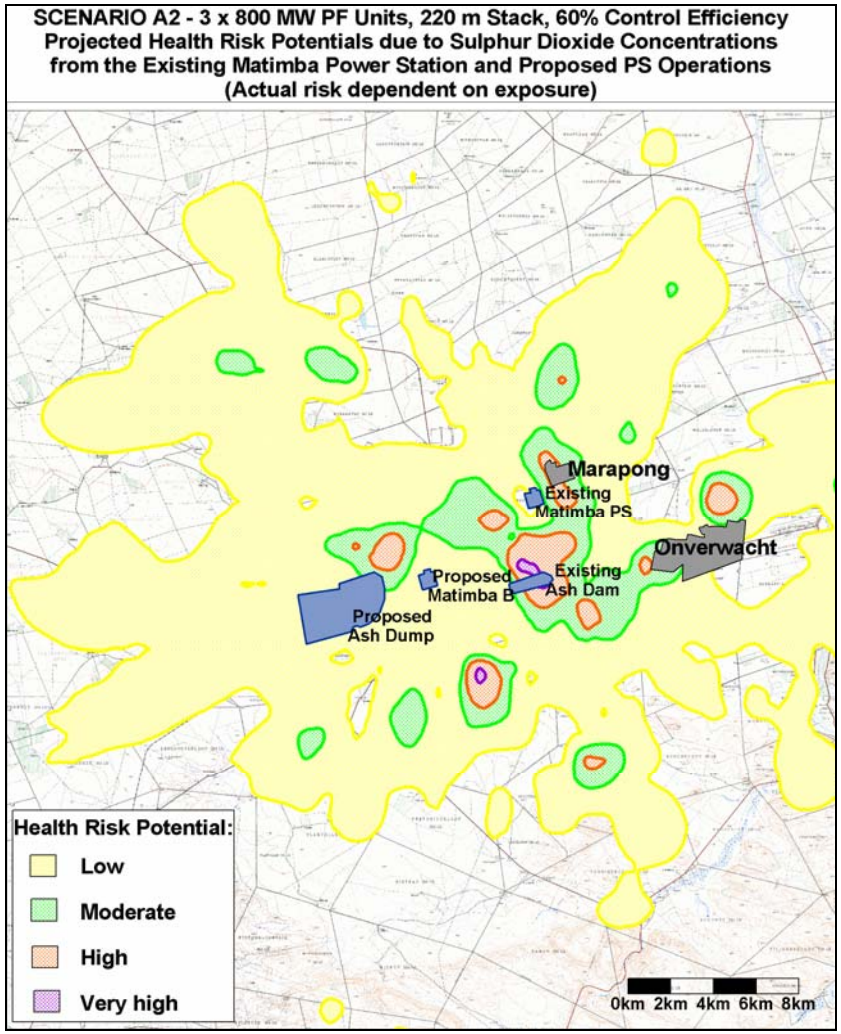

Figure 9.42 Projected health risk potential zones for Scenario A2 Operations(i.e. 3 x 800 MW PF units, 220 m stack, 60% CE)

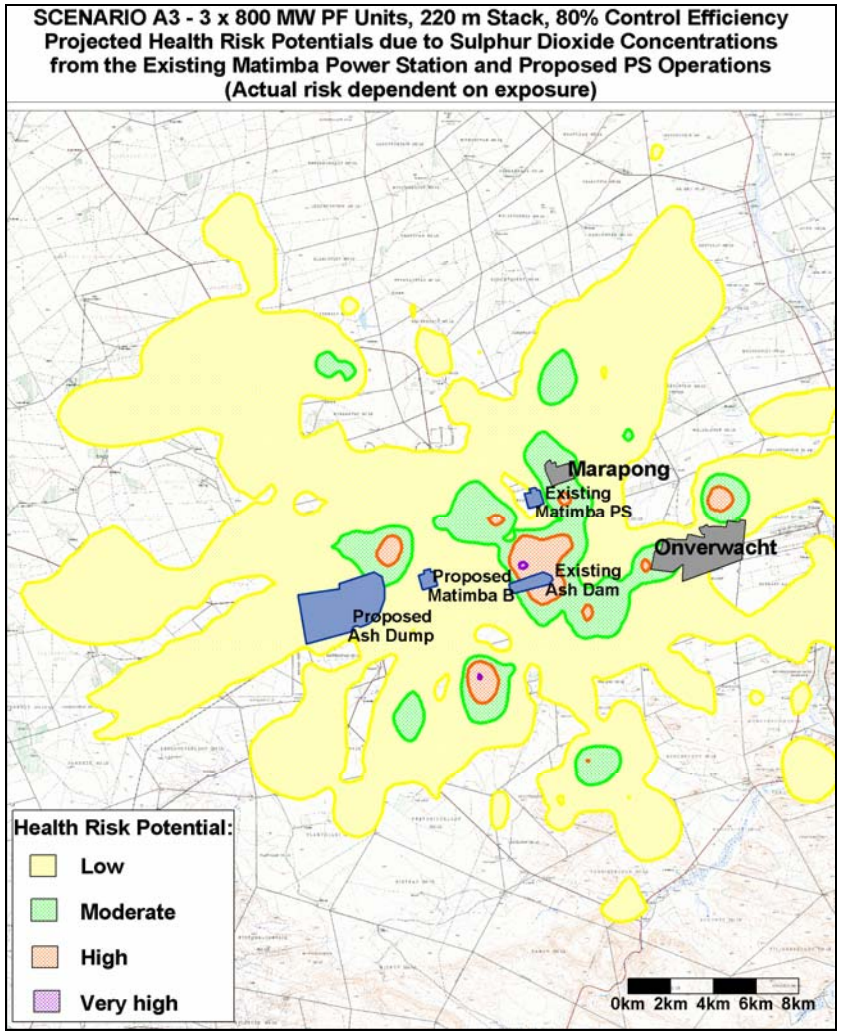

Figure 9.43 Projected health risk potential zones for Scenario A3 Operations(i.e. 3 x 800 MW PF units, 220 m stack, 80% CE)

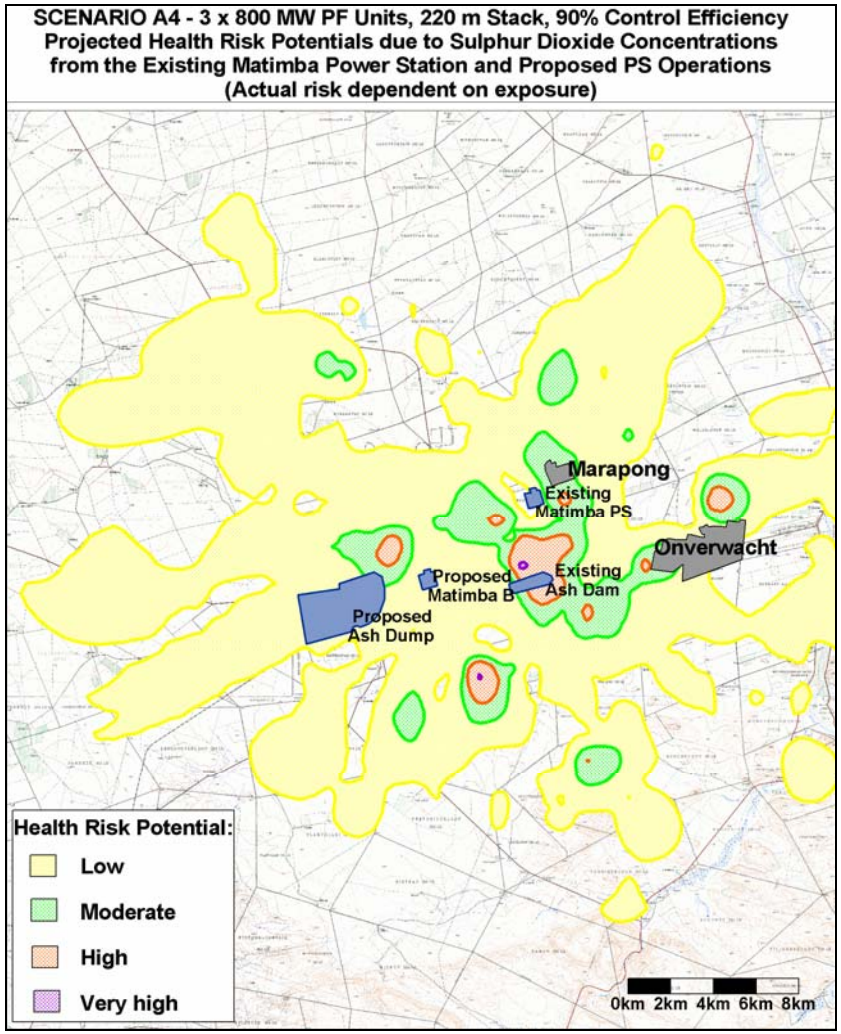

Figure 9.44 Projected health risk potential zones for Scenario A4 Operations(i.e. 3 x 800 MW PF units, 220 m stack, 90% CE)

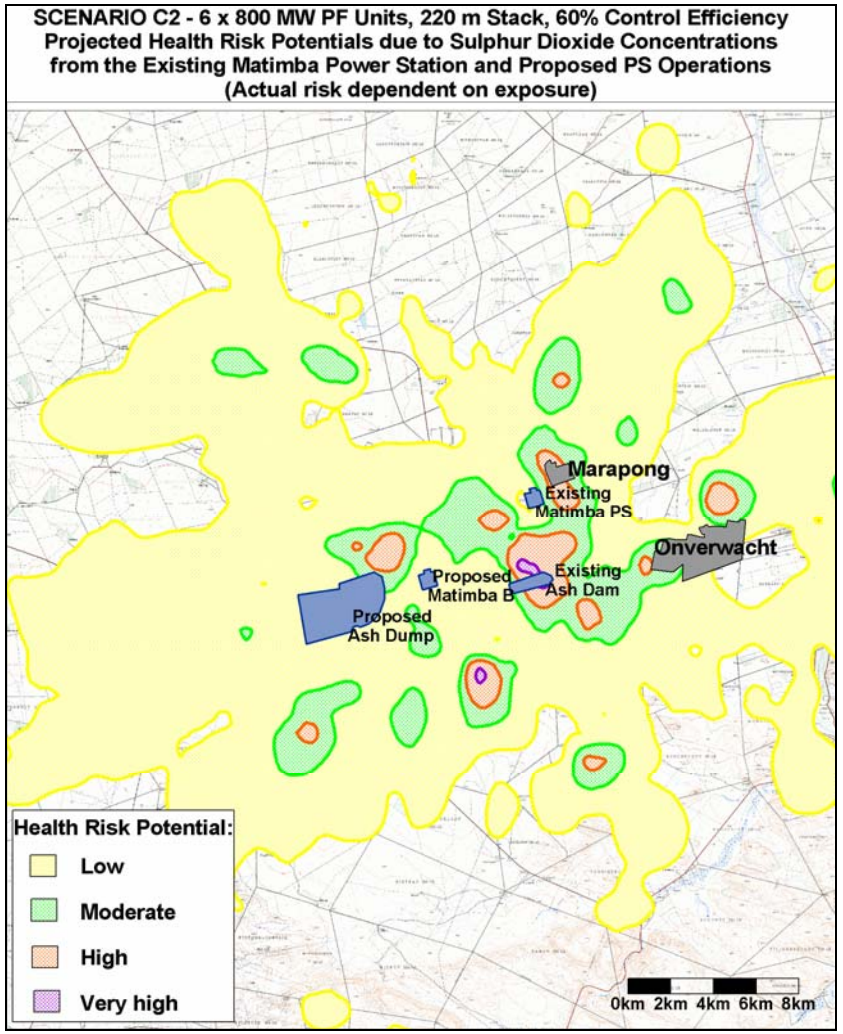

Figure 9.45 Projected health risk potential zones for Scenario C2 Operations(i.e. 6 x 800 MW PF units, 220 m stack, 60% CE)

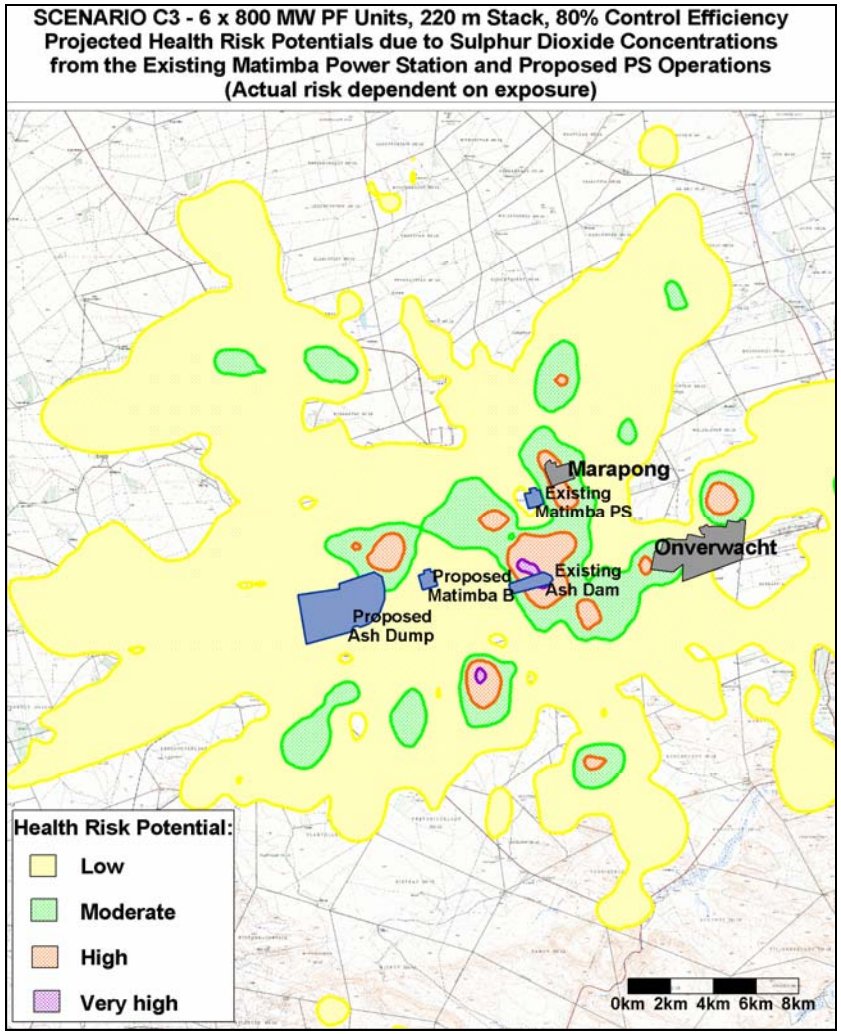

Figure 9.46 Projected health risk potential zones for Scenario C3 Operations(i.e. 6 x 800 MW PF units, 220 m stack, 80% CE)

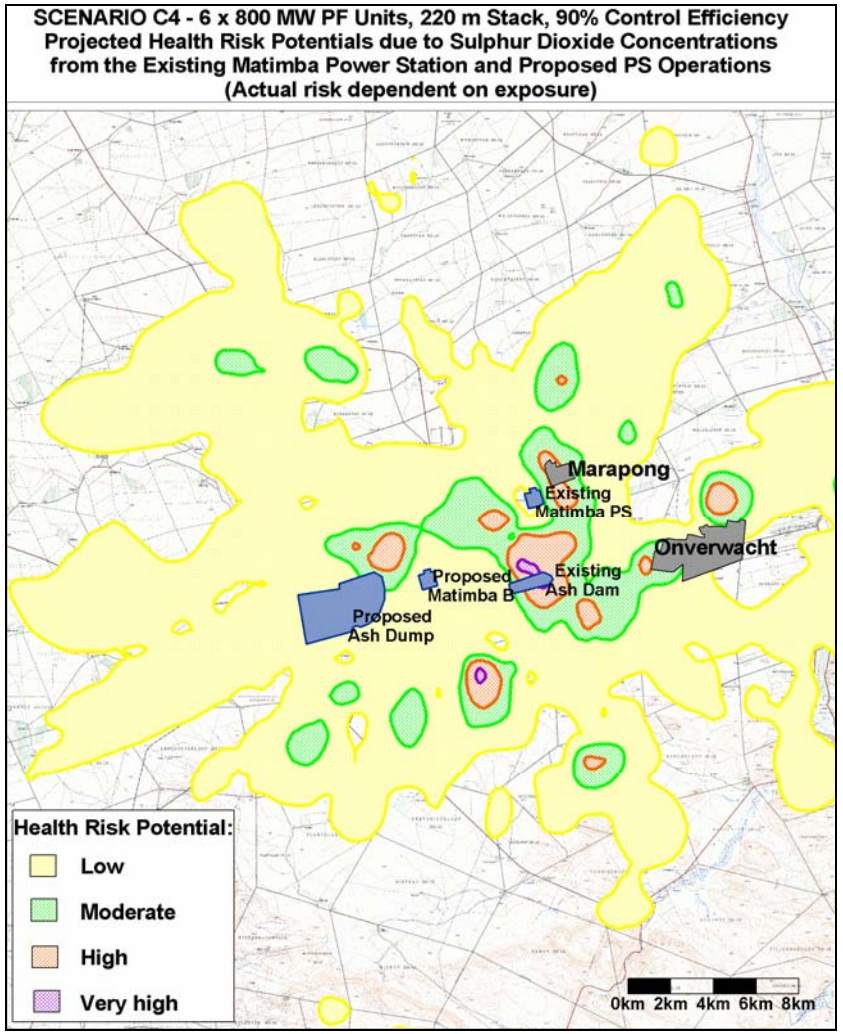

Figure 9.47 Projected health risk potential zones for Scenario C4 Operations(i.e. 6 x 800 MW PF units, 220 m stack, 90% CE)

Table 9.47: Synopsis of health risk categories assigned on the basis of projected sulphur dioxide concentrations arising due to various control and uncontrolled emission scenarios

Emission Scenarios(a)	Health Risk Categories basis of projected sulphur dioxide concentrations (µg/m³)	
	Marapong	**Onverwacht**
Existing Matima Power Station (Base case)	moderate	low
Scenario A1 – 3 x 800 MW PF Units, 220 m stack - 0% CE	moderate - high	low - moderate
Scenario B1 – 3 x 800 MW PF Units, 250 m stack - 0% CE	moderate - high	low - moderate
Scenario C1 – 6 x 800 MW PF Units, 220 m stack - 0% CE	high	moderate - high
Scenario D1 – 6 x 800 MW PF Units, 250 m stack - 0% CE	high	moderate - high
Scenario E1 – 6 x 800 MW PF/FBC Units, 220 m stack – 0% CE	high	moderate - high
Scenario F1 – 6 x 800 MW PF/FBC Units, 250 m stack – 0% CE	high	moderate - high
Scenario A2 – 3 x 800 MW PF Units, 220 m stack - 60% CE	moderate - high	low - moderate
Scenario A3 – 3 x 800 MW PF Units, 220 m stack - 80% CE	moderate	low
Scenario A4 – 3 x 800 MW PF Units, 220 m stack - 90% CE	moderate	low
Scenario C2 – 6 x 800 MW PF Units, 220 m stack - 60% CE	moderate - high	low-moderate
Scenario C3 – 6 x 800 MW PF Units, 220 m stack - 80% CE	moderate - high	low-moderate
Scenario C4 – 6 x 800 MW PF Units, 220 m stack - 90% CE	moderate - high	low-moderate

(a) All proposed power station configurations simulated together with the existing Matimba Power Station to determine potential for cumulative sulphur dioxide concentrations.

Sulphur dioxide concentrations occurring due to existing Matimba Power Station emissions are predicted to be associated with "low" and "moderate" health risks within the Marapong and Onverwacht residential areas respectively. The California EPA Acute Reference Exposure Level for sulphur dioxide (above which mild respiratory effects may occur) is predicted to be exceeded ~4 times per year in the vicinity of Marapong. Cumulative sulphur dioxide concentrations given the operation of an additional three 800 MW units at the site proposed is projected to increase this frequency to 7-8 times per year. The frequency of exceedance of this health threshold would be ~14

times/year given the operation of a six 800 MW units in addition to the existing Matimba Power Station's operations. The implementation of sulphur dioxide abatement measures comprising a 60% or greater control efficiency for a 2400 MWe station, or 80% plus for a 4800 MWe station would not increase the frequency of exceedance of this health threshold above baseline levels.

Significant increments in health risk potentials associated with the proposed power station may therefore be avoided by ensuring a >60% reduction in sulphur dioxide emissions should only three 800 MW be installed. In the event that six units were to be installed - regardless of whether or not these units are to be phased in or not – a control efficiency in excess of 80% would be required for all six units to prevent increments in health risk potentials above baseline conditions.

Important points of note:

- The assumption is made that no residential settlements will be developed within the main impact areas of the power station(s) during their operational phases. Should this not be the case the exposure potential, and hence the health risk potential, would need to be reassessed. (The health risk potential plots presented could aid decision making regarding the siting of residential settlements.)
- It is proposed that a contractor camp, comprising ~2000 residents, be established and occupied during the construction and commissioning phases of the power station. The impact of existing and proposed power station emissions on such residents was not included in the current study due to the location of this camp not having been decided during the period of study.

- *Results for Heavy Metals*
  Cancer risks associated with inhalation exposures to predicted lead, arsenic and nickel were calculated based on predicted maximum annual average concentrations occurring due to existing Matimba Power Station operations in addition to a proposed 4800 MWe power station. Given the range of unit risk factors published by the California OEHHA, the WHO and the US-EPA it was decided to calculate cancer risks based on the maximum and minimum unit risk factors available (Table 9.48). Cancer risks were calculated to be very low, with total incremental cancer risks across all carcinogens quantified to be in the range of 1: 10.6 million to 1: 24.8 million.

Table 9.48 Cancer risks calculated due to inhalation exposures to individual carcinogens predicted to be emitted from the existing and proposed (4800 MWe) Matimba Power Stations (stack and ash dam)

Carcinogens / Suspected Carcinogens	US-EPA IRIS Classification	Calculated Cancer Risk (expressed as a 1: xxx chance of contracting cancer)	
		Based on Lowest Risk Factor (least conservative)	Based on Highest Unit Risk Factor (most conservative)
Arsenic	A	41,765,481	14,569,354
Nickel	A	63,644,047	40,196,240
Lead	B2	1,446,465,793	1,446,465,793
Total incremental cancer risk across all carcinogens quantified		24,785,023	10,614,977

Maximum hourly, daily, monthly and annual average heavy metal concentrations occurring due to existing and projected power station fly ash emissions and fugitive emissions from the existing and planned ash dams. These predicted ambient metal concentrations were compared to relevant health thresholds in order to determine the potential for health impacts. Such health thresholds and the predicted concentrations as a fraction of such thresholds are given in Table 9.49. Fractions of greater than 1 indicate an exceedance of the threshold. No inhalation-related, non-carcinogenic health thresholds were predicted to be exceeded.

Annual average arsenic and nickel concentrations were also predicted to be well within the recently promulgated EC limits given as 0.006 µg/m³ and 0.02 µg/m³ respectively.

Table 9.49 Predicted ambient trace metal concentrations (in the PM10 range) due to existing and proposed Matimba Power Station emissions, with concentrations given as a fraction of the relevant health thresholds. Fractions of > 1 indicate threshold exceedances.

Compound	Predicted Ambient Air Concentrations (µg/m³)				Relevant Health Thresholds (µg/m³)				Predicted Concentrations as a Fraction of the Relevant Health Threshold			
	Highest Hourly	Highest Daily	Highest Monthly	Annual Average	Acute Health Threshold	Sub-acute Health Threshold	Intermediate (Sub-chronic) Health Threshold	Chronic Health Threshold	Highest Hourly Concentration as a Fraction of the Acute Threshold	Highest Daily Concentration as a Fraction of the Sub-acute Threshold	Highest Monthly Concentration as a Fraction of the Sub-chronic Threshold	Annual Average Concentration as a Fraction of the Chronic Threshold
As	1.38E-03	8.97E-05	1.69E-05	8.24E-06	0.19			0.03	0.73			0.03
Ba	1.23E-01	7.31E-03	7.41E-04	3.61E-04	50			5	0.25			0.01
Bi	6.43E-04	3.78E-05	3.28E-06	1.58E-06								
Co	2.57E-03	1.53E-04	1.49E-05	7.25E-06				0.1				0.01
Cr	5.32E-02	3.08E-03	2.26E-04	1.07E-04			1	0.1			0.02	0.11
Cu	3.57E-03	2.15E-04	2.40E-05	1.17E-05	100			1	0.00			0.00
Ga	2.96E-03	1.81E-04	2.32E-05	1.13E-05								
Ge	4.32E-04	2.80E-05	5.22E-06	2.55E-06								
Pb	7.80E-03	4.77E-04	6.08E-05	2.98E-05				0.5				0.01
Hg	9.20E-06	6.24E-07	1.42E-07	6.96E-08	1.8			0.09	0.00			0.00
Ni	1.62E-02	9.43E-04	7.05E-05	3.38E-05	6		0.2	0.05	0.27		0.04	0.07
Nb	1.10E-03	6.51E-05	6.18E-06	3.00E-06								
Rb	7.44E-03	4.41E-04	4.17E-05	2.02E-05								

Compound	Predicted Ambient Air Concentrations (µg/m³)				Relevant Health Thresholds (µg/m³)				Predicted Concentrations as a Fraction of the Relevant Health Threshold			
	Highest Hourly	Highest Daily	Highest Monthly	Annual Average	Acute Health Threshold	Sub-acute Health Threshold	Intermediate (Sub-chronic) Health Threshold	Chronic Health Threshold	Highest Hourly Concentration as a Fraction of the Acute Threshold	Highest Daily Concentration as a Fraction of the Sub-acute Threshold	Highest Monthly Concentration as a Fraction of the Sub-chronic Threshold	Annual Average Concentration as a Fraction of the Chronic Threshold
Se	5.25E-02	3.19E-03	3.86E-04	1.89E-04				20				0.00
Th	6.55E-03	3.93E-04	4.27E-05	2.09E-05								
Sn	1.26E-03	7.24E-05	4.78E-06	2.05E-06	20			2	0.01			0.00
W	1.58E-03	9.51E-05	1.06E-05	5.18E-06	10			1	0.02			0.00
U	2.06E-03	1.20E-04	9.30E-06	4.47E-06			0.4	0.3			0.00	0.00
V	1.55E-02	9.29E-04	1.00E-04	4.89E-05		0.2				0.46		
Y	7.01E-03	4.15E-04	3.93E-05	1.91E-05								
Zn	3.06E-02	1.74E-03	1.07E-04	4.20E-05	50			5	0.06			0.00
Zr	2.84E-02	1.69E-03	1.65E-04	8.01E-05	50			5	0.06			0.00

9.6.4. Potential for Vegetation Injury and Corrosion

Based on the dose-response thresholds the exposure of vegetation and ecosystems to ambient sulphur dioxide concentrations outlined previously and the ambient air quality limits issued by the EC and WHO for protection of ecosystems, the potential for vegetation injury was characterised as follows:

Category of Risk for Vegetation Injury(a)	Maximum Hourly Average SO_2 Concentration (µg/m³) (99th percentile)		Maximum Annual Average SO_2 Concentration (µg/m³)	Basis
Low	< 1 300 µg/m³	AND	< 20 µg/m³	EC annual SO_2 limit given as 20 µg/m³ for the protection of ecosystems WHO guideline for annual SO_2 given as in range of 10 – 30 µg/m³ depending on sensitivity of receiving environment Hourly average of 1300 µg/m³ given as being associated with visible effects on the leaves of sensitive plant species (~5% of leaf area affected)
Moderate	> 1 300 µg/m³	OR	20 – 30 µg/m³	
High	> 1 300 µg/m³	AND	> 30 µg/m³	

(a) Assumption of availability of vegetation at all sites – comprises a conservative assumption in certain instances, e.g. where mining activity prevails.

The methodological approach outlined in Section 9.2 was applied in the assessment or the potential for corrosion given exposures to ambient sulphur dioxide concentrations arising due emissions from existing operations and from proposed power station operations. Corrosion was categorised as follows:

Corrosion Potential	Maximum Annual Average SO_2 Concentration (µg/m³)
Low	< 20 µg/m³
Medium	20 – 657 µg/m³
High	> 657 µg/m³

In order to facilitate the tabulation of data for easy reference, the centrepoints of neighbouring farms were simulated as discrete receptors with air pollutant concentrations being predicted for each of these points. A synopsis of vegetation injury and corrosion potential characterisation for each farm (based on predictions for its centre point) is given in Tables 9.50 and 9.51 respectively. More detailed information is provided in Appendix E.

Table 9.50 Potential for vegetation damage due to SO_2 concentrations from existing and proposed power station operations

Receptor Category	Receptor Name	Existing Matimba	Proposed Power Station Configurations - Uncontrolled						Proposed Power Station Configurations - Controlled					
			A1	B1	C1	D1	E1	F1	A2 (60% CE)	A3 (80% CE)	A4 (90% CE)	C2 (60% CE)	C3 (80% CE)	C4 (90% CE)
Maximum	Maximum Impact Zone	Low	moderate	moderate	high	high	high	high	moderate	low	low	moderate	moderate	moderate
Residential areas	Marapong	low	low	low	low	low	low	low	low	low	low	low	low	low
	Onverwacht (maximum)	low	low	low	low	low	low	low	low	low	low	low	low	low
	Onverwacht (central)	low	low	low	low	low	low	low	low	low	low	low	low	low
Farms (centre point)	Eendracht	low	low	low	low	low	low	low	low	low	low	low	low	low
	Altoostyd	low	low	low	moderate	low	moderate	low	low	low	low	low	low	low
	Worcester	low	low	low	low	low	low	low	low	low	low	low	low	low
	Paarl	low	low	low	low	low	low	low	low	low	low	low	low	low
	Turfvlakte	low	low	low	low	low	low	low	low	low	low	low	low	low
	Hieromtrent	low	low	low	moderate	moderate	moderate	moderate	low	low	low	low	low	low
	Leeuwdrift	low	low	low	low	low	low	low	low	low	low	low	low	low
	Hanglip	low	low	low	low	low	low	low	low	low	low	low	low	low
	Wellington	low	low	low	low	low	low	low	low	low	low	low	low	low
	Kromdraai	low	low	low	low	low	low	low	low	low	low	low	low	low
	Kuipersbult	low	moderate	moderate	moderate	moderate	moderate	moderate	low	low	low	low	low	low
	Grootvallei	low	low	low	moderate	low	moderate	low	low	low	low	low	low	low
	Nooitgedacht	low	low	low	moderate	low	moderate	low	low	low	low	low	low	low
	Peerboom	low	low	low	low	low	low	low	low	low	low	low	low	low
	Nelsonskop	low	low	low	low	low	low	low	low	low	low	low	low	low
	Appelvlakte	low	low	low	low	low	low	low	low	low	low	low	low	low
	Zongezien	low	low	low	low	low	low	low	low	low	low	low	low	low
	Droogeheuvel	low	low	low	low	low	low	low	low	low	low	low	low	low
	Vooruit	low	low	low	low	low	low	low	low	low	low	low	low	low
	Ganzepan	low	low	low	low	low	low	low	low	low	low	low	low	low
	Goedehoop (mine, dump)	low	low	low	low	low	low	low	low	low	low	low	low	low
	Enkelbult (mine, pit)	low	low	low	low	low	low	low	low	low	low	low	low	low

	Grootgeluk (mine, pit)	low	low	low	moderate	low	moderate	low	low	low	low	low	low	low
	Vaalpensloop	low	low	low	low	low	low	low	low	low	low	low	low	low
	McCabesvley	low	low	low	low	low	low	low	low	low	low	low	low	low
	Graaffwater	low	low	low	low	low	low	low	low	low	low	low	low	low
	Verguldehelm	low	low	low	moderate	moderate	moderate	moderate	low	low	low	low	low	low
	Daarby (mine, dump)	low	low	low	low	low	low	low	low	low	low	low	low	low

Table 9.51 Potential for corrosion due to sulphur dioxide concentrations from existing and proposed power station operations

Receptor Category	Receptor Name	Existing Matimba	Proposed Power Station Configurations - Uncontrolled						Proposed Power Station Configurations - Controlled					
			A1	B1	C1	D1	E1	F1	A2 (60% CE)	A3 (80% CE)	A4 (90% CE)	C2 (60% CE)	C3 (80% CE)	C4 (90% CE)
Maximum	Maximum Impact Zone	low	medium	medium	medium	medium	medium	medium	medium	low	low	medium	medium	medium
Residential areas	Marapong	low	low	low	low	low	low	low	low	low	low	low	low	low
	Onverwacht (maximum)	low	low	low	low	low	low	low	low	low	low	low	low	low
	Onverwacht (central)	low	low	low	low	low	low	low	low	low	low	low	low	low
Farms (centre point)	Eendracht	low	low	low	low	low	low	low	low	low	low	low	low	low
	Altoostyd	low	low	low	low	low	low	low	low	low	low	low	low	low
	Worcester	low	low	low	low	low	low	low	low	low	low	low	low	low
	Paarl	low	low	low	low	low	low	low	low	low	low	low	low	low
	Turfvlakte	low	low	low	low	low	low	low	low	low	low	low	low	low
	Hieromtrent	low	low	low	medium	medium	medium	medium	low	low	low	low	low	low
	Leeuwdrift	low	low	low	low	low	low	low	low	low	low	low	low	low
	Hanglip	low	low	low	low	low	low	low	low	low	low	low	low	low
	Wellington	low	low	low	low	low	low	low	low	low	low	low	low	low
	Kromdraai	low	low	low	low	low	low	low	low	low	low	low	low	low
	Kuipersbult	low	medium	medium	medium	medium	medium	medium	low	low	low	low	low	low
	Grootvallei	low	low	low	medium	low	medium	low	low	low	low	low	low	low
	Nooitgedacht	low	low	low	medium	low	medium	low	low	low	low	low	low	low
	Peerboom	low	low	low	low	low	low	low	low	low	low	low	low	low
	Nelsonskop	low	low	low	low	low	low	low	low	low	low	low	low	low

	Appelvlakte	low	low	low	low	low	low	low	low	low	low	low	low	low
	Zongezien	low	low	low	low	low	low	low	low	low	low	low	low	low
	Droogeheuvel	low	low	low	low	low	low	low	low	low	low	low	low	low
	Vooruit	low	low	low	low	low	low	low	low	low	low	low	low	low
	Ganzepan	low	low	low	low	low	low	low	low	low	low	low	low	low
	Goedehoop (mine, dump)	low	low	low	low	low	low	low	low	low	low	low	low	low
	Enkelbult (mine, pit)	low	low	low	low	low	low	low	low	low	low	low	low	low
	Grootgeluk (mine, pit)	low	low	low	low	low	low	low	low	low	low	low	low	low
	Vaalpensloop	low	low	low	low	low	low	low	low	low	low	low	low	low
	McCabesvley	low	low	low	low	low	low	low	low	low	low	low	low	low
	Graaffwater	low	low	low	low	low	low	low	low	low	low	low	low	low
	Verguldehelm	low	low	low	medium	medium	medium	medium	low	low	low	low	low	low
	Daarby (mine, dump)	low	low	low	low	low	low	low	low	low	low	low	low	low

The potential for vegetation damage and corrosion due to current monitored and predicted ambient sulphur dioxide concentrations is classifiable as "low". The operation of a 2400 MWe power station at the proposed site is predicted to result in "moderate" risks for vegetation damage and "medium" risks for corrosion at Kuipersbult farm and parts of Hanglip and Kromdraai should no sulphur dioxide abatement measures be implemented (Figure 9.48). Sulphur dioxide abatement with a 60% control efficiency would result in the potential for corrosion and vegetation damages for these farms being classified as "low" (Figure 9.49).

The operation of a 4800 MWe power station without SO_2 abatement in place is predicted to result in "high" corrosion and vegetation potentials within the 'zone of maximum impact' and "medium" corrosion and "moderate" vegetation damage potentials for the farms of Altoostyd, Hieromtrent, Kuipersbult, Grootvallei, Nooitegedacht and Verguldehelm (Figure 9.50). The 'maximum impact zone' refers to the area where the plume "loops" to ground level as a result of enhanced atmospheric convective mixing. By increasing the stack height from 220 m to 250 m, the corrosion and vegetation damage potentials for Altoostyd, Grootvallei and Nooitgedacht would be reduced to "low". Sulphur dioxide abatement with a 60% control efficiency would result in the potential for corrosion and vegetation damages being primarily classified as "low" (Figure 9.51).

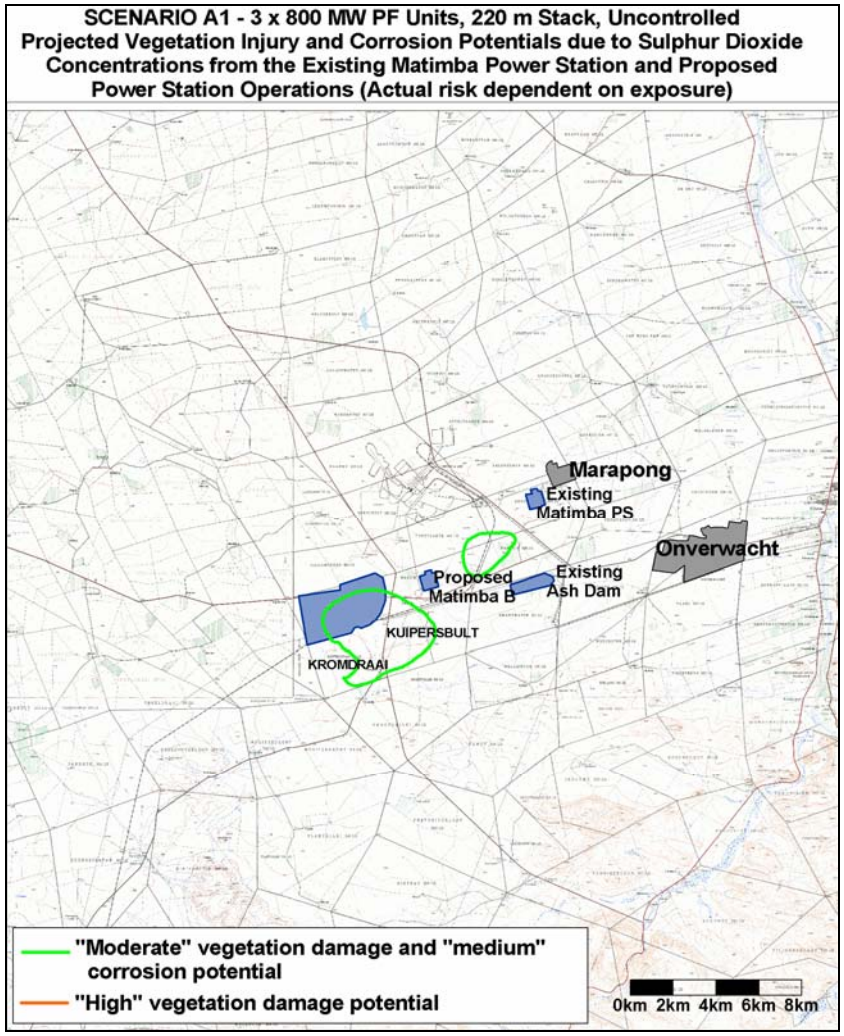

Figure 9.48 Projected vegetation damage and corrosion potential zones for Scenario A1 Operations (i.e. 3 x 800 MW PF units, 220 m stack, uncontrolled)

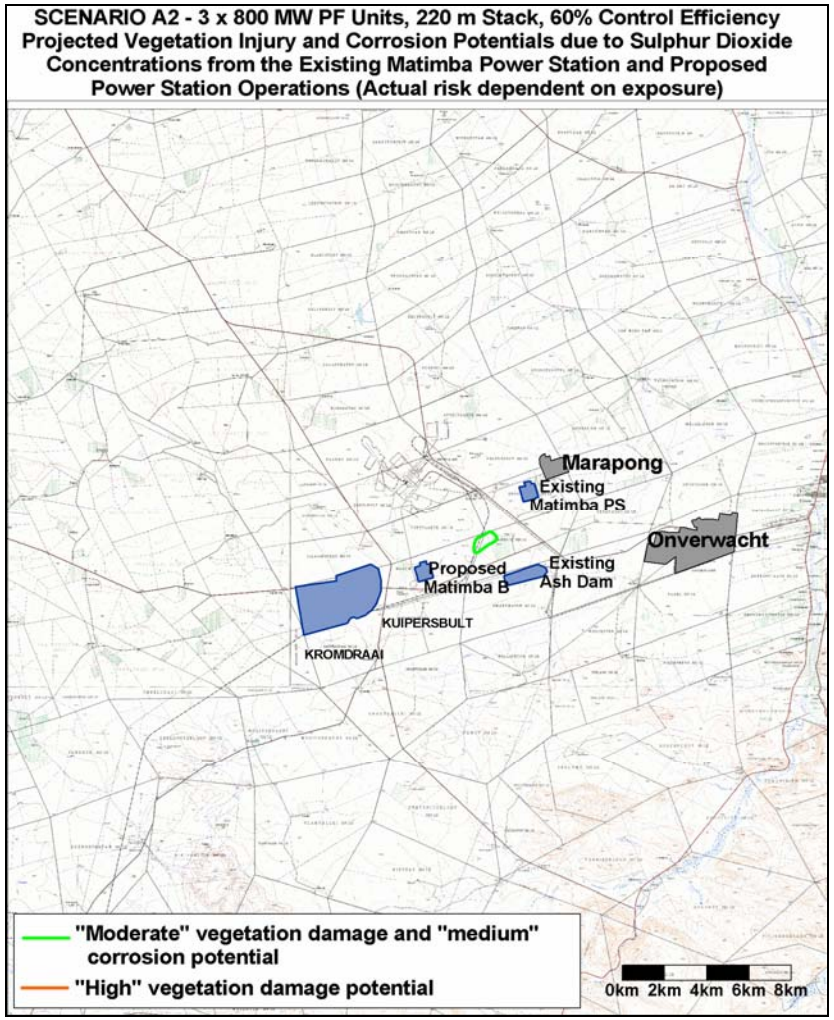

Figure 9.49 Projected vegetation damage and corrosion potential zones for Scenario A2 Operations(i.e. 3 x 800 MW PF units, 220 m stack, 60% control efficiency)

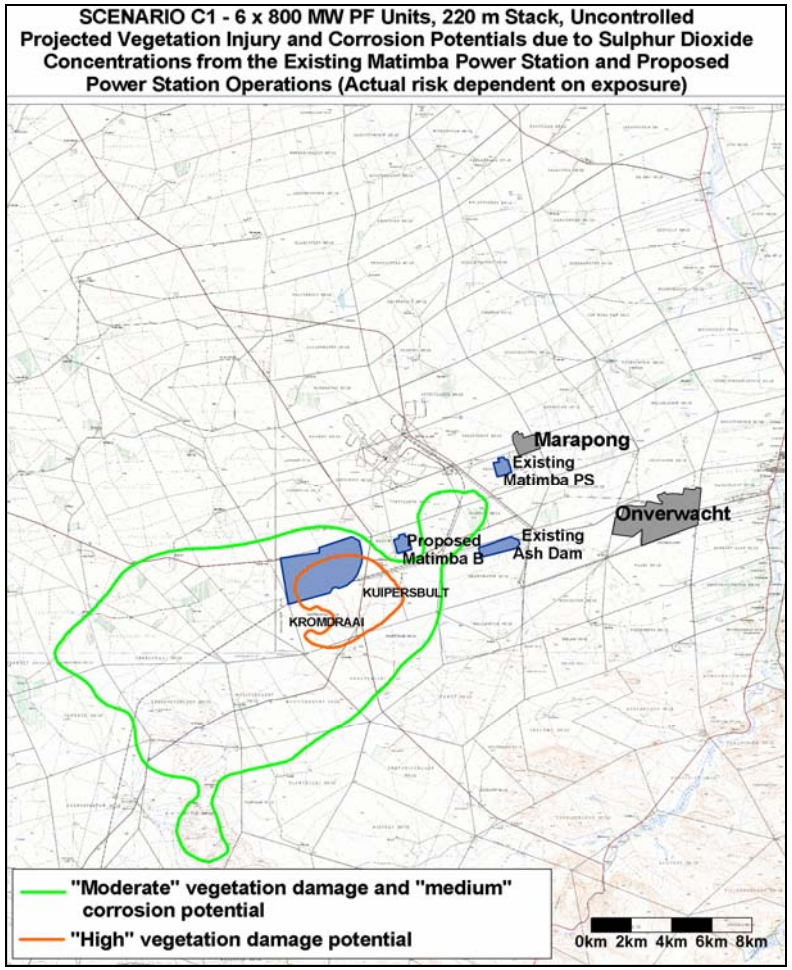

Figure 9.50 Projected vegetation damage and corrosion potential zones for Scenario C1 Operations (i.e. 6 x 800 MW PF units, 220 m stack, uncontrolled)

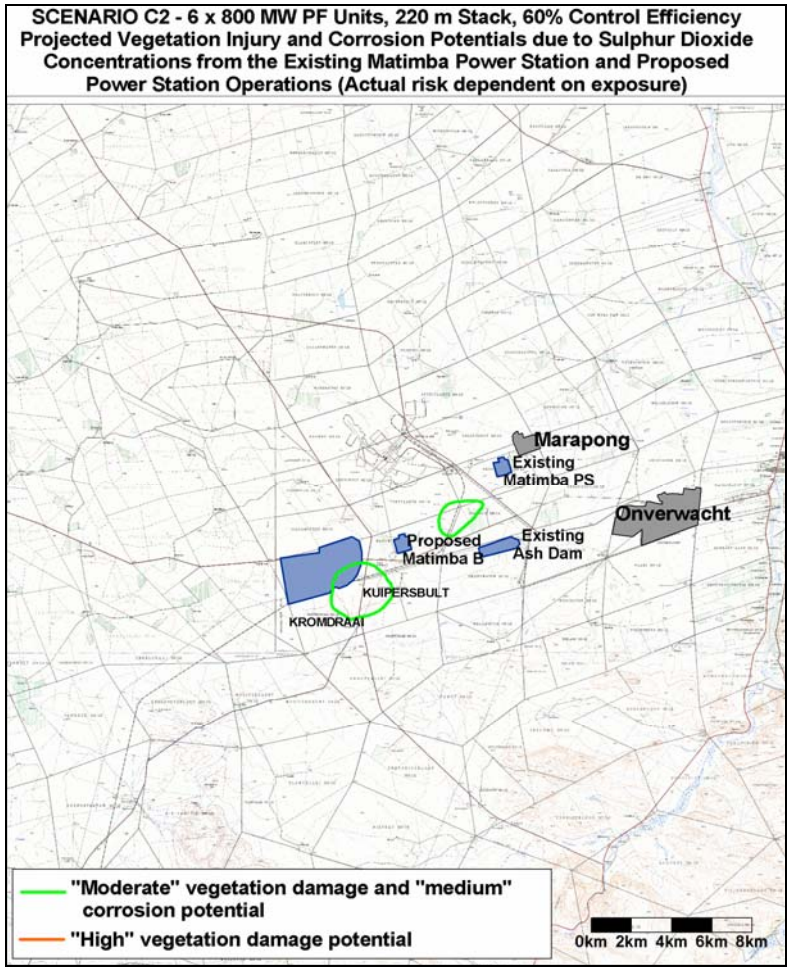

Figure 9.51 Projected vegetation damage and corrosion potential zones for Scenario C2 Operations (i.e. 6 x 800 MW PF units, 220 m stack, 60% control efficiency)

9.5.6. Contribution to Greenhouse Gas Emissions

In order to facilitate the estimation of contribution of the proposed power station to global warming potentials, nitrous oxide (N_2O) and carbon dioxide (CO_2) emissions were estimated with nitrous oxide releases being calculated as CO_2 equivalent emissions[4] (Table 9.52). Total greenhouse gas emissions reported to be emitted within South Africa for the year 1994, expressed as CO_2 equivalents, are given in Table 9.53. No more recent data are available.

Table 9.52 Calculated CO_2 equivalent emissions from proposed power station operations

Power Station Capacity	Coal Consumption (tpa)	Annual Emissions		Annual Emissions
		CO_2	N_2O	CO_2 Equivalent
		kT/ann	kT/ann	kT/ann
4800 MWe	17,117,436	29,895	0.342	30,001
2400 MWe	8,558,718	14,948	0.171	15,001

Table 9.53 Emissions of CO_2, CH_4 and N_2O in South Africa in 1990 and 1994

Greenhouse Gas Source	Gg CO_2 Equivalent							
	CO_2		CH_4		N_2O		Aggregated	
	1990	1994	1990	1994	1990	1994	1990	1994
Energy	252 019	287 851	7 286	7 890	1 581	1 823	260 886	297 564
Industrial Processes	28 913	28 106	69	26	1 810	2 254	30 792	30 386
Agriculture			21 304	19 686	19 170	15 776	40 474	35 462
Waste			14 456	15 605	738	825	15 194	16 430
						Total	347 346	379 842

Source: South African: Initial National Communication under the United Nations Framework Convention on Climate Change, November 2003.

The emissions from the proposed 4800 MWe power station would increase the energy sectors emissions by 9.2% and would increase the country's contribution to global warming by 7.3%

[4] Nitrous oxide emissions are converted to carbon dioxide equivalents using global warming potentials (GWPs). GWPs are conversion factors that are used to express the relative warming effects of the various greenhouse gases in terms of their carbon dioxide equivalents. The values for a 100 year timeframe have been used, which are equivalent to 310 for nitrous oxide as are recommended by the IPCC (South Africa Initial National Communication under the United National Framework Convention on Climate Change, November 2003).

9.6.6. Significance Rating of Proposed Power Station Configurations

The significance of impacts associated with atmospheric emissions from the proposed power station options were rated based on the methodology provided by Bohlweki Environmental. This method makes provision for the assessment of impacts based on their temporal and spatial scales, severity and likelihood, in addition to the degree of confidence placed in the assessment of the impact. Results from the significance rating are provided in Table 9.54.

Table 9.54: Significance rating of proposed power station options, including and excluding mitigation, based on significance rating criteria provided by Bohlweki Environmental

Power Station Configuration	Impact	Temporal Scale	Spatial Scale	Severity	Significance	Risk Likelihood	Degree of Confidence
2400 MWe PF PS, no SO_2 abatement	Health risk	Long term	Localised	Moderately severe	Moderate	May occur	Probable
	Vegetation damage	Long term	Localised	Slight	Low	Unlikely to occur	Possible
	Corrosion	Long term	Localised	Slight	Low	Unlikely to occur	Possible
	Global warming	Permanent	International	Uncertain	Uncertain	Uncertain	Unsure
4800 MWe PF or PF/FBC PS, no SO_2 abatement	Health risk	Long term	Localised	Sever	Moderate to High	Likely to occur	Probable
	Vegetation damage	Long term	Localised	Slight	Low to Moderate	May occur	Possible
	Corrosion	Long term	Localised	Slight	Low to Moderate	May occur	Possible
	Global warming	Permanent	International	Uncertain	Uncertain	Uncertain	Unsure
2400 MWe PF PS, SO_2 abatement in place	Health risk	Long term	Localised	Slight	Low	May occur	Probable
	Vegetation damage	Long term	Localised	Slight	Low	Unlikely to occur	Possible

(>60% CE)	Corrosion	Long term	Localised	Slight	Low	Unlikely to occur	Possible
	Global warming	Permanent	International	Uncertain	Uncertain	Uncertain	Unsure
4800 MWe PF or PF/FBC PS, SO_2 abatement in place (>90% CE)	Health risk	Long term	Localised	Slight to moderate	Moderate	May occur	Probable
	Vegetation damage	Long term	Localised	Slight	Low	May occur	Possible
	Corrosion	Long term	Localised	Slight	Low	May occur	Possible
	Global warming	Permanent	International	Uncertain	Uncertain	Uncertain	Unsure

9.7. Recommendations And Conclusions

9.7.1. 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:

- **Sulphur dioxide** concentrations have been measured to infrequently exceed short-term air quality limits at several of the monitoring stations (Zwartwater, Grootstryd, Waterberg, M2, M3 and M5) within infrequent exceedance of such limits modelled to occur at the nearby residential areas of Marapong and Onverwacht.

  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. This has being confirmed through atmospheric dispersion modelling of the power station's stack emissions. Other sources which may contribute significantly due to their low release level include: spontaneous combustion of coal discards associated with Grootgeluk mining operations, clamp firing emissions during brickmaking at Hanglip and potentially household fuel burning within Marapong. The highest ground level concentrations due to the Matimba Power Station stack emissions are expected to occur during unstable conditions when the plume is brought to ground in relatively close proximity to the power station.

  The comparison of measured and predicted sulphur dioxide concentrations to thresholds indicative of the potential for health, corrosion and vegetation impacts resulted in the following observations:

  - The health threshold given as being associated with mild respiratory effects (660 µg/m³ as an hourly threshold for SO_2) was measured to be exceeded at Zwartwater and at the M3 and M5 monitoring sites. This threshold was predicted to be exceeded a maximum of 3 to 4 hours at Marapong.
  - Measured and predicted sulphur dioxide concentrations were within limits indicative of low corrosion potentials. This is substantiated by the corrosivity monitoring documented by Northcott (2004).
  - Measured and predicted sulphur dioxide concentrations were within the EC annual sulphur dioxide limit of 20 µg/m³ which aims to protect ecosystems. The WHO guideline to protect ecosystems is given as a range of 10 to 30 µg/m³, depending on ecosystem sensitivity. The lower end of the WHO guideline range (viz. 10

µg/m³ intended for protection of highly sensitive vegetation types) was predicted and measured to be exceeded only on the southwestern side of the Matimba Power Station to a maximum distance of ~10 km (i.e. covering Turfvlakte, Hanglip, Zwartwater, Naauwontkomen and Kuipersbult farms). Given the nature of the vegetation on these farms it is unlikely that injury to the annual averages measured/predicted is likely to occur.

- Although the Matimba Power Station contributes to ambient **nitrogen oxide** and nitrogen dioxide concentrations in the region, local and international air quality limit exceedances are not predicted, nor measured, to occur. Other low level sources of NO_x anticipated to occur in the region include combustion within coal discard dumps, brick firing operations and possibly also household fuel burning and infrequent veld burning.

- Although ambient **PM10** concentrations were measured to be within the current lenient SA Standards (as given in the second schedule of the Air Quality Act), exceedances of the more stringent SANS and EC limit values were observed to occur. (The highest PM10 concentrations recorded to date were measured on-site within the Grootgeluk Mine. Due however to these being on-site measurements, the should not be evaluated based on ambient air quality limits which are intended for use beyond the fenceline of industrial and mining operations.)

  The contribution of Matimba Power Station to primary and secondary particulates was simulated, with the SANS and EC limits only predicted to be exceeded immediately downwind of Zwartwater ash dump operations. (Secondary particulates form in the atmosphere through the conversion of SO_x and NO_x emissions to sulphate and nitrate.)

  Various local and far-field 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 large-scale biomass burning in countries to the north of 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).

- Based on the screening of the potential for health risks occurring due to inhalation exposures to trace metals released from existing Matimba Power

Station it was concluded that predicted concentrations were within acute and chronic health thresholds and that total incremental cancer risks were very low. This is due to the high control efficiency of fly ash abatement systems in place on stacks and the dust abatement measures being implemented at the ash dam. The study was however restricted to the trace metals included in the fly ash and bottom ash composition studies (e.g. excluded metals like cadmium, beryllium and others which are likely to occur). Furthermore, the gaseous trace metals released could not be quantified. Given the volatility of the various trace elements, and the ratio between the trace metal composition of the coal and the composition of the fly and coarse ash, mercury is expected to occur primarily in the gaseous phase **(subsequent to the compilation of the draft Air Quality Assessment further work has been conducted in order to more accurately assess the potential for mercury emissions and associated impacts with reference being made to the mercury content of the coal and emission factors published internationally for power generation. These findings are summarised and attached as Appendix AF)**.

Given the elevated levels of sulphur dioxide and fine particulate concentrations measured/predicted to occur within parts of the study region it is imperative that the potential for cumulative concentrations due to any proposed developments be minimized and carefully evaluated.

9.7.2. Compliance and Air Quality Impact Assessment for Proposed Power Station

Atmospheric emissions released during the construction phase are primarily restricted to fugitive dust from land clearing and site development operations. Such emissions can be significantly reduced, and their impact rendered negligible, through the selection and implementation of effective dust mitigation measures.

Sources of emission associated with the operational stage include particulate and gaseous emissions from the power station stacks, in addition to low-level, fugitive releases from materials handling and ash disposal. Pollutants releases include particulates, sulphur dioxide, oxides of nitrogen, various trace metals, carbon dioxide and nitrous oxide. (The latter two are important due to their global warming potential.)

Stack emissions were estimated and quantified for the following power station configurations as requested by Eskom:

Scenario	No. of Units	Technology	Stack Height (m)	SO_2 Control Efficiency
A.1	3 x 800 MW	PF	220	0%
B.1	3 x 800 MW	PF	250	0%
C.1	6 x 800 MW	PF	220	0%
D.1	6 x 800 MW	PF	250	0%
E.1	3 x 800 MW 3 x 800 MW	PF FBC	220	0%
F.1	3 x 800 MW 3 x 800 MW	PF FBC	250	0%
A.2	3 x 800 MW	PF	220	60%
A.3	3 x 800 MW	PF	220	80%
A.4	3 x 800 MW	PF	220	90%
C.2	6 x 800 MW	PF	220	60%
C.3	6 x 800 MW	PF	220	80%
C.4	6 x 800 MW	PF	220	90%

- *Compliance with Ambient Air Quality Limits*
  In assessing "compliance" with air quality limits it is important to note the following:
  - Variations in where air quality limits are applicable. The EC (and UK) stipulate that air quality limits are applicable in areas where there is a reasonable expectation that public exposures will occur over the averaging period of the limit. In the US, the approach is frequently adopted of applying air quality limits within all areas to which the public has access (i.e. everywhere not fenced off or otherwise controlled for public access). In South Africa there is still considerable debate regarding the practical implementation of the air quality standards included in the schedule to the Air Quality Act. The Act does however define "ambient air" as excluding air regulated by the Occupational Health and Safety Act of 1993. This implies that air quality limits may be required to be met beyond the fencelines of industries.
  - The SA standards included in the schedule to the Air Quality Act are incomplete when compared to legal limits issued by other countries. Air quality standards typically comprise: thresholds, averaging periods, monitoring protocols, timeframes for achieving compliance and typically also permissible frequencies of exceedance. (Thresholds are generally set based on health risk criteria, with permissible frequencies and timeframes taking into account the existing air pollutant concentrations and controls required for reducing air pollution to within the defined thresholds. The practice adopted in Europe is to allow increasingly more limited permissible frequencies of exceedance, thus encouraging the progressive reduction of air pollution levels to meeting limit values.)

NOTE: Given the above uncertainties a conservative approach was adopted in assessing compliance with SA air quality standards, with single exceedances of thresholds beyond the "fenceline" of the power station being taken as constituting "non-compliance". In order however to demonstrate areas of "non-compliance" should permissible frequencies be issued at a latter date reference was made to the UK air quality limits. (The UK and SA primarily support similar short-term thresholds for sulphur dioxide. The UK however permits a number of annual exceedances of these short-term thresholds to account for meteorological extremes and to support progressive air quality improvement.)

- Nitrogen Oxides
  Predicted NO and NO_2 concentrations were predicted to be within local and international air quality limits for all proposed power station configuration scenarios (including cumulative concentrations due to existing Matimba Power Station emissions) (Appendix D).

- Airborne Fine Particulates and Dust Deposition
  Predicted PM10 concentrations were within the SA daily and annual standards but exceeded the SANS and EC limit values in the vicinity (within 4 km) of the ash dump at Zwartwater and the proposed ash dump on Eenzamheid. Farms downwind of these dams include Wellington and Grootvallei (existing Zwartwater ash dam) and Kromdraai, Veguldeheim and Nooitgedacht (proposed ash dam). Public exposure within this area is restricted to scattered farmsteads with an average residential density of ~5 persons/km².

  Maximum monthly dustfall rates were typically "moderate" (i.e. 250 - 500 mg/m²/day) immediately downwind of the Zwartwater ash dump and materials handling section of the power station, with "slight" dustfalls (i.e. < 250 mg/m²/day) occurring beyond these areas.

- Sulphur Dioxide Emissions - Uncontrolled
  Emissions from the existing Matimba Power Station are predicted to be responsible for exceedances of SA standards particularly downwind of the facility. Given this baseline it is evident that no future development resulting in sulphur dioxide emissions within the same area can be in compliance with the SA standard. It is due to this cumulative impact that all proposed power station configurations are considered to be in non-compliance with SA standards. The magnitude, frequency of occurrence and area of exceedance of air quality limits varies significantly however between configurations.

The main observations made regarding compliance implications of various power station configurations given uncontrolled emissions were as follows:

- SA short-term standards (10-minute and daily) are exceeded within the zone of maximum impact occurring to the SW of the power station(s) due to basecase and all proposed configurations. At Marapong the SA 10-minute standard is exceeded for basecase and all proposed configurations, whereas the SA daily standard is only predicted to be exceeded when an additional six 800 MW units are in operation.
- Under current Matimba PS operations there is predicted to be compliance with the UK hourly sulphur dioxide standard at Marapong. This standard is however exceeded at Marapong with the addition of three or more 800 MW units.
- Under current Matimba PS operations, the exceedance of the SA 10-minute standard is predicted to extend to include western parts of Onverwacht. Given the addition of three new units, this standard will be exceeded over the entire Onverwacht and broader Lephalale area. The exceedance zone is projected to extend beyond the modelling domain with the addition of six new units.
- The increase of the stack height from 220 m to 250 m is predicted to result in relatively small reductions in ground level maximum, with only marginal changes in the areas of non-compliance.

It may be concluded that the addition of 3 new 800 MW PF units with no sulphur dioxide abatement in place would result in significant increases in the magnitude, frequency and spatial extent of non-compliance with SA standards. A further 3 units would more than double the magnitude and spatial extent of non-compliance, whilst resulting in a 3 to 4 fold increase in the frequency of exceedance of air quality limits. The extension of the height of the stack by 30 m, from 220 m to 250 m, is not sufficient to negate the need for considering abatement measures.

- Sulphur Dioxide Emissions - Controlled

  Changes in projected ground level sulphur dioxide concentrations and limit value exceedances were simulated for various control efficiencies (60%, 80% and 90%) for two proposed power station configurations, viz. Scenario A (3 x 800 MW PF with 220 m stack) and Scenario C (6 x 800 MW PF with 220 m stack). Observations made regarding compliance implications of various power station configurations given controlled emissions were as follows:

  - Even given a 90% control efficiency for Scenario A (3 x 800 MW units, PF, 220 m stack), cumulative sulphur dioxide concentrations would exceed the SA 10-minute standard at the maximum impact zone and

at Marapong and the SA daily standard in the maximum impact zone – primarily due to emissions from the existing Matimba Power Station.

- The implementation of abatement measures with a 60%+ control efficiency for Scenario A (3 x 800 MW units) would be sufficient to reduce the magnitude, frequency and spatial extent of non-compliance to levels comparable to those projected for current operations. With a 90% control efficiency, the magnitude of maximum daily and annual average concentrations, the spatial extent of non-compliance with the daily limit and the frequency of exceedance of both short-term limits closely reflects the current situation. (The magnitude of the highest hourly concentration and the spatial extent of non-compliance with the 10-minute limit are marginally higher than for current.)
- Given Scenario C (6 x 800 MW units) an 80%+ control efficiency would be required to bring the magnitude, frequency and spatial extent of non-compliance within levels comparable to those projected for current operations. Even given a 90% control efficiency the maximum predicted concentrations and the frequencies of exceedance at Marapong would be higher – albeit relatively marginally higher – than for current operations.

It may be concluded that a 60%+ control efficiency would suffice to ensure that the proposed 3 units could operate coincident with the existing Matimba Power Station without substantial changes in the magnitude, frequency or spatial extent of non-compliance. This is however assuming that no further units are installed at a latter date, or that more stringent air quality limits are not introduced.

With the addition of six new units (whether commissioned together or phased in) operating coincident with the existing Matimba Power Station, at least a 90% control efficiency would be required to ensure that the magnitude, frequency and spatial extent of non-compliance was within levels comparable to those projected for the basecase. Even given 90% control efficiencies on all six units, the maximum predicted hourly concentrations, the spatial extent of non-compliance with the 10-minute limit and the frequencies of exceedance at Marapong would be *marginally* higher than for current operations.

- *Potential for Health Effects due to Proposed Power Station Operations*
  Sulphur dioxide concentrations occurring due to existing Matimba Power Station emissions are predicted to be associated with "low" and "moderate" health risks within the Marapong and Onverwacht residential areas respectively. The proposed 2400 MWe power station option, without SO_2 abatement in place, is predicted to increase health risk potentials to "moderate to high" for Marapong and "low to moderate" for Onverwacht.

Health risk potentials associated with the proposed 4800 MWe power station configurations (without abatement) were classified as "high" for Marapong and "moderate to high" for Onverwacht.

Significant increments in health risk potentials associated with the proposed power station could be avoided by ensuring at least a 60% reduction in sulphur dioxide emissions should only three 800 MW be installed. In the event that eight units were to be installed - regardless of whether or not these units are to be phased in or not – a control efficiency in excess of 80% would be required for all six units to prevent significant increments in health risk potentials above baseline conditions.

Cancer risks associated with maximum possible exposures to trace metals released were calculated to be very low, with total incremental cancer risks across all carcinogens quantified to be in the range of 1: 10.6 million to 1: 24.8 million. Maximum hourly, daily, monthly and annual average metal concentrations were predicted to be within non-carcinogenic health thresholds. Annual average arsenic and nickel concentrations were also predicted to be well within the recently promulgated EC limits given as 0.006 µg/m³ and 0.02 µg/m³ respectively.

- *Potential for Vegetation Injury and Corrosion*
  The potential for vegetation damage and corrosion due to current monitored and predicted ambient sulphur dioxide concentrations is classifiable as "low". The operation of a 2400 MWe power station at the proposed site is predicted to result in "moderate" risks for vegetation damage and "medium" risks for corrosion at Kuipersbult farm and parts of Hanglip and Kromdraai should no sulphur dioxide abatement measures be implemented. Sulphur dioxide abatement with a 60% control efficiency would result in the potential for corrosion and vegetation damages for these farms being classified as "low".

  The operation of a 4800 MWe power station without SO_2 abatement in place is predicted to result in "high" corrosion and vegetation potentials within the 'zone of maximum impact' and "medium" corrosion and "moderate" vegetation damage potentials for the farms of Altoostyd, Hieromtrent, Kuipersbult, Grootvallei, Nooitegedacht and Verguldehelm. The 'maximum impact zone' refers to the area where the plume "loops" to ground level as a result of enhanced atmospheric convective mixing. By increasing the stack height from 220 m to 250 m, the corrosion and vegetation damage potentials for Altoostyd, Grootvallei and Nooitgedacht would be reduced to "low". Sulphur dioxide abatement with a 60% control efficiency would result in the potential for corrosion and vegetation damages being primarily classified as "low").

- *Contribution to Greenhouse Gas Emissions*
  The emissions from the proposed 4800 MWe power station would increase the energy sectors emissions by 0.01% and would increase the country's contribution to global warming by 0.008%

9.7.3. Mitigation Recommendations

Compliance with ambient air quality standards given for sulphur dioxide cannot be achieved due to the implementation of SO_2 abatement measures for the proposed power station given that non-compliance already occurs due to existing operations.

The need for and required control efficiency of abatement measures was assessed on the basis of avoiding any significant increment in non-compliance or health risks. The aim being to identify SO_2 control efficiencies at which there will be:

- no substantial changes in the magnitude, frequency or spatial extent of non-compliance; and
- no significant increment in the health risk within dense neighbouring settlement areas.

From the study it was concluded that a >60%+ control efficiency would be required for the proposed 2400 MWe PF power station to ensure that it could operate coincident with the existing Matimba Power Station without substantial changes in the magnitude, frequency or spatial extent of non-compliance, nor significant increment in health risks. This is however assuming that no further units are installed at a latter date. It also assumes that more stringent air quality limits are not introduced prior to the decommissioning of the existing Matimba Power Station.

With the addition of six new units (whether commissioned together or phased in) operating coincident with the existing Matimba Power Station, at least a 90% control efficiency would be required to ensure that the magnitude, frequency and spatial extent of non-compliance was within levels comparable to those projected for the baseline. Even given 90% control efficiencies on all six units, the maximum predicted hourly concentrations, the spatial extent of non-compliance with the 10-minute limit and the frequencies of exceedance at Marapong would be *marginally* higher than for current operations.

Various abatement technologies may be implemented to achieve the required control efficiencies. Flue Gas Desulfurization (FGD), which includes wet, spray dry and dry scrubbing options, are capable of reduction efficiencies in the range of 50% to 98%. The highest removal efficiencies are achieved by wet scrubbers,

grater than 90%, and historically the lowest by dry scrubbers. New dry scrubber designs are however capable of higher control efficiencies, in the order of 90%.

Although the implementation of technologies such as wet or dry FGD would be required to reduce the potential for sulphur dioxide emissions, care should be taken in assessing the environmental implications of the use of such control technologies. Atmospheric emissions are associated with the production, transportation and handling of the reagents used in the process (e.g. limestone, lime) and with the waste produced. FGD may also be associated with a visible plume which could impact on aesthetics. Furthermore, the use of FGD will lower stack gas temperatures and hence reduce plume rise, resulting in potential increases in ground level concentrations of other pollutants not removed by the abatement measures. The use of FGD or any other abatement technology is also likely to impact on the combustion efficiency which would result in increased coal consumption to meet the required energy output requirements. It is recommended that the impacts associated with likely control operations be quantitatively assessed.